Stony Brook University
Mechanical Engineering

STUDENT LAUNCH COMPETITION

2018-2019 Proposal

September 19, 2018

Address:
Stony Brook AIAA Chapter
113 Light Engineering Building
Stony Brook, New York 11794-2300

Shaping the Future of Aerospace

Table of Contents

General Information

School and Project Information

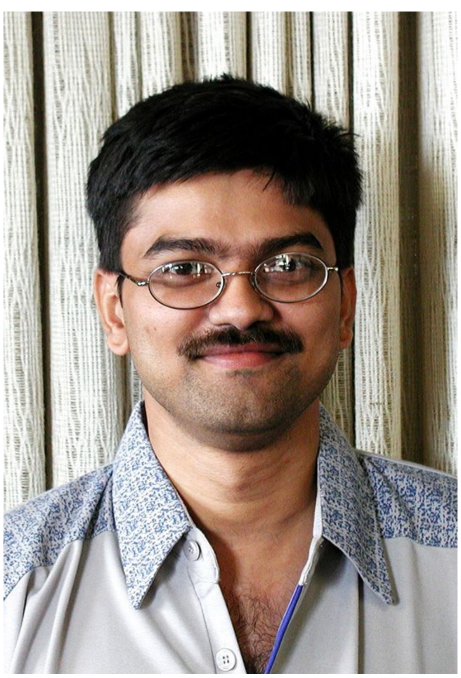
School Name:	University of Stony Brook
Supporting Organizations:	AIAA, Stony Brook University Chapter (AIAA-SBU) Long Island Advanced Rocketry Society (LIARS) Stony Brook Department of Mechanical Engineering
Location:	American Institute of Aeronautics and Astronautics College of Engineering and Applied Sciences 231 Engineering Building Stony Brook, NY 11794-2200
Project Title:	Seawolves Student Launch Competition

Faculty Advisors

Advisor Name: Dr. Sotirios Mamalis
Phone: (631) 632-8077
Email: Sotirios.Mamalis@stonybrook.edu

Dr. Sotirios Mamalis' research interests lie in the area of power generation and propulsion systems with an emphasis on internal combustion engines. His research focuses on the modeling of advanced combustion modes in engines, such as Homogeneous Charge Compression Ignition (HCCI), using conventional and alternative fuels, and development of physical models appropriate for powertrain simulation and analysis. Another of his interest areas is the thermodynamic analysis of propulsion systems using exergy concepts for identifying processes that promote efficient energy conversion.

Advisor Name: Dr. Nilanjan Chakraborty
Phone: (631) 632-9327
Email: Nilanjan.Chakraborty@stonybrook.edu



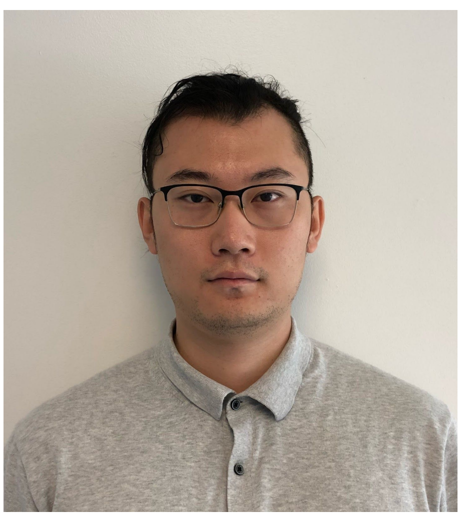
Dr. Nilanjan Chakraborty's research interests are in robotics, artificial intelligence, dynamical systems, and applied optimization. He is interested in developing capabilities for robots that will allow them to work robustly and reliably with or without human teammates and enable long-term autonomy in robotic systems. He specializes in developing contact dynamics-based algorithms for manipulation planning, robot motion planning, and distributed planning for multi-robot systems. He is a member of the IEEE Robotics and Automation Society and ACM.

Student Leadership

Name: Christos (CJ) Liopyros
Position: Student Team Leader, Outreach Team Leader, Safety Officer
Email: Christos.Liopyros@stonybrook.edu

CJ Liopyros is a senior pursuing a Bachelor's degree in Mechanical Engineering. He plans to pursue both work and graduate studies in the aerospace field upon graduation. CJ is currently president of Stony Brook University's chapter for the American Institute of Aeronautics and Astronautics (AIAA-SBU), and will be working to ensure that this project is used as a high-quality educational tool for students that are interested in aerospace.

Name: Jun (Albert) Yang
Position: Payload System Leader, Safety Officer
Email: Jun.Yang@stonybrook.edu



Albert Yang is currently a senior pursuing a Master's in Mechanical Engineering. He formerly served as a petty officer of the third class in the U.S. Navy. His interests lie in robotics design and internal combustion engines. He plans to pursue graduate study in these fields later on. He currently researches robotics with Professor Chakraborty.

Name: Yongxin (Jack) Guo
Position: Overall Design Leader
Email: yongxin.guo@stonybrook.edu

Yongxin Guo is a senior in mechanical engineering. He is interested in robotics and aerospace engineering. He has done research in robotics, serving as a technical advisor and a teaching assistant for two robotics courses. He also served as one of judges in his high school robotics competition. He has participated in the Reusable Abstract Manufacturing Process (RAMP) competition with his teammates and been selected as a finalist to present his work at the Manufacturing Science and Engineering Conference of 2018.

Name: Nicholas Lamberson
Position: Structures, Aerodynamics, and Propulsion Leader
Email: Nicholas.Lamberson@stonybrook.edu

Nicholas Lamberson is a senior pursuing a Master's in Mechanical Engineering. His interests lie in propulsion, computational methods, and thermofluids. He is currently a MEC and Physics tutor through the College of Engineering and Applied Sciences.

Name: Brayan Ruiz Arias
Position: Recovery and Navigation Leader, Website/Social Media Leader
Email: Brayan.RuizArias@stonybrook.edu

Brayan Ruiz Arias is currently a senior pursuing a Master's Degree in Mechanical Engineering. He has plenty of experience as an IT professional, from making web applications to setting up corporate computer networks. He is interested in CAD/CAM design, computer programming, and numerous topics in the thermofluids field.

Organizational Structure

The student launch team at Stony Brook University consists of nine core student members, four faculty advisors, and three professional advisors. The work will be broken down into three technical sections and two non-technical sections. These sections are as follows:

- Vehicle Structure, Aerodynamics & Propulsion (SAP)
- Recovery and Navigation (R&N)
- Payload (PAY)
- Website/Social Media Leader
- Outreach

A separate team will be in charge of each section. In total, three senior design teams are working on the project, each taking a different design section. Additionally, AIAA-SBU will host the Website Design & Outreach section. The breakdown of the organizational structure is shown in the image below.

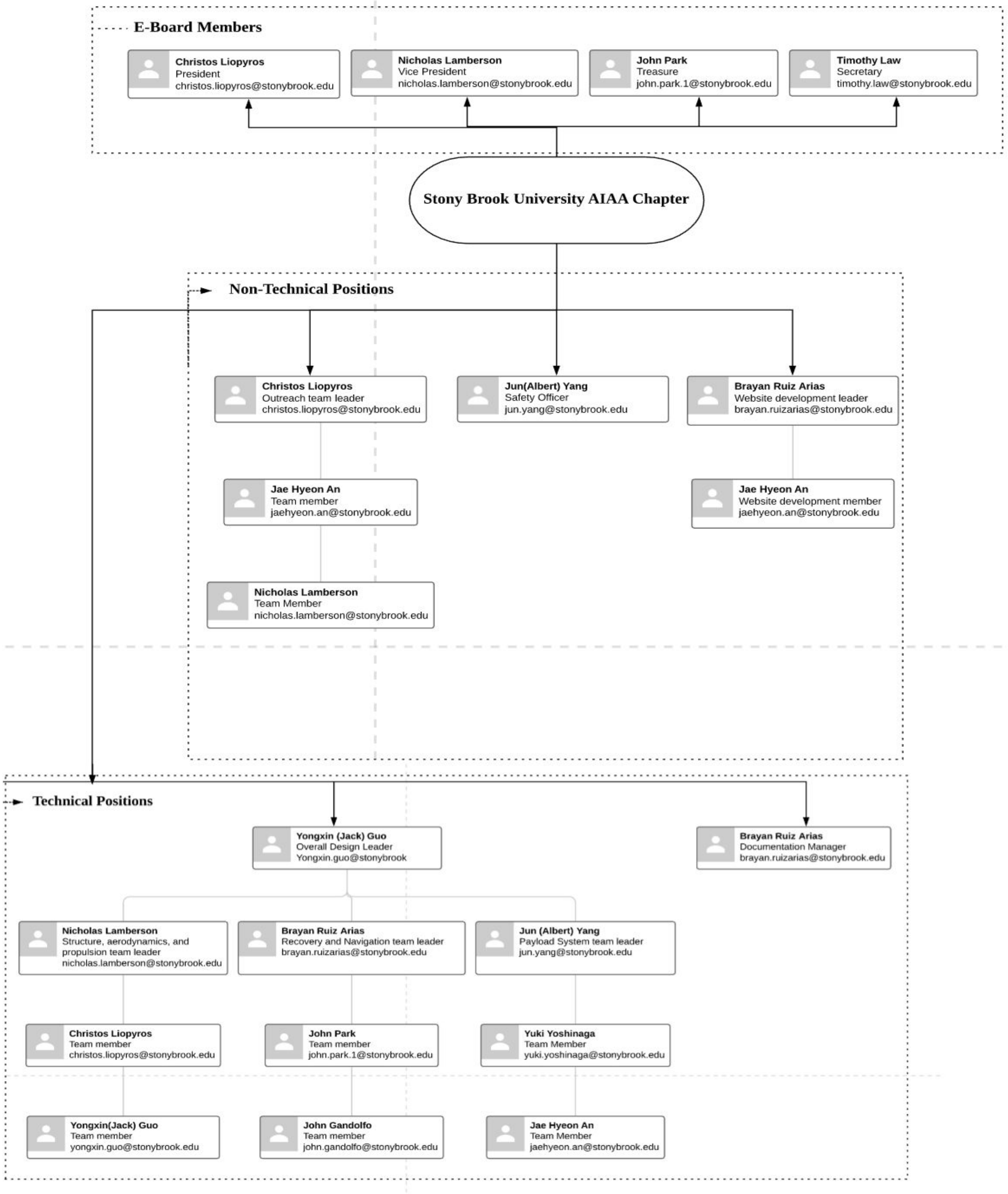


Figure 1: Graphical Representation of the Organization Structure

NAR and TRIPOLI Sections

The team intends to work with the following NAR/TRA sections:

Long Island Advanced Rocketry Society (LIARS)

National Association of Rocketry North Shore Section (NAR #142)
Tripoli Long Island, Prefecture #29

Contact Information

Dr. Brian S. Meyer
Email: drbriansmeyer@gmail.com
Level 2 Certification:
- TRA Member #2210
- NAR Member #9814

Responsibilities

Dr. Meyer will perform all the relevant duties of a certified mentor, including but not limited to general advising and review of the team's design ideas, the purchasing, handling, and safety of motors and black powder, and assistance with launch and testing setup.

Facilities/Equipment

There are multiple on-campus facilities for design work, performing analysis, building, and testing made available to the Seawolves competition team at Stony Brook University. These include the Engineering CAD Labs, SBU iCREATE Innovation Lab, Student Machine Shop, and Senior Design Lab. The team also has access to campus recreational fields, as well as Stony Brook's Research and Development Park for testing.

Engineering CAD Labs

The Engineering CAD Labs are two separate facilities owned and operated by the College of Engineering and Applied Sciences at Stony Brook University. The first lab contains 40 computers, the second 24. These computers provide the team with access to software for design and analysis, including but not limited to the SolidWorks CAD program, and multiphysics software such as COMSOL.

Hours of Operation

Monday - Thursday:	9:00 AM to 8:00 PM
Friday:	12:00 PM to 8:00 PM

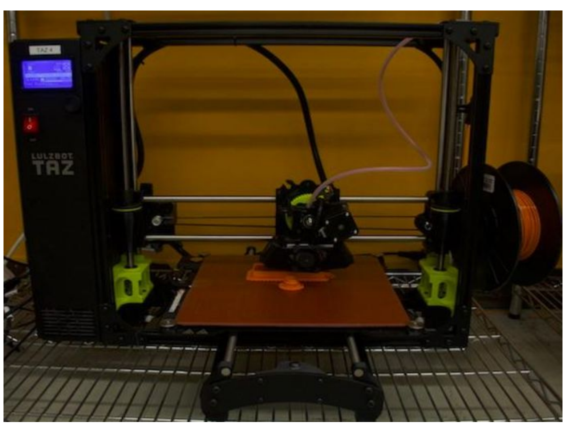
Figure 2: Images of the first (left) and second (right) engineering CAD Lab

SBU iCREATE Innovation Lab

The Innovation lab at Stony Brook University provides an environment designed to help bring different ideas and concepts to fruition. To this end, the lab offers a wide array of equipment for students to use free of charge; this includes soldering irons, supplies for creating electrical circuits, various paints, chemicals, miscellaneous tools, and wiring for computers. The lab also houses a variety of 3D printers which can be utilized for rapid prototyping of part designs. The types of printers available include a LulzBot Taz 5, Flashforge Creator Pro, Printrbot Simple Metal, as well as UP Mini printers.

Hours of Operation

Monday:	10:00 AM - 7:00 PM
Tuesday:	10:00 AM – 4:00 PM
Wednesday:	10:00 AM – 7:00 PM
Thursday:	10:00 AM – 4:00 PM
Friday:	10:00 AM – 4:00 PM



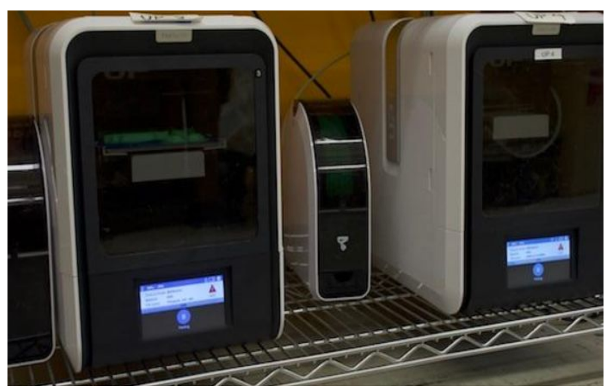


Figure 3: 3D printers at the Innovation Lab

Student Machine Shop

Located underneath the main engineering building at Stony Brook, the student machine shop is a location for qualified students to operate power tools and machining equipment. It has three rooms that students may access as long as they have a partner to work with and a supervisor is on the premises. The shop features lathes, milling machines, drill presses, bandsaws, CNC machines, welding equipment, and various power tools. Skilled machinists are available throughout the work week to assist with any academic or personal projects.

Figure 4: Images of various equipment from the student machine shop

Hours of Operation

All weekdays excluding Wednesday   10:00 AM - 3:00 PM

Senior Design Lab

Located underneath the main engineering building at Stony Brook, the senior design lab is a space allocated to students working on their senior design projects. The primary purpose of this lab is to help students store and assemble their projects. The equipment available at this location mainly consists of tables, chairs, hand tools, and necessary electrical equipment for testing. No work requiring personal protective equipment may be conducted in the senior design lab.

Figure 5: Senior Design Lab Workstation

Hours of Operation

This facility is accessible at all times by any senior student working on a design project, as long as he/she does not work alone.

Research and Development Park

A center located on the outskirts of the Stony Brook campus called the Research and Development Park supports researchers and corporations with regards to scientific research. It houses the Advanced Energy Research & Technology Center (AERTC), the Center of Excellence in Wireless and Information Technology (CEWIT), and the Rehabilitation Research and Movement Performance (RRAMP) laboratory. The entire center is about 1.5 km long and 0.5 km wide and houses the testing track for the motorsports team as well as the cross-country course. This facility will be used as a primary launch site for the subscale and main launches, pending approval from the Environmental Health and Safety department.

Figure 6: Google Maps snapshot of the Research and Development Park

Necessary Personnel

Name: Rafael Tejada
Occupation: Mechanical Laboratory Technician
Email: rafael.tejada@stonybrook.edu

Rafael Tejada is a Stony Brook University alumnus who, after working in industry and specializing in the fields of production and manufacturing management, came back to work for the Department of Mechanical Engineering as a Mechanical Laboratory Technician. Rafael is responsible for operating machinery that is crucial to manufacturing critical components of the launch vehicle. He also serves as a manufacturing consultant for the design team. Additionally, Rafael serves as the Director of the Senior Design Laboratory, teaches courses in manufacturing methods, and has also served on various university committees involving facilities and safety.

