WARRIOR ONE

20 25

WARRIOR ENGINEERING NASA SLI TEAM

Abstract

The Oconee County Rocketry Association (OCRA) proudly presents Project RANCH, a student-designed high-power rocket that meets the NASA Student Launch Initiative mission criteria. The final design centers around a modular, carbon-fiber rocket system targeting an apogee of 4,300 feet. The rocket is 92 inches long, has a diameter of 4 inches, and weighs 16.6 lbs with a motor (Page 231). The vehicle consists of three main sections: a booster section, a central avionics bay, and a forward payload section capped by a 3D printed, adjustable-infill elliptical nose cone. This innovative nose cone doubles as a ballast, with infill density customized to optimize the center of gravity for flight stability (Page 280).

Structurally, the airframe is built from roll-wrapped carbon fiber tubing. Fins are laser-cut from Delrin to ensure aerodynamic stability and comply with NASA safety guidelines (Page 274). The recovery system includes a dual-deployment parachute configuration using an 18” Rocketman drogue deployed at apogee and a 48” Rocketman main deployed at 652 feet. Redundancy is ensured by two RRC3+ altimeters and dual black powder charges per deployment phase (Page 252).

The payload, titled Acorn, is housed directly beneath the nose cone and includes a STEMnaut figure, sensors, and a data transmission system. The payload’s mission is to record and transmit three primary data points - maximum velocity, apogee, and time of landing - via a Featherweight GPS transmitter to a ground receiver (Page 168). Internally, the payload features 3D printed sleds and support structures for optimal electronics arrangement, shock protection, and minimal aerodynamic disturbance. Additionally, a custom 3D printed mount was developed for an Insta360 camera to capture 360° VR footage of the flight, ensuring free rotation and stability during descent (Page 233).

After numerous subscale and full-scale tests, design refinements were implemented, including a shift from Ogive to elliptical nose cone geometry, reinforcement of lower airframe joints for stability, and the final selection of an Aerotech K1100T-14A motor to meet altitude and thrust requirements (Page 234). These choices reflect careful balancing of performance, modularity, and material accessibility, supported by a student-driven engineering process and in-house manufacturing capabilities. Project RANCH embodies the core values of STEM education and aerospace innovation, built by students to perform reliably under rigorous flight conditions.

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WARRIOR ONE

2025

WARRIOR ENGINEERING NASA SLI TEAM

NASA UNIVERSITY STUDENT LAUNCH PROPOSAL

Section 1: General Information

1.1 External Leadership

1.1.1 Bradley W. Sayers, Advisor

- Contact: bwsayers@oconeeschools.org , [redacted]

1.1.2 Sam Rodriguez, Advisor

- Contact: [redacted]

1.1.3 Armando Rodriguez, Mentor

- Contact: armandorod60@aol.com , [redacted]

1.2 Internal Leadership

1.2.1 Campbell Patterson, Student Team Leader

- Contact: cpa11549@oconeeschools.org, [redacted]

1.2.2 Zoe Steckel, Safety Officer

- Contact: zst55770@oconeeschools.org, [redacted]

1.2.3 Saahil Doshi, Outreach Coordinator

- Contact: sdo92122@oconeeschools.org [redacted]

1.2.4 Caleb Antwine, Treasurer

- Contact: can15756@oconeeschools.org, [redacted]

1.3 Membership and Responsibilities

1.3.1 General Membership

Table 1: Allocation of Duties

Propulsion	Payload
Zoe Steckel	Campbell Patterson
Caleb Antwine	Saahil Doshi
	Sihoo Kim
	Cashton Isaac
	Emily Peng

- The table above indicates nominal roles in the construction of the rocket. Team members often crossed over between duties to assist other team members with certain tasks. As the proposal stage closes, we expect to add 3-5 members to the team who are not listed in the table, leading to a total of 10-12 team members.

1.3.2 Responsibilities of Student Team Leader

- Our student team leader, Campbell Patterson, is responsible for the overall management of the team. This includes setting up meetings, communicating the goals of the group, being a point of contact for any questions regarding the project, ensuring that the team is able to accomplish all goals in a timely manner, and much more. On top of group management, Campbell communicates all progress with our external leadership (see 1.1).

1.3.3 Responsibilities of Safety Officer

- Our safety officer, Zoe Steckel, is responsible for all that has to do with ensuring the safety of those involved, directly or indirectly, with our project. This includes reviewing laws, regulations, and guidelines that pertain to rocket launch and flight, ensuring that team members have received proper training on tools used during the fabrication process of the rocket, and creating a checklist for the launch of the rocket that includes all steps necessary to a safe launch (See 7.2).

1.3.4 Responsibilities of Treasurer

- Our treasurer, Caleb Antwine, is responsible for the fundraising and distribution of funds needed for the rocket. This includes reaching out to potential sponsors, setting and maintaining a budget, conducting extensive research on material cost, as well as communicating with External Leadership about funding.

1.3.5 Responsibilities of Outreach Coordinator

- Our Outreach Coordinator, Saahil Doshi, is responsible for all educational outreach opportunities. This includes running our Instagram, which has the handle “oconeerocketry” as well as coordinating with elementary and middle school administrators and teachers to organize events in which we will inform students about rocketry and how we use the engineering design process to facilitate our projects.

1.4 Design

1.4.1 Propulsion Design

- Those listed in the propulsion section of Table 1 will be responsible for designing and fabricating the lower air frame, which will house key components such as the motor and fins. This group will be responsible for meeting the requirements listed in the SLI rules in regards to motor specifications, size requirements, etc. This group will also work closely with the payload group to allow for their section of the rocket to be integrated with the upper air frame of the rocket, which will be discussed in 1.4.3.

1.4.2 Payload Design

- Those listed in the Payload section of Table 1 will be responsible for the design and fabrication of most of the upper air frame of the rocket, which will house all electronic components of the rocket, including the radio transmitter, the altimeter, etc. This group will also be responsible for the recovery system. This group will also work closely with the rest of the team to integrate their system with propulsion's system.

1.4.3 Other Design Aspects

- Once we feel that our team has achieved our goals in regards to the design, fabrication, and assembly of the main aspects of the propulsion and payload systems, we expect to reallocate certain team members' tasks to working on some of the smaller parts of the rocket as well as finer details of the rocket. This includes the nose cone, transition between the four required sections of the rocket, aesthetic design of the rocket, etc.

1.5 NAR/TRA Section Collaborations

- Our primary points of contact for mentorship and advice on rocketry throughout the project will be Sam and Armando Rodriguez.
- At the time of this proposal, we have not yet determined which launch site we are going to use. However, we will collaborate with the Rodriguez's in order to determine what site we will use to launch.
- Our team is considering attending this year's annual GRITS (Georgia Rockets in the Sky) launch in November. Located in Nashville, GA at Gaskins Farm, the site is approved by the FAA for launches up to 17,999 feet.

1.6 Time Availability

- During the course of the 3 weeks we have worked on this proposal, our group has been able to meet regularly during a thirty minute study hall during the school day. Multiple of our members are dual enrolled at local universities and/or have off-campus work-based learning opportunities, making it challenging to meet all at once. To combat this, our members were able to work on their assignments individually, often at irregular and inconsistent hours.

1.7 Time Spent on Proposal

- Our team members each individually kept track of their hours spent on the proposal. Each of the 8 team members spent between 4-12 hours each on the proposal individually, and our team averaged approximately 5.5 hours per person, totaling to about 48 individual hours of proposal writing. In addition to this, team members met regularly as a group during a 30 minute study hall, and over the course of the three weeks had 12 meetings during this time, adding an additional 6 hours of group work. This brings the total number of hours spent on the proposal to be around 54 hours.

1.8 Letter of Administrative Support

Figure 1: Letter of Administrative Support

Mr. Matt Stephens
Principal

OCONEE

Kelly Maffeo
Assistant Principal

Alyssa House
Assistant Principal

Dr. Curt Miller
Assistant Principal/Athletic Director

OCONEE COUNTY HIGH SCHOOL

Discover Your Why. Find Your Place. Make a Positive Impact.

By signing this document, the OCHS administration gives permission for students involved in the Student Launch Initiative project to be exempt from class time for scheduled zoom conferences, launch days, and virtual Q&A sessions that are required by the Student Launch Initiative project requirements. The timeline of these events are as follows:

Fall Semester 2024
- October 7: Initial Q&A session
- November 4-26: As these dates get closer, a date and time will be chosen to hold the first of three required video conferences.
- December 3: Second Q&A session

Spring Semester 2025:
- January 15 - February 6: Second video conference
- February 11: Third Q&A session
- March 24 - April 11: Third and final video conference
- April 30 - May 4: Launch week in Huntsville Alabama
    - Let it be noted that during this week our team would have the opportunity to travel to Huntsville to participate in the official launch week. This is not a required event, and our teams attendance would be decided at a later date.

The list above includes all the possible dates that would be necessary for students involved in SLI to be exempted from class. However, our project is structured in phases and requires approval to move onto each phase. If our project does not gain approval at any point throughout the year, it will no longer be necessary for students to miss class on dates following the termination of the project.

Administrator Signature ____________ Date: 9/5/24

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OCONEE COUNTY SCHOOLS

Section 2: Facilities and Equipment

2.1 Facilities Overview

Table 2: Facilities Overview

Facility	Equipment & Resources	Access
OCHS Design Lab	• Computers • Tables	**Mon-Fri** 8:00 A.M. - 4:00 P.M.
Robotics Room	• CNC Machine • Laser cutters • 3-D printers	**Mon-Fri** 8:00 A.M. - 4:00 P.M.
Workshop	• Band saw • Hand saw • Electronic solders • Drill Press • Table Saws • Belt Sander • Hand tools • Heat guns	**Mon-Fri** 8:00 A.M. - 4:00 P.M.
3D Printer Room	• 3D printers • Calipers • Rulers	**Mon-Fri** 8:00 A.M. - 4:00 P.M.
External Workshops	• Metal cutter • Welders	**Mon-Fri** 8:00 A.M. - 4:00 P.M.

2.2 Design Lab

The Design Lab is where students design builds on Autocad or Fusion. It has 24 Dell desktops, in addition with 6 hexagonal tables for planning builds with team members.

Room Manager: Bradley Sayers

Contact: bwsayers@oconeeschools.org

Required Training:

Student Shop Safety Agreement

Basic safety training

2.3 Robotics Room

The Robotics room is where students test out robots, primarily for robotics competitions. The robotics room has one CNC machine as well as seven 3-D printers. There are ample metal and plastic parts previously used in FTC robotic competitions.

Room Manager: Bradley Sayers
Contact: bwsayers@oconeeschools.org
Required Training:
Student Shop Safety Agreement
Basic safety training

2.4 Workshop

The workshop is where the majority of the construction of the rocket will take place. The workshop is home to more than enough machinery and tools than will be required to construct the rocket. The main tools that will be used are basic hand tools, a band saw, a soldering machine, heat gun, table saw, hand saw, belt sanders and more. The room has 4 square tables used to work on as well as 3 long rectangular tables used for cutting and building longer projects. Eyewear is heavily suggested when inside the workshop even when not using any of the tools.

Room Manager: Bradley Sayers
Contact: bwsayers@oconeeschools.org
Required Training:
Student Shop Safety Agreement
Basic safety training

2.5 3D Printer Room

The Printer room contains 15 3-D printers. The printers are used more often for smaller pieces of printed materials because the printers are 12” x 8”. The room also has a cabinet full of smaller measuring tools such as: Calipers, Rulers, and tape measures.

Room Manager: Bradley Sayers
Contact: bwsayers@oconeeschools.org
Required Training:
Student Shop Safety Agreement
Basic safety training

2.6 External Workshops

The external workshop is found in the agricultural mechanical room. There are a lot of hand tools such as drills, wrenches, metal cutters, and welders. Everyone who enters into this workshop is required to wear eye protection and sometimes required to wear certain clothing.

Room Manager: John Collins

Contact: jcollins@oconeeschools.org

Required Training:

Student Shop Safety Agreement

Basic safety training

Metal cutter training

2.7 Supplies For Rocket Build

- Supplies Readily Available
    - At our in-house facilities, OCRA already has the ability to make 3D printed parts in multiple materials, including ABS carbon fiber, PLA, and TPU. We also have a large supply of auxiliary hardware, such as nuts, bolts, rivets, etc., as well as Delrin Sheets on hand and all tools and machinery required to complete the construction of the rocket.
- Supplies To be Bought
    - All other necessary supplies (not listed in above section) are referenced in Section 6.3 and will need approval to be bought at the time of necessity.

Section 3: Safety

3.1 NAR/TRA Regulations

The OCRA mentor, Armodna Roderiguz, is the primary NAR/TRA personnel. He has HPR Level 3 certification, and will be responsible and oversee all energetic device storage, handling, and use. His is NAR number 112382.

OCRA's advisor, Bradley W. Sayers is the secondary NAR/TRA personnel. With HPR Level 1 certification, he will work with the OCRA mentor and Safety Officer for the following responsibilities:

- Ensure the safety of the launch vehicle and members during all ground tests and launches.
- Ensure that all members adhere to NAR/TRA regulations.
- Ensure that the NAR High Power Safety Code is maintained.

Table 3: NAR High Power Safety Code

Section	Compliance
1. Certification I will only fly high power rockets or possess high power rocket motors that are within the scope of my used certification and required licensing.	The OCRA mentor, Armando, has HPR level 3 certification, he will be responsible for the purchasing, handling, and transportation of all motors classed higher than I. OCRA advisor, Bradley W. Sayers has level 1 HPR certification, he will not handle or possess impulse motors classed higher than I.
2. Materials I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.	The Launch vehicle will be primarily constructed out of fiberglass. Metal, which will mostly likely be aluminum or alloyed steel, will only be used for internal mechanisms and mounting hardware. Any other materials will be part of the internal hardware system, or screws.
3. Motors I will use only certified, commercially made rocket motors, and will not tamper with	OCRA will only purchase certified motors from trusted suppliers, made by manufacturers like CTI, Loki, and

these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.	AeroTech. We will use motors as instructed. These motors, if within OCRA's NAR certification scope, will be stored in a locked motor box inside a locked storage room. The room is climate controlled and smoking is prohibited.
4. Ignition System I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.	OCRA is using electrical motor igniters compatible with our selected motor. These will be only installed on the launch vehicle on launch day, when the launch vehicle is on the launch pad or designating prepping area. The launch switch will be a horizontal spring switch that will return to "off" after release. The onboard electronics will be powered off until ready for launch. The onboard electronics will then be powered on using a screwdriver to activate a Schurter rotary switch. This will not have any impact on the ignition System.
5. Misfires If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.	Either the OCRA's SO, advisor, or mentor will ensure that in the case of a misfire, the launcher's safety interlock will be removed and that 60 seconds will elapse before anyone is allowed to approach the launch vehicle.
6. Launch Safety I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety	The OCRA SO will ensure that a loudspeaker or other speech amplifier is used to inform the nearby spectators that a launch will occur. The SO will ask for all spectators to move to a safe distance outlined by the NAR Minimum Distance Table (see Fig 23), to stand up, and to track the rocket during launch. The SO will then count down from 5 and launch the rocket. During descent, spectators are asked to shout when they

personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.	see the rocket and point at it. This will ensure that all nearby spectators can move out of the landing path.
7. Launcher I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.	For launches prior to the competition launch in April, OCRA will construct or borrow a steel 12' launch pad which provides structural stability and allows the rocket to attain a safe velocity before separation. The launch pad allows angles of up to 10 degrees from the vertical. The launch pad has a blast deflector to prevent the exhaust from hitting the ground. NASA provided launch pads will be used during the competition launch in April. Dry grass is always cleared around the launch pad in accordance with the NAR Minimum Distance Table (see Fig 23). In the event that OCRA uses a rocket motor containing titanium sponge, we will clear additional space as required.
8. Size My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.	OCRA will not exceed an L-impulse class motor, a maximum of 5,000 Ns of impulse. This is below the allowable size. The thrust to weight ratio of the launch vehicle will be calculated before launch and guaranteed to be greater than 5:1.

9. Flight Safety I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.	OCRA will only perform launches in FAA authorized airspace after submitting the proper FAA documentation and receiving approval. If there are low clouds, airplanes, high winds, or spectators in the path of the launch vehicle, the launch will be delayed until the obstruction has Cleared. OCRA will consider launch site altitude limits when selecting sites, and will only perform launches within those limits. OCRA will not put explosive or flammable materials in its payloads.
10. Launch Site I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).	OCRA will only perform launches in FAA authorized airspace after submitting the proper FAA documentation and receiving approval. OCRA will perform launches at the Tripoli Pitts. All sites are in agreement with these specifications; They do not present hazards such as trees, power lines, or occupied buildings, and persons not involved in the launch will not be present on the site during launches.
11. Launcher Location My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.	OCRA will only perform launches at the Dalzell, SC launch site, at GRITS launch site, or the Huntsville, AL launch site. All sites are large enough to allow us to meet these specifications. OCRA will ensure all launches take place in a location that meets both the distance requirements from any buildings and roads, as well as acting in accordance with the NAR Minimum

	Distance Table (see Fig 23).
12. Recovery System I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.	The launch vehicle will be equipped with a dual deploy recovery system. A drogue chute deployed at apogee and a main parachute will be deployed between 500 and 800 ft above the ground. All parachutes will be protected by flame shields to prevent the charges from damaging the parachutes.
13. Recovery Safety I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.	The OCRA SO will enforce safe launch vehicle recovery practices by preventing members from retrieving the rocket from dangerous places. The SO will also determine whether the launch location/weather is appropriate prior to the launch.

OCRA will also abide by all relevant state and federal regulations set forth by the Federal Aviation Association (FAA), National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), National Fire Protection Association (NFPA), and the Department of Transportation (DOT).

3.2 Safety Plan Briefing

The OCRA official Safety Officer (SO) will be in charge of issuing safety instructions before team members begin to work on the launch vehicle making sure that all team members are adequately informed and understand hazards in relation to handling the launch vehicle. Members must have attended a safety briefing, completed the warrior engineering safety shop training, and have signed a safety agreement to work on the launch vehicle. Members of the team must have all been briefed on correct safety procedures in relation to launch vehicle launching.

The safety plan will be openly available for all members to reference throughout the course of the project. Furthermore, warning stickers and safety memos will be fixed to all OCRA equipment that presents a safety hazard. Members will be able to see the proper safety procedures and PPE for each piece of equipment, such as the Dremel or power drill, before using it. The SO will be responsible for updating these safety procedures as needed during the course of the project, and including the updated procedures in all future working documents.

As part of the safety briefings, all members will also be made aware of the consequences for failing to comply with safety policies. "Willful neglect" of the procedures and policies laid out in Section 5 will be defined when assessing each situation by the SO or Mr. Sayers. If a member is determined to have committed willful neglect, they will receive an "offense" and will be subject to the following consequences:

1. Members who have committed an offense without prior having received a warning will receive a warning and then be refreshed on the correct safety protocol.
2. Members who have committed an offense with a having prior received a warning will be placed on temporary ban from working on the project spanning from 3 days to 2 weeks depending on the severity of the "Willful Neglect"
3. Members who continue to commit offenses after being temporarily banned and warned will be removed from the project altogether.

3.3 Safety Regulation Compliance

- Each Team member will be required to comply with all safety rules and regulations. Team members will be provided with all rules documentation including rules on procedures, PPE, permissions, and other safety related information when they join the team. Members will be required to read and sign the safety agreement established in section 3.9. The team Safety Officer (SO), will be responsible for overseeing team member compliance with safety regulations. Members are ultimately responsible for their safety and compliance with the established rules. If members are found to be in violation of the safety rules they will be reported to the team advisor for disciplinary action. This action may result in the termination of their team membership.

3.4 Energetic Device Handling Plan

3.4.1 Motor Purchase

All motors class higher than H will be purchased with OCRA's mentor Armando Rodriguez's express permission. Armando Rodriguez is level 3 certified, he will use his certification to verify the motor is correct for the Launch vehicle, and verify the validity of the purchase with the motor company in question. All motors will be shipped directly to Mr. Rodriguez. OCRA is not planning to use any motor classed lower than H.

3.4.2 Motor Storage

For all motors classed higher than H will be kept inside their original packaging stored inside the Engineering rooms's Hazmat box. The box is a fire-resistant, metal box, which can only be unlocked with Mr. Sayers' key. The box is located in a small ventilated climate controlled storage room which is located inside room K-26, in the CTAE hall. The room is maintained at low humidity, and stored at a temperature of $\pm$ 3°, of 70°F. Smoking is prohibited on campus at all times.

3.4.3 Motor Transportation

The OCRA Mentor, Armando Rodruiguez, will handle all transportation of the motors and other energetic devices. The motor box will be located in his car, kept secure in a locked trunk. The motor box will be kept away from any potential electrical or heat sources. Our mentor will drive his car, containing the motor box, to all launches including sub-scale, full-scale, and the competition launch at Huntsville, Alabama. In the event that our mentor is unable to drive to the competition launch in Huntsville, and instead uses an alternate form of transit, the purchased motors will be directly shipped to the NASA University Student Launch team representatives in Huntsville, to be retrieved by OCRA following our arrival during launch week. If he is unable to transport motors to any other launch, we will reschedule the launch until such time as he is able to drive the motors to our launch site.

3.4.4 Motor Use

The OCRA mentor, Armando Rodruiguez, will perform all handling of energetic devices, including rocket motors and the black powder ejection charges during the subscale launch, full-scale launch, and competition launch. Our mentor will prepare the reloadable motor, install it in the motor retention system, and install the ignition system. Our mentor will measure the black powder ejection charges, pour the charges into the canisters on the recovery bay, and seal the canisters. If a student handles energetics for training purposes, they will do so under the close supervision of our mentor Armando Rodruiguez.

3.5 Materials Safety

- Procedures: Over the course of the project our team will utilize a wide variety of materials. Those materials may include, but are not limited to, composites, cardboard, epoxy, wood, metal, plastic, and electronic components. Each material has its own unique properties meaning that they must each be treated properly. Each team member will be briefed on how to handle the materials that they will be using. Members will be trained on the procedures to handle materials in a safe manner. This training will include storage, handling, hazards, risk avoidance, and how to react in the event of an emergency.
- PPE: In addition to the procedural briefing, members will be briefed on the Personal Protective Equipment(PPE) that will be used when handling materials. Members will know which materials require PPE and to what degree they need to be prepared. Members will wear eye protection at all times throughout the project. Each member is responsible for their own safety but they will be closely monitored by our team's Safety Officer at all times.

3.5.1 Chemical Safety

There are many hazards presented by the use of chemicals necessary in the rocket-building process. Possible hazards include skin, eye, and respiratory irritation and/or damage from contact with or inhalation/ingestion of the material. Direct skin exposure to certain hazardous chemicals may also result in chemical burns or allergic reactions. Additional risks include exposure to chemical spills and accidental destruction of laboratory equipment. To prevent this, members of the CMRC team will be required to use nitrile gloves when handling any hazardous chemicals, most notably epoxy and solvents. When sanding epoxy or using epoxy filler, safety glasses, and a mask will also be mandatory. The OCRA team will be trained on how to use these chemicals with care to avoid destroying lab equipment. OCRA is expecting to use the following potentially dangerous chemicals:

- 5 Minute Epoxy
- 15 Minute Epoxy
- 60 Minute Epoxy
- 24 Hour Epoxy
- Epoxy Filler
- Epoxy Clay
- Rubbing Alcohol
- Spray Paint
- Primer

Before using a new hazardous material, OCRA's SO will take care to review any warnings and/or MSDS documentation on the material, and instruct team members on proper protection and use. Any injuries resulting from contact with these chemicals will be reported to the safety officer, the mentor, an advisor, or a qualified personnel over 18; and addressed immediately.

3.5.2 Composites

The fabrication of the launch vehicle will include cutting fin slots and other small features in
commercially available carbon fiber tubes. Additionally, CMRC will be using commercially available fiberglass parts, with similar small features. Cutting, sanding, or drilling carbon fiber or fiberglass composites releases air contamination which can damage the eyes and lungs and irritate the skin, so proper masks, eye protection, and gloves will be used. In addition, all operations on the airframe tubes will be conducted in proper locations equipped with an exhaust hood to expel the air contamination. Any injuries resulting from contact with carbon fiber or fiberglass materials will be reported to the safety officer and addressed immediately.

3.5.3 Lithium Polymer/ Ion Batteries

OCRA uses rechargeable lithium-ion (Li-Ion) and lithium polymer (LiPo) batteries to power all of our avionics equipment. Li-Ion or LiPo batteries may catch fire and explode if punctured, overcharged, or otherwise damaged. As such, OCRA takes additional safety precautions when using lithium-based batteries.

All LiPo and Li-Ion batteries will be labeled with brightly colored fire hazard markings. LiPo and Li-Ion batteries will be charged and discharged using proper connectors, balance board, and charger. A member must be present at all times during the charging and discharging process. LiPo and Li-Ion batteries will be stored at approximately 75% of their maximum voltage. During long term storage, LiPo and Li-Ion batteries must be periodically charged back to 75% voltage to prevent the battery from becoming depleted. All Li-Ion and LiPo batteries will be charged and stored in a room with an ABC-class fire extinguisher.

To dispose of Li-Ion and LiPo batteries, OCRA will first discharge the battery as safely as possible. Then CMRC will deliver the discharged battery to CMU's Environmental Health & Safety Department (EH&S) or the battery's supplier for disposal. OCRA members will not attempt to dispose of batteries in standard garbage receptacles.

3.5.4 Hazardous Material Disposal

When disposing of materials or components made up of hazardous substances, OCRA members will comply with the recommendations stated by Bradley Sayers, at OCHS:

- Minimization of hazardous waste generation,
- Use of secondary containment,
- Use of certification tags detailing chemical makeup and concentration, name of SO, and date of use
- Use of the local hazardous waste pickup service,
- Hazardous waste training for SO and all members handling hazardous materials as determined by the SO.

3.6 Facilities Safety

- Over the course of the project team members will work in many different facilities. Each facility has certain rules and regulations that must be followed for team member safety. All members will be monitored by the team Safety Officer
    - Workshop: While working in the Oconee County High School Engineering workshop members will be expected to follow all posted rules and regulations. Members must all review and pass the regulations test that is required to operate machines in the shop. Members must wear the required PPE for the equipment they are operating at all times.
    - Robotics/ Laser Cutting Lab: Members who are working in the Oconee County High School Engineering Robotics/ Laser Cutting Lab are required to follow all posted rules and regulations for the equipment that they will be operating. Members must all review and pass the regulations test that is required to operate machines in the lab. Members will be required to have permission from the advisor and be supervised by the Safety officer while working in the lab.
    - OCHS Design Lab
    - 3D Printer Room
    - External Workshops

3.7 Risk Assessment

The Risk Assessment Code (RAC) is used to explain the qualifiers for different risks associated with specific actions, events, or substances used throughout the time working on the project. It is borrowed from NASA's MWI 8715.15 directive. Tables 4, 5, 6, and 7 define the RAC labels, levels of management approval required, associated severity, and probability of occurrence respectively. These are followed by a risk assessment of different aspects of this project in Tables 8 to 11.

Table 4: RAC Labels

	Severity			
Probability	1 Catastrophic	2 Critical	3 Marginal	4 Negligible
A - Frequent	1A	2A	3A	4A
B - Probable	1B	2B	3B	4B
C - Occasional	1C	2C	3C	4C
D - Remote	1D	2D	3D	4D
E - Improbable	1E	2E	3E	4E

Table 5: Levels of Management Approval Required

Level of Risk	Level of Management/Approving authority
High Risk	Highly Undesirable. Documented approval from the MSFC / EMC or an equivalent level independent management committee.
Medium Risk	Undesirable. Documented approval from the facility/operation owner's Department/Laboratory/Office Manager or designee(s) or an equivalent level management committee.

Low Risk	Acceptable. Documented approval from the supervisor directly responsible for operating the facility or performing the operation.
Minimal Risk	Acceptable. Documented approval not required, but an informal review by the supervisor directly responsible for operating the facility or performing the operation is highly recommended. Use of a generic JHA posted on the SHE Webpage is recommended.

Table 6: Associated Severity

	Project Completion	**Personnel Safety and Health**	**Facility/ Equipment**	**Environment**
1 - Catastrophic	Project Progress terminated	Life changing/ debilitating injury or death (ex: arm cut off or death)	Loss of facility, systems, or associated hardware.	Irreversible severe environmental damage that violates law and regulation
2 - Critical	Project Progress Delayed beyond 2 weeks	Severe injury or illness (ex: broken bone or sick building syndrome)	Major damage to facilities, systems or equipment.	Reversible environmental damage causing a violation of law or regulation.
3 - Marginal	Project Progress delayed beyond 4 days	Minor injury or illness (ex: sprained ankle or covid)	Minor damage to facilities, systems, or equipment.	Mitigatable environmental damage without violation of law or regulation

				where restoration activities can be accomplished.
4 - Negligible	Project progress delayed for a maximum of two days	First aid injury or minimal illness (ex: allergies or paper cut)	Minimal damage to facilities, systems, or equipment.	Minimal environmental damage without violation of law or regulation.

Table 7: Probability of Occurrence

Description	**Qualitative Definition**	**Quantitative Definition**
A - Frequent	High likelihood to occur immediately or expected to be continuously experienced.	Probability is > 0.1
B - Probable	Likely to occur or expected to occur frequently within time.	0.1≥Probability>0.01
C - Occasional	Expected to occur several times or occasionally within time.	0.01≥Probability>0.001
D - Remote	Unlikely to occur, but can be reasonably expected to occur at some point within time.	0.000001≥Probability
E - Improbable	Very unlikely to occur and an occurrence is not expected to be experienced within time.	0.000001≥Probability

3.7.1 Project Completion

Table 8: Possible Obstacles Related to Project Completion

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
Project falls behind schedule for a large amount of ; time	Circumstances take time that would be otherwise spent on completing the project.	Project is not completed within given deadlines; Members are unable to produce a working launch vehicle that completes design parameters	2C	Project workload will be distributed among project members sorted into areas according to their areas of comfort and expertise; Progress will be monitored closely by project leads.	Hold weekly project assessment meetings in which teams report their progress as well as concerns and challenges; See Section 6.2 for Project Calendar	2E
Budget exceeds organizational funds	Funds are not properly allocated; Prices of components miscalculated Lower-than expected yields from crowdfunding or sponsorships	Unable to purchase necessary parts until funds are found; Delays in project complete due to not being able to get parts Members are required to pay for parts out of pocket.	2B	Thorough research and planning on prices of components to mitigate miscalculations. Budget set aside for emergencies or accidents, such as a part breaking.	See Section 6.3 for budget that has been approved by the treasurer. See Section 6.4 for funding sources	3D
Parts are damaged,	Mishandling of tools	Inability to complete the	2B	Thorough research into	Leaders will be in charge	3D

unavailable or otherwise become unusable at any point	or parts; Unable to properly obtain tools or parts due to shipping/funds. Ordered parts do not meet criteria / do not work to desired standards.	launch vehicle in a timely manner or inability to have the launch vehicle meet design parameters		parts and tools to understand how to handle them. Briefings and lectures on how to handle certain equipment Purchase parts in surplus if available.	of making sure all team members are up to date and understand how to handle equipment.	
Lack of communication between team members	Team members do not understand how to complete work/ handle equipment damaging tools and equipment.	Inability to complete launch vehicle in a timely manner due to lack of work. Inability to complete launch vehicle due to damaged parts. Team members get injured due to not understanding how to properly handle	3B	Make sure to train and keep members up to date on how to properly handle equipment. Make sure members are kept up to date with activities and what they need to do. Split rolls among team members.	See Section 6.2 for Project Calendar that will be used during project completion. Leaders will be tasked with ensuring communication and tasks are completed.	2E

		equipment.				
Launch schedules changed	Weather conditions, Launch vehicle is not ready to be launched due to incomplete or inadequate team members not being available for launch days.	INability to compete in NASA's competition. Unable to launch the launch vehicle at all.	2C	Use alternative launch dates, and make sure to keep clear communication to make sure people are able to attend launch dates.	Section 6.2 Project Calendar has expected launch dates.	3D
Launch schedules are canceled	Weather Conditions The Launch Vehicle isn't fit for flight whatsoever.	Failure to adequately progress on the Launch Vehicle project. Scheduling issues, due to tests.	2D	Use alternative launch dates to ensure a launch and use weekly meetings to check progress and avoid unnecessary delays	Section 6.2 Project Calendar has expected launch dates.	3D
Student/Staff cannot work	Differing schedules, upcoming tests, or other schoolwork	Delay working on Launch vehicle Unable to complete project of adequate design	2B	Mentors and leaders will constantly check in and remind members of work. Students and staff will keep	Mentors and leaders will be in charge of reminding and calendar updates bi-montly	3B

		standards		a joint calendar to help with scheduling conflicts		

3.7.2 Manufacturing Risk Assessment and Mitigation

Table 9: Manufacturing Risk Assessment and Mitigation

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
Errors during 3D printing of the payload and electronics bay components	Lack of education and/or experience with 3D Printing or CAD software; malfunctioning equipment.	The final assembly will require more time and money because the components will not be adequate for use.	3C	Students involved in 3D printing will have prior knowledge and/or training; equipment will be inspected before being used.	Inspection of printed components will occur before installation and before launch, to ensure structural integrity.	3D
Serious errors during assembly of rocket parts	Incorrect utilization of machinery or tools Inattention to assembly instructions	Important Structural components will be damaged Parts may need to be	1C	Follow all safety procedures on all tools and Machines; Ensure all manufacturing team members are	Weekly team meetings will be held in which the design is discussed.	2D

	and rocket schematics.	re-ordered Timeline may be delayed		up to date on detailed design process and have them review rocket schematics and best assembly practices.	A Fusion team has been created and will be utilized throughout the year to ensure everyone is up to date on the rocket design and plan of fabrication.	
Accident occurs while using soldering iron during wiring/ assembly of avionics systems.	Lack of training or supervision Ignorance of the established safety protocols and proper soldering techniques Exposed wires or hot soldering iron.	Members may experience dangerous Burns Equipment and/or facilities could be damaged Components could be damaged Fires can occur and damage the electronics or rocket body.	1C	Training on all required tools and machines Instruction on safe shop and work practices Additional components will be purchased as backup in case of damage.	All use of tools and/or a shop will be supervised by either the safety officer or other qualified personnel.	2E
Accident during assembly of rocket involving	Lack of proper training or supervision	Members experience minor to serious injuries	2C	Require training on all tools and machines used for assembly	Hand tools are used under the supervision of the safety officer	3D

tools or manufacturing equipment	Ignorance of established safety and maintenance rules or protocols	Equipment and/or facilities are damaged		Having officer/mentor provide oversight during assembly processes	or advisor. Adherence to the rules of external resources	
Inhalation of chemical dusts and/or fumes during assembly.	Exposure to hot surfaces or fire. Lack of ventilation Unexpected chemical reactions.	Irritation of the respiratory system. Breathlessness, dizziness, and fatigue. Prolonged exposure may result in respiratory issues.	2C	Only work in well-ventilated environments Use fume hoods in workshops when needed. Provide training and ensure limits on exposure times are followed.	MSDS compliance. Hazardous substances will only be handled in specialized workshops/labs under supervision.	3D
Swelling and/or explosion of the battery.	Undercharging, overcharging, or shorting of the battery. Battery damaged from blunt forces. Batteries short when terminals come into contact with each other. Batteries are	Electrolyte leaking, gassing, explosion, and/or fire. Severe damage to lungs, skin, eyes, nose, mouth, hands, etc. Death. Surrounding materials and items damaged.	1D	Batteries will be kept in their appropriate packaging until needed and handled with caution when removed. Batteries will only be charged per the manufacturer's recommendations; Batteries will be kept away from sources of	Routine inventory checks and oversight by safety officer during construction.	2E

	exposed to heatsource (Only swelling which hurts performance)			excessive heat or exposed wiring.		
Exposure to hazardous chemicals during assembly or launches.	Improper use of personal protective equipment (PPE). Accidental spill or unforeseen chemical reactions in the workshop or inside the rocket.	Skin or eye irritation. Burns or severe chemical reactions.	3C	Training on the correct use of PPE Training on hand-washing, eyewash stations, and emergency showers in the workspace.	MSDS compliance. Work with hazardous chemicals will occur only in designated laboratory/wo rkshop areas, under supervision by trained personnel.	3E

3.7.3 Launch and Flight Risk Assessment

Table 10: Launch and Flight Risk Assessment

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
Black powder unintention ally detonates during loading,	Failure to follow safety procedures during loading or at the launch pad.	Team members could be injured or killed. Damage	1B	Only mentors will handle black powder. All nearby electronic components will	MSDS compliance. All work involving black powder will be	1E

or launch pad, or goes off prematurel y during flight.	The substance comes into contact with fire, heat, or sparks due to improper insulation of electrical components. Exposure to friction or impact forces.	could occur to equipment or facilities The rocket may veer off course. The recovery system may fail to deploy. Significant damage to the rocket may occur.		be adequately insulated and shielded from recovery explosives.	overseen by a Level 3 certified mentor.	
Target altitude range is not reached or exceeded.	Weather cocking modifies upward trajectory An inability to reach necessary exit velocity at launch pad.	Failure to meet altitude requirements set by competition Possible disqualificati on from the competition. Lower competition ranking.	2C	Use simulation software to ensure proper weight distribution Accurately measure rocket mass, center of pressure and center of gravity.	Simulations will be done with the specifications of the rocket to determine the correct weight distribution to use for the launch. Test flight will allow for real-world testing and confirmation of simulation results.	3E
Not enough black	Incorrect measurement	Parachutes will not	1D	The amounts necessary will be	A test on the ground	3D

powder is inserted into ejection charges.	or determination of powder needed. Recovery system is not designed or assembled properly.	deploy and the rocket will enter freefall Team members or spectators may be injured. Rocket may be damaged beyond repair		calculated prior to launch and measured out, then checked by our mentor or advisor.	will be performed to ensure that the ejection charge is appropriate for a safe rocket recovery.	
Power supplied to electronics is lost prior to launch or during flight.	Hardware is damaged during launch. Components shift or disconnect during handling and/or launch. Batteries discharge on the launch pad.	Inability to perform technical task(Goal). Ejection charges will not activate. Rocket may be damaged due to failure of in recovery system deployment.	2C	Test power levels and electronic components. Ensure the security of the connections between power sources and electrical components. Change batteries between launches. Ensure batteries are properly stored and maintained.	Ground and flight testing to ensure that the avionics system will stay sound under flight conditions.	3D
Ejection charge does not ignite.	Malfunction of ignition system	Recovery system will not deploy	1D	Test ejection charges several times prior to	Verify reliability of component	2D

	due to flaws in design or assembly. Poor choice of vendor for materials.	and rocket may be damaged. Bystanders may be injured by falling rocket.		launch.	and of its vendor.	
Motor shifts or loosens within the mount tube.	Improper construction of motor mount. Structural damage occurs upon launch.	Motor may be ejected from the body of the rocket. Payload may not reach safely.	2D	Use a robust and proven motor retention system. Proper manufacturing of motor mount and rocket body.	Run test flights and ground testing. Check state of motor mount and/or body tube frequently- especially before launches. Calculate forces to ensure that they are within tolerance for the components.	2E
Premature motor ignition.	Exposure to nearby flame, heat, or electric current during motor insertion or	Members and spectators may experience serious burns or toxic	1C	Isolate the motor from possible sources of heat and from electric fields.	Supervision of safety officer and mentor or trained personnel when	1E

	on the launch pad.	chemical exposure. Engine exhaust may cause fires. Rocket and equipment may be damaged.			appropriate.	
Motor does not ignite upon launch command.	Malfunction of ignition system. Motor is made from defective materials.	Rocket will not launch. Motor may ignite unexpectedly or misfire during disassembly	1D	Correctly use and setup tested ignition systems.	Flight testing of the launch vehicle will reveal any problems with motor ignition. Ensure that the motor is being used as recommended by vendor.	2E
Explosive materials from rocket ignite surroundin g environme nt.	Rocket explodes on the pad, during flight, or upon hard landing.	Flaming debris and sparks may ignite surrounding trees or brush	1D	Follow fire safety procedures and ensure that flammable materials do not ignite accidentally.	Ensure fire extinguishers are near launch site and flammable materials are only handled by authorized individuals.	2E
The rocket	Weather	The rocket	2D	The main	Simulations	2E

encounters strong winds on descent.	conditions suddenly shift during flight.	will land outside of the predetermined landing area. Team members or spectators may be harmed by falling rocket. The rocket may be hard or impossible to retrieve.		parachute will be deployed so as to minimize drift while meeting the maximum allowed kinetic energy on landing. The rocket will carry a GPS tracker for retrieval. Launch will be postponed and/or canceled should conditions remain unfavorable.	and flight tests will be utilized to confirm the optimal deployment height for the main parachute with various wind speeds. GPS accuracy will be confirmed via multiple ground and flight tests. Launch guidelines will be developed establishing launch will be scrubbed if winds exceed tolerance.	
Cuts from miss handling equipment during project	Improper handling of equipment, not wearing proper protection.	Wounds and cuts from equipment, bleeding, infection from cuts.	3C	Proper handling of equipment and refreshers on how to do it.	SO, advisor, and mentor will make sure all team members understand how to use	3D

					equipment properly.	

3.7.4 Failure Procedures and Effect

Table 11: Failure Procedures and Effect

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
Recovery system fails to deploy properly during flight	Parachute becomes tangled. Ejection charge fails to ignite. Malfunction of altimeter during flight.	Spectators may be injured. Rocket and internal components may become damaged. Payload may be damaged.	2C	Perform ground testing of recovery system. Test the recovery system with a smaller scale model. Use redundant altimeters to reduce likelihood of equipment failure.	Analyze recovery system deployment of the small-scale model for the desired functionality.	2E
The rocket lands in a body of water (lake, pond, creek, etc.) upon landing.	Rocket drifts out further than the designated landing area due to either an early parachute deployment or the use of an improperly large parachute.	Electronics within the rocket bay short out. Body of the rocket becomes damaged. Rocket may not be retrievable if the body of water is too deep	2C	Rigorous calculations of the drift distance will be used to optimize main parachute deployment. Rocket body will be made of water-resistant carbon fiber	Simulations will confirm the veracity of calculations. Small-scale and full-scale testing will additionally test calculations. Materials data on	2E

					carbon fiber will be gathered. Avoid large bodies of water.	

3.8 Safety Agreement

Figure 2: Safety Agreement

2024-2025 NASA Student Launch Oconee County Rocketry Association
Safety Agreement

I, ______________________________ hereby agree to the following rules and procedures detailing in this safety agreement in order to participate with OCRA in the 2024-25 NASA SL.

1. I will always adhere to the policies set forth by Oconee County High School facilities in which OCRA will be using during the duration of the competition.
2. I will always adhere to the policies set forth by the Safety Officer during the duration of the competition.
3. I will always adhere to the policies set forth by the Mentor during the duration of the competition.
4. I will always adhere to the policies set forth by the Advisors during the duration of the competition.
5. I will follow the rules and regulations from the external leadership to internal leadership in this order, Mentor, Advisors, Qualified Personnel over 18, Safety Officer, Student Team Leader, and Treasurer.
6. I will always refer to the safety document or MSDS of chemicals to ensure proper safety precautions are taken.
7. I will always ask the Safety Officer, the Mentor, an Advisor, or a Qualified Personnel over 18, if I have a question regarding a Safety procedure. Asking in that order.
8. I will always notify the Safety Officer, the Mentor, an Advisor, or a Qualified Personnel over 18, if I have heard of, or have witnessed a safety incident.
9. I agree to a Range Safety Inspection on the Launch Vehicle before it is allowed to take flight.
10. I agree that the Range Safety Officer has the final authority over the Launch Vehicle's safety, and whether it can fly.
11. Iunderstand that the team Mentor is responsible for the flight safety and recovery of the Launch Vehicle; that the Launch Vehicle cannot be flown unless the team Mentor has thoroughly examined the Launch Vehicle and has given the final green light.

I understand that failure to comply with the Launch vehicle Safety requirements can result in not having the Launch Vehicle be allowed to take flight.

I understand that failure to adhere to any of the above procedures can result in disciplinary action and possible removal form OCRA

By signing this document, I verify that I have read and understand this agreement completely.

____
Name (Printed)

____
Signature

____
Date

Section 4: Technical Design

4.1 Launch Vehicle Overview

4.1.1 Material Selection

OCRA has decided to use carbon fiber for the airframe of the rocket, Delrin for the fins, ABS carbon fiber print for the nose cone, and MDF and aluminum bulkheads. Carbon fiber is an excellent choice for rocket components because of its composite behavior, increasing the strength to weight ratio. Carbon fiber coupler will be used for payload. Fiber glass tube for motor mounts because of its durable, lightweight, and heat resistant nature.

The main benefit of carbon fiber is weight reduction, due to its lower density and superior strength and stiffness. Although carbon fiber is significantly more expensive, its benefits to the team outweighs the costs.

4.1.2 Airframe Overview

All airframe components are composed of 4” inner diameter roll wrapped carbon fiber tubes. This internal diameter will provide a sufficient amount of space to house the payload and components.

4.1.3 Nose Cone

The main objective while comparing nose cone designs was to minimize drag and maximize the altitude to create the optimal flight. Despite the competition’s goal being reaching a target height, a lower drag nose cone gives us more flexibility to compensate for higher rocket weight, stronger winds, or other unexpected complications that reduce our altitude at apogee. After much deliberation OCRA chose to use an Ogive nose cone, because of its ease in printing and its ability to to reach high speeds.

4.1.4 Fins

The launch vehicle will have 3 symmetrical trapezoidal fins, laser cut off of Delrin sheets. Each of the fins will be a 1/16th inch thick and laser cut for ease. The fins will be bolted onto the booster using M5 nuts and bolts. The trapezoidal fin set will help reduce drag while still maintaining being lightweight to increase speed.

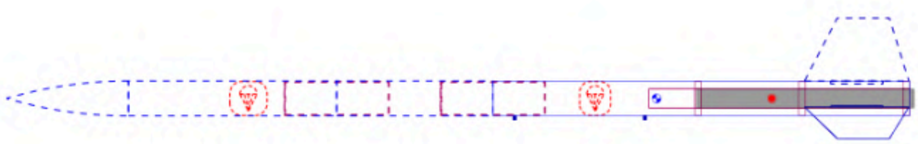
4.2 Projected Altitude

OCRA has chosen to design a rocket that will reach an apogee of 5,280 feet. To reach this desired altitude OCRA has decided upon a motor and aerodynamics configuration that will reach this altitude based on preliminary simulations that our team has run. This altitude of 5,280 was selected because it is exactly one mile in the air and is an achievable altitude within the motor constraints that we face.

4.2.1 Open Rocket Simulations

Figures 3-5: Open Rocket Simulations

Rocket Design



Rocket
Stages: 1
Mass (with motor): 5266 g
Stability: 3.3 cal / 12.8 %
CG: 74.855 in
CP: 88.127 in

H669-P

Altitude	551 ft
Flight Time	19.8 s
Time to Apogee	5.83 s
Optimum Delay	5.55 s
Velocity off Pad	35.7 m/s
Max Velocity	60.4 m/s
Velocity at Deployment	N/A
Landing Velocity	19.2 m/s

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Motor Wt	Size
H669N	675 N	0.325 s	1178 N	220 Ns	19.81:1	96 g	38/152 mm

H242-P

Altitude	642 ft
Flight Time	23.1 s
Time to Apogee	6.69 s
Optimum Delay	5.4 s
Velocity off Pad	19.8 m/s
Max Velocity	59.8 m/s
Velocity at Deployment	N/A
Landing Velocity	19.2 m/s

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Motor Wt	Size
H242T	204 N	1.24 s	247 N	253 Ns	5.96:1	115 g	38/152 mm

H999-P

Altitude	994 ft
Flight Time	33.5 s
Time to Apogee	7.65 s
Optimum Delay	7.32 s
Velocity off Pad	44 m/s
Max Velocity	87.7 m/s
Velocity at Deployment	N/A
Landing Velocity	19.2 m/s

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Motor Wt	Size
H999N	982 N	0.326 s	1710 N	320 Ns	28.17:1	144 g	38/203 mm

I1299-P

Altitude	1458 ft
Flight Time	47.2 s
Time to Apogee	8.99 s
Optimum Delay	8.7 s
Velocity off Pad	49.2 m/s
Max Velocity	115 m/s
Velocity at Deployment	N/A
Landing Velocity	19.9 m/s

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Motor Wt	Size
I1299N	1291 N	0.329 s	1491 N	424 Ns	36.09:1	192 g	38/249 mm

G64-P

Altitude	125 ft
Flight Time	6.79 s
Time to Apogee	3.54 s
Optimum Delay	1.15 s
Velocity off Pad	11 m/s
Max Velocity	20.1 m/s
Velocity at Deployment	N/A
Landing Velocity	20.1 m/s

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Motor Wt	Size
G64W	60.9 N	1.92 s	108 N	118 Ns	1.84:1	62.5 g	29/124 mm

K850-P

Altitude	5275 ft
Flight Time	150 s
Time to Apogee	15.4 s
Optimum Delay	13.3 s
Velocity off Pad	24.4 m/s
Max Velocity	312 m/s
Velocity at Deployment	N/A
Landing Velocity	23.2 m/s

Motor	Avg Thrust	Burn Time	Max Thrust	Total Impulse	Thrust to Wt	Motor Wt	Size
K850DM	921 N	2.03 s	1065 N	1869 Ns	17.83:1	1224 g	54/635 mm

4.2.2 Altitude Data Collection

- All of the altitude data collection will be achieved through the use of dual altimeters. This use of dual altimeters gives us redundancy to verify that the rocket is actually at the altitude that it claims. This data will be backed up by the on board flight computer which will profile the flight in real time. This data will then be transmitted on the 2m radio band back to a ground receiver.

4.3 Recovery System

OCRA will be using a dual-deployment recovery system for the launch vehicle, a drogue chute deployed shortly after apogee and a larger main chute deployed closer to the ground. The parachute we are planning to use is the (PARACHUTE) from (PLACE). The parachute will deploy using programing, when the altimeter detects a certain altitude, the drogue chute will deploy. At a measurement of 800 feet or lower, the main chute will deploy.Deploying the main chute after deploying the smaller drogue chute reduces the maximum acceleration that the rocket will experience, which reduces the chance of damaging the rocket, payload, or chute. Additionally, deploying the main chute closer to the ground reduces the cross range drift of the rocket due to wind.

4.4 Motor Selection

OCRA proposes to use a K850-P as the propulsion system for the launch vehicle, based on Open Rocket Simulations that showed the launch vehicle reaching an apogee of 5,275 feet. OCRA chose this motor because it is strong enough to propel the rocket, as well as small enough to fit within the rocket too.

4.4.1 Supporting Research

OCRA decided to choose K850-P because it was the best possible fit for OCRA's criteria. The motor would need to be from a reliable company, with safe materials and readily available for consumer purchase. The motor would need to be able to fit within the launch vehicle, while also being considerably lightweight.

4.5 Payload

4.5.1 Overview

The payload aboard our rocket will be responsible for carrying everything, with the exception of the motor, that is necessary on board the rocket. That is to include, STEMNAUTS, electronics, batteries, altimeters, and supporting material. The payload will be held into the airframe by a carbon fiber coupler. The interior sections of the payload will be divided by bulkhead sections that will be supported by threaded rods that run throughout.

4.5.2 Design Overview

Figures 6-12: Payload Design Drawings

PROJECT	NASA	TITLE	Payload Section
DRAWN Campbell Patterson 8/30/2024	SCALE 1:3	SIZE A	SHEET 1/7

PROJECT NASA	TITLE Payload Section	
DRAWN Campbell Patterson 8/30/2024	SCALE 1:3	SIZE A	SHEET 2/7

PROJECT NASA		TITLE Payload Section	
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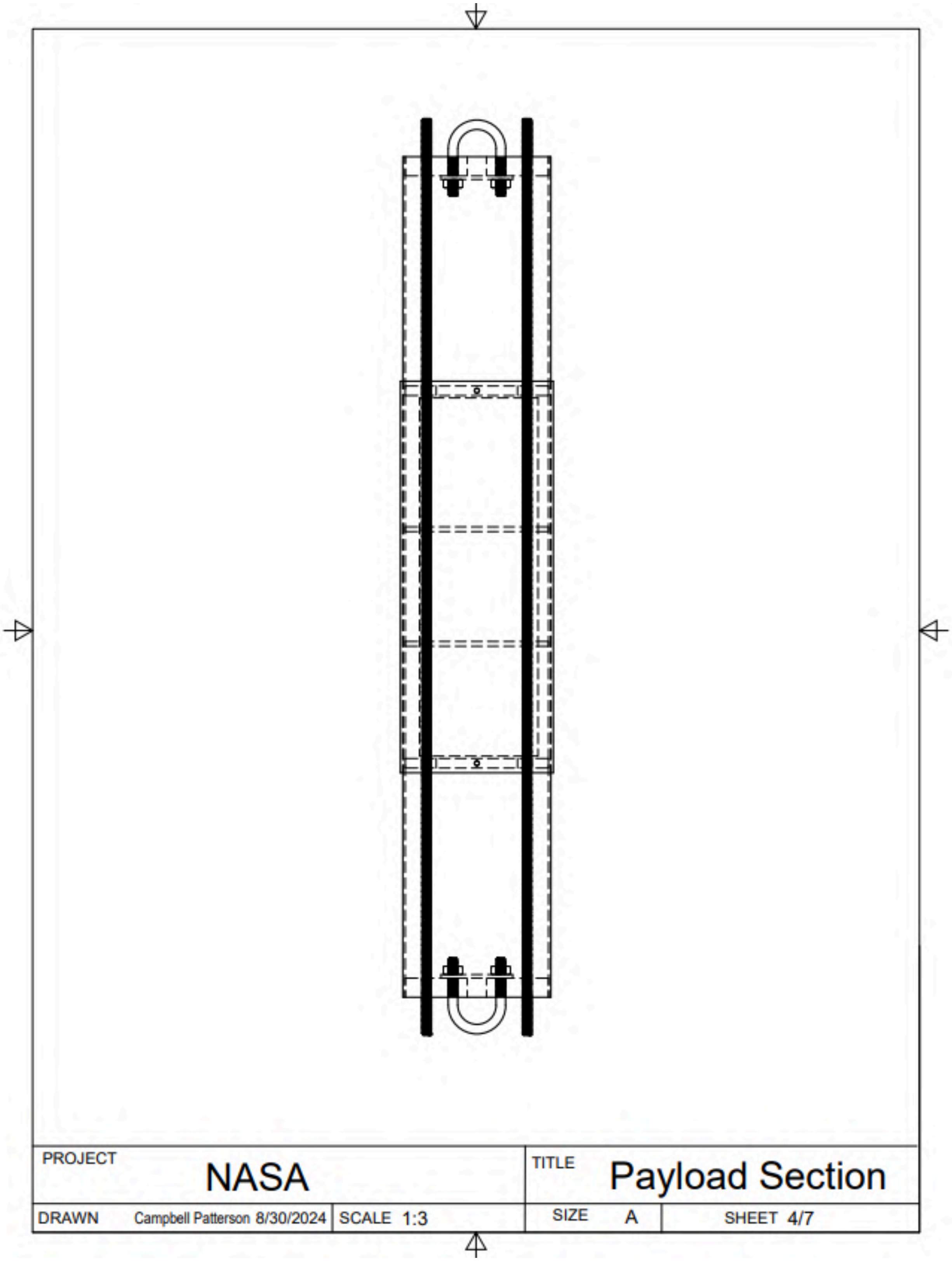
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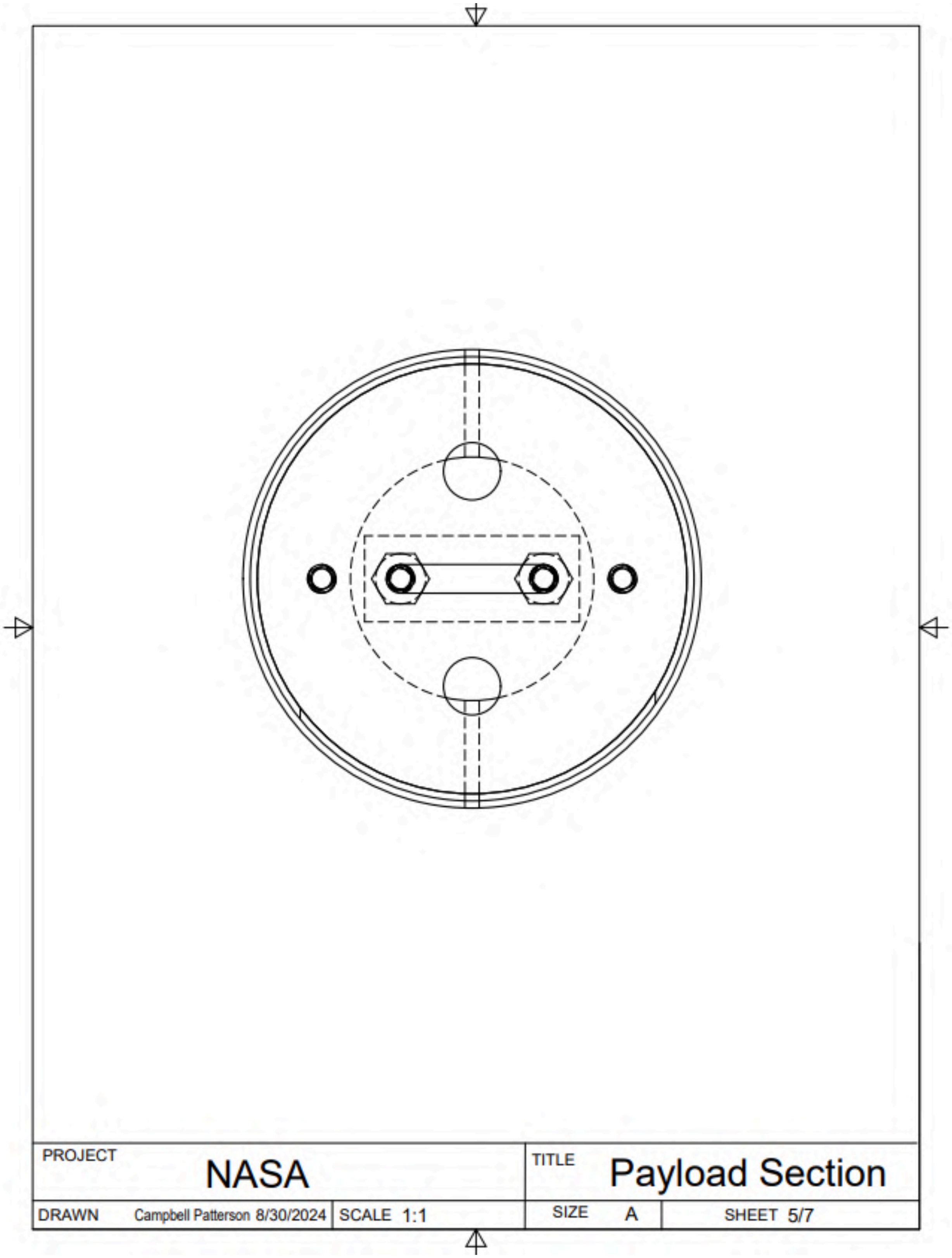
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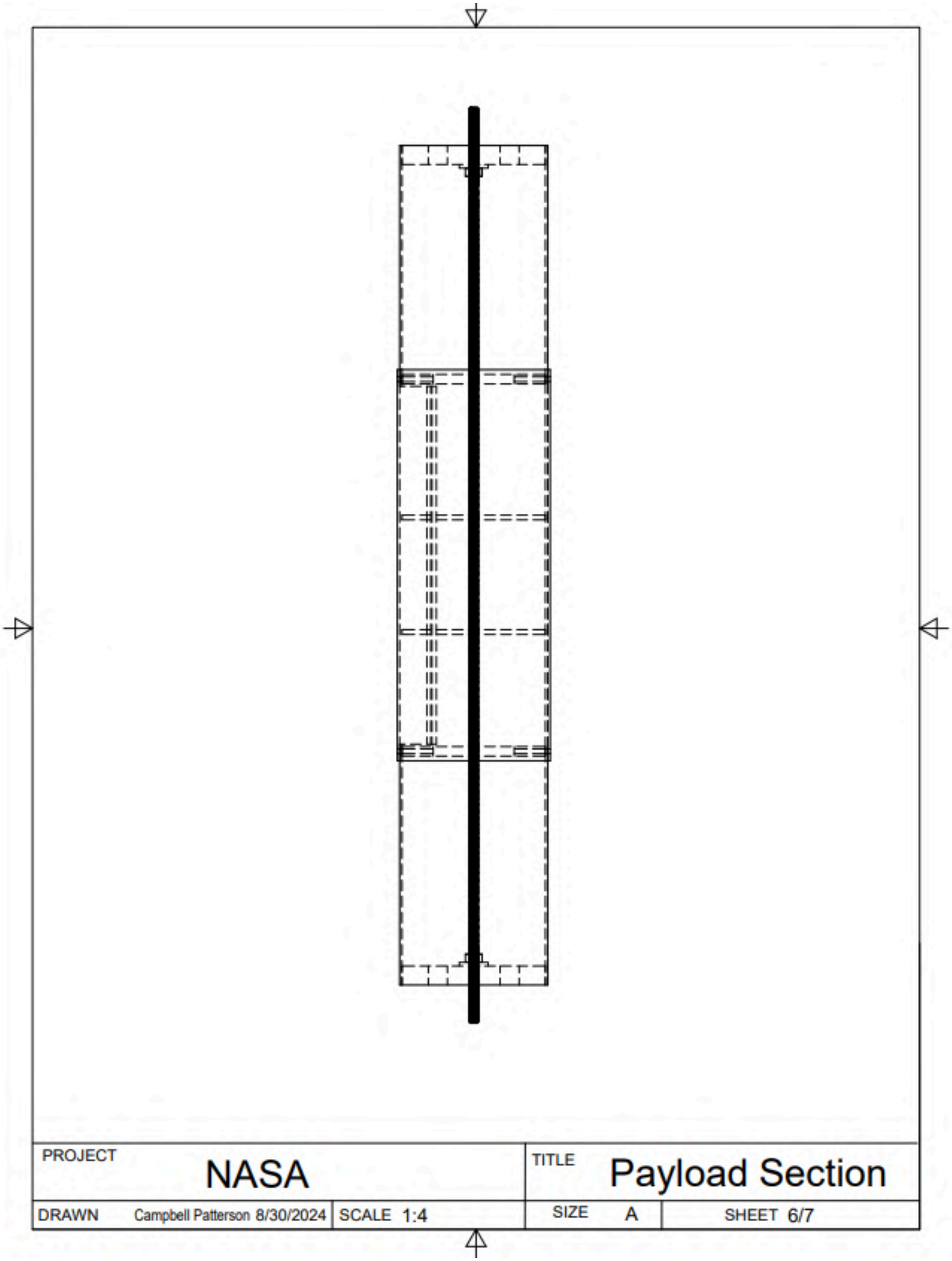
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NASA
TITLE
Payload Section
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Campbell Patterson 8/30/2024
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SIZE A
SHEET 6/7

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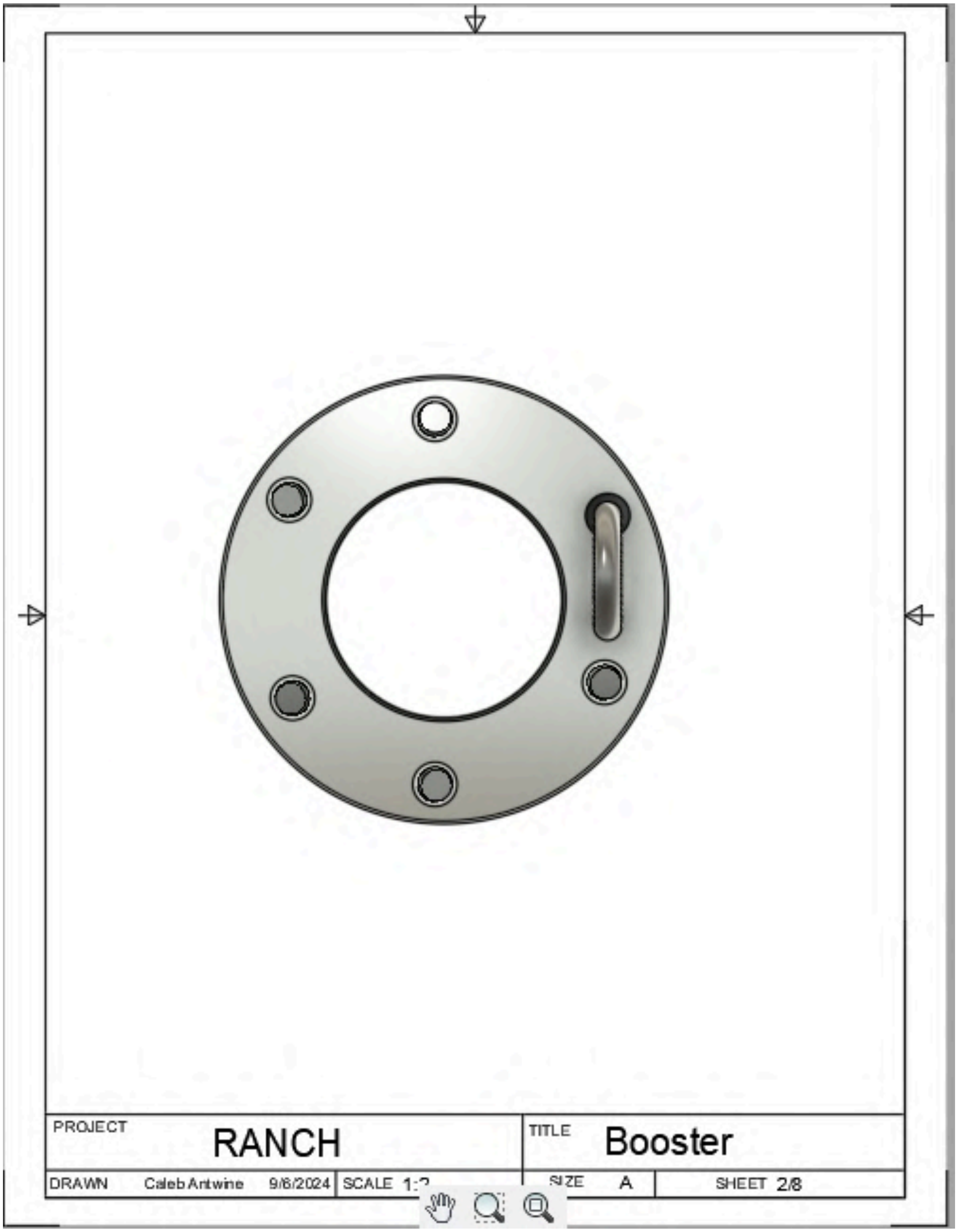
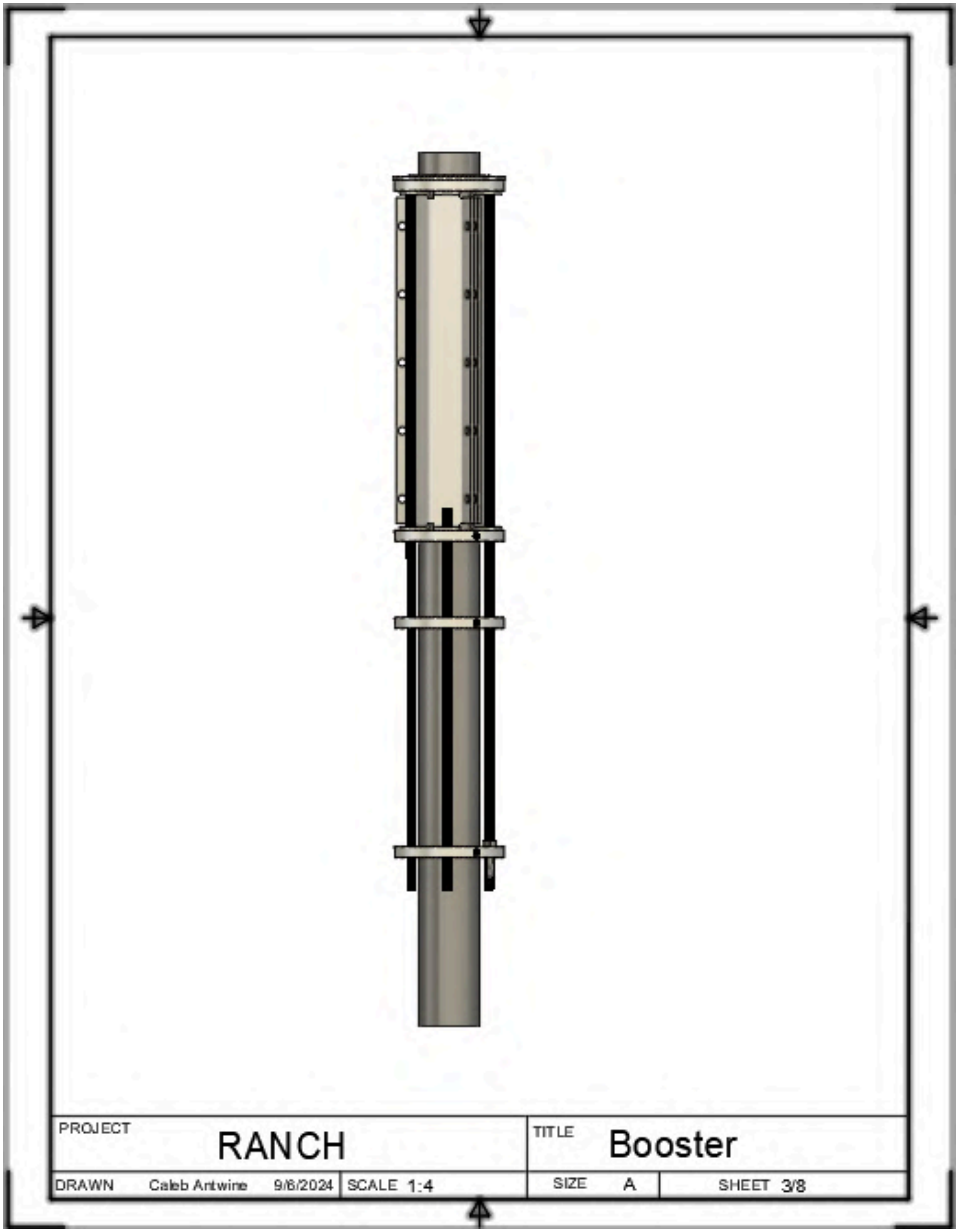
DRAWN Campbell Patterson 8/30/2024	SCALE 1:7	SIZE A	SHEET 7/7

Figures 13-20: Booster Design Drawings

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Booster
DRAWN
Caleb Antwine
9/6/2024
SCALE 1:4
SIZE
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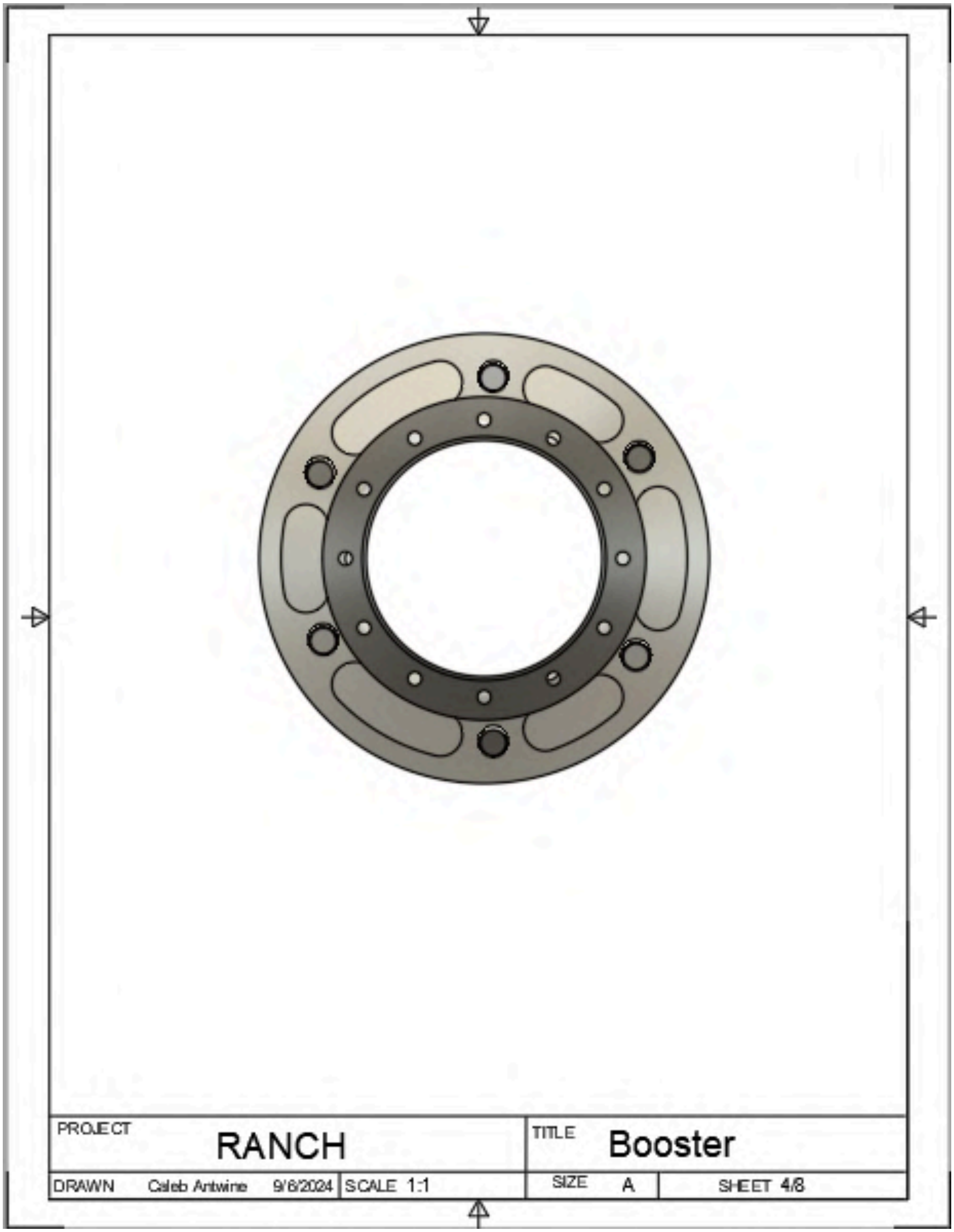
SHEET 3/8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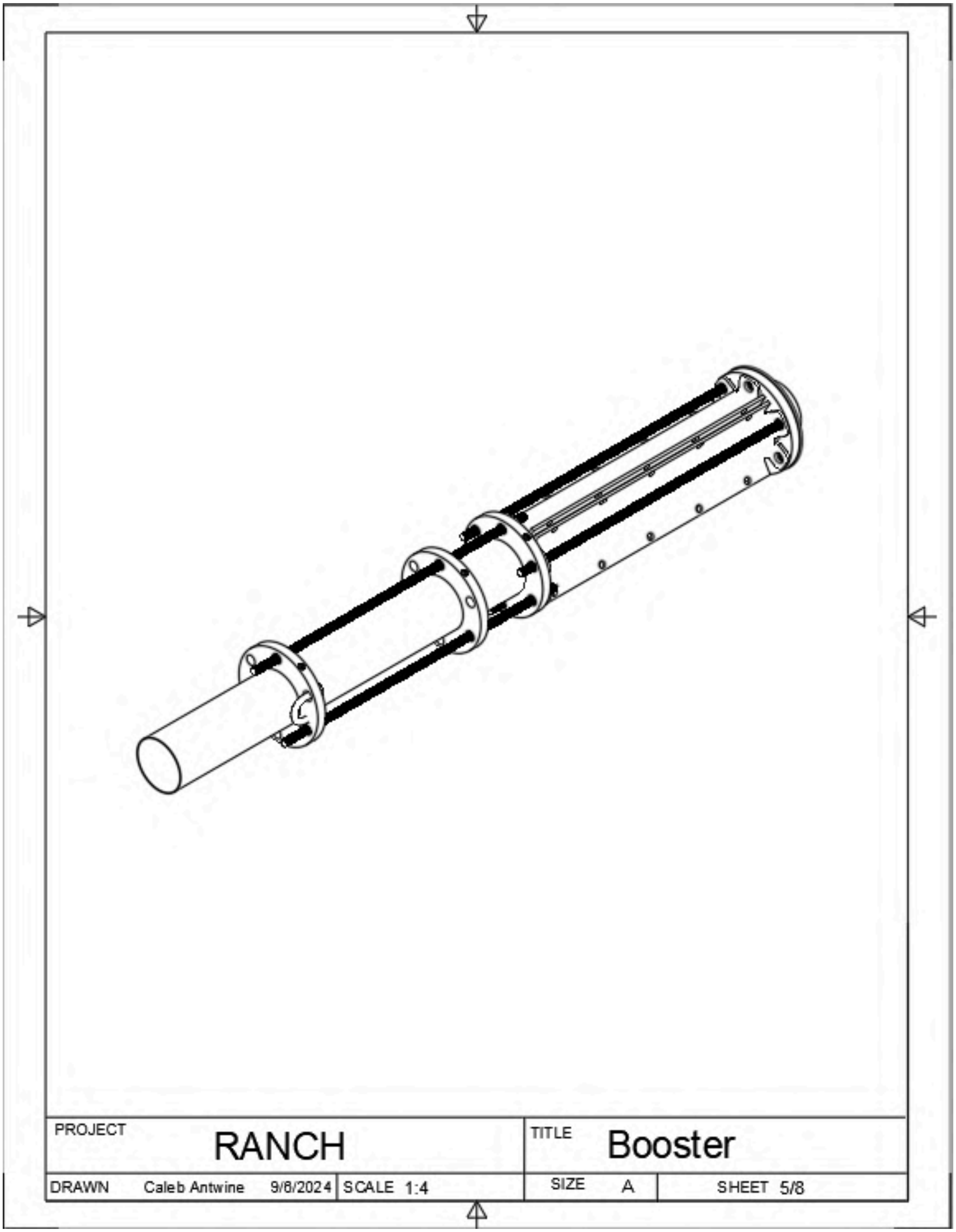
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4.5.3 Data Selection

- Our team has chosen to collect certain amounts of data. Those data points will be transmitted from the rocket on the 2m radio band to a ground receiver. The data points that we transmit will be Max Velocity, Apogee Reached, Time Landing, Landing Velocity. We will also have hardware installed in our launch vehicle that will be able to record Stem naught orientation and survivability, as well as battery status and temperature of landing site. Though we currently do not plan to include this data we have the ability to add this data to transmission later in the project.

4.5.4 Data Collection

- As mentioned earlier in the project, all data will be collected by the flight computer and altimeter. This data that is collected will then all be gathered into the flight computer for interpretation. Once the data has been collected it will be transmitted to the ground receiver on the 2m radio band frequency that is predetermined.

4.6 Technical Challenges

4.6.1 Mechanical Design

- When designing a complex launch vehicle, such as the one we have designed, there are many mechanical challenges that present themselves. In our design we experienced challenges in designing a payload that could perform the requisite duties. It was relatively difficult to produce a design that was strong enough to hold the payload while also compact enough to fit into the area. We also had to consider weight in balance in our quest to keep the rocket stable. This led to additional challenges in the fin design that were changed often to increase the stability of the rocket. With each change affecting other parts of the rocket there were many mechanical issues that we were forced to overcome.

4.6.2 Other Challenges

- We faced other challenges in the electronics selection portion of the project. Due to the fact that our team has never designed a rocket with such complex systems, we were at an early loss trying to figure out what we needed to do to complete the payload. This particular challenge came with the requirement to have a 2m radio transmitter on board the rocket. Due to the outdated nature of radio transmissions our team had to do loads of research on which transmitters could actually transmit the data that we needed. After much research we landed on a transmitter that would get the job done.

Section 5: STEM Engagement

5.1 Plan For STEM Engagement

OCRA is involved in engaging other students and community members in regards to STEM and rocketry interest. We especially engage elementary school and middle school students, because OCRA visits local elementary and middle schools in the area and speaks to individual classrooms. OCRA also engages the students in these events through interactive projects that teach students about the important skills required for engineering and other scientific work.

Oconee County Elementary School/Oconee County Middle School

OCRA will have the opportunity to give a presentation at both Oconee County Elementary School and Oconee County Middle School that will involve various small, engaging projects and a lecture. This will be related to the elementary school's curriculum on gravity, and the middle school has a STEM team that we will present to. For each school, we will give a slideshow covering elementary rocketry and then assist students in building their own rockets. As described in the sustainability section, these presentations will help ensure the sustainability of OCRA by increasing awareness of the club as well as giving future potential members an idea of what the program is like.

Colham Ferry Elementary School/High Shoals Elementary School

At the time of this proposal, OCRA is working to get in touch with administrators and STEM teachers to set up a day to give presentations (which will be similar to the one given at Oconee County Elementary School) to the students at these elementary schools.

CTAE Day

Each year, towards the end of the spring semester, students in OCRA have the opportunity to visit elementary schools around the county to participate in their CTAE day. This is a day for the elementary school students to learn about Career, Technical, and Agricultural Education. Our students represent the engineering aspect of CTAE and give a presentation about how we design and build rockets using the engineering design process.

Youth Force

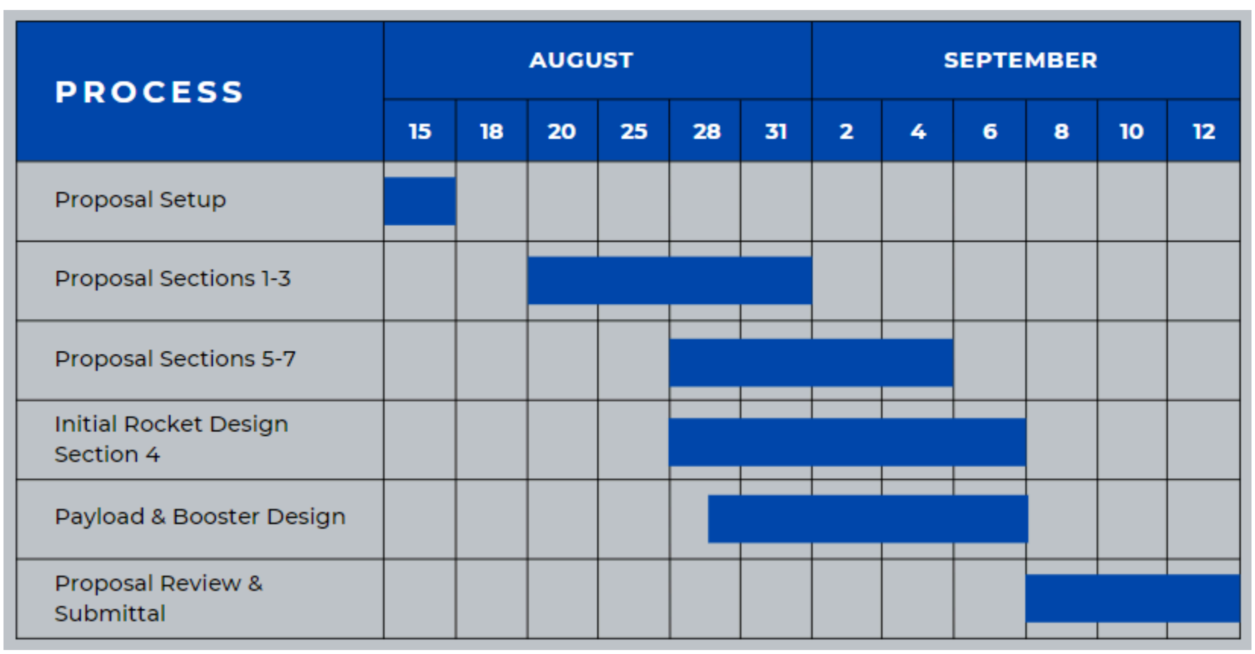
Youth Force is a local program that is connected with the Boys & Girls Club of Athens, whose goal is to prepare underprivileged children for after middle and high school so that they can explore their options. Youth Force has several STEM related programs, such as their rockets and robotics initiatives. OCRA will have the opportunity to help with these projects and encourage career readiness for engineering and technology to students.

Section 6: Project Plan

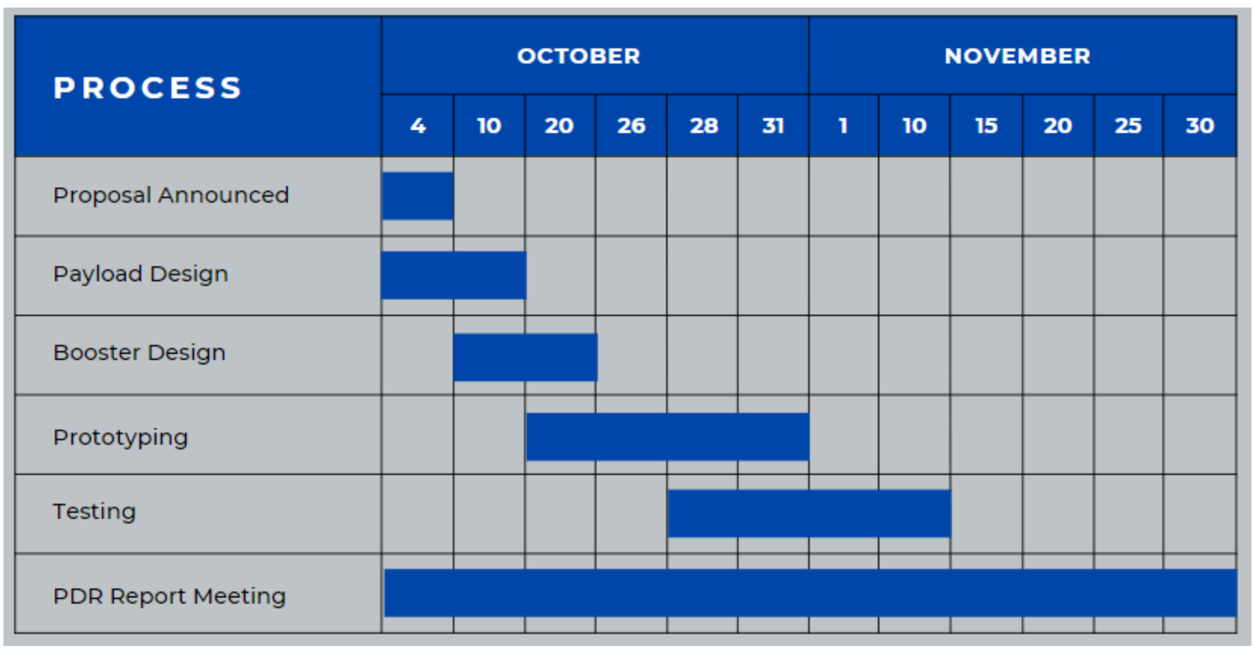
6.1 Timeline

- Our project will be split up into phases based on the deadlines that are already set for us.
- The project phases will be as follows: Initial Design/ Proposal, Final Design/Critical Design Phase, Rocket Manufacturing/Flight Readiness Phase, Final Testing/Launch Readiness Phase
- Initial Design/ Proposal Timeline

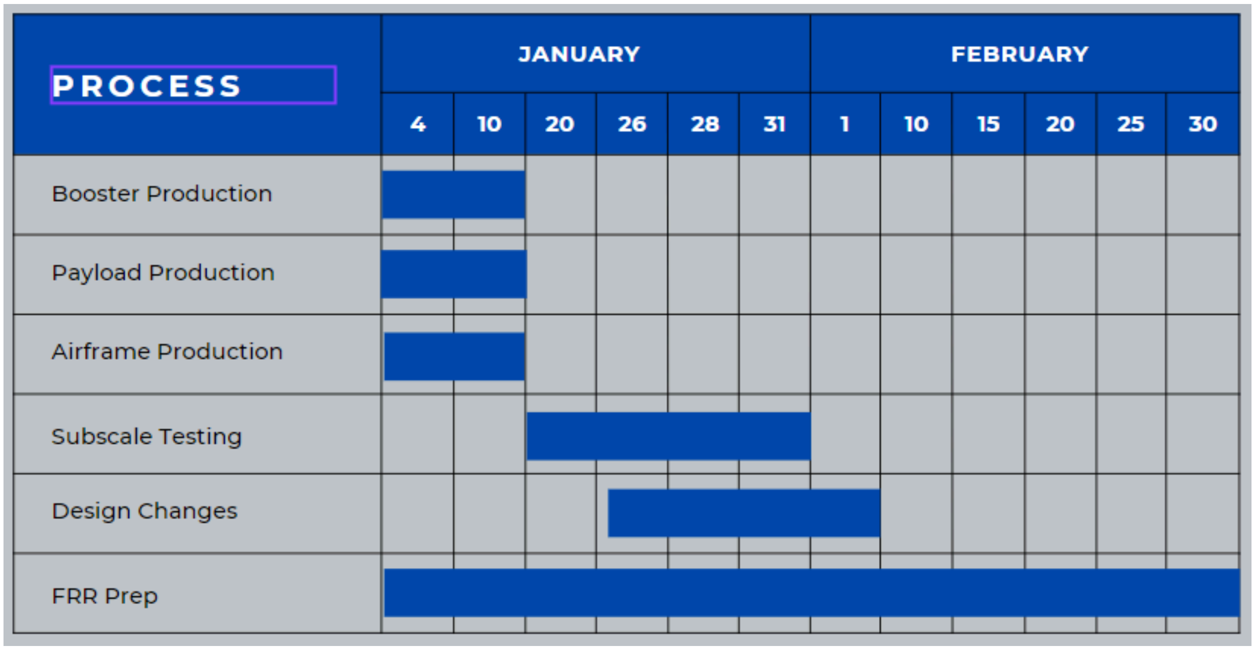
Figure 21: Proposal Timeline



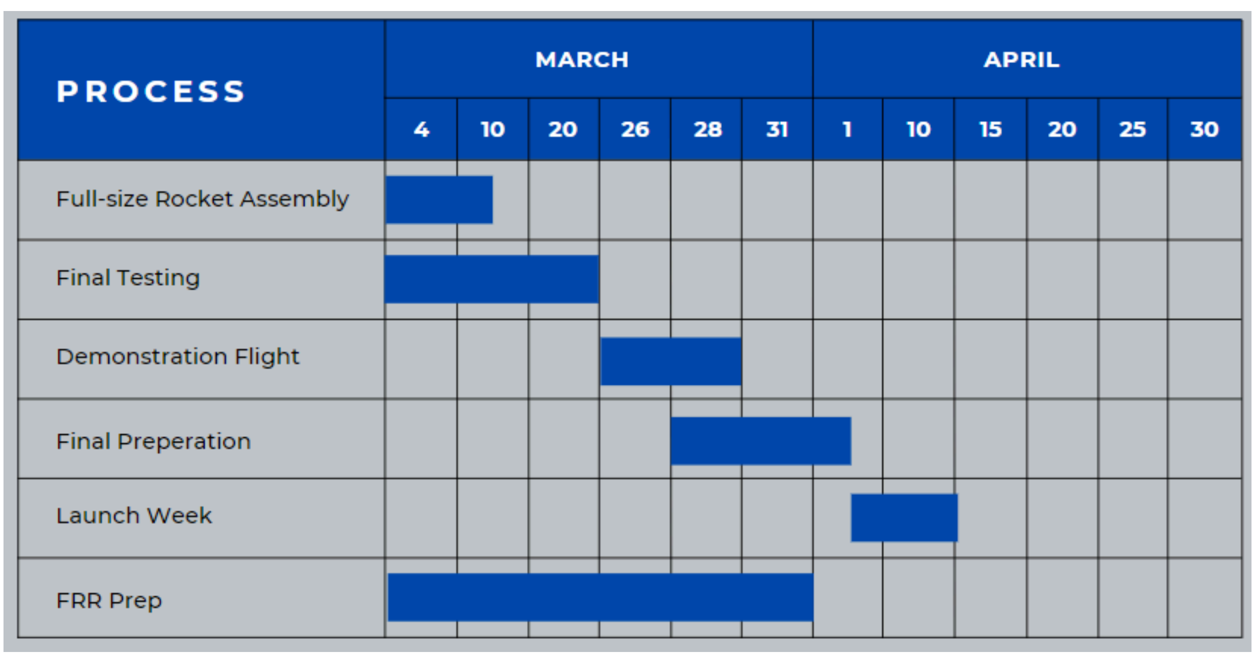
- Final Design/Critical Design Phase



- Rocket Manufacturing/Flight Readiness Phase



- Final Testing/Launch Readiness Phase



6.2 Calendar

Figure 22: Project Calendar

Task	Start Date	End Date
Proposal Writing	Sep 1	Sep 18
Recruitment	Sep 1	Sep 20
Sponsorship Outreach	Sep 1	Oct 15
Proposal Submission	Sep 11	Sep 11
Recovery System Design	Sep 20	Oct 15
Payload Design	Sep 20	Oct 18
Structure Design	Sep 20	Oct 18
ATS Design	Sep 20	Oct 18
Scale Model Design	Oct 2	Oct 23
PDR Q&A	Oct 5	Oct 5
PDR Writing	Oct 6	Oct 23
Website Submission	Oct 26	Nov 20
PDR Submission	Oct 26	Oct 26
Scale Model Fabrication	Oct 26	Nov 20
Structure Redesign	Oct 30	Nov 13
Payload Redesign	Oct 30	Nov 20
PDR Presentations	Nov 1	Nov 30
Payload Prototyping	Nov 13	Nov 29
CDR Q&A	Dec 7	Dec 7
Subscale Launch	Dec 3	Dec 3
Post-flight Analysis	Dec 4	Dec 10
CDR Writing	Dec 7	Jan 3
CDR Submission	Jan 8	Jan 8
CDR Presentations	Jan 16	Feb 6
Payload Fabrication	Jan 17	Feb 12
Full Scale Fabrication	Jan 17	Feb 12
FRR Q&A	Feb 8	Feb 8
FRR Writing	Feb 4	Feb 28
Payload Testing	Feb 12	Feb 19
Full Scale Launch	Feb 18	Feb 19
Post-flight Analysis	Feb 19	Feb 26
FRR Submission	Mar 4	Mar 4
FRR Presentations	Mar 11	Mar 29
LRR Writing	Mar 21	Apr 1
Travel to Huntsville	Apr 10	Apr 10
LRR Due	Apr 12	Apr 12
Launch Day	Apr 13	Apr 13
Travel To Athens	Apr 14	Apr 14
Post-flight Analysis	Apr 15	Apr 22
PLAR Writing	Apr 15	Apr 23
PLAR Submission	April 23	April 23

6.3 Budget

Table 12: Expenses

Airframe	Booster	Payload	Hardware	Reserve
Carbon Fiber Tubing: $660	3D Printed Material: $100	Flight Computer: $300	U Bolts: $10	Reserve Funding: $500
Polycarbonate Tubing: $125	Delrin Fins: $20	Radio Transmitter: $228	Nuts: $10	
3d Printed Material: $100	Aluminum Centering Rings: $50	Batteries: $5	Screws: $10	
	Motors: $900-$1500	Altimeter: $250	Epoxy: $10	
	Bulkheads: $50	Power Switches: $20	Super Glue: $10	
	Threaded Rods: $10	Wiring: $10	LocTite: $10	
	Fiberglass Motor Tube: $5	Bulkheads: $5	Rivets: $10	
	Aluminum Fin Brackets: $10	Threaded Rods: $10	Shear Pins: $10	
	Motor Retaining Ring: $50	Stemnauts: $5		
		Cameras: $200		
		Couplers: $80		

		Nomex: $50		
		Parachutes: $50		
		Quicklinks: $10		
		Shock Cord: $20		
		Percussion Caps: $35		
		Black Powder: $50		
$885	$1,195	$1,350	$80	$500

6.4 Funding

- To complete the project our team will need to raise $4,500 including reserves. In order to accomplish this we will take a three pronged approach to gathering funds
    - Club Support: Our club will be able to supply us with a limited number of funds. These funds will come in most part by the resources that the school can provide.
    - Merchandise Sales: Our team has merchandise in many capacities that are sold to our supporters and members of our school. This will bring in limited funds to support the team
    - Corporate Sponsorship: The largest portion of our fundraising efforts will come from corporate sponsors. We will sell sponsorships to local businesses who want to support our mission. Though many of these monies have not been donated yet, our sponsors will donate money upon approval of the proposal. These funds will go to all other expenses that our team needs to take on.

6.5 Local Sustainability

- Our sustainability plan consists of both a 1 and 4 year plan to sustain our rocket team

1. One Year Plan
    a. Membership: Each year OCRA has an incoming class of members who have the ability to be on the team. Our club is well known in our community because of the extensive STEM engagement that exists throughout the year. Potential members who are enrolled in middle school have the opportunity to interact with team members at club fairs and other STEM engagement events. These events help the team to keep recruitment up and refresh our team each year.

b. Funding: Over the course of OCRA'S existence our club has established working relationships with many sponsoring organizations in our community. These organizations are actively involved in supporting and continuing to support our team. Over the next year our funding will be sustained through effective communication and fostering of relationships. Through these partnerships our team will continue to operate at a high level.

2. Four Year Plan
    a. Membership: As mentioned above, our membership is a cyclical process that replenishes itself each year. Over the course of the next five years this process will continue to happen. However, we intend to initiate additional efforts to gain new members. These efforts will include: Increasing Social Media Presence and Increasing STEM Engagement events
    b. These events should contribute to participation at a much higher rate in five years than it will be in the next one year.
    c. Funding: Due to the fact that our funding largely comes from corporate sponsors, our plan over the next five years is to expand the amount of sponsors that our team has. We will do this by continuing to engage the community in education about our team and rocketry in general. We will hold fundraising information sessions where companies can learn about our team and how they can best support us. Through expansion of our corporation network we will be more resilient to economic shifts that may reduce our funding.

Section 7: Appendix

7.1 Applicable Laws, Rules and Regulations

7.1.1 Title 14, Chapter 1, Part 101, Subpart C - Amateur Rockets
§ 101.21 Applicability.

(a) This subpart applies to operating unmanned rockets. However, a person operating an unmanned rocket within a restricted area must comply with § 101.25(g)(2)) and with any additional limitations imposed by the using or controlling agency.

(b) A person operating an unmanned rocket other than an amateur rocket as defined in § 1.1 of this chapter must comply with 14 CFR Chapter III.

§ 101.22 Definitions.

The following definitions apply to this subpart:

(a) ***Class 1—Model Rocket*** means an amateur rocket that:

(1) Uses no more than 125 grams (4.4 ounces) of propellant;

(2) Uses a slow-burning propellant;

(3) Is made of paper, wood, or breakable plastic;

(4) Contains no substantial metal parts; and

(5) Weighs no more than 1,500 grams (53 ounces), including the propellant.

(b) ***Class 2—High-Power Rocket*** means an amateur rocket other than a model rocket that is propelled by a motor or motors having a combined total impulse of 40,960 Newton-seconds (9,208 pound-seconds) or less.

(c) ***Class 3—Advanced High-Power Rocket*** means an amateur rocket other than a model rocket or high-power rocket.

§ 101.23 General operating limitations.

(a) You must operate an amateur rocket in such a manner that it:

(1) Is launched on a suborbital trajectory;

(2) When launched, must not cross into the territory of a foreign country unless an agreement is in place between the United States and the country of concern;

(3) Is unmanned; and

(4) Does not create a hazard to persons, property, or other aircraft.

(b) The FAA may specify additional operating limitations necessary to ensure that air traffic is not adversely affected, and public safety is not jeopardized.

§ 101.25 Operating limitations for Class 2-High Power Rockets and Class 3-Advanced High Power Rockets.

When operating *Class 2-High Power Rockets* or *Class 3-Advanced High Power* Rockets, you must comply with the General Operating Limitations of § 101.23. In addition, you must not operate *Class 2-High Power Rockets* or *Class 3-Advanced High Power* Rockets—

(a) At any altitude where clouds or obscuring phenomena of more than five-tenths coverage prevails;

(b) At any altitude where the horizontal visibility is less than five miles;

(c) Into any cloud;

(d) Between sunset and sunrise without prior authorization from the FAA;

(e) Within 9.26 kilometers (5 nautical miles) of any airport boundary without prior authorization from the FAA;

(f) In controlled airspace without prior authorization from the FAA;

(g) Unless you observe the greater of the following separation distances from any person or property that is not associated with the operations:

(1) Not less than one-quarter the maximum expected altitude;

(2) 457 meters (1,500 ft.);

(h) Unless a person at least eighteen years old is present, is charged with ensuring the safety of the operation, and has final approval authority for initiating high-power rocket flight; and

(i) Unless reasonable precautions are provided to report and control a fire caused by rocket

§ 101.27 ATC notification for all launches.

No person may operate an unmanned rocket other than a Class 1—Model Rocket unless that person gives the following information to the FAA ATC facility nearest to the place of intended operation no less than 24 hours before and no more than three days before beginning the operation:

(a) The name and address of the operator; except when there are multiple participants at a single event, the name and address of the person so designated as the event launch coordinator, whose duties include coordination of the required launch data estimates and coordinating the launch event;

(b) Date and time the activity will begin;

(c) Radius of the affected area on the ground in nautical miles;

(d) Location of the center of the affected area in latitude and longitude coordinates;

(e) Highest affected altitude;

(f) Duration of the activity;

(g) Any other pertinent information requested by the ATC facility.

§ 101.29 Information requirements.

(a) ***Class 2—High-Power Rockets.*** When a Class 2—High-Power Rocket requires a certificate of waiver or authorization, the person planning the operation must provide the information below on each type of rocket to the FAA at least 45 days before the proposed operation. The FAA may request additional information if necessary to ensure the proposed operations can be safely conducted. The information shall include for each type of Class 2 rocket expected to be flown:

(1) Estimated number of rockets,

(2) Type of propulsion (liquid or solid), fuel(s) and oxidizer(s),

(3) Description of the launcher(s) planned to be used, including any airborne platform(s),

(4) Description of recovery system,

(5) Highest altitude, above ground level, expected to be reached,

(6) Launch site latitude, longitude, and elevation, and

(7) Any additional safety procedures that will be followed.

(b) ***Class 3—Advanced High-Power Rockets.*** When a Class 3—Advanced High-Power Rocket requires a certificate of waiver or authorization the person planning the operation must provide the information below for each type of rocket to the FAA at least 45 days before the proposed operation. The FAA may request additional information if necessary to ensure the proposed operations can be safely conducted. The information shall include for each type of Class 3 rocket expected to be flown:

(1) The information requirements of paragraph (a) of this section,

(2) Maximum possible range,

(3) The dynamic stability characteristics for the entire flight profile,

(4) A description of all major rocket systems, including structural, pneumatic, propellant, propulsion, ignition, electrical, avionics, recovery, wind-weighting, flight control, and tracking,

(5) A description of other support equipment necessary for a safe operation,

(6) The planned flight profile and sequence of events,

(7) All nominal impact areas, including those for any spent motors and other discarded hardware, within three standard deviations of the mean impact point,

(8) Launch commit criteria,

(9) Countdown procedures, and

(10) Mishap procedures.

7.1.2 NAR High Power Rocket Safety Code

Certification. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.

1. Materials. I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.
2. Motors. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.
3. Ignition System. I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the “off” position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.
4. Misfires. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher’s safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.
5. Launch Safety. I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.
6. Launcher. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation

from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.

7. Size. My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.
8. Flight Safety. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.
9. Launch Site. I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).
10. Launcher Location. My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.
11. Recovery System. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.
12. Recovery Safety. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.

Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors

Figure 23: Minimum Distance Table

MINIMUM DISTANCE TABLE

Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 — 320.00	H or smaller	50	100	200
320.01 — 640.00	I	50	100	200
640.01 — 1,280.00	J	50	100	200
1,280.01 — 2,560.00	K	75	200	300
2,560.01 — 5,120.00	L	100	300	500
5,120.01 — 10,240.00	M	125	500	1000
10,240.01 — 20,480.00	N	125	1000	1500
20,480.01 — 40,960.00	O	125	1500	2000

7.2 Launch Checklists

OCRA's Launch Checklist, this checklist will be refined further into the season, and as problems arise.

7.2.1 Launch Pad Inspection

- ☐ Perform visual inspection of the launch pad before moving the launch vehicle onto the pad. Ensuring the launch pad is clear of debris and is properly mounted and secured onto the ground.
- ☐ Perform inspection of the launch vehicle to ensure there is no damage or loose components.
- ☐ Ensure that each component of the launch vehicle airframe is attached by shear pins and/or screws
  - ☐ Shear pins and/or screws between payload and recovery bay at payload bay coupler
  - ☐ Shear pins and/or screws between nose cone and payload bay

    - ☐ Shear pins and/or screws between airframe sleeve to protect payload electronics
- ☐ Ensure the payload deployment motor is set to the “locked position”
- ☐ Place the launch vehicle onto the launch rail; ensure the launch vehicle is secure before releasing the launch vehicle.
- ☐ Ensure the launch vehicle’s payload components are turned on and connected.
    - ☐ Ensure that the altimeters are connected and on
    - ☐ Ensure the flight computer is on and connected
    - ☐ Ensure the radio is connected and on
- ☐ Adjust the angle of the launch rail to ensure the launch vehicle launches to an apogee of 5,280 feet
- ☐ Complete final visual inspection of the launch pad and the launch vehicle to ensure all components are not damaged and in working order before moving onto motor and igniter installation.

7.2.2 Final Launch Prep and Igniter Installation

- ☐ Inspect the igniter for damage, imperfections, cracks and ensure it has proper electrical resistance.
- ☐ Feed the igniter carefully into the motor cavity until it reaches a hard stop against the propellant grain
- ☐ Mark the point on the igniter wire where the igniter tip hits the of the propellant grain
- ☐ Take the igniter out and make a loop at that marked point
- ☐ Reinsert the igniter into the motor
- ☐ Place the nozzle cap on the motor nozzle
- ☐ When properly cleared with the safety officer and NASA officials for the launch, place the launch lead clips onto the igniters. Make sure to maximize the amount of contact on the leads by wrapping the wire around the lead clips to reduce the chance of ignition failure from lack of proper contact.

7.2.3 Flight Procedure

- ☐ Wait for clearance from the RSO to launch
- ☐ Ensure all personnel are at a minimum of 300 feet away from the launch pad in accordance with NAR regulations for complex rockets.

- ☐ Ensure all persons nearby are alert to the fact the range is hot and launch is imminent
- ☐ Give countdown and execute launch command
- ☐ Ensure all persons in vicinity of launch are aware of the launch vehicle location in case of a recovery system failure or flight path deviation
  - ☐ If any team member notices a recovery event (drogue or main deployment), they should alert the other team members of said event and point in the direction of the launch vehicle.
- ☐ Wait for the range safety officer to give the all-clear for vehicle recovery so that the designated retrieval team may track down the launch vehicle and payload.

7.3 Social Media Presence

OCRA has a team instagram account with the handle, “oconeerocketry”. This instagram account was made to promote all fundraising endeavors as well as to keep members of our community informed. All fundraising events will be posted on the instagram account. Also any updates with team progress will be posted as well. The team instagram will help engage members of our community, so our team can have the support we need.

WARRIOR ONE

20 25

WARRIOR ENGINEERING NASA SLI TEAM

NASA UNIVERSITY STUDENT LAUNCH

PRELIMINARY DESIGN REVIEW

Preliminary Design Review

Section 1: Summary of PDR Report

1.1 Team Summary

School Name	Oconee County High School
Mailing Address	2721 Hog Mountain Rd, Watkinsville, GA, 30677
Team Name	Oconee County Rocketry Association
Project Title	Project RANCH
Project Lead	Campbell Patterson : cpa11549@oconeeschools.org
Safety Officer	Zoe Steckel: zst55770@oconeeschools.org
Team Mentor Information	Armando Rodriguez <armandorod60@aol> Certification Level: HPR Level 3 NRA #: 89194
Adult Educators	Bradley W Sayers bwsayers@oconeeschools.org
NAR	NAR Section #112382
Indication of Plans in Huntsville	We will launch our rocket and collect data through a radio band that will send data to the NASA ground base receiver in person on launch week.
Time Spent	8 people, average 5.5 hours each, total 44 hours.
Social Media Info	Instagram: @oconeerocketry Twitter: @ochsengineering

1.2 Launch Vehicle Summary

Official Target Altitude	4200 ft
Possible Motor Choices	K695-P By AeroTech and HP-K535W By AeroTech

Size and Mass of Individual Sections	Upper Section Airframe: 38 inch, 557.62g Payload Section: 18 in, 1,311.96g Booster Section: 48 in, 2796.348g
Recovery System	Main Parachute: 60” with 7.75” Vent Hole, Ripstop Drogue Parachute: 18” with 2” Spill Hole, Nylon Swivels: Stainless steel rated for up 25lb rockets Quicklinks: ⅛” Stainless Steel Shock Cords: ⅝’ tubular Nylon

1.3 Payload Summary

Payload Title	MAYO
Summarize Payload Experimental Data	Data includes: maximum velocity, apogee, and time landing. This data will be transmitted on the 2M radio band to the NASA ground based receiver when the rocket hits the ground.

Section 2: Changes Made Since Proposal

2.1 Adjustments to Team Membership

Since the proposal stage, we have added several members to the team in order to help manage the increased workload we have.

Additional members include:

- Cashton Isaac
  - cis27516@oconeeschools.org
- Emily Peng
  - epe35768@oconeeschools.org
- Sihoo Kim
  - ski38441@oconeeschools.org
- Benjamin Sayers
  - bsa15830@oconeeschools.org
- Christina Rabon
  - cra11538@oconeeschools.org

OCRA has also removed members Malcolm and Samuel Cohen from the original team due to lack of effort.

2.2 Changes made to Vehicle Criteria

- In order to compensate for the projected weight of our rocket, we are going to change the target altitude from the original one-mile (5280 feet) to 4200 feet. This should be easier to achieve because our rocket is relatively heavy as it is, and it will allow us to reach the ground before the maximum descent time is hit.
- Due to shortages of propellant, rocket motors are hard to come by as of now. In order to ensure that we will be able to have easy access to motors, we no longer plan on using single-use motors. Instead we will use a reloadable motor. Reloadable motors do not sacrifice quality for convenience, and thus we decided that they would be a more reliable purchase considering the lack of propellant in stock across the industry.

2.3 Changes made to Payload Criteria

- Originally, we planned on transmitting all of the following data points: Max Velocity, Apogee Reached, Time Landing, Landing Velocity. We have decided to reduce the amount of data to maximum velocity, apogee, and time landing. This will make interfacing and receiving data easier.

2.4 Changes made to Project Plan

- Funding, being a crucial issue, has led us to more needs. We have had to come up with a plan to have the correct amount of funding needed to be able to shoot a good amount of trials into the air. We have also found every part that we currently plan on using for the Launch Vehicle allowing for a more precise funding plan.
- Sponsorships have been added since material prices have rounded total costs to a larger amount.
- Our apogee was lowered from 5,280 feet to 4,500 feet to better accommodate the motors available to us.
- We eliminated the focus on the orientation of the STEMnauts and instead chose to focus on only three data values to record: maximum velocity, apogee, and time landing.

Section 3: Vehicle Criteria

3.1 Selection, Design, and Rationale of Launch Vehicle

3.1.1. Mission Statement and Mission Success Criteria

Our mission is to design and build a rocket that, while following all the criteria outlined in the SLI challenge, reaches an apogee of 4200 feet and transmits specific data back to the operators on the ground. In the event of a launch, certain criteria need to be met in order for the launch to be considered successful. These criteria include:

- The vehicle must operate in a completely safe manner and follow all guidelines and regulations put forth by SLI
- The rocket must reach apogee at or close to the intended altitude of 4200 feet
- While in flight, certain data will be transmitted back to the ground receiver. This data could include, but is not limited to, apogee, velocity, time to apogee, time to land, temperature, air pressure, etc.

3.2 System Level Design Review

3.2.1 Booster Section Design

The primary design of our booster section, outlined in the proposal, is composed of a K850-P motor, carbon fiber airframes, aluminum fins, and aluminum bulkheads. One concern that we have with these materials is that they may be too heavy, making it difficult for the rocket to reach our intended apogee.

3.2.2 Booster Section Alternatives

If this is the case, one alternative would be to use lighter materials. For example, we may use cardboard tubing as opposed to carbon fiber airframes. Aluminum is also a relatively heavy material, and the aluminum bulkheads could be substituted for MDF.
Another potential alternative design for the booster section would be to change the design and material of the fins. Our primary design incorporates trapezoidal aluminum fins. One alternative to this would be to increase the surface area of the fins and use Delrin, which would be lighter weight and create more stability.

3.2.3 Booster Section Pros and Cons

For our primary booster design, there are several pros that led us to choosing that design. For example, the materials we chose are extremely durable and the wear that occurs on each launch will be at the very most insignificant. Another advantage of our booster section is that its overall design errs on the side of simplicity, meaning that fewer problems are likely to occur during the manufacturing/construction phase of our rocket. However, our primary design has cons as well, the largest concern being the weight of materials. Another con with this design is that since it incorporates aluminum, we will have to use off-campus resources (a local company has agreed to partner with us to help manufacture our aluminum parts) and thus not all parts will be able to be manufactured in-house.

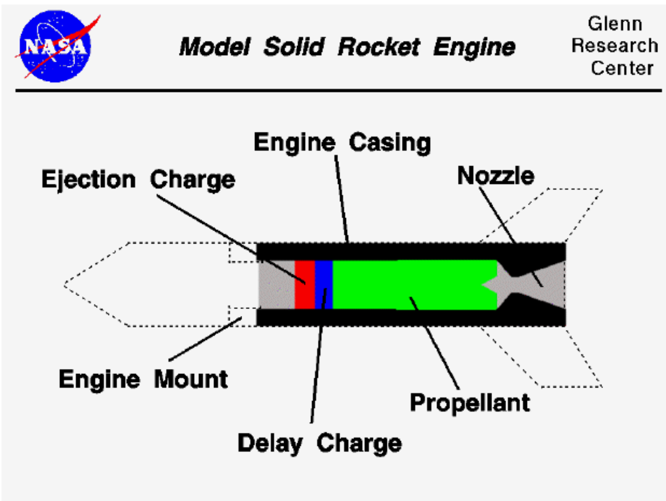
For our alternatives, there are also several pros and cons which were alluded to in the previous section. By exchanging aluminum and carbon fiber for lighter materials such as MDF and cardboard tubing, we sacrifice durability for weight. If this design is implemented, it will be of concern that the rocket could wear in-flight, especially considering the high temperatures and forces that the vehicle will experience. However, material costs and difficulty to use materials would be much lower with these materials.

If we were to exchange our trapezoidal aluminum fins for Delrin ones with a greater surface area, we would gain stability while cutting weight. However, the rigidity of the aluminum is advantageous because the torsion and flexing that can occur in a lighter material such as Delrin could affect the rocket. One possible issue with this alternative would be that the rocket could become overstable.

3.2.4 Booster Section Research and Feasibility

The motor is the primary component of the booster section, and thus the research will focus on it.

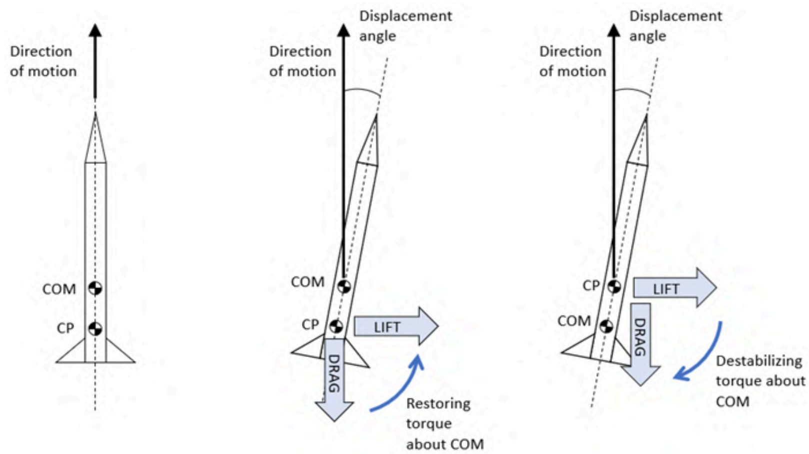
Figure 24: Rocket Motor Diagram



The image above displays a simple diagram of a typical motor. In general, the motor functions in the following manner: the propellant, delay charge, and ejection charge are packed into the engine casing. When the propellant is ignited using an electrical charge or heat source of some sort, the propellant burns and expands, causing pressure in the engine to be released through the nozzle, which is designed to accelerate the hot gas moving through it. The action of this gas being pushed out of the nozzle results in the equal and opposite reaction of thrust forcing the rocket into the air. Once all of the propellant has been burned through, there is no longer any thrust on the rocket and the rocket will decelerate until reaching apogee. Simultaneously, the delay charge has been ignited and is being burned through. Usually the delay charge lasts between 2 and 8 seconds. After the delay charge, the ejection charge is ignited and causes a small explosion which sends hot gas out of the front of the engine mount. This is used to separate the rocket and deploy the parachute.

In addition to the motor, the fins are also included in the booster section. Fins create stability in a rocket in the same way that fletching (feathers) create stability in archery.

Figures 25-26: Drag Diagrams



In the image above, the rocket is being displaced from the intended direction of motion. This happens due to a number of reasons, such as changes in air pressure during ascent, changes in the wind, and destabilizing torque. As the displacement angle of the rocket changes, the fins create drag in the opposite direction. The greater the surface area of the fins, the more drag and stability the rocket will have. If the fins of a rocket are too small, then the rocket will be likely to tip because there is a low drag force from the fins to resist displacement. However, if the fins are too large and the rocket is overstable, it is susceptible to "weathercocking," where wind causes the rocket to travel in an arc rather than the ideal straight up and down. Generally, if the stability factor of a rocket is greater than 2.00, it is considered overstable.

3.2.5 Recovery System Design

Our rocket will utilize a dual deployment recovery system. Our recovery system will be driven by our dual flight computers. When our rocket reaches apogee the primary flight computer will send an electric charge into the primary black powder cell. This will ignite the black powder and blast the bottom section off of the rocket. This process will deploy our 30 inch drogue parachute. Under this parachute, our rocket will fall at approximately 50 to 70 ft per second. If the primary flight computer fails to blast the drogue chute out at apogee, our secondary flight computer will send a second charge one second later to a second black powder blast cap. Our rocket will then descend on the drogue parachute until it reaches an altitude of 1,000 feet. At 1,000 feet our primary flight computer will send an electric charge to the upper black powder blast cap which will shear the upper section of our rocket off. This process will deploy our 72 inch main parachute. On this parachute, our rocket will descend at approximately 17 feet per second all of the way down to the ground. In the case that our chute does not deploy at 1,000 feet our secondary flight computer will send a second charge to a second blast cap at

800 feet to ensure that our main chute is deployed well above the 500 foot minimum. All Sections of the rocket will be tethered to the parachute by tubular kevlar rope between 7/12 and ½ inches in size.

3.2.6 Recovery System Pros and Cons

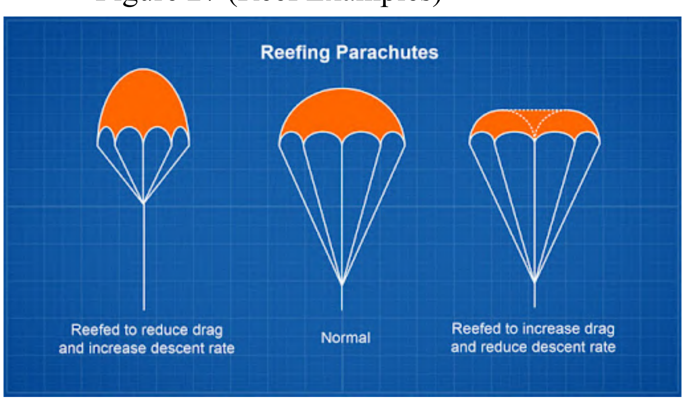
There are several pros and cons of our current recovery system design. The two parachute system is designed to reduce drift during descent, making the rocket safer. Also, it is logical to split the rocket twice to deploy multiple parachutes because per SLI requirements the rocket must have 4 individual sections that come apart during flight. Having multiple parachutes to deploy makes this more achievable. However, since the second parachute's deployment requires electrical components to be programmed and installed, this design is not as simple as it could be. Also, using two parachutes is heavier than using one.

Alternatively, using one parachute is not only lighter, but it also only relies on one deployment using a delay charge, meaning the design is simpler. However, a one parachute design will result in a single larger parachute that will likely lead to much greater drift than a two parachute design because of the slower descent.

3.2.7 Recovery System Research and Feasibility

Parachutes are relatively simple in comparison to many other aspects of the rocket, however they are still extremely important. Parachutes must be folded and packed into the rocket carefully in order to ensure that the parachute will not be tangled in the shock cords. Our parachutes are made of nylon, largely because of its strength, durability, and lightweight characteristics. The shape and design of parachutes can impact how they perform. For example, parachute "reefing."

Figure 27 (Reef Examples)



The image above displays how different parachutes can be reefed to alter the effective surface area of the parachute. That is, although the three parachutes shown above may have the same surface area when lying flat, the effective surface area can be increased or decreased based on how the parachute is reefed. This can be used to control the acceleration of the rocket after parachute deployment and to slow down the inflation of the parachute. If a parachute inflates too quickly, it can cause stress on the tether and/or cause the recovery system to malfunction.

3.2 Recovery/Decent Data

Table 13: Recovery/Decent

	Drogue Parachute	Main Parachute
Parachute Size	18 Inch	60 Inch
Drag Coefficient	1.5	2.2
Drogue Deployment Altitude	Apogee(4,200 ft) + 2 seconds	n/a
Main Deployment Altitude	n/a	700 ft
Kinetic Energy at Deployment	952.26 ft*lbs	68.44 ft*lbs
Rate of Descent	70.50 ft/s	16.5 ft/s
Blast Cap Load	1.60g	2.15g
Landing Kinetic Energy	N/A	2,283.1

3.2.9 Blast Cap Design

The blast cap system on our rocket is crucial to the success of the recovery system. The blast caps will be made out of brass Pex fittings. These fittings provide a brass cavity that will be loaded with the correct amount of black powder. The black powder will be ignited by an e-match that is placed inside of the blast cap. This e-match will receive an electronic charge from the flight computer that has its own independent 9 volt battery.

3.2.10 Altimeter

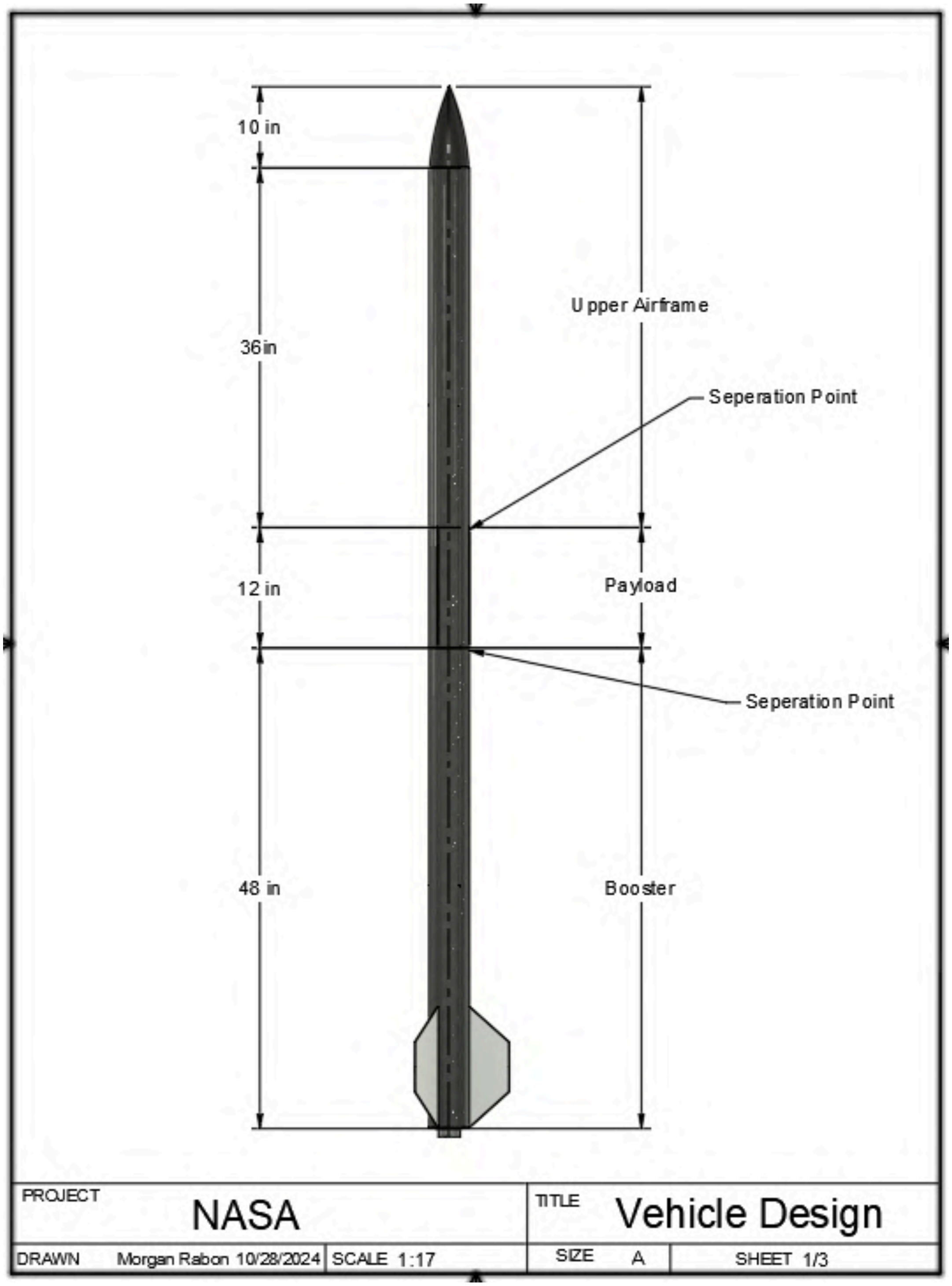
The altimeter system that will control the blast cap discharge is integrated into the flight computer that will be used on the flight. This flight computer, the Telemega produced by Altus Metrum, will serve as the source to power the blast cap. The main flight computer will be backed up by a secondary flight computer also produced by Altus Metrum. For the purposes of deployment, the drogue chute will deploy at apogee, with the back up being 2 seconds after that, and the main chute will deploy at 700 feet with the back up being at 600 feet. Both altimeters are powered by independent 9V batteries.

3.3 Vehicle Design with Current Leading Alternatives

Our current vehicle is designed around two air frames that will compose the main exterior of the rocket. The nose cone caps the upper payload airframe, which will contain the altimeter bay and the drogue chute. The lower airframe contains the motor and main chute. In our current design, the drogue chute will deploy after the ejection charge separates the rocket at the transition between airframes. One alternative to this is to only separate the nose cone from the rocket and deploy the drogue chute from there. However, this requires us to redesign the rocket, and we decided that this alternative likely does not have enough advantages to justify spending time redesigning our vehicle.

3.3.1 Dimensioned Drawings

Figure 28: Dimensioned Rocket Drawing



3.3.2 Estimated Mass

Table 14: Part List

Part	Qty	Mass Singular (Grams)	Mass Total (Grams)
Nose Cone	1	96	96
60" Parachute	1	151.664	151.644
QuickLink	1	8.5	8.5
Nomex Cloth	1	40	40
Swivel	1	22.679	22.679
Shock Cord *	8	0.08	6.4
Lower Bulkhead 1	2	117.402	234.804
Upper Air Frame *	1	230	690
94435A325	2	130.158	260.316
Upper Airframe Cover Bulkhead	2	80.416	160.832
Coupler 1 *	2	238.14	476.28
Outer Airframe 1 *	1	230	230
Micropeak Altimeter	1	0.7	0.7
Telemega Flight Computer	1	24.95	24.95
2 Meter BLGPs radio	1	25	25
Permanent Payload Panel	1	38.773	38.773
Removable Payload Electronics Panel	1	35.839	35.839
90012A240	7	1.595	11.165
9V Battery	3	22.5	67.5
Nomex Cloth	1	12	12
Drogue Parachute	1	10	10
Swivel	1	22.679	22.679
QuickLink	1	8.5	8.5
Shock Cord *	8	0.08	6.4

94435A361	6	4.315	25.89
Retaining Ring Set	1	64.5	64.5
Motor Tube *	1.8333	170.89	313.292637
Sheet Metal Fin Mounts	3	128.2	384.6
Center Rings	3	70	210
3035T11	3	25.587	76.761
Thrust Plate	1	83	83
Trapezoidal Fin Set	3	124.667	374.001
Lower Airframe *	4	230	920
TOTAL MASS			4997.005

* These are calculated at Grams per ft. Meaning that the QTY = how many ft

3.3.3 Justification for Design Selections

Our team has justified the initial design of our rocket based on the simulation data that exists below. After researching and reviewing all of the alternatives, we believe that we have chosen the best materials and design to produce a safe and efficient rocket. This design will complete all of the things that we are requiring of it and do it in a safe manner.

3.3.4 Motor Options

Motor Type	Velocity Off Rod	Apogee	Velocity at Deployment	Time to Apogee	Max. Velocity	Max. Acceleration	Flight Time
K695R-P	57.6 ft/s	4331 ft	67.3 ft/s	15.9s	633 ft/s	397 ft/s^2	110 s
HP-K535W-P	52.5	4175 ft	67 ft/s	15.9s	586 ft/s	279 ft/s^2	109 s
K2050ST-P	98.1 ft/s	4099 ft	67.8 ft/s	14.9 s	669 ft/s	1052 ft/s^2	105 s
K805G-P	61.2 ft/s	5183 ft	67.8 ft/s	17 s	735 ft/s	422 ft/s^2	122 s

3.3.5 Motor Selections and Data

OCRA decided to not use motors K2050ST-P and K805G-P for various different reasons. K805G-P went largely above OCRA's new desired Apogee, which automatically put it out of the running. It was also far from the desired time constraints from parachute deployment, meaning the descent time from recovery deployment would be too long. The next motor that OCRA stimulated using OpenRocket was K2050ST-P which had the opposite problem of K805G-P which was the apogee using K2050ST-P was entirely too low for our desired apogee that OCRA wants. OCRA decided to put both HP-K535W-P and K695R-P because the were reasonably close to the desired apogee OCRA has set for the Launch Vehicle to reach with minimal new designs.

3.4 Mission Performance Predictions

3.4.1 Official Target Altitude(Ft)

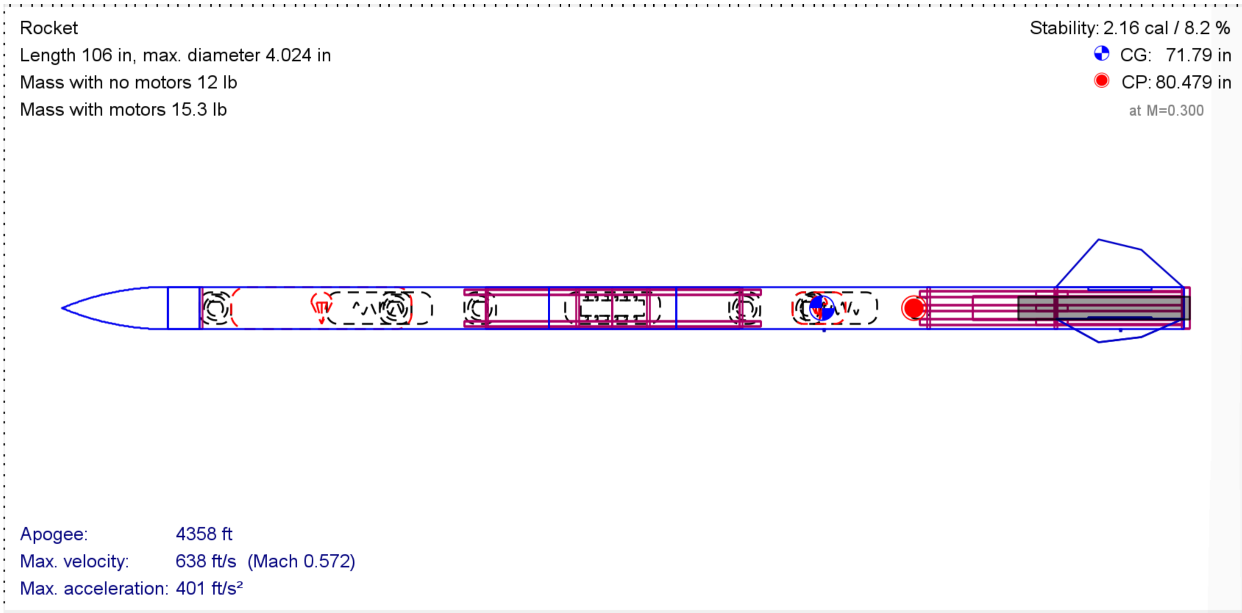
The target apogee for project RANCH will be set at 4200 feet. With the parameters of 4000 to 6000 feet we determined that 4200 feet would be a reasonable target altitude with our team being limited to nothing more than k sized motors.

Table 15: Target Data

Parameter	Value
Target Apogee	4,200 feet
Stability margin	2.25 cal
Velocity off Rail	56 ft/s
Maximum Velocity	625 ft/s
Drogue Parachute Deployment	2 seconds after apogee
Main Parachute Deployment Altitude	700 feet
Maximum Landing Kinetic Energy	65 foot-pounds at most per section
Decent Time	80 seconds

3.4.2 Flight Profile Simulation

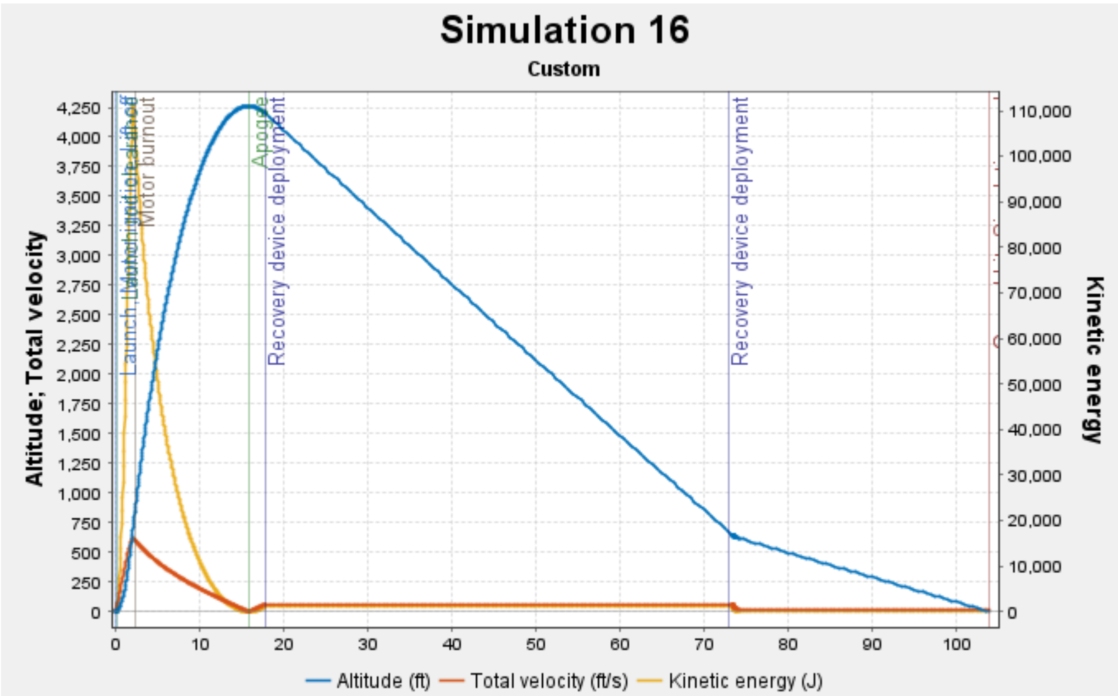
Figure 29: Open Rocket Rocket



This is a model of the rocket that we created to meet the parameters listed above. The rocket with a K695R-P will get up to 4,358 feet and reach a max velocity of 628 ft/s. The rocket is 106 inches long with a diameter of 4.024. The rocket should weigh 12 lbs without the motor and 15.3 lbs with the motor.

3.4.3 Simulations

Figure 30: Open Rocket Simulation



In this simulation we pass the parameter of 4,200 feet and the drogue parachute is deploying 2 seconds after apogee. The main parachute also deploys close to the targeted 700 feet for deployment.

3.4.4 Component Weights List

Table 16: Upper Airframe

Component	Material	Mass (lbs)
Nose Cone	PETG	0.432
Bulkhead	Al 3003	0.187
Forged I bolt	Steel	0.057
Outer Airframe	Carbon Fiber	1.52
48” Parachute 2.2Cd	Nylon Ripstop	0.45
Recovery Hardware: Nomex Quicklink Swivel	Kevlar, Steel	0.118
⅝” Tubular Nylon Shock Cord 30ft.	Nylon	0.461
	TOTAL	**3.23 lbs**

Table 17: Payload

Component	Material	Mass (lbs)
12” length 4” diameter airframe	Carbon Fiber	0.507
12” length 4” airframe coupler X2	Carbon Fiber	0.56
U-bolt X2	Aluminum	0.114
Payload Bulkhead X2	Al 3003	0.354
Payload Centering Ring X2	PLA	0.114

Threaded Rods X2	Aluminum	0.0574
Electronics Bay: Altimeter/ Flight CPU Batteries Stemnauts Switches	MDF, electronic components	0.399
	TOTAL	**2.11 lbs**

Table 18: Lower Airframe

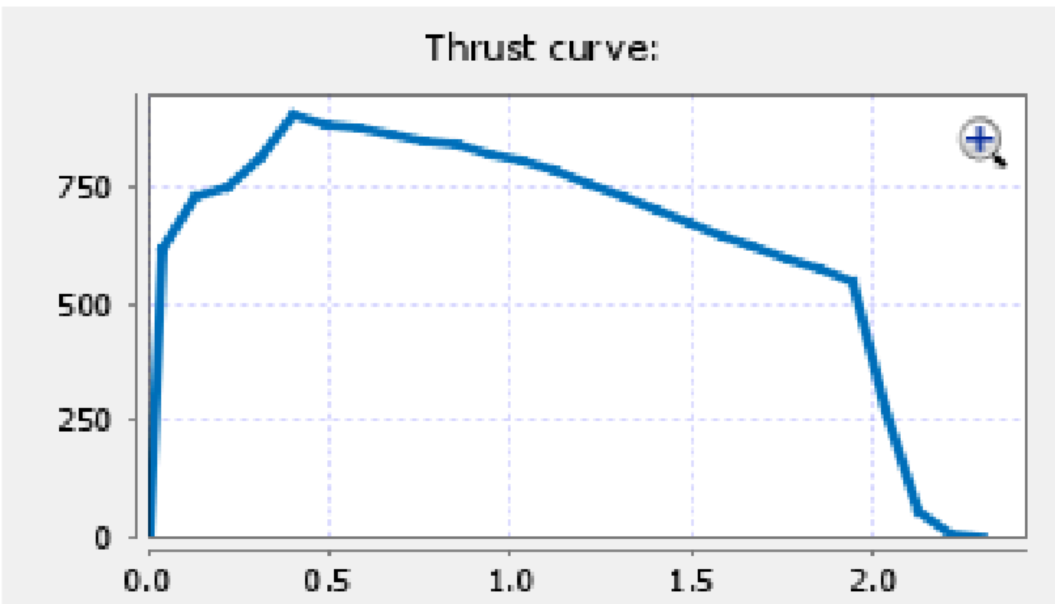
Component	**Material**	**Mass (lbs)**
48” length 4” diameter airframe	Carbon Fiber	2.02
30” length 4” diameter motor tube	Fiberglass	0.858
Trapezoidal fin set	Al 3003	0.656
Centering ring X2	Al 3003	0.308
Thrust Plate	Fiberglass	0.183
18” Drogue Parachute cd 1.5	Ripstop Nylon	0.033
Threaded Rods X6	Aluminum	0.906
Retaining Ring Set	Aluminum	0.142
Sheet Metal Fin Mounts	Al 3003	0.848
U-Bolt	Aluminum	0.057
⅝” Tubular Nylon Shock Cord 30ft.	Nylon	0.461
Recovery Hardware	Kevlar, Steel	0.118

Rail Button X2	Delrin	0.002
	TOTAL	**6.59 lbs**

3.4.5 Motor Thrust Curve

Our primary motor, K695R-P, has a motor trust shown in the graph below

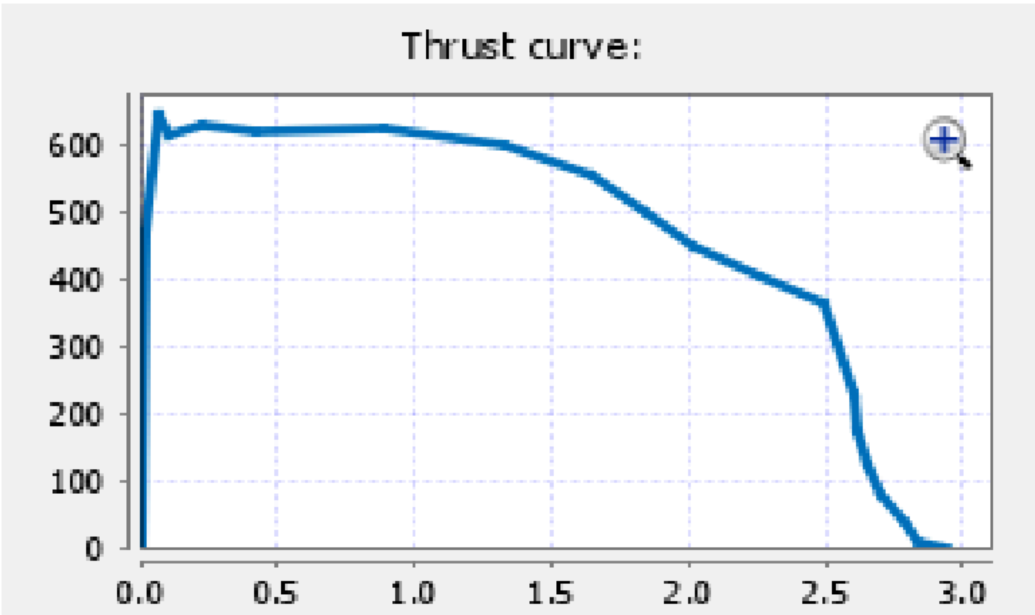
Figure 31: K695R-P Thrust Graph



The K695R-P motor has a gradual drop off starting around 0.75 seconds and the drop off increases significantly around 2 seconds. This results in most of the force being applied after 2 seconds.

Our secondary motor, HP-K535W, has a motor thrust shown in the graph below

Figure 32: HP-K535W Thrust Graph



The HP-K535W motor starts its gradual drop off earlier at around 0.18 and increases earlier as well at 1.65 seconds. This results in a greater amount of force being applied for longer.

With this data the K695R-P motor would fit our needs better because it applies a lesser amount of force for a shorter amount of time. Also, with the K695R-P motor, the rocket lands quicker than the HP-K535W motor.

3.4.6 Stability Margins

Below is a list of the stability of the rocket with the motors we have selected. The simulations are based on data from OpenRocket.

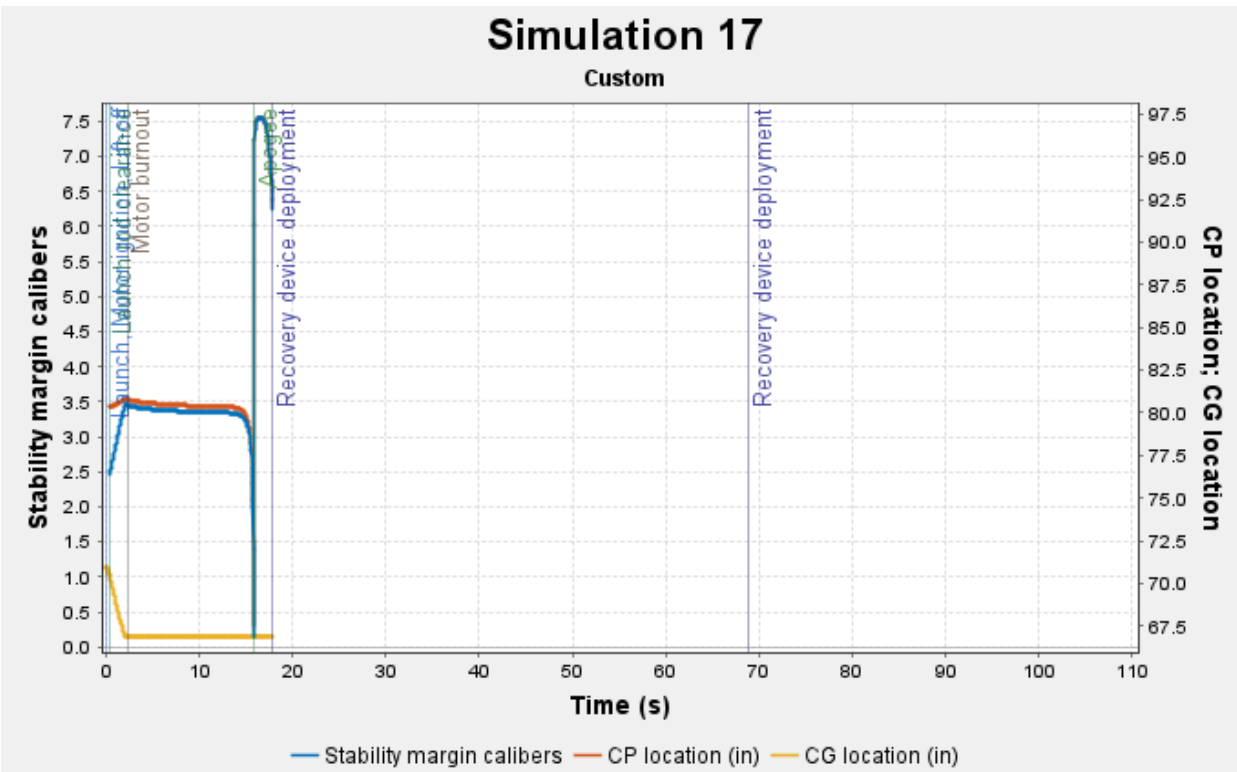
Table 19: Center of Gravity, Center of Pressure, and Stability Margin

Configuration	Center of Gravity (in)	Center of Pressure (in)	Stability Margin (cal)
No motor	63.67	80.48	4.18
AeroTech K695R-P	71.01	80.48	2.35

Aerotech HP-K535W	70.30	80.48	2.53

Image showing the initial center of gravity and pressure in relation to the rocket can be found in section 6.1.8. These values change as the motor burns out. Below is a graph that plots these values in comparison to key flight events.

Figure 33: Stability Simulation



At launch the stability is around 2.4 cal. for both of our primary and secondary motor choices. For a majority of our flight our stability is above 3 cal. however it drops off as the apogee approaches. The stability is closely related to the center of pressure of the rocket.

3.4.7 Estimated Descent Time and Kinetic Energy

Using OpenRocket simulations, we have determined that our terminal velocity is around 70.85 ft/s, with a separation point after the payload section. Splitting the rocket into these two sections, we get the following results for kinetic energy under the drogue parachute:

Table 20: Kinetic Energy under Drogue

Section	Mass (lbs)	Kinetic Energy (ft*lbs)
Upper	5.34	564.90
Lower	6.59	387.36

We feel that these values are reasonable given the overall mass of our rocket.

Using the results of our OpenRocket report, our landing velocity is 16.1 ft/s. Using this with the section masses of our rocket we can see the kinetic energy of each section is as follows:

Table 21: Masses and Kinetic Energy of each Section

Section	Mass (lbs)	Kinetic energy (ft*lb)
Upper section	3.23	26.68
Payload	2.11	13.92
Booster	6.59	27.84
Total (on landing)	11.93	68.44

The descent time on OpenRocket is estimated to be 89 seconds.

3.4.8 Wind Drift or Lateral Distance

For the drift calculations, OCRA chose to use Open Rocket simulation. The results of wind speeds is show below in a table

Table 22: Wind Drift

Wind Speed (mph)	Lateral Distance (feet)
5	480
10	1100
15	1840

20	2540

The maximum launch vehicle drift of 2540 feet occurs with wind speeds of 20 mph. We understand that this is high so if we ever launch in those conditions we would add mass to the rocket or use a smaller parachute to lower our descent rate. Because the simulation is on one axis so a difference in displacement corresponds with drift distance.

Section 4: Payload Criteria

4.1 Selection, Design, and Rationale of Payload

4.1.1 Payload Objective and Experimental Data

The payload on board of our rocket will collect a plethora of data about its performance over the course of the flight. Our rocket's systems will collect the rockets Max Velocity, Apogee Reached, Time Landing, Landing Velocity, STEMnaut Survivability and Orientation, and Battery Status. The payload must accurately collect this data and transmit that information back to the ground based receiver on the given radio frequency.

4.1.2 What is a Successful Mission

In addition to the successful flight of the rocket, a successful mission will be marked by the accurate collection of at least three of the data points. Those three of the proposed data points must be accurately collected and transmitted back to the ground based receiver per the competition regulation.

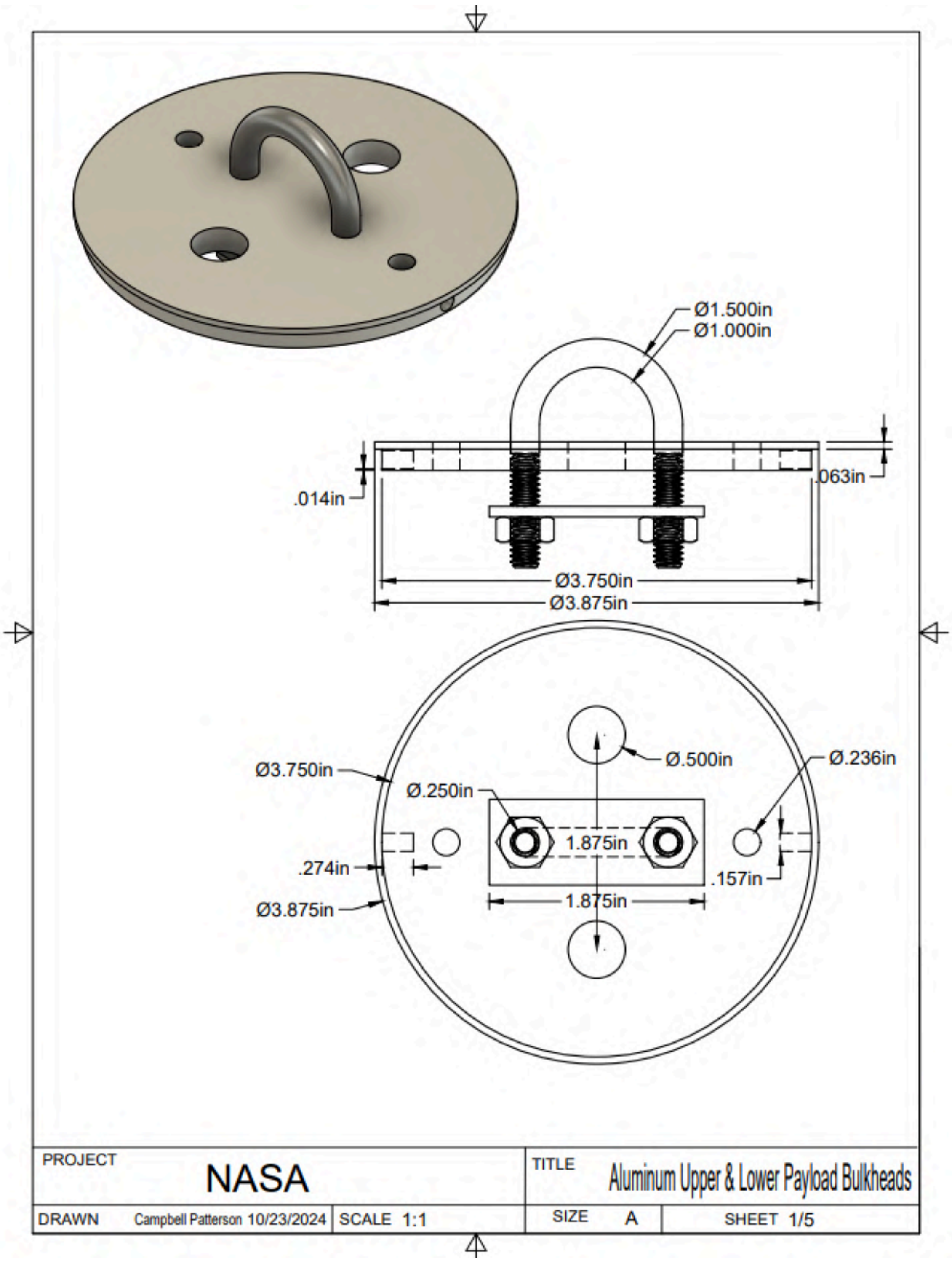
4.2 Payload System Level Review

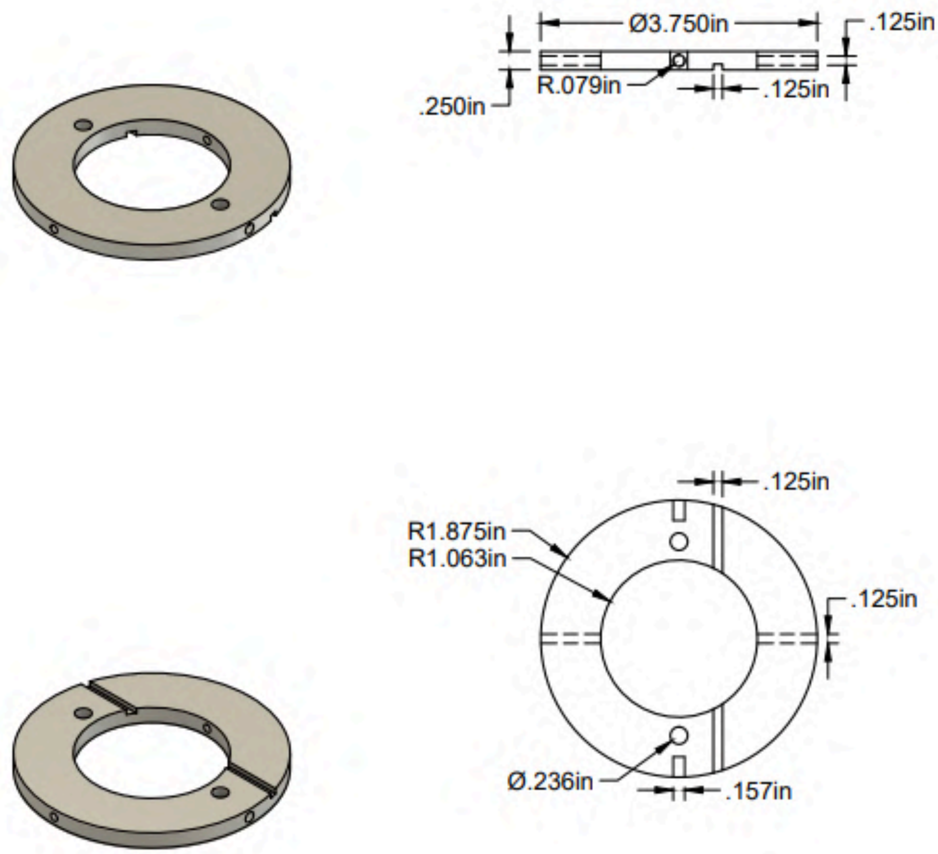
The payload is located in the upper airframe and will consist of the altimeter bay, which is described in section 4.3.1. The altimeter bay houses electronics and Stemnauts. In order to access the inside of the altimeter bay, one will need to unscrew the bolts that secure the two sides of the housing for the bay. Alternatively, we are considering a design that would allow us to slide the top half of the tube off, allowing easier access to the electronic components. Another alternative to the current design we have would be to exchange the carbon fiber tubing for a lighter material.

4.2.1 Structure and Bulkheads

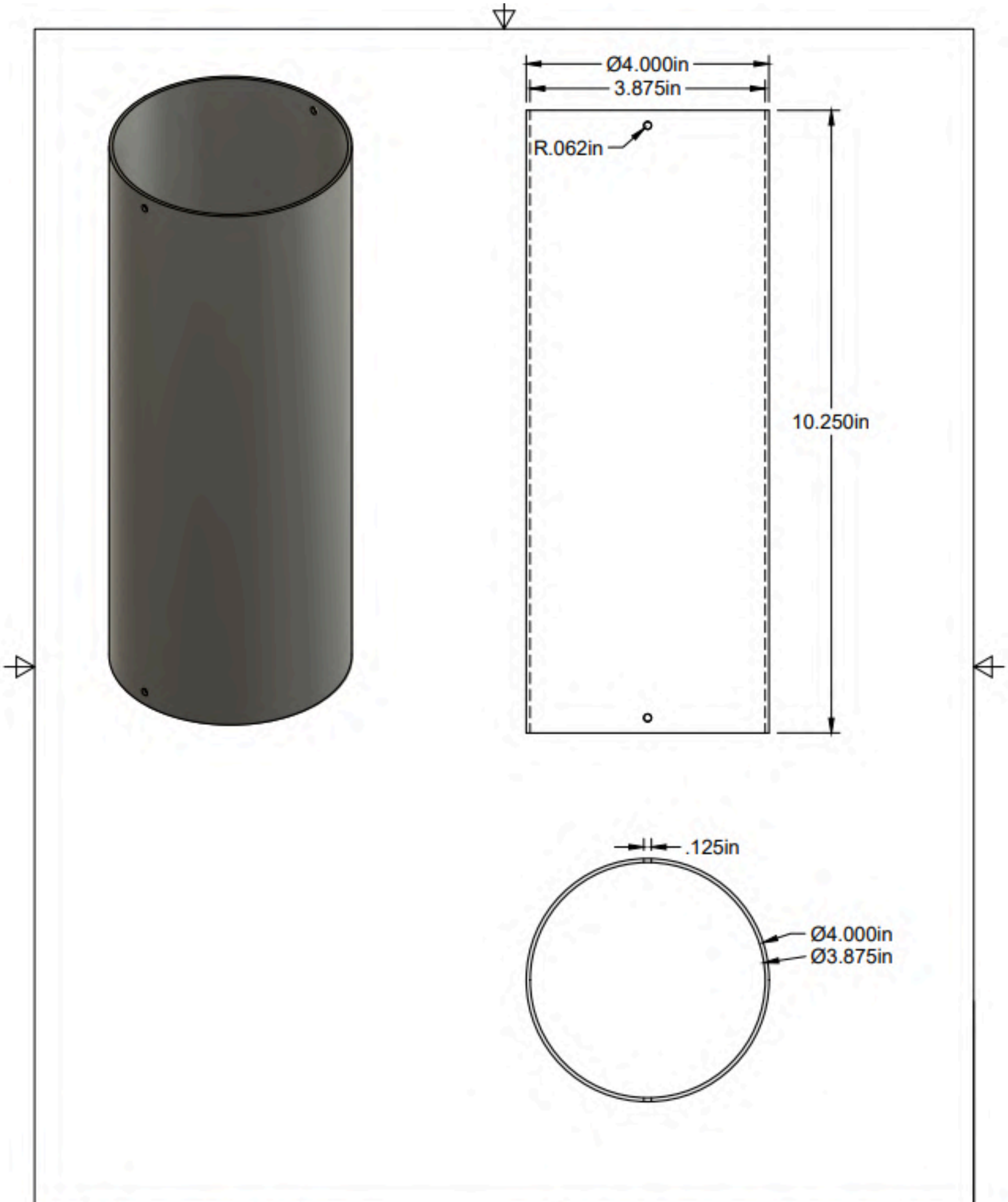
The payload will be constructed from a carbon fiber tube. The carbon fiber tube will fit inside of the outer airframe and stretch between the upper and lower sections of the main airframe. This tube will have bulkheads that divide the payload into sections as well as access holes to remove electronics and Stemnauts. The middle section will have a carbon fiber shoulder to receive the other sections of the airframe. The payload structure will be supported by two aluminum rods that run through the length of the payload. Those rods will determine the spacing between bulkheads and provide structural rigidity to the payload even during the most demanding parts of the flight. The payload bulkheads will be produced in multiple different materials. The larger bulkheads that will provide the most structural support will be made out of aluminum. Other interior bulkheads, that are used to separate out sections of the payload, will be made out of wood.

Figure 34-38: Airframe Drawings

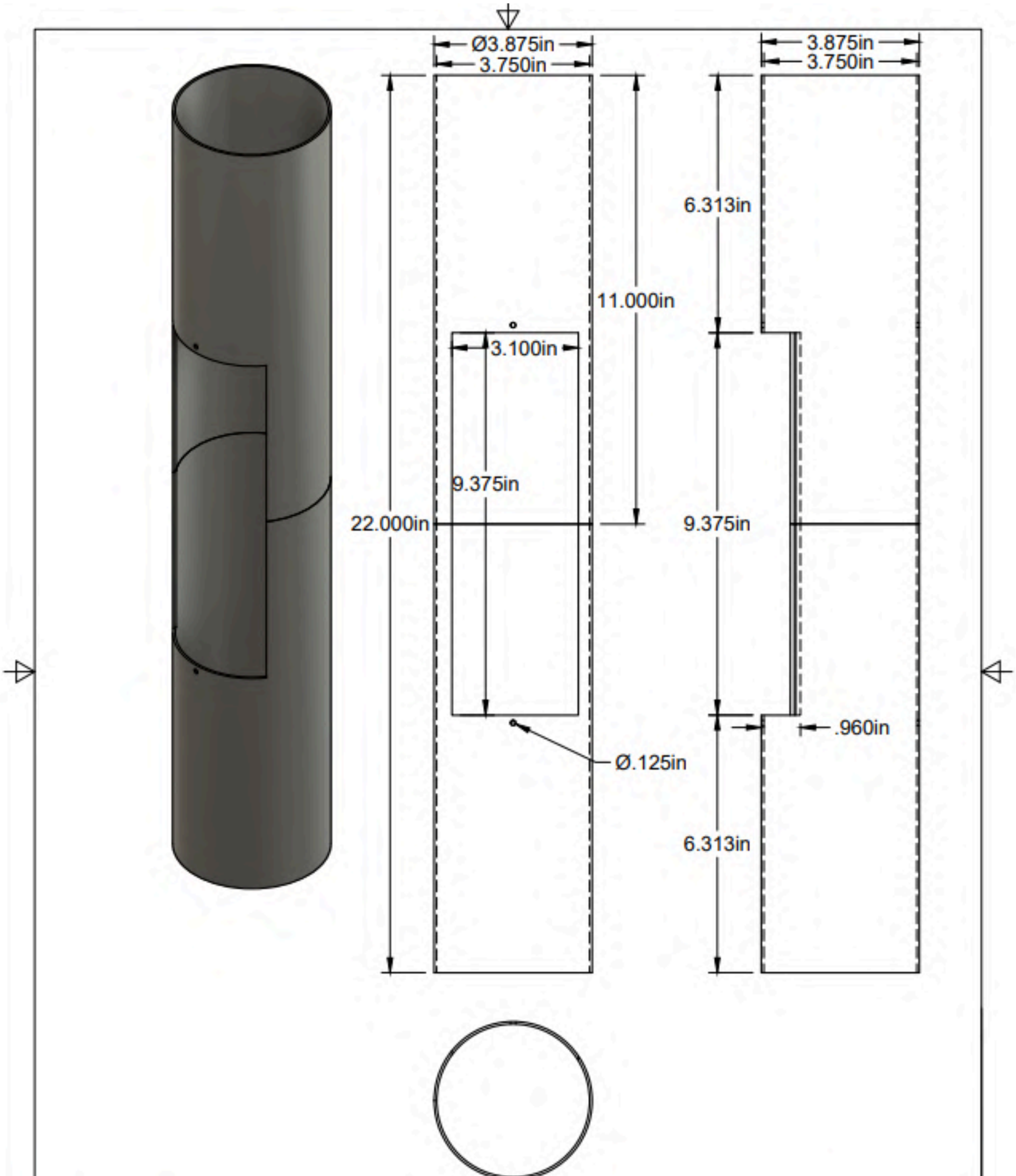




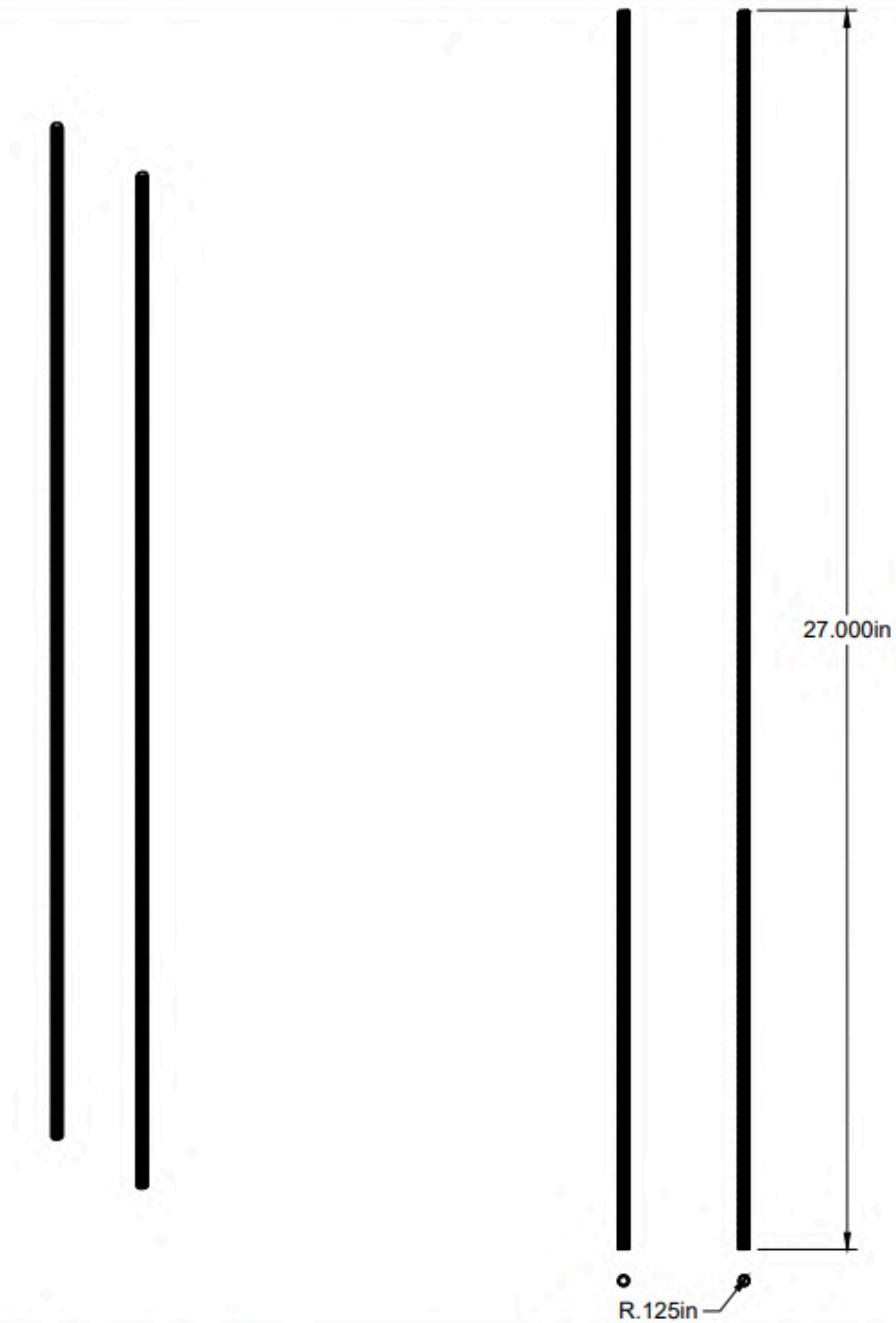
PROJECT NASA		TITLE PETG Payload Divider Bulkheads	
DRAWN Campbell Patterson 10/23/2024	SCALE 1:2	SIZE A	SHEET 2/5



PROJECT NASA		TITLE Carbon Fiber Payload Outer Airframe	
DRAWN Campbell Patterson 10/23/2024	SCALE 1:2	SIZE A	SHEET 3/5



PROJECT NASA	TITLE Carbon Fiber Payload Coupler
DRAWN Campbell Patterson 10/23/2024 · SCALE 1:3	SIZE A · SHEET 4/5



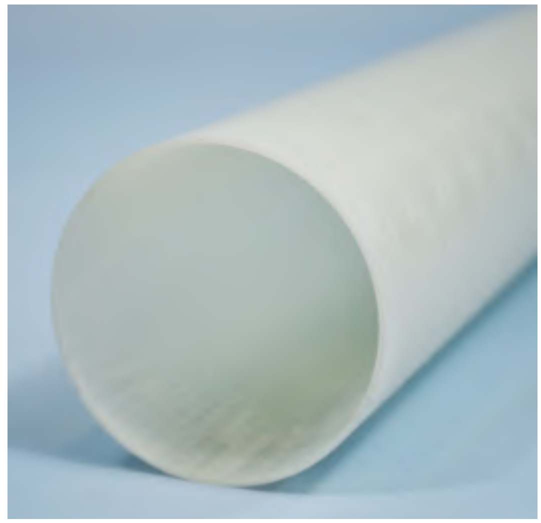
PROJECT NASA		TITLE Aluminum Threaded Rod	
DRAWN Campbell Patterson 10/23/2024	SCALE 1:3	SIZE A	SHEET 5/5

4.2.2 Structure and Bulkheads Alternatives and Feasibility

One of the largest concerns with our current proposed bulkheads is their weight. Aluminum, though it is a strong material, is also a bit more heavy than some other materials. Due to the weight requirements of our rocket, this means we must explore other materials for the bulkheads. If the aluminum bulkheads that are proposed wind up being too heavy there are other alternatives that we can turn to. MDF bulkheads can provide an easy to produce, cheap, and lightweight alternative to aluminum. These can be used if necessary to reduce weight. Further options include 3D printed bulkheads that can be produced in PETG or ABS Carbon fiber filament. These options provide an even lighter weight alternative and can provide another easy to produce and strong alternative. These bulkhead options both provide lower weight and easy to produce products, however they are not necessarily feasible for use in all sections of the payload. The upper and lower bulkheads will take on most of the strain of our descending rocket. This means that the materials would have to withstand the forces of the parachute. 3D printed options may not be able to hold this kind of weight. The MDF options are easy to produce but also offer us less flexibility. With thicker aluminum stock, we can produce a much more complex part than MDF would allow for. MDF is not a good option because it would cause many more design considerations to be changed in order to accommodate their constraints.

The outer airframe material is another section where alternatives may provide good insight. Our current carbon fiber tubes are very strong and create a high quality build. However, other options like fiberglass or cardboard tubes can be good options. Fiberglass and cardboard are both more budget friendly options and can be purchased in many different places. Fiberglass is also a very rigid material that can provide a very sturdy airframe. Cardboard is a good alternative because it is the lightest material that could be used. Fiberglass is not as good of an alternative because it is very heavy. This added weight could make us miss our target altitude. Cardboard, which is the lightest option, is also the least structurally sound of the options. Cardboard would not be a good alternative because it may not be able to withstand the forces of flight that it will be subject to on this flight.

Figures 39-41: Airframe Materials



4.2.3 Flight Computer and Electronics

The payload section will house the electronics bay for our rocket. The rocket will need a complex electronics system to successfully complete the flight and collect our experimental data. The electronics bay will house our flight computer, a Telemega flight computer produced by Altus Metrum, on the electronics sled. This computer will serve as the primary flight controller for the rocket. The electronics bay will also house our power source, two nine volt batteries, as well as our altimeter system, manufactured by Altus Metrum. The bay will also hold our radio transmitter that can transmit on the 2M radio bands. Our electronics payload will house everything that is needed to complete electronic communication on the rocket. The electronics layout will be optimized to produce the highest performing rocket possible.

Figures 42-44: Electronic Components

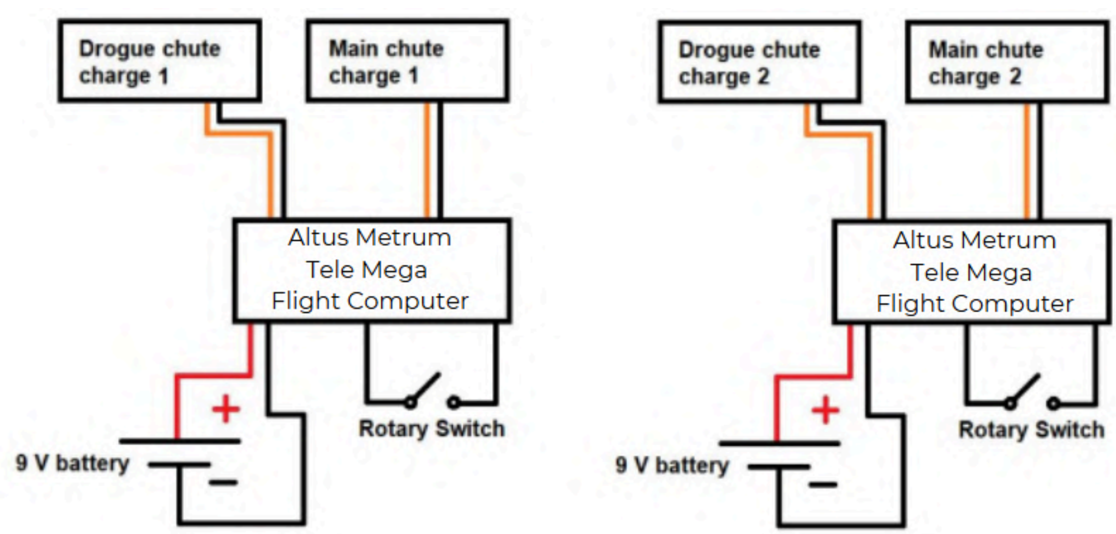
4.2.4 Flight Computer and Electronics Alternatives and Feasibility

The electronics are a key component to a successful flight. This level of importance means that we should choose the best electronics to install in our rocket. The flight computer that we have selected is very good, however it is expensive. In order to keep an eye on the price of our rocket, there are some less sophisticated alternatives that may be able to get the job done. The Easy mega flight computer, slightly less advanced than the telemega computer, is a slightly more affordable option. However, this option is less advantageous to us because it does not provide us with as much flexibility in other electronics options. In our current design we are powering the electronics system with 9V batteries. As an alternative we could change to LIPO batteries. These batteries would provide our system with much more power and can last for a longer time. However, they are also much heavier than the 9V options. Other issues with the LIPO batteries could include their tendency to be more volatile than 9V batteries.

4.2.5 Wiring Schematics

It is of utmost importance that the wires that travel throughout the payload are attached correctly. Each wire must be protected from outside interference and secured in position throughout the duration of the flight. To accomplish this we have mapped out exact wiring schematics that show where each wire comes from and terminates. Each wire will be held in place by zip ties that secure them to the electronics board.

Figure 45: Wiring Schematic



4.2.6 Black Powder Blast System

We will use a black powder charge of 1.6 grams for the drogue chute and 2.15 grams for the main chute. The black powder blast system utilizes brass pex fittings mounted on the bulkheads of the payload to blast the parts away. These blast caps will be ignited by an e-match that is set off by the flight computer. We used this formula to calculate the charge.

Figure 46: Black Powder Formula

$$Grams(BP) = \frac{454grams}{1lbf} \times \frac{Pressure(psi) \times Volume(inches^3)}{266\frac{inches\bullet lbf}{lbm} \times 3307 \circ R}$$

4.2.7 Black Powder Blast System Alternatives and Feasibility

There are certainly other options that exist in terms of deploying the parachutes on our rocket. The pex fittings that we are using are made of brass and are relatively heavy. We may explore other options for the vessel that could carry the black powder. Other options include a more mechanical deployment of the capsule. In replacement of a black powder system we could use a mechanical system that deploys the rocket. The problem with the mechanical system is that it is fairly underpowered and does not do as good of a job. The black powder system that we have selected is relativity proven and is most likely the best option. It is simple, powerful, and predictable.

4.2.8 Stemnaut Capsule

The Stemnaut capsule will be a subsection of the larger payload section of the rocket. Our Stemnauts will be housed on a removable sled that sits inside of our payload. The Stemnauts will be held permanently in place on their sled and all aligned in the same direction. This alignment will allow us to add more data like Stemnaut orientation into our data collection system. This capsule will be removable from the payload by the access panel located in the side of the payload section.

4.2.9 Stemnaut Capsule Alternatives and Feasibility

The Stemnaut capsule is a key part of our payload design. The current design has the Stemnauts in close proximity to many of the systems within the rocket. Some alternatives to the placement of the Stemnauts include the addition of a separated section for the Stemnauts. This could be accomplished by adding a bulkhead to our payload area that would separate the Stemnauts from the electronics. This is a feasible option however it is not ideal because it could add considerable weight to the center of our rocket. It would also create a much harder area to remove the Stemnauts from. Another alternative would be to add an entirely new bay in the rocket. This bay could be another section that is separate from the payload. In this section the Stemnauts would be much more accessible and would be in their own protected capsule. This capsule would be a good option however, it adds significant complexity to the recovery system. With a separate bay we would have to add a different recovery system in order to get all of the rocket parts back down to the ground. This design would also add significant weight as compared to both other alternatives.

4.2.10 Recovery System Integration

The recovery system is a key component to the success of our rocket. This subsystem also operates in close proximity to the payload. Our dual deployment parachute system will be connected to the payload on both ends. The top and bottom bulkheads of the payload, which are machined out of aluminum, each are equipped with a steel U bolt that's purpose is to connect to the parachute system. At the designated points in the flight, after the respective airframe has been blasted away, the U bolts will hold the weight of the rocket that is suspended from the parachute. These U bolts have enough strength to not only hold the weight of the rocket but also survive the tension that is placed on it when the main parachute deploys. These systems will provide a strong and stable descent for our rocket.