Software

Stony Brook University offers its students access to a vast array of software. The software necessary for this project is available to students either online, at one of the various computer labs at Stony Brook, or in the aforementioned engineering CAD labs. For this project, MATLAB will be utilized as the central computing environment. MATLAB can be accessed by students in the engineering SINC sites or on their personal machines through student licenses provided by the University. For CAD software, the team will primarily be using SolidWorks, which is available in the CAD Lab, and through SolidWorks' sponsorship of the AIAA-SBU student team. For Computer-aided engineering and analysis software, the Seawolves team will utilize COMSOL, OpenRocket, and ANSYS. COMSOL is available to all students at Stony Brook at the various sync sites, while OpenRocket and ANSYS are free to download for all students. These software packages will be used for conducting initial calculations for propulsion, fluid dynamics, and structural analysis.

Safety

Safety Officer Position & Duties

Safety Officer Position

The outreach team leader, Christos (CJ) Liopyros, and the payload team leader, Albert (Jun) Yang, will assume the duties and responsibilities of Safety Officer. The Safety Officers will work closely with the project team captain, subsystem leaders, NAR/TRA mentors, and the faculty advisors to ensure that safety is a top priority throughout all stages of construction and testing of independent systems, as well as the final launch.

Safety Officer Required Training

The Safety Officers will have detailed knowledge of NAR/TRA code for high power rocketry, NASA SL 2019 Safety Regulations, NFPA 1127 "Code for High Power Rocket Motors", Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C; "The handling and use of low explosives (Ammonium Perchlorate Solid Rocket Motors - APCP)", and the Code of Federal Regulation 27 Part 55: Commerce in Explosives; Fire Prevention. Also, the officers must be trained in the university facilities' laws compliance courses as outlined in the *University Facilities Laws Compliance* section. The officers must have a detailed knowledge of all the Material Safety Data Sheets (MSDS) for all materials and chemicals used. The officers must have a detailed knowledge of safety regarding the handling and mounting the motors and the ejection charges from manufacturers' manuals. The officers must have detailed instruction on how to safely build and setup level 2 rockets on launch pads from the available literature.

Safety Officer Responsibilities

- Ensuring clear and effective communication to all team members of all safety guidelines.
- Reviewing the detailed design of the launch vehicle to avoid and to minimize any potential risk.
- Updating, maintaining, and organizing all safety-related documentation which includes but is not limited to the following:
    - Chemical and machinery hazard checklist
    - Ground safety checklist
    - Flight safety checklists
    - Launch procedures
    - FAA/Local/University safety laws
    - NAR/TRA safety laws

    - Team members signed safety agreements
    - MSDS of all chemicals used
    - Safety violations history
    - Hazard analysis
    - FMEA (Failure Modes and Effects Analysis)
    - Any other documents pertaining to the explanation and guidance of safety
- Facilitating the NAR mentor in the writing of ground safety checklists, flight safety checklists, and launch procedures in conjunction with team leaders.
- Ensuring all team members comply with NAR safety guidelines throughout all project stages.
- Conducting safety briefings with team members before launches and ground tests.
- Facilitating the NAR mentors in planning to purchase, transport, and store solid motors and black powder ejection charges in compliance with NAR/FAA regulations.
- Analyzing hazard mitigations and establishing FMEA in conjunction with team leaders to identify and mitigate failure modes including but not limited to safety.
- Provide training to all team members and ensuring that all team members fully understand all safety documentation and comply with all safety guidelines.
- Ensuring that all team members wear proper personal protective equipment (PPE) before working in the workspace.
- Ensuring appropriate procedures are enforced when safety violations occur.

Safety Laws and Compliance

NAR Safety Code Compliance

No.	NAR Code	Compliance
1	**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.	Only the NAR mentor, Brian Meyer, is permitted to purchase, store, and handle rocket motors.
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 SAP, R&N, and PAY teams are responsible for using suitable and appropriate materials on the rocketry system, to satisfy this requirement.
3	**Motors**. I will use only certified, commercially-made rocket motors and will	Only certified motors, from Aerotech or Cesaroni will be permitted for purchase.

	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.	Only personel with NAR/TRA level 2 certification will be allowed to purchase, store, and handle high-powered rocket motors.
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.	The Range Safety Officer will have the final say in determining all safety issues. The NAR mentor, team Safety Officers, and the Propulsion team will ensure that the motor igniters are properly installed and that all procedures are followed in compliance with the NAR Safety Code.
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.	All team members will be responsible for meeting this requirement and any further instruction given by the Range Safety Officer during misfires. The Range Safety Officer will have the final say on all misfires.
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 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 team will not fly the rocket until the NAR mentor has reviewed the design, examined the build, and is satisfied with regards to established amateur rocketry design and safety guidelines. Members will also be responsible for meeting this requirement and any further instructions given by the Range Safety Officer during launch. The team leaders will be accountable for determining the stability during launch.

	the additional requirements of NFPA 1127.	
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 from 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.	All team members will be responsible for meeting this requirement and any further instructions given by the Range Safety Officer during launch. Rockets motors are not allowed to expel titanium sponges for the 2019 NASA Student Launch Competition.
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.	SAP is responsible for meeting this requirement.
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.	All team members will be responsible for complying with this requirement. The Range Safety Officer will have the final say on wind speed and direction and rocket launch direction.
10	**Launch Site.** I will launch my rocket outdoors, in an open area where trees,	Location of launch sites for flight testing will be determined in association with

	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).	LIARS, in compliance with FAA/NAR/Local laws for test launches. The Range Safety Officer will have the final say in determining whether it is safe for launching. No other launch sites will be allowed.
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.	Location of Launch sites for flight testing will be determined in association with LIARS, in compliance with FAA/NAR/Local laws for test launches. The Range Safety Officer will have the final say in determining whether it is safe for launching. No other launch sites will be allowed.
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 NAR mentor, with the help of the R&N team, will be responsible for the safe flight and recovery of the launch vehicle. Safety checklists will be used by the R&N team during the integration of the recovery system to ensure compliance of safety code during launch day. The Range Safety Officer will have the final say.
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.	All team members will be responsible for meeting this requirement and any further instructions given by the Range Safety Officer during launch.

Table 1: NAR Safety Code Compliance

Local/FAA/State Laws Compliance

The Stony Brook university team will only conduct tests or launches at locations that are in compliance with all state, local, and FAA regulations. The team has reviewed all regulations regarding unmanned rocket launches and motor handling, including Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C, Amateur Rockets, Code of Federal Regulation 27 Part 55: Commerce in Explosives; and fire prevention, and NFPA 1127 "Code for High Power Rocket Motors." If the launch site does not already have official FAA waivers to launch, the team will consult with members from the LIARS to obtain the necessary documentation for flight. The Stony Brook Rocket team will abide by all rules set forth by the launch site host. The team will not launch in hazardous weather conditions and will consider wind and local visibility before all flights. No vehicle will be launched that is expected to exceed the maximum apogee granted by the waiver for the launch.

University Facilities Laws Compliance

Stony Brook University offers numerous courses for which a passing grade grants permission to work in machine shops, handle hazardous chemicals, and perform other tasks with potential dangers. The courses that a student must pass to participate in the rocket project are listed below. A physical copy of proof of a passing grade for each course is required by each team member.

- EOS 029 - Machine Shop Safety (Must be taken every 5 years)
- ENV 001 - Hazardous Waste (One-time training)
- ELS 002 - Lab Chemical Safety (One-time training unless means of generating waste changes.)

Risk Analysis

Safety Meeting

The safety meeting will be held with all team members and the NAR mentor. The mentor and the safety officers will brief all team members on hazard recognition, accident avoidance as well as the mitigation. The team members will also be informed on the use and purpose of each material for the project. Personnel with experiences will demonstrate to the team members of proper ways of handling the materials. If any hazardous material is involved with any work, members must consult with the MSDS before participating in the work. The Safety Officers will ensure that, depending on the nature of the work and the hazardous materials that are involved, each task may only be conducted in the designated working facilities (such as the SBU iCREATE Innovation Lab, Student Machine Shop, Senior Design Lab), and that the proper PPE, personal protective equipments (such as gloves, respirators, goggles, etc.) is provided to the working facilities. Members who are not equipped with appropriate PPE will not be allowed to work in the working stations.

Safety Pre-Launch Briefing

The Pre-Launch Briefing is to be conducted by the Safety Officers and the project mentor with participating team members before to the launches and ground tests. The Pre-Launch Briefing covers the detailed safety procedures and rules affiliated with the launch site, the NASA SL Safety Regulations, the High-Powered Rocketry TRA Code, our goals for the launch, and launch procedures. The Pre-Launch Briefing serves as a reminder to all participating team members of the safety regulations and rules, restating that all warnings are final and any member who misbehaves is not allowed to participate in the launch and subject to be ejected from the launch site.

Motors and Black Powder

Only the NAR/TRA certified mentors are permitted to purchase and handle motors and black powder. The mentor will ensure that all ejection charges will be safely stored and that the ejection charges will not be exposed to any heat or ignition. The mentor will also ensure that the motor is maintained in the original package, remained disassembled before the immediate launch and at temperature ranges out of 45 F^{o} to 100 F^{o}. The motor and the ejection charges will only be stored and transported in LIARs facilities that satisfies the above safety requirements.The Safety Officers will work closely with the mentor to identify any potential risks and ensure safety throughout the handling of motors and black powder. The specific black powder that the Recovery & Navigation team deems acceptable will be identified in the near future.

Hazardous Materials

Fiberglass and Carbon Fiber

Materials like fiberglass and carbon fiber must be approached cautiously when considering any modifications such as drilling or sanding. The small fibers that are produced from any such modification can cause harm in several ways, including but not limited to rashes if fibers come in contact with the skin, irritation in the eyes if exposed to fibers, soreness in the nose and throat if fibers are inhaled, aggravation of asthma and bronchitis if fibers are inhaled, and irritation in the stomach if fibers are swallowed. It is the responsibility of the Safety Officers to ensure that members who intend to modify fiberglass or carbon fiber are prepared to use the appropriate personal protective equipment (PPE), like safety glasses and respirators. Any work done with these materials should be conducted in a well ventilated area to minimize safety risks[1].

Hazardous Chemicals

Those responsible for the structure of the rocket anticipate the use of chemicals like epoxy resin and hardener, acetone, Bondo body filler, and mold releases in the construction of the launch vehicle. Exposure to such chemicals has the potential to cause harm in ways similar to that of fiberglass and carbon fiber, such as irritation of the skin, eyes, and respiratory system. The Safety Officers is responsible for storing, updating, and maintaining the Material Safety Data Sheets (MSDS) for all chemicals in the team's Safety folder, located in the overall Project Folder of the Seawolves team Google Drive, where every member will have access to this information. Similar to the previous section, the Safety Officers will be responsible for ensuring that those who intend to use chemicals are equipped with the appropriate PPE. Any usage of chemicals should also be done in a well ventilated area.

Hazard Analysis(Risk Matrix)

Potential risk and hazard in the project events will be mitigated by utilizing the Risk Assessment Code(RAC) developed by Industrial Safety Bastion Technologies. The RAC table is shown below:

Probability	***Severity***			
	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 2: Risk Assessment Code (RAC)

Risk Level

[1] "Environmental Health Factsheets: Fiberglass." Division of Environmental Health, Illinois Department of Public Health, http://www.idph.state.il.us/envhealth/factsheets/fiberglass.htm.

High risk
Moderate risk
Low risk
Minimal risk

Table 3: Risk Level Color Code Scheme

Description	Personal Safety and Health	Facility/Equipment	Environmental
1 Catastrophic	*Loss of life or a permanent disabling injury.*	*Loss of facility, systems of associated hardware.*	*Irreversible severe environmental damage that violates law and regulation.*
2 Critical	*Severe injury of occupational related illness.*	*Major damage to facilities, systems, or equipment.*	*Reversible environmental damage casing a violation of law or regulation.*
3 Marginal	*Minor injury or occupational related illness.*	*Minor damage to facilities, systems, or equipment.*	*Mitigatable environmental damage without violation of law or regulation where restoration activities can be accomplished.*
4 Negligible	*First aid injury or occupational related illness.*	*Minimal damage to facilities, systems, or equipment.*	*Minimal environmental damage not violating law or regulation*

Table 4: Definitions of Severity

Description	Qualitative Definition	Quantitative Definition

A-Frequent	*High likelihood to occur immediately or expected to be continuously experienced.*	Probability > 0.1
B-Probable	*Likely to occur to 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.*	0.001 ≥ Probability> 0.000001
E-Improbable	*Very unlikely to occur and an occurrence is not expected to be experienced within time.*	0.000001 ≥ Probability

Table 5: Definitions of Probability

Hazard	**Cause**	**Effect**	**Pre-RAC**	**Mitigation**	**Post-RAC**
Injury from high power machinery	*Lack of experience, knowledge of utilizing machinery, tiredness, etc.*	*Death or severe personal injury*	**1C**	*Training all personnel through completion of EOS029-Machine Shop Safety.* *Not overworking members.* *Allowing frequent breaks.* *Abiding safety agreement.*	**1E**
Injury from chemical	*Chemical Spills, Contact with eyes, Fume inhalation, etc.*	*severe personal injury*	**1B**	*Reading and understanding MSDS.* *Abiding safety agreement.*	**1E**
Injury during handling motor and black powder	*Lack of experience, knowledge of handling motors and preparing black powder ejection charges, etc.*	*Death or severe personal injury*	**1C**	*Allowing only NAR certified personnel to handle motor and black powder.* *Abiding safety agreement*	**1D**
Injury from during launch	*Failing to appropriately utilize flight checklists. Bystanders unaware of safety*	*Mission failure. Severe personal injury.*	**1A**	*Attending and abiding by instructions during pre-launch briefings.* *Attention to detail while following flight checklists and launch procedures*	**1E**

	procedures				
Injury during ground testing	*Failing to appropriately utilize ground checklists.Bystanders unaware of safety procedures*	*Mission failure. Severe personal injury.*	**2A**	*Attention to detail while following flight checklists. Performing FMEA for mission critical systems.*	**2E**

Table 6: Example of Hazard Risk Analysis Matrix

The Hazard Risk Analysis Matrix, shown in Table 6 will be used. And further risk and hazards, if identified, will be analyzed and added.

Failure Mode & Effects Analysis (FMEA)

FMEA serves as a Hazard Analysis tool to identify, predict, prioritize and mitigate failure modes including but not limited to safety in all stages of the project. The effects of failure modes corresponded with all mission-critical systems can be quantified with the FMEA. The FMEA tool is still being developed, however, the format will be similar to the following:

Team name:				**System Description:**		**System type:**		**FMEA date:**	
process /Procedure step location	**Potential failure modes**	**Potential causes of failure**	**occurrence**	**Potential effects of failure**	**severity**	**Individuals responsible for system**	**Mitigation action taken**	**occurrences**	**severity**

Table 7: Example of FMEA format.

The format shown in Table 7 is modeled based on "Standard for Performing a Failure Modes and Effects Analysis" by NASA Goddard Space Flight Center.

Team Safety Tools

Safety Checklists

Ground Safety Checklist

The safety officers are responsible for organizing, maintaining, updating the Ground Safety Checklist while coordinating with each of the team leaders. A Safety Officer approved checklist will be required before any fabrication of parts, assembly, or ground testing of each sub-system.

Safety Agreement

As a contract between team members and AIAA-SBU, the safety agreement will bind each of the team members participating in the project to the following requirements. As stated in the agreement, all team members are required to read, understand and abide by all requirements put forth by this agreement. The signed agreements will be documented and maintained by the Safety Officers. The safety agreement is shown below:

I_____________ abide to the following safety requirements and rules mentioned in this document and understand that I will not be able to work on the fabrication and launch phases of the project until doing so.

1. I agree to read, understand and abide by following regulations:
    i) NAR/TRA code for high power rocketry
    ii) NASA SL 2019 Safety Regulations
    iii) NFPA 1127 "Code for High Power Rocket Motors"
    iv) Federal aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C ;" The handling and use of low explosives (Ammonium Perchlorate Solid Rocket Motors -APCP)", Code of Federal' Regulation 27 Part 55: Commerce in Explosives; Fire Prevention.
    v) University Facility Laws (EDS 029 - Machine Shop Safety, ENV 001- Hazardous Waste Training, ELS 002-Lab Chemical Safety)
2. I agree to attend all contribute, read, understand and abide by all ground safety checklists (during ground testing and assembly) and flight safety checklists (during pre-launch assembly).
3. I agree to read, understand and follow MSDS of any chemicals I will be using.
4. I agree to attend, understand and follow the requirements highlighted during safety briefings
5. I agree to notify the safety officers of any concerns over any safety issues.
6. I agree to abide by the following requirements as highlighted in NASA SL 2019 document,
    i) Range Safety Inspection of each rocket before it is flown. Each team shall comply with the determination of the safety Inspection at may be removed from the program.
    ii) The Range Safety Officer has the final say on all rocket safety issues. Therefore, the Range safety officer has the right to deny the lunch of any rocket for safety reasons.
    iii) Any team that does not comply with the safety requirement will not be allowed to launch their rocket.

I understand that violation of any of the mentioned requirements will result in disciplinary action. I understand it is my responsibility to read, understand and abide by all of the requirements put forth by this agreement.

Printed Name_____________________ Date:_____________________

Figure 7: Team member safety agreement

Launch Operations Checklist

To cope with an increased risk associated with project participants as well as the mission success, the Launch Operation Checklist will include the instructions for final assembly, which increases the attention to safety by highlighting the mission-critical components.The team leaders of each team is responsible for ensuring that all respective team members adhere to the checklist requirements. The safety officers will only initiate the launch after receiving a clear verbal confirmation sign "go" from each team leader.The safety officer will make sure the requirement for the checklist is included during the pre-launch briefing.

The general format of the ground safety checklist is as follow:

1) List of Equipments with indications of hazard and risk level
2) Proper PPE required for each Equipment
3) Identify and highlight failure modes from procedures and associated consequences, which is to be identified with the sign below:

RISK!

4) Identify and highlight explosives, high voltages, and other high risk action including instructions on how the danger can be handled. The symbol used to identified high risk as shown below:

Danger!

Senior Design Laboratory and Safety Rules

Laboratory Safety

Every effort must be made by all who work in such a manner as to ensure safe and efficient utilization of the workspace. The following rules apply for the benefit of all concerned.

1. Observe the “Buddy System.” No student is permitted to work alone in a laboratory.
2. Students are responsible for the cleanliness of the laboratory. Students must clean work areas. Equipment issued for laboratory use must be returned at the close of the laboratory period.

3. Students will be held financially responsible for any breakage or damage due to their own negligence or abuse. Do not modify or change any of the laboratory equipment without the permission of the Lab Manager as the student shall be held financially responsible.
4. Smoking, eating/drinking, or unruly behavior is prohibited in all laboratory areas. Unruly behavior is defined as acting in a manner that might produce unsafe conditions.
5. Stay aware of everyone in lab. Students must observe general safety precautions. Safety hazards should be reported to the Lab Manager as soon as possible.
6. Proper attire is required at all times in the laboratory. This includes but is not limited to:
    a. Only closed-toed shoes.
    b. No loose fitting clothing.
    c. No exposed jewelry of any kind.
    d. No exposed skin below the waist.
    e. No clothing below the elbow on the arms.
    f. Long hair (shoulder length or longer) must be tied up and secured.
7. Students must have taken and passed the EH&S safety courses EOS 029, ELS 002, and ENV 001. Students must provide a printed record to the Manager. This must all be done by each and every member of a lab group before the commencement of work.
8. Only work on assigned workstations. Do not tamper with the materials or project of another group.
9. Report any accidents or injuries to the Lab Manager immediately. In the event of an emergency see “For an Emergency” poster.
10. No power tools of any kind can be used in this laboratory.
11. Laboratory access may be revoked at any time due to inappropriate conduct at the sole discretion of the Lab Manager. Access revocation may be individual or group based, at the Lab Manager’s discretion.

For an Emergency

For an Emergency, Dial (631) 632-3333 on any cell phone or 2-3333 from a university phone.

1. **Nearest Telephone**: Located in the Lab
2. **Nearest Fire Extinguisher:** Located in the Hallway
3. **Nearest First Aid Box:** Located in the Lab

Evacuation plan:

1. **Primary:** Exit the laboratory, ascend the south stairwell to the vestibule level, and exit the building on the east side. Meet next to the Engineering Drive bus stop.
2. **Secondary:** Exit the laboratory, ascend the north stairwell, and exit the building on the north side. Meet next to the Campus Drive bus stop.

Technical Design

Structure

Overall View of the Rocket

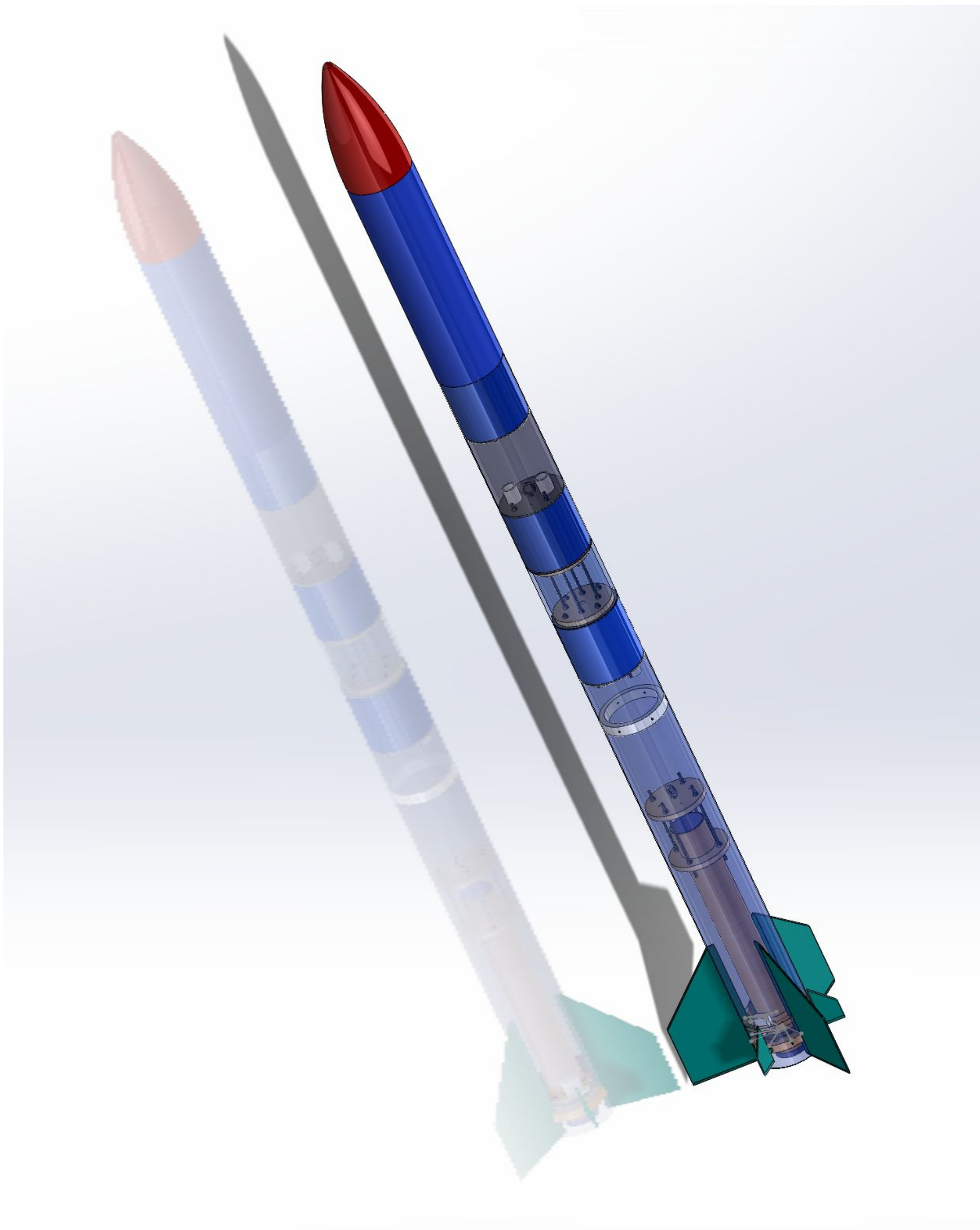


Figure 8.1.1 : Full Assembly of Rocket in SolidWorks

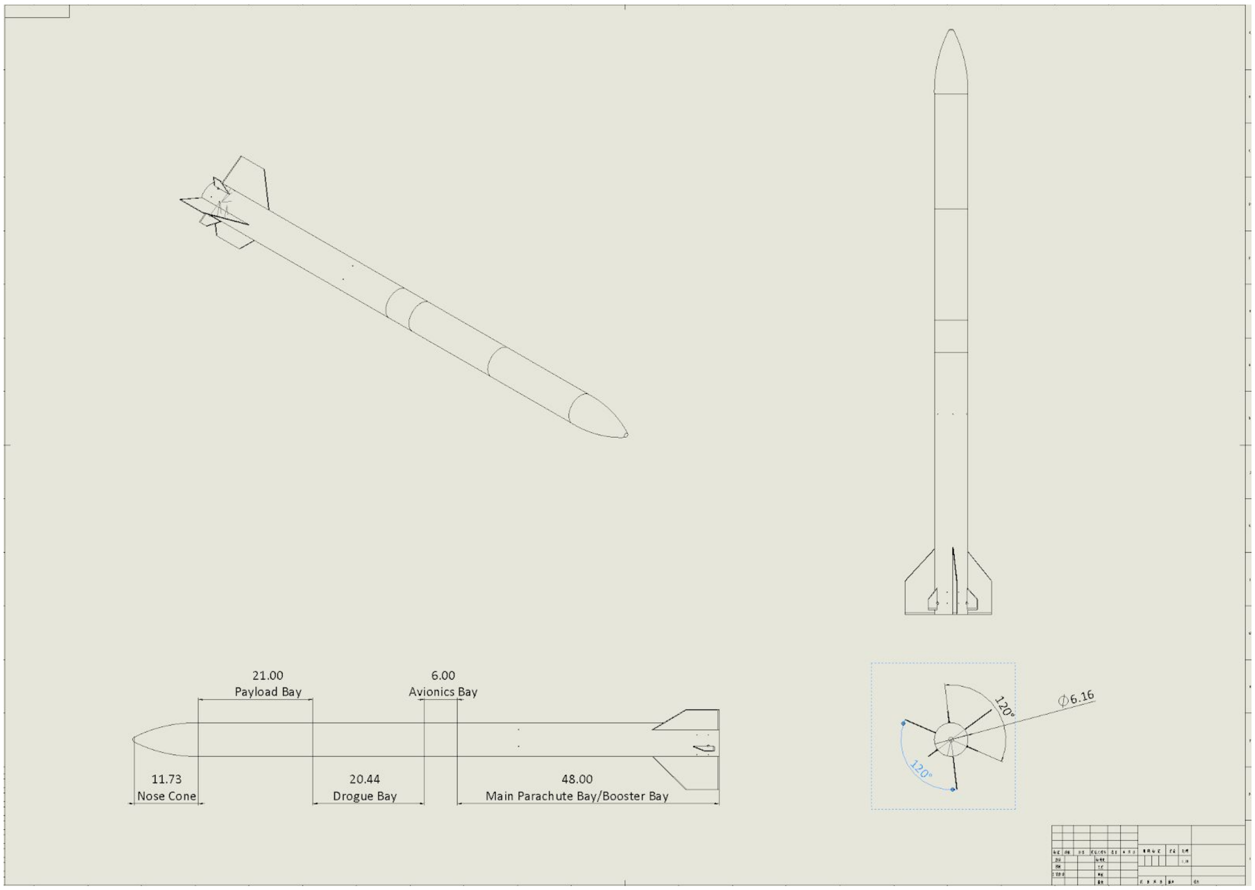


Figure 8.1.2: CAD Drawing of Full Rocket Assembly

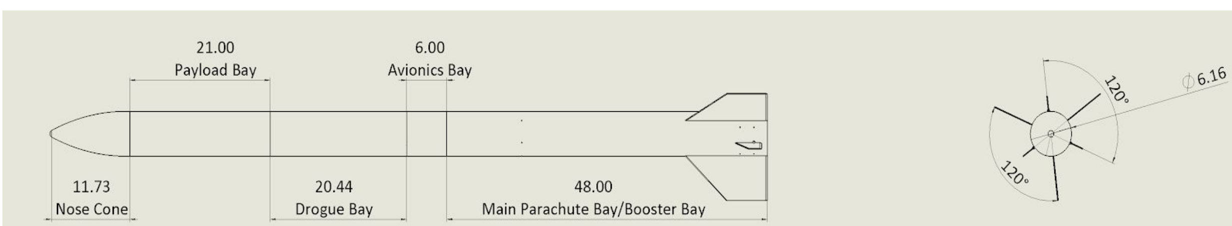


Figure 8.1.3 Overall size of the Rocket.

Nose Cone

Since the nose cone is the most crucial part of a rocket, we selected a design that would minimize the drag experienced by the rocket. A conical nose cone shape is not necessary for the scope of this project, as we are in the subsonic region, so a spherically-blunted tangent ogive design was chosen. The dimensions were chosen based off of rocket diameter and desired characteristics. The chosen material for the nose cone is PLA plastic as it decreases manufacturing costs and 3D printers are readily available. The nose cone is defined by several factors such as, fineness ratio and bluntness ratio. The fineness ratio represents the ratio of nose cone length to the base diameter. The fineness ratio is calculated as follows:

$$FR = \frac{L_{nose}}{D_{base}} \qquad \text{Equation [1.1]}$$

where:

L_{nose} = length of nose cone
D_{base} = Base Diameter

The optimal fineness ratio is determined to be 5. The bluntness ratio is calculated as follows:

$$BR = \frac{R_{nose}}{R_{base}} \qquad \text{Equation [1.2]}$$

where:

R_{nose} = radius of spherical tip
R_{base} = radius at the base of the nose cone

The optimal bluntness ratio is determined to be 0.15.