4.2.11 Recovery System Integration Alternatives and Feasibility

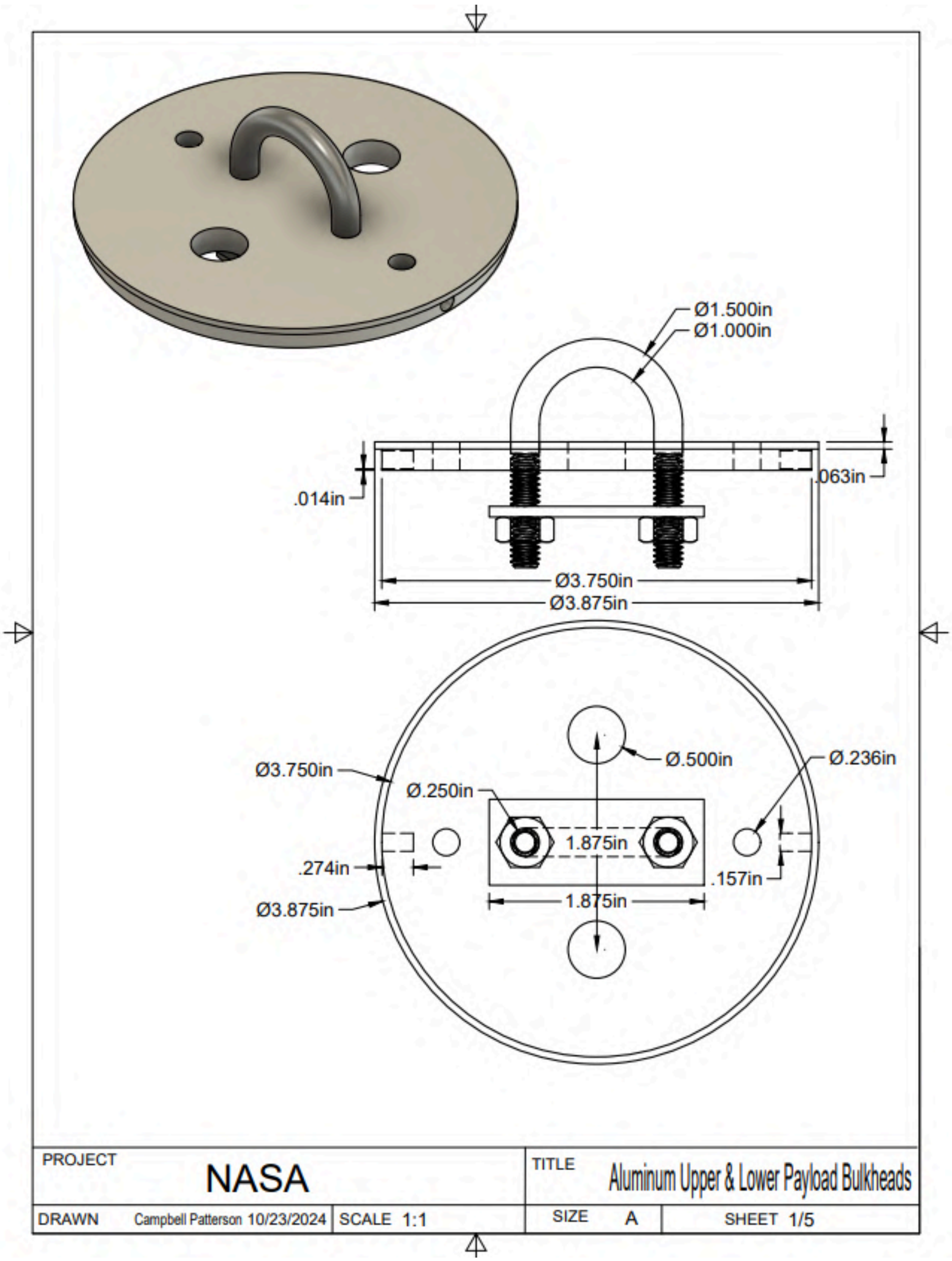
There are a few alternative designs to our payload. The recovery system has potential to change in its design which could lead to a change in the integration into the payload system. We could switch the current U blot that the recovery system is tethered to. This bolt is very large and is possibly excessive for the system. We could look into a lighter and smaller option. We also could look into separating the rocket at different points. The rocket currently has to split in the middle, we could alter the system to blast the nose cone off. If we changed that design, the recovery system integration would become completely different.

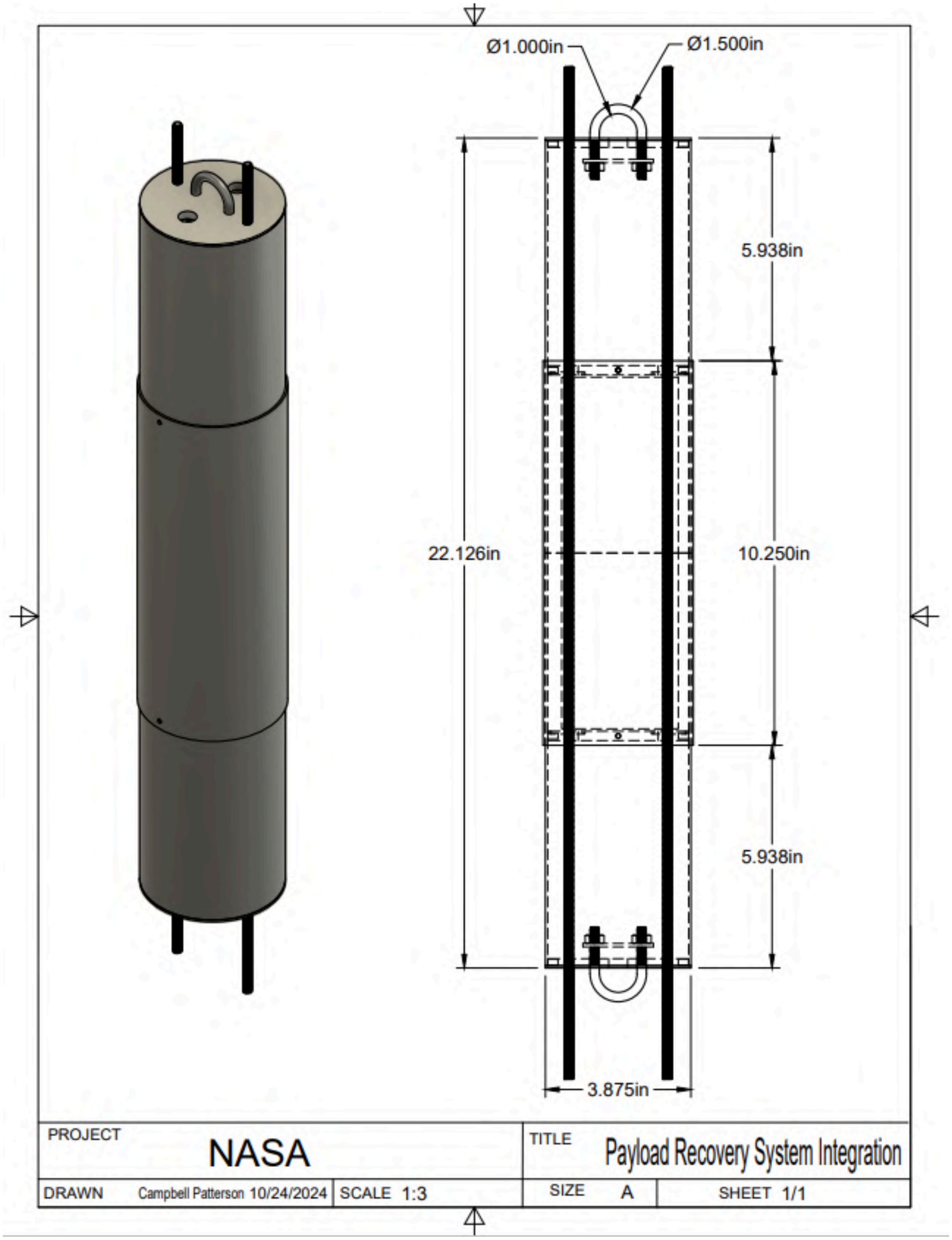
4.3 Current Payload Design and Justification

Our current payload design includes a carbon fiber coupling structure that is supported by bulkheads and aluminum rods. The payload will have a two part carbon fiber coupler that is joined in the middle. The structure of the payload will be held together by threaded aluminum rods that run through the length of the payload. Those rods support bulkheads that hold the structure of the payload together and disperse the tension load that is applied to it. The stemnauts and electronics will be held to the payload on a removable sled that mounts to the bulkheads by standoffs. We believe that this is the best option for us to complete the mission well. This complex payload design will provide a stable base for our rocket to operate off of.

4.3.1 CAD Drawings of Payload

Figure 47-48: Payload Drawings




Ø1.000in
Ø1.500in
5.938in
22.126in
10.250in
5.938in
3.875in
PROJECT
NASA
TITLE
Payload Recovery System Integration
DRAWN
Campbell Patterson 10/24/2024
SCALE 1:3
SIZE A
SHEET 1/1

4.3.2 Component Masses

Figure 49: Component Masses

Part #	Qty	Material	Mass Singluar (GRAMS)	Mass Total (GRAMS)
Nose Cone	1	(3d Print, weight is FiberGlass)	300	300
72" Parachute	1		214.917	214.917
QuickLink	1	steel	8.5	8.5
Smaller Nomex Cloth	1		20	20
Nomex Cloth	1		40	40
Swivel	1		5	5
Shock Cord	8		0.08	6.4
Lower Bulkhead 1	2	Aluminum 3003-H16	117.402	234.804
Upper Air Frame	3	Carbon Fiber	230	690
94435A537	2	6061 Aluminum	130.158	260.316
Upper Airframe Cover Bulkhead	2	Aluminum 3003-H16	80.416	160.832
Coupler 1	2	Carbon Fiber	127	254
Outer Airframe 1	1	Carbon Fiber	230	230
Telemega Flight Computer	1	Electronic part	24.95	24.95
2 Meter BLGPs radio	1	Electronic part	25	25
Permanant Payload Panel	1	Birch	38.773	38.773
Removable Payload Electronics Panel	1	Birch	35.839	35.839
90012A240	7	Aluminum 6061	1.595	11.165
3201T48 FLAG FOR EDIT	2	Black-Oxide Steel	47.738	95.476
9V Battery	2	Battery	22.5	45
Nomex Cloth	1	Kevlar	12	12
Drouge Parachute	1	nylon	62	62
Swivel	1	steel	5	5
QuickLink	1	steel	8.5	8.5
shock Cord	8	Kevlar	0.08	6.4
94435A342	6	6061 Aluminum	4.315	25.89
Retaining Ring Set				64.5
Motor Tube	1	Fiberglass	389	389
Sheet Metal Fin Mounts	3	Aluminum 3003-H16	128.2	384.6
Center Rings	3	Aluminum 3003-H16	70	210
3035T11	1	Aluminum	25.587	25.587
Thrust Plate	1	Aluminum 3003-H16	83	83
Trapzoidal Fin Set	3	Delrin	124.667	374.001
lower Airframe	4	carbon fiber	230	918.5

4.3.3 Preliminary Interfaces between Payload and Launch Vehicle

The payload and launch vehicle airframes are both made out of carbon fiber tubing. These tubes have the ability to slide into each other. The lower section of the payload will slide into the top of the booster section until it reaches a shoulder. This will allow the payload and booster to be joined together and hold well during the launch sequence. This is a good design because it will help in the recovery process at the end of the launch.

Section 5: Safety

5.1 Risk and Delay Impacts

The project's Safety Officer, Zoe Steckel, is responsible for maintaining safety protocols, managing hazard documentation, and ensuring all activities are conducted safely. This includes maintaining checklists, final sign-offs, and conducting safety briefings. Any delays due to safety concerns could impact the project timeline but are necessary to ensure safety compliance. The team follows strict safety standards set by NASA, NAR, and NFPA.

5.2 Risk Assessment

Table 23: Probability Levels

Description	Percentage
A - Frequent	85%> chance of occurance
B - Probable	50% to 85% chance of occurance
C - Occasional	15% to 50% chance of occurance
D - Remote	1% to 15% chance of occurance
E - Improbable	<1% chance of occurance

Table 24: Severity Definition

	Personnel Health	**Facility/ Equipment Health**	**Mission Health**
1 - Catastrophic	Life changing/ debilitating injury or death (ex: arm cut off or death)	Loss of facility, systems, or associated hardware.	Possibly irrecoverable setback/Major reconstruction, mission success could be lost
2 - Critical	Severe injury or illness (ex: broken bone or sick building syndrome)	Major damage to facilities, systems or equipment.	Reconstruction required, but mission success is still possible
3 - Marginal	Minor injury or illness (ex: sprained ankle or covid)	Minor damage to facilities, systems, or equipment.	Moderate reconstruction, mission success is probable
4 - Negligible	First aid injury or minimal illness (ex: allergies or paper cut)	Minimal damage to facilities, systems, or equipment.	Minor reconstruction, mission success not affected

Table 25: Risk Assessment Levels

Level of Risk	Acceptance Level
High Risk	Unacceptable
Medium Risk	Undesired. Will require rigorous documentation and mitigation to obtain approval through proper safety channels
Low Risk	Acceptable. Documented approval from the supervisor directly responsible for operating the facility or performing the operation.
Minimal Risk	Acceptable. Documented approval not required, but an informal review by the supervisor directly responsible for operating the facility or performing the operation is highly recommended.

Table 26: Risk Assessment Matrix

	Severity			
Probability	1-Catastrophic	2-Critical	3-Marginal	4-Negligible
A - Frequent	1A	2A	3A	4A
B - Probable	1B	2B	3B	4B
C - Occasional	1C	2C	3C	4C
D - Remote	1D	2D	3D	4D
E - Improbable	1E	2E	3E	4E

5.3 Preliminary Personal Hazard Analysis

A personal hazard analysis identifies potential risks that can occur during manufacturing, assembly, and launch preparation. The table below outlines some major risks and prevention methods:

Table 27: Safety

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
Errors during 3D printing of the payload and electronics bay components	Lack of education and/or experience with 3D Printing or CAD software; malfunctioning equipment.	The final assembly will require more time and money because the components will not be adequate for use.	3C	Students involved in 3D printing will have prior knowledge and/or training; equipment will be inspected before being used.	Inspection of printed components will occur before installation and before launch, to ensure structural integrity.	3D
Serious errors during assembly of rocket parts	Incorrect utilization of machinery or tools Inattention to assembly instructions and rocket schematics.	Important Structural components will be damaged Parts may need to be re-ordered Timeline may be delayed	1C	Follow all safety procedures on all tools and Machines; Ensure all manufacturing team members are up to date on detailed design process and have them review rocket schematics and best assembly practices.	Weekly team meetings will be held in which the design is discussed. A Fusion team has been created and will be utilized throughout the year to ensure everyone is up to date on the	2D

					rocket design and plan of fabrication.	
Accident occurs while using soldering iron during wiring/ assembly of avionics systems.	Lack of training or supervision Ignorance of the established safety protocols and proper soldering techniques Exposed wires or hot soldering iron.	Members may experience dangerous Burns Equipment and/or facilities could be damaged Components could be damaged Fires can occur and damage the electronics or rocket body.	1C	Training on all required tools and machines Instruction on safe shop and work practices Additional components will be purchased as backup in case of damage.	All use of tools and/or a shop will be supervised by either the safety officer or other qualified personnel.	2E
Accident during assembly of rocket involving tools or manufacturing equipment	Lack of proper training or supervision Ignorance of established safety and maintenance rules or protocols	Members experience minor to serious injuries Equipment and/or facilities are damaged	2C	Require training on all tools and machines used for assembly Having officer/mentor provide oversight during assembly processes	Hand tools are used under the supervision of the safety officer or advisor. Adherence to the rules of external resources	3D
Inhalation of	Exposure to hot surfaces	Irritation of the	2C	Only work in well-ventilated	MSDS compliance.	3D

chemical dusts and/or fumes during assembly.	or fire. Lack of ventilation Unexpected chemical reactions.	respiratory system. Breathlessness, dizziness, and fatigue. Prolonged exposure may result in respiratory issues.		environments Use fume hoods in workshops when needed. Provide training and ensure limits on exposure times are followed.	Hazardous substances will only be handled in specialized workshops/labs under supervision.	
Swelling and/or explosion of the battery.	Undercharging, overcharging, or shorting of the battery. Battery damaged from blunt forces. Batteries short when terminals come into contact with each other. Batteries are exposed to heatsource (Only swelling which hurts performance)	Electrolyte leaking, gassing, explosion, and/or fire. Severe damage to lungs, skin, eyes, nose, mouth, hands, etc. Death. Surrounding materials and items damaged.	1D	Batteries will be kept in their appropriate packaging until needed and handled with caution when removed. Batteries will only be charged per the manufacturer's recommendations; Batteries will be kept away from sources of excessive heat or exposed wiring.	Routine inventory checks and oversight by safety officer during construction.	2E

Exposure to hazardous chemicals during assembly or launches.	Improper use of personal protective equipment (PPE). Accidental spill or unforeseen chemical reactions in the workshop or inside the rocket.	Skin or eye irritation. Burns or severe chemical reactions.	3C	Training on the correct use of PPE Training on hand-washing, eyewash stations, and emergency showers in the workspace.	MSDS compliance. Work with hazardous chemicals will occur only in designated laboratory/workshop areas, under supervision by trained personnel.	3E

5.4 Hazard Research Data

The project involves various hazardous materials that pose significant risks if handled improperly. The table below lists these materials, their hazards, and prevention methods:

Table 28: Safety

Material	Hazard	RAC	Prevention	Post RAC
Epoxy	Respiratory and skin irritation	4B	Work in a well ventilated area with proper PPE.	4C
Black Powder	Explosion risk	2C	Work alongside mentor, Armando Rodriguez, on charge sizing and placement.	2D
Lithium Polymer	Fire risk due to battery failure	1C	Take proper precautions while charging and while placing battery in the rocket as defined by manufacture	2C
Cyanoacrylate	Skin irritation and toxicity	1C	Work in a well ventilated area with proper PPE.	2D

Fiberglass	Respiratory and skin irritation	1C	Work in a well ventilated area with proper PPE.	2D
Carbon Fibers	Irritation of the skin, eyes, or upper respiratory tract	1C	Work in a well ventilated area with proper PPE. Work in a well ventilated area with proper PPE.	2D
Solid Propellant Motor	Explosion risk	3C	Work alongside Armando Rodriguez, mentor, while handling and installing motor, and preparing an electronic ignition system.	3D
Kevlar Sock	Skin irritation	1C	Use proper PPE while installing Kevlar sock to prevent skin irritation.	2D

5.5 Preliminary Failure Modes and Effects Analysis (FMEA)
This section identifies potential points of failure in the rocket's structure and systems, along with corresponding mitigation measures:

Table 29: Safety

Structures					
Failure	Cause	Effect(s)	PRE RAC	Prevention	Post - RAC
Buckling of the Body Tube	Overload on Body Leading to Extreme Axial Stress	Vehicle Loss, Internal Component Loss	1D	Perform stress analysis using CAD as well as perform tests using higher load standards.	1E

Failure of Bulkhead	Overload of Forces on Hardpoints	Airframe Damage, Structural Integrity Loss, Attached Component Loss	D2	Institution of an increased safety factor in design in order to avoid launch failure.	3E
Slippage of the Bulkhead	Error in the Epoxy Application to the Bulkhead	Structural Integrity Loss, Attached Component Loss	D2	Inspections of the bulkhead after placement in the rocket will occur during testing to ensure there are no mistakes.	4D

Cracking of the Body Tube	Material Defects, Holes Drilled in the Body Tube	Vehicle Loss due to Failure of Body Tube	2E	Strict inspection of the materials used during construction of the body tube. Limit drilling of the tube in order to maintain integrity.	4E
Failure of Coupler	Rocket Bending	Structural Integrity Loss	D2	Design coupler for testing under bending loads that exceed expectations.	3E
Collapse of Nose Cone	Unprepared for Force Overload on Nose Cone,	Unable to Relaunch, Loss of Attached or Contained Components	E2	Cautious building of nose cone and precise installation will be put in place to ensure the nose cone survives. Testing will study the integrity of the nose cone.	4D

	Improper Installation				
Failure of Fins	Improper Installation of Fins to the Airframe, Fluttering Fins	Airframe Damage, Fin Loss	2D	Inspection and testing of fin installation will occur before launch.	4E
Motor Tube is Off-Centered	Misalignment of Motor Casing or Centering Rings	Airframe Damage, Unstable and Unpredictable Projection of the Rocket	2C	Precise alignment of the motor casing will occur during rocket construction. Close inspection will occur before the launch.	4D

Propulsion					
Failure	Cause	Effect(s)	PRE RAC	Prevention	POST RAC
Catastrophic failure of the motor	Damaged Motor, Defect in Manufacturing	Critical Damage to All Rocket Components, Injury to Personnel	E1	Motor will be selected from certified distributors and manufacturers for quality control.	4E
Failure of Motor Ignition	Defect in Manufacturing, Failure of the Igniter	No Ignition of Motor, Rocket Remains on Launch Pad	D1	Follow all procedures in NAR safety code. Have backup motor(s) to replace the failed motor in supply if applicable.	4E

Recovery					
Failure	Cause	Effect(s)	PRE RAC	Prevention	POST RAC
Failed Ignition of Ejection Charges	Disconnection in Wiring, Loss of Power	Failure to Properly Deploy Recovery System	D3	Secure all connections to attachment points. Inspect batteries during launch preparation. Possibly install a backup system.	4E

Flame Damage to Components	Inadequate Thermal Protection	Recovery System Damage	3B	Recovery system components shall be flame retardant.	4D
Premature Ejection	Altimeter Malfunction, Inaccurate Altimeter Readings	Airframe Damage, Component Damage	2C	All wires will be shielded. Usage of reliable altimeters to ensure accuracy of ejection charges.	3D
Premature Separation	Failure of Shear Pins	Airframe Damage, Component Damage	2C	Sections will be secured with reliable shear pins.	3D
Recovery Attachment Point Failure	Quick Links Come Undone or Hardware Fails	Complete Loss of Recovery System	D3	Visual inspection of all links and knots before launch. Select hardware for a system that has a high safety factor.	4D
Sections Self-Impact	Sizing of Bridle is Improper, Parachute Placement is Improper	Airframe Damage, Component Damage	2C	Inspection of rigging and bridle sizes will occur to prevent collision of rocket sections.	4D
Separation Failure	Inadequate Black Powder Charge, Improper Placement	Failure to Properly Deploy Recovery System	D3	Follow all procedures in NAR safety code. Have backup motor(s) to replace the failed motor in supply if applicable.	4E

Uncontrolled Inflation of Parachute	Oversized Parachute, Parachute Packed Improperly	Internal Component Damage, Rocket Peak Load is Increased	2C	Methods of parachute packing and deployment will be tested.	4E

Payload					
Failure	Cause	Effect(s)	PRE RAC	Prevention	POST RAC
Batteries Catching on Fire	Improper Charging of Batteries	Open Flames, Burns	D3	Secure all connections to attachment points. Inspect batteries during launch preparation. Possibly install a backup system.	4E
Metal Components on Rover Becoming Projectiles	Improper Linear Spring(s) Installation, Payload Construction Faulty	Linear Springs Detach From Payload Becoming Projectiles, Bystanders Hit by Projectiles	D2	Recovery system components shall be flame retardant.	4D

Motor(s) Catching on Fire	Motors Stall with continuous current draw	Destruction of Electrical Components, Burns from Flames	2C	Sensors will be put in place to start and stop motors during motor stall to prevent continuous current draws.	4D

Overc urrent Issues	Large Amount of Flowbac k due to Current Requirem ent of Motors	Electronic Components Destroyed due to Short-circuit	2B	Install flyback diode with combination of resistor for overcurrent production as well as using our aluminum chassis as a grounding plate.	3E
Premature Ejection of Rover	Early Ejection of Drogue Shoot, Retainment Failure	Aerodynamic Changes, Unpredictable Flight Path, Payload Becomes a Projectile, Bystanders Hit by Projectiles	E3	All wires will be shielded. Usage of reliable altimeters to ensure accuracy of ejection charges.	4E

5.6 Environmental Concerns

Environmental factors can greatly affect both the outcome of the launch and the project itself. Key environmental hazards include:

Table 30: Safety

Environmental Hazards					
Failure	Cause	Effect(s)	PRE RAC	Prevention	POST RAC
Excessive Wind Speeds	Possible Storm Fronts	Unpredictable Flight Path, Possibility of Rocket Turning Into Projectile, Recovery is Off Site	2C	Monitor wind speed. Cancellation of launch will occur if wind speed exceeds 20 miles per hour (MPH)	4D
Inclement Weather	Storm Fronts	Electronic Component Damage	1C	Store all electronic components in waterproof containers until launch. Monitor and maintain knowledge of the weather forecast.	4E
Launch Pad Damp/Wet	Precipitation	Electronic Component Damage	1C	Store all electronic components in waterproof containers until launch.	4E

Low Visibility	Cloud Ceiling is Low, Dense Layer of Fog	Tracking of Rocket and Vehicle will be Difficult	2C	Monitor and maintain knowledge of the weather forecast.	4E
Terrain	Launch Field Obstructed by Terrain Features	Failure to Reach the FEA Successfully	2B	Perform adversity testing on different types of terrains and obstacles to ensure maximum capability.	3E
Waste	Trash is Left On Site	Pollution of Earth	D2	Trash bags will be readily accessible.	4E

Section 6: Project Plan

6.1 Requirements Verification

6.1.1. Vehicle Requirements

For the 2025 SLI, OCRA's goal is to deliver our payload to an apogee of 4,200 feet. To achieve this, our rocket will be built using carbon-fiber airframes and aluminum trapezoidal fins. The rocket's nose cone, 3D printed using PETG, uses an Ogive design necessary for minimizing drag while still being secure and stable. Since it is 3D printed, it also allows us to control the mass and thus the stability of the rocket. This design would also allow us to maximize speed and get our rocket to our defined apogee much more efficiently.

The launch vehicle will use a K695R-P reloadable rocket motor. We chose this motor because it provides enough thrust to get our 16 lbs. rocket to 4,200 feet while still fitting in our 4 in. airframes. Since the motor is not single use, it also helps us avoid any troubles with motor access in the future.

6.1.2. Payload Requirements

This year's competition requires OCRA's rocket to carry and return a payload of 4 STEMnauts to our apogee and back safely. We plan on using figurines from the show *Octonauts* as our STEMnauts. They will be secured in a vessel within the payload throughout the whole flight.

All data collection will be performed by a dual altimeter system located in the payload. We will use the Telemega Flight Computer and the Micropeak Altimeter to measure key data picked up during our flight. For 2025 SLI, OCRA has chosen to focus on three main data points: maximum velocity, apogee, and time to landing. To return this data back to the launch pad, a BigRedBee 2M radio will transmit all data along that radio frequency in real time. All programs and functions will be monitored by a TeleMega or EasyMega flight computer also stored in the payload section of the rocket.

6.1.3. Recovery Requirements

To achieve a recoverable and reusable landing, OCRA plans to use a dual deployment recovery system. For this system, two parachutes will be present within the rocket airframe: a drogue parachute and a primary parachute. Because the initial drogue parachute helps the rocket descend both rapidly and safely, the system should allow us to keep the rocket within the 2,500 ft. landing radius as well as the 90 second descent time maximum. The primary parachute will provide for most of the drag and provide for a safer landing.

The drogue parachute will be made of ripstop nylon and have a 24 in. diameter. It will deploy within 2 seconds after reaching apogee. As mentioned, this parachute will help minimize drift from cross winds while still slowing the descent. At around 800 ft., the main parachute, also made of ripstop nylon, will be released. This parachute is very large at 72 in. in diameter to account for our 16 lbs. weight. This primary parachute should be able to adequately slow the descent further and help the rocket land in a safe and reusable state.

Both parachutes will be connected using 20 foot long, ½ inch thick tubular kevlar shock cords. OCRA chose this material because it will be able to withstand the force of deployment both parachutes will enact on it. The shock cords and parachutes will each be released at their predetermined height by a TeleMega or EasyMega computer that interprets the altitude data collected by the altimeter.

6.2 Budgeting and Timeline

6.2.1. Itemized Budget

Table 31: Expenses

Nose Cone	$ -
60" Parachute	$ 105.00
QuickLink	$ 4.06
Nomex Cloth	$ 17.59

Swivel	$ 14.00
Shock Cord	$ 13.50
Lower Bulkhead 1	$ -
Upper Air Frame	$ 686.00
94435A325	$ 9.37
Upper Airframe Cover Bulkhead	$ -
Coupler 1	$ 148.00
Outer Airframe 1	$ -
Micropeak Altimeter	$ 38.17
Telemega Flight Computer	$ 508.85
2 Meter BLGPs radio	$ 265.00

Permanent Payload Panel	$ 3.00
Removable Payload Electronics Panel	$ 3.00
90012A240	$ 47.50
9V Battery	$ 11.43
Nomex Cloth	$ -
Drogue Parachute	$ 21.50
Swivel	$ -
QuickLink	$ 4.06
Shock Cord	$ -
94435A361	$ 40.38
Retaining Ring Set	$ 48.99
Motor Tube	$ 41.00
Sheet Metal Fin Mounts	$ -
Center Rings	$ 9.69
3035T11	$ -

Thrust Plate	$ -
Trapezoidal Fin Set	$ 56.05
Lower Airframe	$ -
Motor	$ 1,000.00
Black Powder	$ 33.00
Shipping	$ 500.00
Emergency Funds	$ 500.00
Extra Hardware	$ 200.00
TOTAL PRICE	$ 4,329.14

6.2.2. Funding Plan

OCRA's Funding Plan currently is to gather funds from various different sources. The bulk of our funds will be coming from company sponsorships. Our members have reached out to several companies within the area who are interested in sponsoring. The rest of the funds will be raised through sales that directly benefit this project. Other plans to fund this project but that have not been enacted are a bake sale, raffles, and earring sales. These are still in the planning process and will move along soon. More funds will be secured as the project advances.

6.2.3 Funding Sources

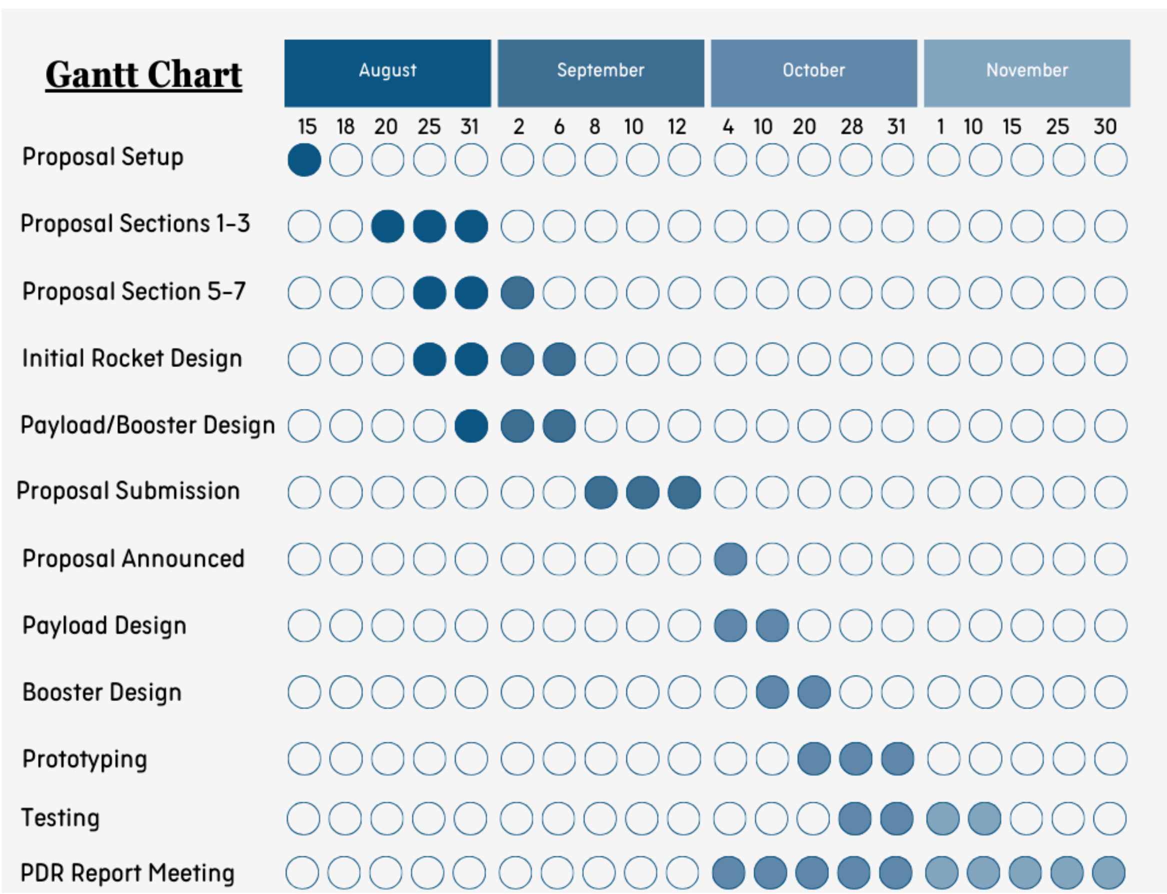
The current funding sources are Merchandise Sales headed by team lead Campbell and Company Sponsorships. Company Sponsorships will be gathered from local businesses, and some larger corporations in the state of Georgia to help fund the project.

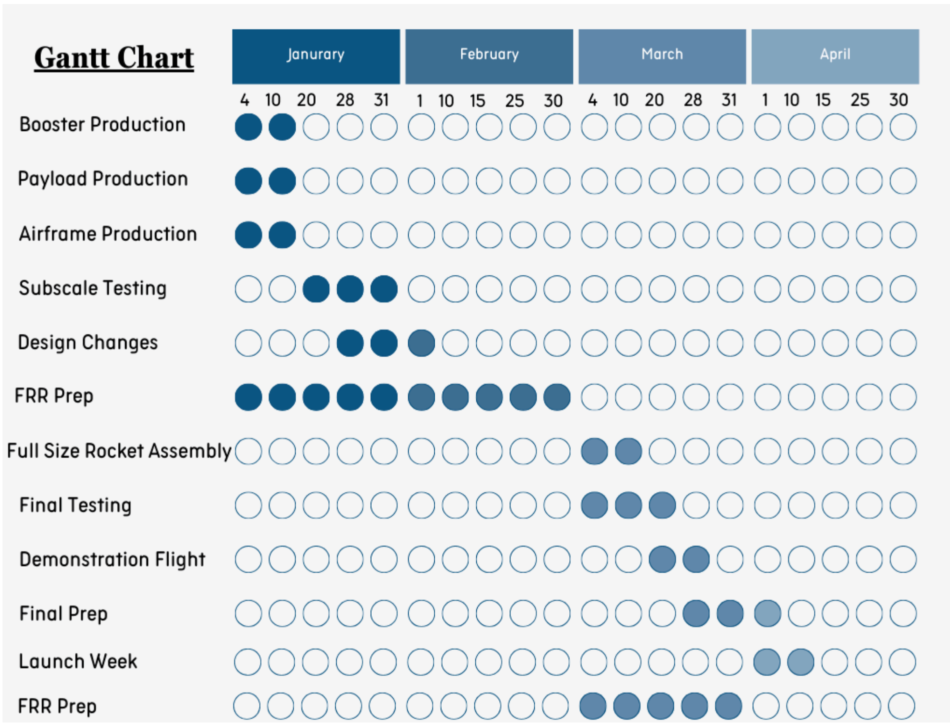
6.2.4 Material Acquisition Plan

OCRA plans on acquiring the Materials needed to complete the launch vehicle by ordering them off of the websites or having them donated. We have about several sheets of scrap Aluminum donated to us by a local Company for the manufacturing of several parts in the rocket. The other materials that we do not already have on hand (a nomex cloth, pla printing material or some hardware) will have to be purchased. As there is no rocket part store near us, we will be purchasing these parts online. The materials will be ordered online as soon as possible and in reasonable time.

6.2.5 Timeline

Figure 50: Gantt Chart





6.2.6 Team Member Activities and Durations

Table 32: Activities and Durations

TEAM MEMBER	ACTIVITY	DURATION
Campbell Patterson	Section 3 Recovery System	10/9/2024 - 10/28/2024
Zoe Steckel	Section 2	10/9/2024 - 10/28/2024
Caleb Antwine	Section 3 Vehicle Design	10/9/2024 - 10/28/2024
Saahil Doshi	Section 4	10/9/2024 - 10/28/2024
Emily Peng	Section 1	10/18/2024 - 10/28/2024
Sihoo Kim	Section 6 Timeline/Budget	10/21/2024 - 10/28/2024
Benjamin Sayers	Section 3 OpenRocket Sims.	10/9/2024 - 10/28/2024
Cashton Isaac	Section 6: Project Plan	10/18/2024 - 10/28/2024
Morgan Rabon	Flysheet	10/9/2024 - 10/28/2024

WARRIOR ONE

20 25

WARRIOR ENGINEERING NASA SLI TEAM

NASA UNIVERSITY STUDENT LAUNCH
CRITICAL DESIGN REVIEW

Section 1: Summary of CDR Report

1.1 Team Summary

Table 33: Team Summary

School Name	Oconee County High School
Mailing Address	2721 Hog Mountain Rd, Watkinsville, GA, 30677
Team Name	Oconee County Rocketry Association
Project Title	Project RANCH
Project Lead	Campbell Patterson: cpa11549@oconeeschools.org
Safety Officer	Zoe Steckel: zst55770@oconeeschools.org
Team Mentor Information	Armando Rodriguez: armandorod60@aol Certification Level: HPR Level 3 NRA #: 89194
Adult Educators	Bradley W Sayers: bwsayers@oconeeschools.org
NAR, TRA sections	NAR Section #112382
Launch Plan	We plan to launch our rocket at Huntsville, AL, and collect data through radio transmission that will send the information to a NASA ground receiver in person on launch week.
Time Spent	8 people, average 7 hours, total of 56 hours
Social Media Information	Instagram: @oconeerocketry Twitter: @ochsengineering

1.2 Launch Vehicle Summary

Project RANCH has an Official Target Altitude of 4,300 feet. The rocket is designed with a length of 100.9 inches, with a diameter of 4 inches, and a mass of 15.6 lbs with a motor. Our main motor choice is the Aerotech K550W. The rocket will have 2 points of separation, separating the rocket into three parts. The rocket's three parts consist of the avionics bay/mid sections, the booster section, and the forward section with the nose cone and payload. The forward section has a total mass of 3.784 lbs. The mid section has a total mass of 1.626 lb. The booster section holds the motor and has a mass of 6.874 lb. The wet mass of the launch vehicle is 15.6 lbs. OCHS will use a launch rail of 12'. Our recovery system will use a rocketman 18” star polyconical as our drogue parachute and we will use a 48” Rocketman as main parachute. To ensure redundancy we will use two RRC3+ altimeters that will deploy the drogue parachute at apogee and deploy the main parachute at 652 feet.

1.3 Payload Summary

1.3.1 Payload Title

- Our payload is titled Acorn

1.3.2 Experiment Summary

- Our payload experiment will look very similar to the payload from the USLI challenge. Our payload will contain monitoring and radio transmission equipment that will complete our mission. That mission is to record data points over the duration of the flight and transmit that data back to a ground base received when the rocket lands. The data is to include time landing, appogee reached, and maximum velocity.

Section 2: Changes Made Since PDR

2.1 Changes Made to Vehicle Criteria

- Our Vehicle Criteria has seen some changes due to the amount of changes we have made with the payload design. The new design will have shifted our weight and center of gravity. Our Criteria has changed in order to compensate for this.
- We have changed our outer airframes of the launch vehicles to G12 instead of using carbon fiber. This has helped us increase the weight of the rocket. This assists us because it lowers our descent time to be within 90 seconds of reaching apogee. Another benefit of using G12 instead of Carbon fiber is the lower costs and therefore lower expenses. Carbon fiber was much more expensive.
- Along with changing the outer airframes of the launch vehicles to fiberglass we have also changed the motor tube to fiberglass. We changed the motor tube along with the outer airframes to make sure that they all fit properly
- By choosing to buy the frames and motortube from the same company and same material we are eliminating the chances for tolerance problems.
- We changed the fins for the project from aluminum to delrin. We switched from aluminum because of the fact that it does not follow NASA SLI Guidelines, as well as the fact that Delrin is a more accessible thicker material. This will help with reducing fin flutter and allow for a more stable flight path.
- We have changed our projected altitude apogee to 4300 from 4200 ft. We changed it because we decided to change motors. Due to the fact that we had to redesign our rocket so much and so severely, we were forced to make changes to the motor to accommodate all the added weight. Our motor is currently the Aerotech K550W.

2.2 Changes Made to Payload Criteria

- Our payload has seen major changes since the PDR phase of the project. On initial design we planned on a large-two piece payload in the middle of the rocket. That payload was designed to hold the flight computers, critical sensors, radio transmitter, and the STEMnauts. However, after review of the design, it became evident that the payload structural design would not meet the technical standards that were expected. With this in mind we reinvented our payload design in order to create a much safer and ultimately, more simple rocket.
- The new payload will be split into two sections. We will have a more traditional avionics bay that is in the midsection of the rocket and we will move the payload section of the rocket to a bay below the nose cone. In the center of the rocket, an avionics bay will hold the primary and

backup flight computers as well as the batteries that power them and the power switches. There will also be black powder blast caps that are used in the recovery stage of the rocket. The upper payload will be located below the nose cone and will hold our payload sensors, radio transmitter, and STEMnauts.

- This new design allows for increased safety, a stronger rocket, and a more simple design. These factors have led us to believe that this will be the best option to complete our mission.
- The criteria regarding what the payload will accomplish remains unchanged, the rocket will be tasked with the same things as before but it will perform these tasks off of a much better platform.
- The final payload criteria change regards the radio transmitter that we will use. In the previous document we claimed that we would try to transmit data on the 2M band however, this is no longer the case. We have transitioned and will transmit our data(the same data points) back to the ground receiver with a featherweight GPS transmitter. This will simplify our design and provide us with a much better connection allowing for us to get the best transmission possible.

2.3 Changes Made to Project Plan

- We have changed our subscale testing dates, we changed them from early January to early December. This was to account for CDR deadlines as well as to fit around winter break for OCHS.
- Other than the fact that we have had to spend more time redesigning our rocket, we have been relatively successful not having any major disruptions to our project plans. We continue to adapt and adjust for the wind.

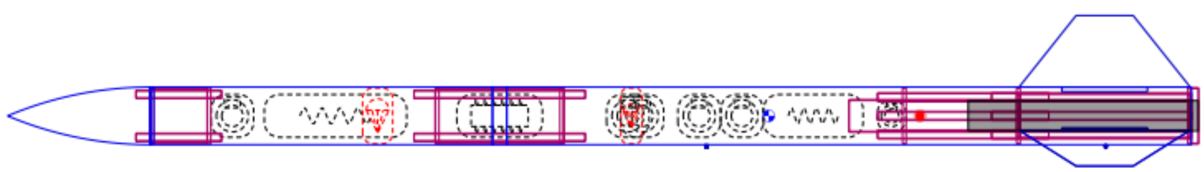
Section 3: Vehicle Criteria

3.1 Design and Verification of Launch Vehicle

3.1.1 Mission Statement

Our mission is to design and build a rocket that, while following all the criteria outlined in the SLI challenge, reaches an apogee of 4300 feet and after reaching apogee performs two dual deployment parachute launches, one drogue and one main. The rocket must also reach the ground within 90 seconds of reaching apogee. The rocket after landing will be able to safely radio transmit three data points chosen by the electronics team.

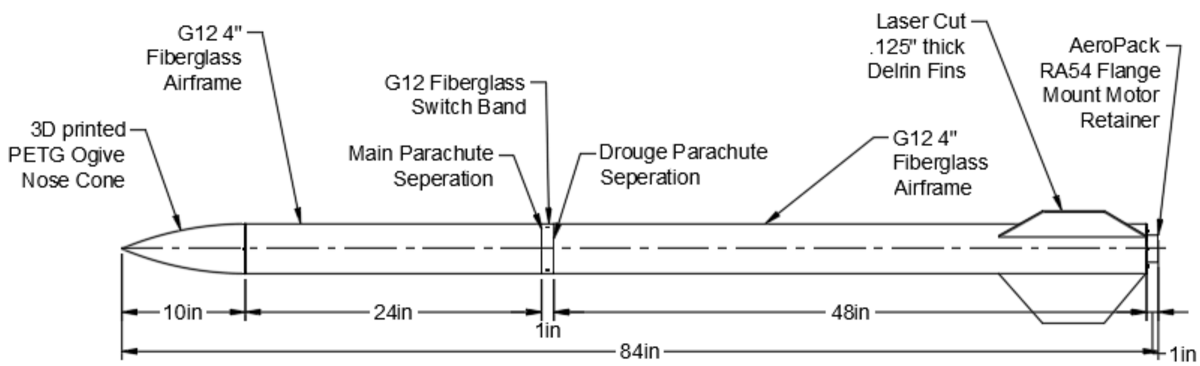
3.1.2 Final Design

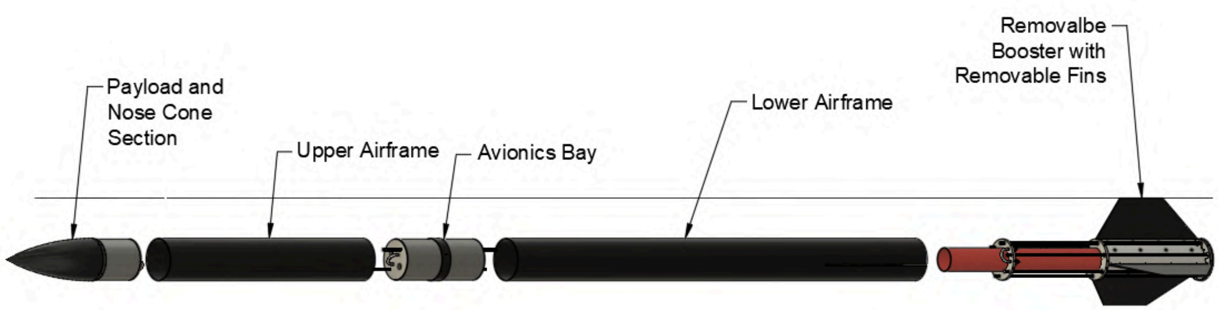


Rocket
Stages: 1
Mass (with motor): 15.6 lb
Stability: 2.63 cal / 12.8 %
CG: 53.369 in
CP: 63.97 in

3.1.2.1 Launch Vehicle Drawings

Figure 51: Full Assembly of Rocket Design with Dimensions and Components





3.1.2.2 Booster Drawings

Figure 52: Removable Booster Design with Removable Fins

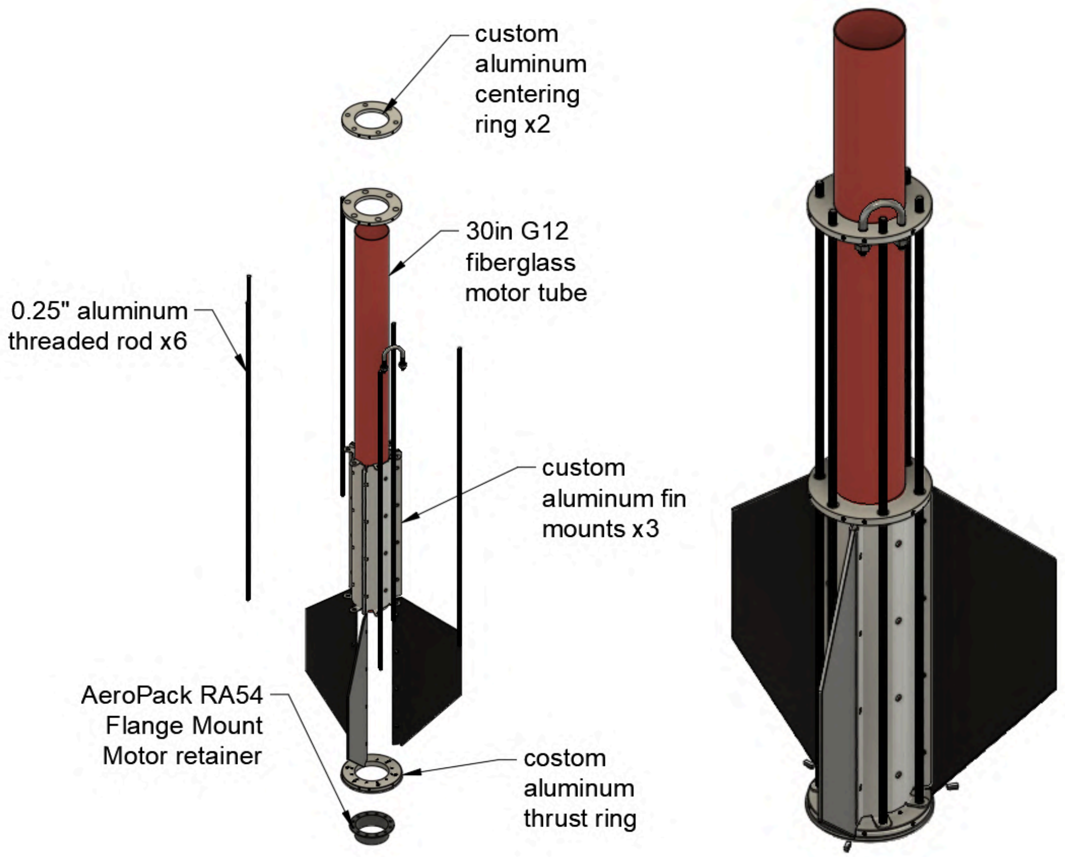


Figure 53: Booster Section Front View and Bottom Dimensions

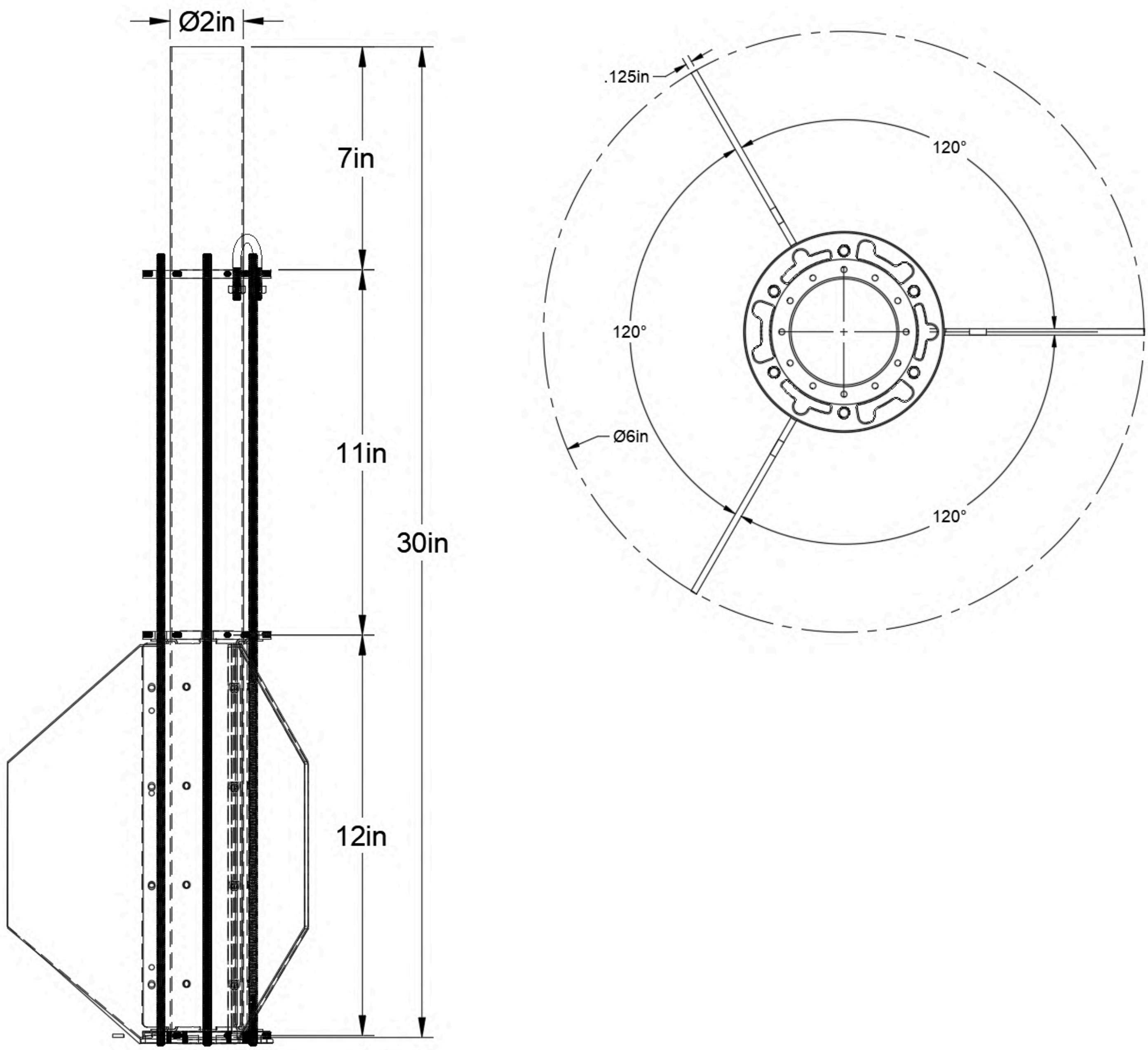
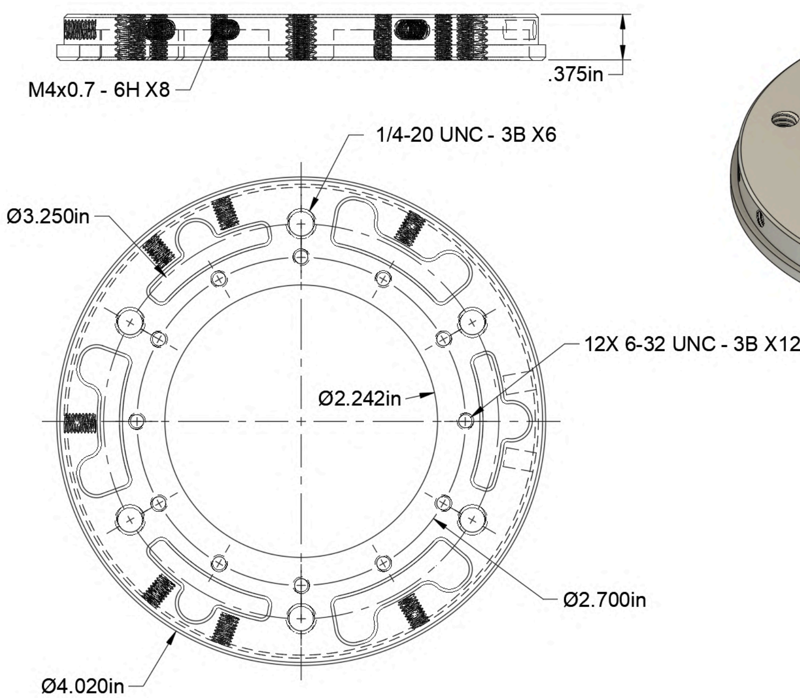


Figure 54: Thrust Plate



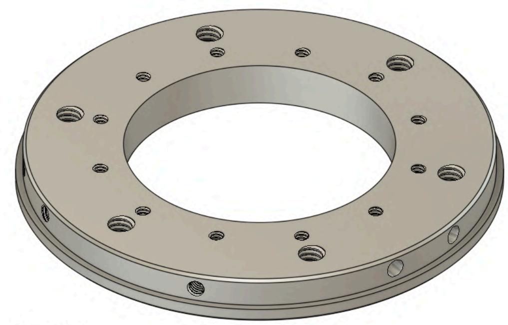
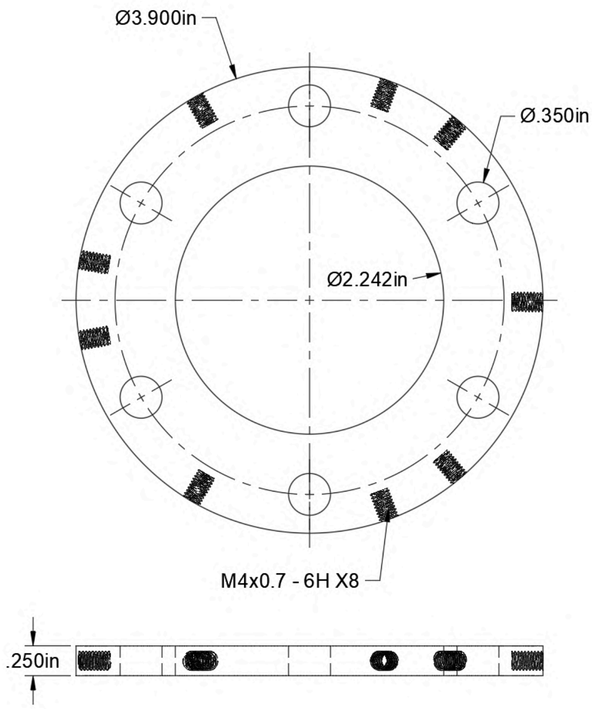


Figure 55: Centering Rings



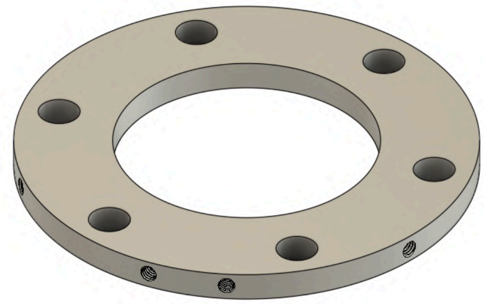


Figure 56: Fins Dimensions

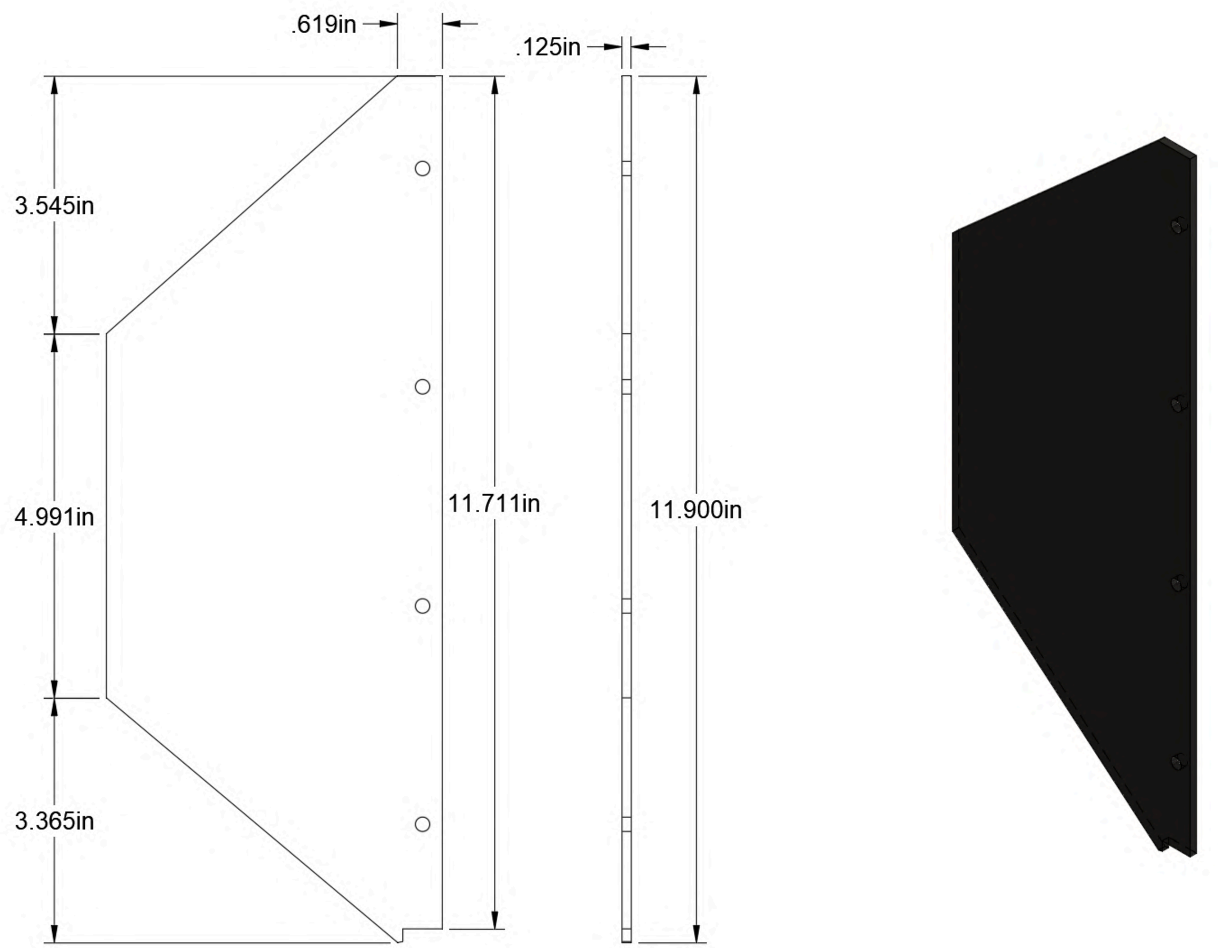


Figure 57: Aluminum Fin Mounts

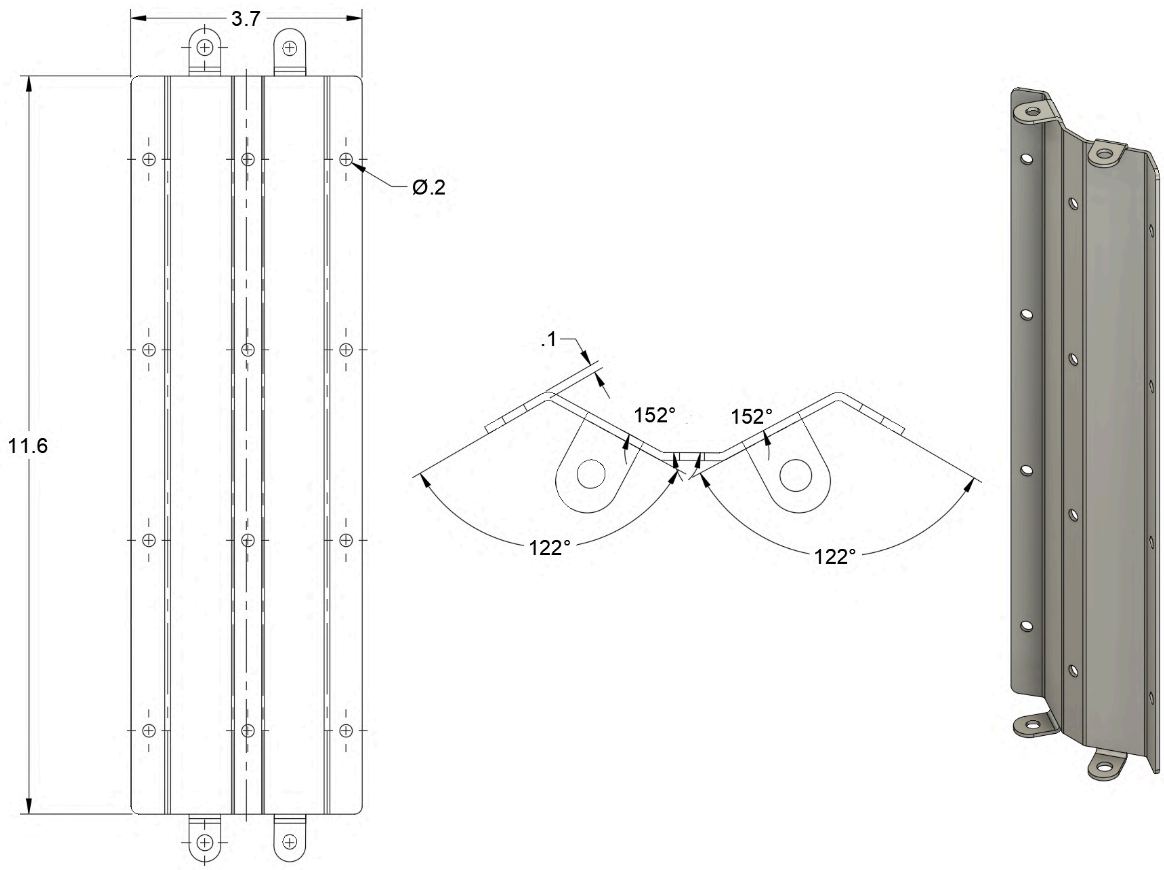
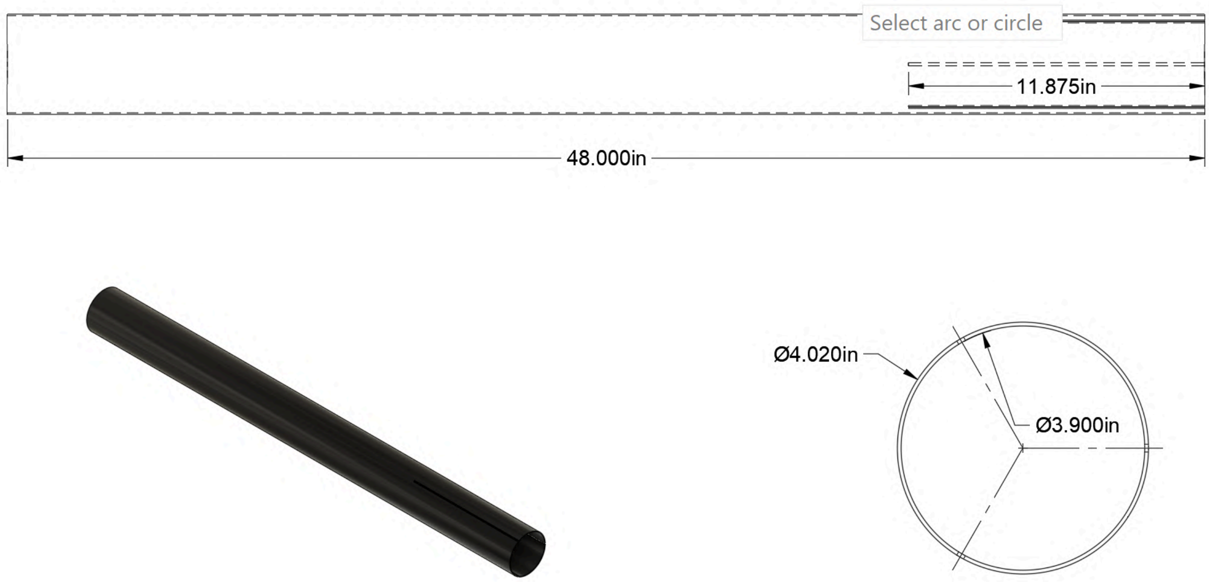
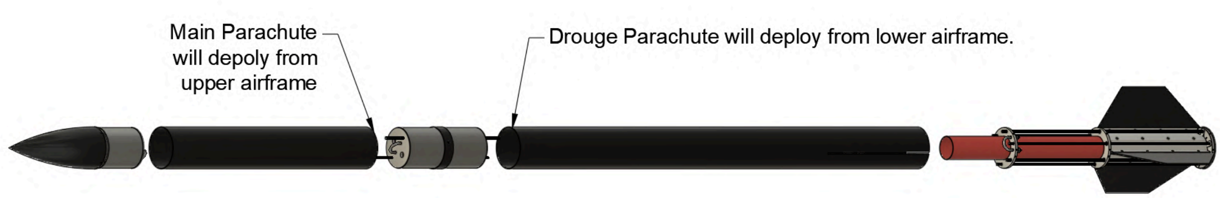


Figure 58: Lower Airframe with Slots



3.1.2.3 Recovery Drawings

Figure 59: Rocket with Deployment Sections



3.1.2.5 Point of Separation Drawings and Location of Energetics Materials

Figure 60: Location of Energetics on the Avionics Bay

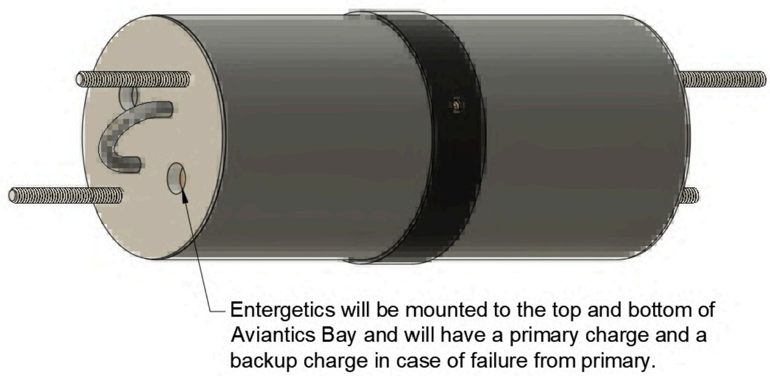
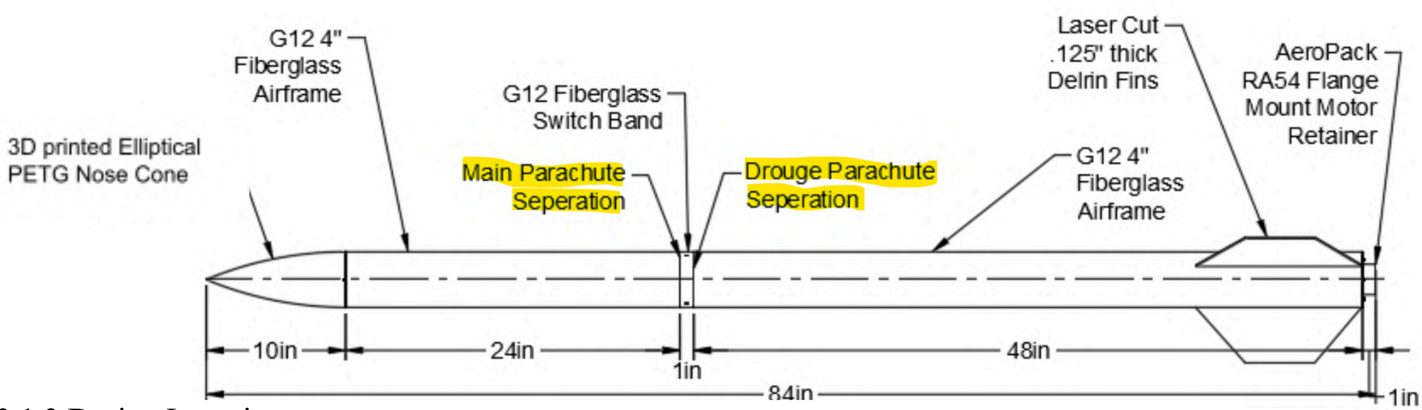


Figure 61: Rocket Separation Points



3.1.3 Design Integrity

In order to ensure that our rocket will be safe, we will inspect materials used to make sure that they are suitable for the functions required of them. This includes purchasing and manufacturing from qualified suppliers, not using machinery that could potentially decrease the structural or functional integrity of components, and ensuring that in the final construction of the rocket that the parts are properly able to be secured to each other.

3.2 Subscale Flight Result

- To create the subscale rocket, scaling factors were selected. Our full scale rocket has 4" diameter body tubes and the subscale rocket was built using a BT-70 (2.2") diameter body tube. This established a 1:1.8181 ratio that was used to scale the rocket. The length to width ratio was held constant as well as the nose cone sizing. There were a few factors that were changed including the weights of certain items in the rocket so that we could establish the stability margins that were to be expected.

3.2.1 Flight Data

Table 34: Flight Data

Data Point	**Simulated Result**	**Actual Result**	**Percent Error**
Flight Duration	35 seconds	22.7 seconds	35%
Descent Rate	18.95 mph	19 mph	<1%
Time from Apogee to Ejection	2.2 seconds	4.1 seconds	46%
Coast to Apogee	5 seconds	4.3 seconds	14%
Peak Acceleration	60.85 m/s2	5.0 G's	N/A
Thrust Time	2.5 seconds	2.17 Seconds	13%
Top Speed	141 mph	140 mph	<1%
Altitude	782 feet	576 feet	26%

3.2.2 Launch Day Conditions

- Weather Conditions

Table 35: Weather Conditions

Data	**Result**
Temperature	43 F
Humidity	59%
Wind	6 mph

3.2.3 Subscale Flight Analysis

- Our subscale flight was successful. The flight accomplished exactly what we wished. Our rocket safely launched and reached a good altitude with a good deployment of the parachute. On our flight many of the data points were inaccurate, this is largely due to the high winds that we were launching in. With higher winds we saw a larger amount of weather cocking which in turn reduced the flight time and total altitude reached of our rocket.
- After reflecting on our successful subscale flight, we were confident that we had gathered enough data and seen everything necessary in order to make changes to our final, full scale design.

3.2.4 Impact on Full Scale Rocket Design

- After seeing the results of the subscale flight our team was able to make a few changes to the rocket that will help our performance in the long run. We did experience some weather cocking on the flight which skewed some of the data points that we gathered.
- This sideways moment at the launch pad was a result of over stabilization of our rocket. The rocket was designed with a stability around 3 which we have now learned is very high. With such a high stability we are very susceptible to weather changing the direction of flight and knocking us off of our intended track. To counteract this, we have lowered our stability closer to 2 which will help us to maintain a vertical vector off of the launch pad even in higher wind situations.
- The simple event of weather cocking is primarily responsible for the other large errors in our data. However, the factors that the weather cocking could not affect were all simulated fairly close. Our descent rate was calculated very close to what actually happened and our motor performed very close to how it was simulated. This gives us confidence that our simulation will do a good job of predicting our descent rates and help us with our motor selection. We do believe that the simulation was for the most part accurate in all regards, even though the errors in our data would suggest something different.

3.2.5 Pictures

Figure 62: Subscale Rocket on Ground after Launch

Figure 63: Subscale Rocket on Ground after Launch

3.3 Recovery Subsystem

3.3.1 Concept of Operations for Recovery

Our rocket will utilize a dual deployment recovery system. Our recovery system will be driven by our dual altimeters that we are using for redundancy. When our rocket reaches apogee the primary flight computer will send an electric charge into the primary black powder cell. This will ignite the black powder and shear the bottom section off of the rocket. This process will deploy our 18 inch drogue parachute. Under this parachute, our rocket will fall at approximately 70.5 feet per second. If the primary flight computer fails to blast the drogue chute out at apogee, our secondary flight computer will send a second charge one second later to a second black powder blast cap. Our rocket will then descend on the drogue parachute until it reaches an altitude of 1,000 feet. At 1,000 feet our primary flight computer will send an electric charge to the upper black powder blast cap which will shear the upper section of our rocket off. This process will deploy our 60 inch main parachute. On this parachute, our rocket will descend at approximately 16.5 feet per second all of the way down to the ground. In the case that our chute does not deploy at 1,000 feet our secondary flight computer will send a second charge to a second blast cap at 800 feet to ensure that our main chute is deployed well above the 500 foot minimum. All sections of the rocket will be tethered to the parachute by tubular kevlar rope between 7/12 and 1/2 inches in diameter.

3.3.2 Recovery Items

3.3.2.1 Parachutes

Table 36: Parachute Data

Parachute	**Size**	**Material**	**Deployment Altitude**	**Descent Rate**	**Protection Method**

Drogue	24 inches with a 2 inch spill hole	Ripstop Nylon	Apogee (4,300 ft)	70.5 ft/s	Nomex Cloth
Main	48 inches with a 7.75-inch vent hole	Ripstop Nylon	1,000 feet (primary) or 800 feet (secondary)	16.5 ft/s	Nomex Cloth

3.3.2.2 Other Items:

Shock Cord:

- Material: 3/8-inch flat Kevlar
- Length: 30 feet
- Diameter: 0.625 inches
- Strength Rating: 4,000 lbs tensile strength

Anchor Point Hardware:

- Type: Steel U-bolts
- Location: Attached to bulkheads in the payload and booster sections
- Strength Rating: 3,000 lbs

Table 37: Recovery Materials

Item	**Length (ft)**	**Diameter (in)**	**Material**	**Anchor Point Hardware**	**Strength (lbs)**
Shock Cord	30	0.625	Flat Kevlar	Steel U-Bolts	4,000
Anchor Points	N/A	N/A	Steel	Bulkheads	3,000

3.3.3 Recovery Electrical Components

a. Altimeter: Two RRC3+ Altimeters to discharge black powder capsules at defined altitudes.

Figure 64: RRC3+ Altimeter

Table 38: Recovery Altimeter

Name	**RRC3+ Altimeter**
Cost	**$74.95**
Dimensions	**Length: 65 mm** **Width: 25.5 mm**
Weight	**15 grams**
Voltage	**3.5 - 10 VDC**
Availability	**Available on Missile Works**

b. Power Source: 3.7 LiPo battery for each separate system. 2000mAh for high battery life.

Figure 65: 3.7 LiPo Battery

Table 39: Recovery Battery

Name	**3.7 LiPo Battery (2000mAh)**
Cost	**$23.99**
Dimensions	**34.5 x 56 x 10.6 mm**
Weight	**40 grams**
Voltage	**3.7 VDC**
Availability	**Available on Amazon**

c. Power Switch: Rotary switch that can be turned on and off using a small, flathead

Figure 66: Dipole Rotary Switch

Table 40: Recovery Power Switch

Name	**2-Pole Rotary Switch**
Cost	**$6.95**
Dimensions	**26.67 x 15.24 mm**
Availability	**Available on Missile Works**

d. Ejection Charges: Black powder charges of 1.6g for drogue and 2.15g for main parachutes.
e. Wiring: Secured with zip ties and protected against vibrations

The electrical system includes:

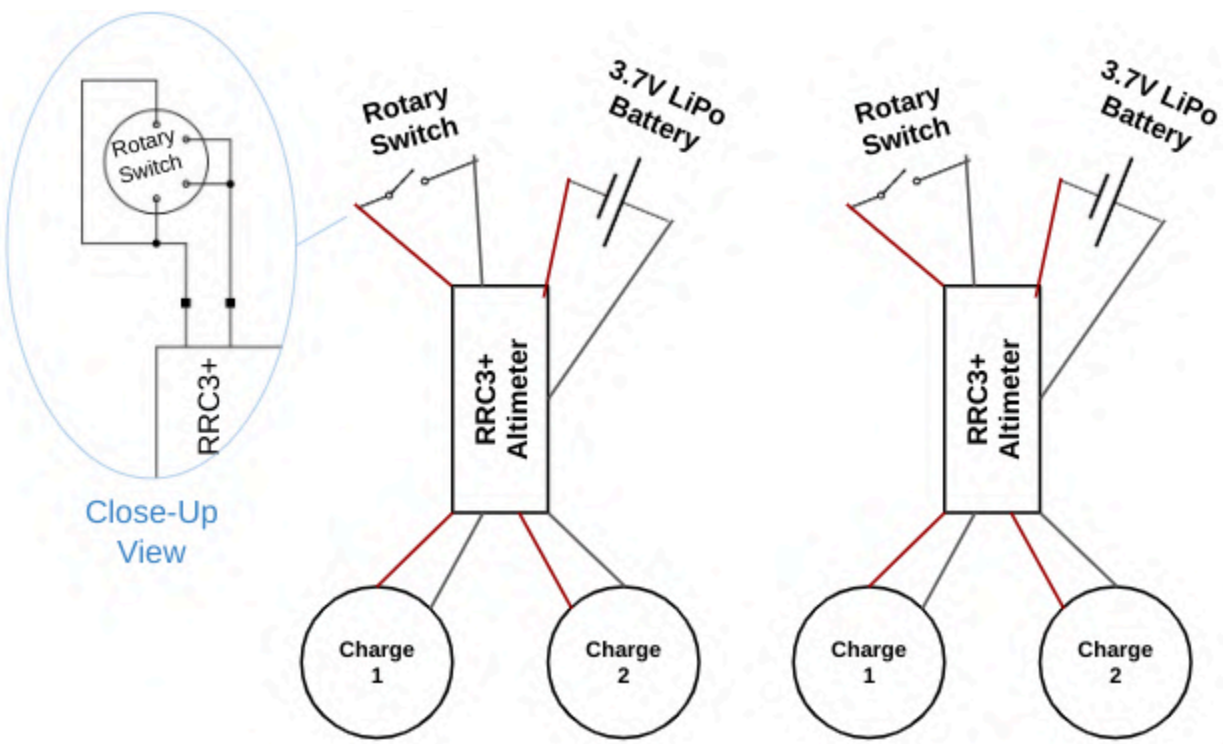
1. Independent circuits for primary and backup altimeters.

2. Respective black powder charges for each circuit for redundancy.

3. Rotary switches accessible from the rocket's exterior to activate each altimeters

3.3.4 Recovery Electrical Schematics

Figure 67: Electrical Schematics



3.4 Mission Performance Predictions

3.4.1 Target Altitude

The target altitude for project RANCH is 4300 feet. Based on our previous experience with open rocket, we find that the simulations usually overestimate the altitude so it would be better to pick a motor that brought us greater than the altitude. We found that 4300 feet would bring us on the lower side of the descent rates.

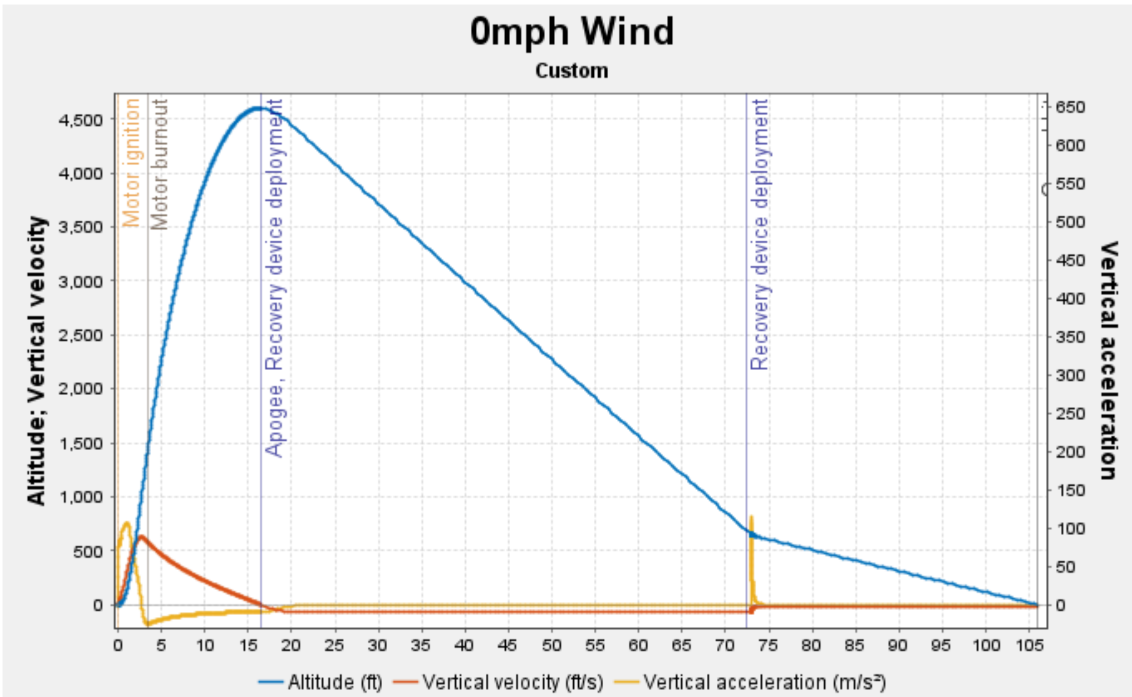
3.4.2 Flight Profiles

Using an Aerotech K550W motor with 0 mph wind and 8 ft launch rod angled at 0 degrees, we have the following flight profile properties.

Table 41: Flight Profile

Event	**Time (s)**	**Altitude (ft)**	**Velocity (ft/s)**	**Acceleration (ft/s^2)**
Liftoff	0.06	0.11	5.94	62.51
Launch rod Cleared	0.29	8.31	66.78	85.82
Burnout	3.36	1406.14	584.79	29.73
Apogee	16.46	4602.84	1.135	9.79
Drogue Deployment	16.5	4602.75	2.69	9.79
Main chute Deployment	72.92	652.80	69.80	0.013
Ground Contact	105.92	0.0	19.45	0

Figure 68: Wind Simulation



Maximum velocity occurs at motor burnout, and maximum acceleration occurs at launch rod cleared. These values were confirmed with our open rocket simulation.

3.4.3 Stability Margin

The table below summarizes the stability margin of the rocket with and without the motor. Both configurations have stability margins of over 2.0 cal.

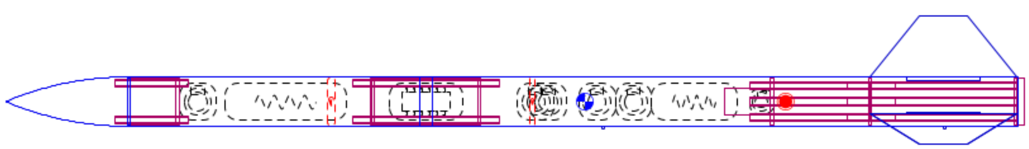


Figure 69: Without Motor

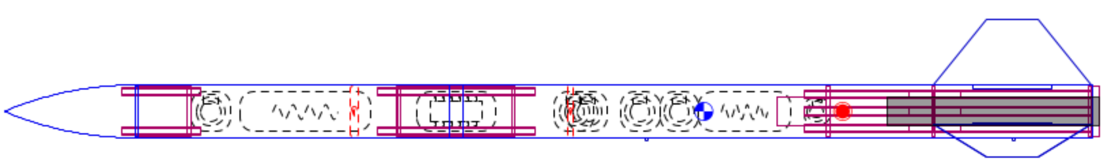


Figure 70: With Motor

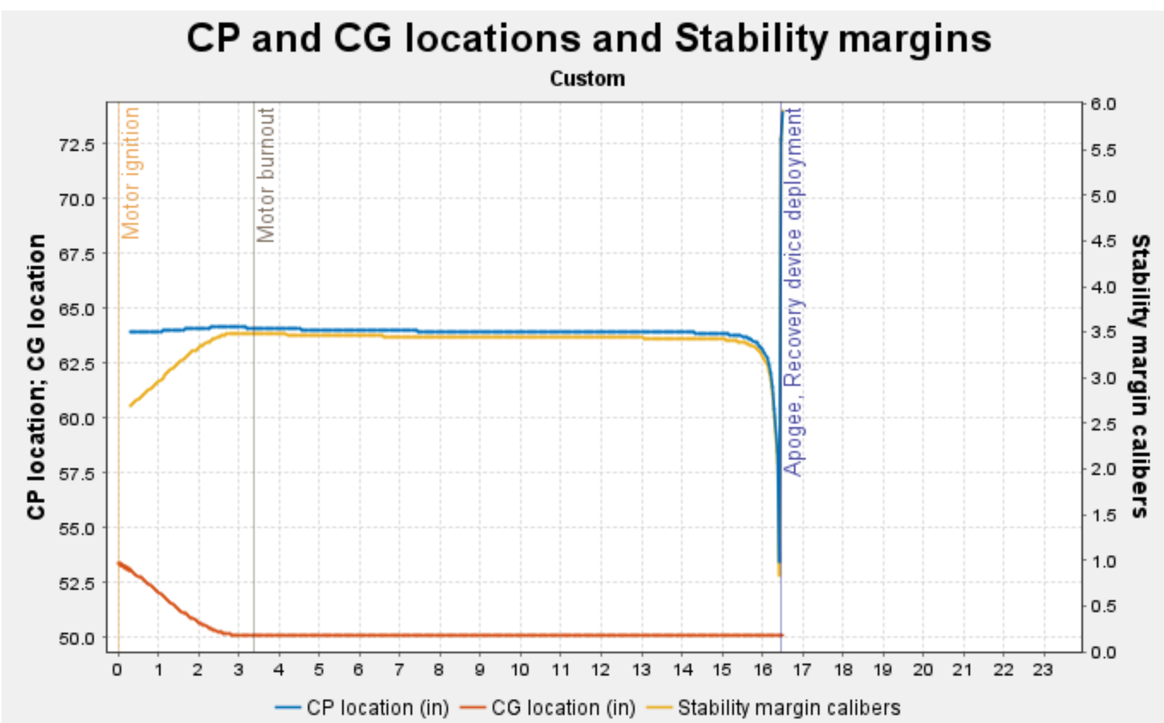
Table 42: Stability Margin

Configuration	Stability (cal)	CG location (in from tip)	CP location (in from tip)
Motor	2.63	53.374	63.97
No Motor	4.09	47.51	63.97

During flight, stability of the launch vehicle will also change dynamically, because mass from the fuel is being ejected and the angle of the vehicle changes. The fuel ejection, as well as the deployment of the parachutes, also changes the center of gravity and center of pressure.

The location of the center of pressure from the tip of the launch vehicle and stability margin overall follow the same trend being very similar. Despite some changes in CP, CG and stability margins, all three variables stay within acceptable parameters.

Figure 71: CP and CG Locations and Stability Margins



3.4.4 Kinetic Energy

Our launch vehicle has a mass of 13 pounds. With a touchdown velocity of 19 ft/s, we have a kinetic energy of 72.9ft/lbf. This is within the maximum acceptable kinetic energy of 75 ft/lbf. Therefore, the selected parachutes allow the rocket to safely land within our acceptable parameters.

3.4.5 Decent Time

The time from apogee to touchdown is roughly 86 seconds, calculated from the simulation done above.Wind conditions decrease this time slightly, with the minimum descent time being 83 seconds occurring at 20 mph wind, launching upwind. All of the possible descent times are within acceptable limits of under 90 seconds.

3.4.6 Drift

Table 43: Drift

Wind Conditions	**Total Drift (ft)**
0 mph	5.77
5 mph	284
10 mph	720
15 mph	958
20 mph	1565

Section 4: Payload Criteria

4.1 Design and Verification of Payload

The payload is designed to house experimental electronics and collect critical flight data, including maximum velocity, apogee, and landing time. These design choices prioritize structural integrity, reliability, and ensure proper data transmission. By opting for a single 9-inch fiberglass tube as the payload coupler, we enhance strength and simplify manufacturing while maintaining a lightweight and compact design. The bulkheads and mounting systems ensure stability during flight and recovery.

4.2 Concept of Operations for Payload

The payload is located within the upper section of the rocket and operates independently from the recovery and propulsion systems. Its primary functions are:

1. Data Collection: Gather data such as apogee, maximum velocity, and time of landing via an integrated altimeter and telemetry system.