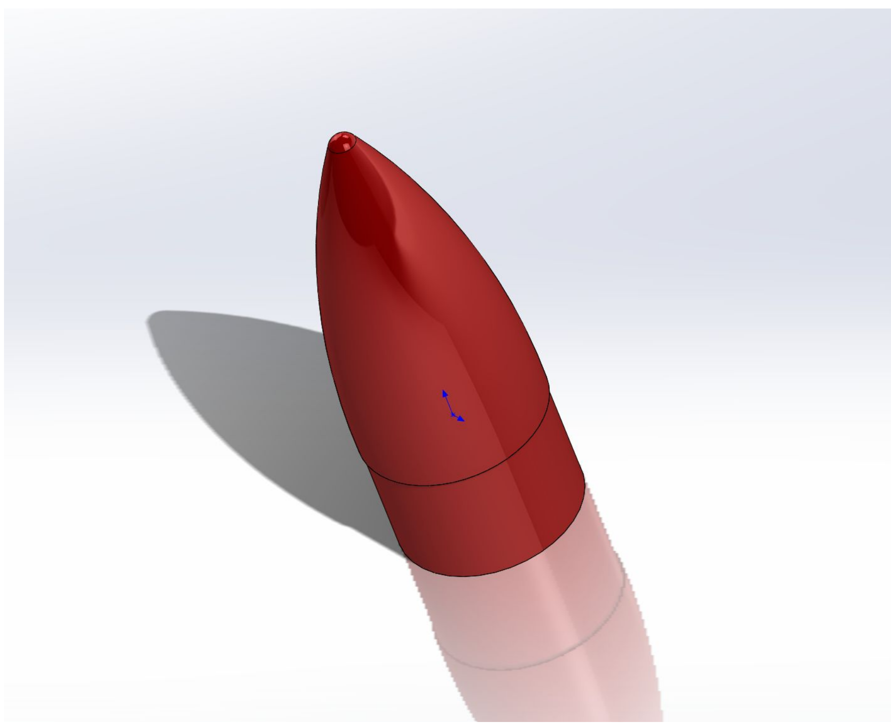


Figure 8.2.1: Perspective View of Nose Cone

Figure 8.2.2: Side View of Nose Cone

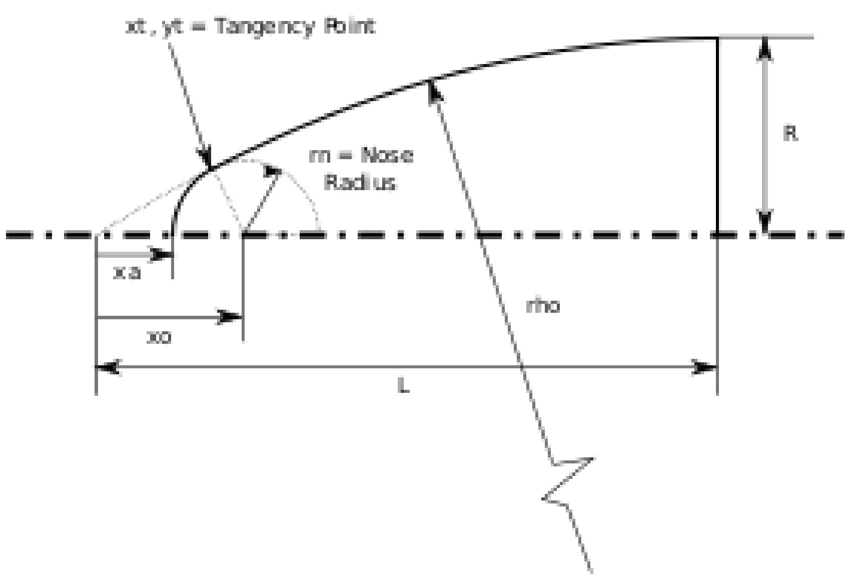


Figure 8.2.3: Design Schematic of Nose Cone

The dimensions of the nose cone were determined from the schematic depicted in Figure 8.2.3. The center of the spherical nose cap, x_0, can be found from:

$$x_0 = L - \sqrt{(\rho - r_n)^2 - (\rho - R)^2} \qquad \text{Equation [1.3]}$$

where:

L = length of nose cone
ρ = ogive radius
r_n = nose radius
R = base radius

The tangency point where the sphere meets the tangent ogive can be found from:

$$y_t = \frac{r_n(\rho - R)}{\rho - r_n} \qquad \text{Equation [1.4]}$$

$$x_t = x_0 - \sqrt{r_n^2 - y_t^2} \qquad \text{Equation [1.5]}$$

Finally, the apex point can be found from:

$$x_a = x_0 - r_n \qquad \text{Equation [1.6]}$$

Payload Bay

Payload Bay is a compartment that protects and fixes the payload, in this case the UAV, and located between the nose cone and drogue parachute bay. The fiberglass material will be selected for the airframe of payload bay. Nylon shear pins will be mounted between the nose cone and the payload bay in order to ensure a dynamic relationship when ejection charge initiates for deploying the UAV after landing, while a coupler, which is made out of fiberglass and woods, will be employed to connect the lower body of payload bay to the drogue parachute bay. The two ends of the coupler that go into the payload bay and drogue bay will be equal to one diameter length, which is 6 inch, according to the rules of thumb for providing enough surface area to withstand the stress at the conjunction point.

$$L_{half\ coupler} \geq D_{in} \qquad \text{Equation [2.1]}$$

The coupler will be built by integrating the woods plate, fiberglass plate and 3D-printed outer shells, and the threaded rods and the hex nuts will provide sufficient clamping force to make it stick to one piece.

Six flat screws will be threaded through the airframe and coupler to ensure a stable configuration that can sustain the amount of shear force generated during the dual deployment of nose cone deployment. The upper bulkhead of the coupler can also serve as an advantage in fixing the payload system, which will have the following systems onboard.

Payload (Unmanned Aerial Vehicle) System	
Sub-systems	Functionality
Autonomous Reorientation System (ARS)	Re-orientate the payload compartment for proper deployment position
Deployment Delivery System (DDS)	Lead screw driven mechanism for linearly delivering the UAV
Self-detached Releasing System (SRS)	Gear driven releasing mechanism when UAV is fully delivered properly outside of the vehicle

Table 8: Payload (Unmanned Aerial Vehicle) System

Analysis of the design for providing enough support for the payload will be discussed in detail in the Payload Section of the report to ensure that the UAV and the entire payload system can be able to sustain unexpected impact, sudden impulse, and maximum G-force.

Drogue Bay

Drogue Bay will be designed to mainly house the drogue parachute (details covered in the Recovery and Navigation Section), piston, and kelva shock cord. Drogue Bay is a cylinder of fiberglass with 6 inch inside diameter and 6.15 inch outside diameter. The kelva shock cord will be connected between the coupler and the upper side of the avionics bay/middle coupler through the eyebolts. Two canisters will be mounted on top of the upper side of avionics bay to store a calculated amount of black powder that will be ignited to eject the upper part of rocket away from the avionic bay by generating a high pressure environment to push against the piston. The piston then will hit against the coupler of payload bay and drogue bay, and the amount of shear force generated will be able to break the shear pins that connect the avionics bay and drogue parachute bay. Drogue bay will initial the deployment when the rocket detects its apogee, and the correct amount of black powder to break the shear pins will be calculated in the Recovery and Navigation section. Obtaining a correct amount of black powder is critical for the deployment mission since either undershooting or overshooting the correct shear force will result in a deployment failure or damaging the airframe and other components in the rocket.

The advantage of this design is that there is no need to construct a piston rest ring that increases the work for putting screws through the airframe. The coupler itself will both do a good job for being a conjunction a point and a piston rest region.

Avionics Bay/Middle Coupler

Avionics Bay is the middle construction of the entire rocket that has the ability to secure the electronic devices such as barometric sensor, altimeter, GPS tracking system, radio wave transmitter and corresponding circuit boards and power supply. The avionics bay was combined with the function of coupler and it serves as the bridge between the upper and lower rocket body. It consists of three layers of structure. Upper and lower layers play as a role of coupler at which the PVC-made canisters and eye-bolts are built. The space of three layers are all connected through several holes that can allow the electric wires to run through it for powering the ejection charge. All of threes layers are put into together by taking advantages of the clamping forces exerted by the interplay of threaded rod and hex nuts. The PVC-made canisters will be attached to the two sides of avionics bay using epoxy.

All three sections in the avionics bay will adopt 3D-printed material, PLA, as the shells (Figure 8.3.1). The middle layer will have all the electronic devices placed in a customized avionics mount that can attach to the threaded rod. A arming switch will be provided along with the hatch door, and a faraday cage will be employed in order to block out electromagnetic field around the devices. More details about this subject will be covered in the Recovery and Navigation Section.

More importantly, in order to prevent the tremendous pressure difference between the inside and outside of the rocket and allow the altimeters and barometric sensors to function, the avionics will have pressure relief holes drilled around the structure.

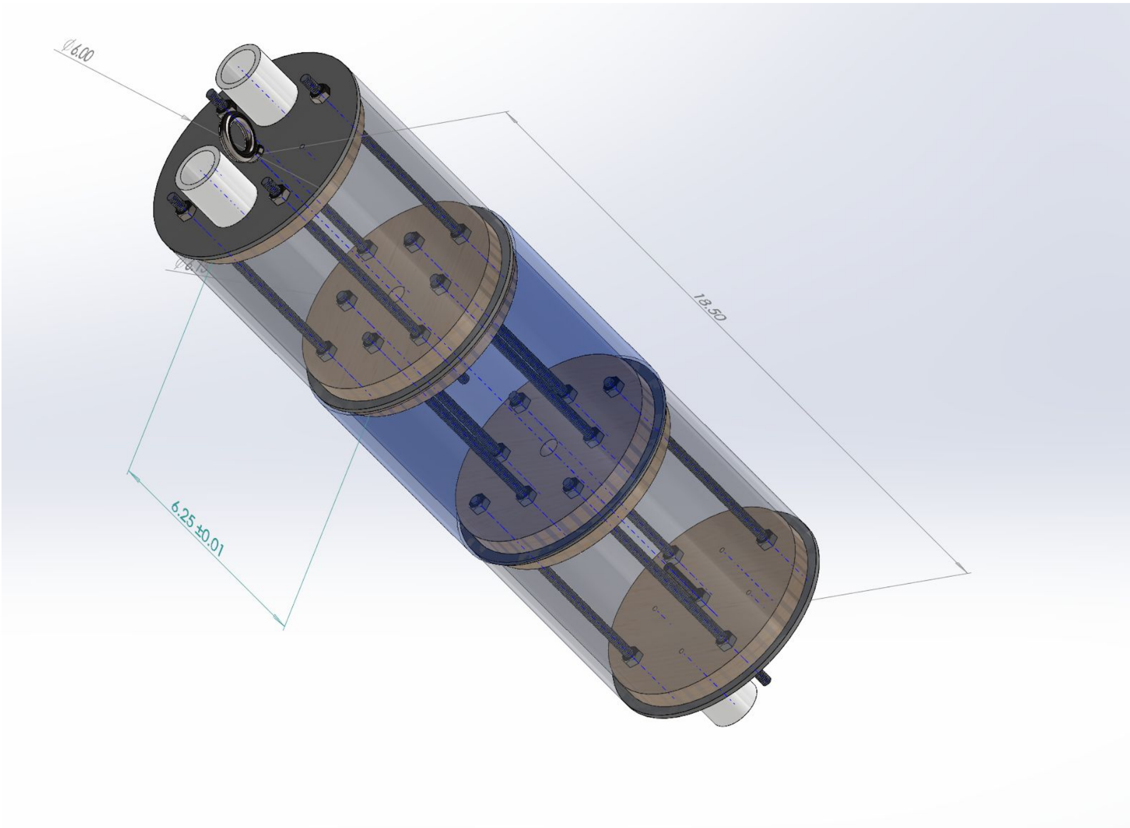


Figure 8.3.1: Perspective View of Avionics Bay

The structure design of the avionics bay is actually considered as a redundancy design in terms of the amount of clamping forces or amount of threaded rods and nuts. There are 4 threaded rods served as the pillar structure, however it is possible to have a stubborn configuration by using only two threaded rods. This redundancy design was taken into account is because of the location of the avionics bay. It is going to suffer tremendous amount of shear stress and normal stress during the course of the rocket if the angle of attack is relatively large. The Center of Gravity (CG) will possibly locate nearby the avionics bay section, which means the free rotation of rocket will be around the avionics bay. The aerodynamic forces acted on the airframe will produce the moment around its CG, and this situation is similar to three-point bending bar, which will always has the moment highest in the middle if looking at the moment diagram. (Figure 8.3.2)

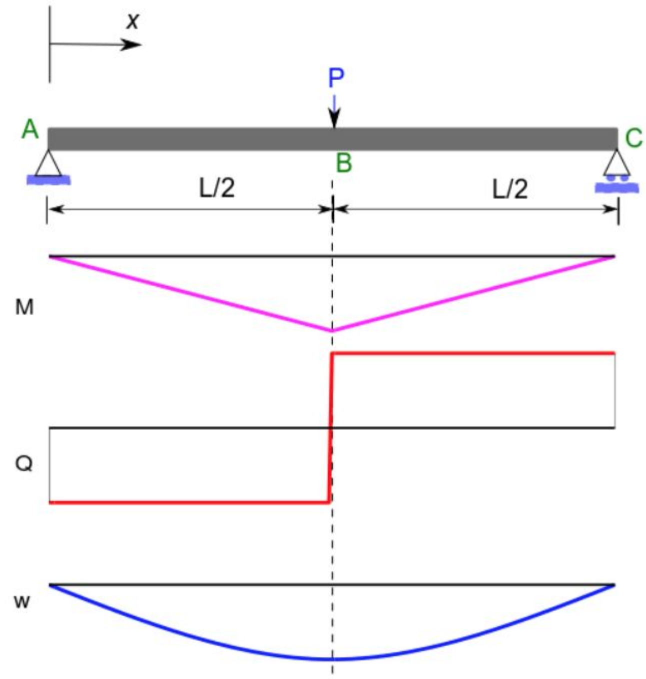


Figure 8.3.2: Three-point Bending Diagram

A reliable Finite Element Analysis will be performed to scrutinize this redundancy design. A elimination of threaded rods will be implemented if FEA analysis shows the unnecessity of the redundancy design. This will clear up space for avionics mounted board and reduce the weight.

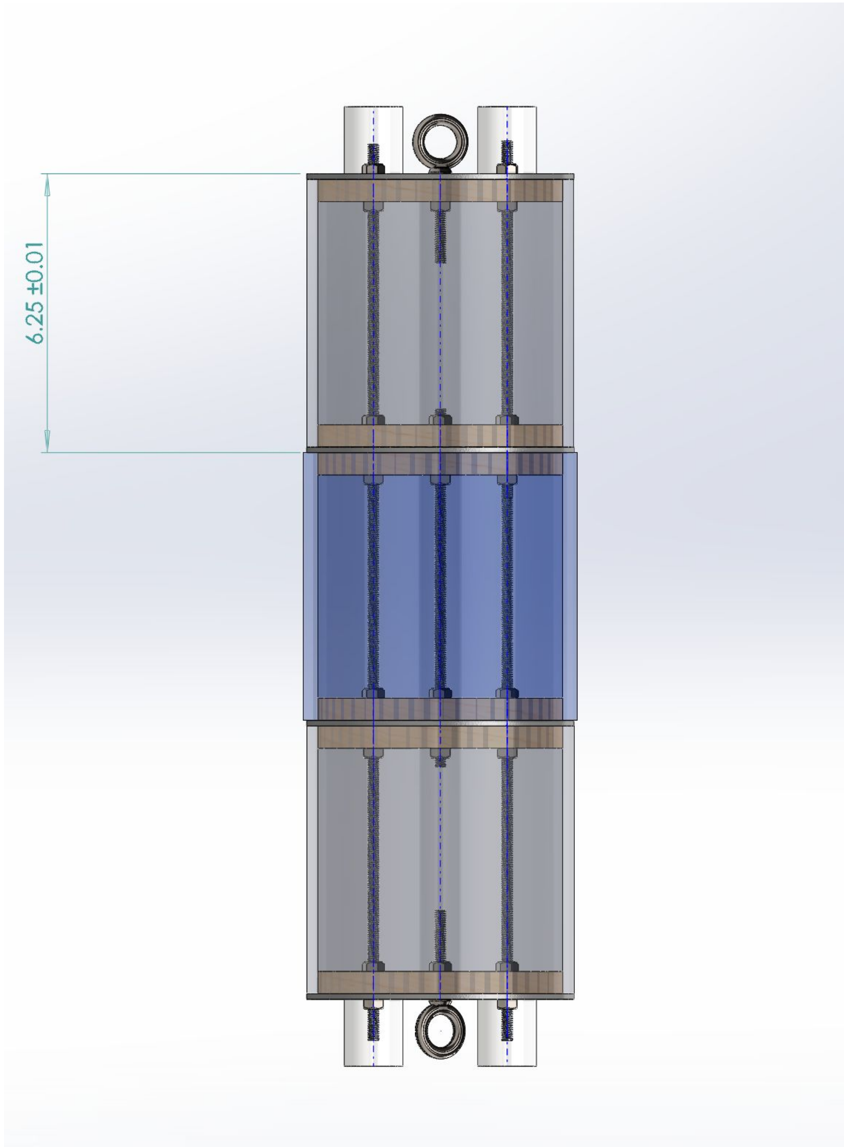


Figure 8.3.3: Side View of Avionics Bay

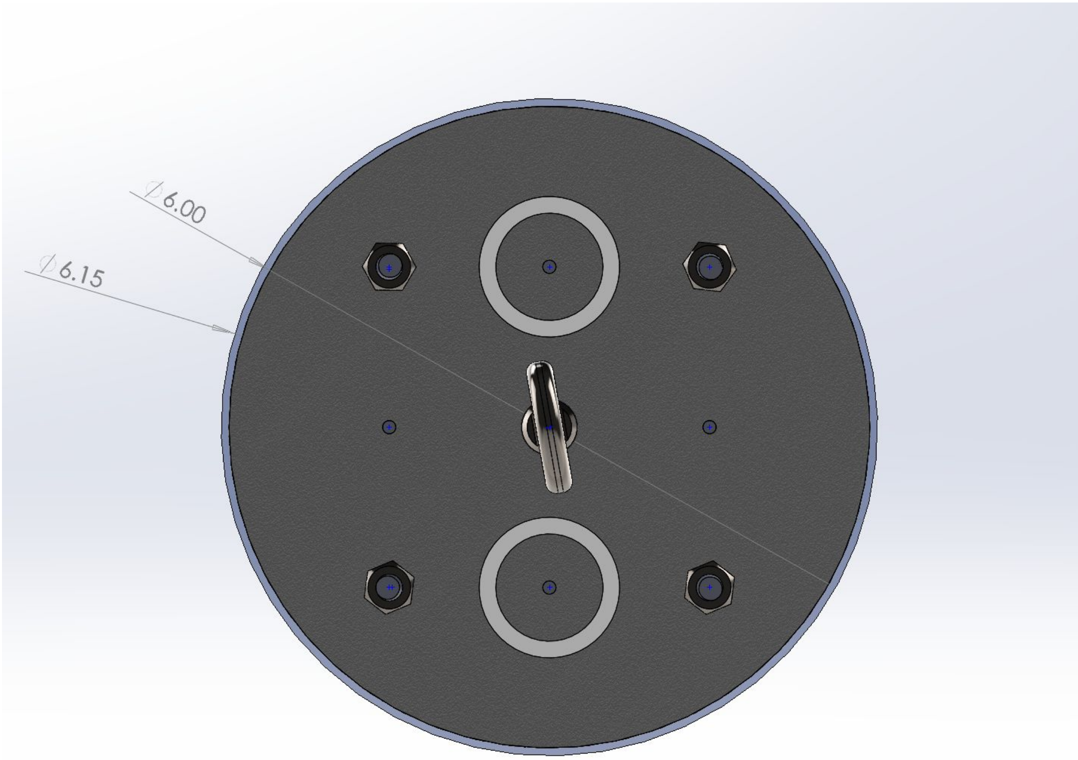


Figure 8.3.4: Top View of Avionics Bay/Middle Coupler

Main Parachute Bay

The main parachute bay is responsible for containing the main parachute for deployment at the necessary altitude. It will be composed of fiberglass. It contains an eye bolt for the shock cord to be attached to. It will be necessary to notice that the main parachute bay and booster bay are combined as one entity in order to not have the coupler connection. Coupler connection at the lower rocket body will not only increase the overall weight of the rocket, but also shift the center of gravity rearward. The main parachute bay will have a PLA-made piston rest ring attached to the airframe using six #6-32 flat head screws. The bulkhead plate of the main parachute bay will be connected with forward centering ring of booster bay by the clamping force generated by the threaded rods and nuts. The bulkhead plate and the forward centering ring will both be fixed at place using six #6-32 flat head screws through the airframe. In addition to that, the forward centering ring will be epoxied to the motor mount tube.

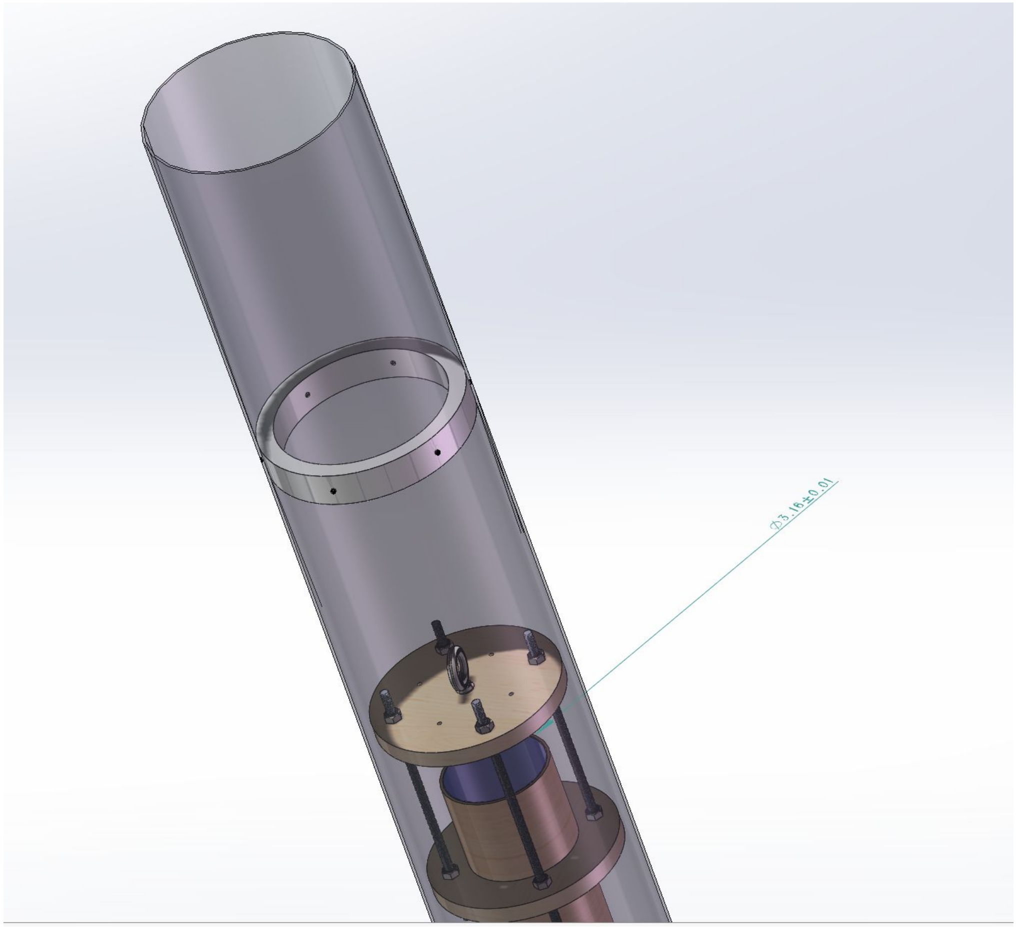


Figure 8.3.5: Perspective View of Main Parachute Bay

Active Stability and Altitude Control Unit

The purpose of the Active Stability and Altitude Control Unit is to help achieve the target apogee by controlling the orientation of the canard fins to stabilize the rocket and eliminate roll, thus decreasing the rotational energy of the rocket. This mechanism will employ the use of bevel gears, a servo motor, linkage arm, and rods connecting the canard fins through the airframe. Normally, a small amount of tilt angle, within 5 degrees, between the fins and the axis of flight can provide a more stable movement by shifting the Center of Pressure (CP) rearwards. Thus, a induced rolling motion can stabilize the rocket. However, a rolling motion can lower the altitude the rocket can reach because a portion of kinetic energy is dissipated during the rolling motion. Another way to look at this is that the tilt angle of canards will generate larger induced drag.

In terms of altitude, the rocket will be able to adjust the flight when the calculated apogee is out of target by actively inducing the rolling rate to lower the velocity or preventing unexpected free rolling motion to reach a higher altitude. A tradeoff between stability and altitude will be studied.

The proposed strategy for employing the Active Stability and Altitude Control Unit will obey the following sequence by having different goals at different altitude.

Active Stability and Altitude Control Unit function sequence.

A. Unexpected free rolling motion will be prevented at the beginning of the flight
B. Inducing the rolling at the mid of the flight.
C. Auto-adjust its rolling rate at the end of flight.

It is safe to ensure the rocket has enough momentum at the beginning of the flight. As the propellent is consumed, the overall stability of the rocket will be improved since CG will be shifted forward. Thus, it is possible that only a tiny amount of adjustment will be needed for Active Stability and Altitude Control Unit.

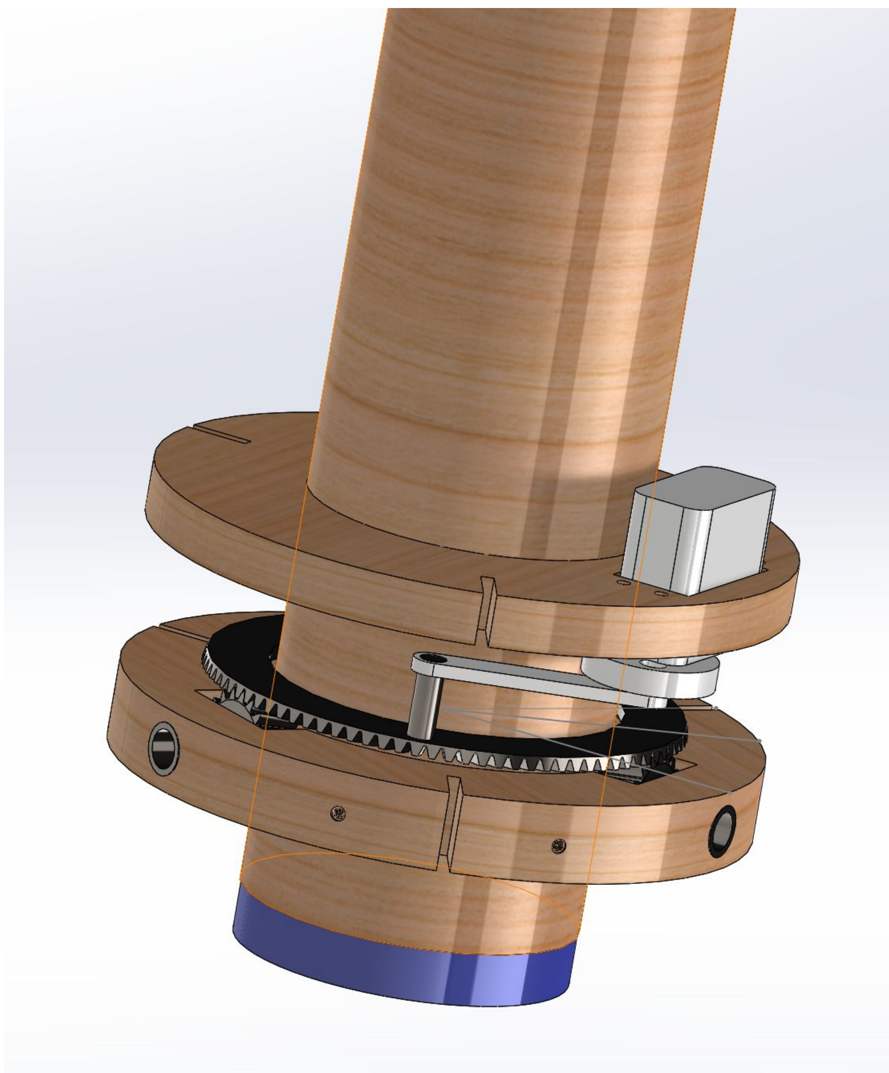


Figure 8.4.1: View of Mechanism for the Active Stability and Altitude Control Unit

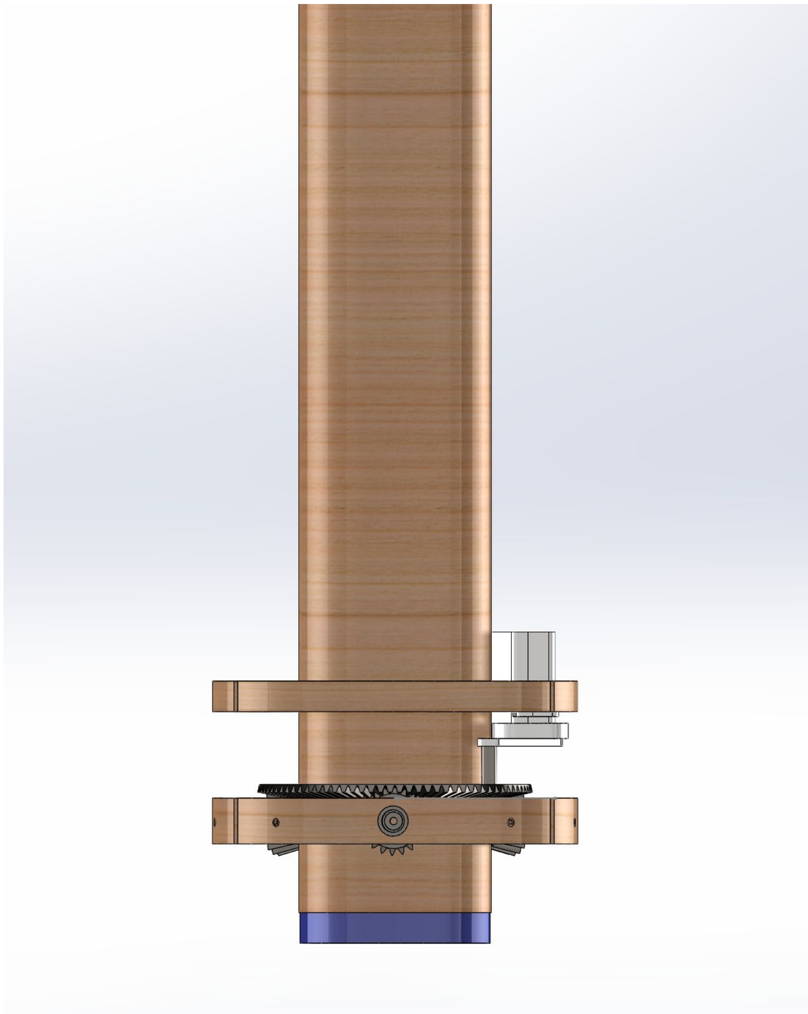


Figure 8.4.2.: Side View of Active Stability and Altitude Control Unit

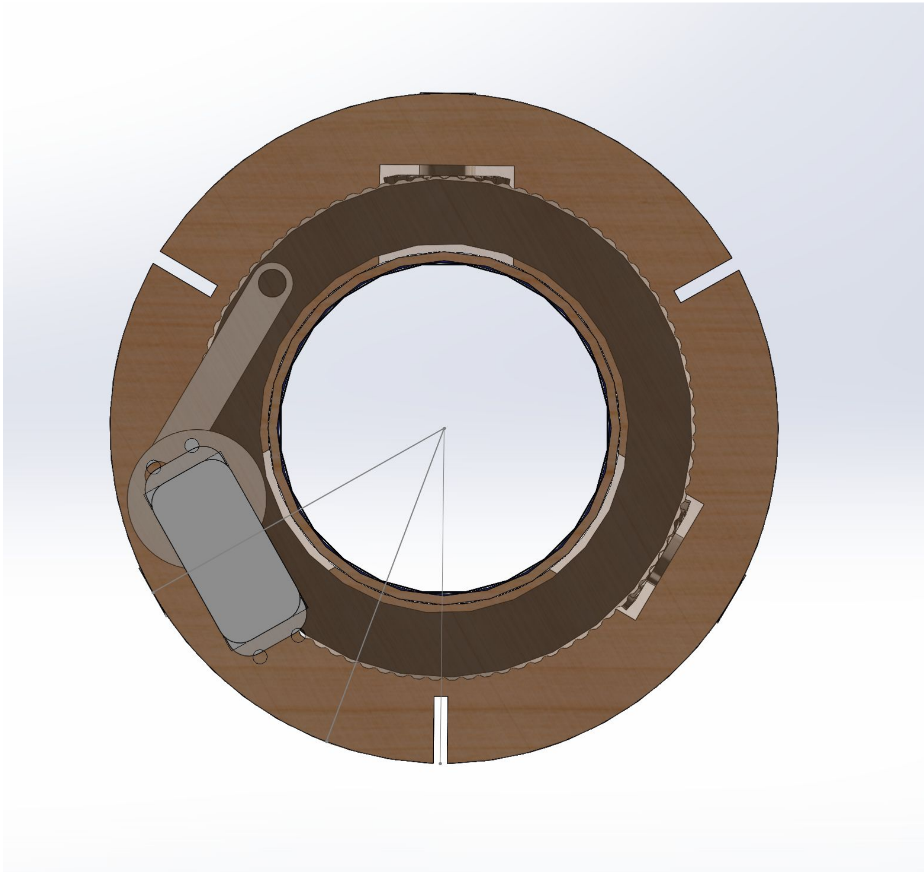


Figure 8.4.3: Top View of Active Stability and Altitude Control Unit

The Active Stability and Altitude Control Unit involves fast-computing microsoftware onboard along with a 6-DOF gyroscope and altimeter.

Figure 8.4.4a: Raspberry Pi 3

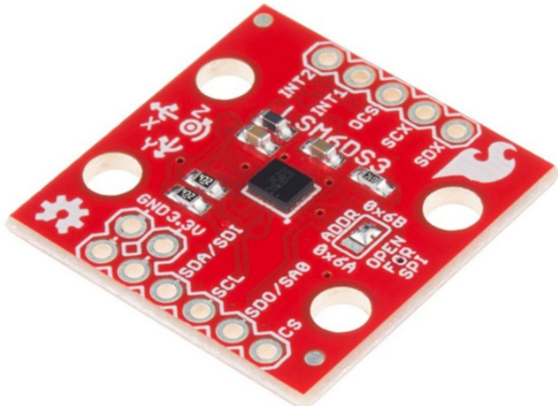


Figure 8.4.4b : 6-DOF Gyro/Accelerometer

A control loop circuit will be investigated, built and tested in the future to provide a stable control on the output. The relationship between the rolling rate and velocity involves theories of aerodynamics. A mathematical model will be proposed and tested in order to know what exactly tilt angle for the canards should be. The subscale launch will test the robustness, accuracy and reliability of the proposed model and control loop circuit.