2. Data Transmission: Transmit collected data to a ground receiver through a 2M radio band transmitter.

3. Structural Support: Provide a rigid housing for electronics, ensuring they remain operational during flight stresses.

4. Ease of Maintenance: A removable sled design allows for quick access to electronics for pre-launch setup or repairs.

4.3 Design Review for Payload

The payload structure and electronics were selected for their balance of durability, performance, and cost-effectiveness. Changes include replacing the segmented coupler with a single 9-inch fiberglass tube for enhanced rigidity and simplified assembly.

Key Components:

• Outer Coupler: 9-inch fiberglass tube, strong and lightweight.

• Bulkheads: Aluminum bulkheads provide structural support and anchor points for electronics and recovery connections.

• Electronics Sled: Houses altimeter, telemetry system, and batteries securely.

• Mounting Rods: Aluminum rods span the length of the payload, ensuring rigidity and stability

4.3.1 Payload Drawings

Figure 72: Assembled Avionics Bay with Dimensions

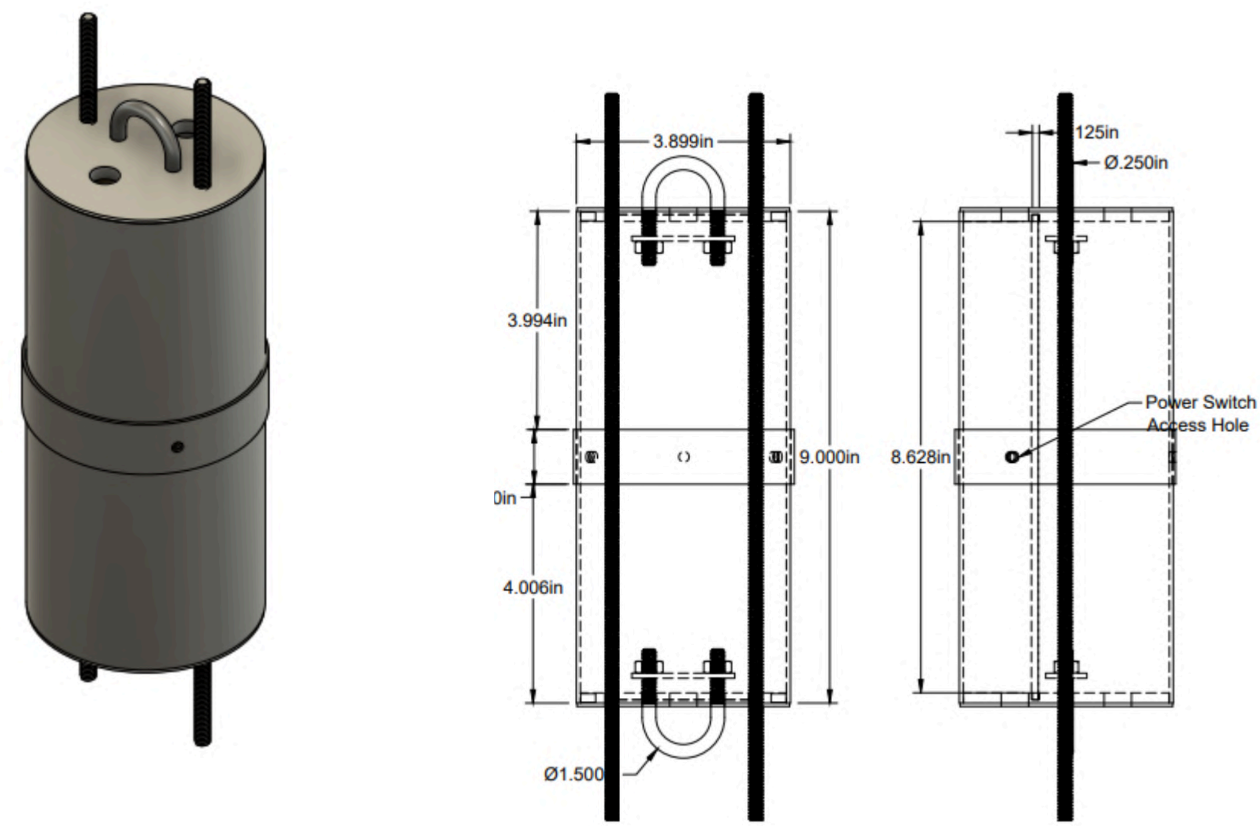
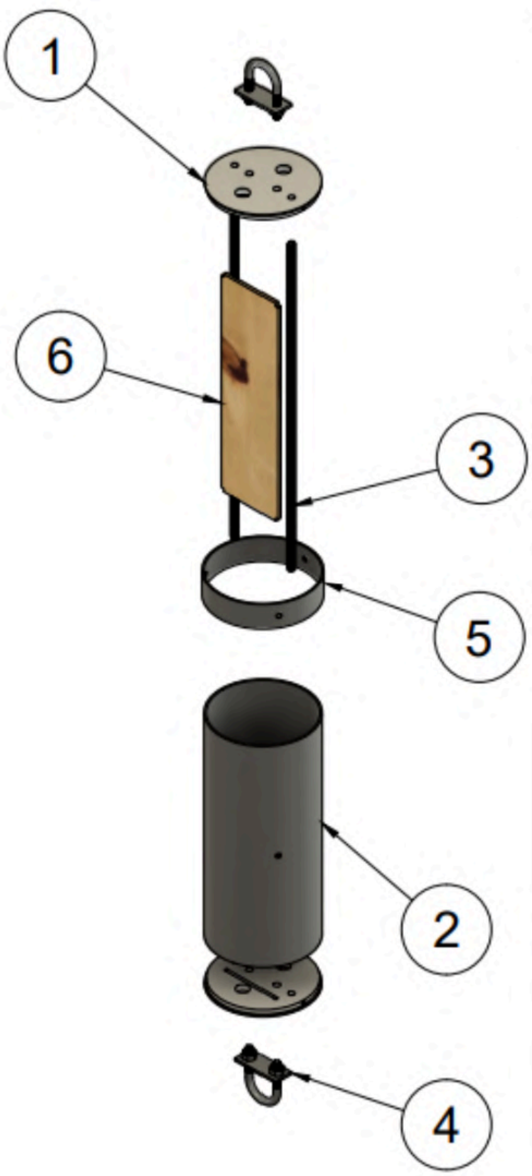


Figure 73: Exploded View of Avionics Bay



PARTS LIST			
ITEM	QTY	PART NAME	MATERIAL
1	2	PAYLOAD EXTREMITY BULKHEAD V1	ALUMINUM 3003-H12
2	1	COUPLER 12IN	STEEL
3	2	ALUMINUM THREADED ROD	
4	2	BULKHEAD U BOLT V2 V1	STEEL
5	1	OUTER AIRFRAME	STEEL
6	1	AVIONICS SLED	PINE

Figure 74: G12 Coupler

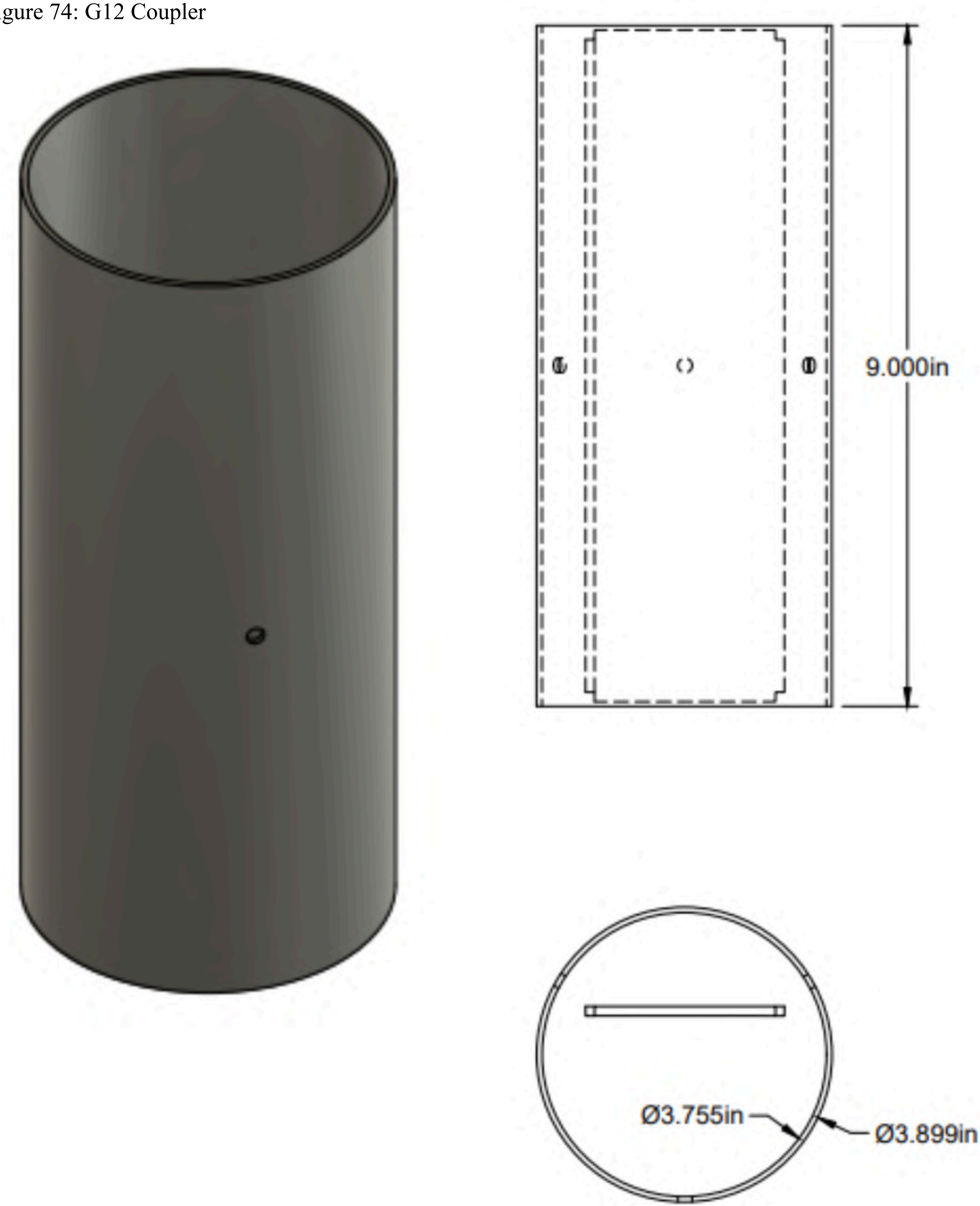


Figure 75: G12 Switch Band

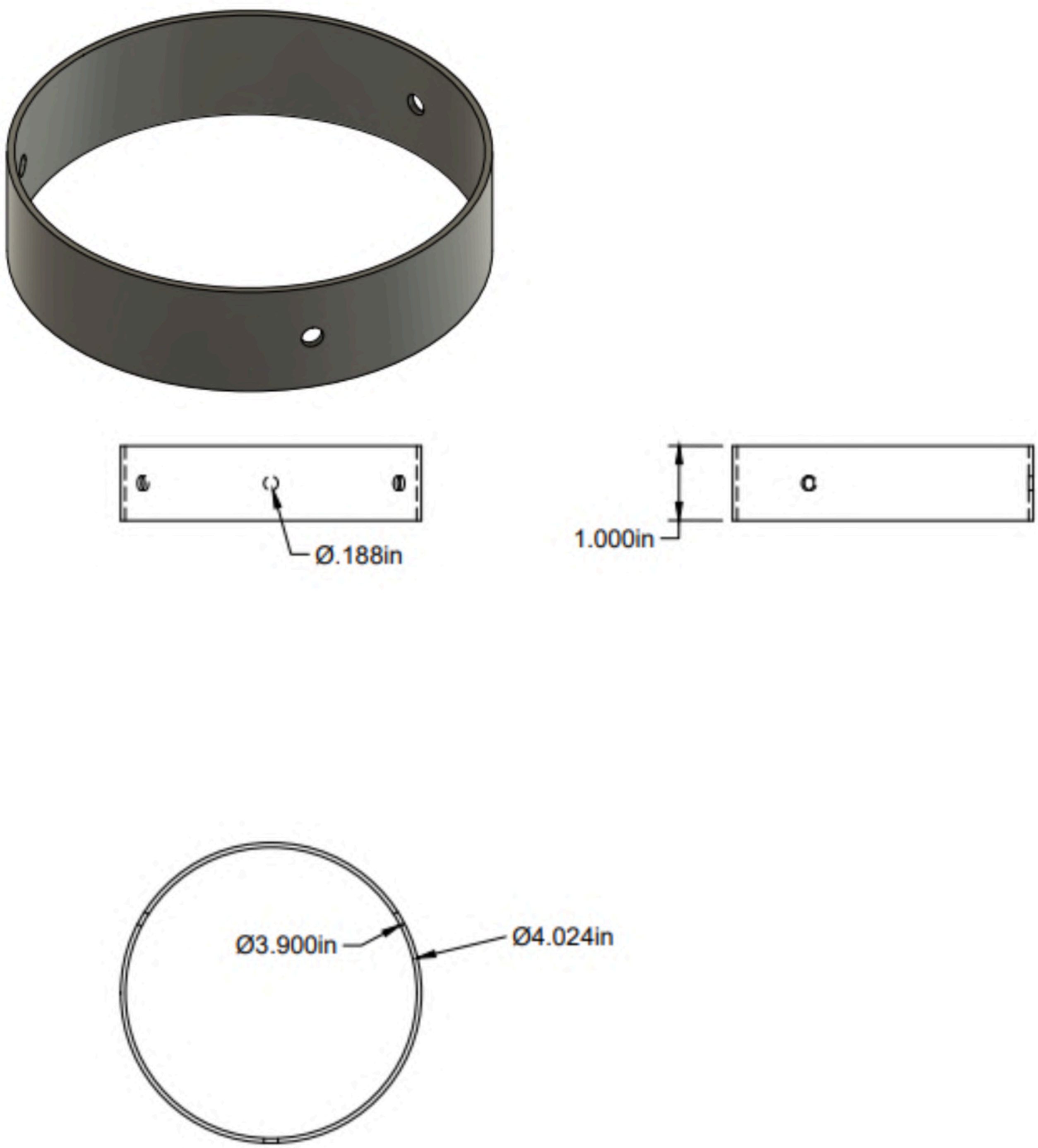


Figure 76: Bulkheads for Avionics Bay

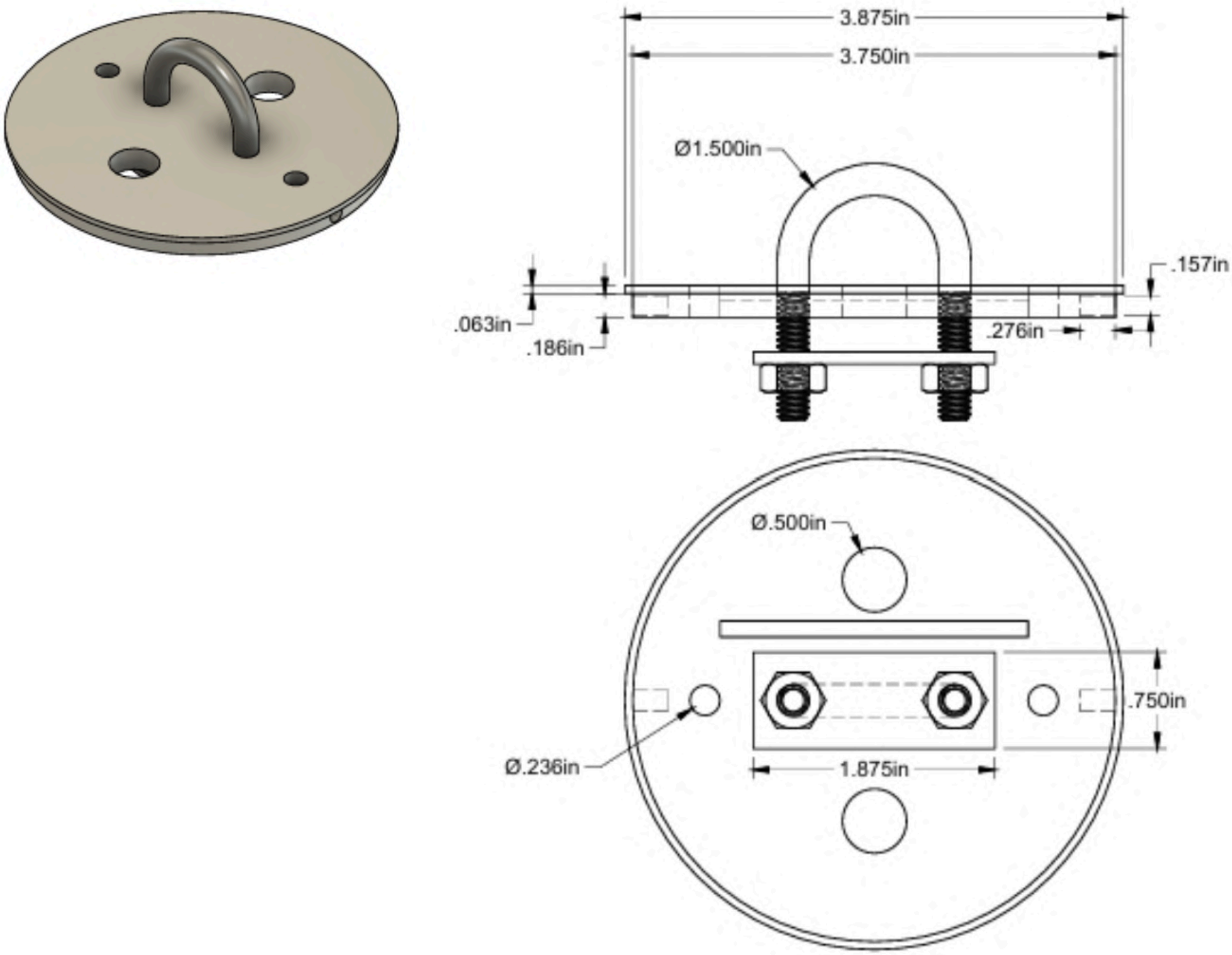
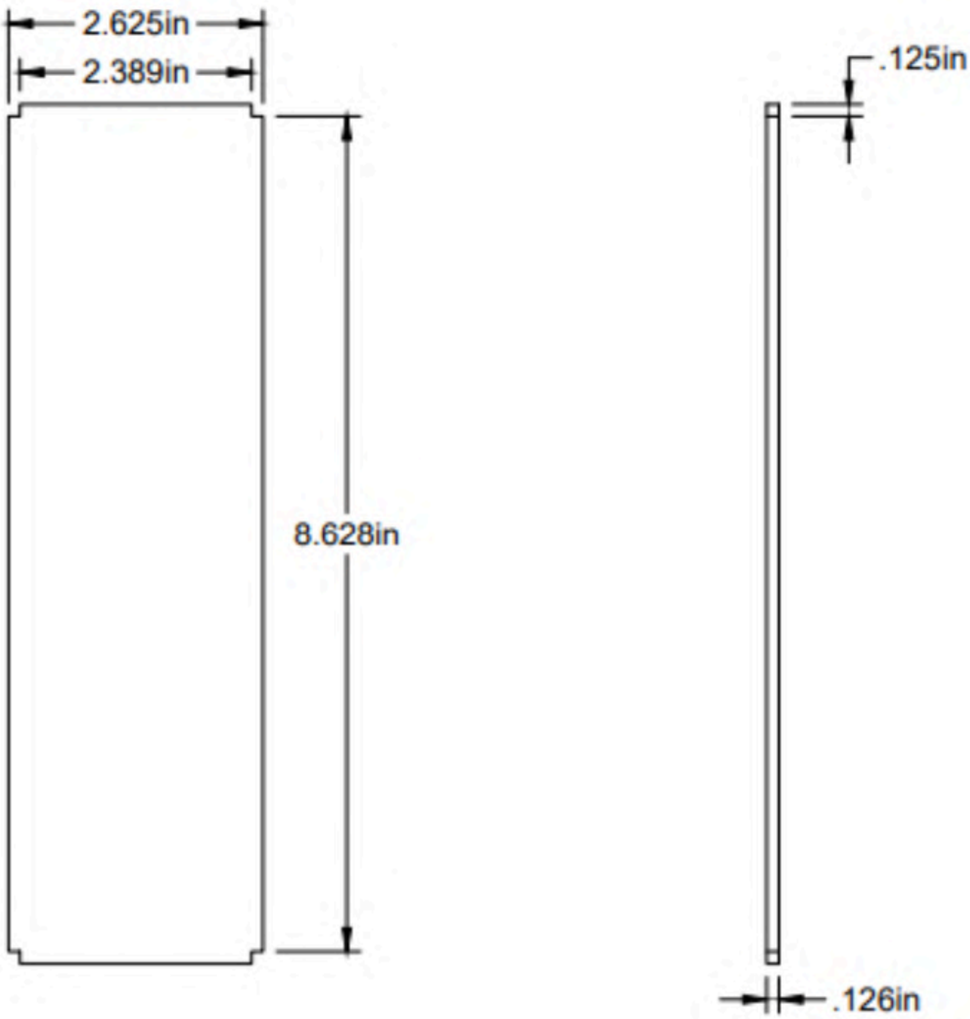
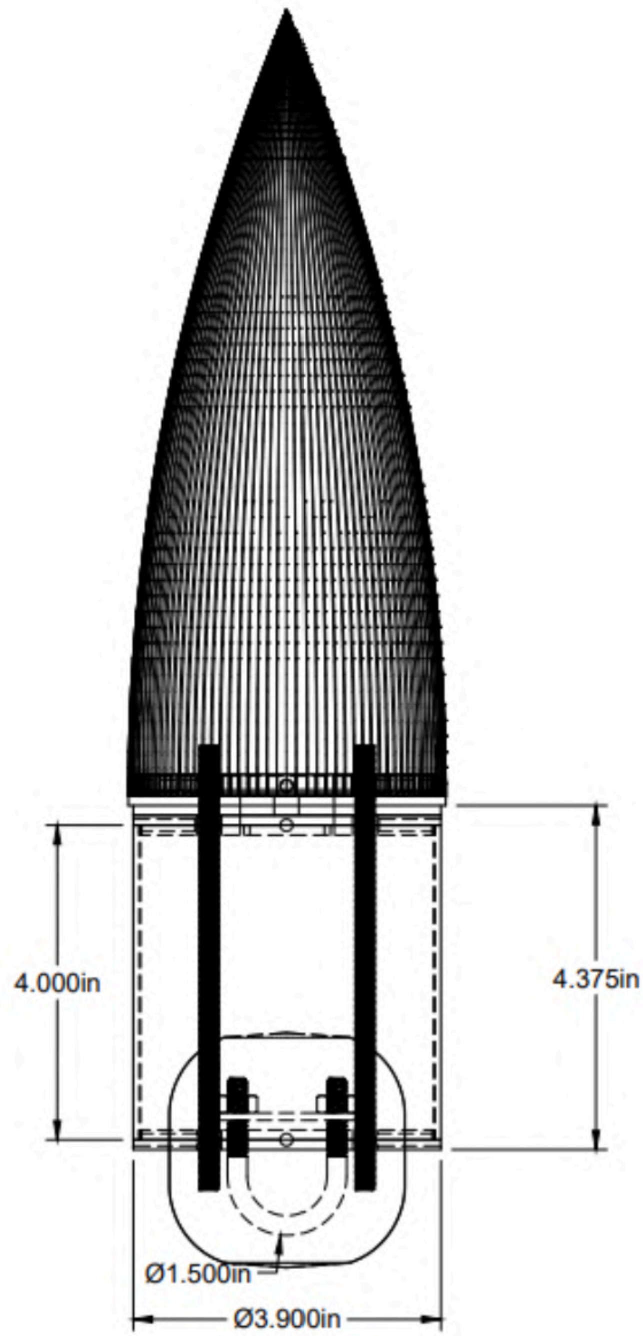


Figure 77: Avionics Bay mounting Sled

Figure 78: Nose Cone Payload Bay




4.000in
4.375in
Ø1.500in
Ø3.900in

4.3.2 Payload Component Interactions

Table 44: Payload Component Interactions

Component	**Function**	**Interaction with other Components**
Fiberglass Tube	Houses and protects payload	Provides mounting space for bulkheads and electronics sled
Aluminum Bulkheads	Structural support	Anchor points for the sled, recovery system, and the integration hardware
Electronics Sled	Mounts electronics securely	Interfaces with bulkheads for stability
Altimeter & Telemetry System	Data collection and transmission	Collects and then sends flight data to the ground station after the completion of the flight
LiPo Battery	Powers Electronics	Connected to altimeters and transmitters.

4.3.3 Payload Integration

The payload integrates seamlessly into the launch vehicle:

• Structural Alignment: The fiberglass coupler slides into the upper airframe and connects with the booster section via a precision-machined shoulder.

• Recovery System Attachment: U-bolts on the bulkheads anchor the recovery shock cords.

• Electronics Compatibility: Wiring for power and telemetry runs internally, protected from external forces.

4.3.4 Payload Retention System

The payload retention system ensures stability during launch, flight, and recovery:

1. Fiberglass Coupler: Provides a tight fit within the airframe.

2. Threaded Rods: Secure bulkheads in place, preventing movement during high-G forces.

3. Bolted Joints: The electronics sled is bolted to the bulkheads for added rigidity.

4. Recovery Connections: U-bolts on bulkheads securely tether the payload to the main and drogue parachutes during descent.

4.4 Payload Electronics

We initially had two transmitter options but have currently decided that transmissions will be done through the Featherweight Altimeter GPS Tracker. This is due to its ability for Bluetooth connectivity, and the access to a downloadable app for iPhone users to track telemetry data up to 262,467 feet. The callsign programmed into it will be “OCHS2025” at a frequency of 915.0MHz.

Table 45: Transmitter Evaluation

Transmitter Type	**Pros**	**Cons**
Featherweight GPS	● Does not require a HAM-certification ● Easy User interface ● Downloadable app for iphone	● 915.5 MHz ● More Expensive

BigRedBee GPS transmitter	• 144-148 MHz • Cheaper	• Not an easy user interface • No downloadable app for tracking • Needs a ground station

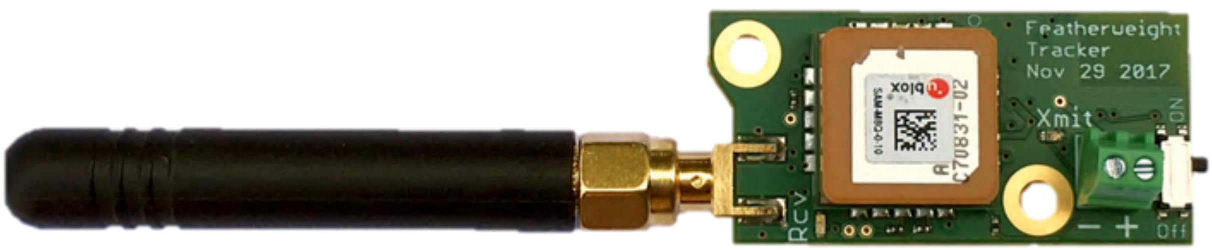


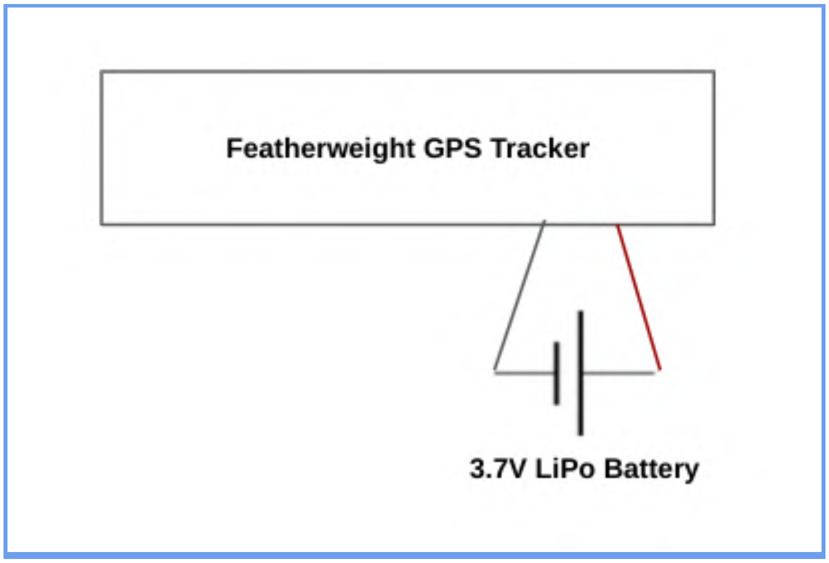
Figure 79: Featherweight Altimeter

Table 46: Payload Transmitter

	Featherweight GPS Tracker
Cost	$365.00
Frequency Band	915 Mhz
Dimensions *with antenna*	Length: 4.1” Width: 0.8” Height: 0.3”
Weight *no battery*	15 grams
Voltage	3.4V-4.5V
Current	86mA
Availability	Available on Featherweight

4.4.1 Payload Schematics

Figure 80: Wiring Schematic



4.5 Payload Justification

4.5.1 Material Justification

- The materials selected for use in our payload have been selected because of their exceptional strength and durability, as well as their ability to accomplish our mission. The fiberglass coupler will provide a strong, durable, and lightweight structure to our payload. The aluminum rods and bulkheads will create advanced, lightweight, and strong joints for our payload. Our wood electronics sled will provide a strong platform for our payload electronics. All materials that are to be used will provide us with a payload that is well equipped to complete the mission and withstand the forces of rocket flight.

4.5.2 Dimensions

- The exact dimensions for every little part of our payload design have been well thought out. Our current dimensions allow us to have the most optimized design providing for the most amount of payload. The design is structurally sound with four inches of shoulder on each side of the payload. The design also has minimum aerodynamic effect with small vent holes and a narrow switch band. Our dimensions provide a safe payload that has adequate space to hold everything to complete our flight successfully.

4.5.3 Placement

- Our main payload has been placed at the top of our rocket. This is because of the interference with the radio and our body tubes. This placement puts our payload in a position where we could complete the mission. This placement puts weight at the top of our rocket and puts the payload in a good position to accomplish its mission. Our secondary payload section is in the middle of the rocket because it will hold our avionics. This placement is key for the recovery system and the energetics that will be used during the recovery phases of flight. This is also a good spot to add weight to the rocket.

Section 5: Safety

5.1 Final Assembly and Launch Procedure Checklist Draft

5.1.1 Troubleshooting Procedure

Any errors with the payload components can be seen in the Featherweight UI app. There are multiple approaches we can take to various errors:

1. GPS-App connection failure:

- ☐ Ensure power LED on the GPS is on
- ☐ Verify the phone's bluetooth is turned on and able to pair with devices
- ☐ Look for devices in the app in "device list" and "scan page"

2. Connection without showing data:

- ☐ Ensure the GPS and the app are on the same frequency using the same TrackerID
- ☐ Make sure that the GPS device is set to "tracker" and the app as "ground station"

3. Units are communication, but no GPS data is available:

- ☐ The GPS is simply not getting a good signal. Try your best to clear the path from the antenna to the sky

5.1.2 Recovery Preparation

Recovery System, Drogue Chute:

- ☐ Check shock cords for cuts, burns, and tangles.
- ☐ Check all shroud lines — no tangles.
- ☐ Check drogue chute for tears and burns.

- ☐ Check deployment bag for tears.

Check all connections. Insure all devices are in good condition and properly secured:

- ☐ Electronics bay shock cord to drogue
- ☐ Booster shock cord to drogue

Pack drogue chute in deployment bag, keep lines even and straight.

- ☐ Fold drogue chute per manufacturer's instructions.
- ☐ Ensure shroud lines are free from tangles.
- ☐ Ensure all quick links are secure.
- ☐ Insert drogue bag/chute into the aft recovery compartment .
- ☐ Insert ejection charge protection.

Recovery System, Main Chute:

- ☐ Check shock cords for cuts, burns, and tangles.
- ☐ Check all shroud lines — no tangles.
- ☐ Check main chute for tears and burns.
- ☐ Check deployment bag for tears.

Check all connections. Insure all devices are in good condition and properly secured:

- ☐ Nose Cone shock cord to drogue
- ☐ Electronics bay shock cord to drogue

Pack main chute in deployment bag, keep lines even and straight.

- ☐ Fold main chute per manufacturer's instructions.
- ☐ Ensure shroud lines are free from tangles.
- ☐ Ensure all quick links are secure.
- ☐ Insert ejection charge protection.
- ☐ Insert main bag/chute into forward recovery compartment

5.1.3 Payload Preparation

Step 1: Power-Up and Ground Test

1. Power Up Payload Systems:

- ☐ Plug in the battery for the payload electronics.
- ☐ Verify power LED is illuminated on all devices.

2. Establish Connections:

- ☐ Connect to the payload via Bluetooth or designated telemetry system.
- ☐ Ensure communication with the ground station:
- ☐ Test data transmission (e.g., altitude, battery voltage).
- ☐ Verify expected telemetry output.

Step 2: Pre-Installation Inspection

Inspect all payload components to ensure no damage:

- ☐ Bulkheads
- ☐ Electronics sled
- ☐ Batteries and wiring harness
- ☐ U-bolts and anchor points
- ☐ Verify all screws, fasteners, and mounting rods are tight.

- [ ] Ensure payload is in the closed configuration for flight.
- [ ] Confirm rotary switch is OFF before installation.

Step 3: Payload Integration into Rocket

- [ ] Align the payload coupler with the rocket airframe.
- [ ] Secure the payload using shear pins at designated locations.

Verify retention system integrity:

- [ ] Check tightness of bulkheads and shear pins.
- [ ] Confirm payload is properly seated within the airframe.

Step 4: Final Verification

- [ ] Turn on the rotary switch to activate the payload.

1. Conduct a final Bluetooth connection test:

- [ ] Confirm all telemetry data is being received.
- [ ] Verify payload systems remain operational under static conditions.

2. Confirm battery status:

- [ ] Ensure sufficient charge for flight.

5.1.4 Electronics Preparation

Step 1: Power-Up and Ground Test

1. Power Electronics Bay:

☐ Plug in the battery for the electronics.

☐ Verify that power LED is illuminated on all devices (eg. RRC3 altimeter, Featherweight GPS, etc)

2. Establish Connections:

☐ Connect to the payload via Bluetooth or designated telemetry system.

☐ Test data transmission (e.g., altitude, battery voltage, gps coordinates).

☐ Ensure all expected telemetry output are received

Step 2: Pre-Installation Inspection

Inspect Electronics and Wiring for Damage:

☐ RRC3 altimeter

☐ Featherweight GPS and antenna

☐ Wiring harness and connectors

☐ Power distribution and battery connectors

☐ Ensure all screws, fasteners, and mounting rods are tight.
☐ Make sure no wires are loose or exposed
☐ Ensure payload is in the closed configuration for flight.
☐ Confirm rotary switch is OFF before installation.

Step 3: Integration into Electronics Bay

☐ Align the RRC3 altimeter, Featherweight GPS, and all other electronics are in the electronics bay

☐ Make sure all devices are securely attached

Verify integrity:

☐ Check tightness of bulkheads and shear pins.

☐ Confirm the electronics bay is properly attached to rocket's airframe

Step 4: Final Verification

☐ Turn on the rotary switch to activate the electronics bay.

1. Conduct a final Bluetooth connection test:

☐ Confirm all telemetry data is being received.

☐ Verify all electronics systems (altimeters, GPS's, etc.) remain operational under static conditions.

2. Confirm battery status:

☐ Ensure sufficient charge for flight.
☐ Ensure backup power systems are functioning

5.1.5 Rocket Preparation

1. Unpack rocket and inspect for damage
2. Place rocket on workstation and separate the different parts: Nose cone, forward section of BT, Av-Bay coupler, Aft end of the rocket
3. Open the Av-Bay coupler and inspect that all wire connections are secure

4. Retrieve batteries to be placed in the Av-Bay electronics and check the voltage of each battery
5. Install the proper battery to each electronic component inside the Av- Bay. Make certain that each battery is properly secured.
6. Activate each component, separately, to check that each component is functioning correctly. Be certain to turn off every electronic component before assembling the Av-Bay
7. Secure the Av- Bay lids to the Av-Bay coupler, be careful not to disconnect any wires or pinch wires while closing off the Av-Bay.
8. During this procedure, wear safety glasses and stay clear of any heat or flame sources. Load the energetic's to the deployment containers on either side of the Av-Bay lids, Primary and Secondary for both Drogue and Main deployment. Set the Av-Bay coupler aside when completed in a safe and secure manner.
9. Attach the drogue end shock cord to the attachment point inside the aft end of the rocket. Give several strong pulls to the shock cord to be certain that the shock is properly attached.
10. Check the integrity of the drogue parachute and fold as required by the manufacturer. Wrap a Nomex blanket around to drogue parachute to protect the parachute. Properly secure the Nomex blanket to the drogue para lines so it protects the drogue but does not interfere with the opening of the drogue parachute. Attach the drogue wrapped parachute to the third loop on the shock cord, make certain it is properly attached.
11. Z fold the drogue side shock cord and lower it, and the drogue wrapped parachute into the aft end of the rocket.
12. Retrieve the Av-Bay coupler, be careful with the attached deployment energetics at either end of the Av-Bay lids.
13. Properly secure the other end of the drogue parachute shock cord to the drogue attachment point on the drogue side Av-Bay lid.
14. Carefully insert the drogue end of the Av-Bay coupler into the aft end of the rocket BT and secure the Av-Bay coupler to the BT with a shear pin.
15. Attach the main parachute shock cord to the main side attachment point on the Av-Bay coupler lid. Be certain that it is properly attached.

16. Retrieve the forward section of the BT. Thread the main parachute shock cord through the forward section of the BT so it is fully extended through the opposite open end.

17. Rotate and insert the forward BT section over the main side Av-Bay coupler section and secure the BT to the Av-Bay coupler with rivets or other forms of securing fasteners.
18. Inspect the main parachute, Make certain that it is not damaged, the para cords are not tangled, and properly fold the main parachute as required by the manufacturer. Wrap a Nomex blanket around the parachute to properly protect the parachute.
19. Secure the Nomex blanket to the main parachute paracord, but be certain that it will not interfere with the opening of the main parachute. Now secure the main parachute to a third loop on the main parachute shock cord. Z fold the shock cord and lower the shock into the forward section of the BT. Then, lower the wrapped main parachute into the forward section of the BT carefully.
20. Secure the main parachute shock cord to the attachment point on the nose cone coupler and carefully insert the coupler into the forward section of the BT. Rotate the nose cone to align the shear pin insertion point. Secure the nose cone to the forward section of the BT with a shear pin.
21. Place the rocket in a vertical position and inspect the entire rocket to ensure that the rocket has been correctly assembled, secured and ready for the motor to be loaded.

Now that the rocket has been correctly assembled and has passed a final inspection, set the rocket in a cradle or supporting stand so it is secure and not damaged while we wait for the final step, motor insertion. Keep the rocket in a shaded area, do not expose the rocket to water, direct sunlight, or any elements which can affect the performance of the rocket.

5.1.6 Motor Preparation

1. Before motor assembling, place safety glasses over eyes, be certain that your workstation is free of clutter, no heat sources or flame devices during this procedure. The assembling of a rocket motor must be completed in a location that will not interrupt you or distract you from this task. Make certain that you have all the necessary tools and supplies for this task.
2. Open the motor packaging and read the manufacturer's instruction sheet. If it is not enclosed, retrieve online and carefully read the instructions. Note; all motor's,

while similar, will have different components and assembled slightly differently. Read all instructions carefully.

3. Carefully place all parts on top of your workstation in the correct order of assembling.
4. Use only correct lubricants, as recommended and maintain your workstation and hands clean during assembling.
5. Carefully assemble the motor as per manufacturer's instruction. Be careful not to damage any O rings or other components.
6. Be certain that your motor casing is clean, properly lubricated, and closure threads, closing without resistance and well lubricated.
7. When inserting motor propellant grains into sleeve, be certain you have each grain in the proper order if required. Avoid getting lubricants on the propellant grains.
8. Assemble the entire motor as instructed, place the whole thing into the motor casing, and close the casing closures as required by the manufacturer.
9. Set the motor casing aside and inspect the motor igniter. One should have been enclosed with the motor. Be certain that the end of the igniter, which is being inserted into the aft end of the motor, is free of cracks and flaws. Use an ohm meter to check continuity resistance. Note; always have more than one igniter in your supplies.
10. Tape the igniter to the side of the rocket airframe.
11. Remove the motor retainer flange from the aft end of the rocket and insert the assembled motor casing into the motor tube on the aft end of the rocket
12. Secure the assembled motor casing with the motor retaining flange, be certain it is properly secured and tight. Note; do not insert the motor igniter into the motor. This last step is only permitted when the rocket is on the pad, and in a safe and vertical position.

The rocket is now ready to be inspected by the Range Safety Officer. Frist, fill out a flight card as required by the launch event. When taking the rocket to the RSO, be careful with the rocket. Don't drop the rocket, don't mishandle the rocket or exert too much forces on the sections of the rocket which are intended to separate during recovery.

5.1.7 Launch Pad Procedure

The following procedure will be carried out by the Team Mentor.

- ☐ Before moving rocket to pad, perform a visual inspection of the pad itself to ensure it is clear of debris from previous launches and properly mounted and secured into the ground
- ☐ Inspect the assembled airframe for any damage or loose components
    - ☐ Make sure that each component of the airframe is attached to an adjacent section by nylon shear pins
    - ☐ Shear pins between payload and recovery bay at coupler
- ☐ Place and double check that the motor is secure inside the rocket
- ☐ Put the fully assembled rocket onto the launch rail, ensure the the rocket is safe before letting go
- ☐ Once the rocket is on the launch rail, insert a small flat-head screwdriver through each of the two holes through the body of the electronics bay and turn the rotary switch on each hole.
- ☐ If required, adjust angle of launch rail to ensure an upwind launch
- ☐ Complete final inspection before proceeding to motor and igniter installation, making sure to double check for any apparent issues with the launch pad, launch rail, or rocket

5.1.8 Flight Procedure

- ☐ Wait for RSO to give clearance to launch
- ☐ Ensure that all personnel are a minimum 300 feet away from the launch pad in accordance with the NAR minimum distance code.
- ☐ Make sure that all people in the surrounding area are alerted to the fact the launch pad is hot and ready for takeoff
- ☐ Wait for countdown to be given and then proceed with launch command
- ☐ Ensure that all personnel in the vicinity are aware of the rocket's path and location incase of flight path deviation or rocket failure
- ☐ If any team members see a deployment (drouge or main) of a parachute immediately alert others to the location of the rocket.
- ☐ Wait for Radio wave transmission of data points. Allow for electronics teams to breathe and get data points.
- ☐ Wait for the RSO to give clearance to allow for the designated retrieval team to locate and retrieve the rocket and its parts.

5.1.9 Post - Flight Procedure

- ☐ Once RSO gives clearance, allow electronics team to utilize the GPS tracking to locate the rocket

- [ ] Follow directions to find the rocket, take picture with team at the rocket grounded site
- [ ] In case of rocket design failure, search the surrounding area for payload and electronics bay sections.
- [ ] Turn off recovery bay altimeters
- [ ] Turn off payload electronics
- [ ] Collect all rocket pieces and load them up into the wagon to be transported
- [ ] Celebrate if all was successful

5.2 Risk Assessment Tables

Figure 81: Minimum Distance Table

MINIMUM DISTANCE TABLE

Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 — 320.00	H or smaller	50	100	200
320.01 — 640.00	I	50	100	200
640.01 — 1,280.00	J	50	100	200
1,280.01 — 2,560.00	K	75	200	300
2,560.01 — 5,120.00	L	100	300	500
5,120.01 — 10,240.00	M	125	500	1000
10,240.01 — 20,480.00	N	125	1000	1500
20,480.01 — 40,960.00	O	125	1500	2000

Table 47: Level of Risk

Level of Risk	Acceptance Level
High Risk	Unacceptable. Will cause harm or significant damage to plans, people or the surrounding environment. Must be immediately fixed and

	not allowed to continue until fixed.
Medium Risk	Undesired. Will cause some harm or some damage to plans, people or the surrounding environment. Must be fixed before continuing, however, does not have to be immediately fixed.
Low Risk	Adequate. Requires either verbal or written approval from supervisor or mentor directly responsible for the operation or action.
Minimal Risk	Acceptable. No need for review or concern by supervisors or advisors. If there is any danger it is equal to a papercut.

Table 48: Probability Key

Description	Percentage
A - Frequent	80%> chance of occurance
B - Probable	50% to 80% chance of occurance
C - Occasional	20% to 50% chance of occurance
D - Remote	1% to 20% chance of occurance
E - Improbable	<1% chance of occurance

Table 49: Severity-Probability Key

	Severity				
Probability	1-Catastrop hic	2-Critical	3- Serious	4-Marginal	5-Negligible

A - Frequent	1A	2A	3A	4A	5A
B - Probable	1B	2B	3B	4B	5B
C - Occasional	1C	2C	3C	4C	5C
D - Remote	1D	2D	3D	4D	5D
E - Improbable	1E	2E	3E	4E	5E

5.3 Preliminary Personal Hazard Analysis

Table 50: Personal Hazards

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
During manufacturing of the rocket an accident happens with equipment.	Lack of proper training or supervision; Ignorance of established safety and maintenance rules or protocols.	Team members sustain minor to severe injuries; People in the area sustain minor to severe injuries; Surrounding equipment sustains minor to severe damage.	1C	Training and information on all of the tools used. Documentation of all members signing the Safety Agreement. Mentor, SO, or advisor supervision when using tools.	OCHS tools are used by members who know how to use them and are operated by members who are of age. Safety Agreement is signed and followed; Adhere to local rules when using external resources.	3E

Accidents occur while using soldering iron during assembly of electronic systems.	Lack of training or supervision; Ignorance of safety protocols and proper soldering techniques; Wires exposed to hot soldering iron and electronic circuits exposed to hot soldering.	Team members may experience 1st or 2nd degree burns; Equipment and/or facilities are damaged; Electronic parts are damaged and/or salvage; Parts would need to be reordered due to damage.	3D	Training on all required tools and machines; Instruction on safe shop and work practices.	All team members will be educated on proper protocol and how to properly handle and use soldering irons; All use of soldering machines and tools will be supervised by either the SO, an Advisor, or Mentor.	4E
Mistakes in 3D printing components for the rocket.	Lack of understandin g on how to properly model pieces in Fusion360 or other CAD programs; Lack of understandin g how to use the 3Dprinters or lasers; Equipment malfunction.	Pieces will not be able to be used for the rocket; Time and money wasted trying to get prints right..	3C	Students have been taught to use 3d printers safely and laser cutter safely;	We will inspect each part we print or laser is inspect and up to standards before installing the parts and again before launch.	5D

5.4 Hazard Research

Table 51: Hazard Research

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
Black powder detonates during loading, on the launch pad, or prematurely during flight.	Safety procedures are not followed to standards during black powder loading; Black powder is exposed to fire, a hot surface or sparks from live electrical components before/during flight ; Black powder experiences too much friction and or impact force.	Team member or surround people may suffer severe injury and/or death; Equipment and/or facilities may be damaged; Recovery systems don't deploy properly; Rocket is severely damaged and part(s) or the whole thing is unsalvageable.	**1C**	Black powder will only be handled by a mentor; All electronic equipment adjacent to the black powder will be properly insulated and shielded from recovery explosives; All fires and hot surfaces as well as live electronics are closely monitored to make sure that none somehow is anywhere near close to black powder.	Black powder will only be handled by our HPR level 3 certified mentor.	2E

Inhalation of chemical or metal particles and/or fumes during assembly.	Substances encounter an open flame or hot surface; Lack of proper ventilation when working with certain chemicals or metals; Unforeseen reaction between chemicals that results in gas products;	Irritation of the respiratory system; Shortness of breath, dizziness, naus and/or fatigue; Prolonged exposure may lead to respiratory damage.	2C	Limit use of dangerous chemicals and metals to well-ventilated areas; Use of a fume hood in workshops when appropriate; Training on and enforcement of exposure time limitations; Required use of protective equipment such as masks, respirators, and safety glasses when dealing with hazardous materials.	Work with hazardous substances will be performed in a designated shop/laboratory space supervised by trained personnel.	2E

5.5 Environmental Concerns

Table 52: Environmental Concerns

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
Parts of the rocket's materials explode and ignite the surrounding environment.	Rocket literally explodes on either the launchpad; in the sky; or on the ground	Surrounding environment is ignited by flaming debris and sparks.	2C	Follow all fire safety procedures and ensure that no materials ignite or explode.	Ensure fire extinguishers are at the launch site and explosives are only handled by people with certifications.	4E

	where it landed.					
The rocket encounters unexpectedly strong winds during flight.	Wind speeds during launch day are not good or are not properly measured.	The rocket takes an unexpected flight path; Possible injury to people because of the errant flight path; Rocket fails to reach the desired apogee. Rocket lands outside of the desired zone.	2C	Design will emphasize flight stability and structural integrity; Launch will be postponed and/or canceled should conditions remain unfavorable. Rocket should weigh a metric ton as to let it fall faster and not be so affected by wind speeds.	Design of the rocket will be reviewed during bi-weekly team meetings; NAR guidelines will be followed if winds exceed allowed conditions; Launch guidelines will be developed so that launch will be canceled if the measured wind speed exceeds our individual rocket's allowable conditions.	4C
High temperatures or strong light sources ignite flammable materials.	Improper storage of flammable material; Improper temperature control of flammable material.	Fire or explosion; Any person may suffer serious injury; Harm or injury to students, faculty, or staff not associated with the project;	**1D**	All flammable materials will be stored in flame-resistant metal cabinets at room temperature or by mentor; Safety officer or mentor will inform all team members on best storage practices.	Routine inventory checks and oversight by SO, mentor or advisors to ensure that the flammable materials are properly stored.	**2E**

		Damage to materials and facility.				
Launch vehicle disrupts the surrounding area by hitting the ground too hard.	Failed to model KE properly. Parachutes fail to deploy properly due to: 1) Failed to fold properly and shock cords get tangled 2)Energetics are wired wrong and the parachutes don't go off.	Ground is damaged, or whatever it hits. Rocket parts are scattered around the impact site and threaten local wildlife.	2D	Rigorous use of simulations and calculations for landing KE. Will use a parachute that allows for a safe amount of drag force to be created. Methodical and calculated measures will be taken when assembling the rocket to ensure that it does not come apart whilst flying.	Simulation and calculation results will be analyzed for accuracy and done by more than one person to then be used to ensure the rocket doesn't disturb the local fauna. Simulations and calculations will determine parachute size. Safety checks will be done pre-flight to ensure the rocket is safe to fly.	3E
Wildlife is injured during launch, landing, and/or flight.	Wildlife approaches the launch pad at time of launch; The rocket hits a flying animal while during flight; The rocket hits any animal while landing.	Wildlife are killed or injured; Rocket is thrown off course due to hitting a flying animal; Rocket is injured or torn about hitting an animal on its way down.	**2D**	Launches will take place on sites that are in agreement with NAR and Tripoli regulations, and launch will only occur when the site is deemed clear of wildlife within the landing area.	NAR and Tripoli guidelines are used to determine acceptable launch locations and conditions.	**3D**

Rocket meets its untimely demise landing in a body of water.	Rocket takes an unexpected flight path; Rocket drifts out too far during descent.	Electronics in rocket short out and are unusable; Rocket parachutes get moldy; Rocket unable to be retrieved due the fact that its too far under water.	**1D**	Lots of calculations on the drift distance to ensure it doesn't drift that much; Choosing parachutes that are safe, but don't create unnecessary drag and let the rocket fly off.	Simulations will confirm the veracity of calculations. Small-scale and full-scale testing will additionally test calculations; Avoid launching near large bodies of water. Make sure the team is keeping a vigilant eye out so that it doesn't fall into a lake.	**2E**
Hazardous materials from rockets (construction or otherwise) end up in either the trash or out in the open.	Not knowledgeabl e on how to properly store and dispose of hazardous materials.	Potential harm to the environment; Potential risk to students and faculty in OCHS	**2E**	SO, mentor, and advisor will be educated on proper disposal of potentially hazardous substances.	Hazardous substance disposal will follow local and federal guidelines as well as MSDS and EPA guidelines.	**3E**
Fumes and dust particles from rockets are expelled into the air.	Lack proper attachment	Team members or spectators near launch may experience the effects of low air quality.	**3B**	Filters will be used on all ventilation fans; Any painting will be done in a well ventilated	Construction will follow safety guidelines to prevent the spread of dust, paint, or other airborne	**3E**

				area by individuals who know how to handle a can of spray paint.	particulates during flight.	

5.6 Preliminary Failure Modes and Effects Analysis

Table 53: Failure Modes and Effects

Recovery systems encounter unexpected failure during flight	Parachute becomes entangled; Ejection charge don't ignite; Too many attachment points; Parachute packed incorrectly; Malfunction of altimeters during flight.	People may be injured by falling rocket; Rocket gathers too much KE and hits the ground with a large force injuring both the surrounding area as well as the inside components; Rocket parts are unusable due to damage from impact.	1C	Fold parachute properly before launch and precisely pack the shock cord with the parachutes in the rocket to reduce entanglement; Use optimal amount of shear pins: enough to keep the rocket together during flight, but not too many as to prevent the recovery system from deploying; Make sure to ground test the recovery system and troubleshoot if needed; Make sure there is redundancy in the recovery system (double altimeters, double black charges etc.) to reduce risk of failure.	Carefully craft electronic systems and recovery systems with approval from the team mentor and NASA. Ensure that all members of the recovery team are up to date and educated on how to correctly pack the tube.	2E

Drag forces damage the rocket whilst flying and descending.	Failure to design rocket components that would withstand drag forces; Rocket components are not assembled correctly.	People may be injured by falling rocket; Fins may be damaged, potentially leading to further damage of the rocket; Unstable or unpredictable flight path.	2D	Use careful calculations and simulations to ensure drag forces will not cause failure of components; Test components by launching a subscale rocket.	Carefully craft the rocket with approval from the team mentor and NASA. Ensure that all members rigorous testing on all components to ensure they withstand forces; Ensure that all simulations and calculations are done at least thrice with multiple people doing them.	**4E**
Rocket takes an unexpected or unstable flight.	Wind speeds knock rocket off its expected path; Body of the rocket is damaged during launch.	People may be injured by rocket; Rocket may be damaged or break up mid-flight;	2B	Use simulations to predict flight pattern and trajectory stability; Test the rocket's flight path with a small-scale model;	Simulations will be performed p in a variety of circumstances to make sure that the final flight is safe and stable;	4E

Rocket fails to meet target altitude, or exceeds it.	Miscalculation of thrust given by motor; Weather cocking messes up the flight path; Didn't reach necessary exit velocity at launch pad.	Failure to meet altitude requirements set by competition; Less points; Less happiness derived from watching the rocket.	3B	Use simulations to ensure proper motor choice; Accurately measure rocket mass and its center of pressure and center of gravity.	Simulations are done with the specifications of the full-scale rocket to determine the correct motor to use for the launch; Make sure to do test launches to gather data to be able to adjust the rocket as needed.	4D

Not enough black powder inserted into ejection charges.	Didn't measure or calculate how much black powder is needed for recovery systems; Recovery systems don't go off correctly or just don't go off at all.	Parachutes will not deploy as shear pins will not break and the rocket will enter freefall; People may be injured by falling rocket; Rocket or rocket subparts may be damaged beyond repair; People and the surrounding area could be very injured from rocket freefall impact.	1B	The amount of black powder necessary will be calculated prior to launch and measured out by our mentor.	A ground test will be performed beforehand to check that the ejection charge detonation is appropriate for rocket recovery.	2E

Rocket experiences fin flutter in flight.	The rocket experiences very strong forces on ascent; Fin material breaks due to manufacturing errors; Fins are not properly mounted.	Fins break or snap off during flight; Rocket takes an unexpected flight path.	2C	The speeds at which fin flutter becomes significant will be calculated using the NACA Flutter Boundary Equations; Fin material will be carefully chosen as to ensure they can withstand high pressure and temperatures; Careful assembly of the rocket to ensure that the fins are safely and securely attached.	Analysis of simulation results will help guarantee that fin flutter will not occur; Materials testing of fin material will be conducted to ensure that the fins can handle the forces while attached to the rocket in flight.	3E

Section 6: Project Plan

6.1 Testing

6.1.1 Tests Identification

The following test is shown as a simulation developed on OpenRocket. There are graphs to display CP and CG stability margins as well as the overall course of the rocket. The tables are included to give a more detailed look into the different elements of this test.

6.1.2 Test Objective and Success Criteria

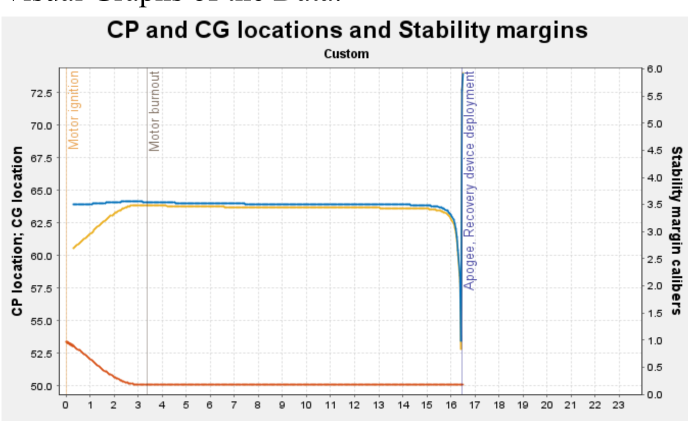
The objective of this test is to evaluate the success of the rocket through various conditions of the entire duration of the flight. This is done through running simulations and collecting all the data necessary for a proper evaluation. The success of these results will lead to the finalization of the rocket design as a whole.

6.1.3 Test Results and Potential Changes

The results of this test can affect the design of the rocket. Because the data collected tells us how the rocket is performing, we can adjust areas that need to be improved before we finalize our rocket's design. This ensures that our rocket meets all of the criteria and is optimal in the overall design and performance.

6.1.4 Test Results

Visual Graphs of the Data:



6.2 Requirements Compliance

Table 54: General Requirements

NASA Requirement:	Compliance Approach	Verification Method
Students must complete 100% of the project (design, construction, reports, etc.).	Assign tasks and duties to all people involved to ensure that all requirements are met and everyone is effectively partaking in the development of this project.	Record all team members' participation within the project.
Submit deliverables by set deadlines in PDF format.	Develop personal deadlines which the team should follow.	Create and follow a timeline that is designed to follow these internal deadlines.

Table 55: Vehicle Requirements

Vehicle must reach an apogee of 4,000–6,000 feet above ground level (AGL).	Set a desired altitude to reach and use simulations, such as OpenRocket, to reach that optimal target apogee.	Complete flight tests with subscale models to provide flight data.
Vehicle must be recoverable and reusable.	Design a rocket that has sturdy materials and a durable design.	Demonstrate reusability through subscale and other test flights.
Vehicle must have a thrust-to-weight ratio of at least 5.0:1.0.	Use a motor that best fits the rocket and the thrust-to-weight ratio when choosing one during the design period.	Calculate the thrust-to-weight ratio using this desired motor and collect data during flight tests.
Maximum motor impulse is L-class (5,120 N-s).	Choose a motor that fits within the given requirements and confirm during the design phase.	Verify compliance during launch and with RSO approval.

Table 56: Recovery System Requirements

Use drogue and main parachutes for staged recovery.	Develop a recovery system in which the deployment of the drogue and main parachute are staggered for optimal usage.	Test this system using simulations and during test flight.
Redundant barometric altimeters must be used.	Create a dual altimeter system which contains a main altimeter and a back up one. Both must have separate power supplies.	Conduct ground ejection tests and verify that the system will work during flights.
Maximum kinetic energy at landing for independent sections is 75 ft-lbf.	Select specific components within the recovery system (i.e. parachutes, shock cords) that adhere to the maximum kinetic energy and the reduction of landing energy.	Accumulate data from simulations and flight tests to ensure the components being selected comply with the desired kinetic energy.
Vehicle sections must land within a 2,500 ft radius of the launch pad.	Execute calculations regarding different wind scenarios that could change the drift.	Verify results in flight tests and include in reports.

Table 57: Payload Requirements

Payload must safely retain STEMnauts and transmit data to a NASA receiver.	Design a housing compartment for the STEMnauts and transmission system that also follow NASA's guide lines.	Test the functionality of this section during test launches.
Transmit up to 8 data points (e.g., apogee, landing velocity, temperature).	Implement sensors for chosen data and ensure transmission complies with power limits.	Validate data transmitted during test launches.

Payload must comply with FAA, NAR, and safety standards.	Choose transmitters and other components within the payload section that follow the safety standards and guidelines.	Ensure payload approval before launches.

Table 58: Safety Requirements

Follow NAR High Power Rocket Safety Code.	Assign Safety Officer to oversee compliance and safety training.	Include checklists in reports; confirm that all regulations are being followed by advisors.
Perform hazard analysis, FMEA, and implement mitigations.	Identify risks and reduce those risks for all project phases in safety documentation.	Provide hazardous analyses within reports.
Conduct ground ejection tests for recovery systems.	Test the recovery and deployment methods to ensure the success before the launches.	Confirm functionality during simulations record the results.
All electronics must be protected and shielded from interference.	Separate the payload electronics from the recovery system; create an enclosure that not only shields the systems appropriately but also allows data to be transmitted without interference.	Verify the performance of the electronics and the enclosure during ground tests and test launches.

6.3 Budgeting

Table 59: Budget

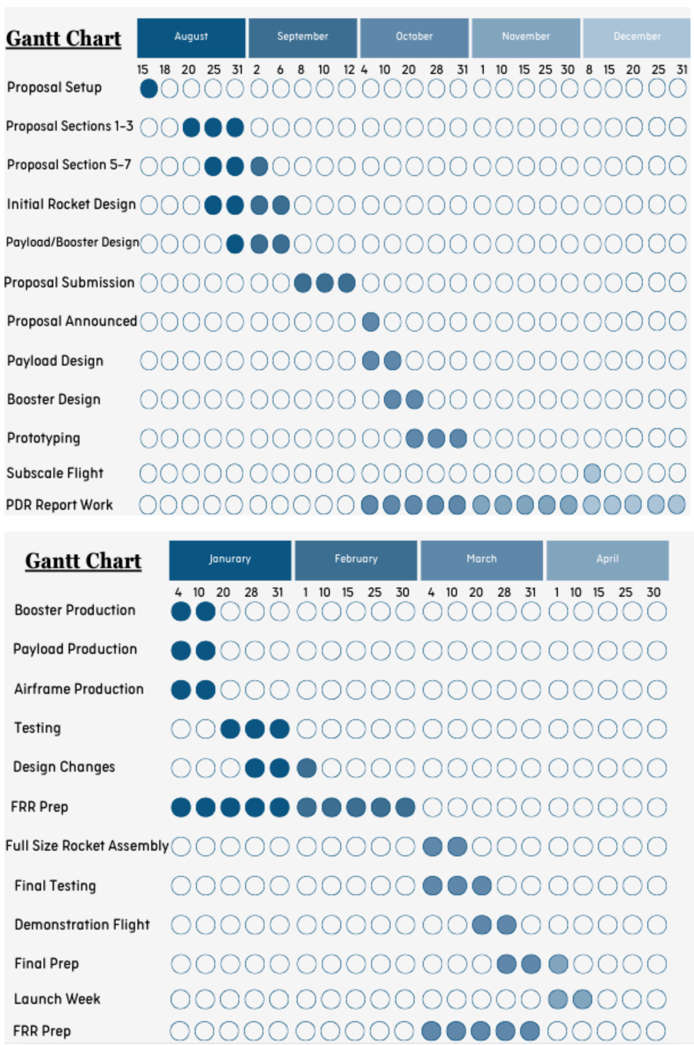
Item	Description	QTY	Material	Price
94435A515	Threaded Rods for the Bottom	6	Aluminum 6061	$ 24.54
Nose Cone	only fits on V400 w/ PETG	1	(3d Print, weight is FiberGlass)	$ -
60" Parachute	6ft Rocketman Star PolyConical	1	1.1 oz Ripstop	$ 105.00
QuickLink	1/8"	1	Steel	$ 4.06
Nomex Cloth	24" x 24"	1	Flame Retardant Fabric	$ 17.59
Swivel	Stainless Steel	1	Stainless Steel	$ 14.00
Shock Cord	3/8" Tubular Kevlar X 30 Ft.- 3 Loop 3/8" Tubular Kevlar X 25 Ft.- 2 Loop	1	Braided Kevlar	$ 91.00
Lower Bulkhead 1	Aluminum Flat With circles	2	Aluminum 3003-H16	$ -
Upper Airframe Cover Bulkhead		2	Aluminum 3003-H16	$ -
Couplers	G12CT-4.0	13	Fiberglass	$ 40.82
RRC3+ Altimeter	Main Flight Computer for Recovery 1-1/16" x 3 21/32"	2	Electronic part	$ 149.90
LiPo Battery Charger	Charger for the recovery 3.7 LiPo Batteries	2	Electronic Part	$ 6.49
Permanent Payload Panel		1	Birch	$ 3.00

Item	Description	QTY	Material	Price
Removable Payload Electronics Panel		1	Birch	$ 3.00
90012A240	Aluminum Coupling Nut	7	Aluminum 6061	$ 47.50
Rotary Switch	2-Pole Rotary Switch	5		$ 34.75
3.7 LiPo Battery		2	Battery	$ 23.99
Altimeter/GPS Tracker	Featherweight GPS tracker Full system (Tracker + GS +Tracker battery)	1	Electronic Part (s)	$ 371.47
Nomex Cloth	9x9 ARC	1	Kevlar	$ -
Drogue Parachute	18" diameter spill hole 2" Cd: 1.5	1	Nylon	$ 21.50
Swivel	Stainless Steel	1	Stainless Steel	$ -
QuickLink	1/8"	1	Steel	$ 4.06
Retaining Ring Set		1	Set of Retainer Rings	$ 48.99
MotorTube	**G12-2.1 - 30"**	1	Fiberglass	$ 52.27
Sheet Metal Fin Mounts	.063" sheet metal	3	Aluminum 3003-H16	$ -
Center Rings		3	Aluminum 3003-H16	$ 9.69
3035T11	Aluminum U-Bolt	3	Aluminum	$ -
Thrust Plate		1	Aluminum 3003-H16	$ -
Trapezoidal Fin Set		3	Delrin	$ 79.87
Airframes	G12-4.0 - 60"	2	Fiberglass	$ 282.54

Item	Description	QTY	Material	Price
Slotting Costs	Cost for slotting the lower airframe	3		$ 20.00
Motor		3		$ 1,000.00
Emergency Funds				$ 500.00
Extra Hardware				$ 200.00
Shipping for Wildman rocketry order				$ 92.51
Extra Shipping				$ 200.00
TOTAL PRICE		77		$ 2,931.00

6.4 Timeline

Figure 82: GANTT Charts



WARRIOR ONE

20 25

WARRIOR ENGINEERING NASA SLI TEAM

NASA UNIVERSITY STUDENT LAUNCH

FLIGHT READINESS REVIEW

Section 1: Summary of FRR

1.1 Team Summary

Table 60: Team Summary

School Name	Oconee County High School
Mailing Address	2721 Hog Mountain Road, Watkinsville, GA, 30677
Team Name	Oconee County Rocketry Association
Project Title	Project RANCH
Project Lead	Campbell Patterson: cpa11549@oconeeschools.org
Safety Officer	Zoe Steckel: zst55770@oconeeschools.org
Team Mentor Information	Armando Rodriguez: armandorod60@aol.com Certification Level: HPR Level 3 NRA #: 89194
Adult Educators	Bradley W Sayers: bwsayers@oconeeschools.org
NAR, TRA sections	NAR Section #112382
Launch Plan	We plan to launch our rocket at Huntsville, AL, and collect data through radio transmission that will send the information to a NASA ground receiver in person on launch week.
Time Spent	9 people, average 7 hours, total of 63 hours
Social Media Information	Instagram: @oconeerocketry Twitter: @ochsengineering

1.2 Launch Vehicle Summary

OCRA's project RANCH has a target altitude of 4,300 ft. The length of the rocket is 92", is 4" in diameter, and weighs 16.6 lbs with a motor. Without the mass of the motor the rocket weighs 13.3 lbs. The Upper Section has a total weight of 4.6 lbs. The Middle Section has a total weight of 1.4 lbs. Lastly, the Lower/Booster Section has a weight of 8.4 without a motor. OCHS will use a 12' launch rail, unless there is not a 12' launch rail available in which we could use a

8’ launch rail. The recovery system is utilizing a 48” main parachute from fruit chutes and a 18” drogue chute from Fruity chute as well. The recovery electronic system will use two RRC3+ ali meters from missile works to ensure redundancy. The two altimeters will be hooked up to black powder charges to deploy the parachutes. The drogue parachute will use a main charge of 1.5 grams and a backup charge of 2.5 grams; the drogue parachute will eject at apogee, and the secondary charge will be set to go off 1 seconds after apogee. The main parachute will use a main charge of 1.5 grams and a backup charge of 2.5 grams; the main parachute is set to launch at 800 feet, with the backup charge set for 600 feet.

1.3 Payload Summary

1.3.1 Payload Title

- Our rocket will carry the payload titled “Acorn.”

1.3.2 Payload Summary

- The payload aboard our rocket will be able to complete many complex tasks while in the course of its duties. Our payload will be experimenting with data collection and transmission within the realm of radio frequencies. The payload will collect performance data from the rocket while in flight. After the rocket has landed, the collected data will be transmitted to a ground based receiver which will hear the data that is being transmitted.
- This payload is going to be housed in a separate payload bay that is located at the upper part of our rocket, just underneath the nose cone. The payload structure and contents will be further discussed in this document.

Section 2: Changes Made from CDR

2.1 Changes Made to the Vehicle Criteria

- Minor Changes to Lower Airframe of Vehicle; added more holes to lower airframe and booster to add more screws. This helped with stability.
- Change in Motors for flight due to availability issues. We had lots of trouble getting Parachutes and motors shipped to us on time or at all. The final motor we chose to fly with is a K1100T-14A from Aerotech.
- Changed what design Nose Cone we decided to fly, switched from an Ogive shape to a more elliptical shape.

2.2 Changes Made to Payload Criteria

- After large changes in design, construction, and criteria of the payload in the CDR phase there will be no Major Changes made to the payload in the FRR phase. The payload was built as expected and has performed to the criteria that we have set for it to meet.
- Upon transmission to the ground receiver there will no longer be a call sign included in the transmission.
- Changed our STEMauts to a LEGO figurine from Octonauts.

2.3 Changes Made to the Project Plan

- We are currently developing a payload design to hold a 360 degree video camera to make a VR video. We plan to use this by our next test launch around the first of April.

Section 3: Vehicle Design and Performance

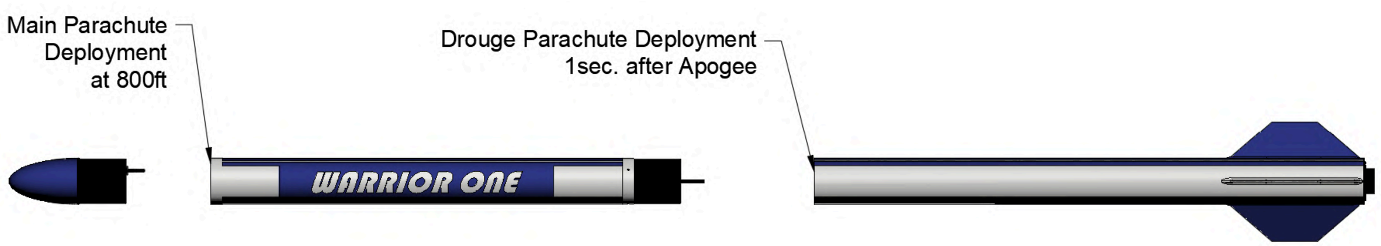
3.1 Design and Construction of Vehicle

3.1.1 Changes made to Vehicle Design

- Minor Changes to Lower Airframe of Vehicle; added more holes to lower airframe and booster to add more screws. This helped with stability.
- Change in Motors for flight due to availability issues. We had lots of trouble getting Parachutes and motors shipped to us on time or at all. The final motor we chose to fly with is a K1100T-14A from Aerotech.
- Changed what design Nose Cone we decided to fly, switched from an Ogive shape to a more elliptical shape.
- There were no major design changes from CDR to FRR.

3.1.2 Final Separation Locations

Figure 83: Separation Locations



3.1.3 Launch and Recovery Features

Our Recovery Features include two parachutes, attached to two altimeters for redundancy, with black powder charges, of both 1.5 grams and 2.5 grams for main and backup for both the parachutes. The parachutes are attached using quick links and kevlar shock cords, onto aluminum bolts. The payload and avionics bays use Delrin bulkheads, with threaded rods inside each to attach the rods. The booster section is made out of aluminum centering rings and sheet metal fins. This allows it to be completely modular which helps with changing fins for stability. Our nose cone is also threaded onto the payload, allowing for us to use it as a ballast.

3.1.4 Construction Process

We started the Vehicle Construction process as soon as we were able too. Unfortunately for us, the centering rings and fin sheets were delayed in getting to us, so we had to wait a good bit before we could properly start construction with the booster section and drilling holes into the lower airframe. Due to this, we started building what we could with mocked up wooden and 3D printed centering rings and fin sheets. However, after we were able to get all the parts necessary we moved very fast in the construction process. We made the centering rings and booster stabilizers, put the motor tube inside, then epoxied the motor tube to the booster stabilizer once we got it to fit correctly.To ensure it was all centered properly, we let it dry inside the lower airframe. After it was done, we removed the booster section from the lower airframe to then get ready to drill the hole inside the airframe. The holes were drilled by hand, penciled out exactly and drilled while the centering frame was on the rocket. This ensures a perfect fit. After the holes are drilled, we are able to screw the booster section into the lower airframe, taking it out as needed.

Figure 84: PreCut Airframes

Figure 85: Booster

Figure 86: Initial Fin Design

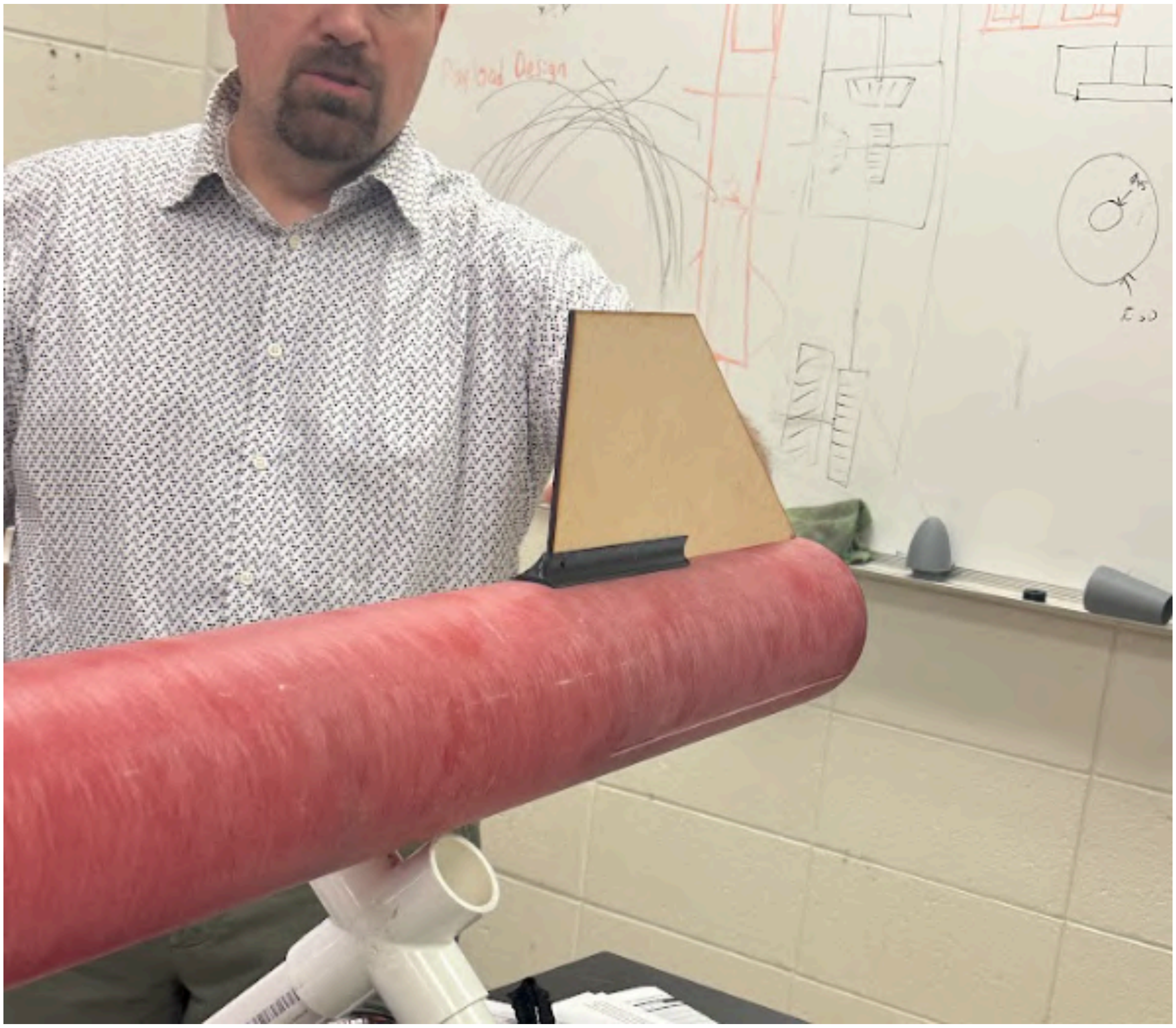


Figure 87 Aluminum Booster Component

Figure 88: Final Fins

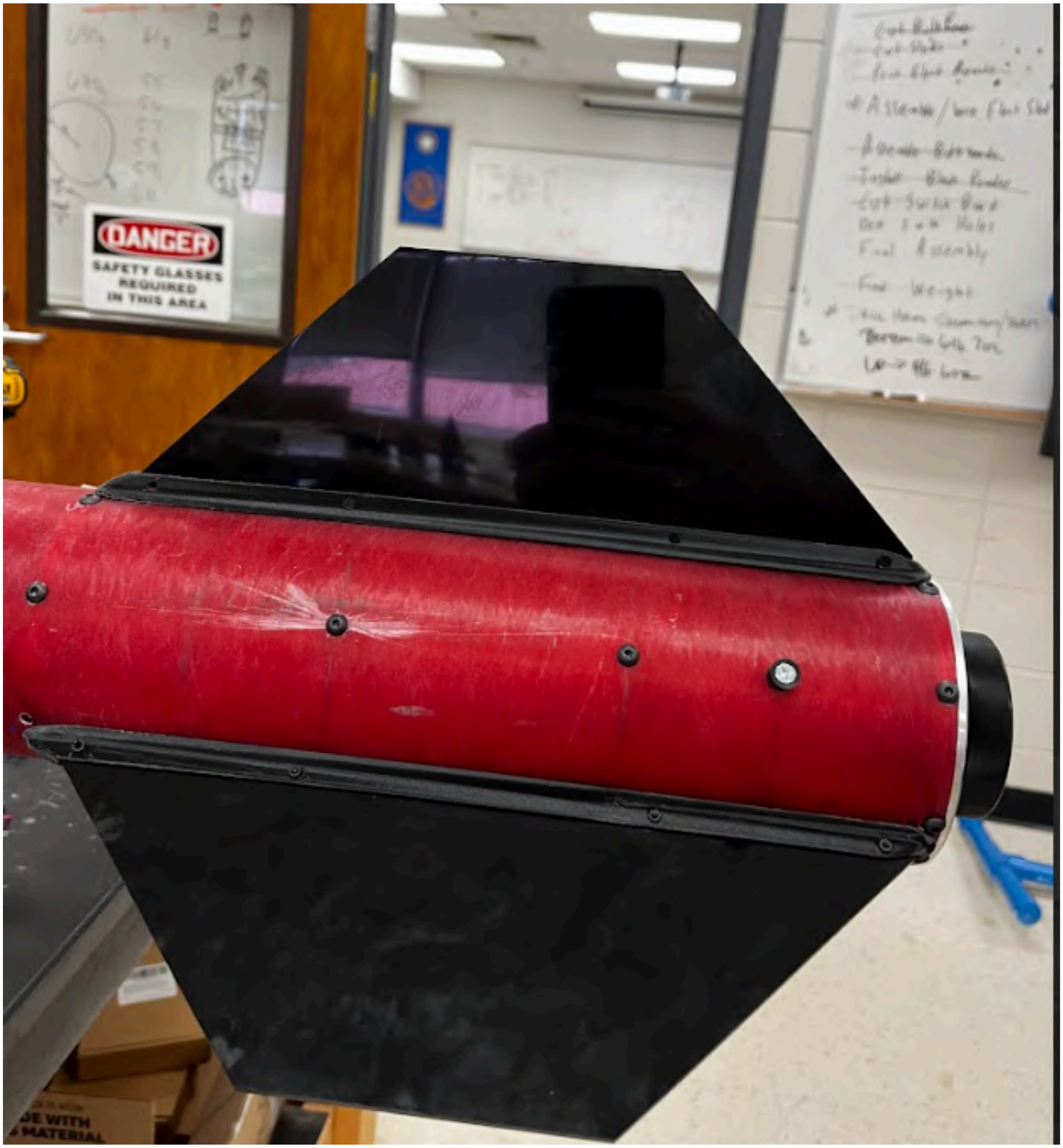
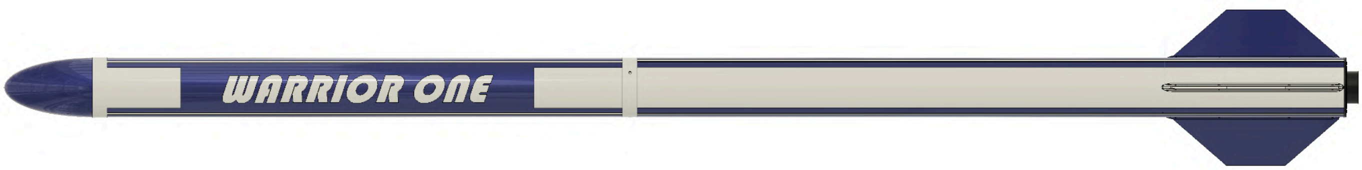


Figure 89: Booster

Figure 90: Finalized Rocket

Figure 91: Painted in Fusion Rocket



3.1.5 Vehicle Schematics and Diagrams

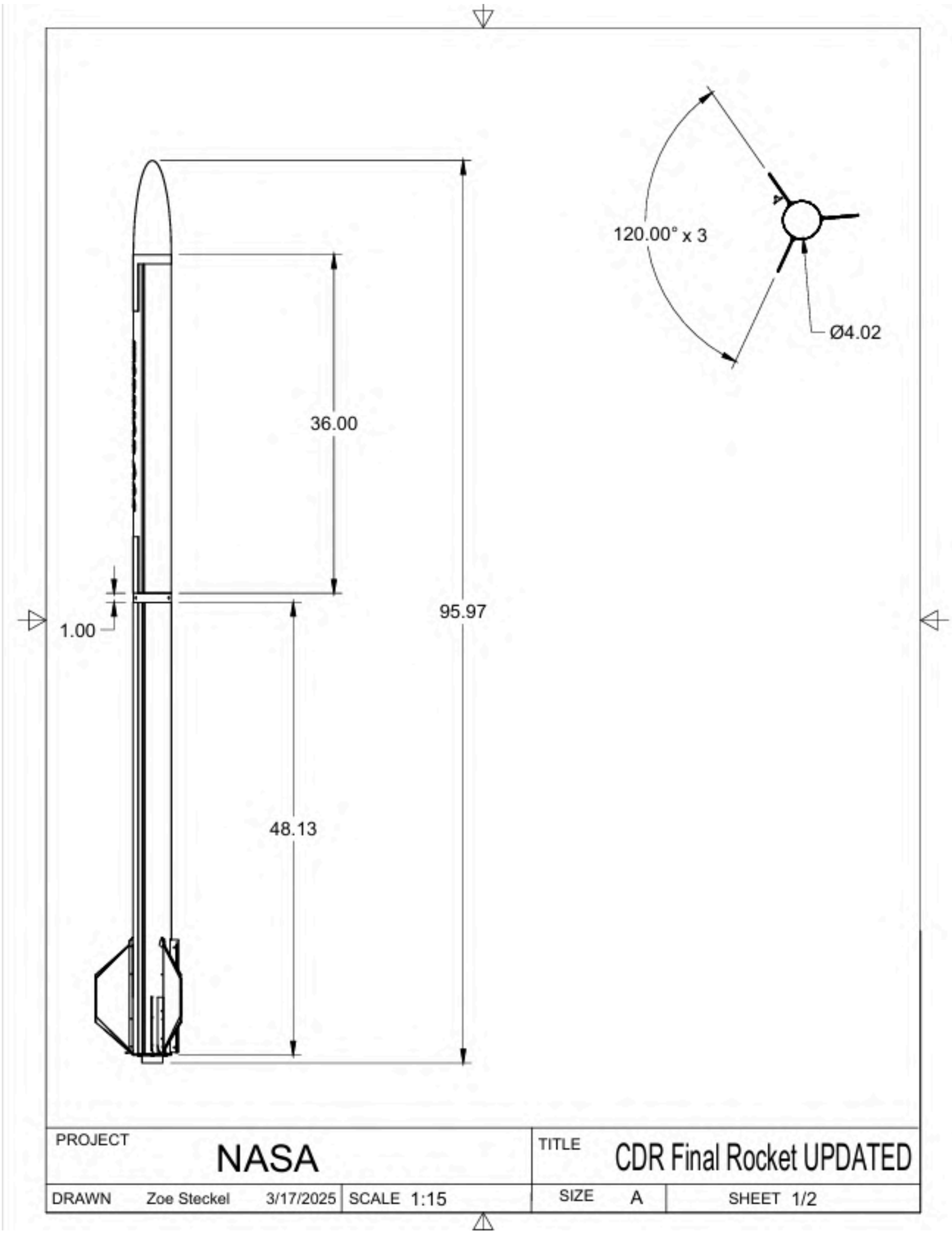


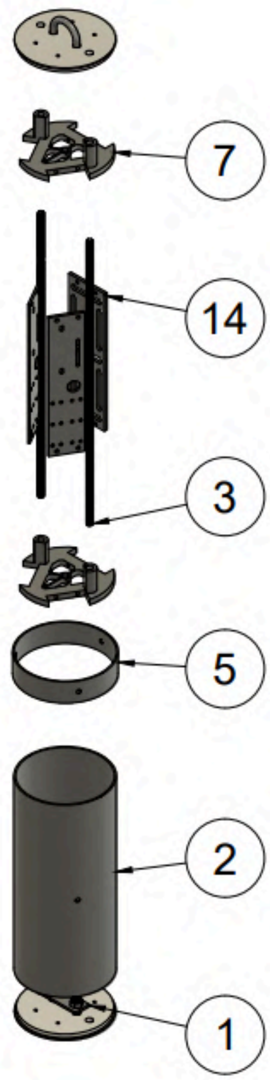
Figure 92: Rocket Dimensions

3.2. Recovery Subsystem

3.2.1. Recovery System Robustness

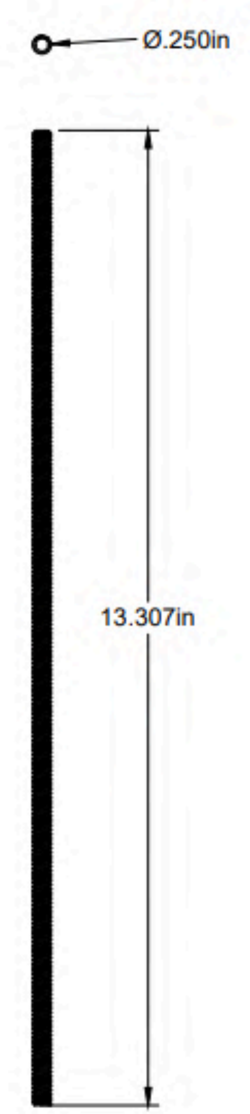
- 7.4 V LiPo batteries used for lightweight, efficient power while still providing enough voltage to prevent a brownout event at 2V.
- The recovery components are mounted on a triangular avionics bay suspended between two threaded aluminum rods. This protects the electronics from any damage during launch, air time, landing, or any unforeseen impacts..
- In the avionics bay, there are two separate altimeter systems, each with their own power source and switch. This allows for a backup drogue and chute charge if the main deployments fail.
- The LiPo batteries are connected via 2 pin JST RCY connectors secured with electrical tape for added security, though the risk of disconnection is very low with these connectors. This allows for the LiPo batteries to be easily rechargeable and replaceable in the event of a dead battery.