The canards locate along with other three primary fins at the same station. It is required by NASA Student Launch Handbook that no forward canards will be allowed for the competition.

It is known that forward canards will cause lots of aerodynamic and structure issue. Forward canards can always induce unexpect rolling if built incorrectly because the air flow will be disturbed after hitting the canards and subsequently exert unexpected force or moment on the aft primary fins that can then cause unexpected rolling rate. It can also create intervene drag. Normally, forward canards will require that primary fins should be able to rotate freely, and this is achieved by building the primary fins upon a bearing.

The structure of Active Stability and Altitude Control Unit incorporate two centering rings that can both be platform at which electronics are mounted and fixture that holds motor mount tube and ensure the alignment of the motor mount tube. The centering ring will be epoxied to the motor mount tube. There are also three slots cut around the centering rings that can be attached to the primary fins.

This structure can be very convenient during assembling the rocket. Primary fins and motor mount tube can be attached to the centering rings first, and then integrate it with the Active Stability and Altitude Control Unit components. Eventually, this structure can be just slided into the booster airframe tube and fix the centering rings with the airframe using six #6-32 flat head screws for each of the centering rings. Then movable fins can be attached to the unit from outside of the airframe.

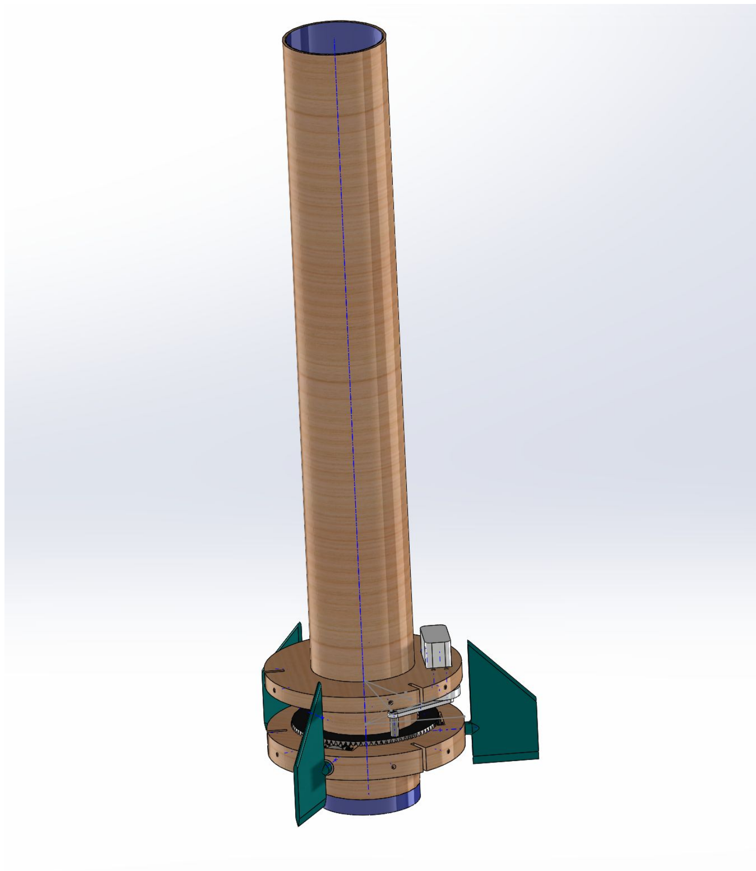


Figure 8.4.5.: Perspective View of Active Stability and Altitude Control Unit with canard fins

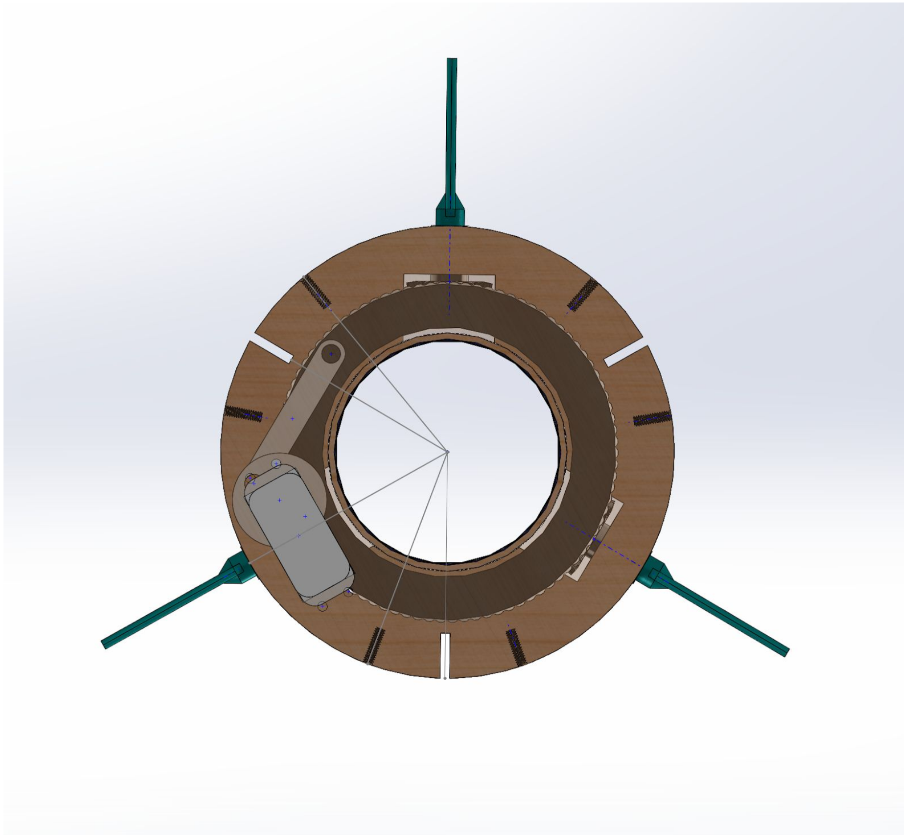


Figure 8.4.6: Top View of Active Stability and Altitude Control Unit with canard fins

For both primary fins and movable canards, they evenly distributed around the booster bay by 120 degrees.

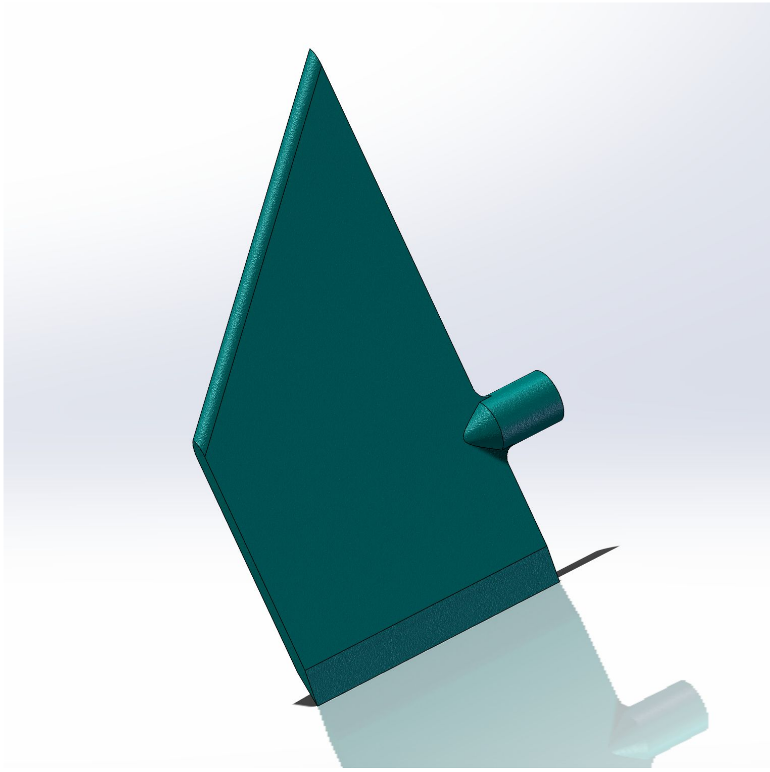


Figure 8.4.7: Perspective View of Canard Fins

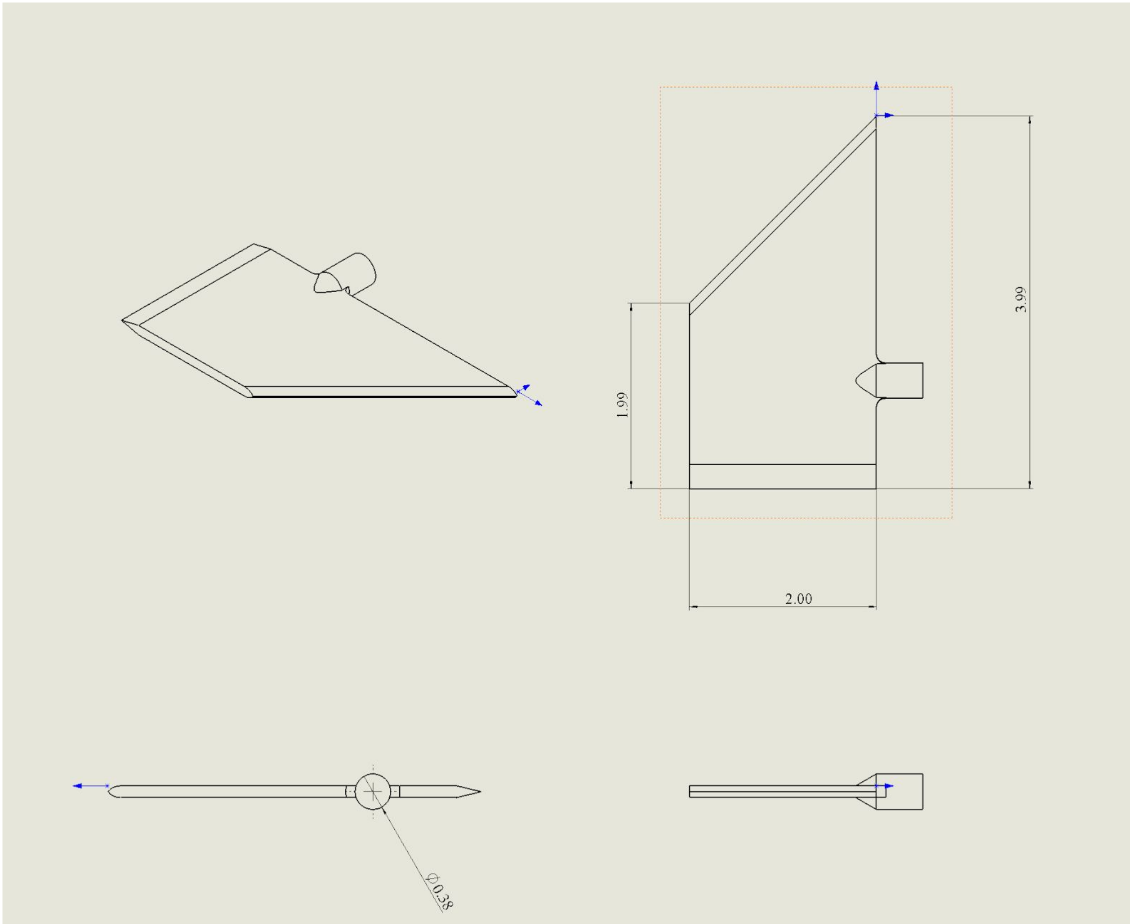


Figure 8.4.8: CAD Drawing of Canard Fins

Booster Bay

The booster bay represents the section of the rocket that will house the specified motor and Active Stability and Altitude Control Unit. This section will be made of fiberglass. The Booster Bay shares same airframe with the Main Parachute Bay. The motor mount tube inside the Booster Bay is used to house the aluminum motor case, and it is fixed and aligned by two aft centering rings and one forward centering rings. The material of the motor mount tube will be 75mm LOC tube.

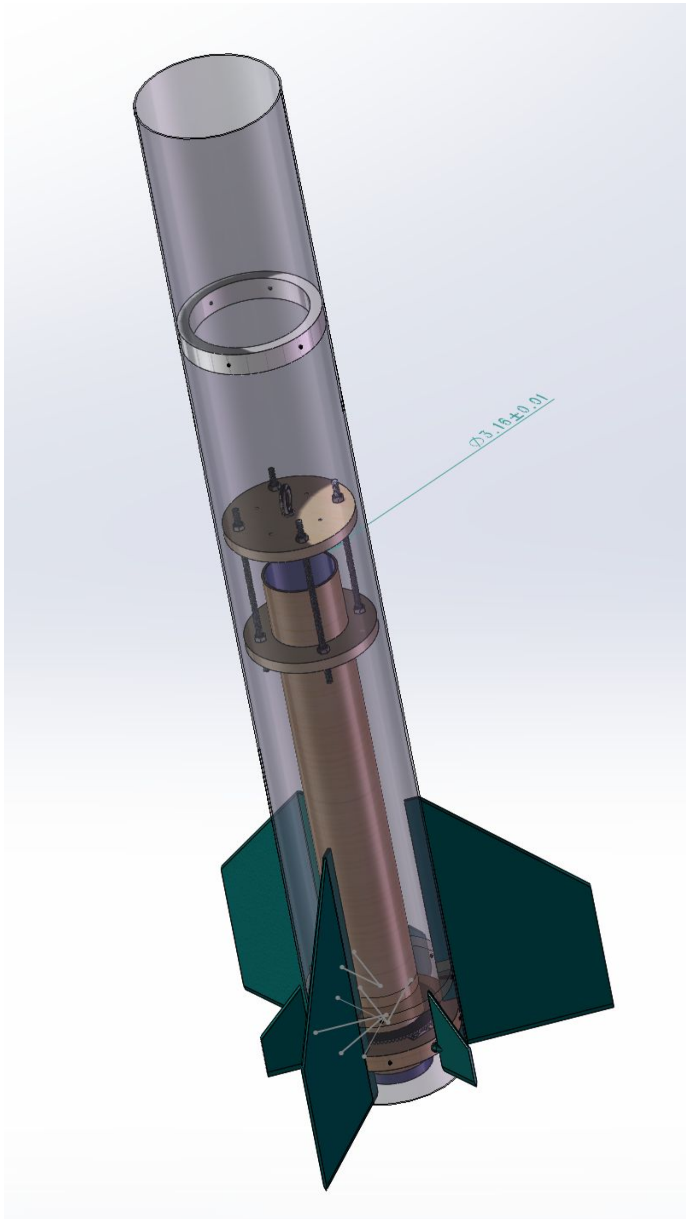


Figure 8.5.1: Perspective View of Booster Bay

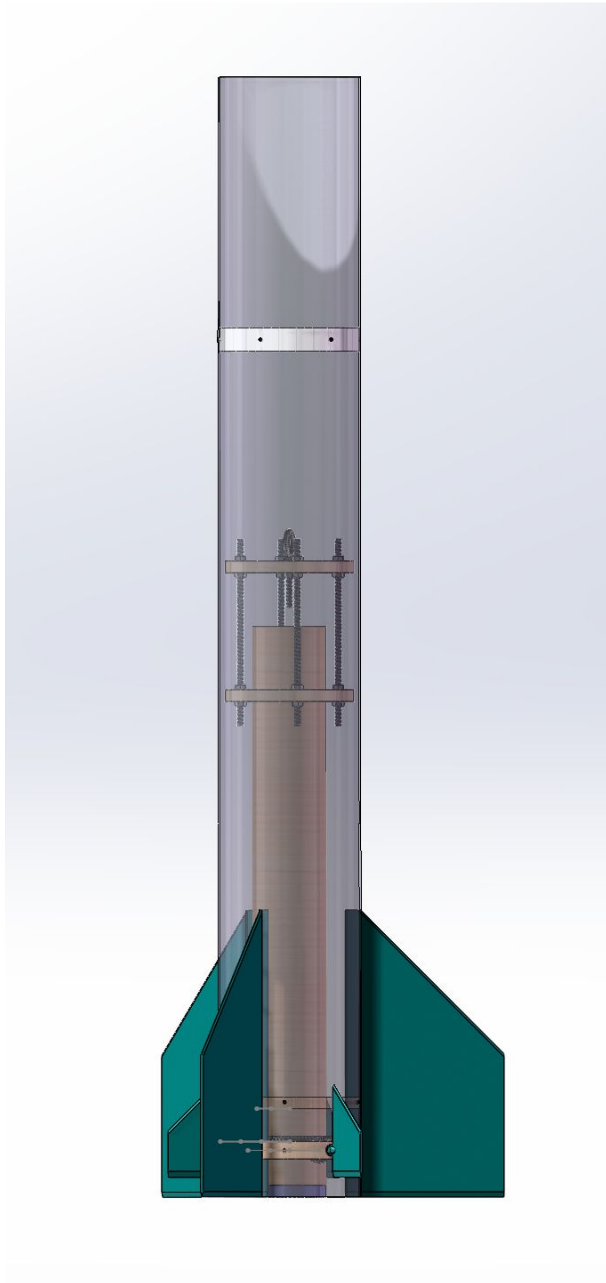


Figure 8.5.2: Side View of Booster Bay

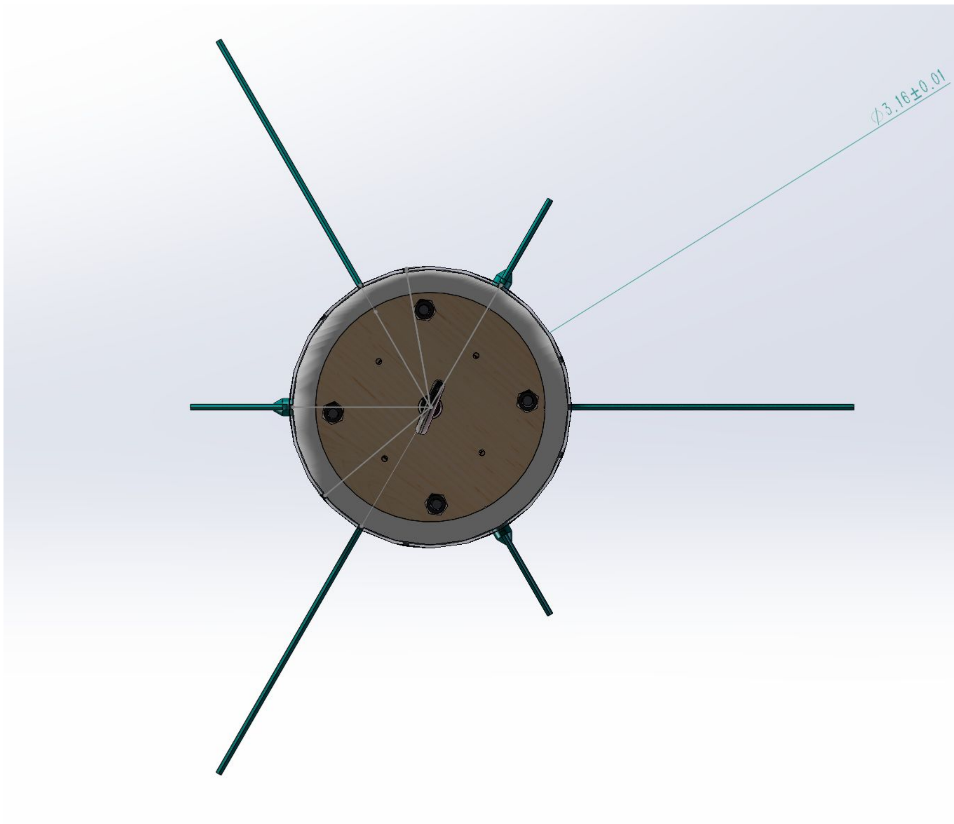


Figure 8.5.3: Top View of Booster Bay

Rocket Fins

The purpose of the fins include lowering the center of pressure (CP) for stability purposes, increase the lift applied to the body and the fin itself in order to correct its path, and induce the rolling motion that may increase the stability and decrease the velocity of the rocket (because it takes energy away from its impulse to rotate the body). A design consideration for the selection of fin design was reducing the induced drag. Elliptical is the theoretically optimal choice, but in the real life, the Clipped/Cropped Delta fin performs better due to the interaction between air flow and other primary external parts. There are two factors that dominate the amount of induced drag: Shape and cross-sectional shape. Cross-sectional shape can have more influence on the induced drag. The ideal cross-sectional shape will be a teardrop shaped airfoil. A most optimal shape will be a Cropped Delta with constant thickness-to-length ratio from root of the fin to the tip of the fin, which means the airfoil of cross-sectional area will change throughout the fin. However, this will be difficult to manufacture. A relatively practical method is to have a Cropped Delta with a fixed tear-drop shaped airfoil, which has a constant thickness throughout. It is also recommend to sand down the thickness of the tip a little bit in order to have a relatively constant airfoil shape. The finalized design incorporates six Cropped Delta fins, three of which are movable canard fins. The fins are oriented 60º with respect to one another.

In the later manufacturing process of fins, the tip of fins will be sanded down a little bit in order to ensure a constant thickness-to-length ratio. This will provide more stable flight.

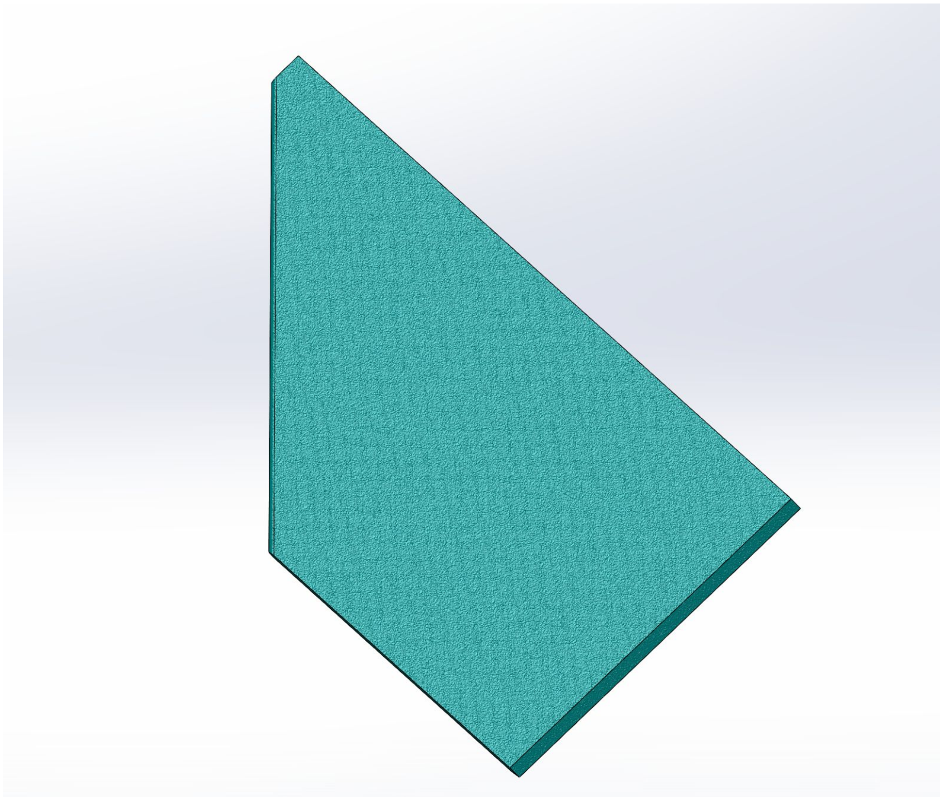


Figure 9.1.1: Perspective View of Primary Fins

The primary fins will adopt Through-The-Wall (TTW) technique to provide a stubborn fix between the fins and rocket. Fins will be first epoxied to the centering rings, and then epoxied again around the conjunction lines between the fins and the airframe. The length of chord, leading and trailing edge, span and etc will be shown below.

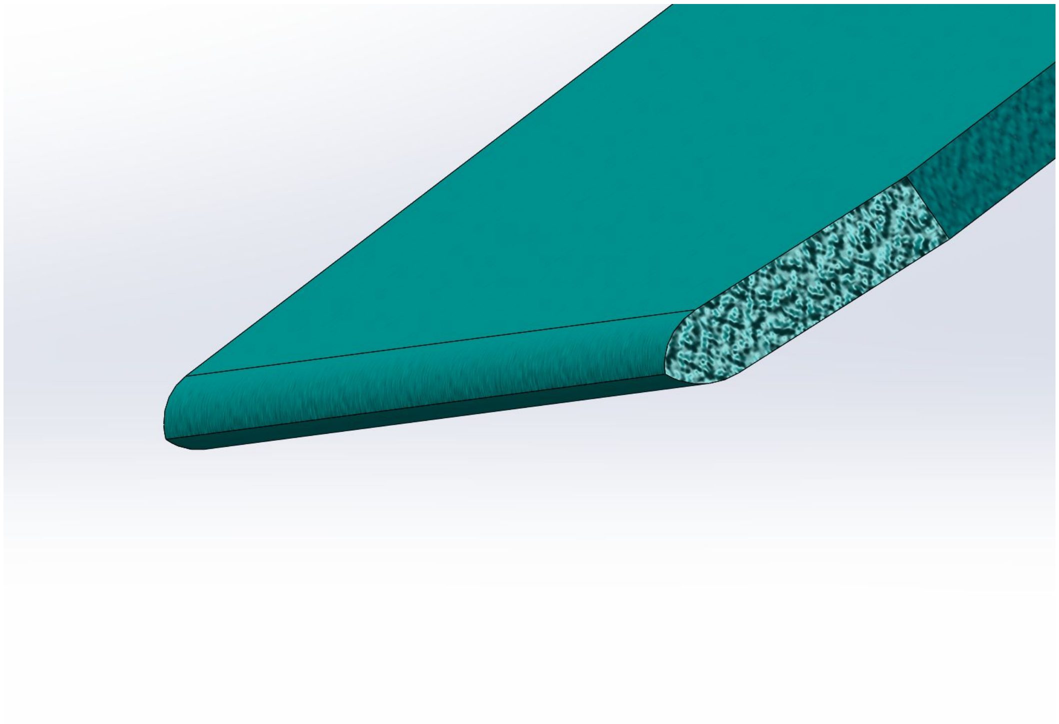


Figure 9.1.2 : Primary Fins Leading Edge

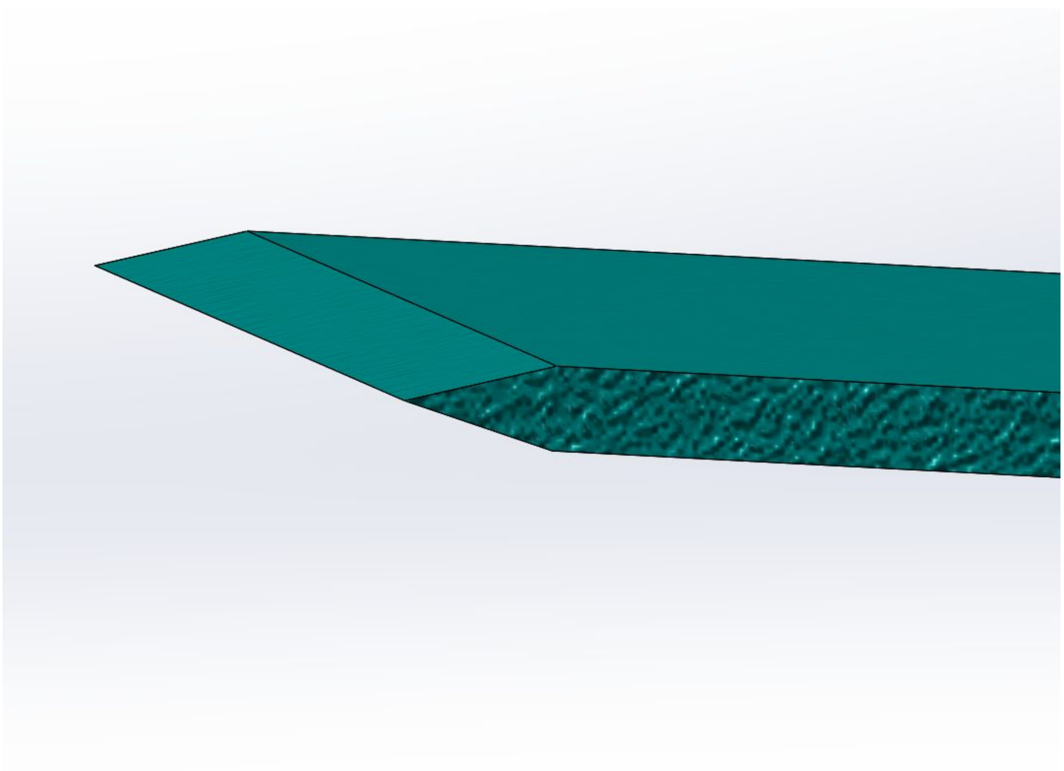


Figure 9.1.3: Primary Fins Trailing Edge

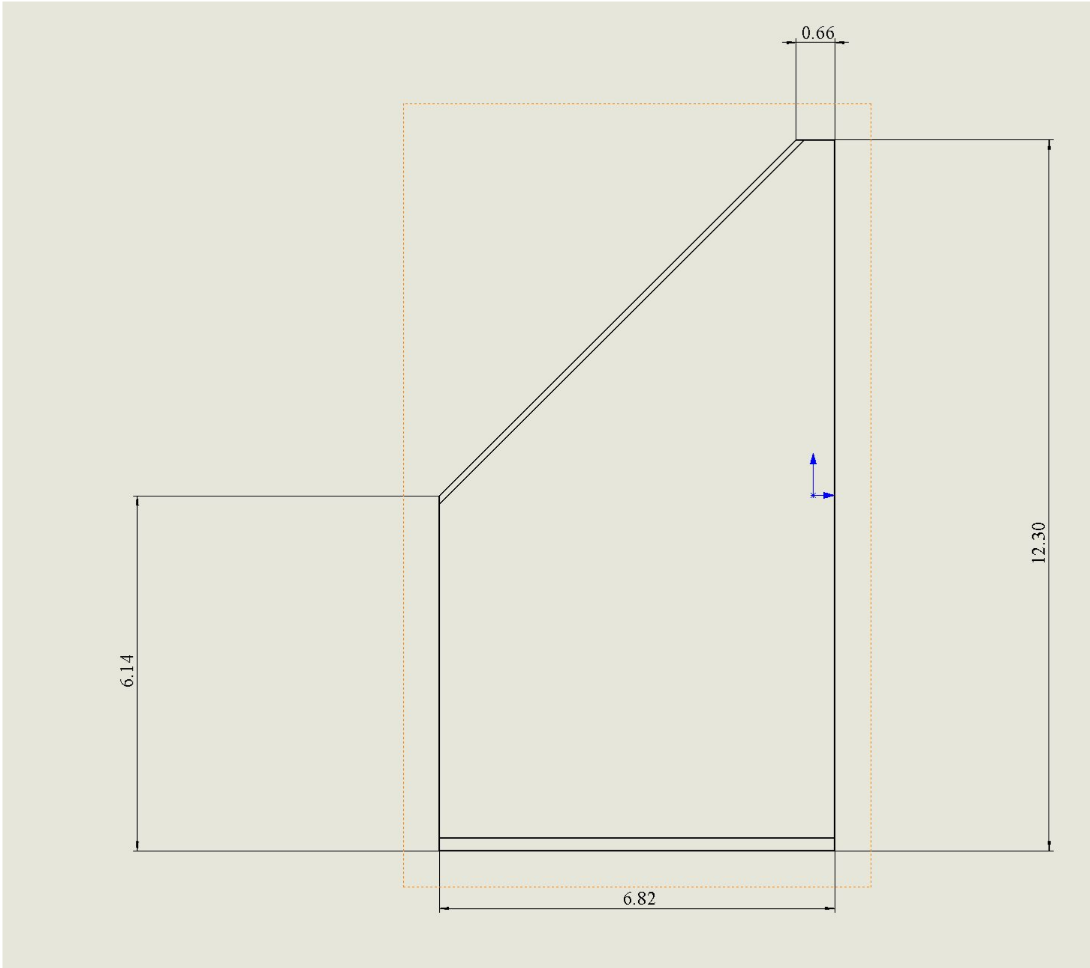


Figure 9.1.4: Primary Fins Drawing

Pressure Relief Holes

The reason for the vent hole is to allow the pressure inside the rocket to equal the external atmospheric pressure. This is important due to the fact that pressure decreases as you go up in altitude and if the pressure difference becomes too great, the nose cone can be ejected mid-flight. The nose cone ejecting at high speeds can lead to catastrophic disasters such as, the rocket cracking in half, the fins snapping off, or the parachute being ripped to shreds. Normally, these relief holes are located in the parachute bay, just below the shoulder of the nose cone, and avionics bay to ensure successful operation of respective components and alleviate the possibility of in-flight failure.. It is standard to use holes with a diameter of ¼ in. There will be two holes drilled of this size at the aforesaid locations.