3.2.1.1. Structural Components



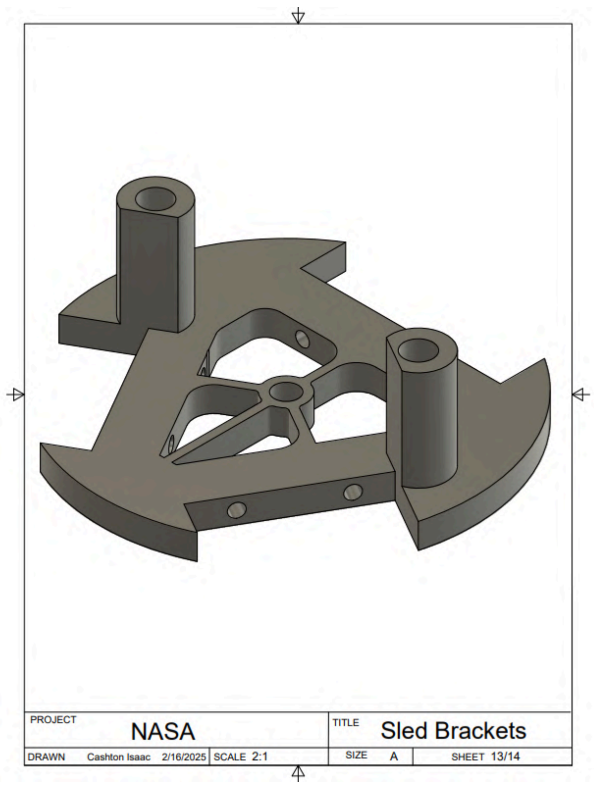
PARTS LIST		
ITEM	QTY	
1	2	Payload Bulkhead
2	1	Coupler
3	2	Aluminum Threaded Rod
5	1	Airframe/Switch Band
7	2	Sled Brackets
14	3	Avionic Sleds

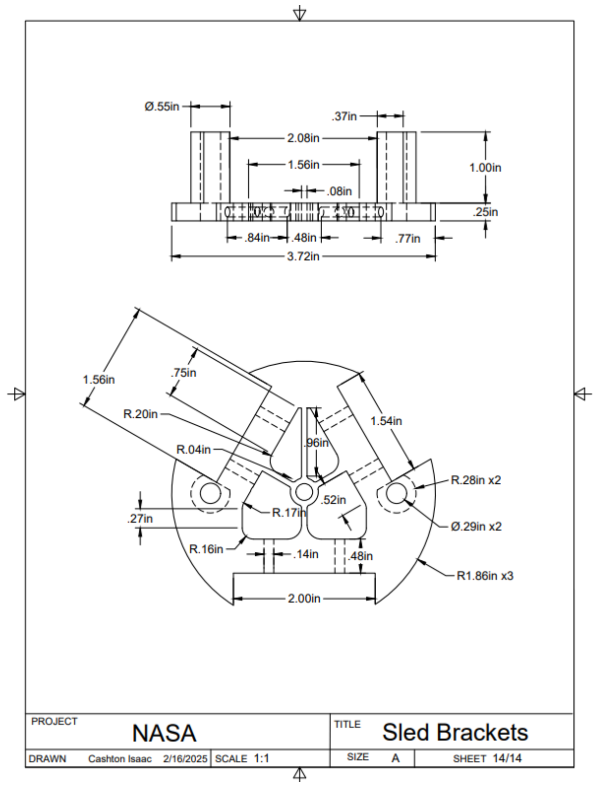
PROJECT NASA		TITLE Avionics Bay	
DRAWN Cashton Isaac 2/16/2025	SCALE 1:5	SIZE A	SHEET 1/1



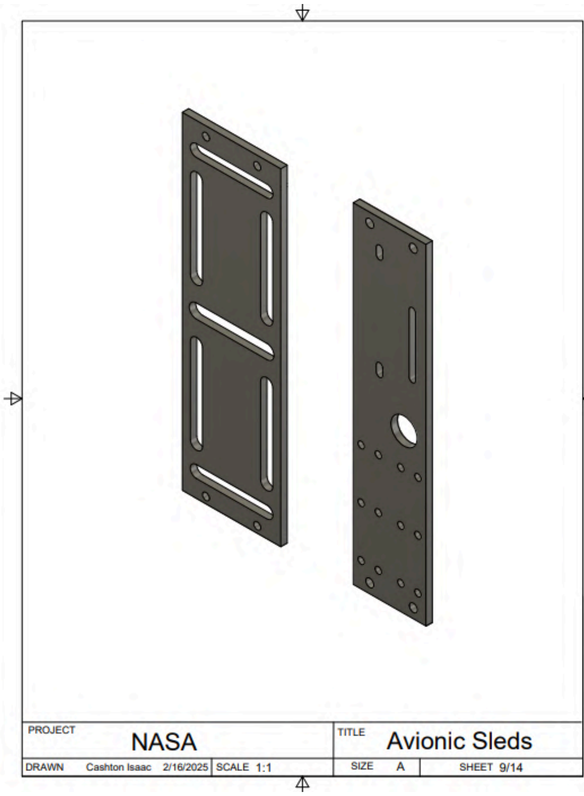
PROJECT NASA		TITLE Aluminum Threaded Rod	
DRAWN Cashton Isaac 2/16/2025	SCALE 1:2	SIZE A	SHEET 12/14

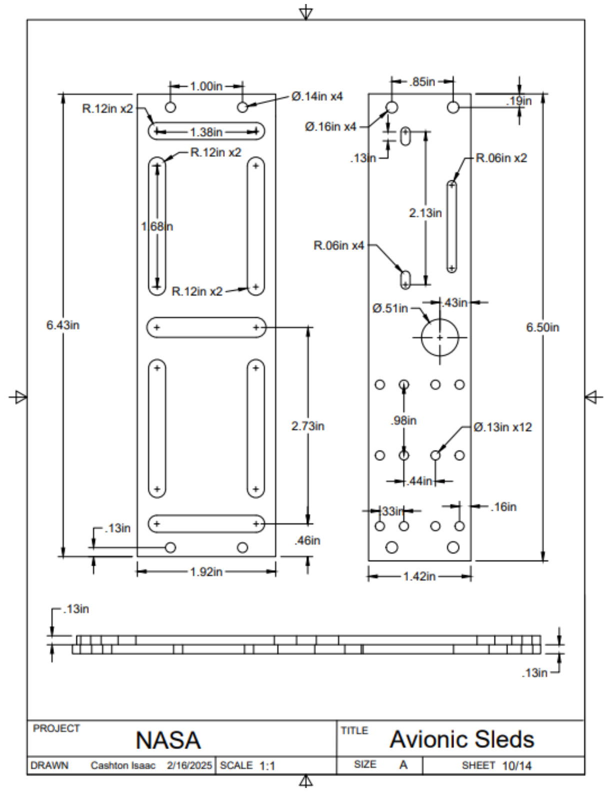
- The avionics bay is suspended between two aluminium threaded bars 13.307 inches in length.



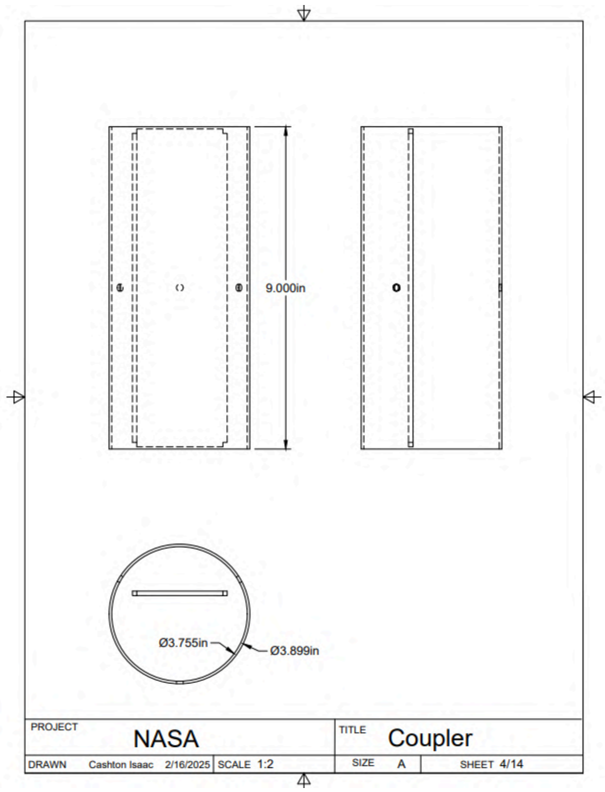


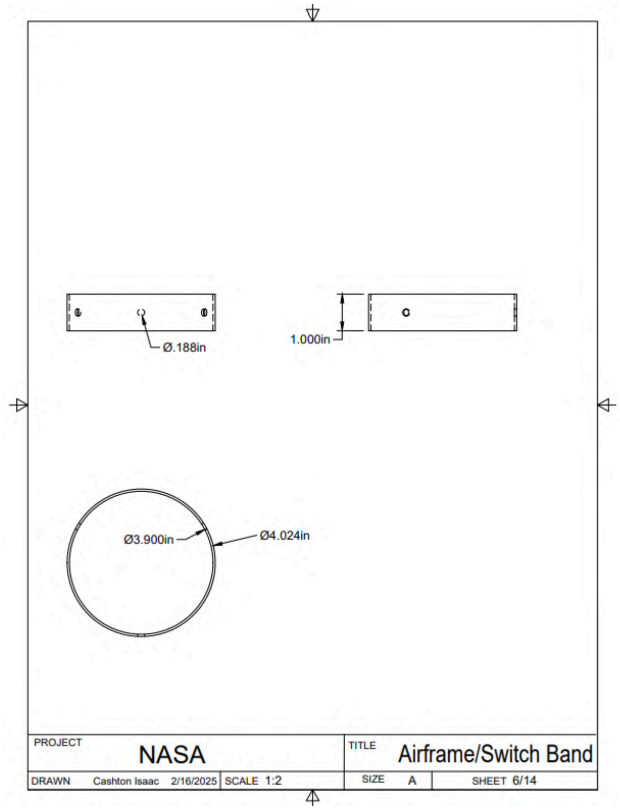
- The aluminum bars are threaded through 3D-printed sled brackets with 3 sides. On each side, a sled running across the avionics bay can be attached.



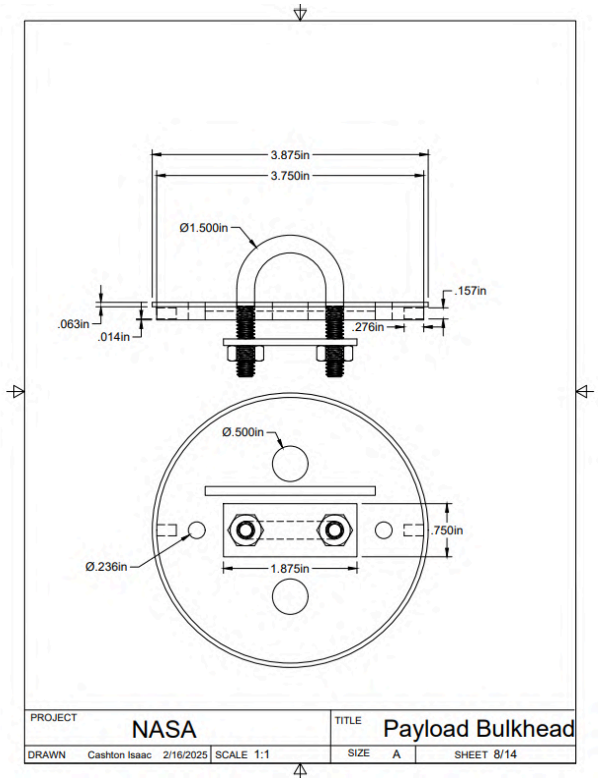


- There will be two of the altimeter sleds (pictured on right) and one battery slide (pictured on left). This triangular avionics system gives each electrical component plenty of space and allows for wires to be managed easily with the given chasers and space in between the plates. Each plate was laser cut out of ⅛” thick Delrin plastic.





- The recovery electronics will be enclosed in a 9” coupler and a switch band that runs along the middle of it.



- To seal the capsule, we have Delrin bulkheads with mounts for the black powder charges.

3.2.1.2. Electrical Components

- The electrical components of the recovery system were created for deployment control and tracking data. The system uses a 7.4V LiPo battery because it is lightweight, compact, and has a stable voltage output. The batteries are connected with 2-pin JST RCY connectors to the altimeters. The recovery system uses RRC3 altimeters, which detects the changes in altitude and triggers deployment events at specified deployment altitudes. Each altimeter is powered by its own LiPo battery in order to make sure there is a fail safe in case one of them does not work. A backup deployment is triggered 1 second after the main deployment in case the primary system fails. For status indication, the RRC3 altimeters will beep three times to confirm they are powered on and functioning well. This signal functions as our pre-launch check to make sure the system is ready.

3.2.1.3. Redundancy Features

- The recovery system uses multiple redundancy features to ensure that the parachute deploys even if there is a component failure event. The system uses two independent RRC3 altimeters that are powered by separate 7.4V LiPo batteries. The dual altimeter system ensures that if one altimeter fails, the second one can still control parachute deployment. Each of the altimeters is connected to a separate power switch, reducing the possibility of parachute deployment failure. The RRC3 emits three consecutive beeps to indicate that the system is active and functioning. Both altimeters are programmed with deployment triggers. In the chance that the primary drogue deployment fails, a backup deployment charge is set to activate 1 second after reaching apogee. The primary altimeter will deploy the main parachute at 800 ft with a backup deployment at 600 ft.

3.2.1.4. As Built Parachute Size an Descent Rates

- The main parachute is a Fruity Chutes Iris Ultra 48 inch diameter toroidal parachute with a drag coefficient of 2.2. On descent, the rocket has a mass of 14.4 lb. According to the calculations shown below, the descent rate of the rocket under the main parachute is 21.12 ft/s (6.438 m/s). However, accounting for the drogue parachute and the body of the rocket will result in a lower velocity than this calculated value. Our test launch data indicated a landing velocity of 16 ft/s.

$$v = \sqrt{\frac{8 \cdot m \cdot g}{\pi \cdot A \cdot C_d D^2}}$$

$v = Velocity\ m/s$

$m = mass\ kg$

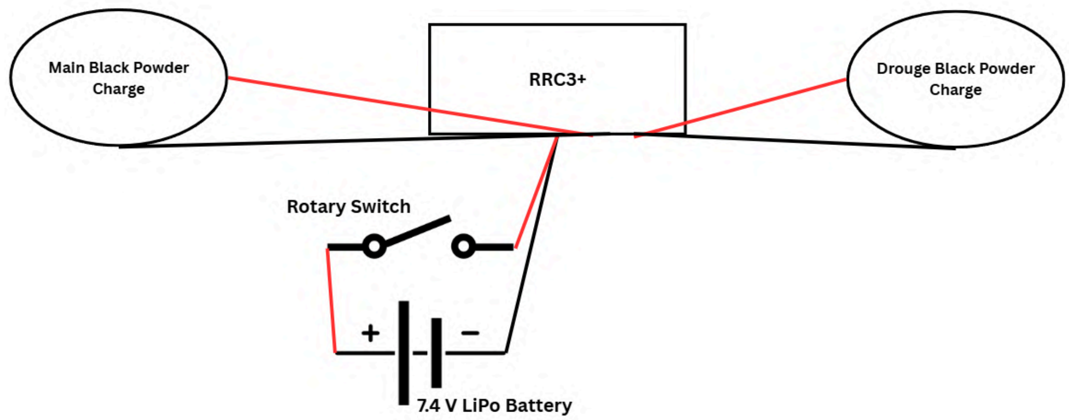
$g = Acceleration\ due\ to\ gravity\ m/s^2$

$A = Air\ density\ kg/m^3$

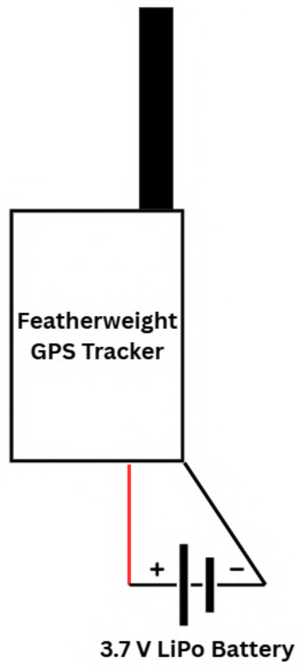
$C_d = Drag\ Coefficient\ of\ Main\ Parachute$

$D^2 = Diameter\ of\ Parachute\ m$

3.2.1.5. Wiring schematics



- This is the wiring schematic for one of our altimeter systems. With built in redundancy, this schematic would simply be replicated for the backup altimeter/charges. We decided to power this system with a LiPo battery instead of a 9 V Alkaline battery, per NASA's recommendation. In our CDR, we decided on using a 3.7 V LiPo battery. However, taking a potential brownout event into account, we decided to use a 7.4 since it was closer to the RRC3+'s recommendation of 9V. Since the RRC3+ can operate on a voltage of 3.5V to 10V, the 7.4V will give the altimeter plenty of power to operate on if we do have an unexpected reduction in voltage during arming.



- To transmit our data, we will be using a Featherweight GPS Tracker. During our flight, it will transmit all of our data over the 915.0 mHZ radio frequency. This is Oconee's declared frequency and should not be confused with any other team's data. Since we are transmitting over a declared frequency instead of over a 2m radio band, we have also negated the need for a callsign, contrary to what we declared in our CDR.
- This system will operate on a 3.7V LiPo battery per the manufacturer's recommendation. When tested, the voltage on the Featherweight GPS Tracker remained consistent throughout launch.
- According to the user, the Featherweight GPS Tracker has a communication range of up to 262,467 feet with a tested maximum height of 137,000 feet. Considering that we have a declared apogee sub 5,000 feet, the range of the featherweight should be more than sufficient to receive data from the rocket during flight.

3.2.2. Recovery System Electromagnetic Sensitivity

- Since the Featherweight GPS Tracker is powered by a 3.7 LiPo battery, it will inherently produce electromagnetic waves that could potentially interfere with barometer readings. However, a physical separation at a distance of 20.964 inches between the avionics bay and the payload helps address the low-power EMI.

- The RRC3+ altimeters also have a built in MSI MS5607 barometer which, according to the manufacturers, has built-in noise reduction techniques that allow for the barometer readings to be as accurate as possible.
- The Featherweight GPS Tracker's antenna is pointed in the opposite direction of the altimeters, so there is no direct RF interference in the altimeters.

3.3.1 Flight Profile

Using an Aerotech K1100T-18 motor with 0 mph wind and 8 ft launch rod angled at 0 degrees, we have the following flight profile properties.

Table 61: Flight Profile

Event	**Time (s)**	**Altitude (ft)**	**Velocity (ft/s)**	**Acceleration (ft/s^2)**
Liftoff	0.04	0.151	11.37	505.56
Launch rod Cleared	0.199	8.465	92.93	502.05
Burnout	1.72	678	641.182	89.8
Apogee	15.792	4395.943	0.405	32.124
Drogue Deployment	15.842	4395.9	1.652	32.124
Main chute Deployment	70.161	747.661	67.09	0.04
Ground Contact	106.95	0.0	20	0

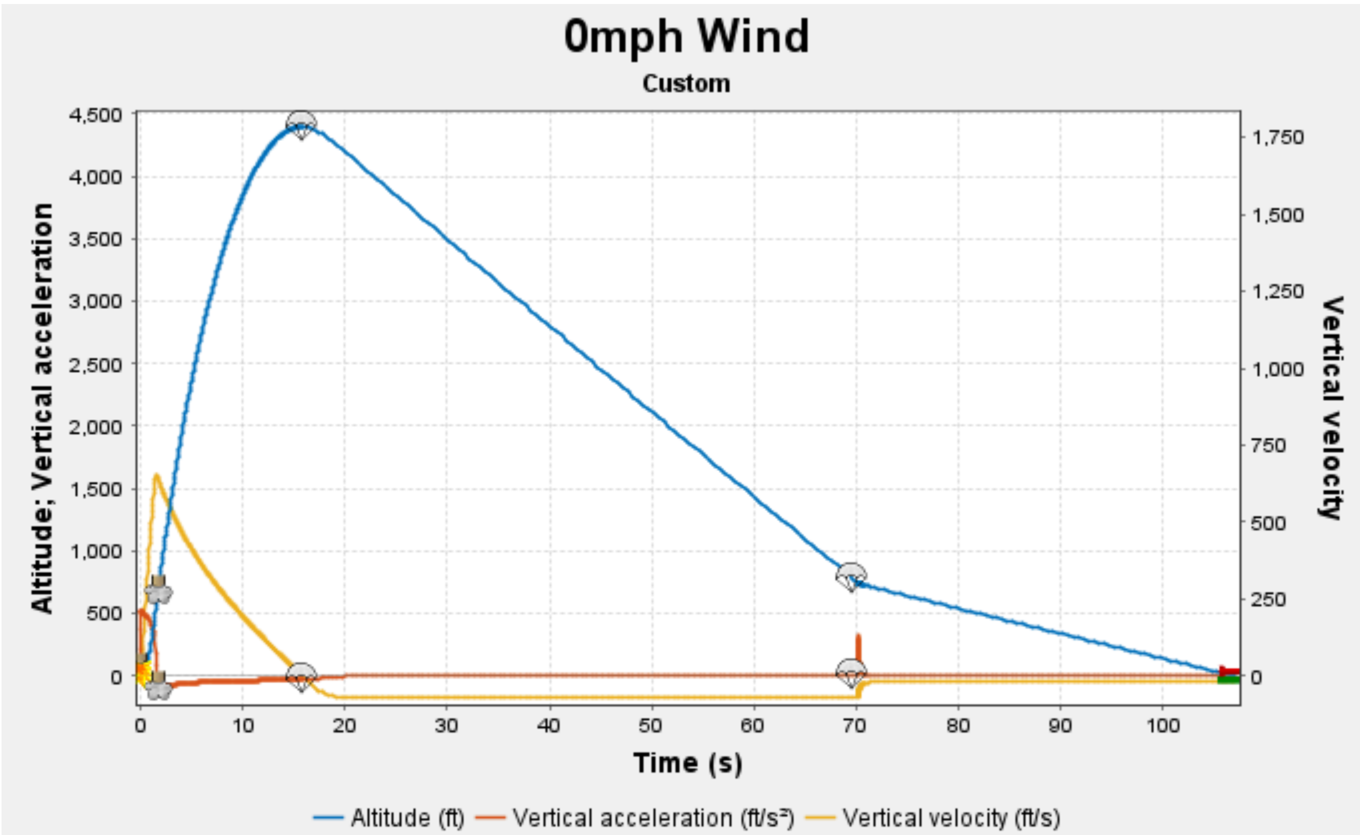


Table 62: Wind Drift Simulations

Maximum velocity occurs at motor burnout, and maximum acceleration occurs at liftoff. These values were confirmed with our open rocket simulation.

3.3.2 Stability Margins

The table below summarizes the stability margin of the rocket with and without the motor. Both configurations have stability margins of over 2.0 cal.

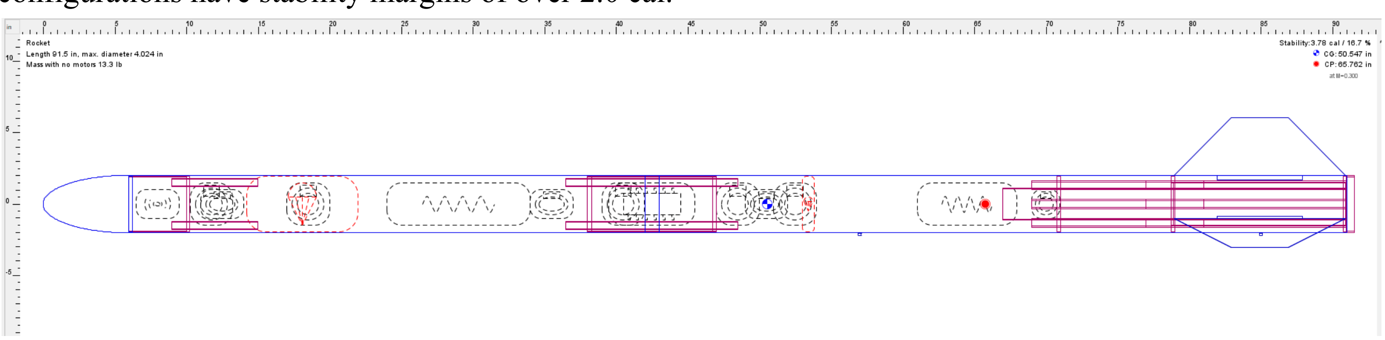


Figure 93: Without motor

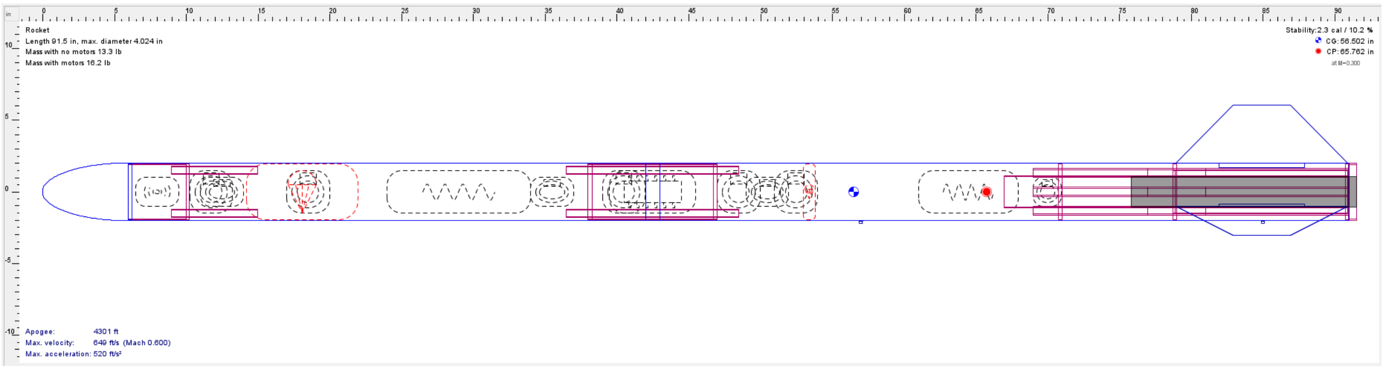


Figure 94: With Motor

Configuration	Stability (cal)	CG location (in from tip)	CP location (in from tip)
Motor	2.3	56.511 in	65.762 in
No Motor	3.78	50.557 in	65.762 in

During flight, stability of the launch vehicle will also change dynamically, because mass from the fuel is being ejected and the angle of the vehicle changes. Fuel ejection, as well as the deployment of the parachutes, also changes the center of gravity and center of pressure.

The location of the center of pressure from the tip of the launch vehicle and stability margin overall follow the same trend being very similar. Despite some changes in CP, CG and stability margins, all three variables stay within acceptable parameters.

3.3.3 Kinetic energy Calculations (From Simulation)

Our launch vehicle has a total mass of 14.4 pounds (6.35 kg) on descent, and will be separated into three parts of 1.4, 4.6, and 8.4 pounds. With a predicted touchdown velocity of 16 ft/s (4.88 m/s) for all sections, we have a predicted kinetic energy of 5.57, 18.3, and 29.44 ft/lbf, respectively. This is within the maximum acceptable kinetic energy of 75 ft/lbf per section of the vehicle. The selected parachutes allow the rocket to safely land within acceptable parameters.

3.3.4 Decent Time

The time from apogee to touchdown is approximately 110 seconds with a 18in drogue parachute. The projected time from apogee to touchdown for a 15in drogue parachute is 82.3 seconds. The simulation says that the decent time is consistent in each wind condition. If we use the 15in drogue parachute then we will be under the acceptable 90 second limit.

3.3.5 Wind Drift

Table 63: Drift

Wind Conditions	Total Drift (ft)
0 mph	5.32
5 mph	436
10 mph	916
15 mph	1400
20 mph	1918

3.3.6 Calculations Through Different Data Methods

Using a basic formula of [wind speed]×[descent time] (assumed average of 80 secs)], we get the following data values:

Table 64: Drift (Basic Calculation)

Wind Conditions	Total Drift (ft)
0 mph (0 ft/s)	0
5 mph (7.3 ft/s)	584
10 mph (14.6 ft/s)	1168
15 mph (22 ft/s)	1760
20 mph (29.3 ft/s)	2344

3.3.7 Calculation Differences

Wind Conditions	Calculated Drift (ft)	Simulated Drift (ft)
0 mph (0 ft/s)	0	5.32
5 mph (7.3 ft/s)	584	436
10 mph (14.6 ft/s)	1168	916
15 mph (22 ft/s)	1760	1400
20 mph (29.3 ft/s)	2344	1918

Evidently, there is a distance in the calculated drift values in comparison to the simulated drift values (MoE of about ~200). However, the calculation does not take as many factors into account as the simulation does, so these values are fairly close given the simplicity of the calculated drift.

3.3.8 Precision Through Simulations

We ran multiple simulations to make sure we had accurate data. Throughout building the rocket we ran many different simulations which helped us stay on track. Before inputting the data into this document we ran many different simulations just to be sure.

Section 4: Payload Criteria

4.1 Payload Design and Testing

4.1.1 Changes Made from CDR

- The payload that was designed during the CDR phase of the project is almost exactly what was produced. There were no major changes in the payload design that happened.
- Minor changes include a new design for our avionics sled in our avionics bay and the GPS sled in the payload bay. The avionics sled was changed to a sled that houses our avionics, batteries, and switches in a triangle shape. The GPS sled was switched to a 3D printed mount that holds the tracker and battery in one casing.
- The only other small changes that were made were in material selection. The upper and lower bulkheads that were designed on the payload and avionics bay have been switched from aluminum to Delrin. This change was made in order to save weight and improve manufacturing efficiency. This change did not change our design or the structure of the payload in any way.

4.1.2 Payload Features

Structural Features:

- The payload bay is constructed using G12 fiberglass. This has the benefit of increasing weight slightly, aiding in descent time control, and reducing cost while maintaining strength.
- The avionics bay is securely mounted within the rocket using a reinforced bulkhead and coupler system, preventing excessive vibrations and ensuring a stable electronics platform.

Electrical Features:

- Dual RRC3+ altimeters provide redundancy for recovery deployment, ensuring parachutes deploy at the correct altitudes.
- A Featherweight GPS transmitter is used to track the rocket's position and transmit essential flight data, such as apogee, descent rate, and maximum velocity.
- Power is supplied by independent LiPo batteries, ensuring consistent voltage and avoiding power failures.

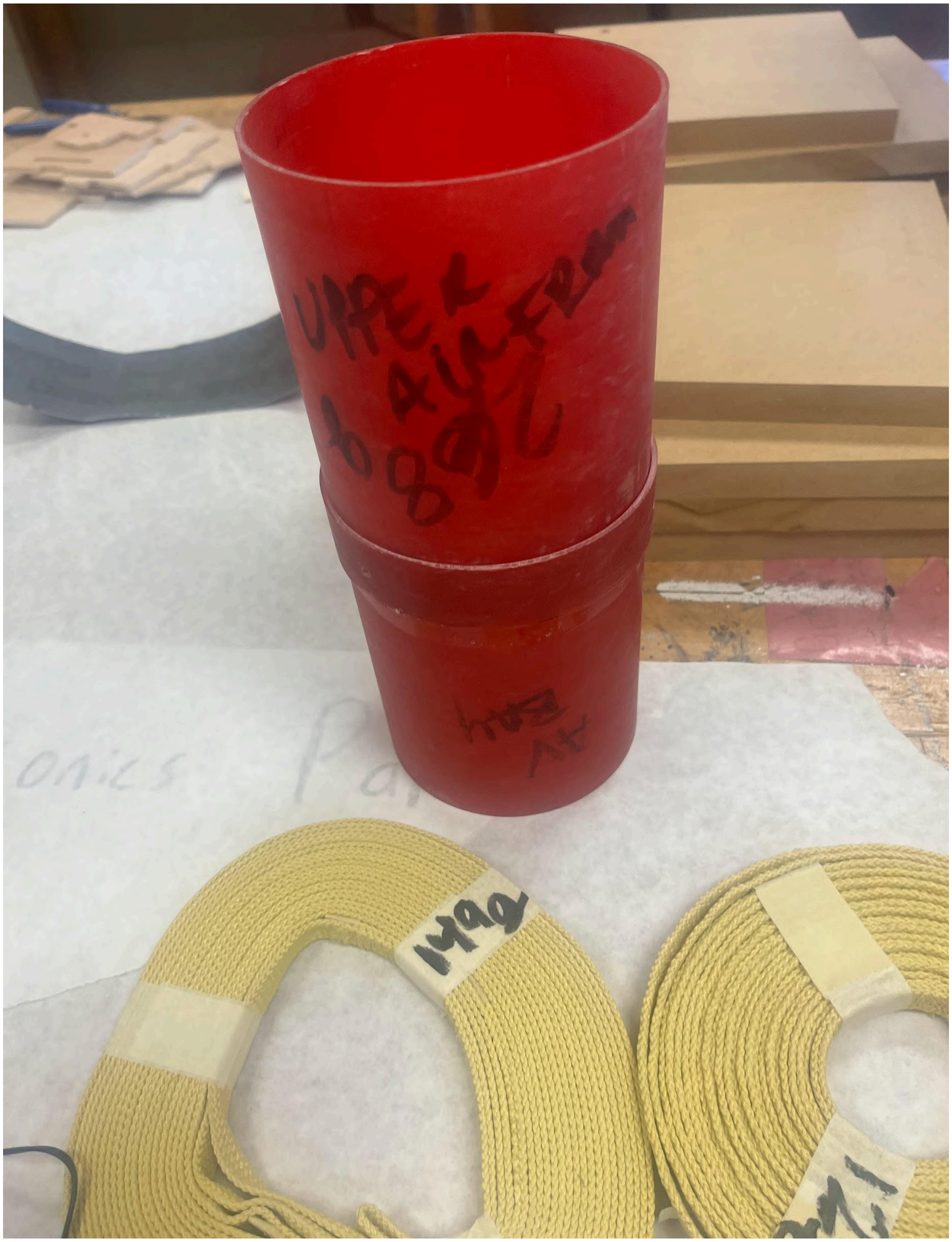
- The system includes fail-safe circuits to prevent premature deployment or component failures.

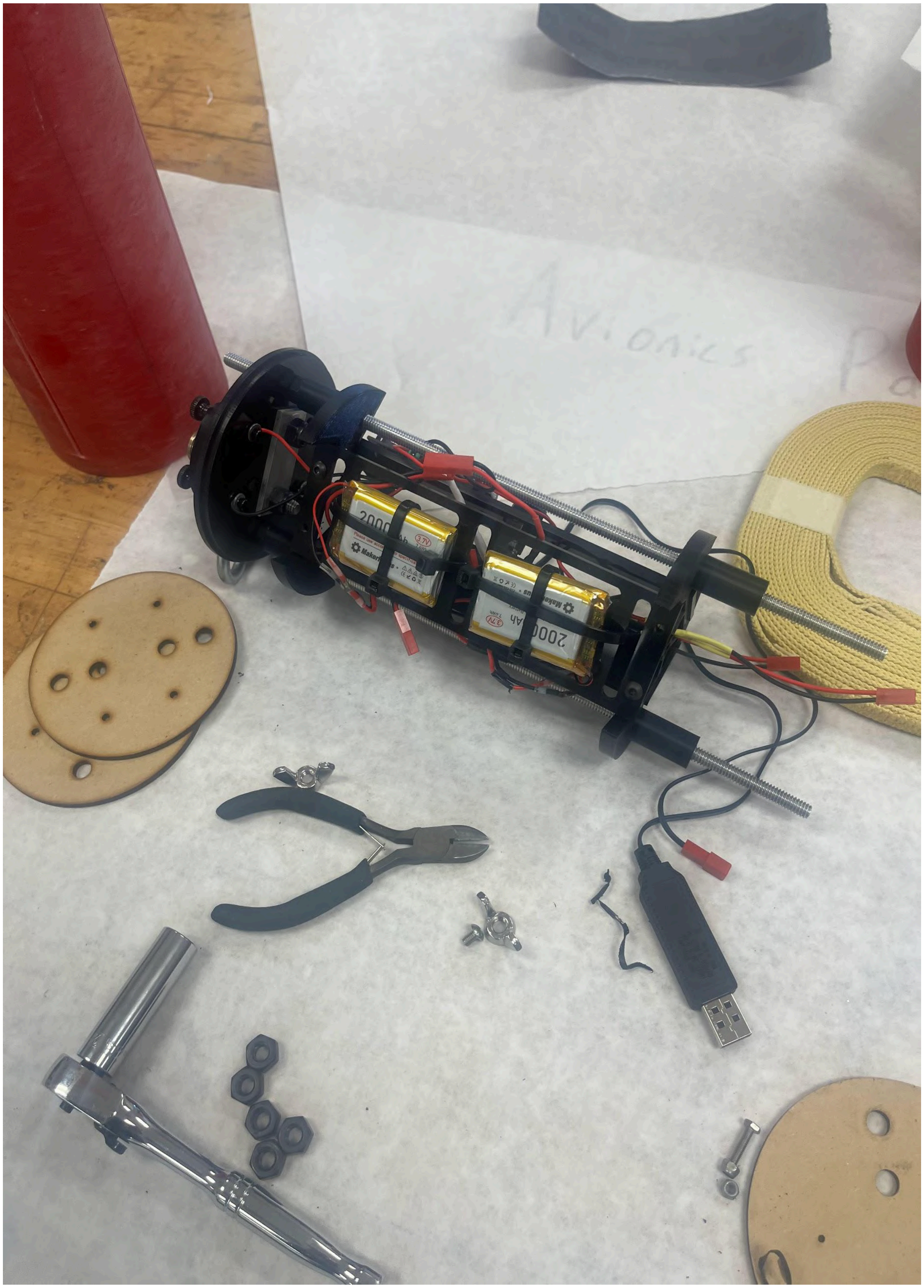
4.1.3 Flight Reliability and Confidence

The payload design is expected to meet all mission success criteria with high reliability. Key factors supporting this confidence include:

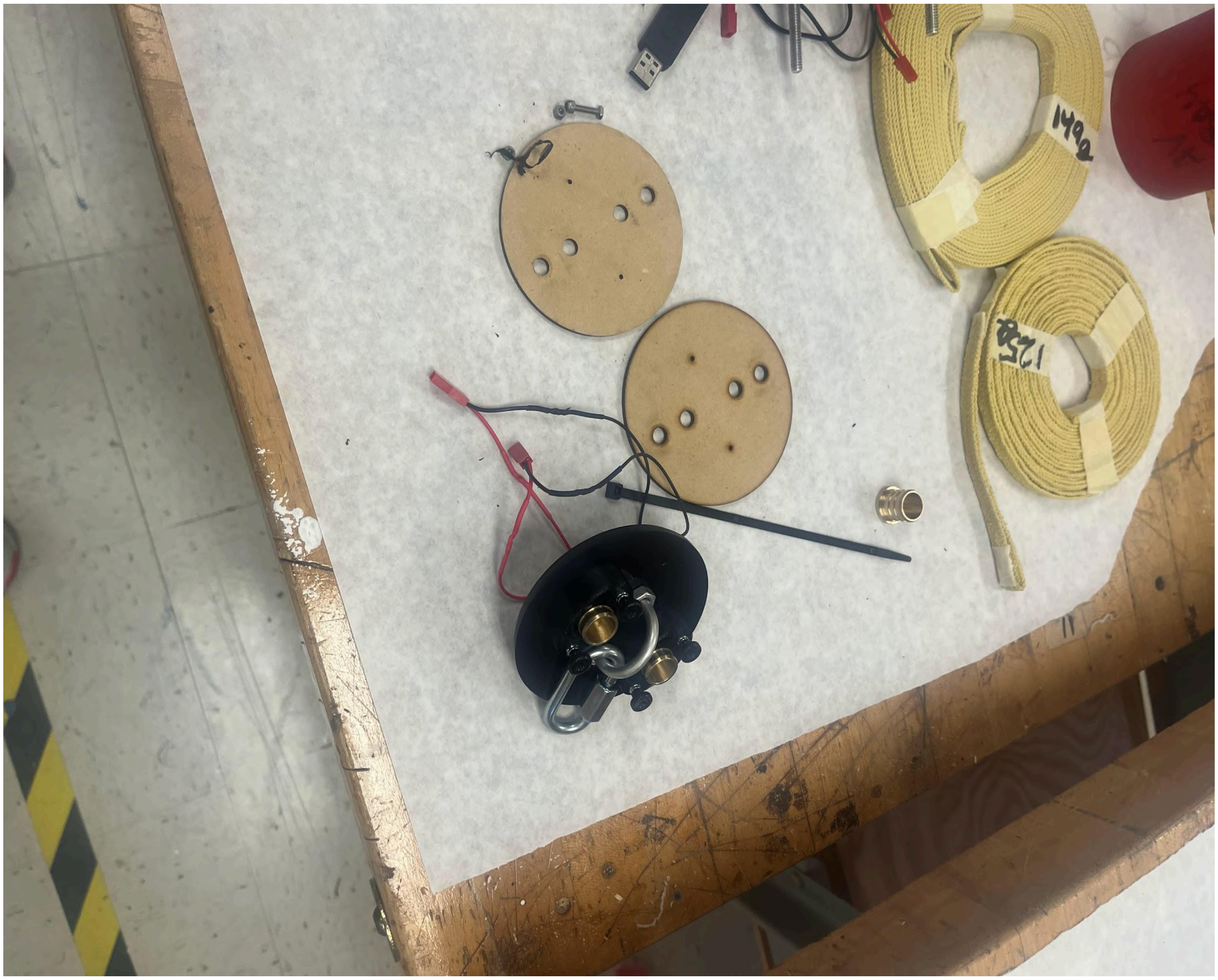
- Subscale Flight Testing: The team conducted a successful subscale flight test, which provided valuable insights into aerodynamic performance and payload stability. Issues such as weather cocking were identified and mitigated by adjusting the stability margin closer to 2.0.
- Structural Reinforcement: The use of G12 fiberglass for the payload and motor tube eliminates material mismatches, reducing manufacturing tolerance errors and increasing durability.
- Redundant Recovery System: The dual RRC3+ altimeter setup ensures that even in the event of a primary system failure, a secondary system will deploy the parachutes at the correct altitude.
- Data Transmission Reliability: The Featherweight GPS transmitter was selected for its robust signal integrity, and ease of use, ensuring that flight data reaches the ground station accurately and in real time.
- Successful Ground Testing: The avionics and payload systems have undergone bench testing, including power checks, deployment simulations, and vibration resistance evaluations.
- In addition, our team has completed a complete demonstration flight during which our payload performed to its exact requirements. We had successful deployment of both parachutes on the first charge and saw a successful backup charge that did not have to be used.

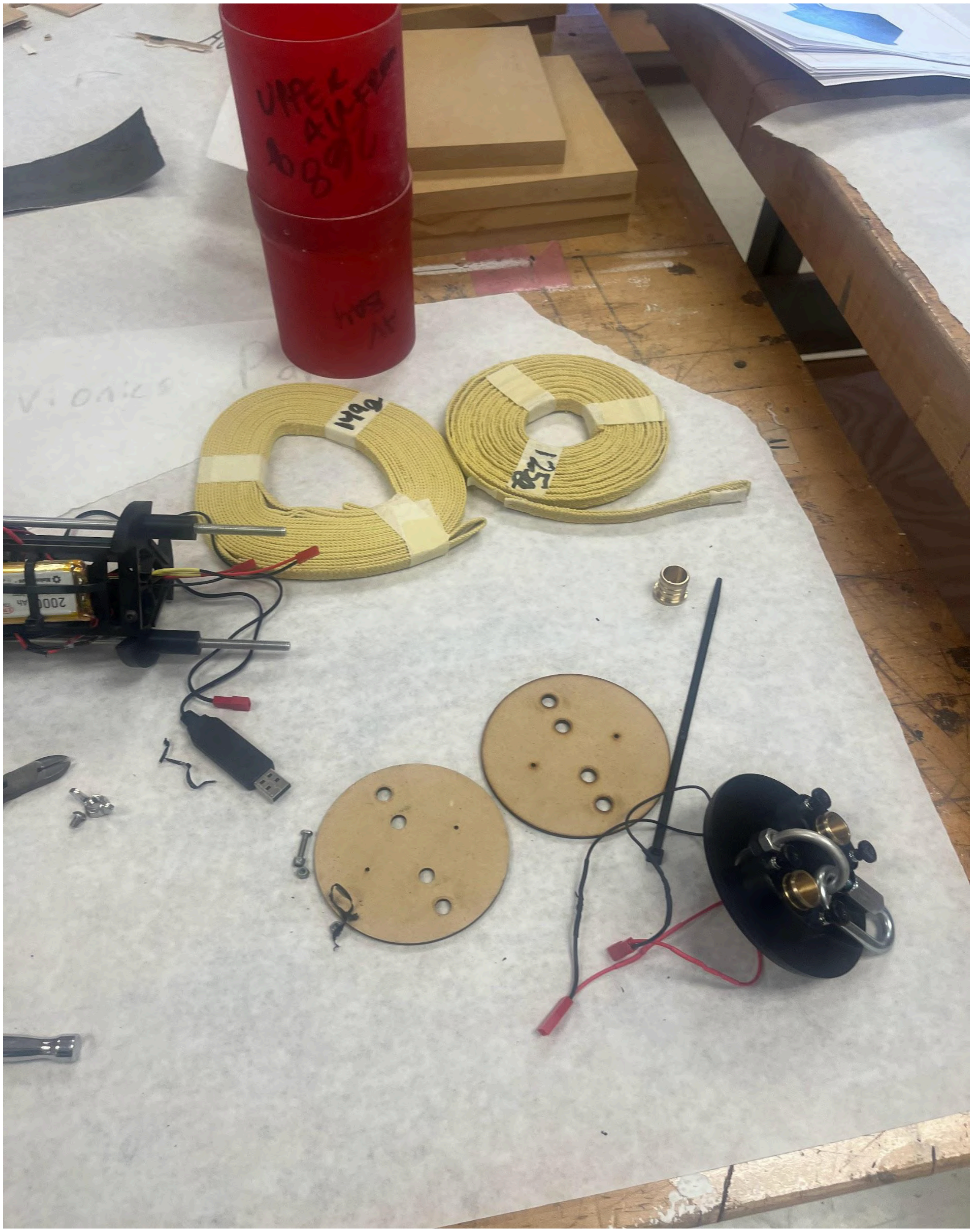
4.1.4 Payload Construction Process

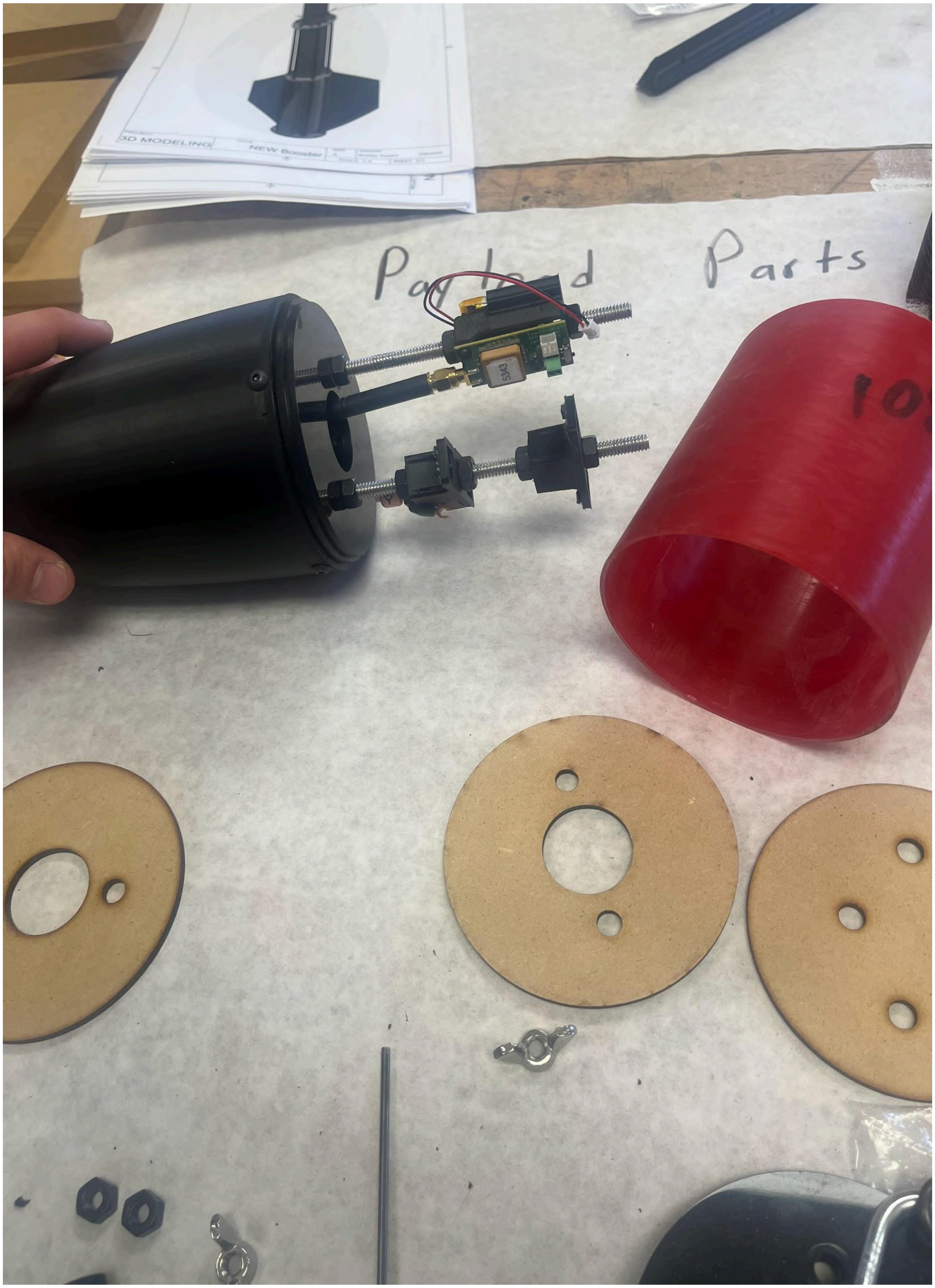



Avionics

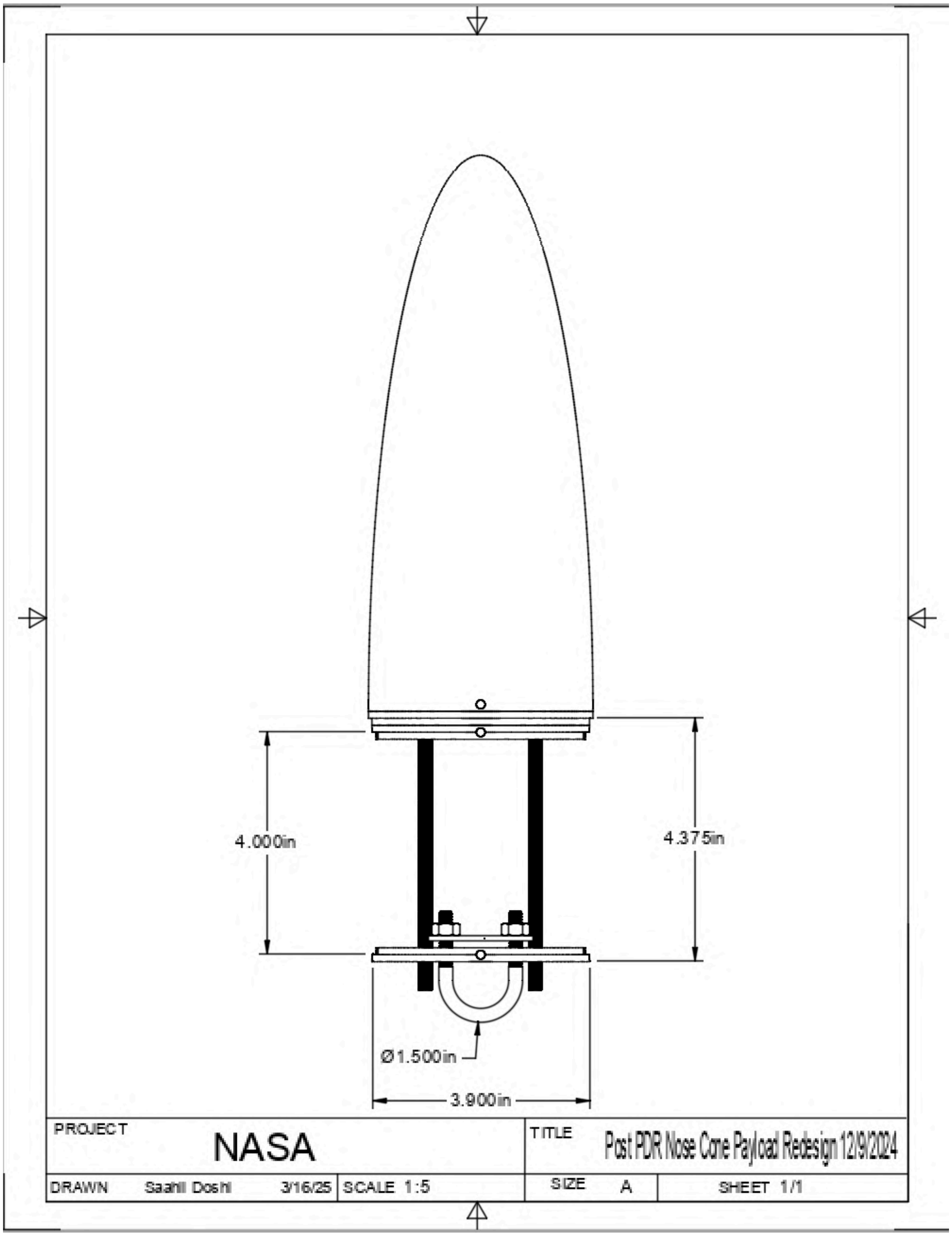
Fig

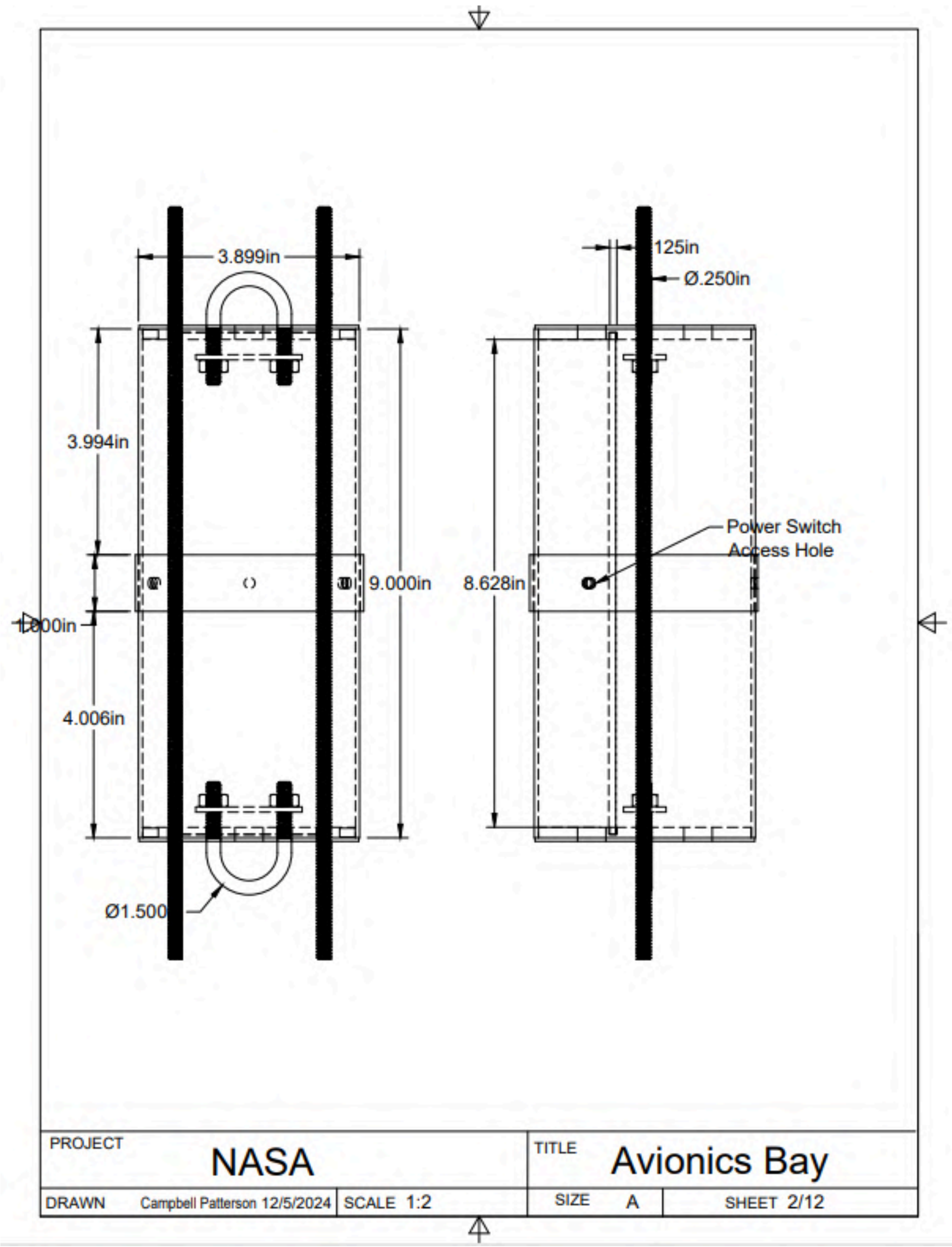


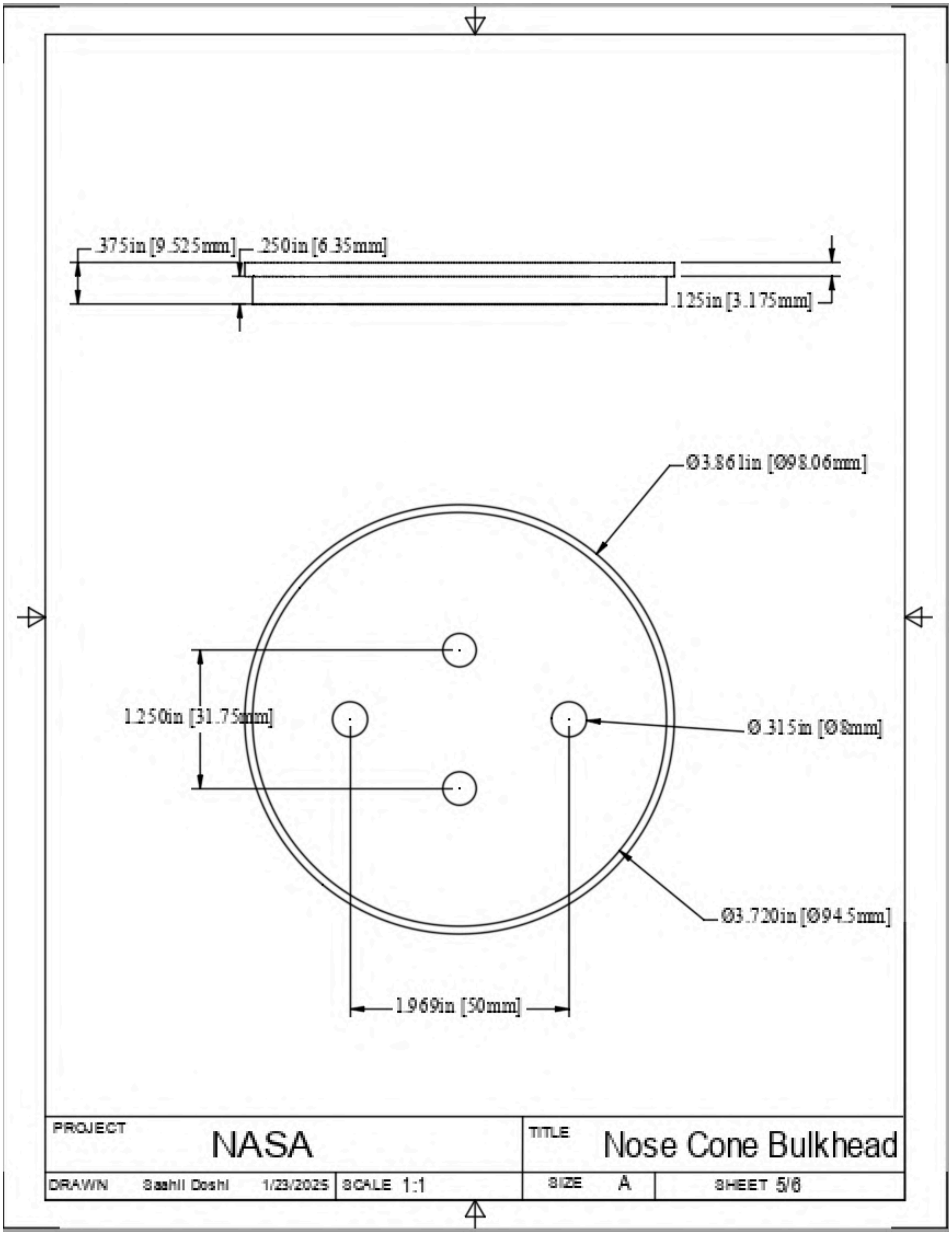



Payload Parts

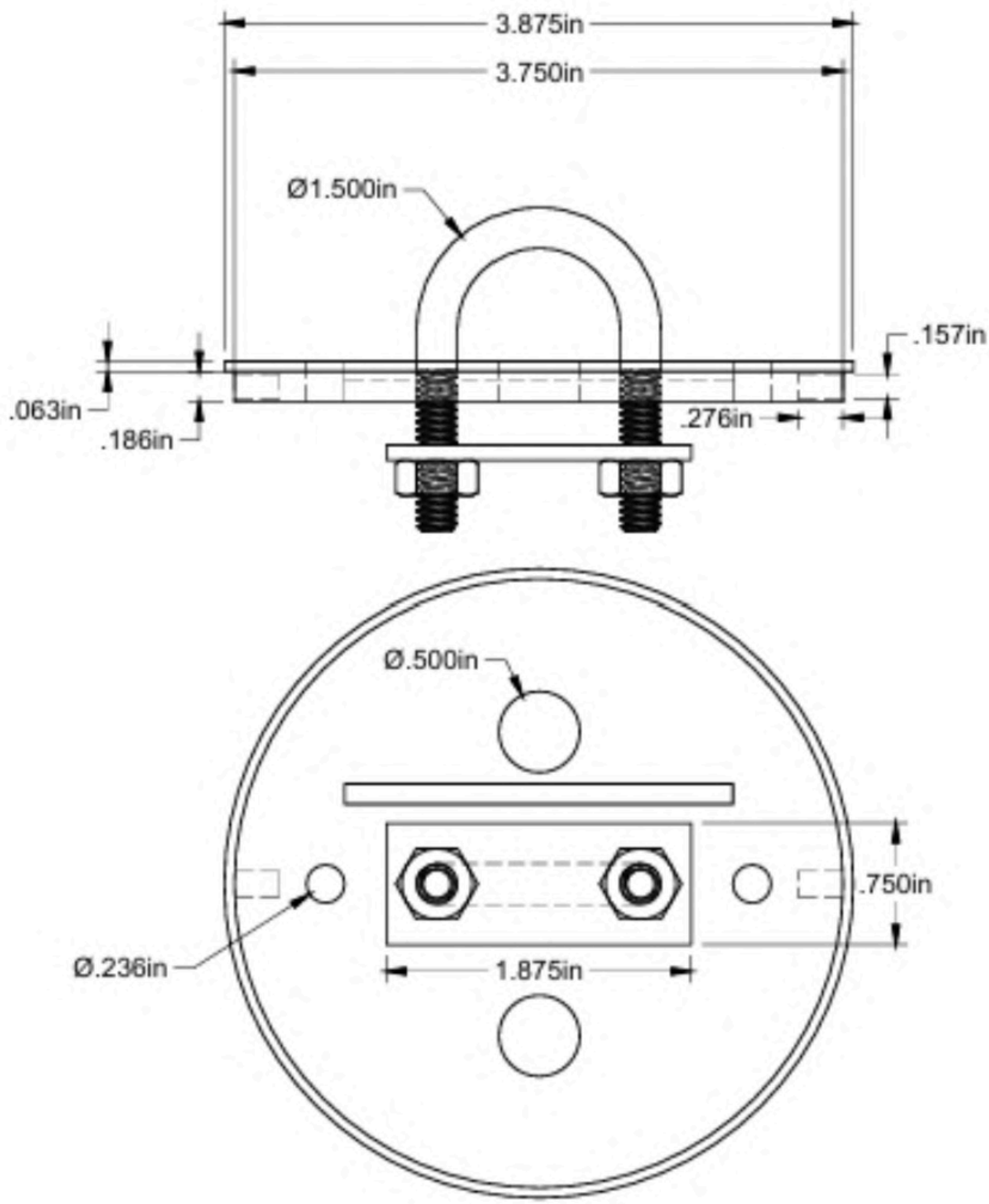
4.1.5 As Built Schematic Drawings

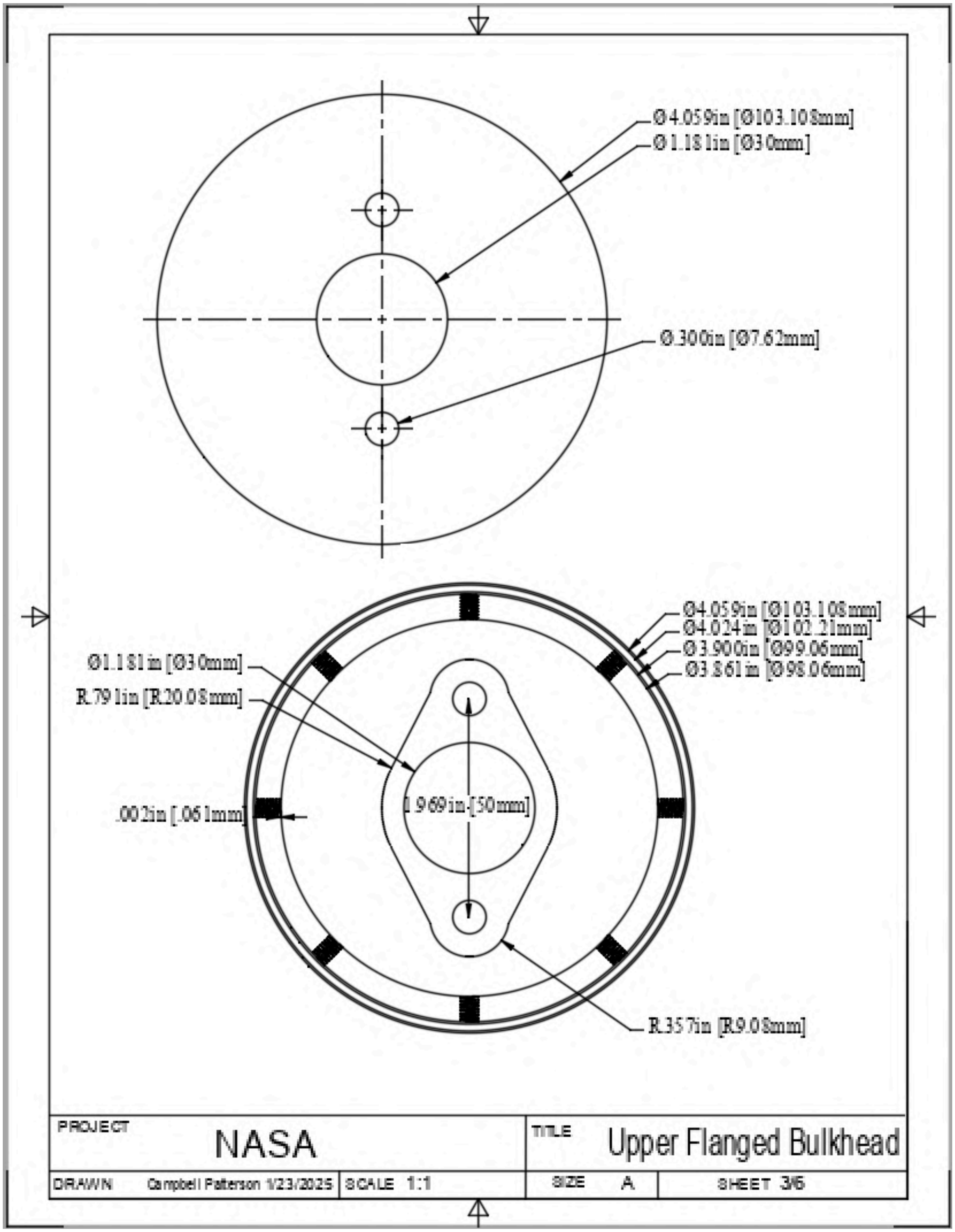



3.899in
125in
Ø.250in
3.994in
Power Switch
Access Hole
9.000in
8.628in
1.000in
4.006in
Ø1.500
PROJECT
NASA
TITLE
Avionics Bay
DRAWN
Campbell Patterson 12/5/2024
SCALE 1:2
SIZE A
SHEET 2/12


.375in [9.525mm]
.250in [6.35mm]
.125in [3.175mm]
Ø3.861in [Ø98.06mm]
1.250in [31.75mm]
Ø.315in [Ø8mm]
Ø3.720in [Ø94.5mm]
1.969in [50mm]
PROJECT
NASA
TITLE
Nose Cone Bulkhead
DRAWN
Saahil Doshi
1/23/2025
SCALE 1:1
SIZE A
SHEET 5/6

Avionics Bay Bulkhead




Ø4.059in [Ø103.108mm]
Ø1.181in [Ø30mm]
Ø.300in [Ø7.62mm]
Ø4.059in [Ø103.108mm]
Ø4.024in [Ø102.21mm]
Ø3.900in [Ø99.06mm]
Ø3.861in [Ø98.06mm]
Ø1.181in [Ø30mm]
R.791in [R20.08mm]
.002in [.061mm]
1.969in [50mm]
R.357in [R9.08mm]
PROJECT
NASA
TITLE
Upper Flanged Bulkhead
DRAWN Campbell Patterson 1/23/2025
SCALE 1:1
SIZE A
SHEET 3/6

4.1.6 How the Payload Differs

- The payload that is built has very little difference to the payload that was designed. For the most part, changes were made to material selection and small mounting additions were made
- In the upper payload, a 3D printed sled was added that holds the Featherweight GPS onto the rocket. There were also 3D printed chairs that were made to hold our Stemnauts. Both of these additions on the inside of the rocket connect to existing structure and did not have any major effect on the payload.
- On both the upper payload and the avionics bay changes were made to the bulkheads that are at the extremities. The structure and design of these payloads remained the same however, we decided to change the material that they were made out of. We switched from aluminum to Delrin for these surfaces. The reason for the switch was for weight reduction and an increase in manufacturing efficiency. We were able to greatly reduce the weight of the bulkheads without changing the design at all or sacrificing structural support. We were also able to produce these parts in house which gave us the ability to prototype and fine tune our manufacturing.

4.1.7 Payload Demonstration Flight

- The payload demonstration flight was completed on Sunday March 9th, 2025. This flight took place in Dalzell, South Carolina.
- For this flight to be considered successful we needed to see many things come into place. Pre-flight we needed to confirm all checklists were complete and that nothing was missing off of the checklist items. We then wanted to see that the payload went together correctly. Next the rocket had to connect to the GPS tracker for tracking operations and we needed to check the transmission of data. With complete data transmission we needed to see good separation of the rocket at the proper points in the flight and safe backups. Finally, the rocket needed to land in the correct configuration and complete transmitting data all of the way back to the ground.
- After flying the rocket on the 9th day of March we could say that we had a successful demonstration flight of the payload. All checklists were complete and did not lack any instructions for the safe preparation of the rocket. The GPS tracker connected to the ground station and to our iPhone and transmitter data correctly. The rocket then took off and deployed our parachute at apogee quickly followed by a well timed backup charge. After falling closer to the ground we had a good deployment of the main parachute and

landed safely on the ground at a good rate of speed. The GPS tracker then finished transmitting data even after it was on the ground. All together this was a perfect flight.

- In analysis of the flight, we could not find much that needed to be changed. We had some operational inefficiencies when preparing the rocket to launch however, those will be worked out in time. The rocket performed well and the payload did its job exactly how it was designed to do.

Section 5: Demonstration Flights

5.1 Flight Requirements

This flight was conducted to both fulfill the requirements for the Vehicle Demonstration Flight and Payload Demonstration Flight.

5.2 Date

March 9, 2025

5.3 Location

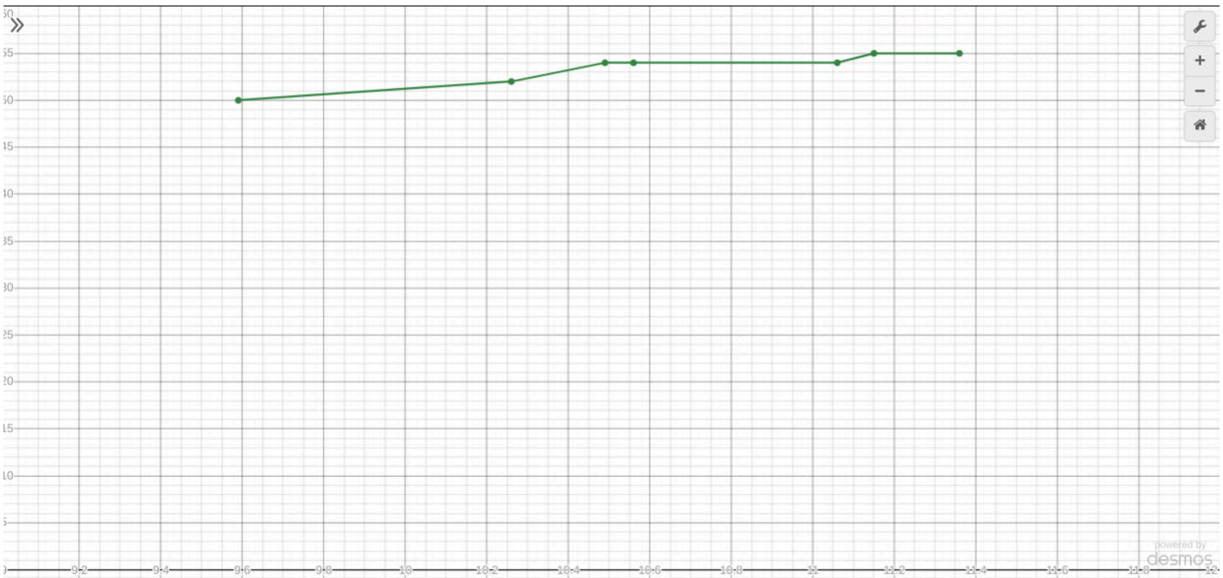
5925 Peach Orchard Rd, Dalzell SC 29040

Figure 95: Picture of Location on Launch Day

Figure 96: Picture of Setup on Launch Day

5.4: Launch Conditions

Figure 97: Graph of Temperatures



Time	Temperature (Measured in Fahrenheit)
9:59 AM	50 F
10:26 AM	52 F
10:49 AM	54 F
10:56 AM	54 F
11:06 AM	54 F
11:15 AM	55 F
11:36 AM	55 F

Figure 98: Graph of Wind Speeds

Table 65: Wind Speeds

Time	Wind (MPH)
9:59 AM	10 MPH
10:26 AM	11 MPH
10:49 AM	10 MPH
10:56 AM	10 MPH
11:06 AM	10 MPH
11:15 AM	10 MPH
11:36 AM	9 MPH

Figure 99: Graph of Wind Gust Speeds

Table 66: Wind Gust Speeds

Time	Wind Gusts (MPH)
9:59 AM	20 MPH
10:26 AM	19 MPH
10:49 AM	18 MPH
10:56 AM	18 MPH
11:06 AM	17 MPH
11:15 AM	17 MPH
11:36 AM	15 MPH

5.5 Motor Flown

RMS K1100T-14A *Blue Thunder*

5.6 Ballast Flown

The Ballast that was flown was our 6 inch Elliptical Nose Cone Ballast. Our Ballast is our Nose cone, which can be printed to different heights and weights to help us reach our desired apogee. The ballast weighed .132 kg.

Figure 100: Ballast/Nose Cone

5.7 Final Payload Flown

The Final Payload we flew was 4 STEMnauts (LEGO Figurines)

5.8 Official Target Altitude

Our official Target Altitude was to reach 4,300 ft.

5.8.1 Simulated Altitude

Our Simulated Altitude with the same weather conditions was 4,190 ft.

5.8.2 Actual Altitude

Our actual altitude gathered from the Altimeters on Flight day was 4,290 ft.

5.9 Altimeter Flight Profile

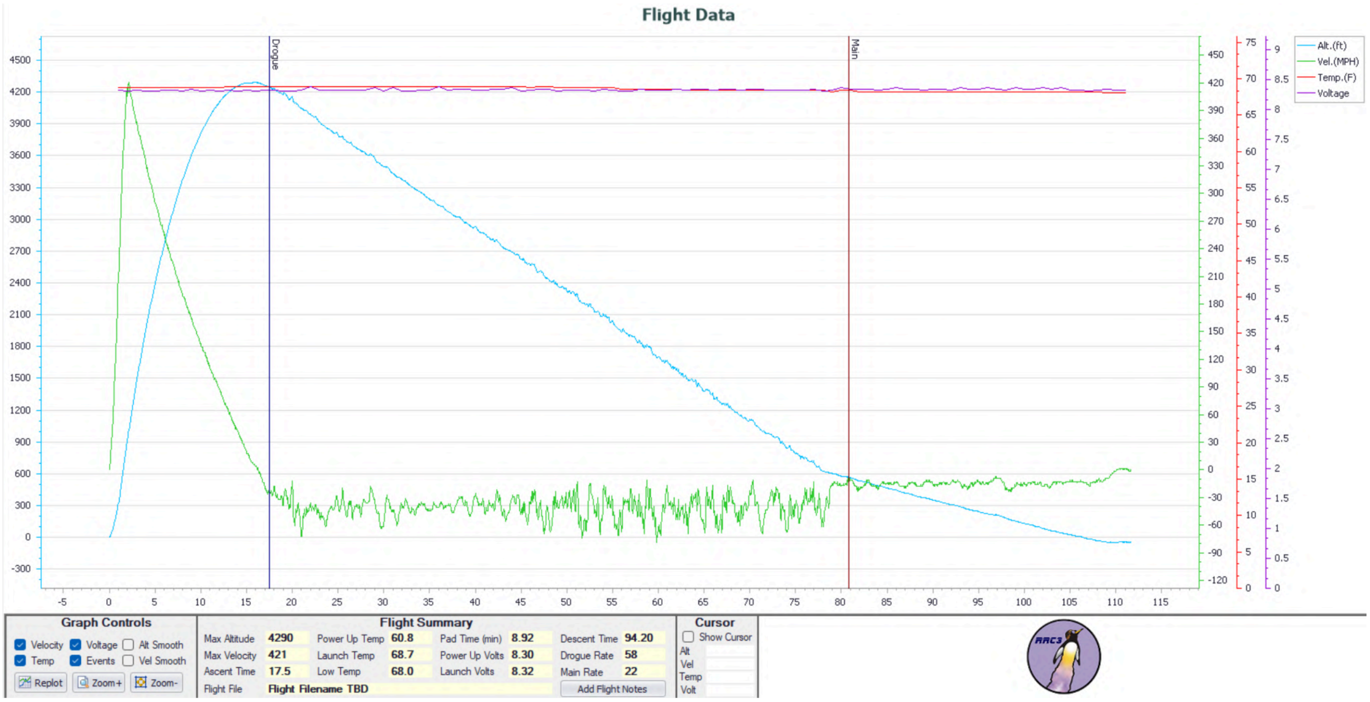


Figure 101: Altimeter Flight Profile Graph

5.10 Landing Pictures

Figure 102: Landing Pictures

5.11 Vehicle Recovery Systems

Our Vehicle Recovery Systems were extremely successful. We were able to mitigate any damage done to the Launch Vehicle, with our biggest worry as dirt and sand that had gotten inside the rocket during the landing However, none of the parts not designed to break or separate broke. Unfortunately, there was minor damage to one of the parachutes, with burn spots on it. The burn sports were not large or numerous, and were only on two panels of the parachute.

5.12 Landing Kinetic Energy

Using the results from our altimeter, our kinetic energy and calculations are as follows:

Velocity: 20.25 ft/s
Payload (1.4 lbs): **8.98 ft-lbs**
Upper Airframe/Avionics Bay (4.6 lbs): **29.34 ft-lbs**
Booster (8.4 lbs): **53.49 ft-lbs**

5.13 Flight Analysis

5.13.1 Simulated Flight Data Compared to Launch Flight Data

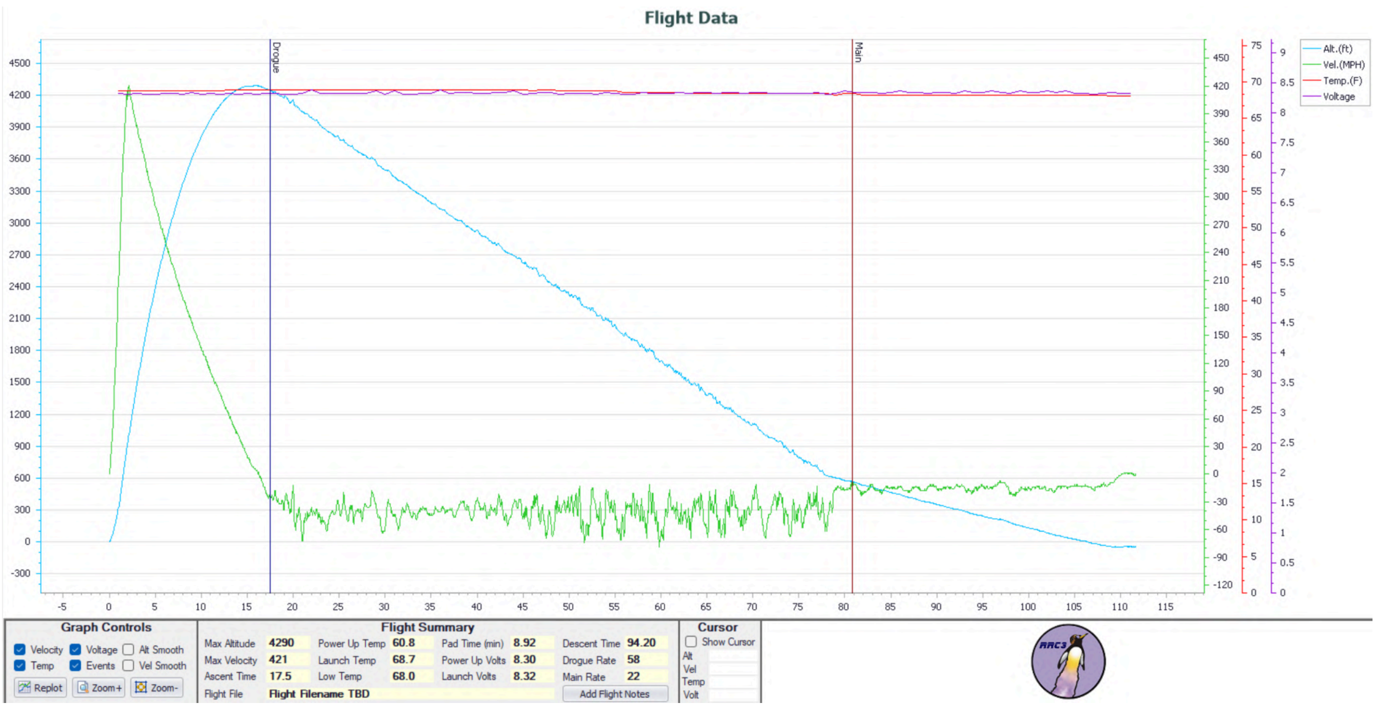


Table 67: Altimeter Flight Data Points

Apogee	4274.8 ft
Time to Apogee	15.6 s
Max Vertical Velocity	608 ft/s
Vertical Velocity At Main Deployment	-40 ft/s
Lateral Distance	986.241ft
Total Flight Time	115.08 seconds

Apogee	4274.8 ft
Descent Time	99.48 seconds

Figure 103: Simulated Flight Graph

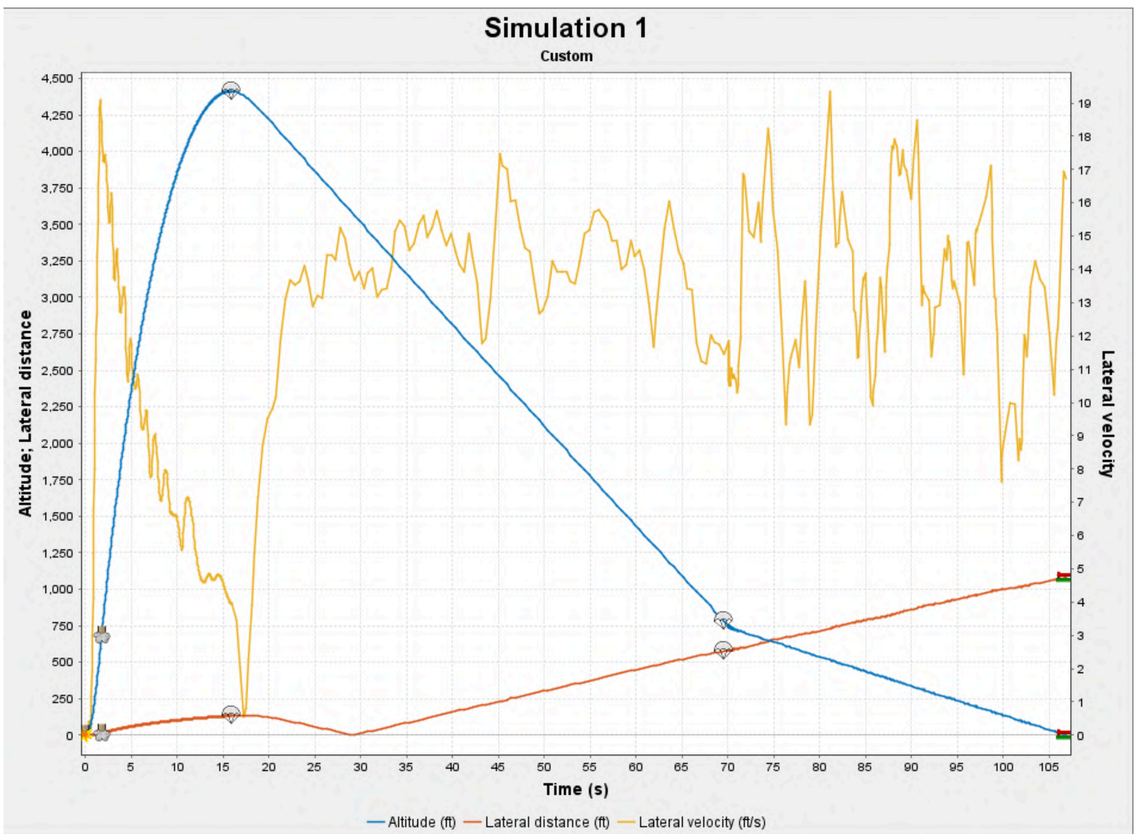


Table 68: Simulated Data Points

Apogee	4412.989 ft
Time to Apogee	15.875 sec
Max Vertical Velocity	644.426 ft/s
Vertical Velocity At Main Deployment	-67.662 ft/s
Lateral Distance	1080.812 ft
Total Flight Time	106.736 sec
Descent Time	90.861 sec

Stimulated Data Points V.S Real data Points

	Stimulation	Actual Flight	Absolute Error (Rounded)	Percent Error (Rounded)
Apogee	4412.989 ft	4274.8 ft	138.19	3.23%
Time to Apogee	15.875 sec	15.6 sec	0.28	1.76%
Max Vertical Velocity	644.426 ft/s	608 ft/s	36.43	5.99%
Vertical Velocity at Main Deployment	-67.662 ft/s	-40 ft/s	27.66	40.88%
Lateral Distance	1080.812 ft	986.241ft	94.57	9.59%
Total Flight Time	106.736 sec	115.08 seconds	8.34	7.25%

Descent Time	90.861 sec	99.48 seconds	8.62	8.67%

There were many errors in the simulation compared to the actual Launch, mostly due to limitations in the simulation. The simulation we use is OpenRocket, unfortunately for OpenRocket there is no area in the simulation to enter wind gust speeds, or account for wind gusts. However, despite this limitation, the percent of error of the stimulation and the actual launch results remain mostly under 10% -with some exceptions of course. The Vertical Velocity I believe is so drastically different due to the difference in apogee, which I believe is the reason for such a drastic percent difference compared to the other data points.

Calculations used:

$$\% \text{ of Error} = \left| \frac{\text{Stimulated Data - Launch Data}}{\text{Launch Data}} \right| * 100$$

$$\text{Absolute Error} = \left| \text{Stimulated Data - Launch Data} \right|$$

$$\text{Drag Coefficient} = \frac{D}{\frac{(p \cdot A \cdot V^2)}{2}}$$

$$A = 1.625 \quad = 1.625$$

$$V = 12.192 \quad = 12.192$$

$$p = 1.293 \quad = 1.293$$

$$D = 6.53173 \cdot 2.698 \quad = 17.62260754$$

Cd = 0.11
(Calculation uses approximates for drag force and velocity values)

5.13.2 Subscale Flight and Full Flight

Both the subscale and full flight were successful in their own capacity. In the subscale flight, heavy wind conditions resulted in a lower altitude. However, the high wind conditions during our full flight still let the rocket reach an apogee similar to the projected one. Also unlike the subscale, our rocket saw a descent time much longer than we predicted. Meanwhile the subscale returned a shorter descent time than expected. In terms of data collection, both flights completed their job successfully.

5.13.3 Flight Errors

Fortunately, we were able to mitigate errors during launch day. One issue however was that we lost visual contact of the vehicle, so we were not able to clearly see deployment events. We were able to regain visual contact of the rocket and see that both the main and drogue parachutes had deployed as it got closer to the ground.

5.13.4 Flight Conclusion

Lessons Learned:

- Ensure that only one person is attempting to connect to the Featherweight Altimeter at one time.
- Ensuring that all connections, including Bluetooth and telemetry systems, are fully tested before flight is crucial to avoid communication issues.
- The thorough pre-installation inspection and verification of all payload components

helped prevent damage and ensured readiness.
- Regular checks of battery status and power systems confirmed sufficient charge, highlighting the importance of backup power systems to prevent unexpected failures.
- The correct installation and verification of retention systems like shear pins and bulkheads were vital for ensuring the payload's secure attachment throughout the flight.

5.14 Payload Retention

During flight, the payload retention system functioned flawlessly. The nylon shear pins released as expected, allowing the payload to separate smoothly. The 3-D printed screw and Delrin bulkheads securely held the payload in place throughout the flight, ensuring stability. The Featherweight GPS worked perfectly, providing accurate tracking data without any issues. The robust retention system, combining shear pins, bulkheads, and threaded rods, effectively handled the forces from the recovery system, ensuring the payload remained securely attached until it was time for separation.

Verifying that the threaded rods and bulkheads were securely fastened helped prevent any potential issues with retention.

5.15 Payload Systems

The mission sequence began with power-up and ground testing of the payload systems. After connecting the payload to the telemetry system, we confirmed data transmission, including altitude, battery voltage, and GPS coordinates. The payload was then inspected for damage, and all components, including bulkheads, electronics sled, batteries, wiring harnesses, and U-bolts, were verified to be secure and in the correct configuration for flight. The payload was integrated into the rocket, secured with shear pins, and final system checks were conducted. The rotary switch was turned on to activate the payload, and the telemetry data transmission was verified one last time before flight.

Payload Systems that Worked Correctly:

- Power-up and telemetry systems worked perfectly, with all devices transmitting expected data (altitude, battery voltage, GPS coordinates).
- All retention systems (shear pins, bulkheads) performed as expected, ensuring secure attachment during ascent.
- The Featherweight GPS and electronics (including RRC3+ altimeter) functioned correctly, transmitting real-time data.

Payload Systems that Did Not Work:

- Featherweight Altimeter Bluetooth was not connecting - This was due to 2 people attempting to connect at the same time.
- All other systems functioned correctly with no failures observed during the mission.

Section 6: Safety and Procedures

6.1 Safety and Environment (Vehicle and Payload)

Risk Assessment Tables

Level of Risk	Acceptance Level
High Risk - Catastrophic	Unacceptable. Will cause harm or significant damage to plans, people or the surrounding environment. Must be immediately fixed and not allowed to continue until fixed.
Medium Risk - Critical	Undesired. Will cause some harm or some damage to plans, people or the surrounding environment. Must be fixed before continuing, however, does not have to be immediately fixed.
Low Risk - Acceptable	Adequate. Requires either verbal or written approval from supervisor or mentor directly responsible for the operation or action.
Minimal Risk - Negligible	Acceptable. No need for review or concern by supervisors or advisors. If there is any danger it is equal to a papercut.

Table 69: Probability Key

Description	Chance of Occurance
Frequent - A	90% >
Occasional - B	50% >
Rare - C	10% >
Improbable - D	1% <

Probability	1-Catastrophic	2-Critical	3- Acceptable	4-Marginal
A - Frequent	1A	2A	3A	4A
B - Occasional	1B	2B	3B	4B
C - Rare	1C	2C	3C	4C
D - Improbable	1D	2D	3D	4D

Table 70: Construction Hazards

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
Accident Happens with Rocket Equipment.	Lack of training or supervision; Ignorance of established safety and maintenance protocols.	Team members sustain minor to severe injuries; People in the area sustain minor to severe injuries; Surrounding equipment sustains minor to	1B	Training and information on all of the tools used. Documentation of all members signing the Safety Agreement. Mentor, SO, or advisor supervision when using tools.	OCHS tools are used by members who know how to use them and are operated by members who are of age. Safety Agreement is signed and followed;	3C

		severe damage.			Adhere to local rules when using external resources.	
Accidents while soldering iron during assembly.	Lack of training or supervision; Ignorance of safety protocols and proper soldering techniques; Wires exposed to hot soldering iron and electronic circuits exposed to hot soldering.	Team members may experience 1st or 2nd degree burns; Equipment and/or facilities are damaged; Electronic parts are damaged and/or salvage; Parts would need to be reordered due to damage.	2B	Training on all required tools and machines; Instruction on safe shop and work practices.	All team members will be educated on proper protocol and how to properly handle and use soldering irons; All use of soldering machines and tools will be supervised by either the SO, an Advisor, or Mentor.	3D
Mistakes in 3D printing components for the rocket.	Lack of understandi ng on how to properly model pieces in	Pieces will not be able to be used for the rocket;	3C	Students have been taught to use 3d printers safely and	We will inspect each part we print or laser is inspect and	4C

	Fusion360 or other CAD programs; Lack of understandi ng how to use the 3Dprinters or lasers; Equipment malfunction .	Time and money wasted trying to get prints right..		laser cutter safely;	up to standards before installing the parts and again before launch.	
Inhalation of chemical or metal particles and/or fumes during assembly.	Substances encounter an open flame or hot surface; Lack of proper ventilation when working with certain chemicals or metals; Unforeseen reaction between chemicals that results	Irritation of the respiratory system; Shortness of breath, dizziness, naus and/or fatigue; Prolonged exposure may lead to respiratory damage.	2B	Limit use of dangerous chemicals and metals to well-ventila ted areas; Use of a fume hood in workshops when appropriate; Training on and enforcement of exposure time limitations;	Work with hazardous substances will be performed in a designated shop/laborat ory space supervised by trained personnel.	2D

	in gas products;			Required use of protective equipment such as masks, respirators, and safety glasses when dealing with hazardous materials.		
Hazardous materials from rockets (construction or otherwise) end up in either the trash or out in the open.	Not knowledgeable on how to properly store and dispose of hazardous materials.	Potential harm to the environment; Potential risk to students and faculty in OCHS	2D	SO, mentor, and advisor will be educated on proper disposal of potentially hazardous substances.	Hazardous substance disposal will follow local and federal guidelines as well as MSDS and EPA guidelines.	3D
Motor Tube is Off-Centered	Misalignment of Motor Casing or Centering Rings	Airframe Damage, Unstable and Unpredictable Projection of the Rocket	2C	Precise alignment of the motor casing will occur during rocket construction. Close	Inspection of Motor Tube and during assembly to ensure that the Motor Tube is properly centered.	4D

				inspection will occur before the launch.		

Table 71: Flight and Launch Hazards

Hazard	Cause	Effect	Pre-RAC	Mitigation	Verification	Post-RAC
Failure of Motor Ignition	Defect in Manufacturing, Failure of the Igniter	No Ignition of Motor, Rocket Remains on Launch Pad	1C	Follow all procedures in NAR safety code. Have backup motor(s) to replace the failed motor in supply if applicable.	Motor will ignite when all goes well.	3D
Parts of the rocket's materials explode and ignite the surrounding environment.	Rocket literally explodes on either the launchpad; in the sky; or on the ground where it landed.	Surrounding environment is ignited by flaming debris and sparks.	2C	Follow all fire safety procedures and ensure that no materials ignite or explode.	Ensure fire extinguishers are at the launch site and explosives are only handled by people with certifications.	4C

The rocket encounters unexpectedly strong winds during flight.	Wind speeds during launch day are not good or are not properly measured.	The rocket takes an unexpected flight path; Possible injury to people because of the errant flight path; Rocket fails to reach the desired apogee.	1C	Design will emphasize flight stability and structural integrity; Launch will be postponed and/or canceled should conditions remain unfavorable. Rocket should weigh a metric ton as to let it fall faster and not be so affected by wind speeds.	Design of the rocket will be reviewed during team meetings; NAR guidelines will be followed if winds exceed allowed conditions; Launch guidelines will be developed so that launch will be canceled if the measured wind speed exceeds our individual rocket's allowable conditions.	4C
High temperatures or strong light sources ignite flammable materials.	Improper storage of flammable material; Improper temperature control of flammable material.	Fire or explosion; Any person may suffer serious injury; Harm or injury to students,	1C	All flammable materials will be stored in flame-resistant metal cabinets at room temperature or by mentor; Safety officers or mentor will	Routine inventory checks and oversight by SO, mentor or advisors to ensure that the flammable materials are properly stored.	2D

		faculty, or staff not associated with the project; Damage to materials and facility.		inform all team members on best storage practices.		
Launch vehicle impacts ground too hard, causing environmental damage	Failure to model KE properly. Parachutes fail to deploy due to: 1) Failed to fold properly and shock cords get tangled 2)Energetics are wired wrong and the parachutes don't go off.	Ground is damaged, or whatever it hits. Rocket parts are scattered around the impact site and threaten local wildlife.	2C	Use of simulations and calculations for landing KE. Will use a parachute that allows for a safe amount of drag force to be created. Methodical and calculated measures will be taken when assembling the rocket to ensure that it does not come apart whilst flying.	Simulation and calculation results will be analyzed for accuracy and done by more than one person to then be used to ensure the rocket doesn't disturb the local fauna. Simulations and calculations will determine parachute size. Safety checks will be done pre-flight to ensure the rocket is safe to fly.	3D

Rocket meets its untimely demise landing in a body of water.	Rocket takes an unexpected flight path; Rocket drifts out too far during descent.	Electronics in rocket short out and are unusable; Rocket parachutes get moldy; Rocket unable to be retrieved due the fact that it's too far under water.	1C	Lots of calculations on the drift distance to ensure it doesn't drift that much; Choosing parachutes that are safe, but don't create unnecessary drag and let the rocket fly off.	Simulations will confirm the veracity of calculations. Small-scale and full-scale testing will additionally test calculations; Avoid launching near large bodies of water. Make sure the team is keeping a vigilant eye out so that it doesn't fall into a lake.	2D
Fumes and dust particles from rockets are expelled into the air.	Lack proper attachment	Team members or spectators near launch may experience the effects of low air quality.	2C	Filters will be used on all ventilation fans; Any painting will be done in a well ventilated area by individuals who know how to handle	Construction will follow safety guidelines to prevent the spread of dust, paint, or other airborne particulates during flight.	3C

				a can of spray paint.		
Drag forces damage the rocket whilst flying and descending.	Failure to design rocket components that would withstand drag forces; Rocket components are not assembled correctly.	People may be injured by falling rocket; Fins may be damaged, potentially leading to further damage of the rocket; Unstable or unpredictable flight path.	1B	Use careful calculations and simulations to ensure drag forces will not cause failure of components; Test components by launching a subscale rocket.	Carefully craft the rocket with approval from the team mentor and NASA. Ensure that all members rigorous testing on all components to ensure they withstand forces; Ensure that all simulations and calculations are done at least thrice with multiple people doing them.	2D
Rocket takes an unexpected or unstable flight.	Wind speeds knock rocket off its expected path;	People may be injured by rocket; Rocket may be damaged	1B	Use simulations to predict flight pattern and trajectory stability;	Simulations will be performed p in a variety of circumstances to make sure that the final	4C

	Body of the rocket is damaged during launch.	or break up mid-flight;		Test the rocket's flight path with a small-scale model;	flight is safe and stable;	
Rocket fails to meet target altitude, or exceeds it.	Miscalculation of thrust given by motor; Weather cocking messes up the flight path; Didn't reach necessary exit velocity at launch pad.	Failure to meet altitude requirements set by criteria Less happiness derived from watching the rocket.	3B	Use simulations to ensure proper motor choice; Accurately measure rocket mass and its center of pressure and center of gravity.	Simulations are done with the specifications of the full-scale rocket to determine the correct motor to use for the launch; Make sure to do test launches to gather data to be able to adjust the rocket as needed.	4D
Insufficient amount of Black Powder in Ejections Charges	Insufficient black powder calculation/preparation. Recovery system	Parachutes will not deploy rocket enters freefall;	1B	The amount of black powder necessary will be calculated prior to launch and measured out by our mentor.	A ground test will be performed beforehand to check that the ejection charge detonation is appropriate for	2D

	partial or complete failure.	People may be injured by falling rocket; Rocket or rocket subparts may be damaged beyond repair;			rocket recovery.	
Flame Damage to Components	Inadequate Thermal Protection; Recovery parts left out in a flame hazard area, causing damage	Recovery System damage; Damage to Recovery System during flight;	2B	Recovery systems are flame retardant; as well as protected properly from exposed flames.	Recovery systems checked to ensure they are properly protected; Recovery systems are stored so they do not catch on fire.	2D
Premature Ejection	Altimeter Malfunction, Inaccurate Altimeter Readings	Damage to Airframe permanently; Failure to reach desired	2C	All wires will be shielded. Usage of reliable altimeters to ensure accuracy of ejection	Altimeters will be checked on ground level to make sure they are coded correctly	4D

		apogee; Failure to reach ground in desired time;		charges.	and work.	
Premature Separation	Failure of Shear Pins	Airframe Damage, Component Damage	2C	Sections will be secured with reliable shear pins.	Testing with shear pins and separation during ground test.	3D
Recovery Attachment Point Failure	Quick Links Come Undone or Hardware Fails	Complete Loss of Recovery System	1C	Visual inspection of all links and knots before launch. Select hardware for a system that has a high safety factor.	Testing configuration of recovery system attachments	2D
Sections Self-Impact	Sizing of Bridle is Improper, Parachute Placement is Improper	Permanent Airframe Damage, Component Damage beyond repair	2C	Inspection of rigging and bridle sizes will occur to prevent collision of rocket sections.	Inspection of rigging and bridle sizes will occur to prevent collision of rocket sections.	4D

Separation Failure	Inadequate Black Powder Charge, Improper Placement of Charges	Failure to Properly Deploy Recovery System	1C	Follow all procedures in NAR safety code. Have backup motor(s) to replace the failed motor in supply if applicable.	Ground Testing to make sure that Black Powder positions are correct.	3D

Table 72: Material Hazards

Material	Hazard	RAC	Prevention	Post RAC
Epoxy	Skin irritation	3B	Work in a well ventilated area with proper PPE.	4C
Black Powder	Explosion risk; Skin irritation; Lung irritation.	2C	Work alongside mentor, Armando Rodriguez, on charge sizing and placement.	2D
Lithium Polymer	Fire risk due to battery failure	1B	Take proper precautions while charging and while placing battery in the rocket as defined by manufacture	2C
Cyanoacrylate	Skin irritation and toxicity	1B	Work in a well ventilated area with proper PPE.	2D
Fiberglass	Respiratory and skin irritation	1A	Work in a well ventilated area with proper PPE.	3C

Solid Propellant Motor	Explosion risk	2C	Work alongside Armando Rodriguez, mentor, while handling and installing motor, and preparing an electronic ignition system.	3D
Kevlar Sock	Skin irritation	1C	Use proper PPE while installing Kevlar sock to prevent skin irritation.	2D
Aluminum	Lung irritation	2A	Use proper PPE in a well ventilated area to prevent inhalation of aluminum dust.	2B

6.2 Launch Operations Procedures

6.2.1 Troubleshooting Procedure

Any errors with the payload components can be seen in the Featherweight UI app. There are multiple approaches we can take to solve various errors:

1. GPS-App connection failure:

- ☐ Ensure power LED on the GPS is on
- ☐ Verify the phone's bluetooth is turned on and able to pair with devices
- ☐ Look for devices in the app in "device list" and "scan page"

2. Connection without showing data:

- ☐ Ensure the GPS and the app are on the same frequency using the same TrackerID
- ☐ Make sure that the GPS device is set to "tracker" and the app as "ground station"

3. Units are communication, but no GPS data is available:

- ☐ The GPS is simply not getting a good signal. Try your best to clear the path from the antenna to the sky

6.2.2 Recovery Preparation

Recovery System, Drogue Chute:

- ☐ Check shock cords for cuts, burns, and tangles.
- ☐ Check all shroud lines - no tangles.
- ☐ Check drogue chute for tears and burns.
- ☐ Check deployment bag for tears.

Check all connections. Insure all devices are in good condition and properly secured:

- ☐ Electronics bay shock cord to drogue
- ☐ Booster shock cord to drogue

Pack drogue chute in deployment bag, keep lines even and straight.

- ☐ Fold drogue chute per manufacturer's instructions.
- ☐ Ensure shroud lines are free from tangles.
- ☐ Ensure all quick links are secure.
- ☐ Insert drogue bag/chute into the aft recovery compartment .
- ☐ Insert ejection charge protection.

Recovery System, Main Chute:

- ☐ Check shock cords for cuts, burns, and tangles.
- ☐ Check all shroud lines - no tangles.
- ☐ Check main chute for tears and burns.
- ☐ Check deployment bag for tears.

Check all connections. Insure all devices are in good condition and properly secured:

- ☐ Nose Cone shock cord to drogue
- ☐ Electronics bay shock cord to drogue

Pack main chute in deployment bag, keep lines even and straight.

- ☐ Fold main chute per manufacturer's instructions.
- ☐ Ensure shroud lines are free from tangles.
- ☐ Ensure all quick links are secure.
- ☐ Insert ejection charge protection.
- ☐ Insert main bag/chute into forward recovery compartment

6.2.3 Payload Preparation

Step 1: Power-Up and Ground Test

1. Power Up Payload Systems:

- ☐ Plug in the battery for the payload electronics.
- ☐ Turn on Insta360
- ☐ Verify power LED is illuminated on all devices.

2. Establish Connections:

- ☐ Connect to the payload via Bluetooth or designated telemetry system.

- ☐ Ensure communication with the ground station:

- ☐ Test data transmission (e.g., altitude, battery voltage).

- ☐ Verify expected telemetry output.

Step 2: Pre-Installation Inspection

Inspect all payload components to ensure no damage:

- ☐ Bulkheads
- ☐ Electronics sled
- ☐ Batteries and wiring harness
- ☐ U-bolts and anchor points
- ☐ Verify all screws, fasteners, and mounting rods are tight.
- ☐ Ensure payload is in the closed configuration for flight.
- ☐ Confirm rotary switch is OFF before installation.

Step 3: Payload Integration into Rocket

- ☐ Align the payload coupler with the rocket airframe.
- ☐ Secure the payload using shear pins at designated locations.

Verify retention system integrity:

- ☐ Check tightness of bulkheads and shear pins.
- ☐ Confirm payload is properly seated within the airframe.

Step 4: Final Verification

- ☐ Turn on the rotary switch to activate the payload.

1. Conduct a final Bluetooth connection test:

- ☐ Confirm all telemetry data is being received.
- ☐ Verify payload systems remain operational under static conditions.

2. Confirm battery status:

- ☐ Ensure sufficient charge for flight.

6.2.4 Electronics Preparation

Step 1: Power-Up and Ground Test

1. Power Electronics Bay:

- ☐ Plug in the battery for the electronics.
- ☐ Verify that power LED is illuminated on all devices (eg. RRC3 altimeter, Featherweight GPS, etc)

2. Establish Connections:

- ☐ Connect to the payload via Bluetooth or designated telemetry system.
- ☐ Test data transmission (e.g., altitude, battery voltage, gps coordinates).
- ☐ Ensure all expected telemetry output are received

Step 2: Pre-Installation Inspection

Inspect Electronics and Wiring for Damage:

- ☐ RRC3 altimeter

- ☐ Featherweight GPS and antenna
- ☐ Wiring harness and connectors
- ☐ Power distribution and battery connectors
- ☐ Ensure all screws, fasteners, and mounting rods are tight.
- ☐ Make sure no wires are loose or exposed
- ☐ Ensure payload is in the closed configuration for flight.
- ☐ Confirm rotary switch is OFF before installation.

Step 3: Integration into Electronics Bay

- ☐ Align the RRC3 altimeter, Featherweight GPS, and all other electronics are in the electronics bay
- ☐ Make sure all devices are securely attached

Verify integrity:

- ☐ Check tightness of bulkheads and shear pins.
- ☐ Confirm the electronics bay is properly attached to rocket's airframe

Step 4: Final Verification

- ☐ Turn on the rotary switch to activate the electronics bay.

1. Conduct a final Bluetooth connection test:

- ☐ Confirm all telemetry data is being received.
- ☐ Verify all electronics systems (altimeters, GPS's, etc.) remain operational under static conditions.

2. Confirm battery status:

- ☐ Ensure sufficient charge for flight.
- ☐ Ensure backup power systems are functioning

6.2.5 Rocket Preparation

- ☐ Unpack rocket and inspect for damage
- ☐ 2. Place rocket on workstation and separate the different parts: Nose cone, forward section of BT, Av-Bay coupler, Aft end of the rocket
- ☐ 3. Open the Av-Bay coupler and inspect that all wire connections are secure
- ☐ 4. Retrieve batteries to be placed in the Av-Bay electronics and check the voltage of each battery
- ☐ 5. Install the proper battery to each electronic component inside the Av- Bay. Make certain that each battery is properly secured.
- ☐ 6. Activate each component, separately, to check that each component is functioning correctly. Be certain to turn off every electronic component before assembling the Av-Bay
- ☐ 7. Secure the Av- Bay lids to the Av-Bay coupler, be careful not to disconnect any wires or pinch wires while closing off the Av-Bay.
- ☐ 8. During this procedure, wear safety glasses and stay clear of any heat or flame sources. Load the energetic's to the deployment containers on either side of the Av-Bay lids, Primary and Secondary for both Drogue and Main deployment. Set the Av-Bay coupler aside when completed in a safe and secure manner.
- ☐ 9. Attach the drogue end shock cord to the attachment point inside the aft end of the rocket. Give several strong pulls to the shock cord to be certain that the shock is properly attached.
- ☐ 10. Check the integrity of the drogue parachute and fold as required by the manufacturer. Wrap a Nomex blanket around to drogue parachute to protect the parachute. Properly secure the Nomex blanket to the drogue para lines so it protects the drogue but does not interfere with the opening of the drogue parachute. Attach the drogue wrapped parachute to the third loop on the shock cord, make certain it is properly attached.
- ☐ 11. Z fold the drogue side shock cord and lower it and the drogue wrapped parachute into the aft end of the rocket.

- ☐ 12. Retrieve the Av-Bay coupler, be careful with the attached deployment energetics at either end of the Av-Bay lids.
- ☐ 13. Properly secure the other end of the drogue parachute shock cord to the drogue attachment point on the drogue side Av-Bay lid.
- ☐ 14. Carefully insert the drogue end of the Av-Bay coupler into the aft end of the rocket BT and secure the Av-Bay coupler to the BT with a shear pin.
- ☐ 15. Attach the main parachute shock cord to the main side attachment point on the Av-Bay coupler lid. Be certain that it is properly attached.
- ☐ 16. Retrieve the forward section of the BT. Thread the main parachute shock cord through the forward section of the BT so it is fully extended through the opposite open end.
- ☐ 17. Rotate and insert the forward BT section over the main side Av-Bay coupler section and secure the BT to the Av-Bay coupler with rivets or other forms of securing fasteners.
- ☐ 18. Inspect the main parachute, Make certain that it is not damaged, the para cords are not tangled, and properly fold the main parachute as required by the manufacturer. Wrap a Nomex blanket around the parachute to properly protect the parachute.
- ☐ 19. Secure the Nomex blanket to the main parachute paracord, but be certain that it will not interfere with the opening of the main parachute. Now secure the main parachute to a third loop on the main parachute shock cord. Z fold the shock cord and lower the shock into the forward section of the BT. Then, lower the wrapped main parachute into the forward section of the BT carefully.
- ☐ 20. Secure the main parachute shock cord to the attachment point on the nose cone coupler and carefully insert the coupler into the forward section of the BT. Rotate the nose cone to align the shear pin insertion point. Secure the nose cone to the forward section of the BT with a shear pin.
- ☐ 21. Place the rocket in a vertical position and inspect the entire rocket to ensure that the rocket has been correctly assembled, secured and ready for the motor to be loaded.
- ☐ 22. Now that the rocket has been correctly assembled and has passed a final inspection, set the rocket in a cradle or supporting stand so it is secure and not damaged while we wait for the final step, motor insertion. Keep the rocket in a shaded area, do not expose the rocket to water, direct sunlight, or any elements which can affect the performance of the rocket.

6.2.6 Motor Preparation

1. Before motor assembling, place safety glasses over eyes, be certain that your workstation is free of clutter, no heat sources or flame devices during this procedure. The assembling of a rocket motor must be completed in a location that will not interrupt you or distract you from this task. Make certain that you have all the necessary tools and supplies for this task.
2. Open the motor packaging and read the manufacturer's instruction sheet. If it is not enclosed, retrieve online and carefully read the instructions. Note; all motor's, while similar, will have different components and assembled slightly differently. Read all instructions carefully.
3. Carefully place all parts on top of your workstation in the correct order of assembling.
4. Use only correct lubricants, as recommended and maintain your workstation and hands clean during assembling.
5. Carefully assemble the motor as per manufacturer's instruction. Be careful not to damage any O rings or other components.
6. Be certain that your motor casing is clean, properly lubricated, and closure threads, closing without resistance and well lubricated.
7. When inserting motor propellant grains into sleeve, be certain you have each grain in the proper order if required. Avoid getting lubricants on the propellant grains.
8. Assemble the entire motor as instructed, place the whole thing into the motor casing, and close the casing closures as required by the manufacturer.
9. Set the motor casing aside and inspect the motor igniter. One should have been enclosed with the motor. Be certain that the end of the igniter, which is being inserted into the aft end of the motor, is free of cracks and flaws. Use an ohm meter to check continuity resistance. Note; always have more than one igniter in your supplies.
10. Tape the igniter to the side of the rocket airframe.
11. Remove the motor retainer flange from the aft end of the rocket and insert the assembled motor casing into the motor tube on the aft end of the rocket
12. Secure the assembled motor casing with the motor retaining flange, be certain it is properly secured and tight. Note; do not insert the motor igniter into the motor. This last step is only permitted when the rocket is on the pad, and in a safe and vertical position.

The rocket is now ready to be inspected by the Range Safety Officer. First, fill out a flight card as required by the launch event. When taking the rocket to the RSO, be careful with the rocket. Don't drop the rocket, don't mishandle the rocket or exert too much forces on the sections of the rocket which are intended to separate during recovery.

6.2.7 Launch Pad Procedure

The following procedure will be carried out by the Team Mentor.

- ☐ Before moving rocket to pad, perform a visual inspection of the pad itself to ensure it is clear of debris from previous launches and properly mounted and secured into the ground
- ☐ Inspect the assembled airframe for any damage or loose components
  - ☐ Make sure that each component of the airframe is attached to an adjacent section by nylon shear pins
  - ☐ Shear pins between payload and recovery bay at coupler
- ☐ Place and double check that the motor is secure inside the rocket
- ☐ Put the fully assembled rocket onto the launch rail, ensure the the rocket is safe before letting go
- ☐ Once the rocket is on the launch rail, insert a small flat-head screwdriver through each of the two holes through the body of the electronics bay and turn the rotary switch on each hole.
- ☐ If required, adjust angle of launch rail to ensure an upwind launch
- ☐ Complete final inspection before proceeding to motor and igniter installation, making sure to double check for any apparent issues with the launch pad, launch rail, or rocket

6.2.8 Flight Procedure

- ☐ Wait for RSO to give clearance to launch
- ☐ Ensure that all personnel are a minimum 300 feet away from the launch pad in accordance with the NAR minimum distance code.
- ☐ Make sure that all people in the surrounding area are alerted to the fact the launch pad is hot and ready for takeoff
- ☐ Wait for countdown to be given and then proceed with launch command
- ☐ Ensure that all personnel in the vicinity are aware of the rocket’s path and location incase of flight path deviation or rocket failure
- ☐ If any team members see a deployment (drouge or main) of a parachute immediately alert others to the location of the rocket.
- ☐ Wait for Radio wave transmission of data points. Allow for electronics teams to breathe and get data points.

- ☐ Wait for the RSO to give clearance to allow for the designated retrieval team to locate and retrieve the rocket and its parts.

6.2.9 Post - Flight Procedure

- ☐ Once RSO gives clearance, allow electronics team to utilize the GPS tracking to locate the rocket
- ☐ Follow directions to find the rocket, take picture with team at the rocket grounded site
- ☐ In case of rocket design failure, search the surrounding area for payload and electronics bay sections.
- ☐ Turn off recovery bay altimeters
- ☐ Turn off payload electronics
- ☐ Collect all rocket pieces and load them up into the wagon to be transported
- ☐ Celebrate if all was successful

Section 7: Project Plan

7.2 Project Requirements Compliance

7.2.1 Handbook Verification

Table 73: General Requirements

NASA Requirement	Compliance Approach	Verification Method
Students must complete 100% of the project (design, construction, reports, etc.).	Assign specific tasks and responsibilities to each team member to ensure full project completion and accountability.	Maintain records of team member contributions and participation.
Submit deliverables by set deadlines in PDF format.	Establish internal deadlines and a structured timeline to ensure timely submission.	Track and document deliverables to verify adherence to deadlines.

Table 74: Safety Requirements

NASA Requirement	Compliance Approach	Verification Method

Follow NAR High Power Rocket Safety Code.	Appoint a Safety Officer to oversee compliance and training.	Maintain safety checklists and ensure advisor validation.
Perform hazard analysis, FMEA, and implement mitigations.	Identify and document potential risks, applying mitigation strategies throughout the project.	Include hazard analysis in safety reports.
Conduct ground ejection tests for recovery systems.	Test the deployment mechanisms before launch.	Validate results through simulations and recorded test data.
All electronics must be protected and shielded from interference.	Isolate payload electronics from the recovery system within a secure enclosure.	Verify shielding effectiveness through ground and flight tests.

7.2.2 Derived Verification

Table 75: Vehicle Requirements

NASA Requirement	**Compliance Approach**	**Verification Method**
Vehicle must reach an apogee of 4,000–6,000 feet above ground level (AGL).	Set a target altitude and use simulation software, such as OpenRocket, to optimize performance.	Conduct subscale flight tests and analyze flight data.
Vehicle must be recoverable and reusable.	Design a structurally sound rocket with durable materials.	Demonstrate reusability through test flights, including subscale models.
Vehicle must have a thrust-to-weight ratio of at least 5.0:1.0.	Select a motor that meets thrust-to-weight requirements during the design phase.	Calculate and verify thrust-to-weight ratio through simulations and flight tests.

Maximum motor impulse is L-class (5,120 N-s).	Choose a compliant motor and confirm specifications during design.	Validate compliance through launch and RSO approval.

Table 76: Recovery System Requirements

NASA Requirement	**Compliance Approach**	**Verification Method**
Use drogue and main parachutes for staged recovery.	Design a dual-stage recovery system with staggered deployment of drogue and main parachutes.	Test deployment through simulations and flight tests.
Redundant barometric altimeters must be used.	Implement a dual-altimeter system with independent power supplies.	Conduct ground ejection tests and validate system performance during flights.
Maximum kinetic energy at landing for independent sections is 75 ft-lbf.	Select appropriate parachutes and shock cords to limit landing kinetic energy.	Analyze simulation and flight test data to ensure compliance.
Vehicle sections must land within a 2,500 ft radius of the launch pad.	Perform drift calculations considering various wind scenarios.	Validate calculations through flight tests and include findings in reports.

Table 77: Payload Requirements

NASA Requirement	**Compliance Approach**	**Verification Method**
Payload must safely retain STEMnauts and transmit data to a NASA receiver.	Design a secure housing compartment for STEMnauts and transmission system following NASA guidelines.	Conduct test launches to verify system functionality.
Transmit up to 8 data points (e.g., apogee, landing velocity, temperature).	Integrate appropriate sensors and ensure compliance with power limitations.	Validate data transmission through test launches.

Payload must comply with FAA, NAR, and safety standards.	Select transmitters and components that adhere to safety regulations.	Obtain necessary approvals before launches.

7.3 Budgeting and Funding Summary

Budget: Costs
Table 78: Budget

Item	Cost
Body Tubes	$300
Aluminum Centering Rings/ Bulkheads	Free
Delrin	$12
Motor Tube	$50
Motor Retainer	$30
Coupler	$40
Avionics	$150
Batteries	$25
Wiring	$10
Featherweight GPS	$370
Nose Cone	$5

Parachutes	$115
Shock Cords	$90
Nomex Clothes	$20
Motors	$1000
Auxiliary Hardware	$260
Total Cost to Build	$2477

Funding

Table 79: Funding

Funding Source	Amount
Corporate Donations	$700
Team Sales	$300
School Motor Purchase	$1000
Club Funded	$477
Total Deficit	$0.00

WARRIOR ONE

2025

WARRIOR ENGINEERING NASA SLI TEAM

NASA UNIVERSITY STUDENT LAUNCH

STEM ENGAGEMENT REPORT

Section 1: Activity Description

1.1 Event Details

Activity Title: High Shoals Elementary School Career Fair
Type of Activity: Outreach - Direct Engagements
Event Date: March 20th, 2025; 8:00 AM - 11:30 AM

1.2 **Learning Target for the Activity**

- Introduce the elementary students to engineering concepts through interactive demonstrations of robotics, 3D printing, 3D modeling, and rocketry.
- Students should develop an understanding of rocket design and engineering principles by analyzing the individual components of a high-powered rocket. They will examine how each component works, fits together, and supports recovery systems, flight performance, and stability. As they apply concepts from material science, systems engineering, and aerodynamics to actual aerospace problems, students will practice critical thinking and problem-solving skills through facilitated discussion and practical experience.

1.3 **Activity Description**

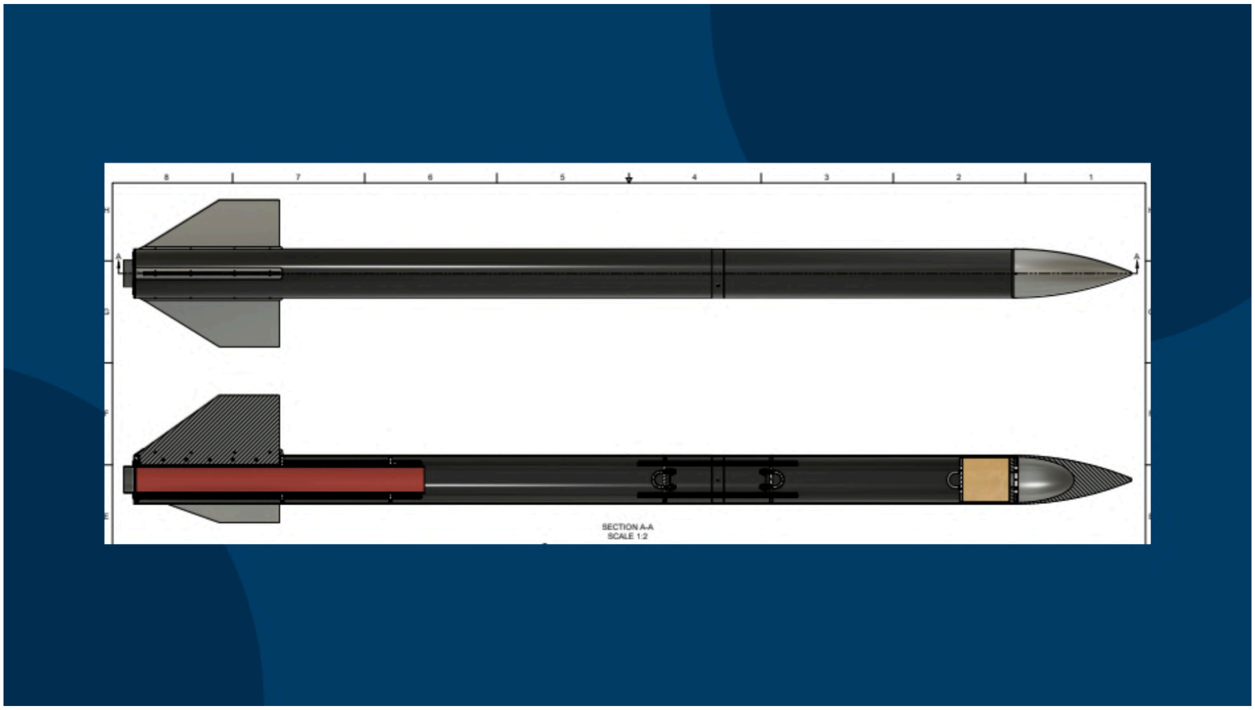
We held an interactive demonstration where students examined the various parts of our NASA Student Launch Initiative rocket as part of our STEM engagement efforts. The nose cone, avionics bay, payload bay, booster, and recovery system were all presented separately. We engaged students by asking questions about their functionality and how the individual pieces connect. Students made hypotheses about how the rocket records flight data, deploys parachutes, and maintains stability through facilitated discussion. They obtained a practical understanding of aerodynamics and structural integrity by working with the fiberglass airframe and 3D-printed nose cone. We discussed design trade-offs with them, including the reasons behind switching from carbon fiber to fiberglass couplers in order to meet NASA's flight time requirements. This activity encouraged critical thinking and problem-solving, allowing students to connect real-world engineering challenges to classroom concepts while fostering excitement for aerospace and rocketry.

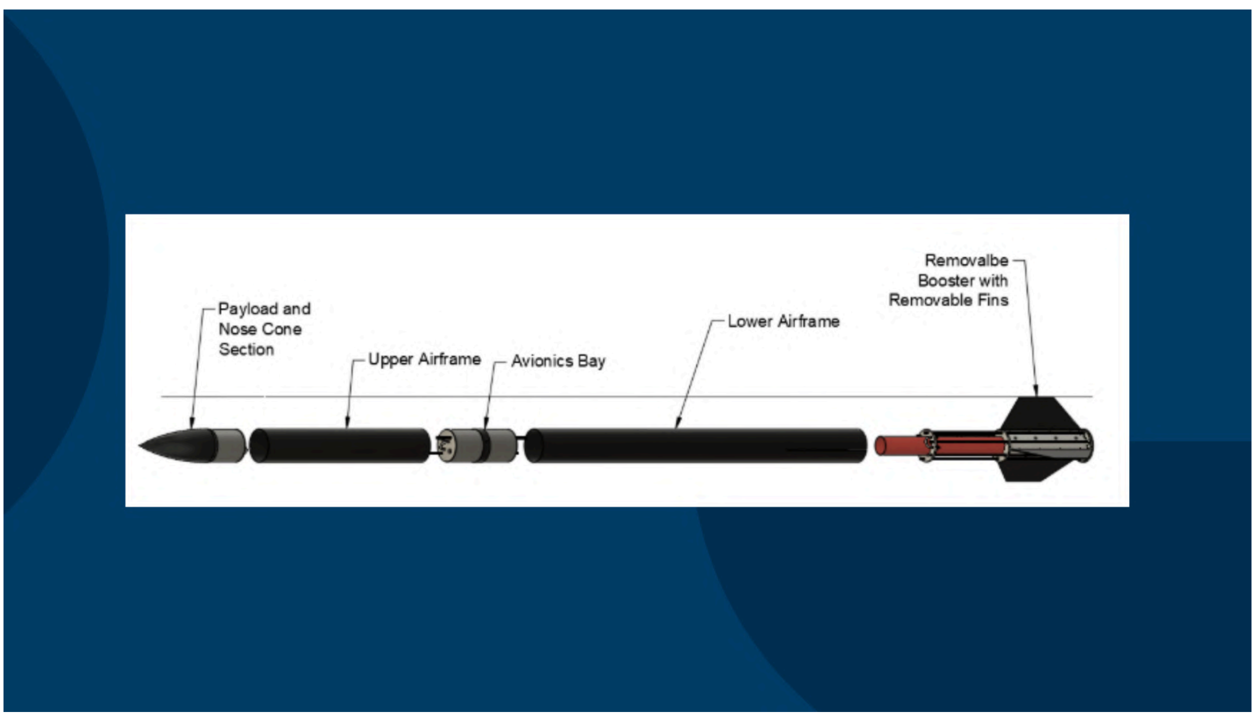
In addition to explaining the functionality of the rocket, our team also demonstrated other facets of engineering to the students. This included mechanical engineering in the form of robotics as well as rapid prototyping via 3D printing. Even more, we also demonstrated the capabilities of 3D modeling with CAD Software (Fusion 360) through a real time recreation of the gymnasium we were presenting in.

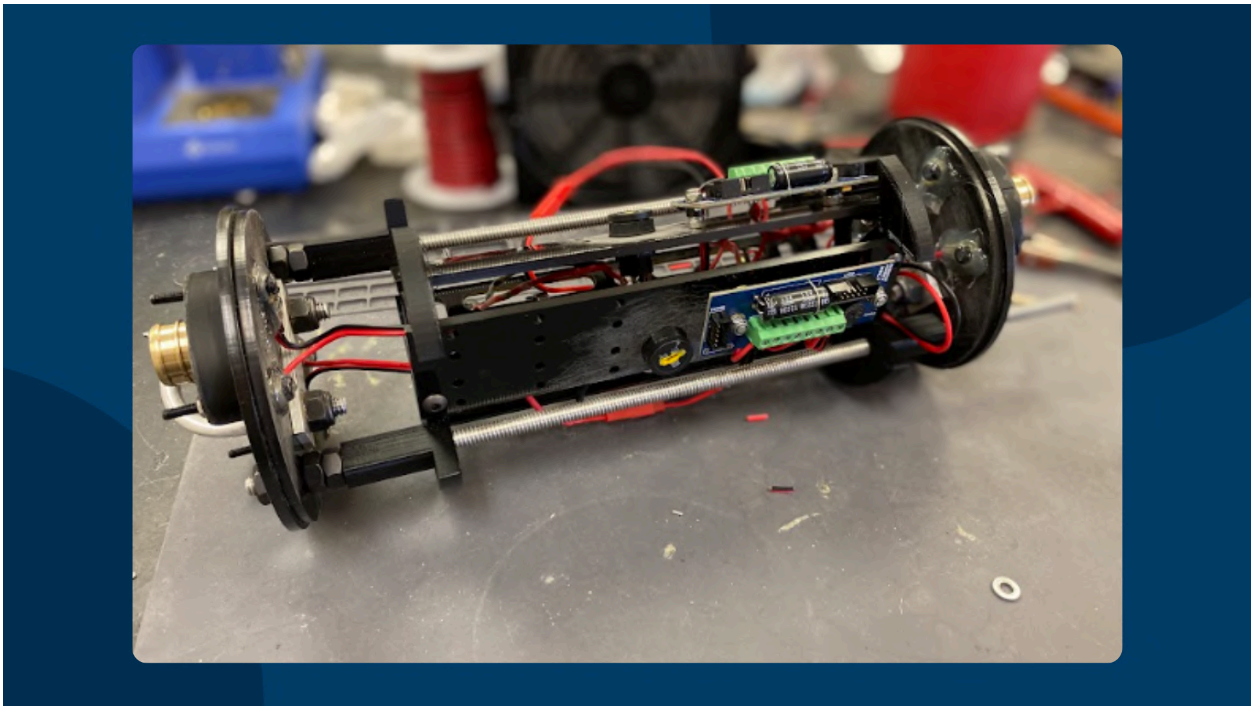
Section 2: Activity Supplementals

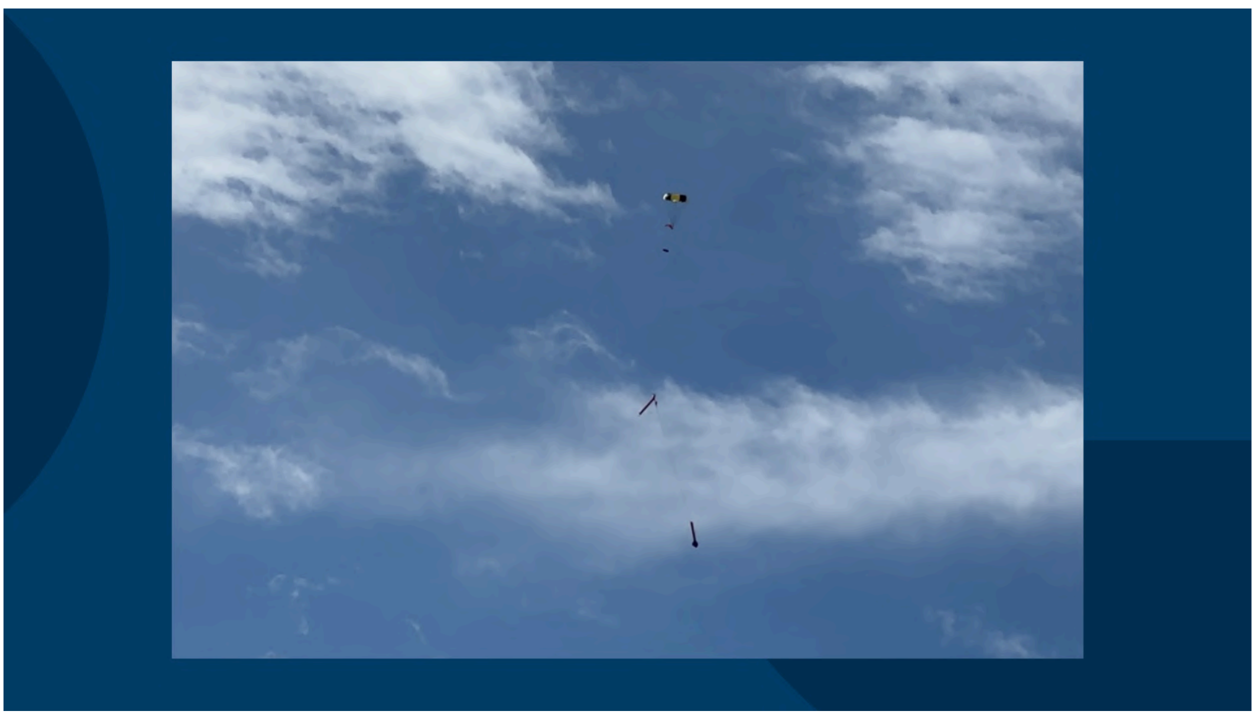
2.1 Image Collage Presentation

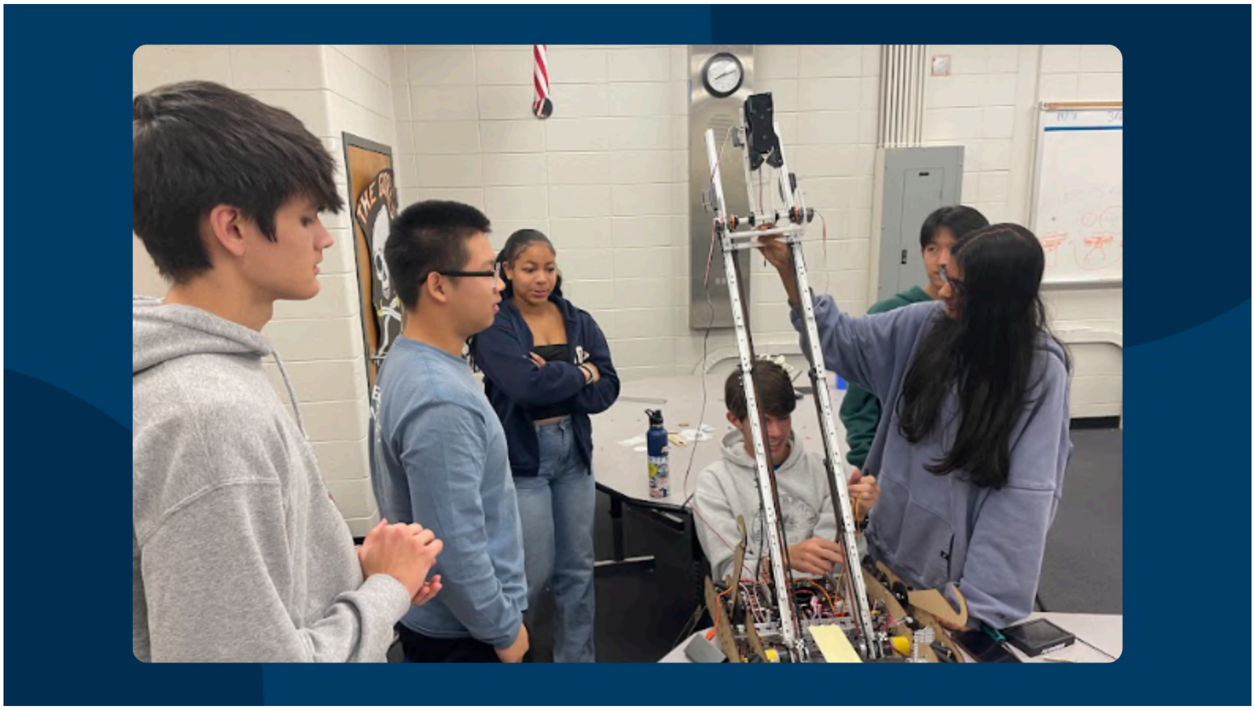
HSES Career Fair
https://docs.google.com/presentation/d/10EmR6-bD7F6NGUP-Ublu1BW7jMMvcuzjmnXQE0qn9gc/edit?usp=sharing

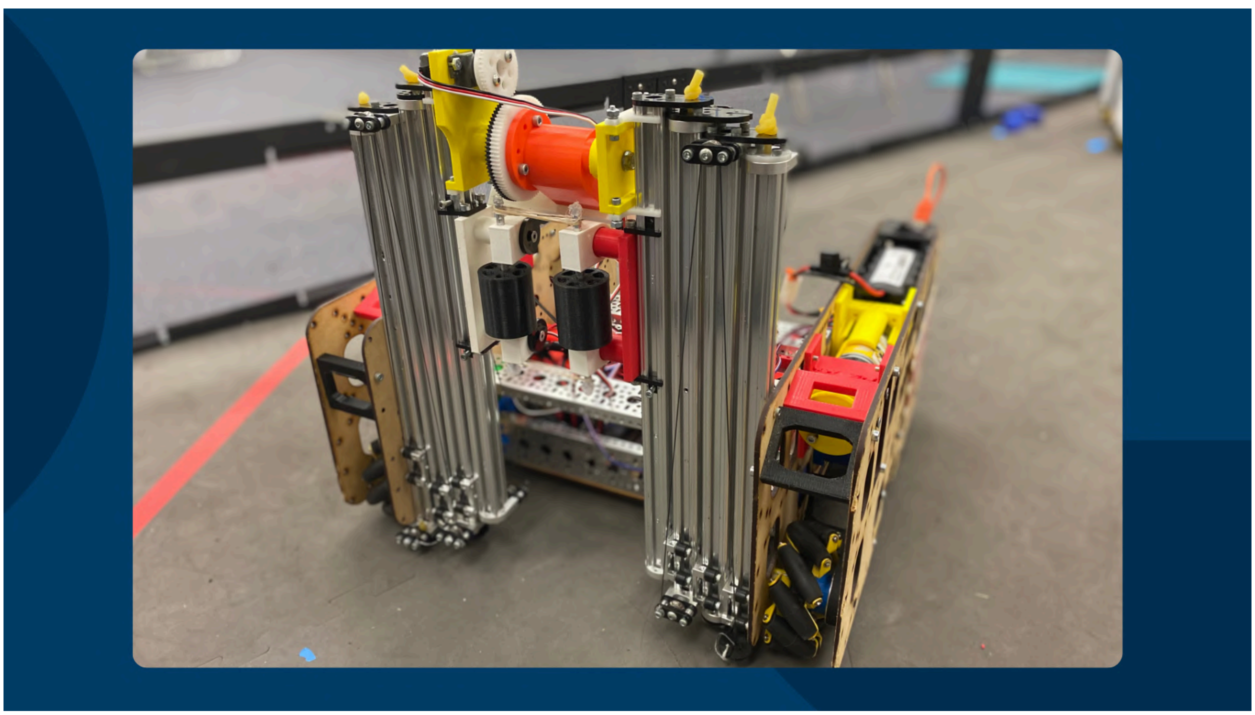

SECTION A-A
SCALE 1:2

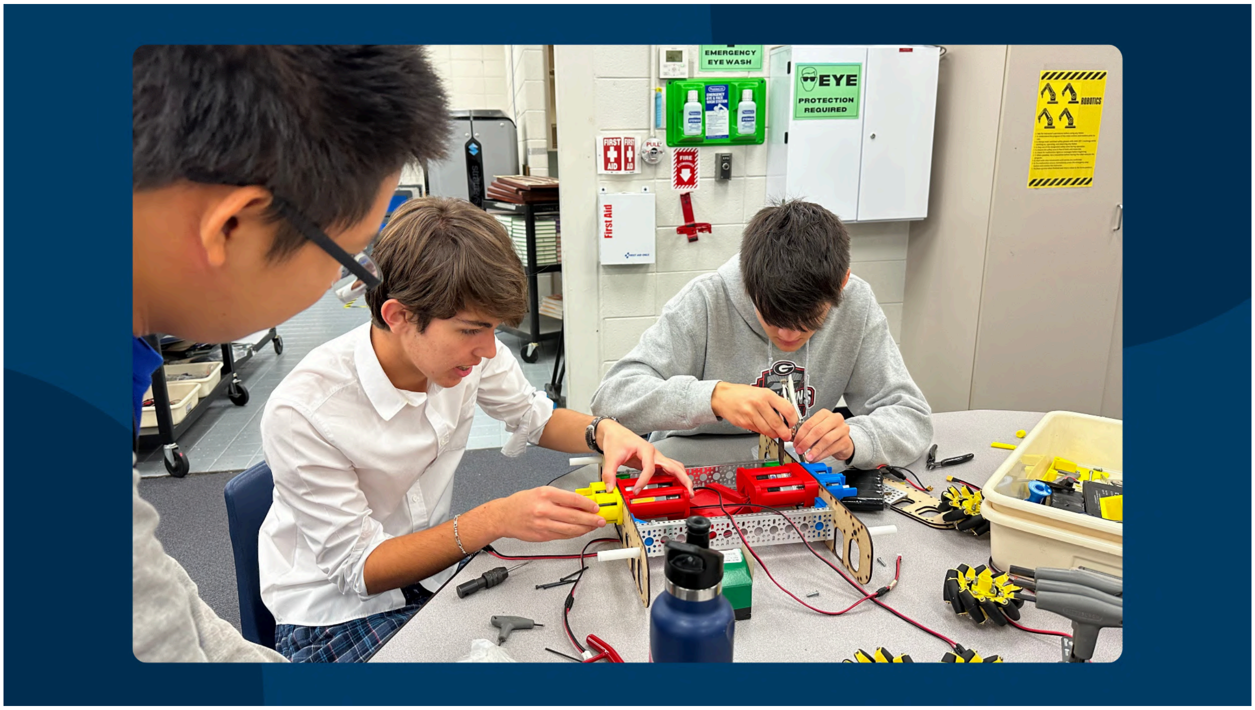

Payload and Nose Cone Section
Upper Airframe
Avionics Bay
Lower Airframe
Removalbe Booster with Removable Fins



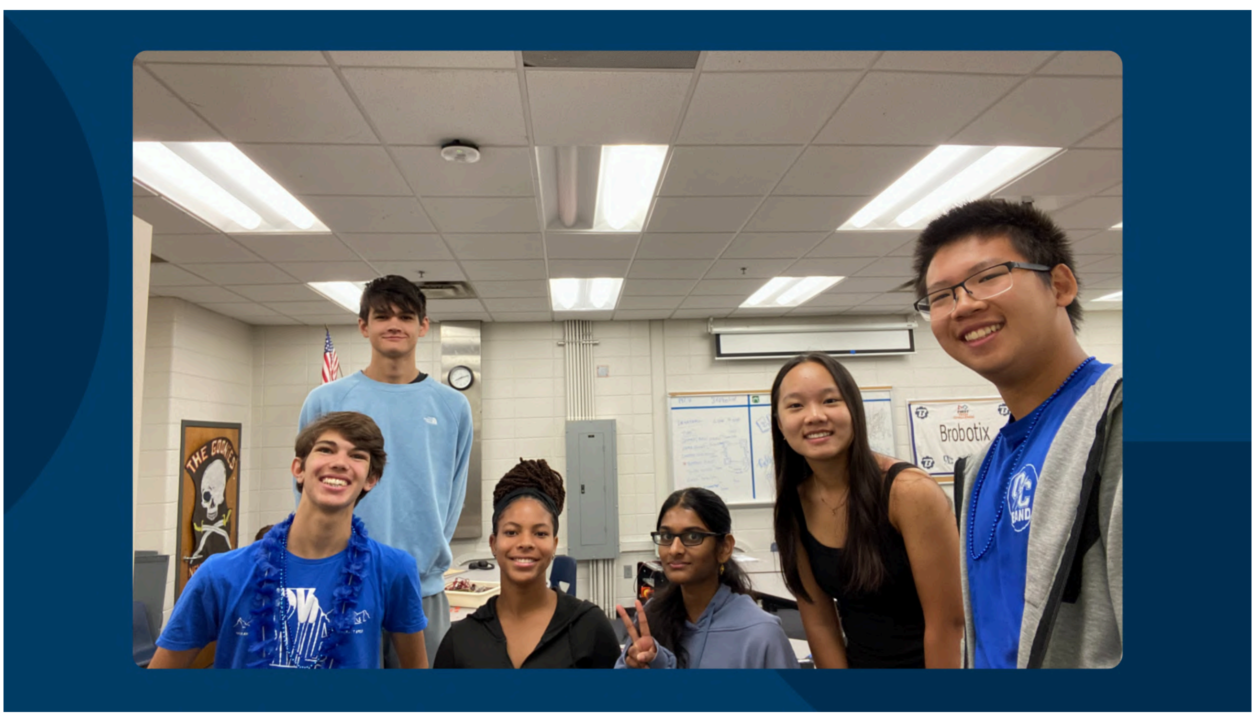


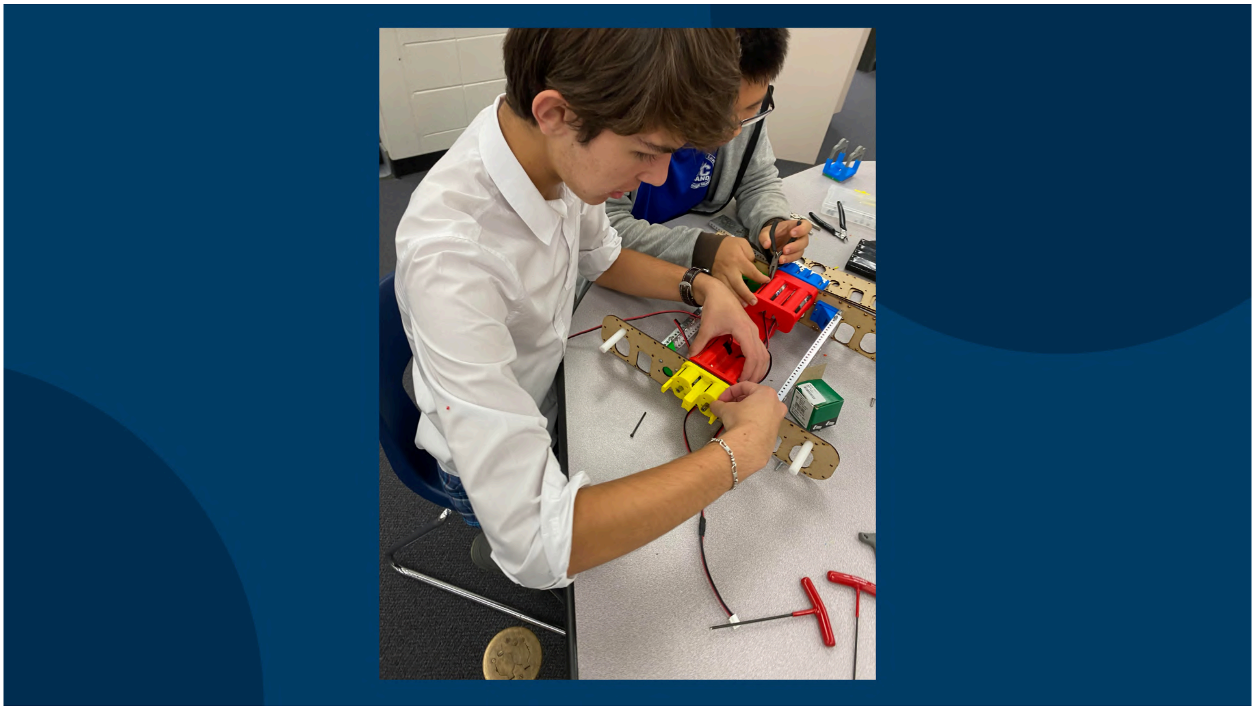





EMERGENCY EYE WASH
EYE PROTECTION REQUIRED
FIRST AID
First Aid

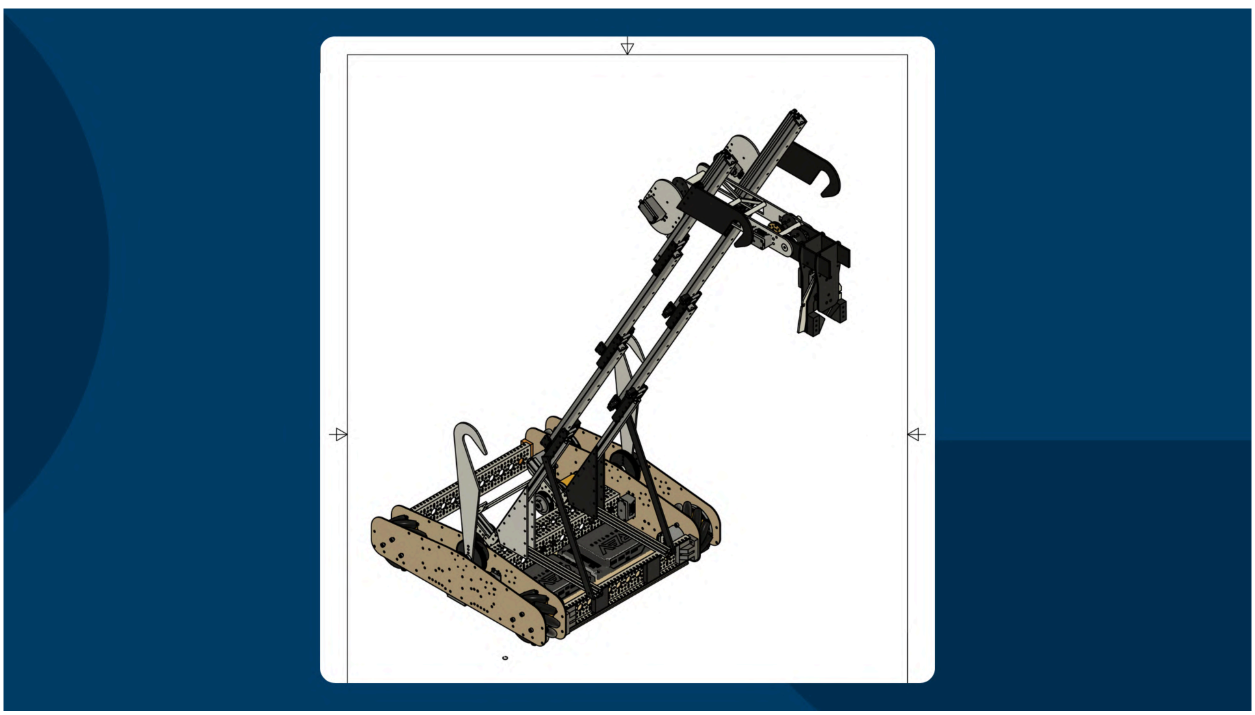

PV
nR
EST. 1861


Brobotix



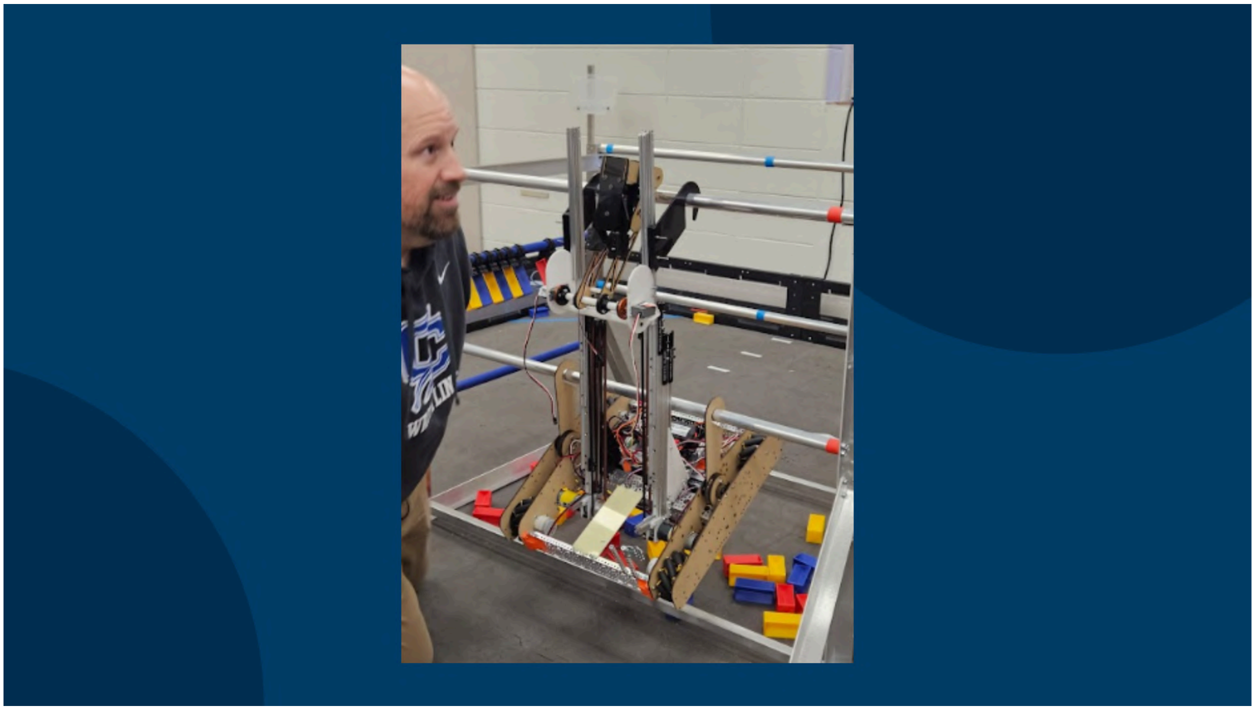

THE GOONIES
NEVER SAY DIE

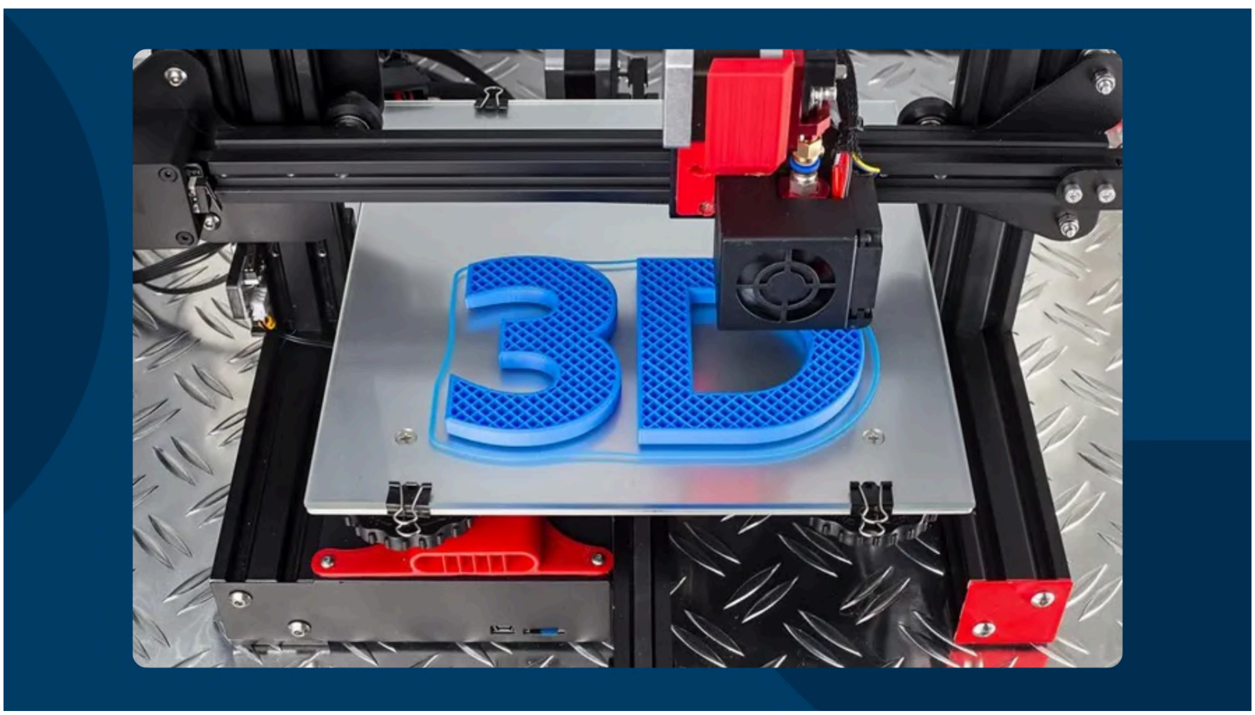

14682

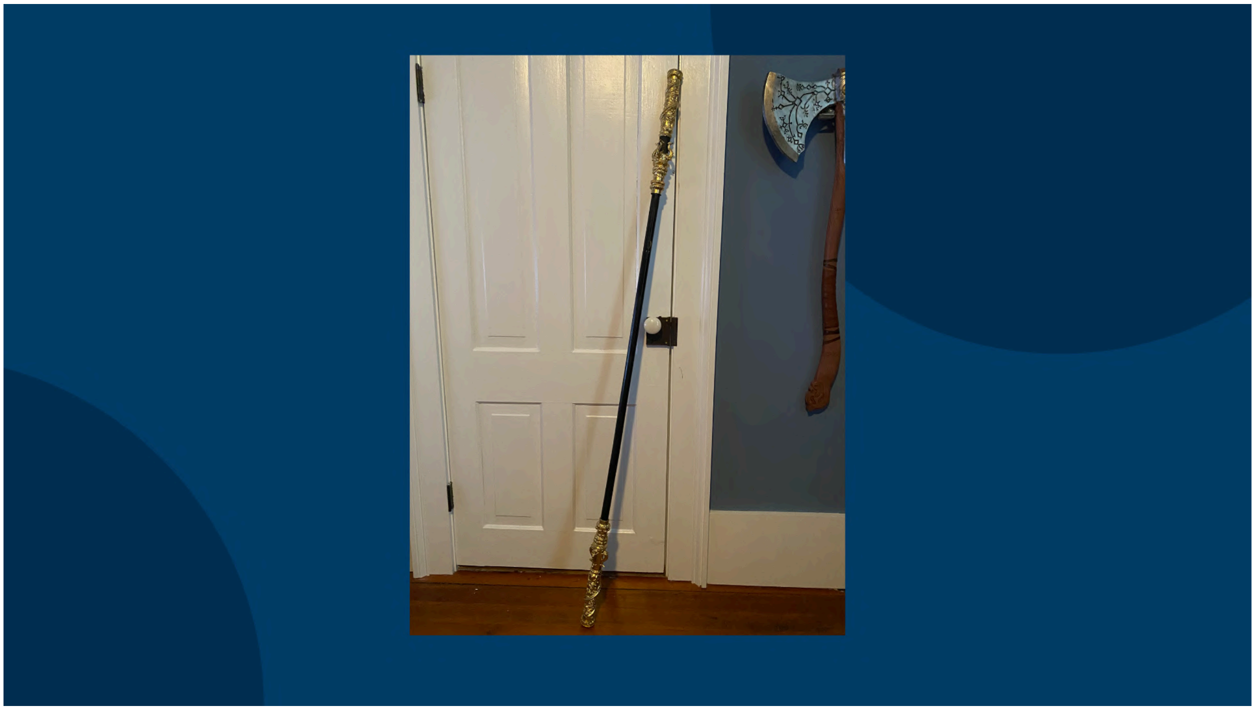



14682


AMALFI




3D



2.2 Rocket Launch Video

Launch.mov
https://drive.google.com/file/d/1a9yFD0kCQwbafbebEchrVekfWY0Ek12b/view?usp=sharing

Section 3: Documentation

3.1 Images from Event

2024-2025
NASA Student Launch Initiative

Oconee County
High School

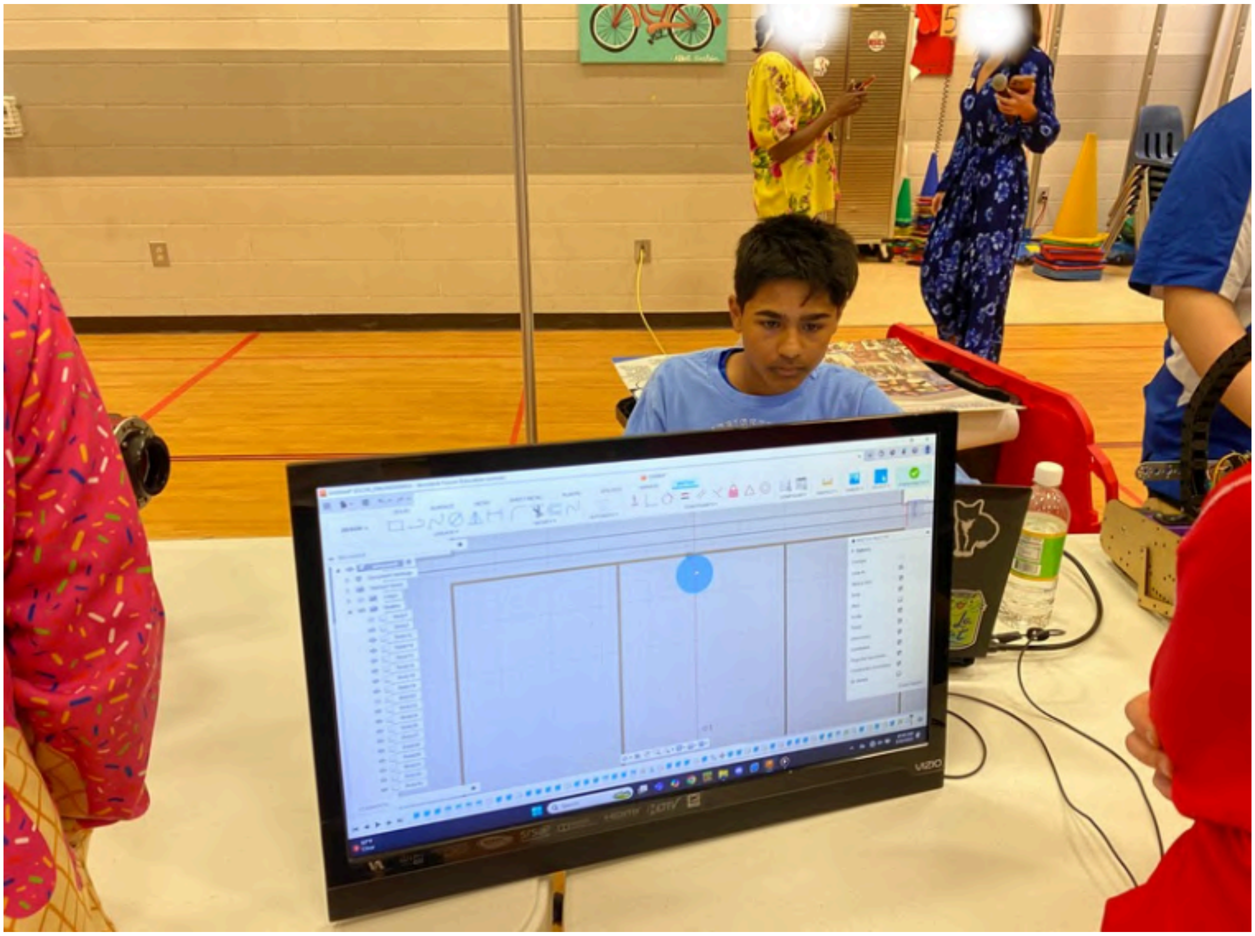

4
SILVERBACK
3
Bicycle
2


TEAM 24-1425
WATKINSVILLE, GEORG

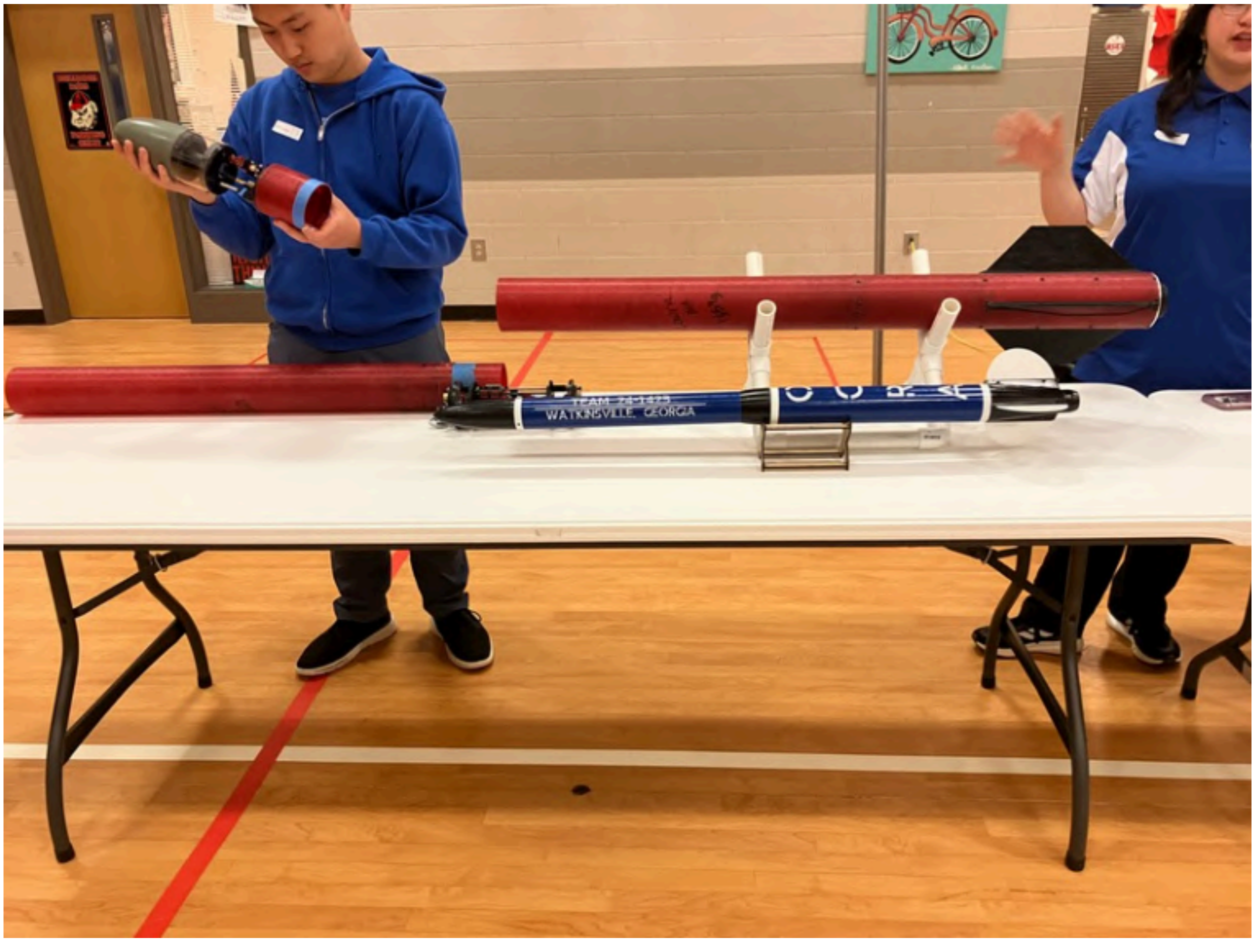

5
4
3


5
3


5
4
3
NFL
CANTON, OH
NFL LICENSED APPAREL
ESTABLISHED 1920
OTTERS




2
5
3
4
EXIT


WATKINSVILLE, GEORGIA


EXIT
Bicycle
5
4
3
2


WARRIOR
ENGINEERING
TEAM 14682 GEARS
& SPEARS
FTC 2021-2022 Freight Frenzy
CHALLENGE
ABOUT US
BESSIE
THE ROBOT
14682


TEAM SNAKE GEARS
& SPEARS
BESSIE

Acknowledgments

Team Members - Oconee County Rocketry Association (OCRA)

- Campbell Patterson - Student Leader
- Saahil Doshi - Outreach Coordinator, Payload Lead
- Zoe Steckel - Safety Officer, Propulsion Team
- Sihoo Kim - Recovery System
- Cashton Isaac - Recovery System & Avionics Bay
- Emily Peng - Recovery System & Avionics Bay

Advisors & Mentors

- Bradley Sayers - Faculty Advisor, Oconee County High School
- Armando Rodriguez - NAR Level 3 Mentor
- Sam Rodriguez - Advisor

Facilities & Technical Support

- Oconee County High School Engineering Department - Use of Design Lab, Robotics Lab, and 3D Printing Facilities
- Tripoli Rocketry Association - Launch Field Access and Oversight

Sponsorship & Financial Support

- Oconee County Schools
- Fundraising and Outreach Events

Special Thanks

- NASA Student Launch Initiative
- National Association of Rocketry (NAR)
- All educators, volunteers, and supporters who contributed to the success of Project RANCH.

Warrior One

Technical Drawings

OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI			
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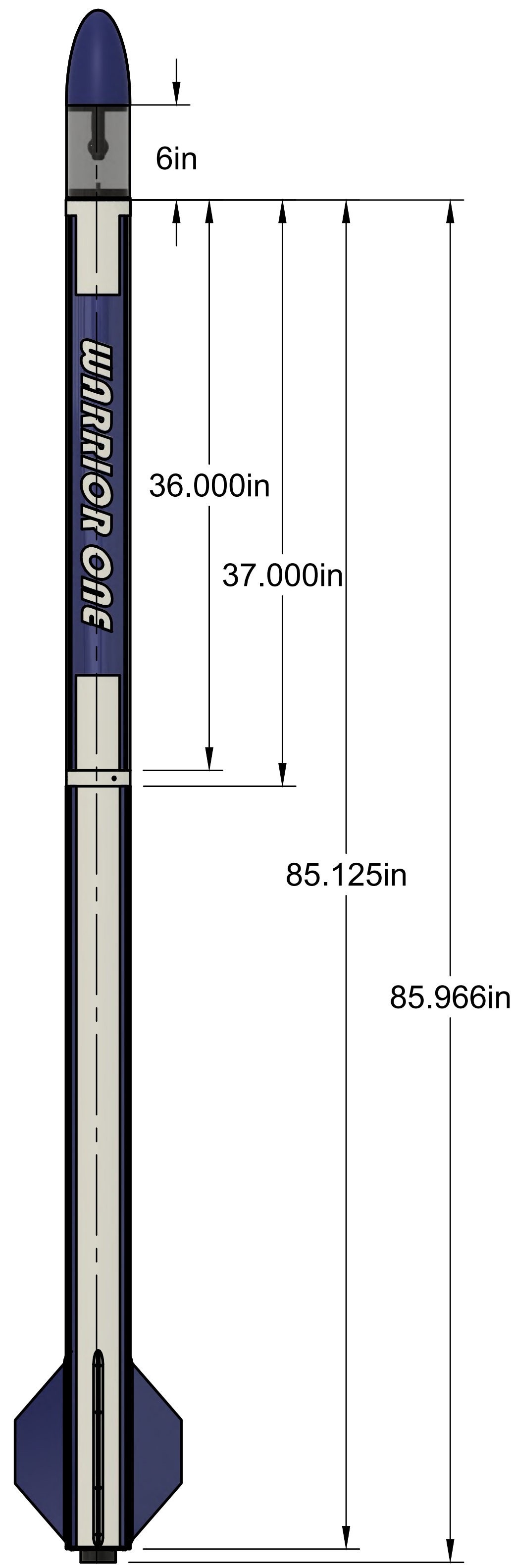
		SHEET 1/83		

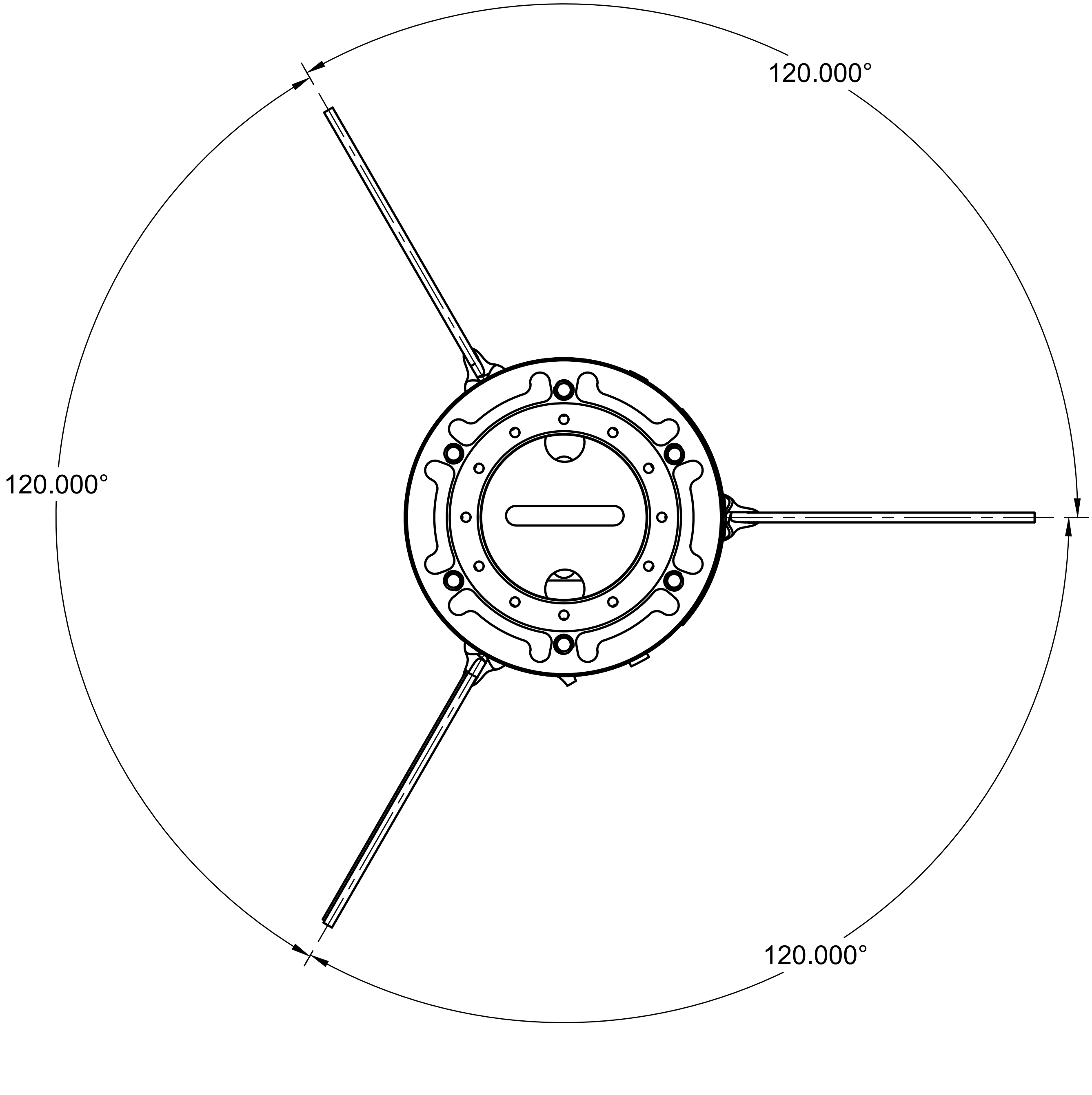


OCeng._1.PNG

PROJECT
Oconee County High School 2025 NASA SLI

TITLE
Rocket Front View

SCALE	1:12	SIZE	A
SHEET	2/83		



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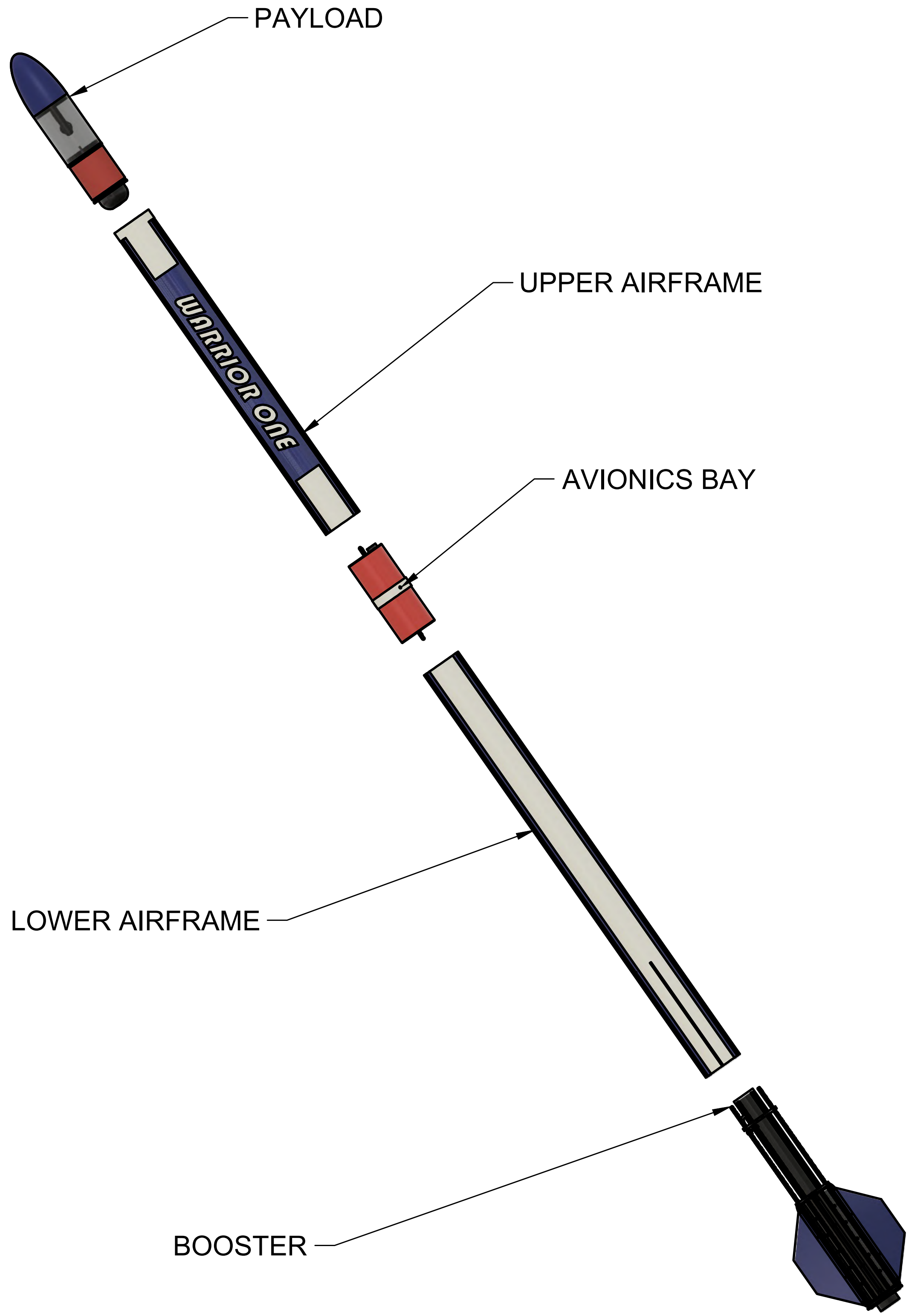

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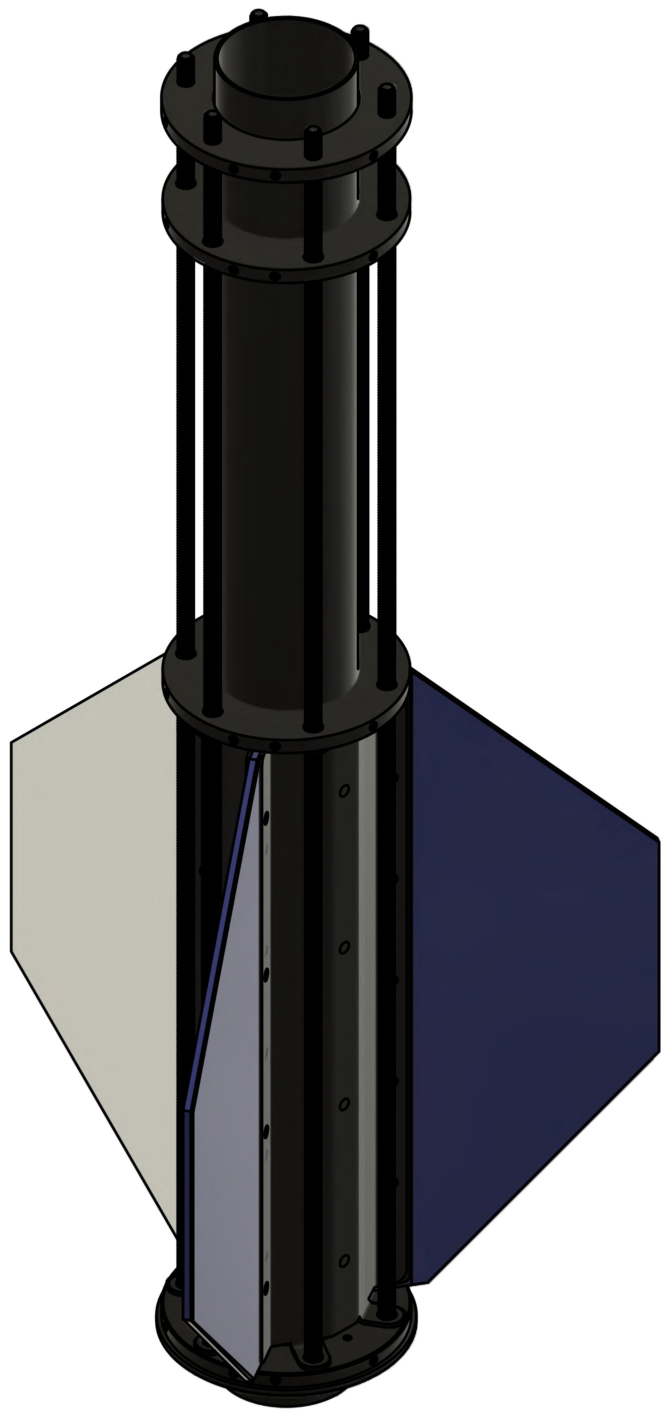
		SHEET 4/83	



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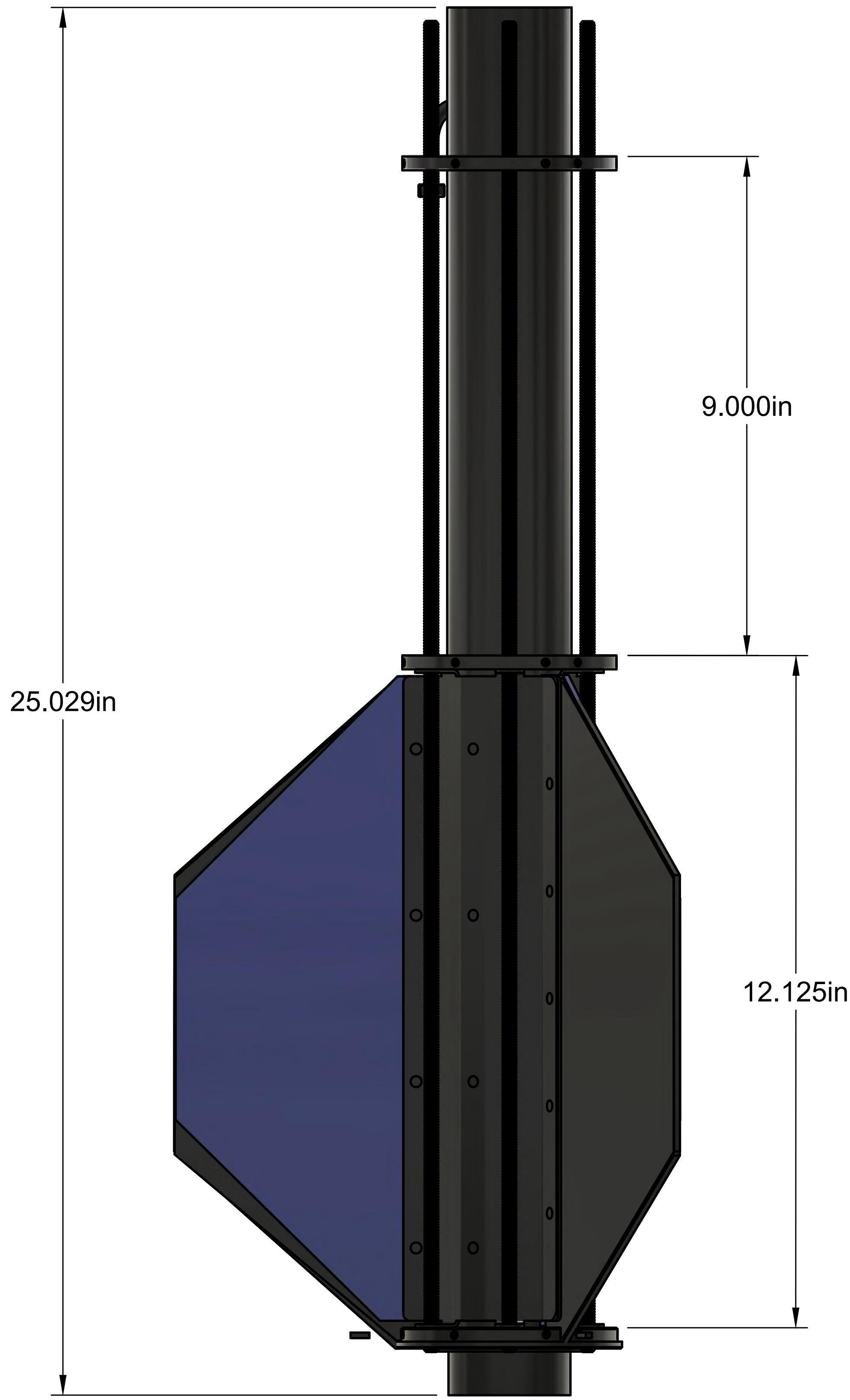
		SHEET 5/83	



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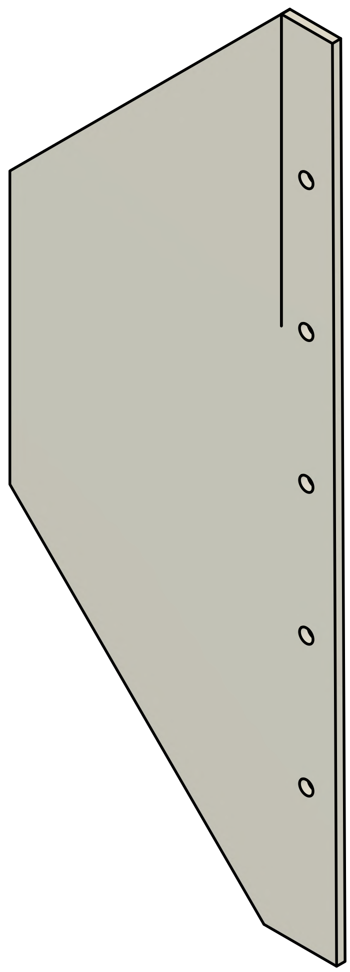
		SHEET 6/83		



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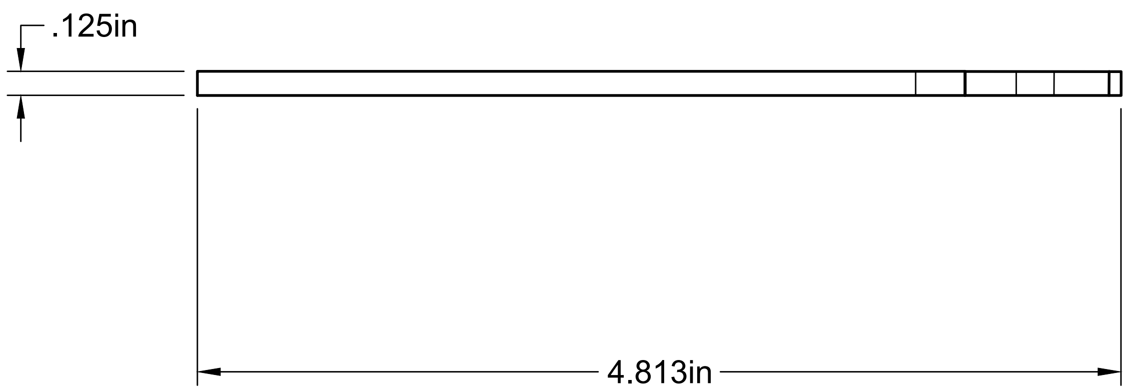

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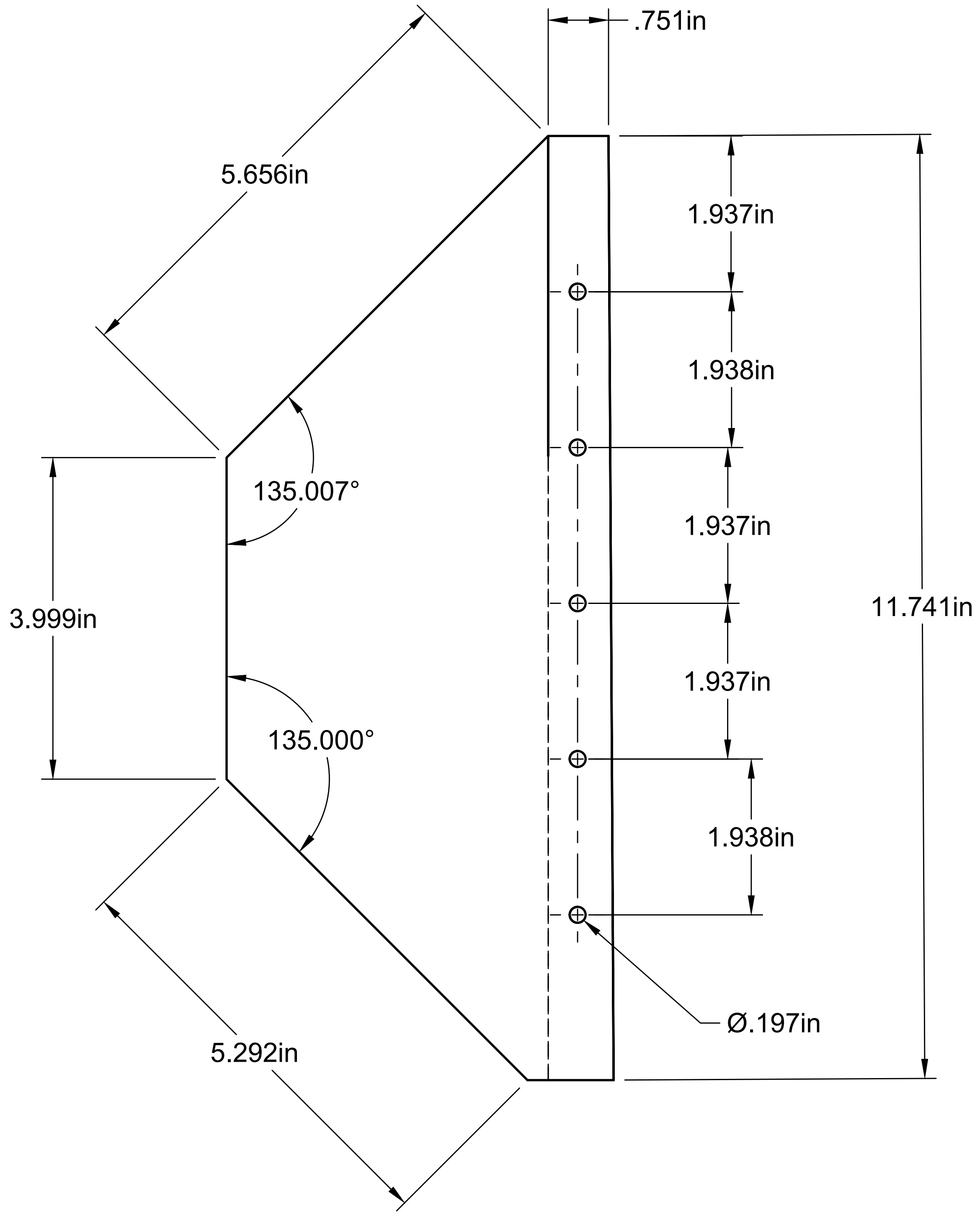
		SHEET	8/83	



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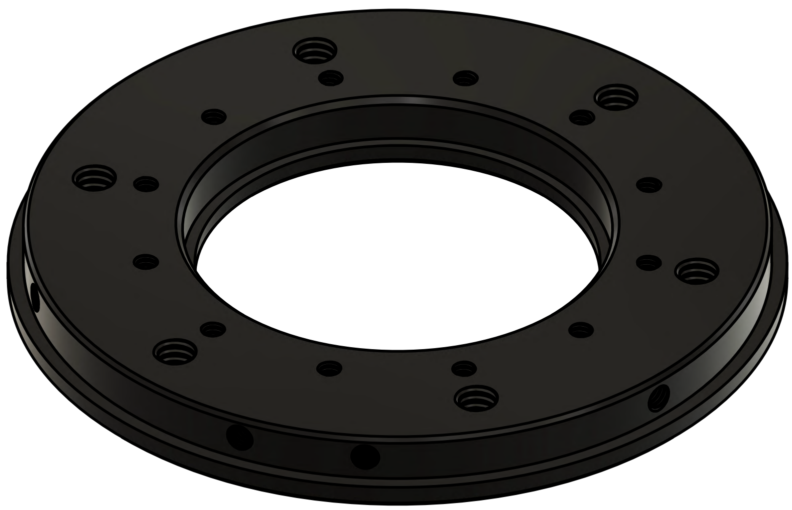
		SHEET 9/83		



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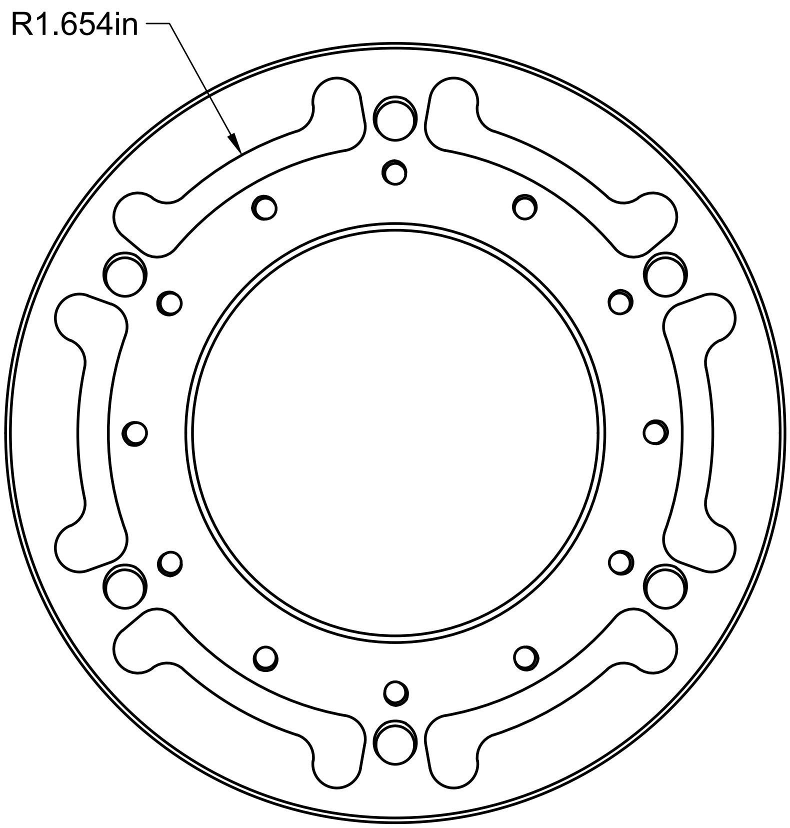

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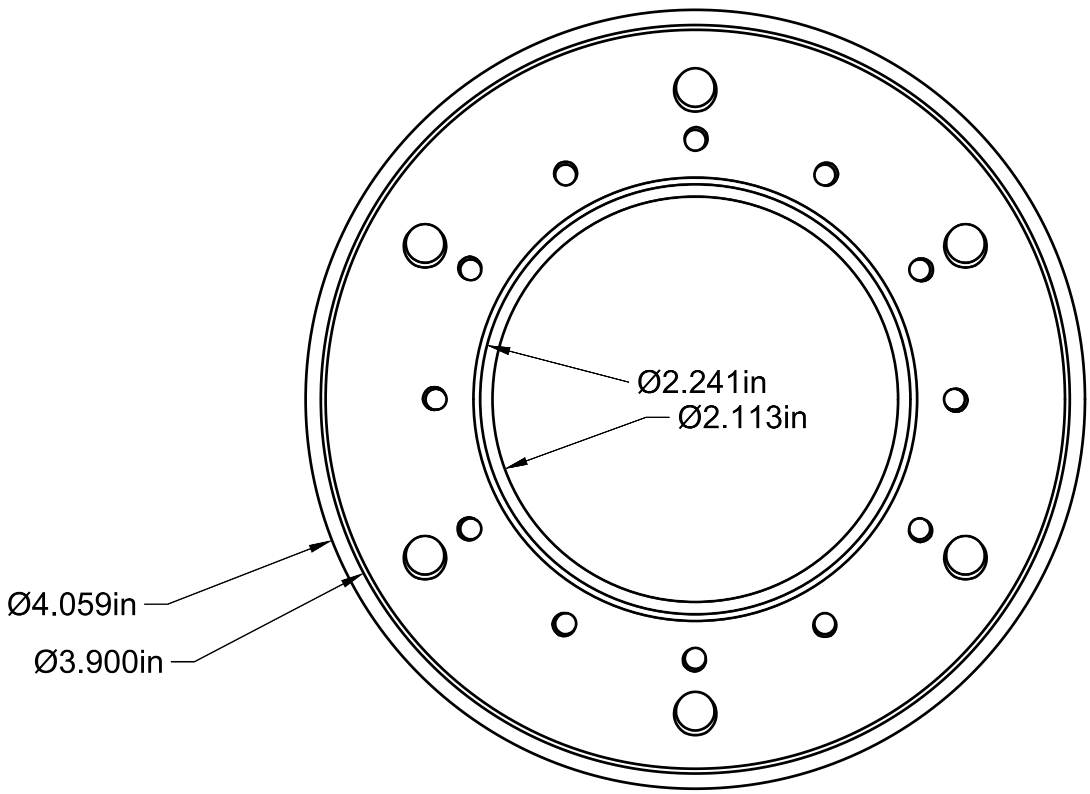
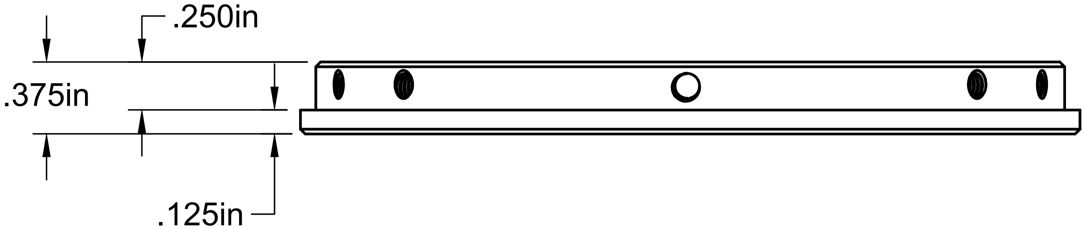


OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Thurst Plate Top	SCALE 1:1 SHEET 12/83	SIZE A



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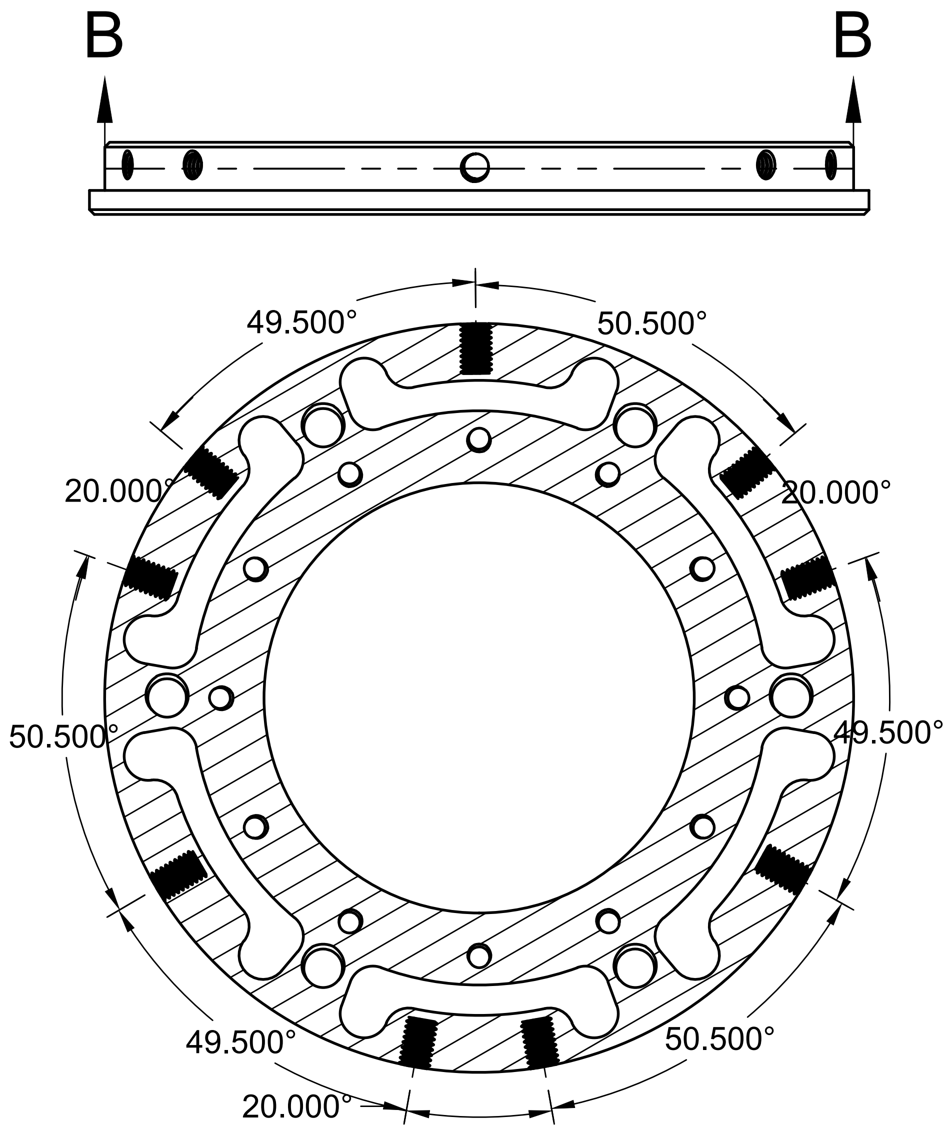
		SHEET	13/83	



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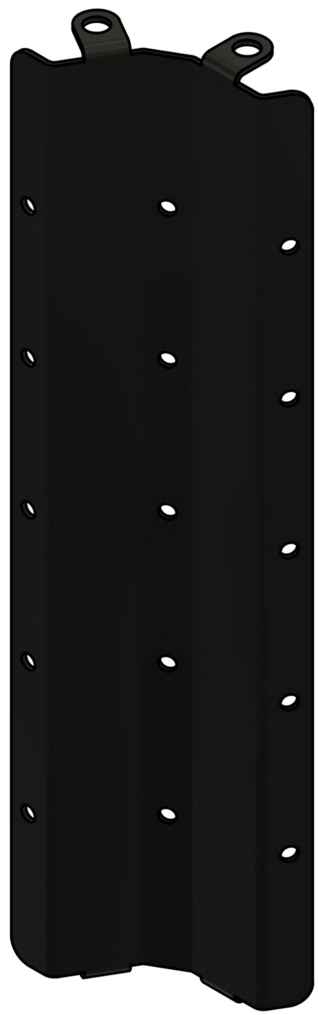

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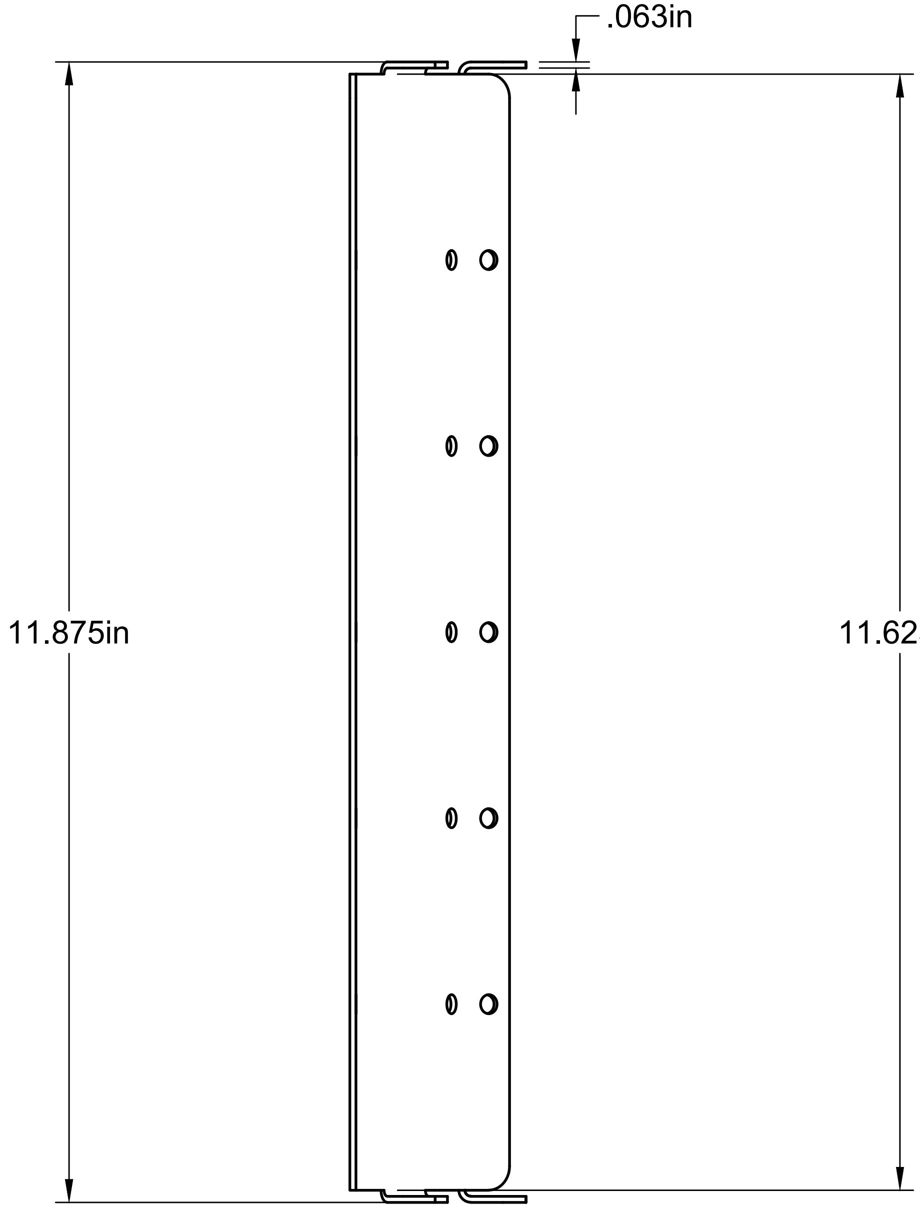

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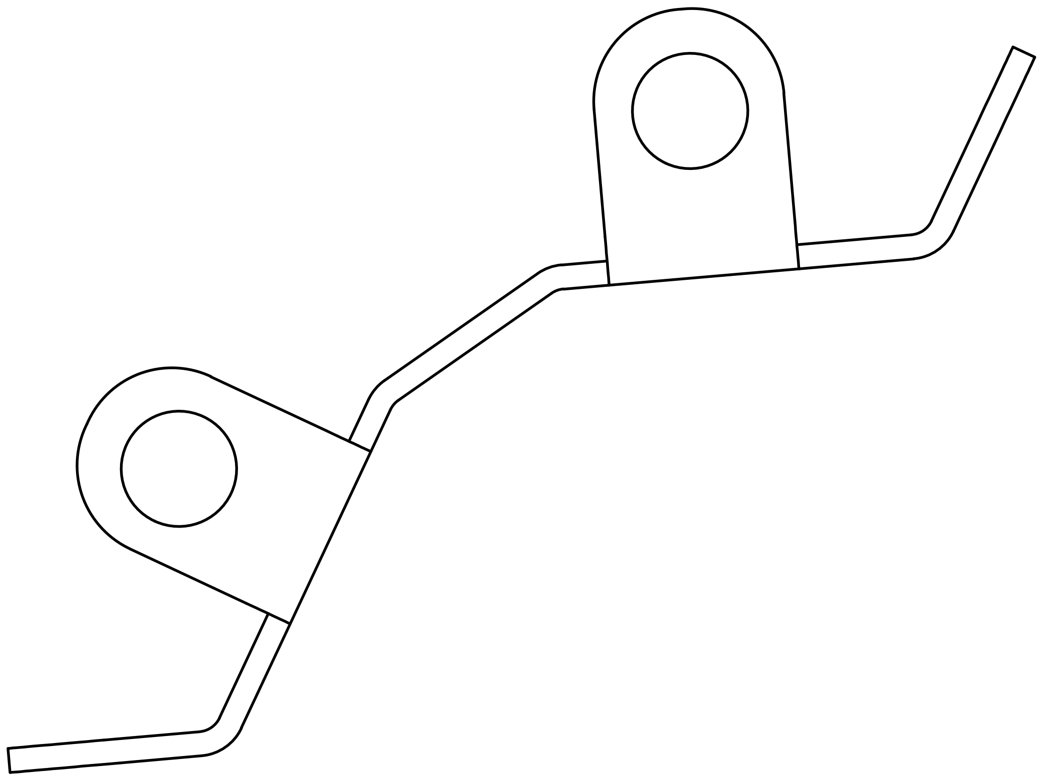

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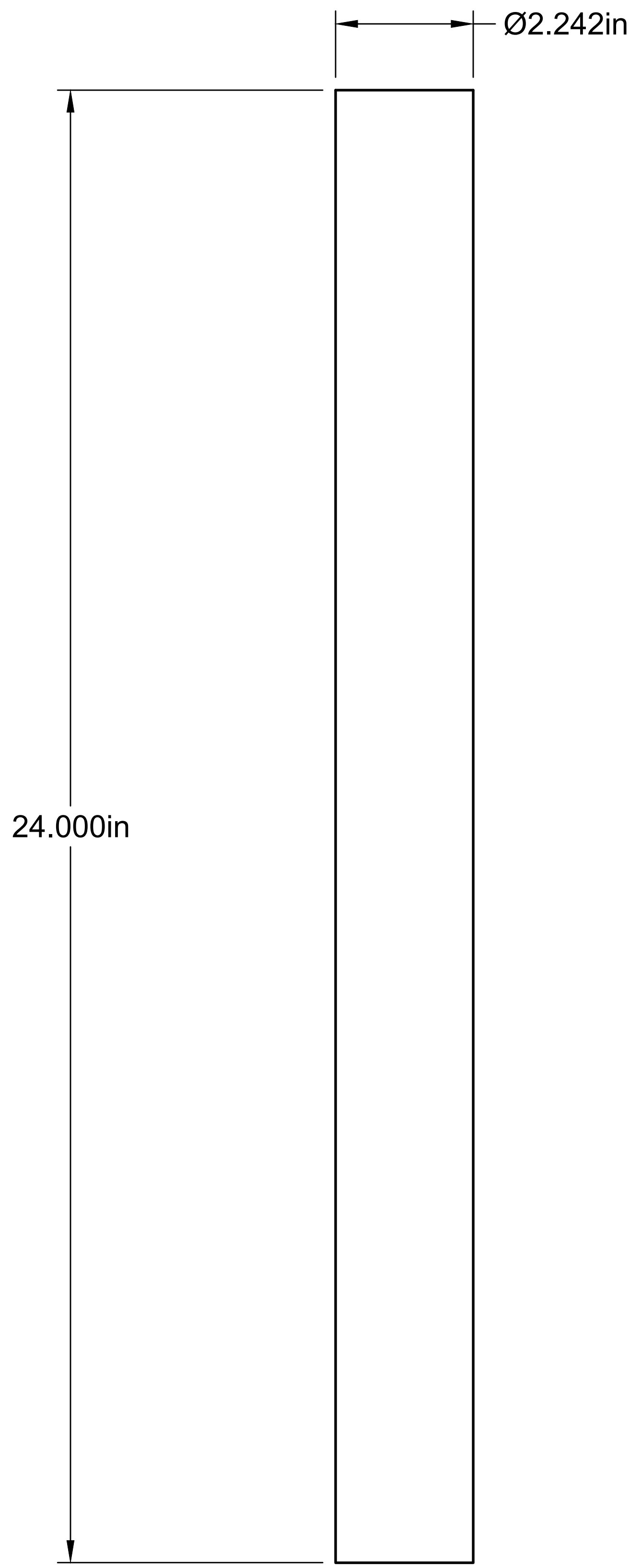
		SHEET 18/83		



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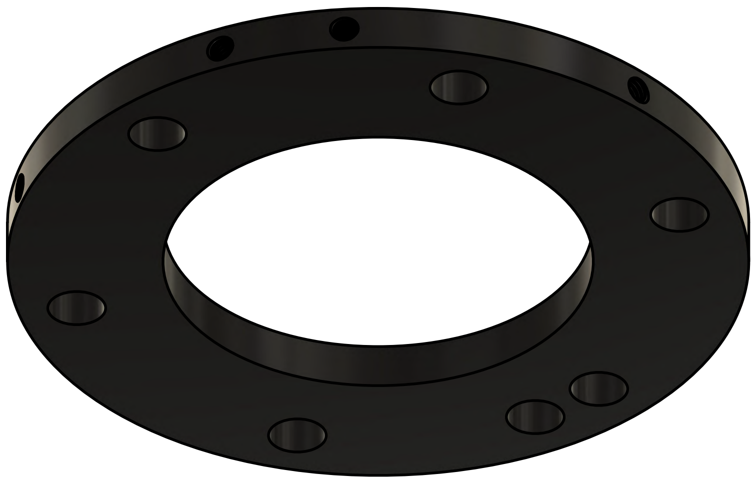

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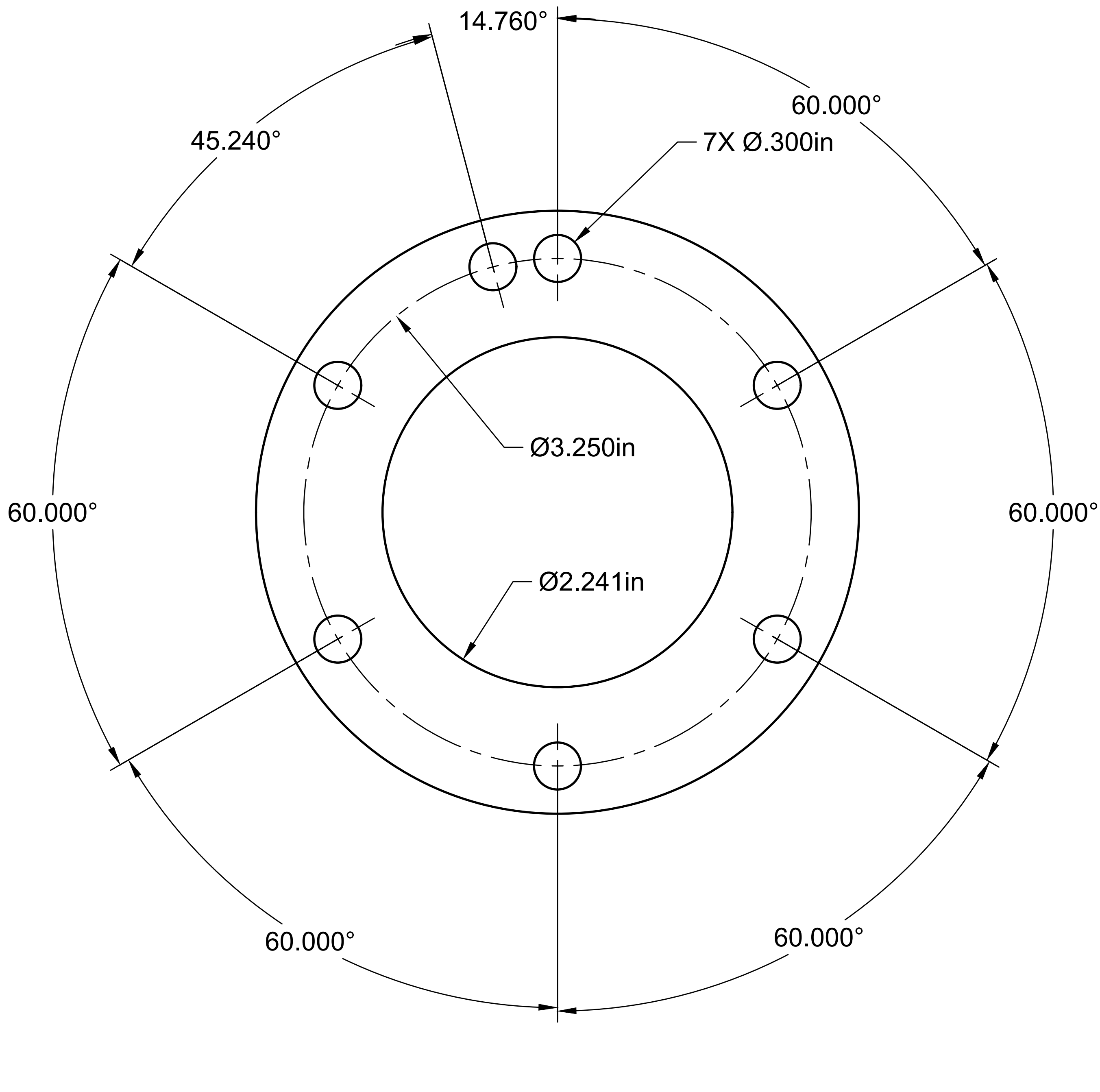
		SHEET 20/83		



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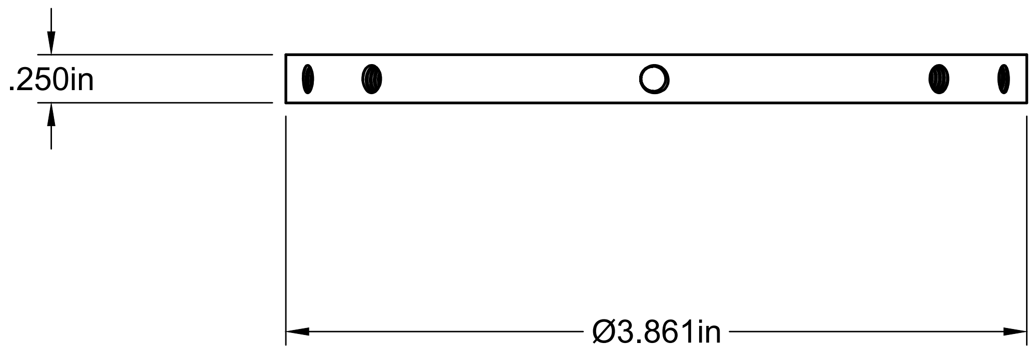

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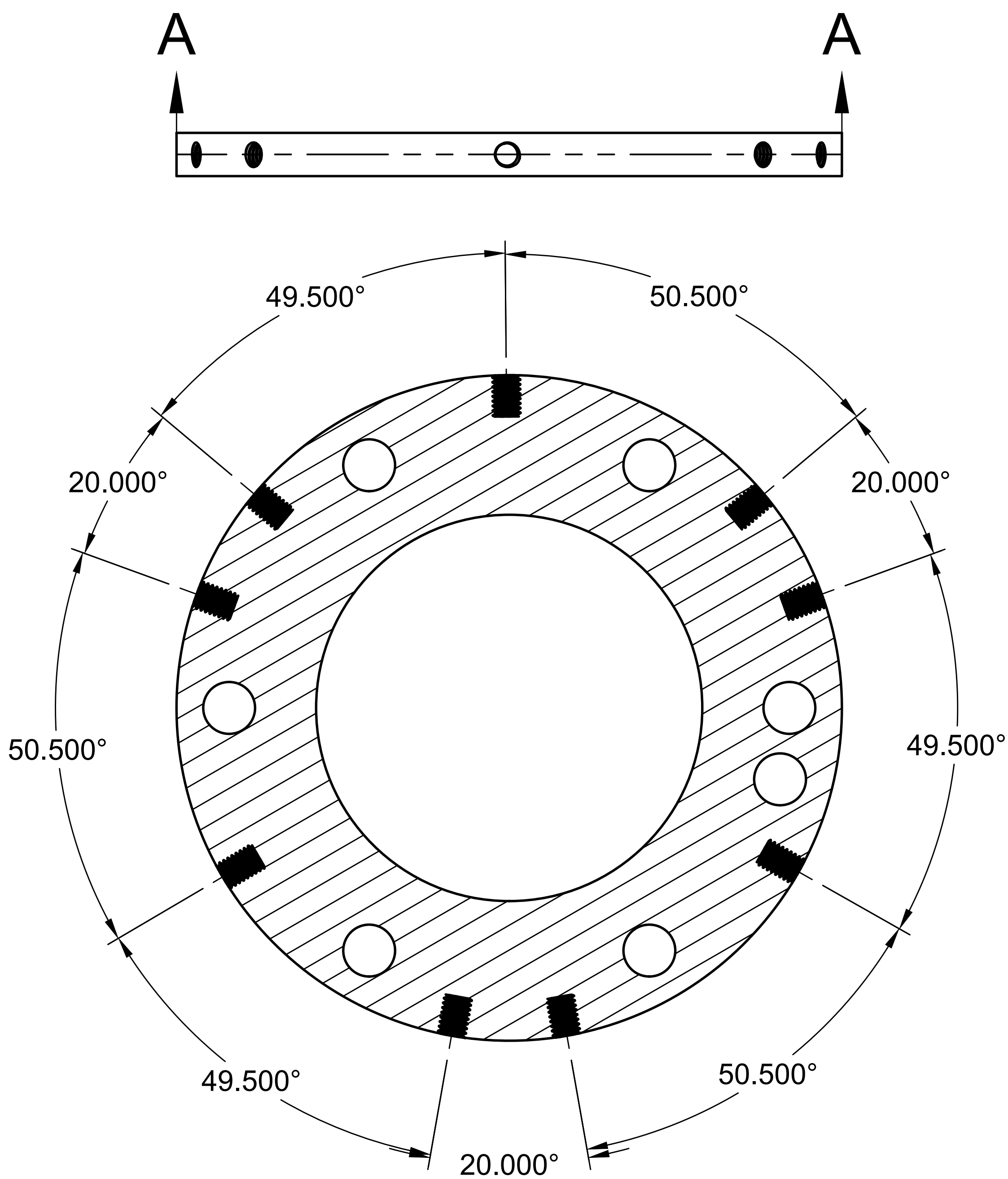
		SHEET 22/83		



SECTION A-A
SCALE 1:1

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		SHEET 23/83	

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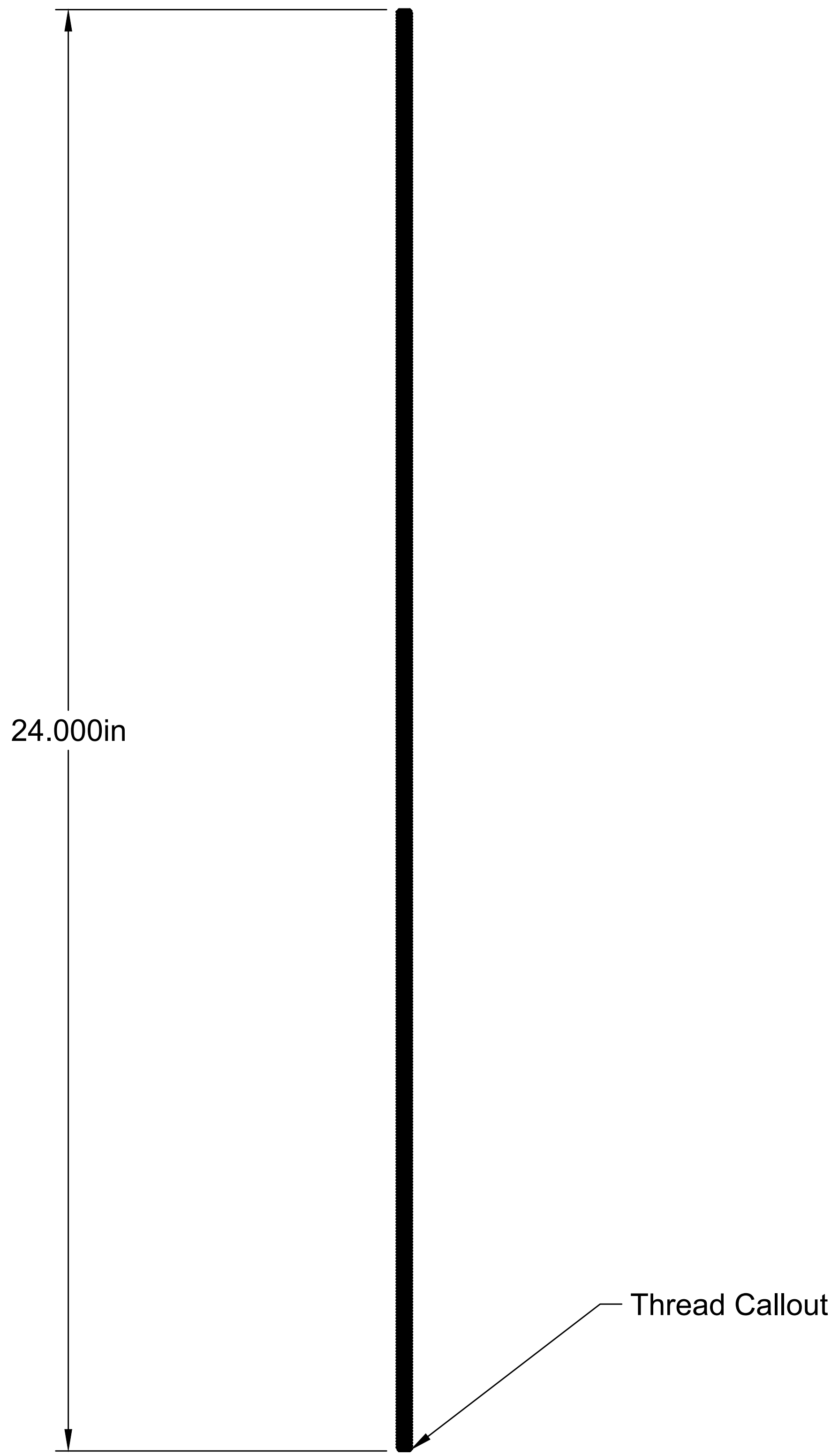
		SHEET	24/83	



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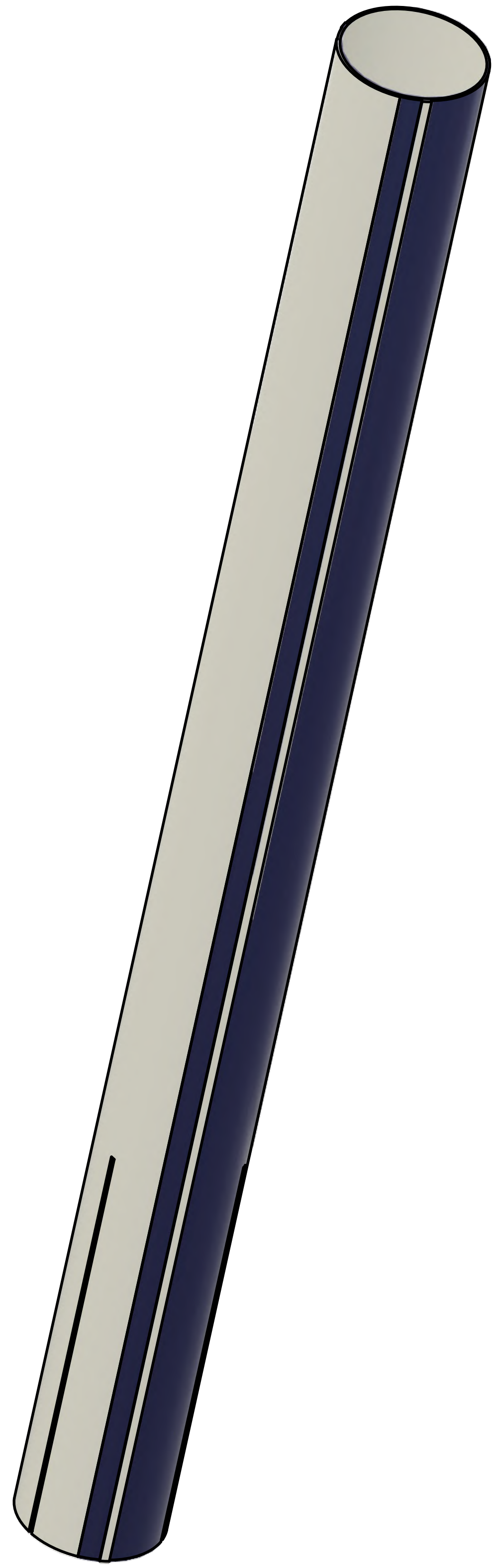


OCeng._1.PNG

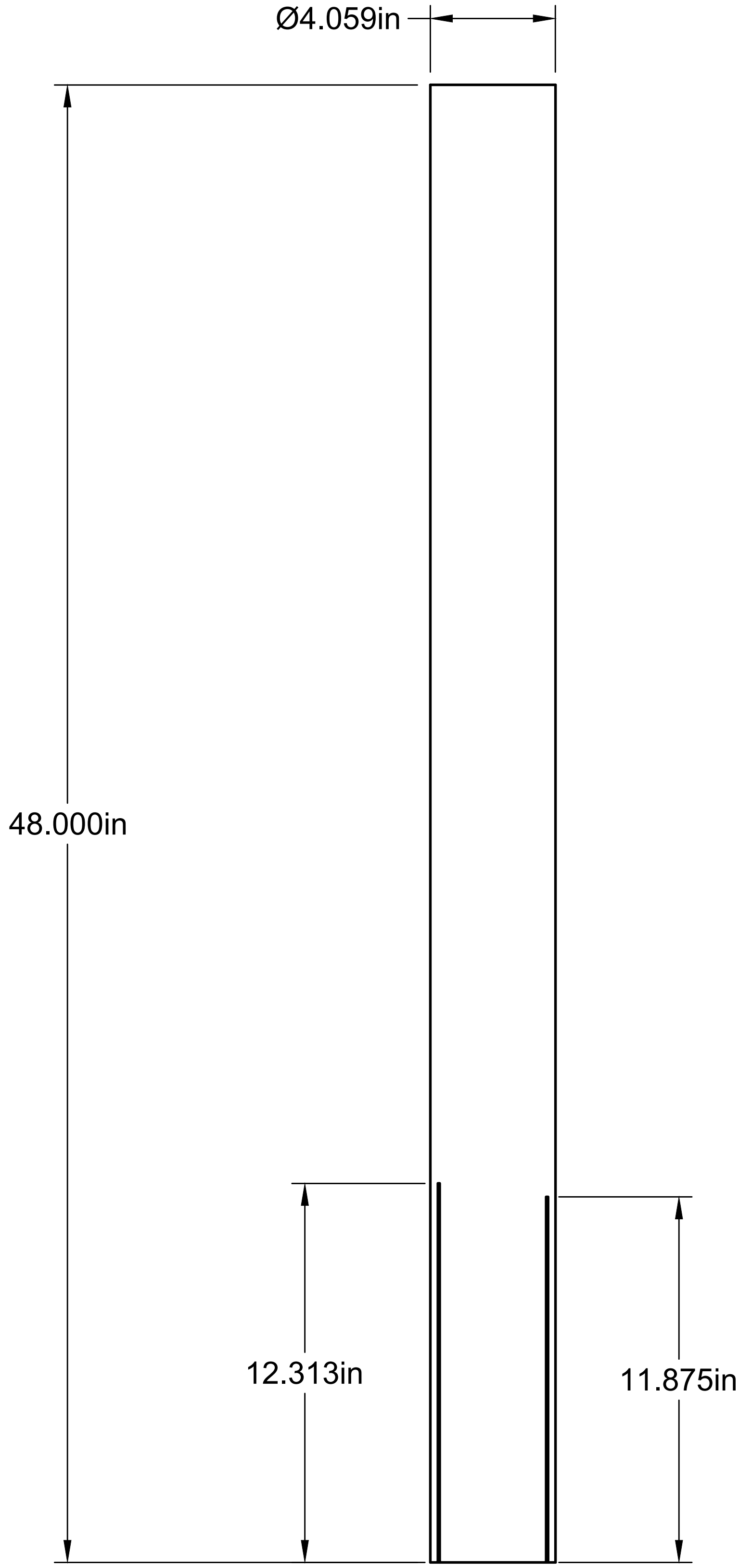
PROJECT

Oconee County High School 2025 NASA SLI

TITLE

Lower Airframe

SCALE	1:5	SIZE	A
SHEET	26/83		



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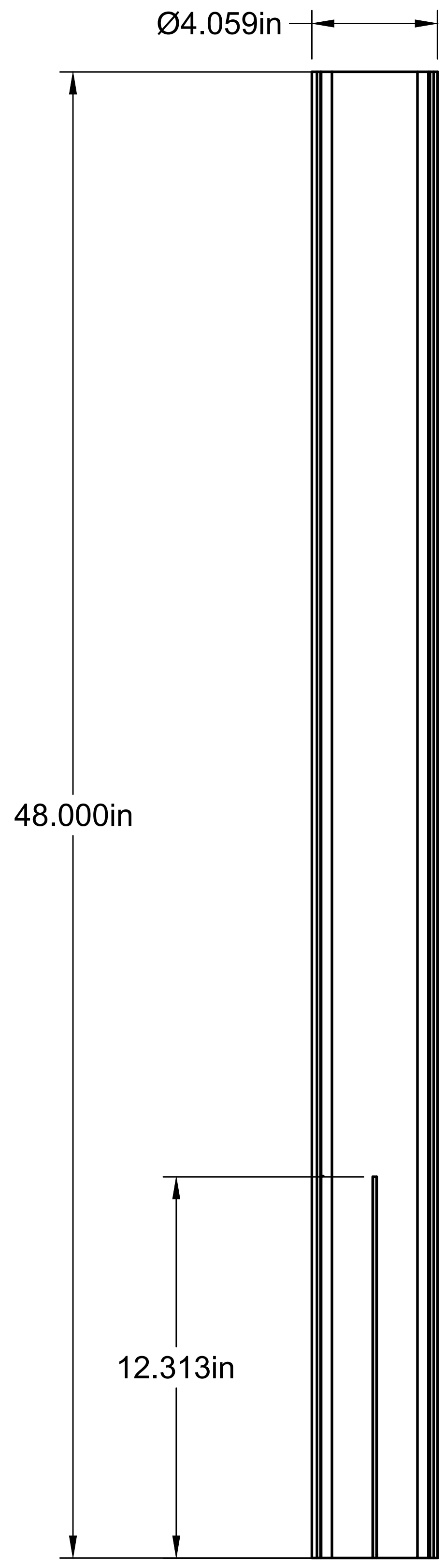
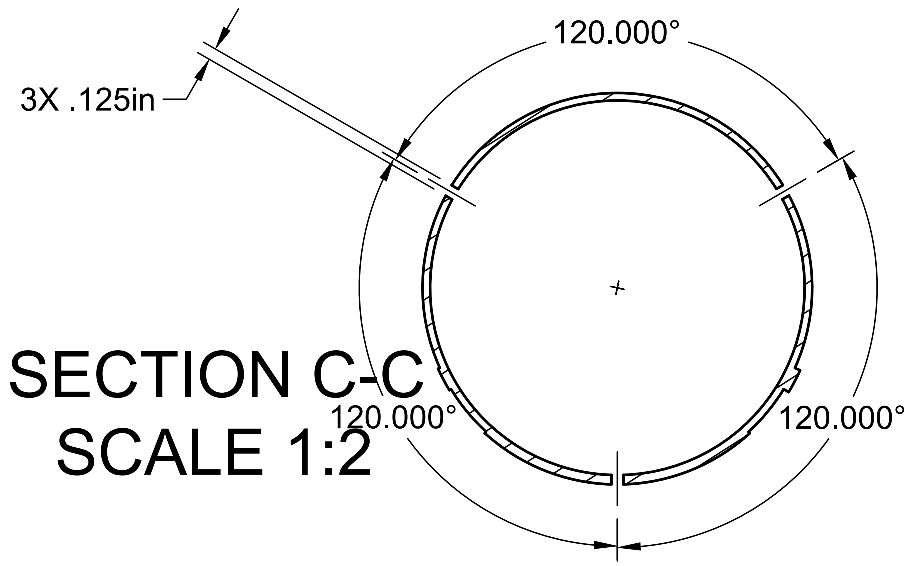


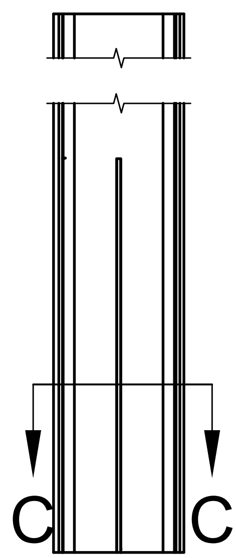
PROJECT
Oconee County High School 2025 NASA SLI

OCeng._1.PNG

TITLE
Lower Airframe Left

SCALE	1:30	SIZE
SHEET	28/83	A





OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI			
	TITLE Lower Airframe Left	SCALE 1:6		SIZE A
		SHEET 29/83		

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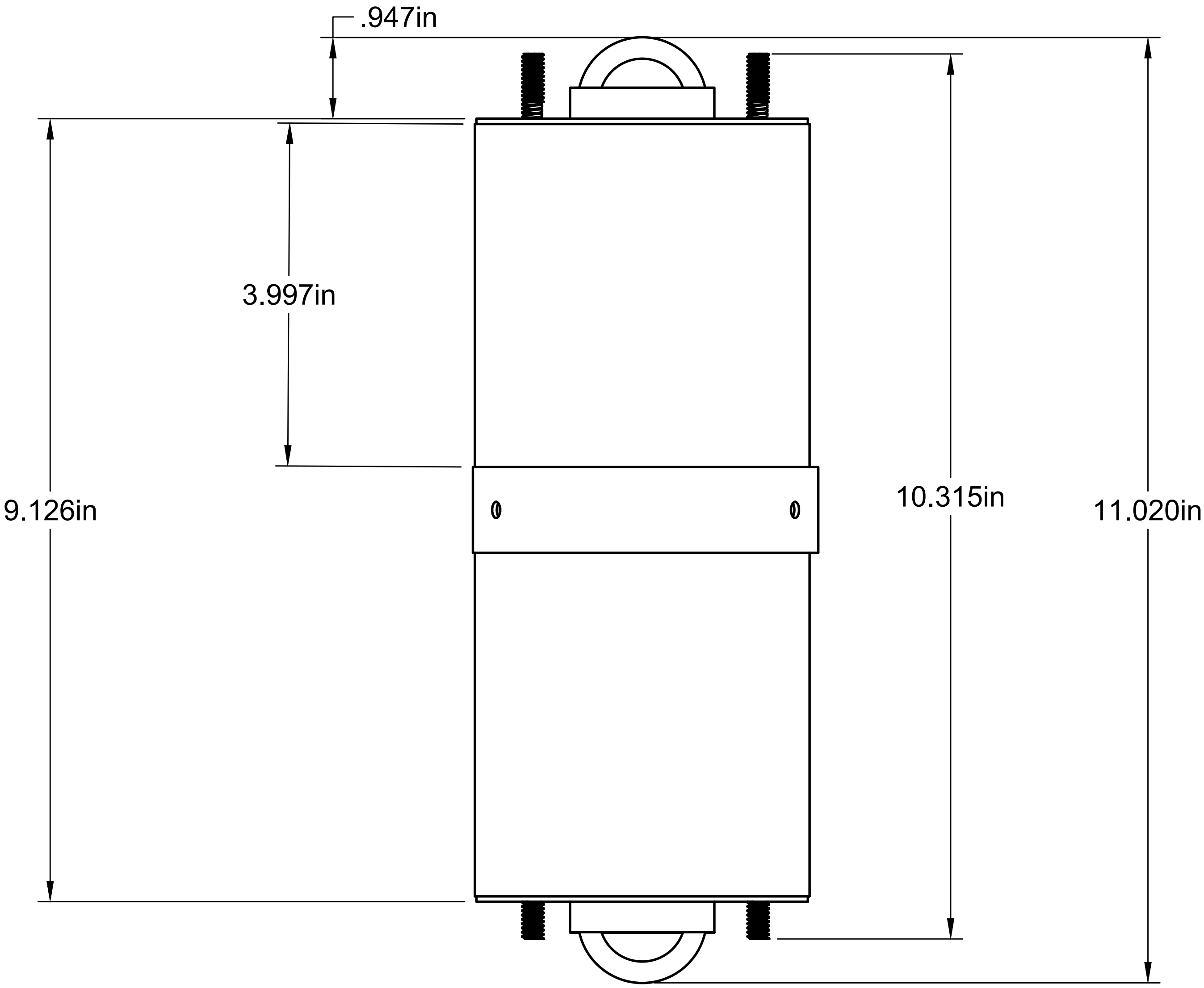
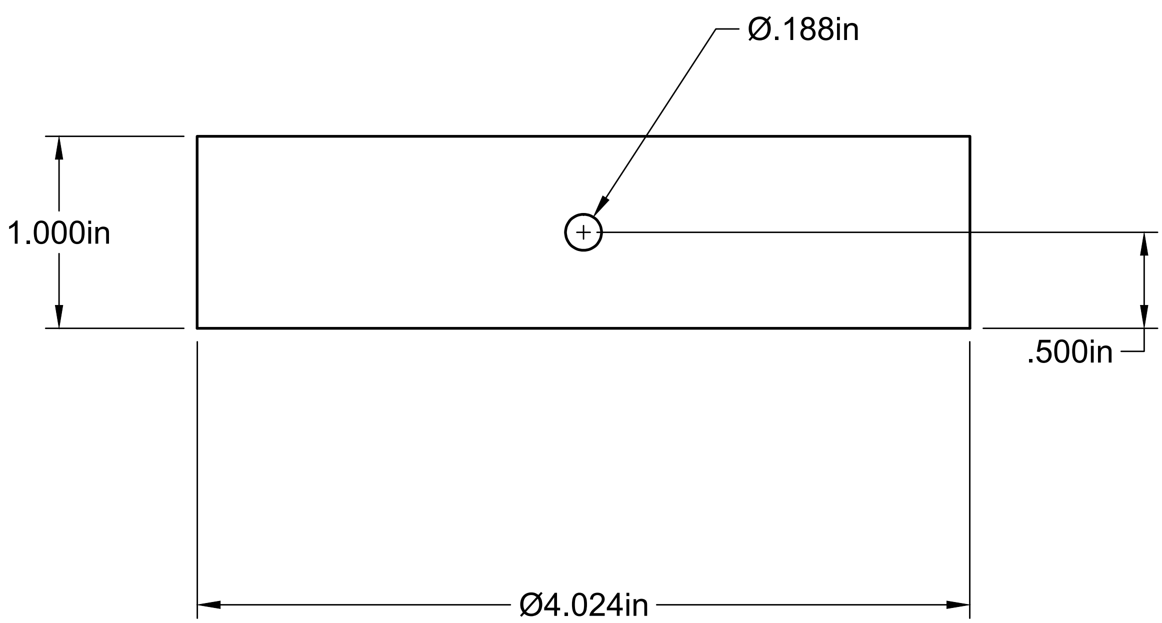
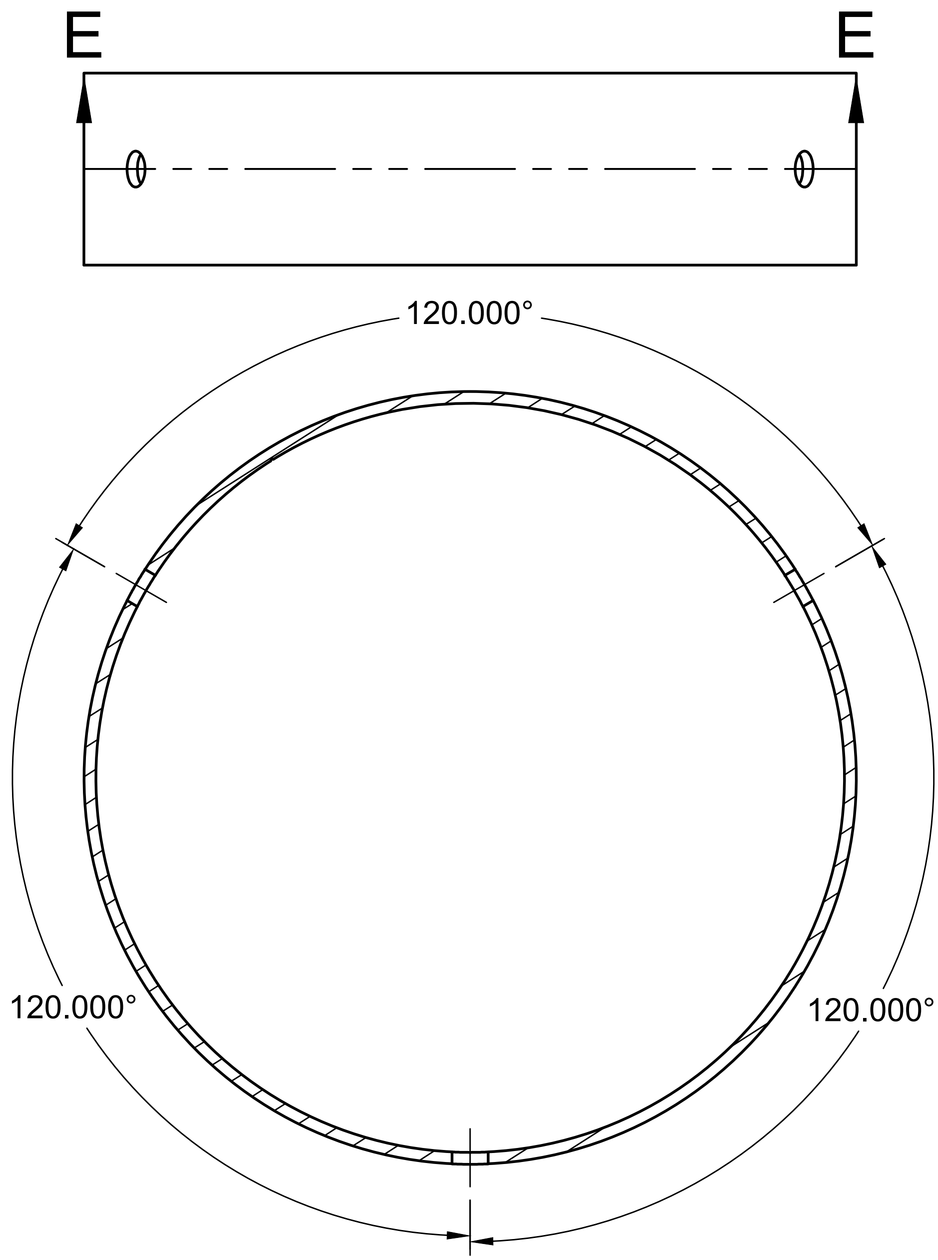


OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Avonics Bay Front	SCALE 1:2 SHEET 31/83	SIZE A

OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Switch Band	SCALE 2:1	SIZE
		SHEET 32/83	A

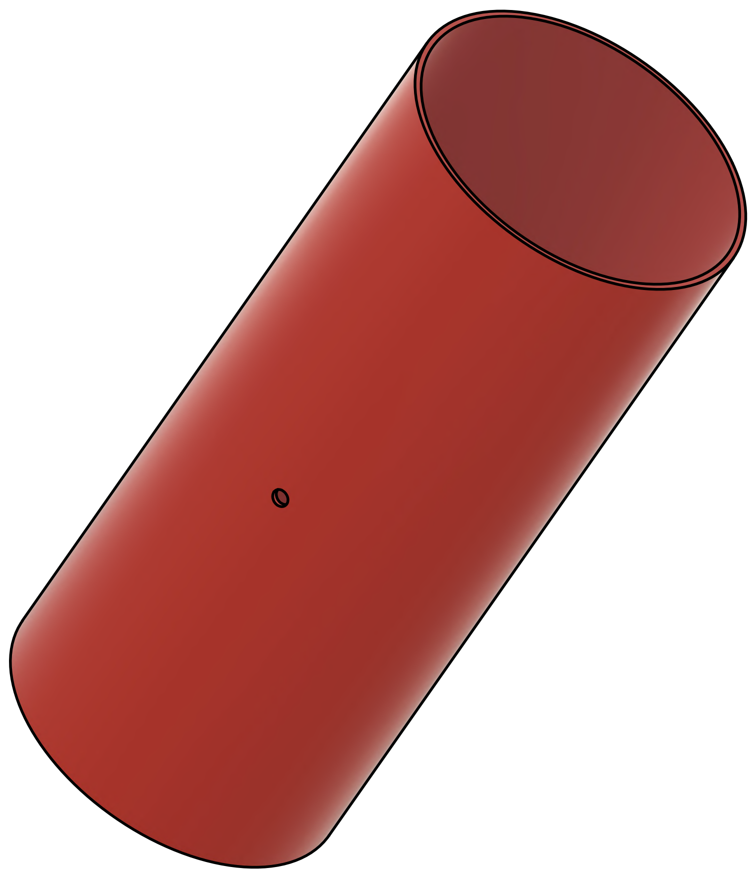


OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Switch Band Back	SCALE 1:1 SHEET 33/83	SIZE A

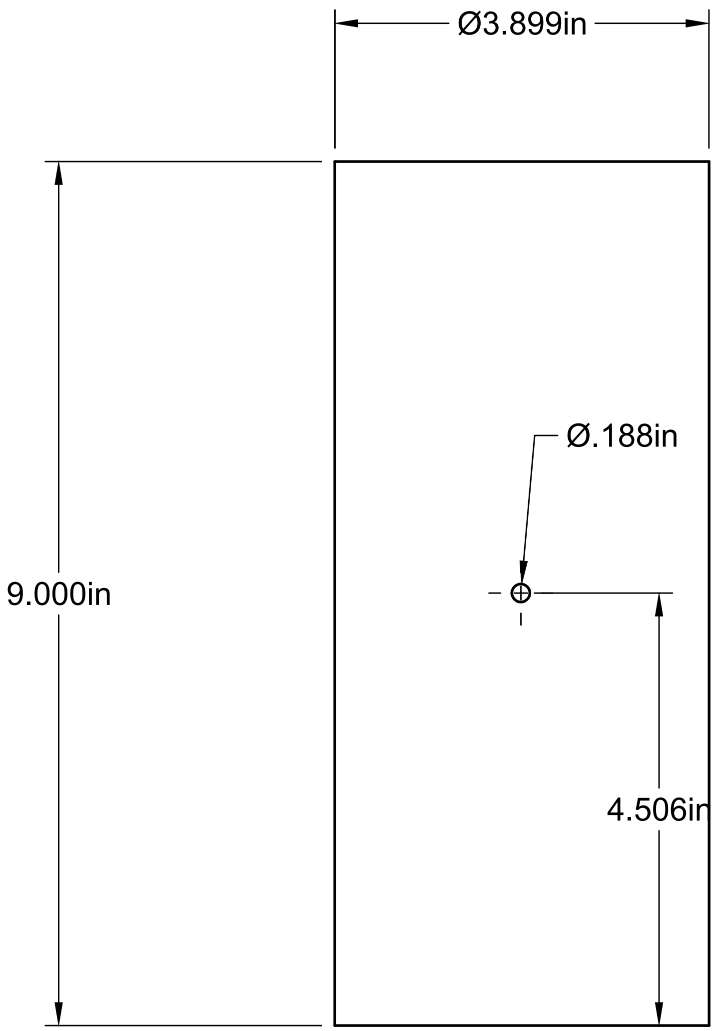


SECTION E-E
SCALE 1:1

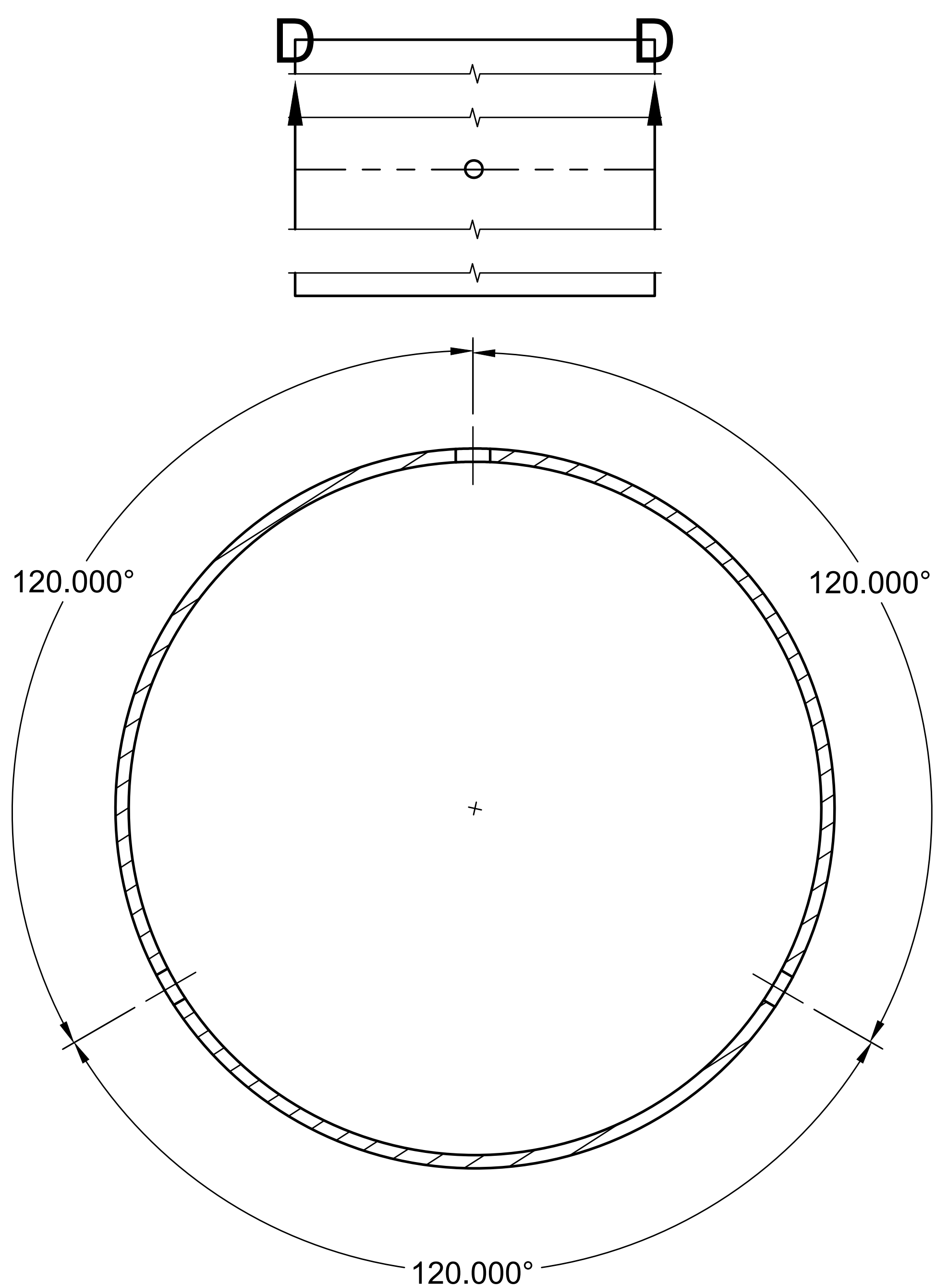
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI			
	TITLE Switch Band Front	SCALE	1:1	SIZE A
		SHEET	34/83	



OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Avionics Payload	SCALE 1:2 SHEET 35/83	SIZE A



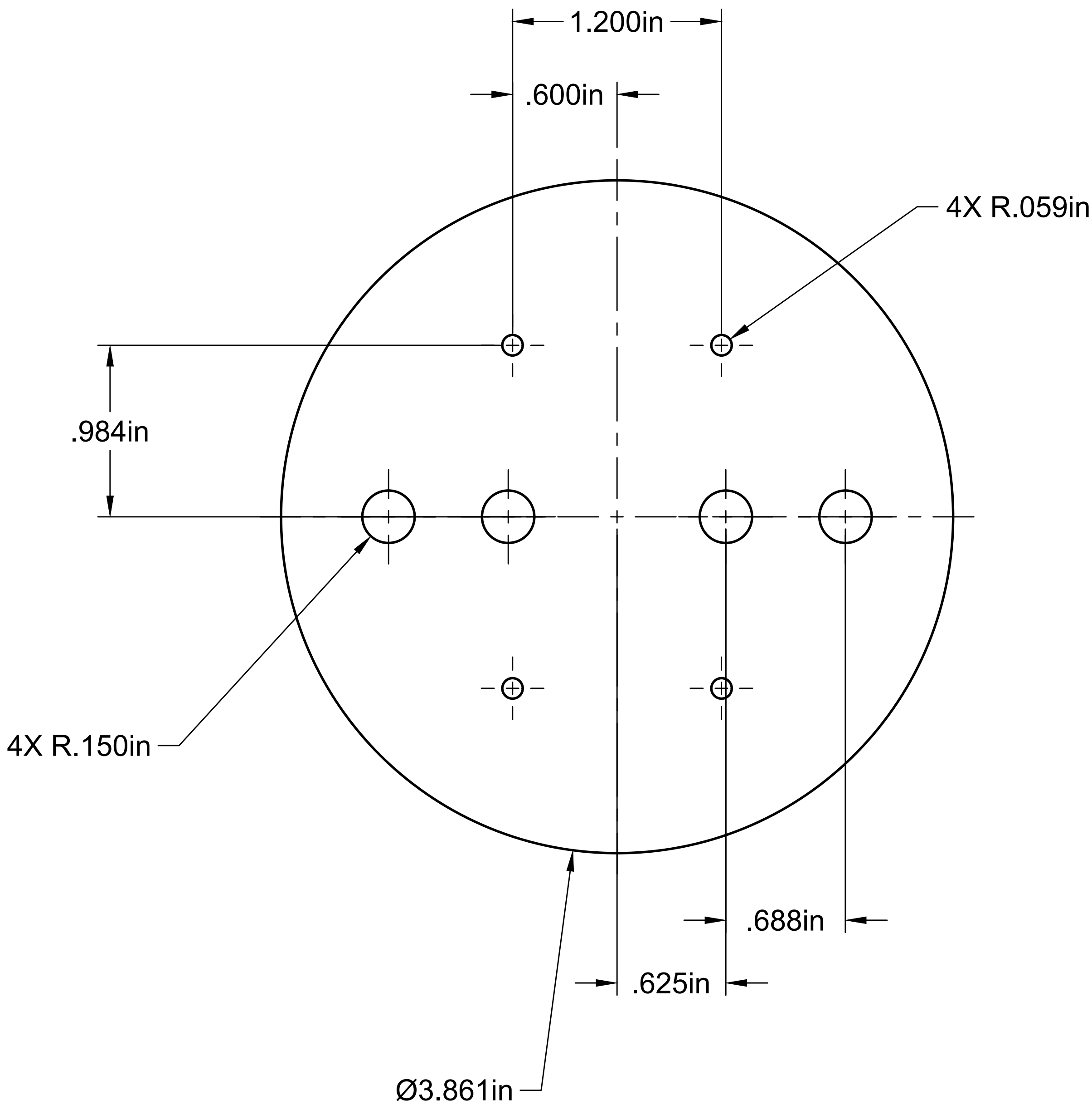
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Avionics Bay Back	SCALE 1:2 SHEET 36/83	SIZE A



SECTION D-D
SCALE 1:1

OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI			
	TITLE Avionics Bay Back	SCALE	1:2	SIZE A
		SHEET	37/83	

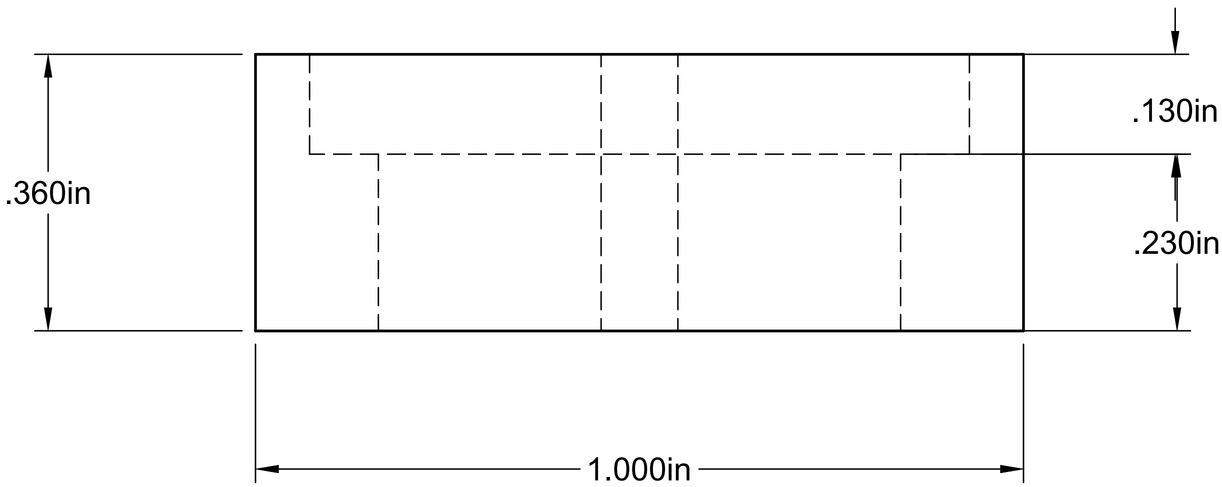
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Avionics Bulkheads	SCALE 2:1 SHEET 38/83	SIZE A



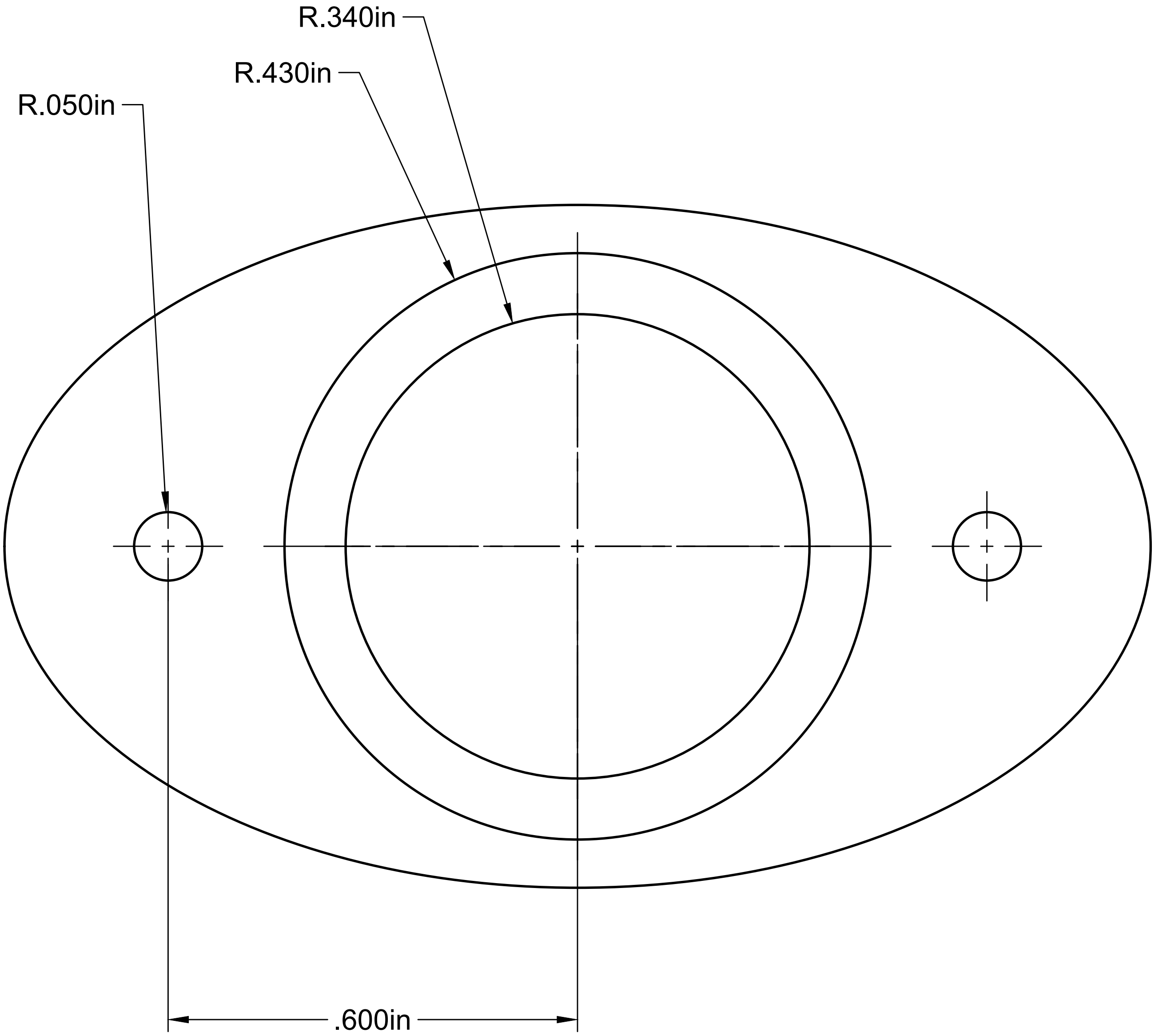
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Avionics Bay Top	SCALE 1:1	SIZE A
		SHEET 39/83	

OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI			
	TITLE Avionics Bay Right	SCALE 1:1		SIZE A
		SHEET 40/83		

OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Pex Holder	SCALE 5:1	SIZE A
		SHEET 41/83	

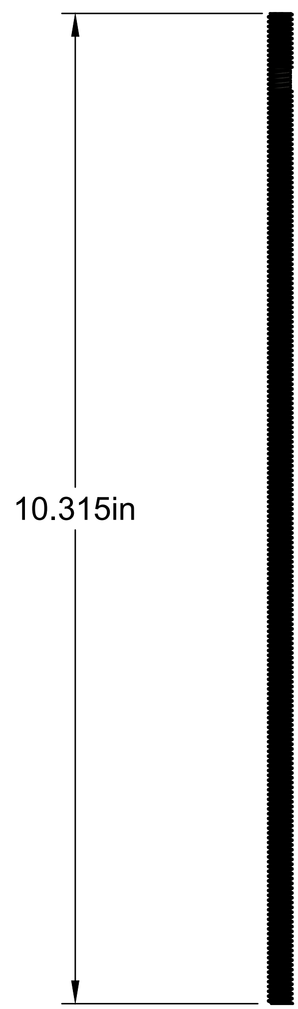


OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Pex Holder	SCALE 5:1 SHEET 42/83	SIZE A

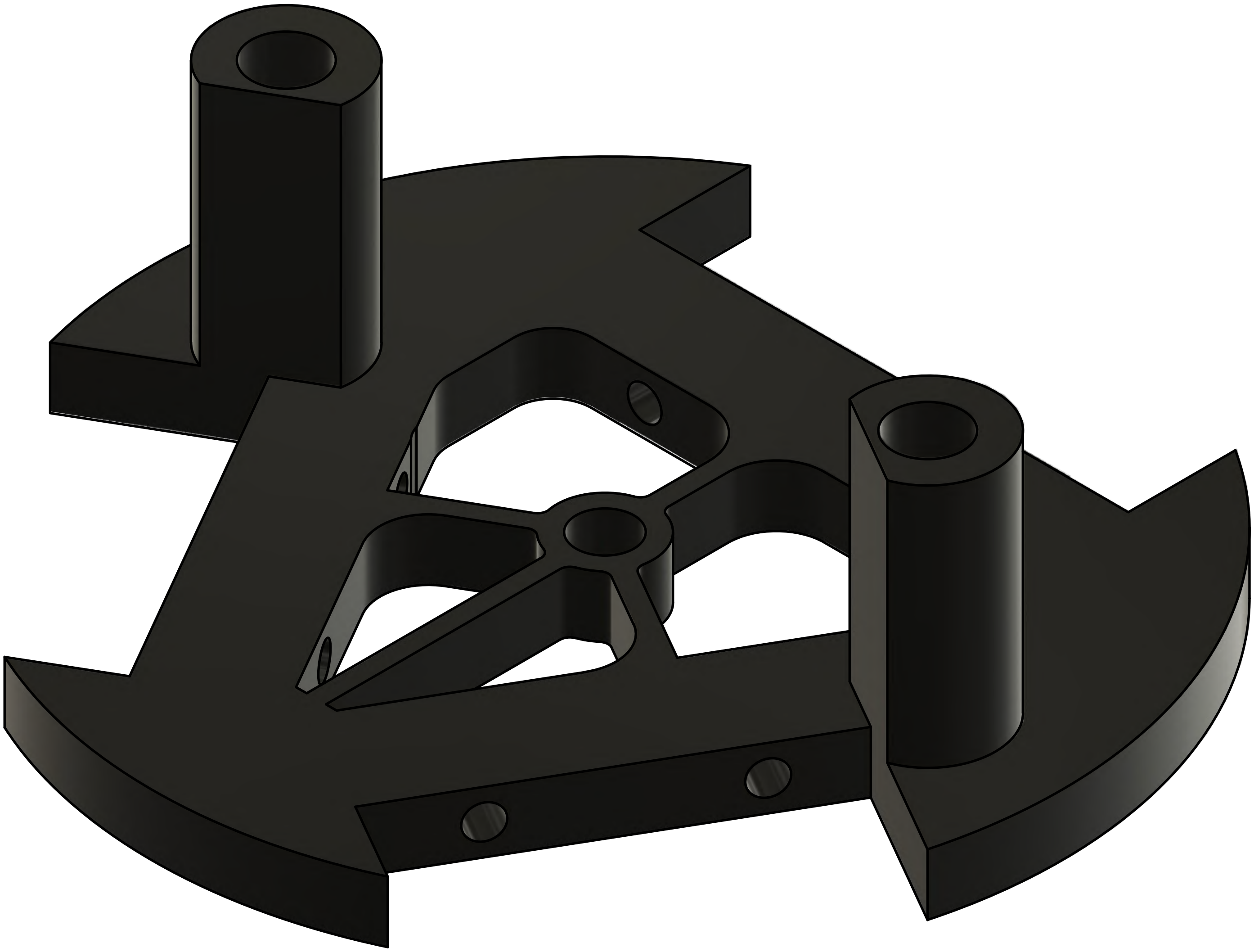


OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Pex Holder	SCALE 5:1 SHEET 43/83	SIZE A

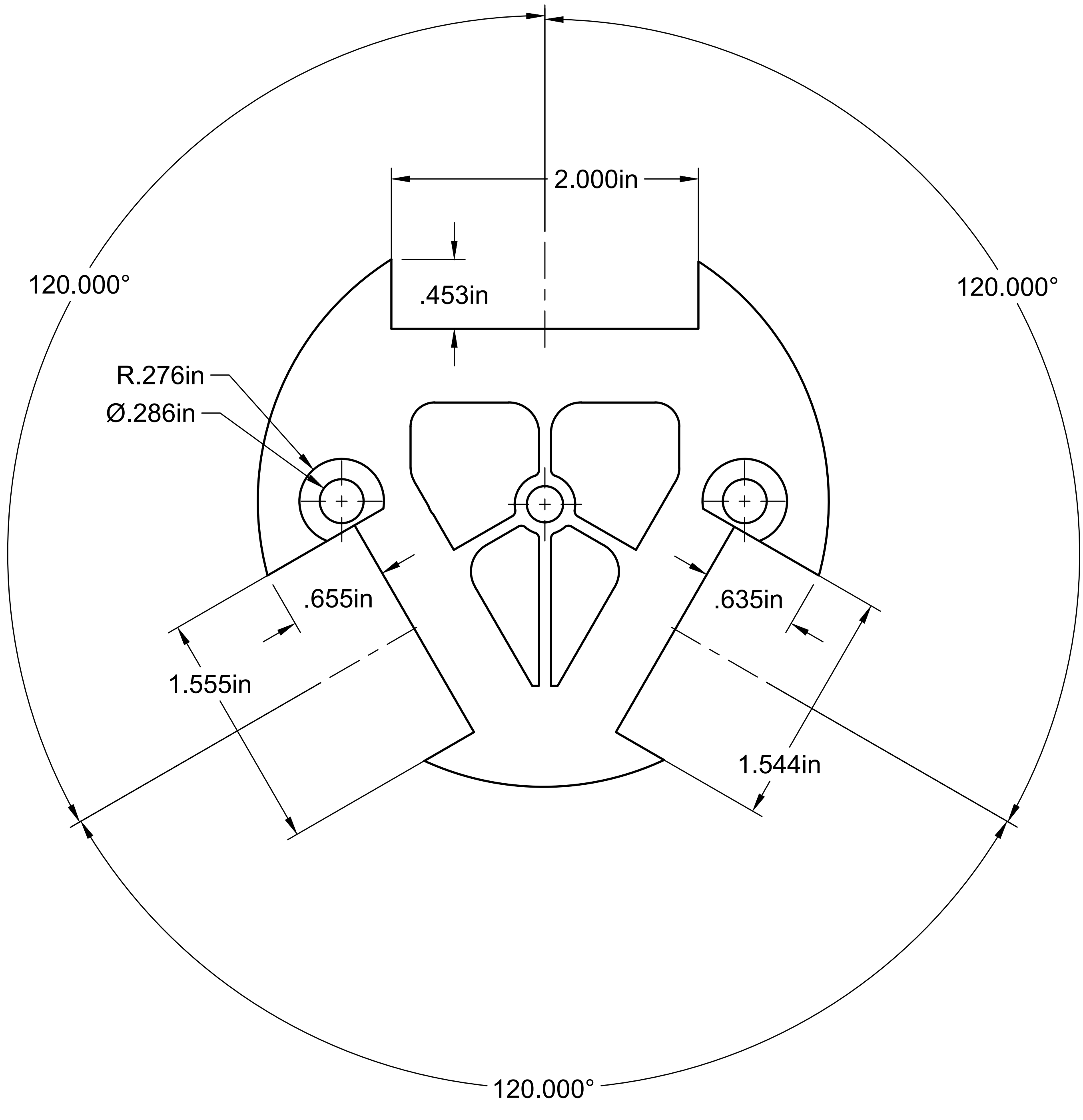
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Fully Assembled Rocket	SCALE 1:30 SHEET 44/83	SIZE A



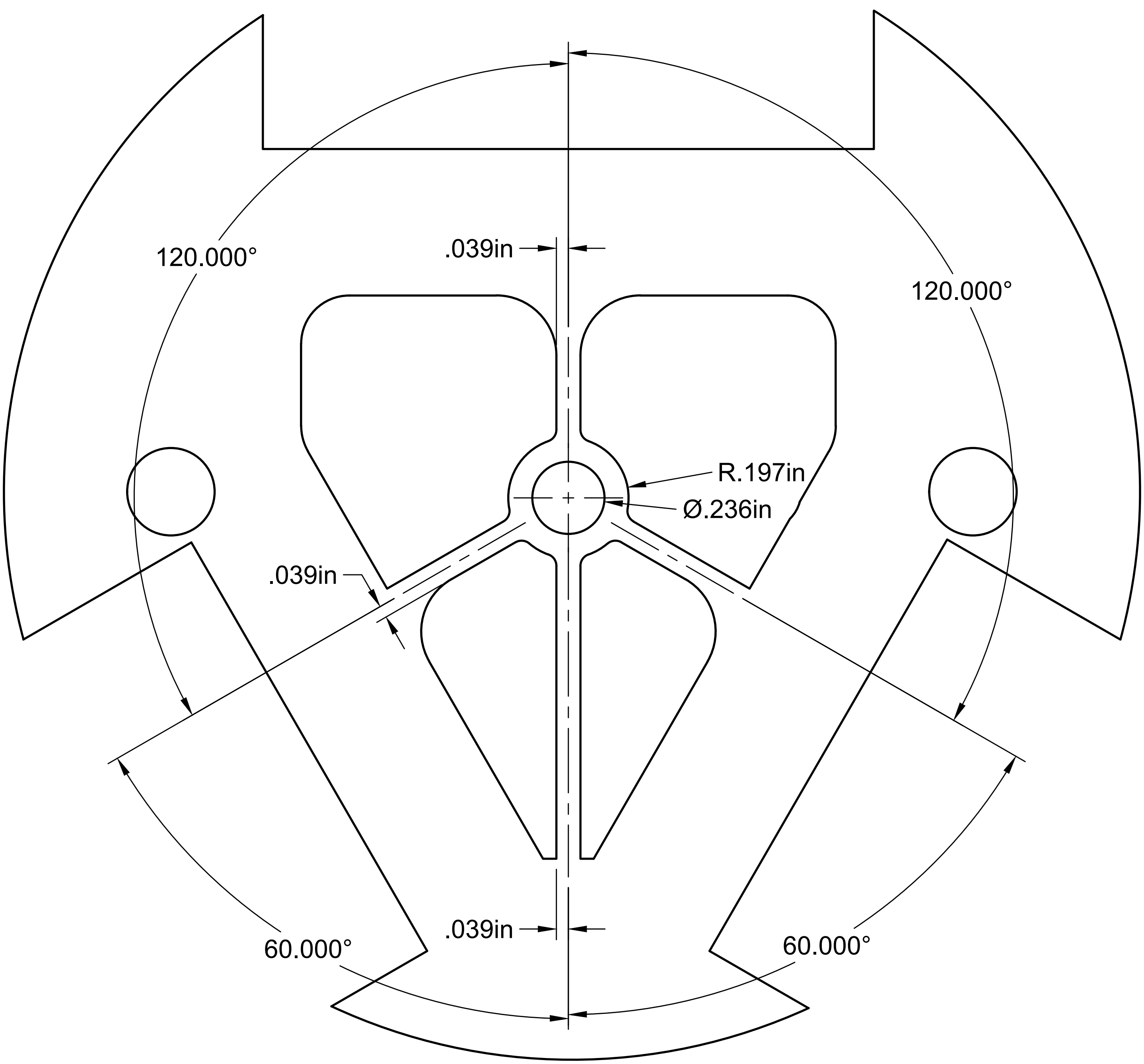
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI			
	TITLE Fully Assembled Rocket	SCALE	1:30	SIZE A
		SHEET	45/83	



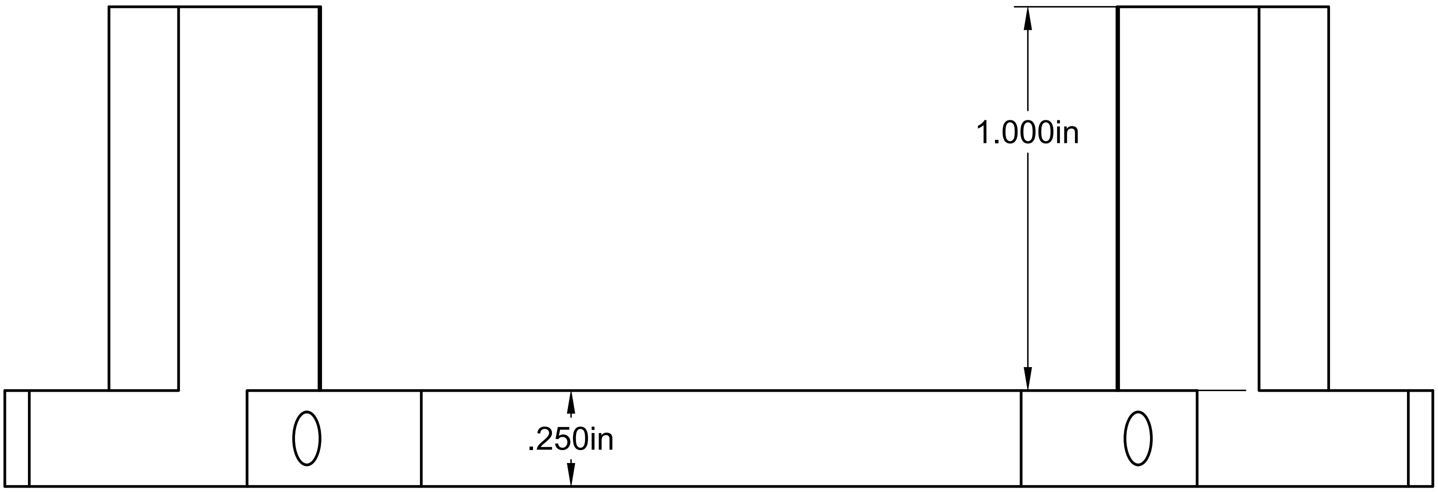
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Payload Stabilization Triangle	SCALE 2:1	SIZE A
		SHEET 46/83	



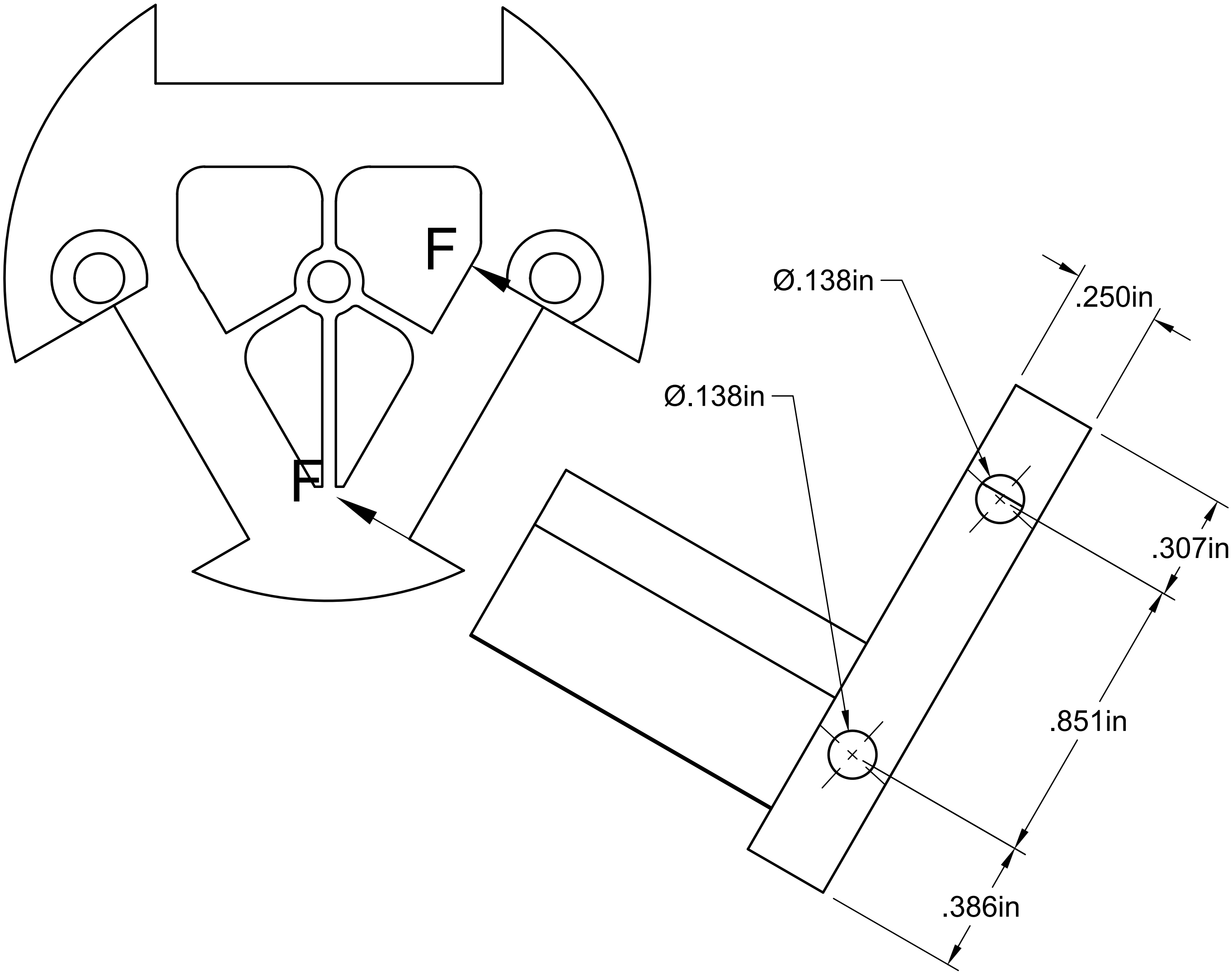
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Payload Stabilization Triangle Top	SCALE 1:1 SHEET 47/83	SIZE A



OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Payload Stabilization Triangle Bottom	SCALE 2:1	SIZE A
		SHEET 48/83	

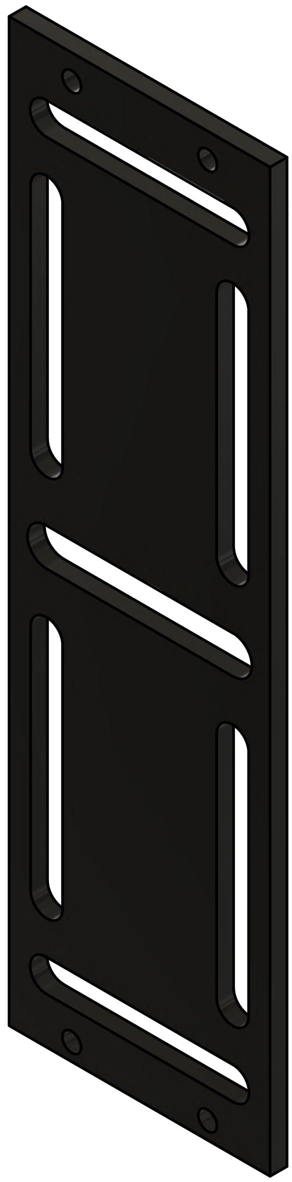


OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Payload Stabilization Triangle Front	SCALE 2:1 SHEET 49/83	SIZE A

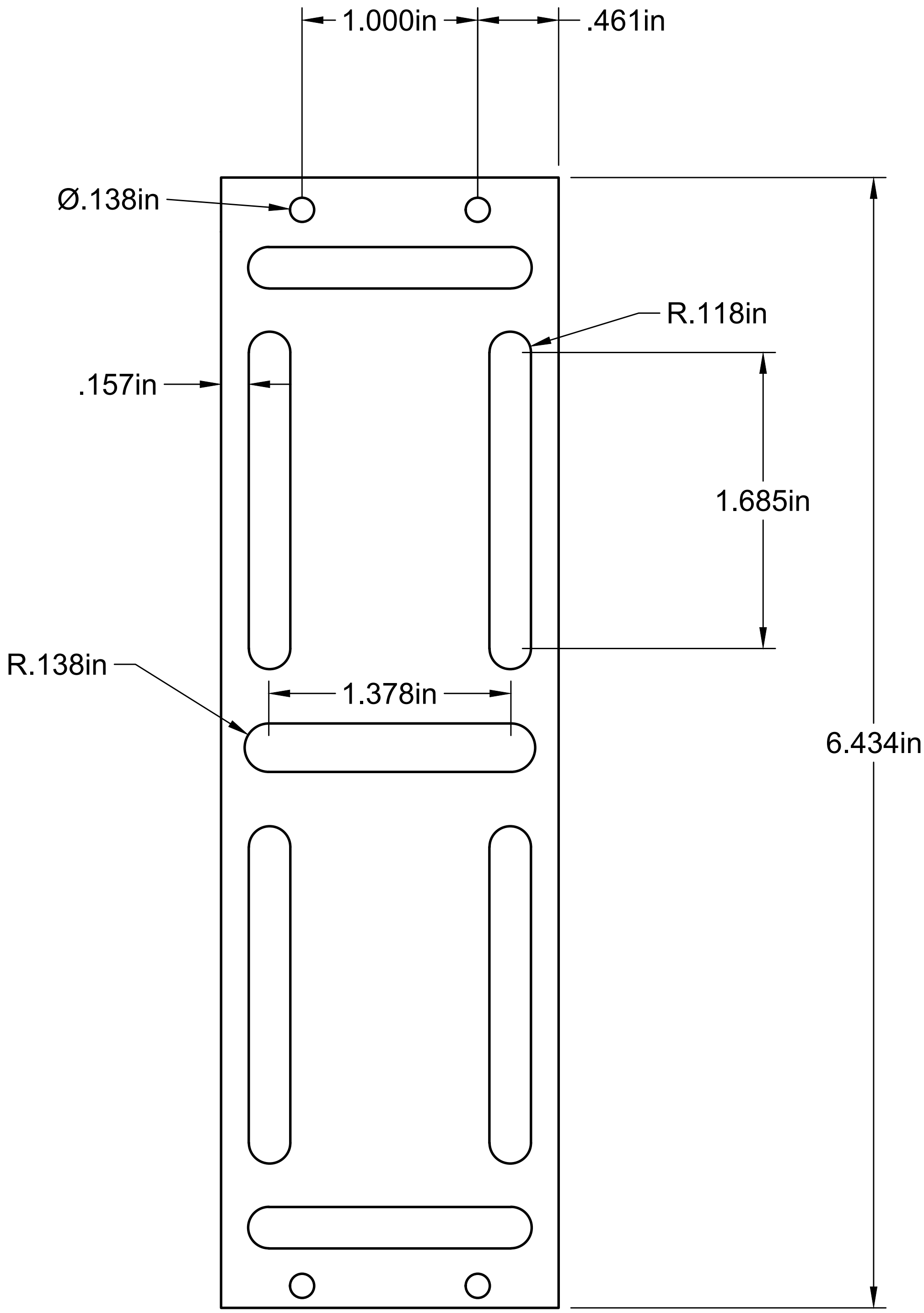


SECTION F-F
SCALE 2:1

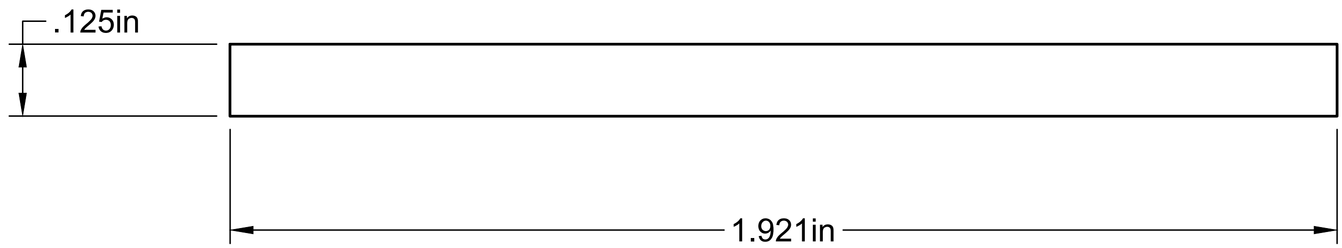
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Payload Stabilization Triangle Top	SCALE 1:1 SHEET 50/83	SIZE A



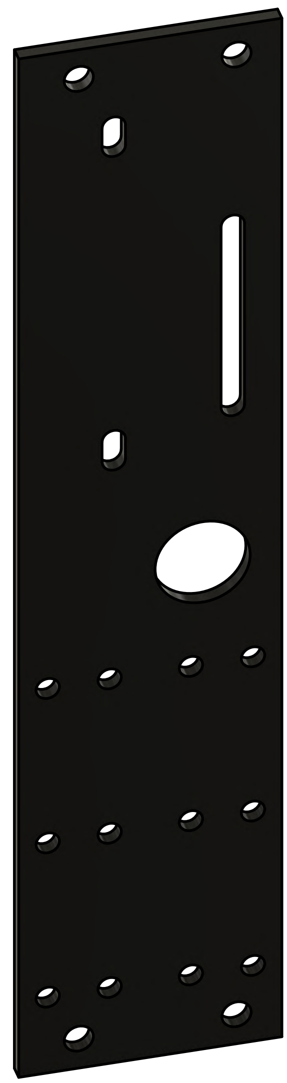
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Avionics Bay Back Sled	SCALE 1:1	SIZE A
		SHEET 51/83	



OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI			
	TITLE Avionics Bay Back Sled Back	SCALE 1:1		SIZE A
		SHEET 52/83		



OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Avionics Bay Back Sled Top	SCALE 3:1 SHEET 53/83	SIZE A



OCeng._1.PNG

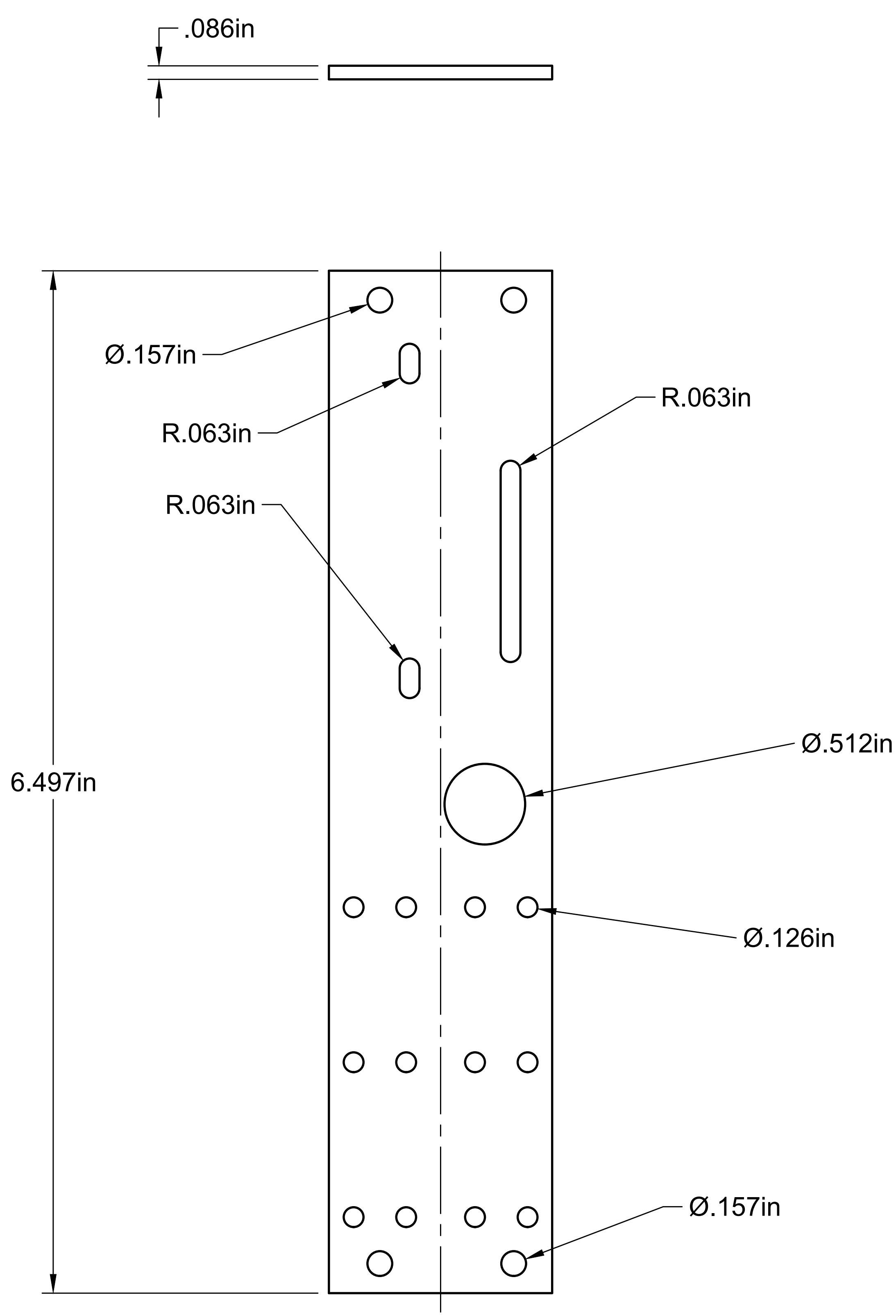
PROJECT

Oconee County High School 2025 NASA SLI

TITLE

Avionics Button Sled

SCALE	1:1	SIZE
SHEET	54/83	A



PROJECT

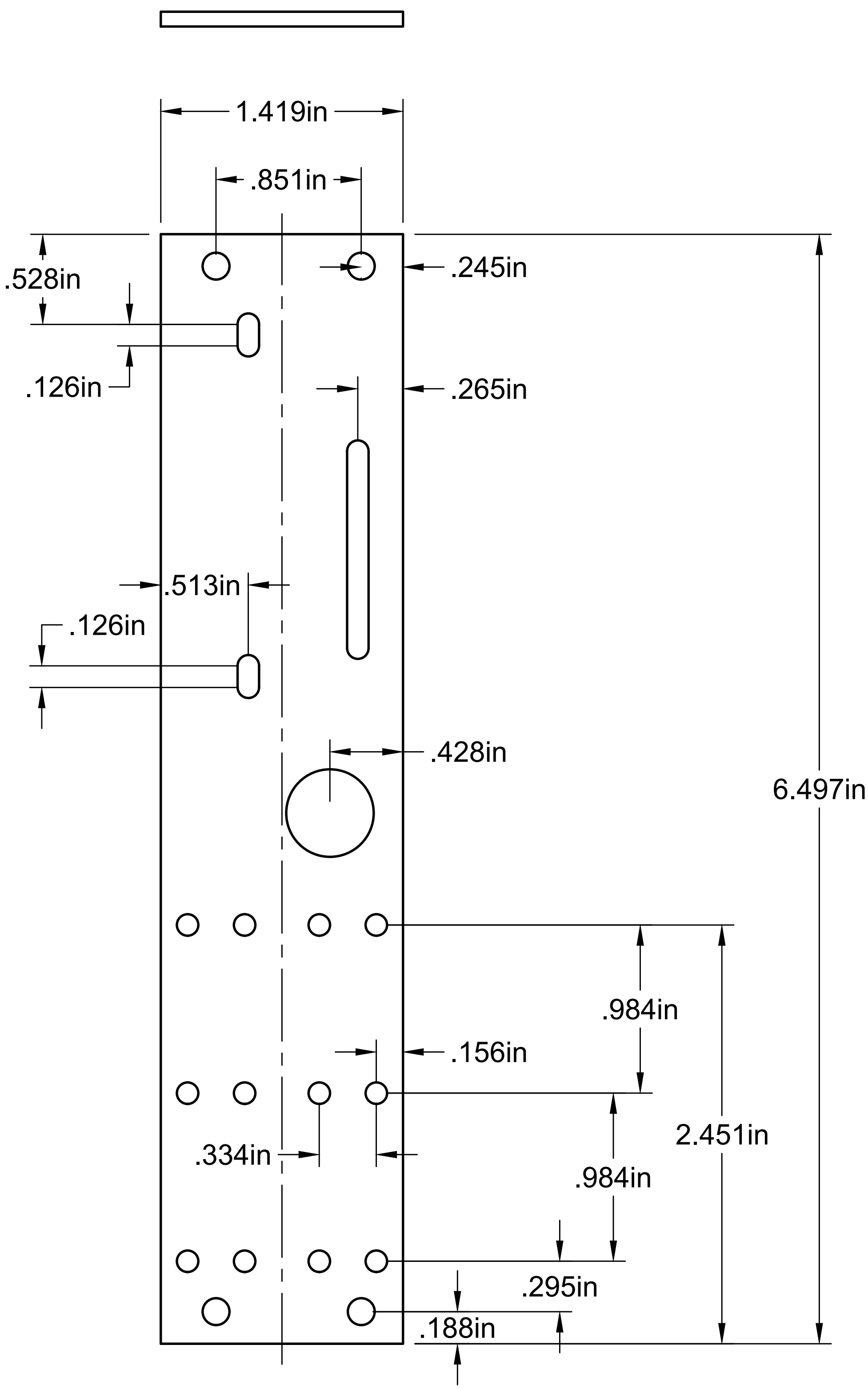
Oconee County High School 2025 NASA SLI

OCeng._1.PNG

TITLE

Avionics Button Sled

SCALE	1:1	SIZE
SHEET	55/83	A



OCeng._1.PNG

PROJECT

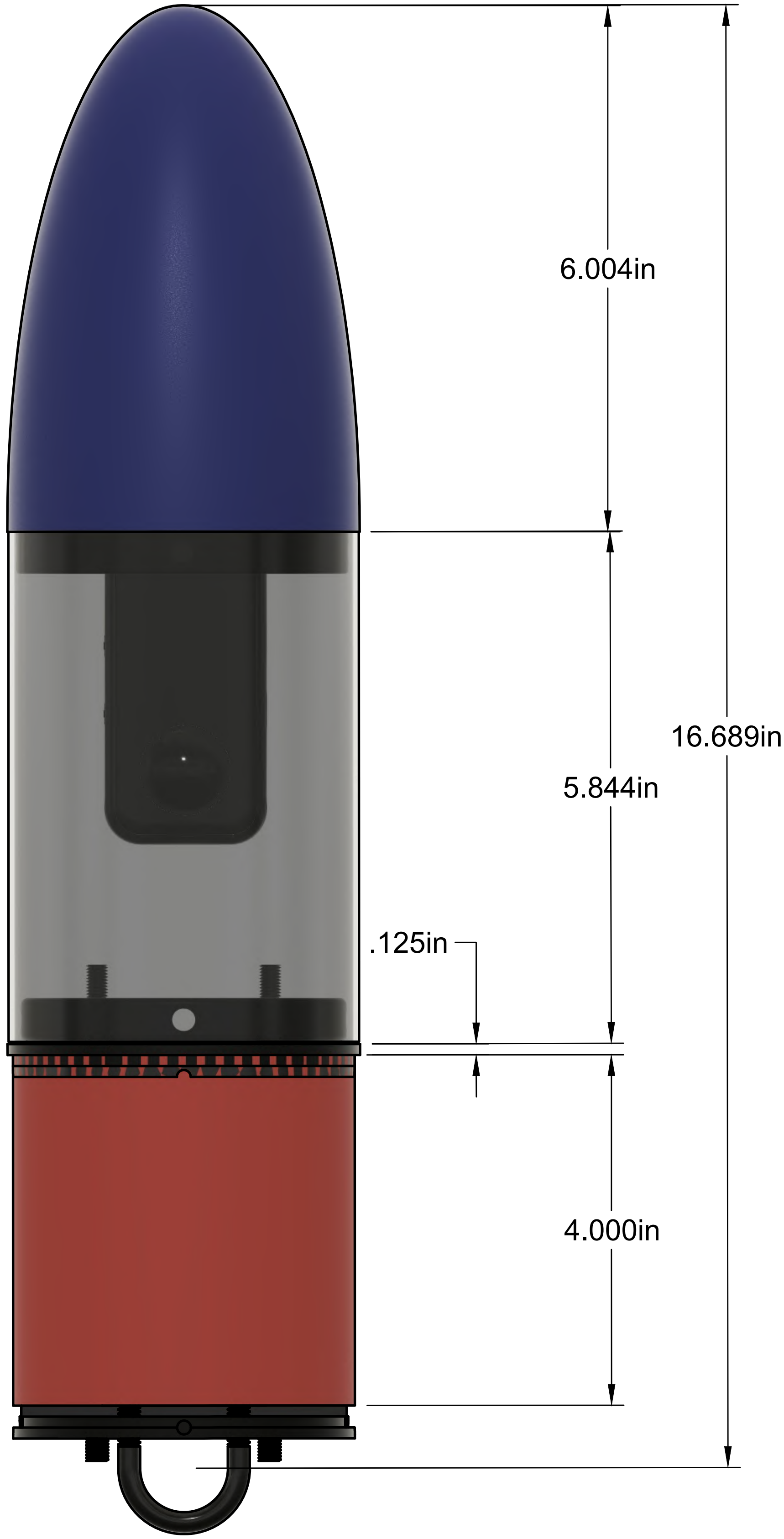
Oconee County High School 2025 NASA SLI

TITLE

Avionics Button Sled

SCALE	1:1	SIZE
SHEET	56/83	A

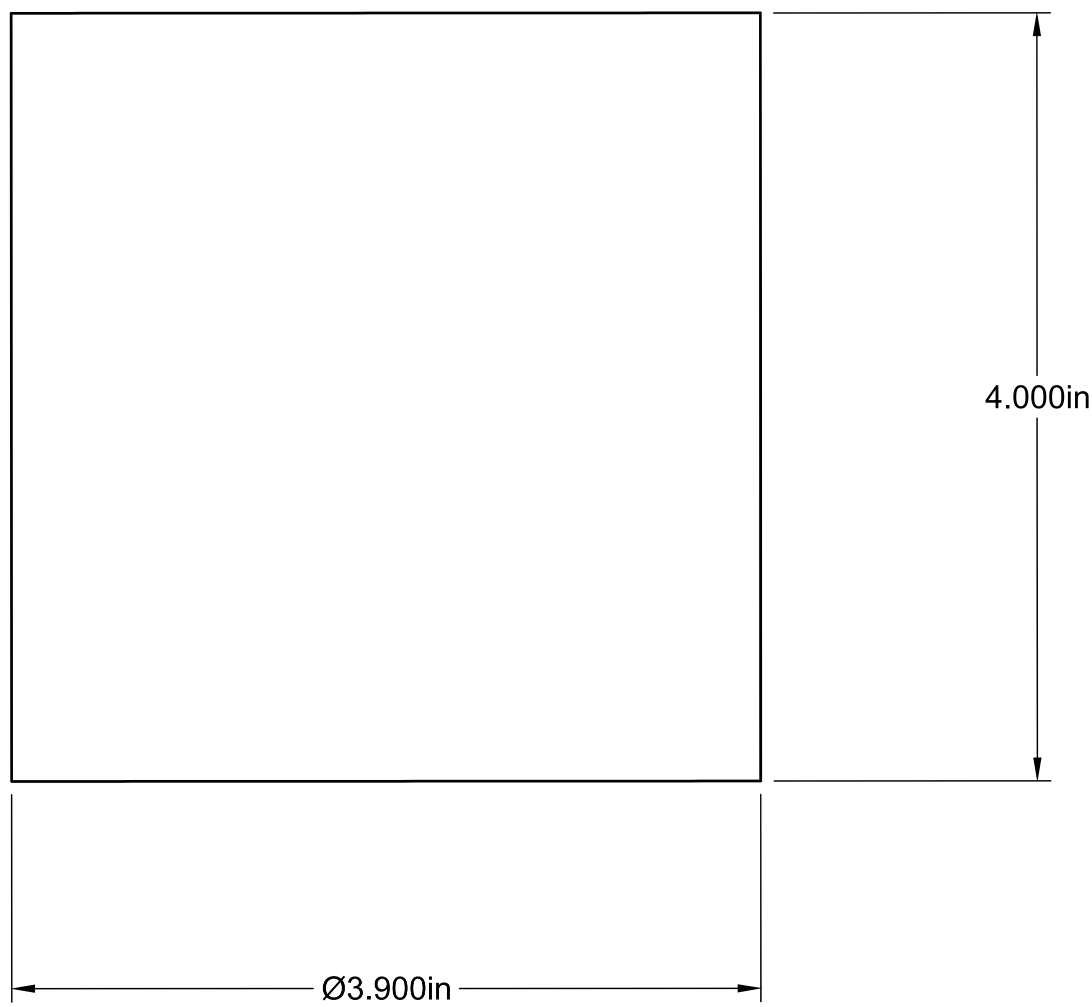
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Payload and Nosecone	SCALE 1:2 SHEET 57/83	SIZE A



OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Payload and Nosecone	SCALE 1:8 SHEET 58/83	SIZE A

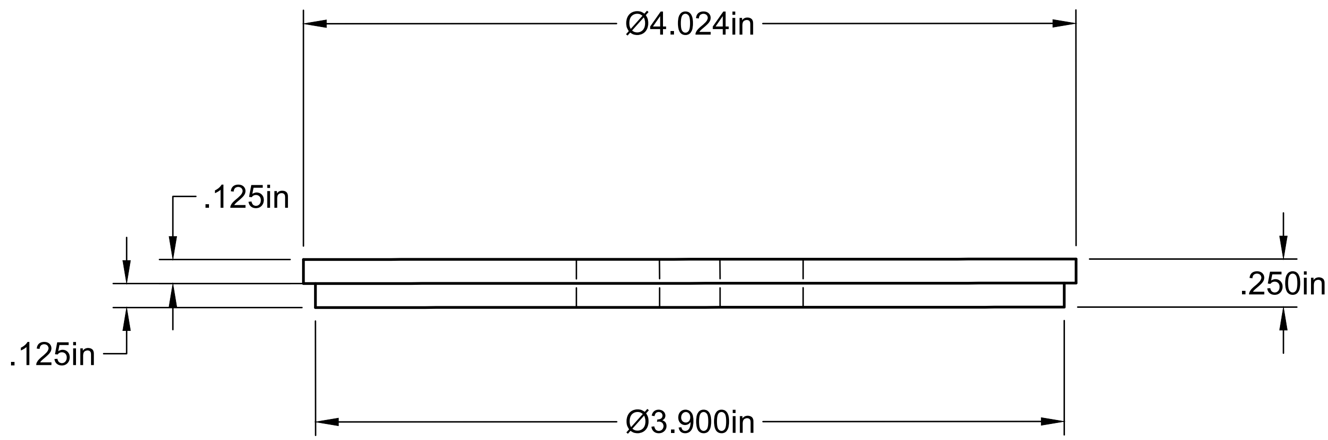
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Payload	SCALE 1:1 SHEET 59/83	SIZE A

OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI			
	TITLE Payload	SCALE 1:1		SIZE A
		SHEET 60/83		

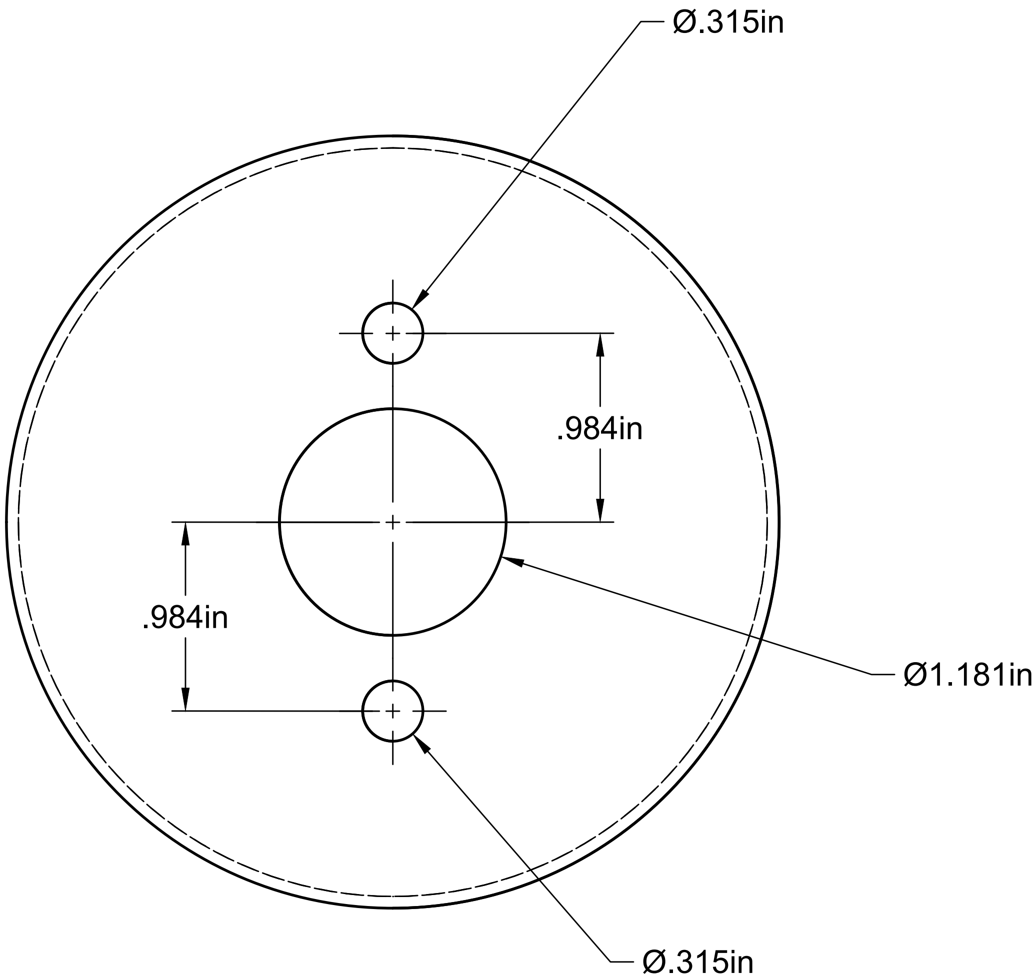


OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Payload	SCALE 1:1 SHEET 61/83	SIZE A

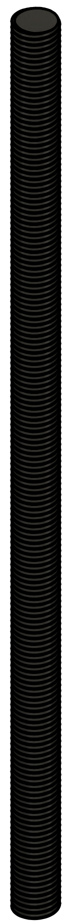
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Upper Payload Bulkhead	SCALE 2:1 SHEET 62/83	SIZE A



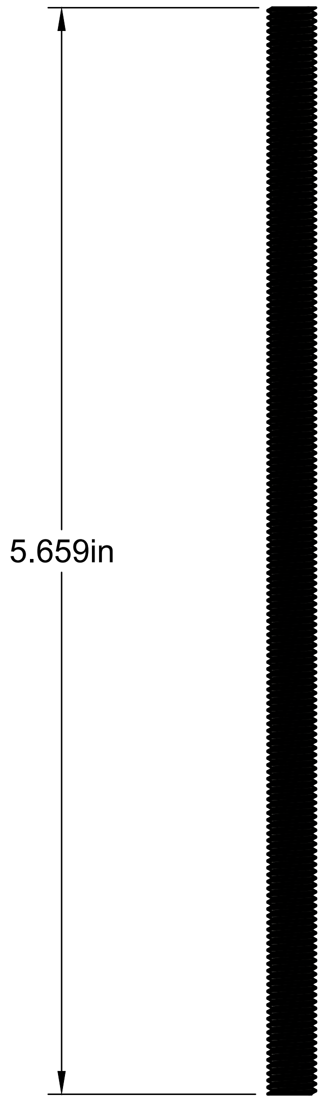
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI			
	TITLE Upper Payload Bulkhead Front	SCALE 1:1	SIZE A	
		SHEET 63/83		



OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Upper Payload Bulkhead Front	SCALE 1:1	SIZE A
		SHEET 64/83	



OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI			
	TITLE Payload Aluminum Rod	SCALE 1:1		SIZE A
		SHEET 65/83		



PROJECT

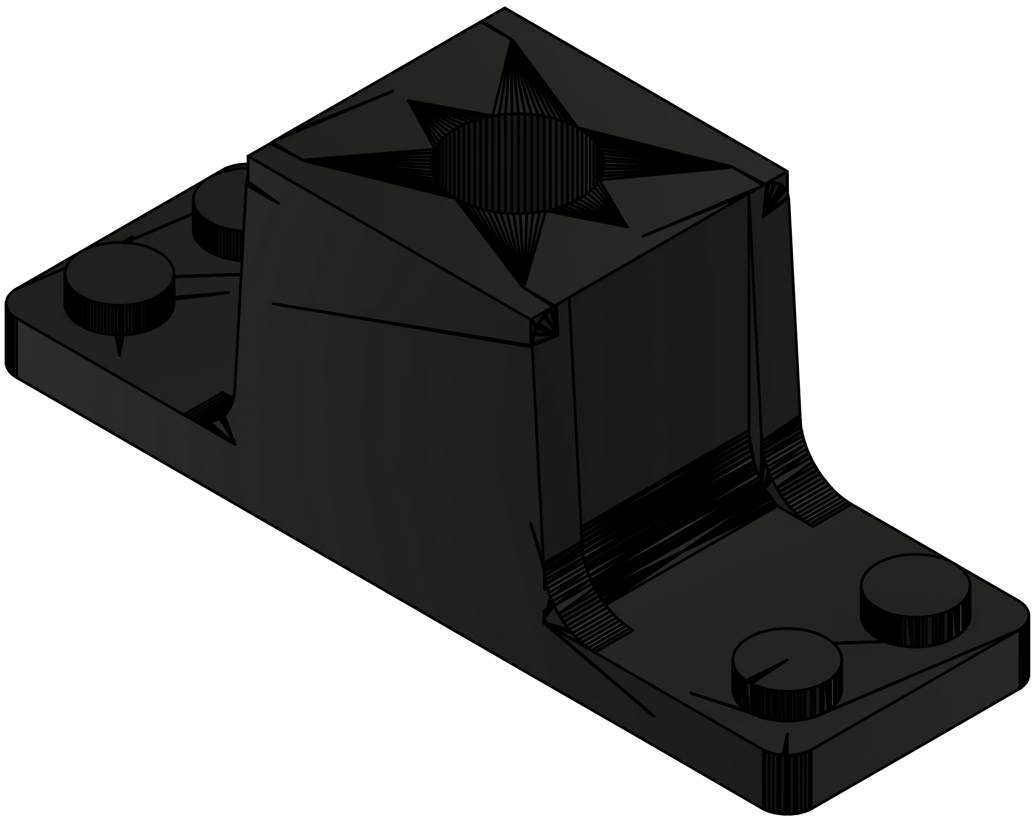
Oconee County High School 2025 NASA SLI

OCeng._1.PNG

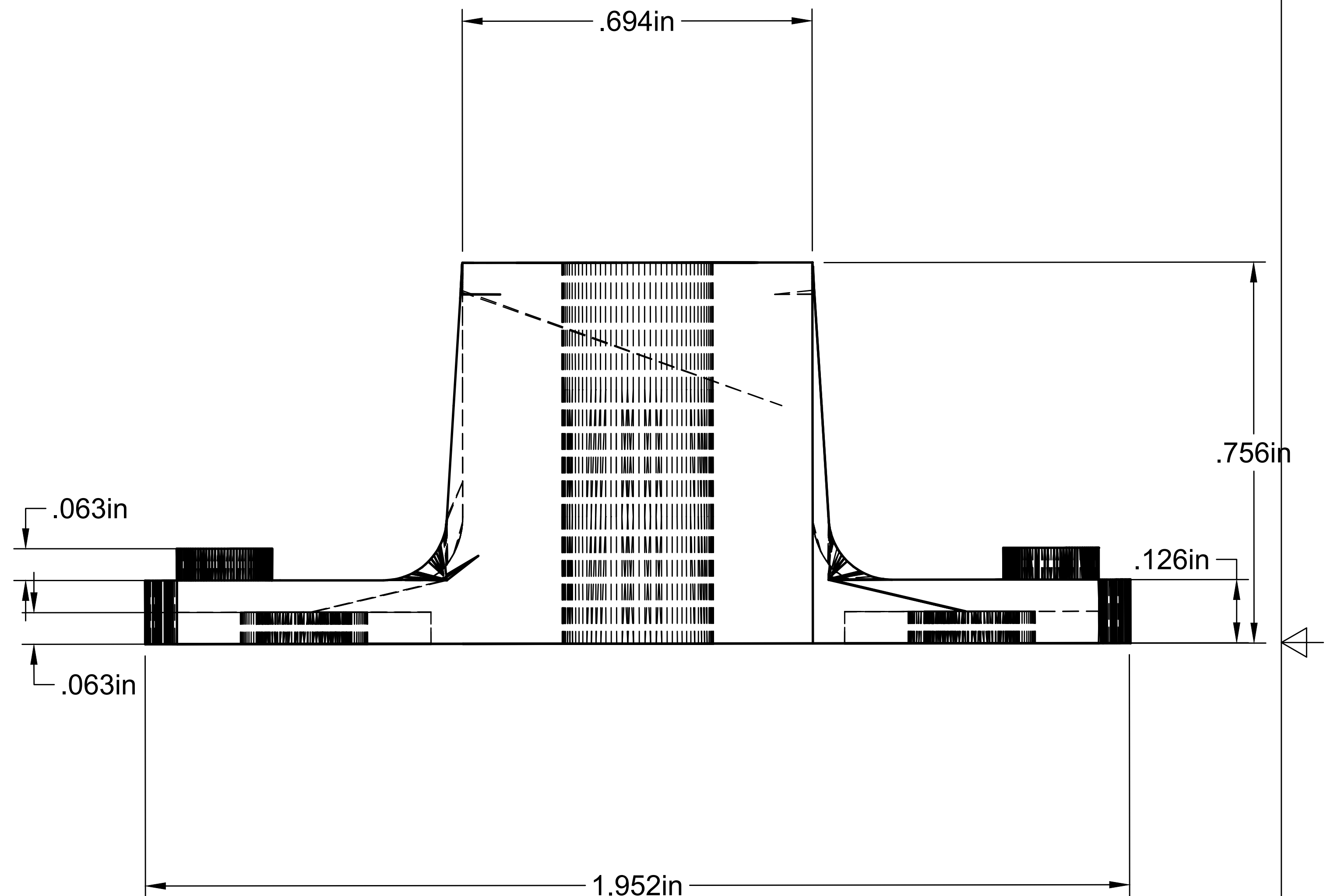
TITLE

Payload Aluminum Rod

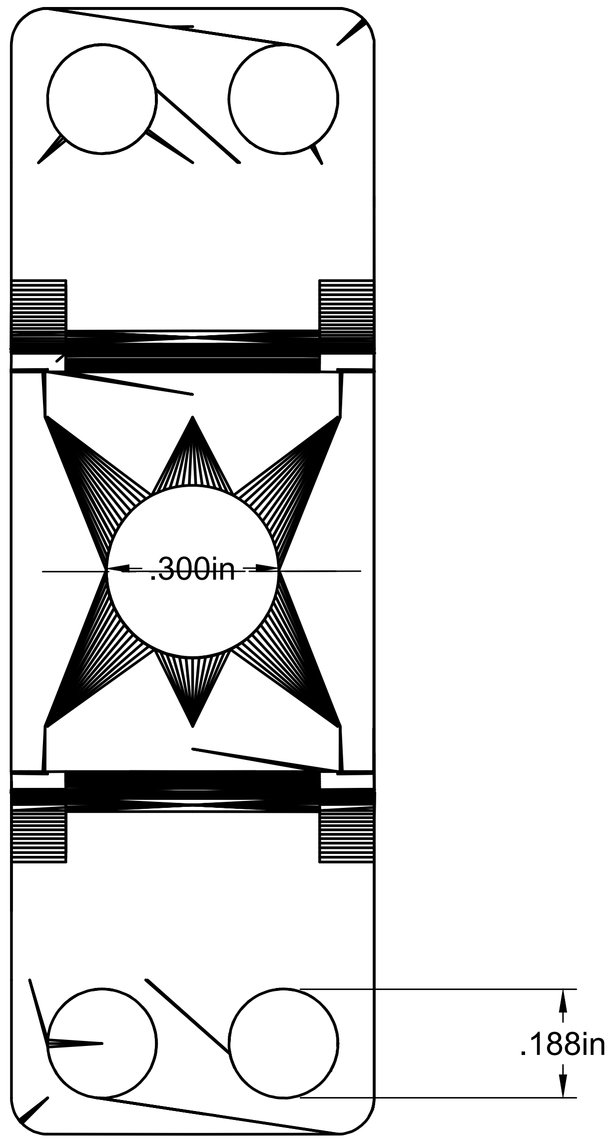
SCALE	1:1	SIZE	A
SHEET	66/83		



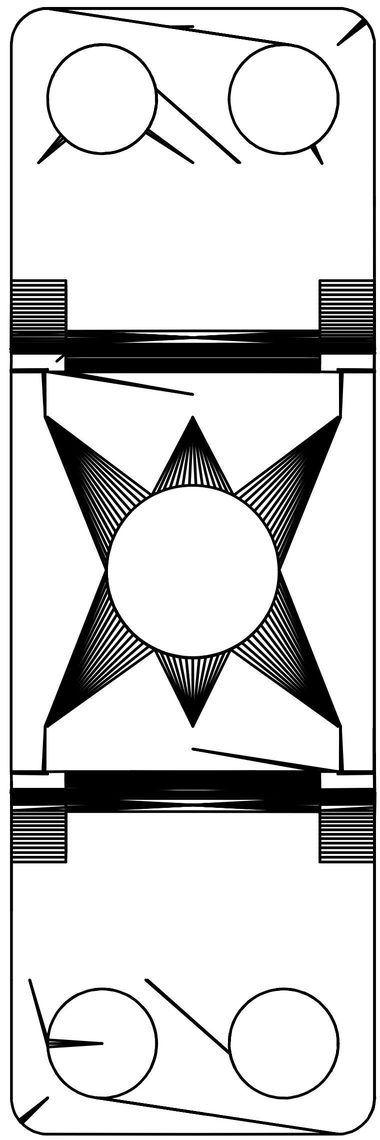
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE STEMNaut Holder	SCALE 3:1 SHEET 67/83	SIZE A



OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE STEMNaut Holder	SCALE 3:1	SIZE A
		SHEET 68/83	



OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE STEMNaut Holder	SCALE 3:1	SIZE
		SHEET 69/83	A



OCeng._1.PNG

PROJECT

Oconee County High School 2025 NASA SLI

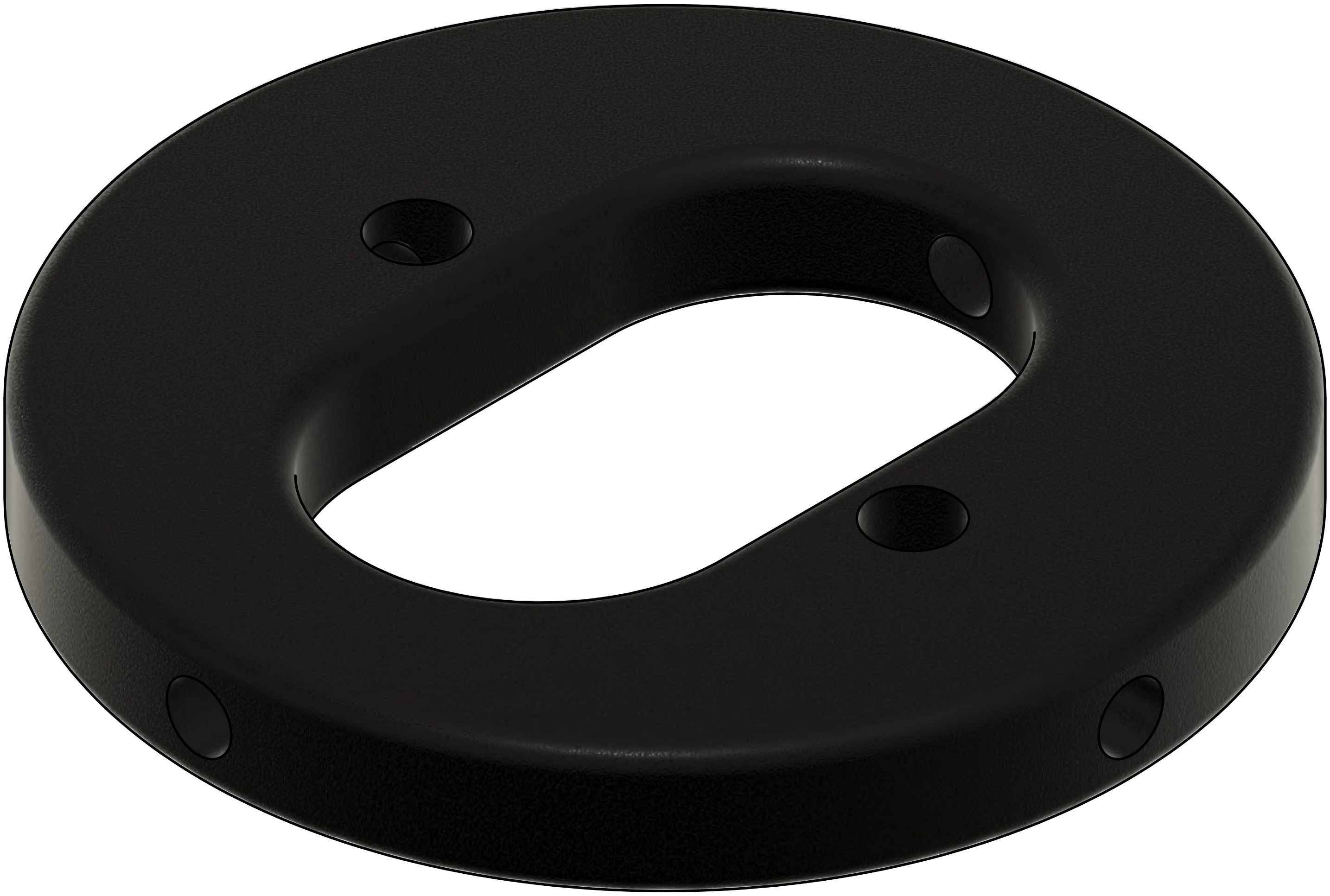
TITLE

STEMNaut Holder

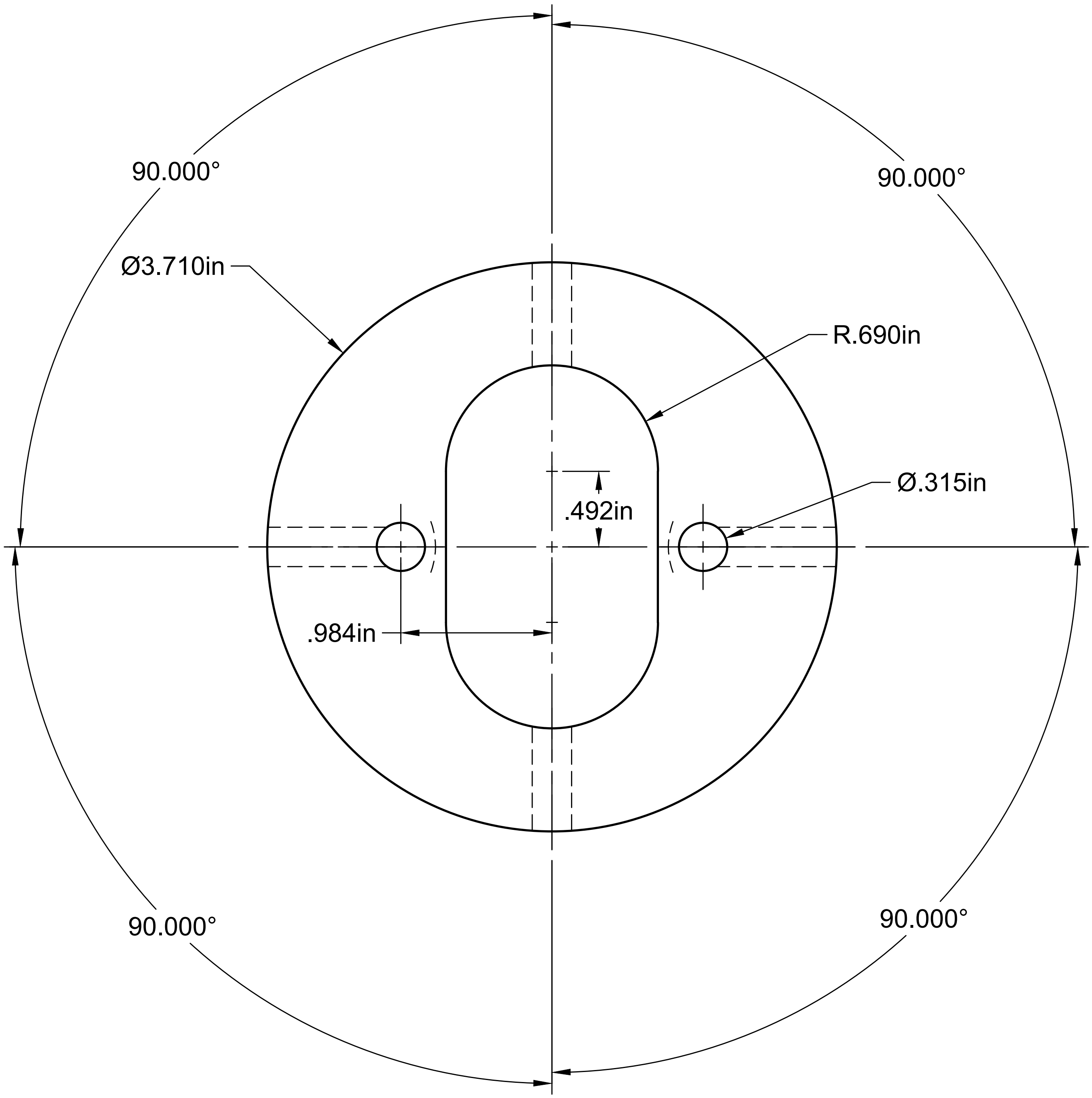
SCALE	3:1
SHEET	70/83
SIZE	A

OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI			
	TITLE Nose Cone and Camera	SCALE 1:2		SIZE A
		SHEET 71/83		

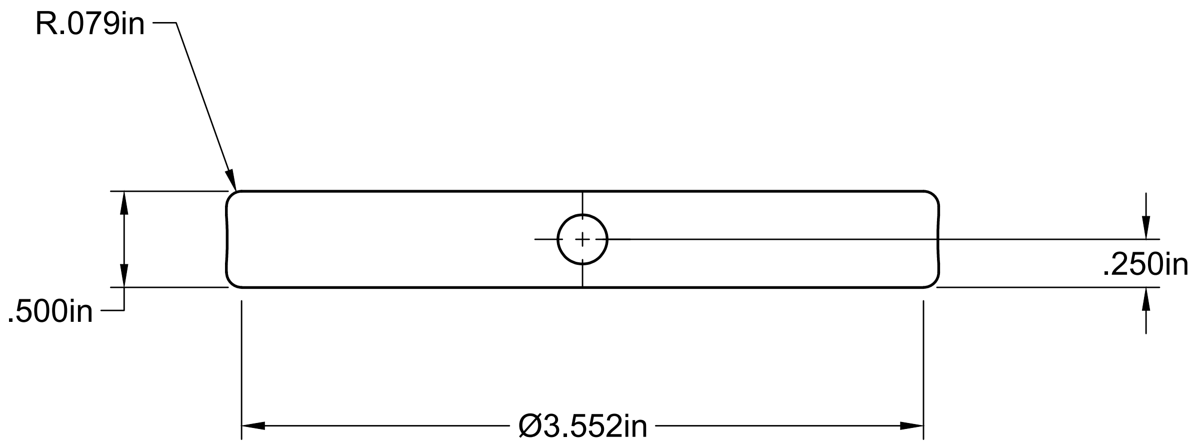
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Nose Cone and Camera	SCALE 1:2 SHEET 72/83	SIZE A



OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Nosecone Attachment bulkhead	SCALE 2:1	SIZE
		SHEET 73/83	A

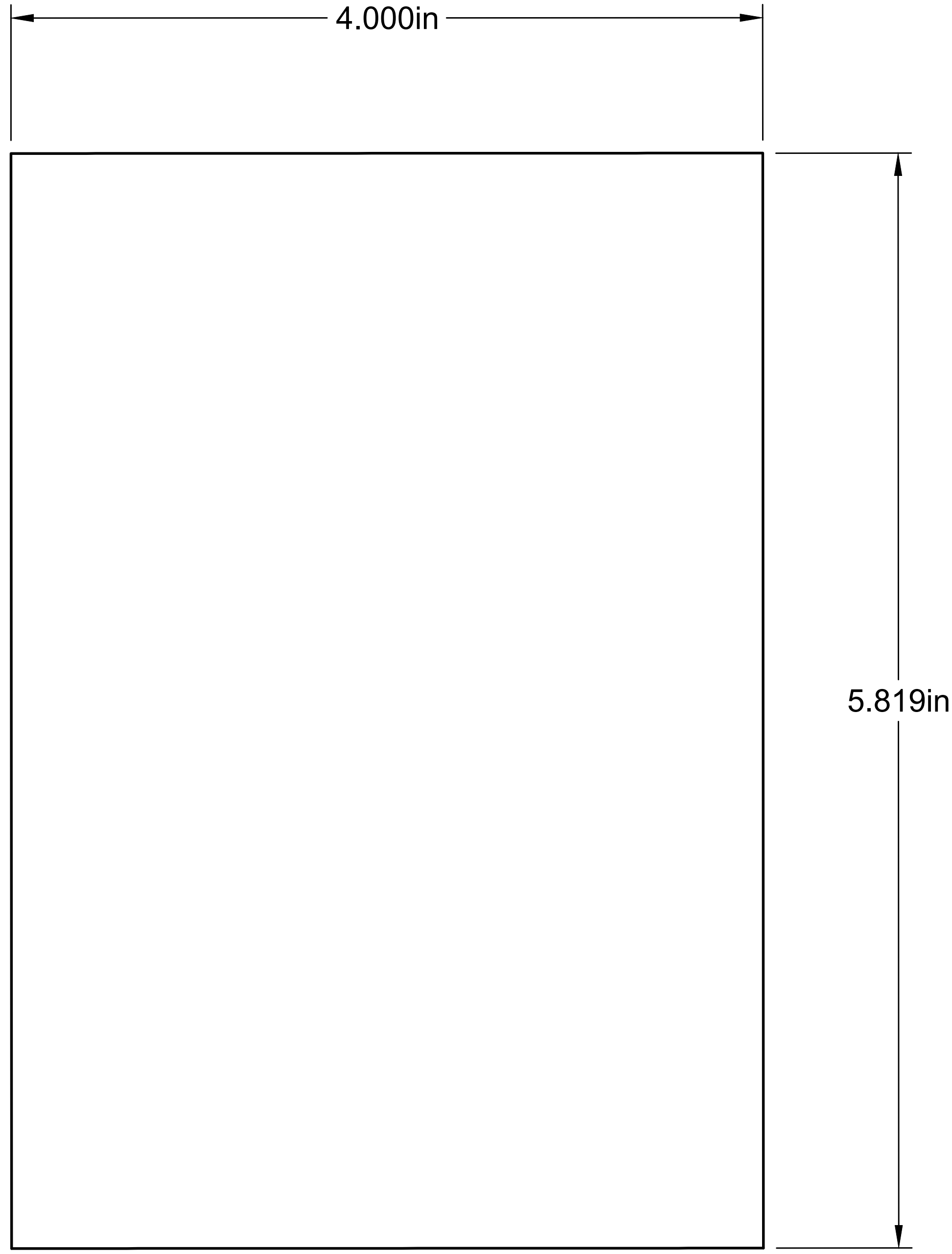


OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Nosecone Attachment bulkhead Top	SCALE 2:1	SIZE A
		SHEET 74/83	



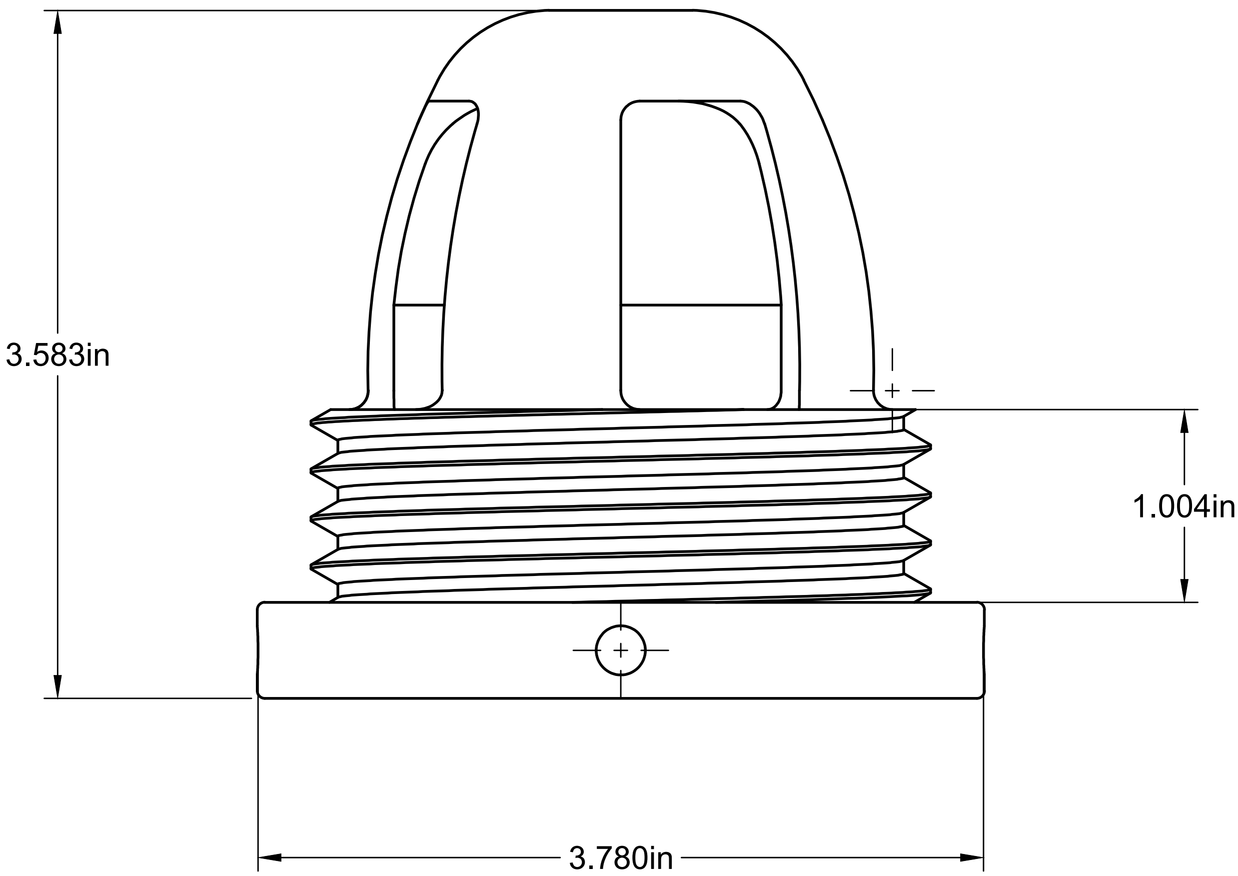
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI			
	TITLE Nosecone Attachment bulkhead front	SCALE	1:1	SIZE A
		SHEET	75/83	

OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI			
	TITLE Window	SCALE 1:1		SIZE A
		SHEET 76/83		



OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Window Front	SCALE 1:1 SHEET 77/83	SIZE A

OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Camera Holder	SCALE 1:1 SHEET 78/83	SIZE A



PROJECT

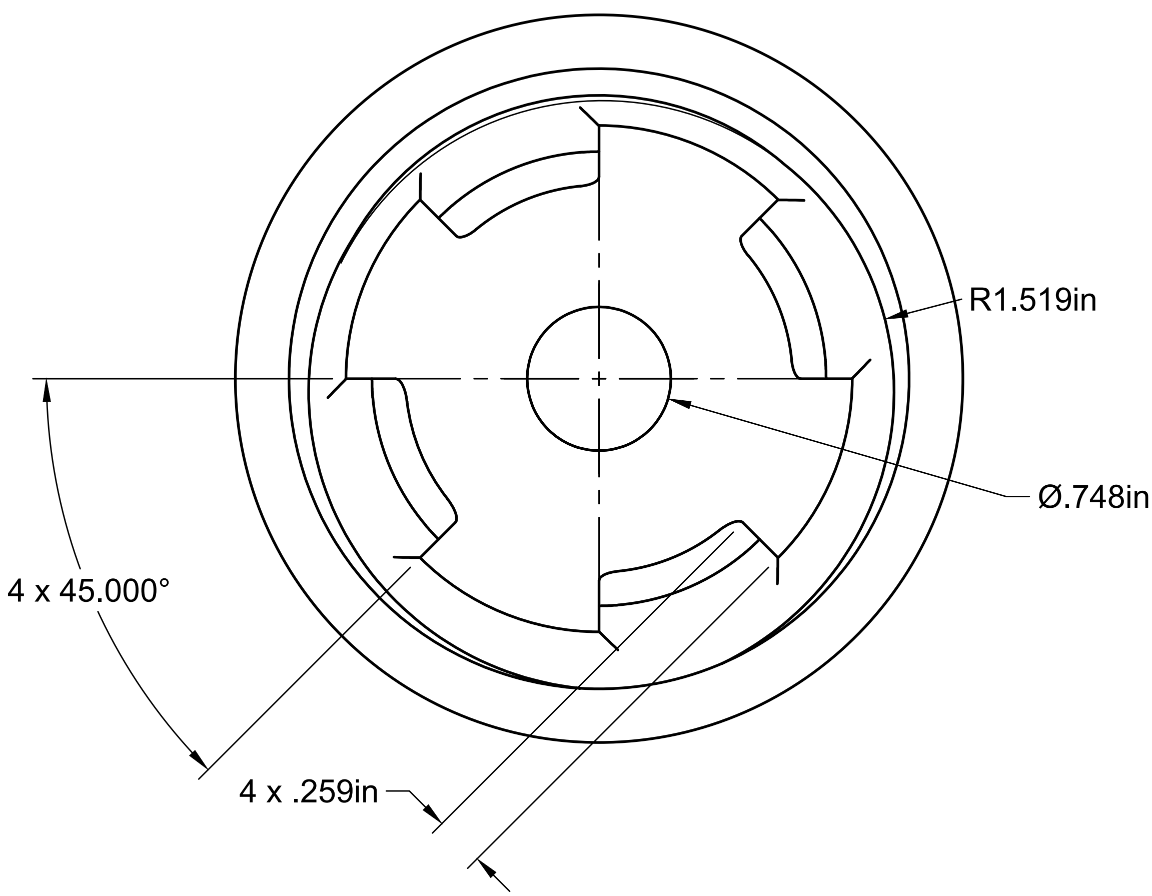
Oconee County High School 2025 NASA SLI

OCeng._1.PNG

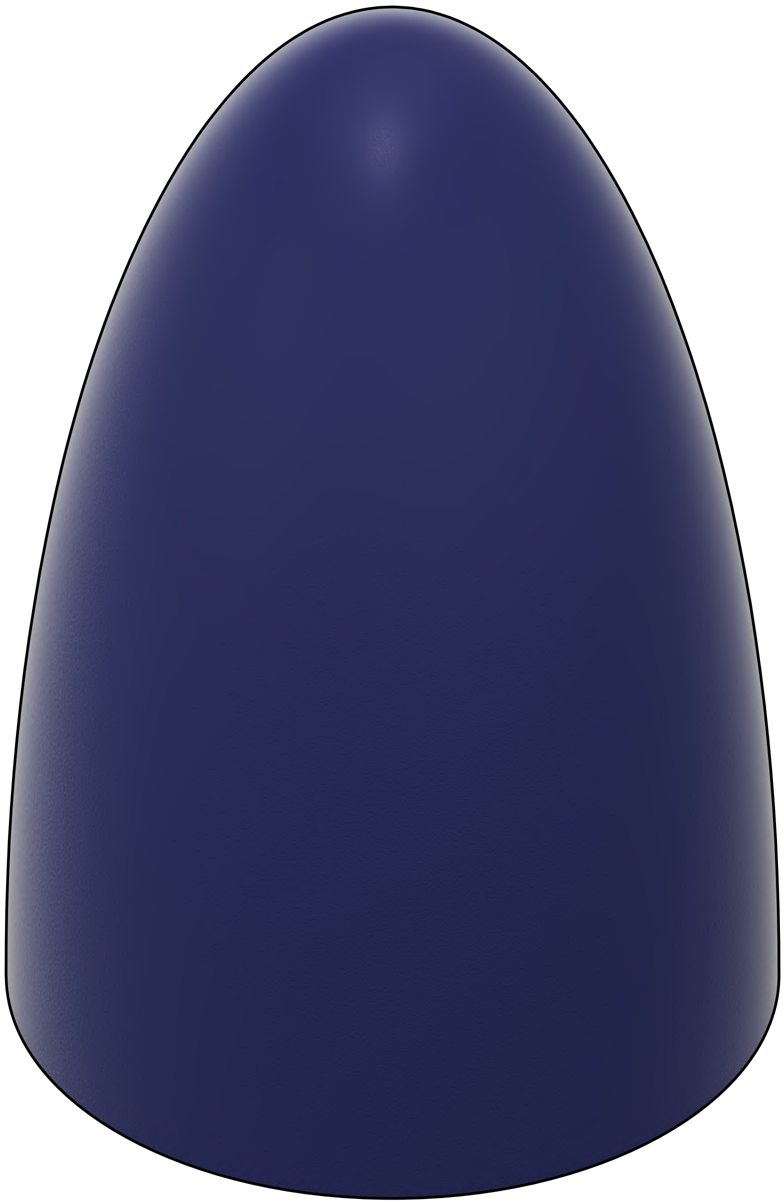
TITLE

Camera Holder

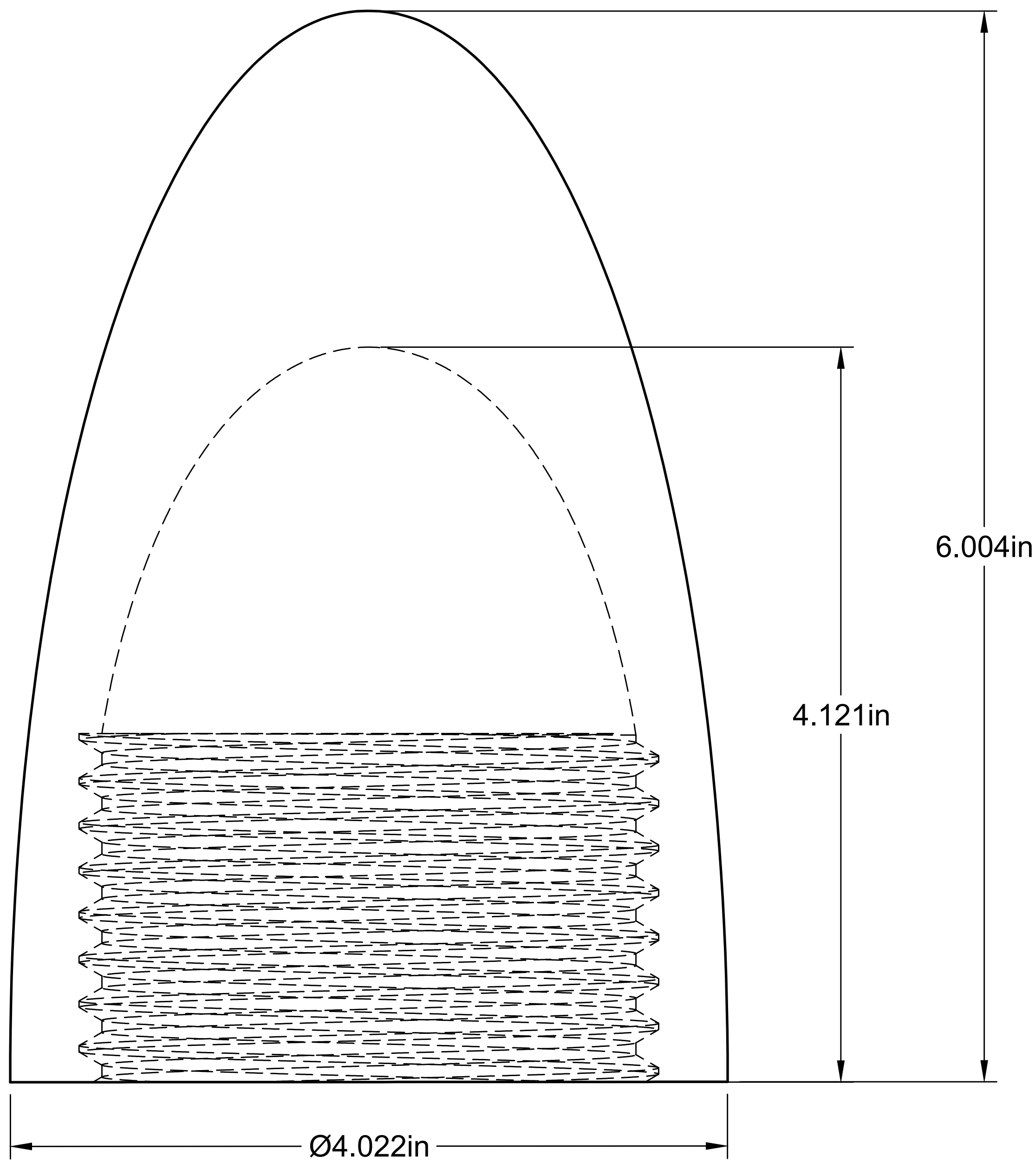
SCALE	1:1	SIZE	A
SHEET	79/83		



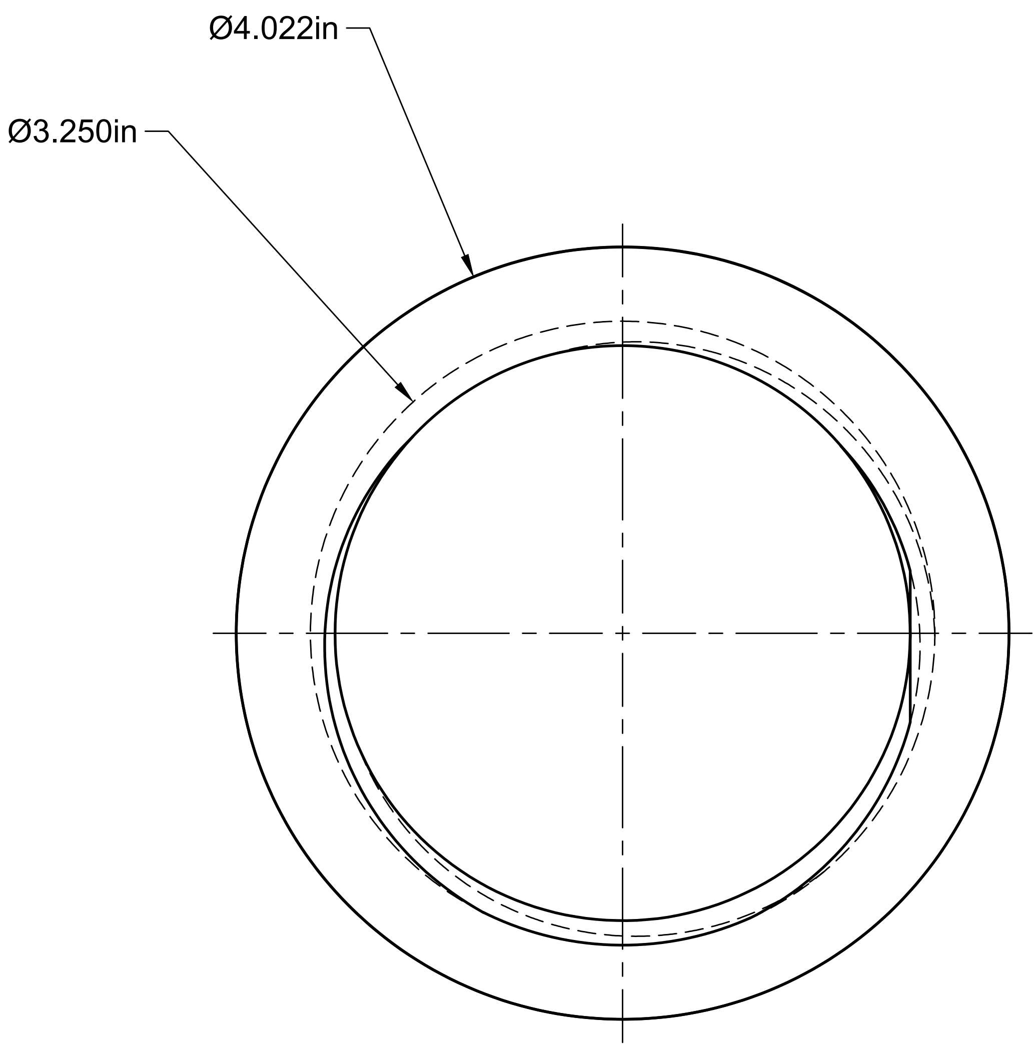
OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Camera Holder	SCALE 1:1	SIZE A
		SHEET 80/83	



OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Nose Cone	SCALE 1:1 SHEET 81/83	SIZE A



OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Nose Cone Front	SCALE 1:1	SIZE A
		SHEET 82/83	



OCeng._1.PNG	PROJECT Oconee County High School 2025 NASA SLI		
	TITLE Nose Cone Bottom	SCALE 1:1 SHEET 83/83	SIZE A