Two Pressure relief holes will be drilled at the each of the following location:

A. Location between the nose cone and the payload bay.
B. Location between the drogue bay and the avionics bay.
C. Middle section of the avionics bay for altimeters and barometric sensors.
D. Location between avionics bay and booster bay/main parachute bay.
E. Location near the Active Stability and Altitude Control Unit.

Rail Buttons

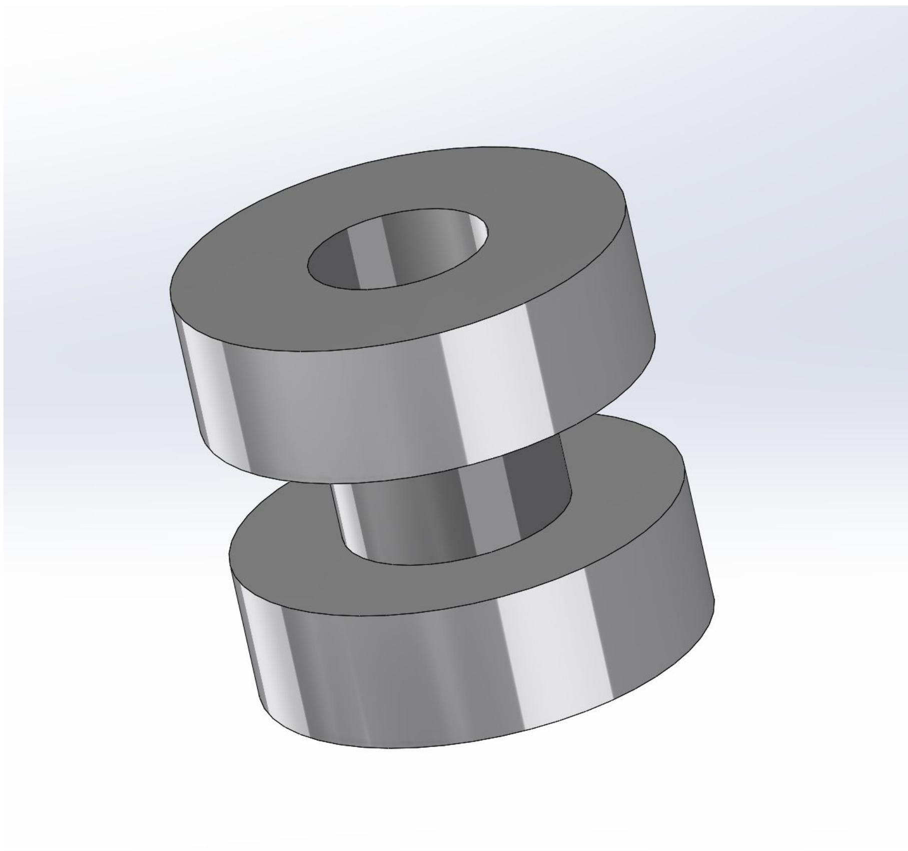


Figure 10.1.1: Perspective View of Rail Button

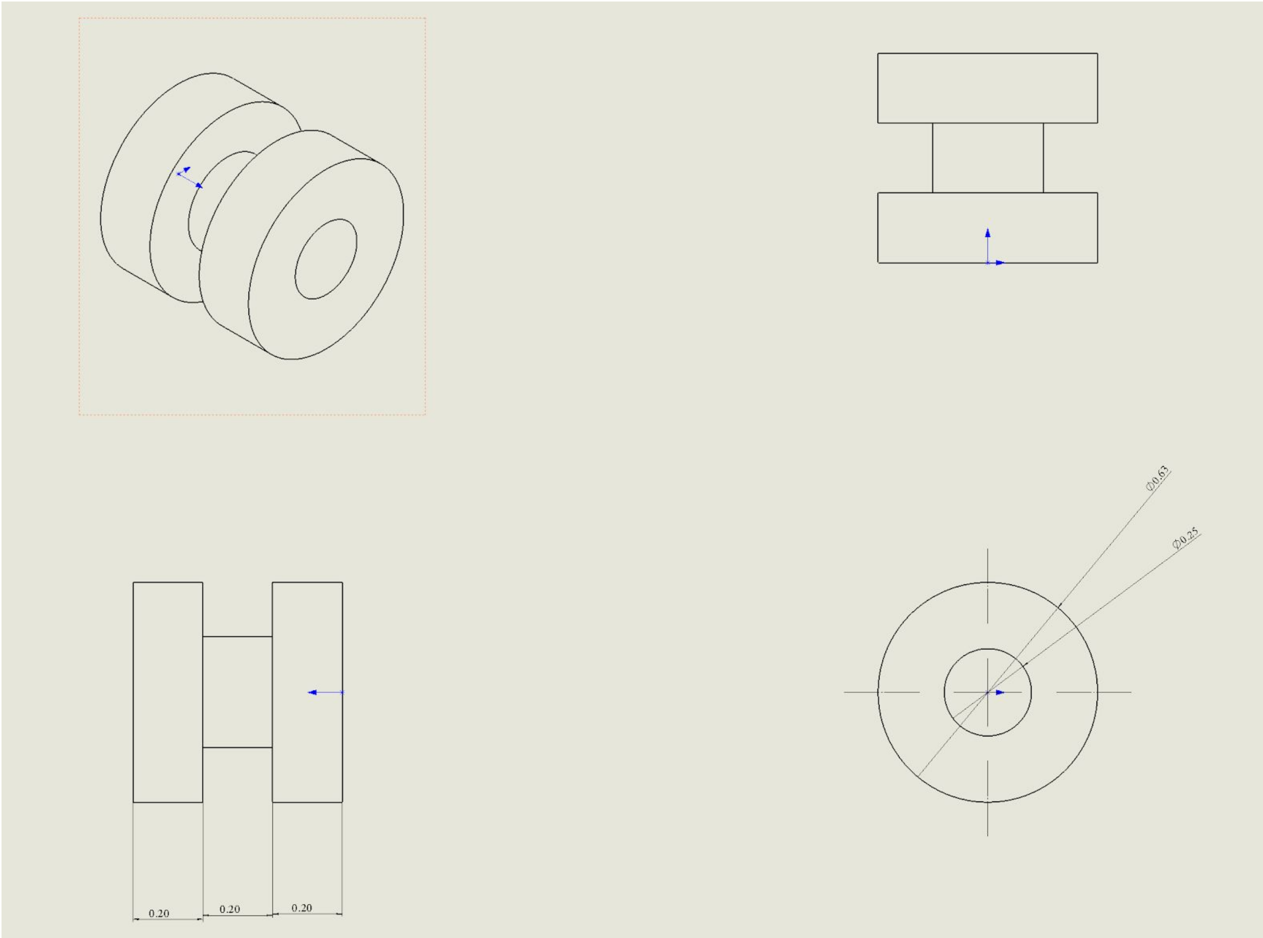


Figure 10.1.2: Rail Button CAD Drawings

Propulsion

Motor Selection

Motors	Total Impulse (N.s)	Burnout Time (s)	Specific Impulse (s)	Weight (oz)
Aero Tech	5051.96	2.3	213.60	168.71
L1685-SS	5069.3	3	137	213.44

Aerodynamics

Stability and Altitude Control

There are mainly four types of drag forces that can happen to the vehicle: Skin friction (profile friction), induced drag, base drag, and intervene drag. For the Stability and Altitude Control Unit, it is located at the very bottom of the rocket, which means it gets rid of intervene drag that happens to the interaction region of any protrude component, and it only involves with induced drag and skin friction drag. The induced drag will increase when the canard fins start moving. As the rocket starts rolling, the induced drag increases, and it can dissipate a portion of kinetic energy. The unit can take advantage of this feature to control the apogee it can reach.

When there is free rolling around its CG, the unit can prevent it from rolling, which can make sure the energy will be converted into kinetic energy efficiently.

Center of Gravity (CG) and Center of Pressure (CP)

The center of gravity and center of pressure are two crucial aspects of a rocket as their respective locations along the rocket body, along with respect to one another, determines the stability of the rocket in flight. In flight, the rocket rotates about the CG, so this is a valuable value to know. The CG is a mass-weighted average of the component locations; since the model rocket is a combination of many parts, each part contributes to the overall weight of the rocket and can be determined by Newton's Second Law.

$$CG = \frac{\Sigma W_i * d_i}{\Sigma W_i} \qquad \text{Equation [3.1]}$$

where:

W_i = Component weight

d_i = distance of corresponding component from reference point

The other beneficial term is the CP which is similar to the CG in that it serves as a simplified point where all forces act. When a rocket moves through air, it experiences various aerodynamic forces that act through a single point, the center of pressure. The amount of aerodynamic force will generate enough lift force or moment to correct the flight path when the rocket is heading away from the vertical direction. Calculating the CP requires some extensive math, but was made simpler through the application of the Barrowan Equation. The Barrowman Equation is as follows:

$$\overline{X} = \frac{(C_N)_N X_N + (C_N)_T X_T + (C_N)_F X_F}{(C_N)_R} \qquad \text{Equation [3.2]}$$

where:

$$X_N = 0.466 \times L_N \text{ (for ogive nose cone)} \qquad \text{Equation [3.3]}$$

$$(C_N)_T = 2\left[\left(\frac{d_R}{d}\right)^2 - \left(\frac{d_F}{d}\right)^2\right] \qquad \text{Equation [3.4]}$$

$$X_T = X_P + \frac{L_T}{3}\left[1 + \frac{1-\frac{d_F}{d_R}}{1-\left(\frac{d_F}{d_R}\right)^2}\right] \qquad \text{Equation [3.5]}$$

$$(C_N)_F = \left[1 + \frac{R}{S+R}\right]\left[\frac{4N\left(\frac{S}{d}\right)^2}{1+\sqrt{1+\left(\frac{2L_F}{C_R+C_T}\right)^2}}\right] \qquad \text{Equation [3.6]}$$

$$X_F = X_B + \frac{X_R}{3}\frac{(C_R+2C_T)}{(C_R+C_T)} + \frac{1}{6}\left[(C_R + C_T) - \frac{(C_R C_T)}{(C_R+C_T)}\right] \qquad \text{Equation [3.7]}$$

For stable flight to occur, it is necessary that the CP be located aft of the CG.

Stability Margin

The stability margin is used to gauge how stable a rocket is, along with other factors. As per the NASA Student Launch handbook, a launch vehicle is to have a static stability margin of at least 2.0 calibers at the point of rail exit. The stability margin is calculated by the distance between the CG and CP divided by the body tube diameter.

$$S = \frac{CG - CP}{D_{body}} \qquad \text{Equation [3.8]}$$

where:

CG = Center of Gravity
CP = Center of Pressure
D_{body} = Diameter of the body tube

Important Theoretical Values

Mass Balance Statement						
Component	**Quantity**	**Length (in)**	**Weight (oz)**	**Margin**	**Weight (oz)**	**Station (in)**
Booster Airframe	1	48.00	59.29	0%	59.29	83.17
Avionics Bay	1	6.00	131.97	5%	138.57	56.17
Drogue Bay	1	20.44	25.40	0%	25.40	42.95
Coupler (Drogue Bay/Payload Bay)	1	12.50	83.53	0%	83.53	32.73
Payload Bay	1	21.00	26.09	0%	26.09	22.23
Payload UAV	1	N/A	160.00	10%	176.00	22.23
Nose Cone	1	11.73	20.99	0%	20.99	9.02
Motor Mount Tube	1	23.98	7.83	0%	7.83	95.25
Motor Case Tube	1	23.84	80.00	5%	84.00	95.25
Motor	1		168.00	0%	168.00	95.25
Straight Bevel Pinions	3	N/A	0.78	0%	0.78	105.17
Straight Bevel Gears	1	N/A	0.72	0%	0.72	104.17
Servo motor	1	N/A	1.60	0%	1.60	103.17
Linkage Arms	1	N/A	0.07	0%	0.07	103.90
Bevel pinions mounted centering ring	1		4.96	0%	4.96	105.17
Servo motor mounted centering ring	1		3.92	0%	3.92	103.17
Primary clipped delta fins	3		21.09	5%	22.15	102.18
Movable canards	3		2.03	5%	2.13	104.61
Booster bay bulkhead plate/Forward centering ring Unit	1	0.50	16.79	0%	16.79	83.33
Booster bay piston rest ring	1		6.02	5%	6.32	65.17
Totals	**26**	**107.17 in**	**821.1 oz**	**28.06 oz**	**849.15 oz**	**N/A**

		14 ft	51.32 lbm	1.75 lbm	53.07 lbm	N/A
		4.2 m	23.28 kg	0.8 kg	24.07 kg	N/A
Center of Gravity (CG)	**60.68 in**	↑↑ **Note that only the lengths of *external primary structural components* are used to calculate the vehicles total length.**				

Table 9: Mass Balance Sheet For Calculating Center of Gravity (CG)

	Center of Gravity (CG)	Center of Pressure (CP)	Stability Margin
Simulation Value (in)	65.94	79.90	2.26
Analytical Value (in)	60.68	80.1	3.15
Relative Error (%)	7.3%	0.22%	31%

Table 10: CG and CP Comparison Table

	Rail Exit Velocity (ft/s)	Maximum Velocity (ft/s)	Maximum Acceleration (ft/s^2)	Time to apogee (s)
AeroTech L2200	82	543	347 (10.84 Gs)	60
Cesaroni L1685	72.2	498	226 (7.02Gs)	54.4

Table 11: Dynamic Data for Two Motors

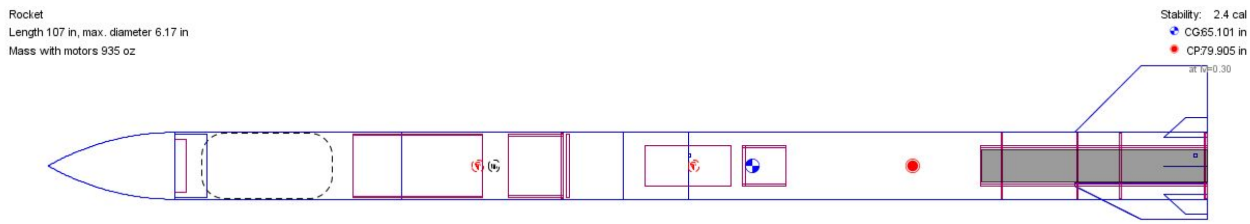


Figure 10.2.1: OpenRocket Rocket Outline

Recovery System

The recovery subsystem oversees the safe recovery of the vehicle following the descent from vehicle apogee.

Dual Deployment

Parachutes

Following the attainment of apogee height, the launch vehicle will deploy the drogue parachute, separating at the junction between the avionics and the drogue bay. Then, between 700-600 feet, main parachute will deploy, safely decelerating the rocket to landing.

To determine the parameters of the main parachutes for our design, we used a low fidelity model utilizing basic dynamics and fluid mechanics equations to obtain the baseline estimates of the nominal diameter of the parachute given the current vehicle parameters. Equation [4.1] specifies the terminal descent velocity needed to achieve the required kinetic energy requirements.

$$v_{terminal} = \sqrt{\frac{2\,KE}{m}} \qquad \text{Equation [4.1]}$$

Here,

$v_{terminal}$: Terminal Velocity

KE : Kinetic Energy

m: Mass of Rocket

Equation [4.2] is the drag force equation.

$$F_{Drag} = \frac{1}{2}\rho v_{terminal}^{2} C_d A_o \qquad \text{Equation [4.2]}$$

Where:

F_{Drag} : Drag Force

ρ : Density

C_d : Drag Coefficient

A_o : Canopy Surface Area

Combining the above equations results in the following:

Assuming a circular shape for the parachute, A_o in equation (4.2) can be replaced by the area of a circle:

$$A_o = \frac{\pi}{4} D_o^{2} \qquad \text{Equation [4.3]}$$

This combined equation can be solved solved for the nominal diameter of the parachute D_o :

$$D_o = \sqrt{\frac{4m^2 g}{K.E.\, \rho \pi C_d}} \qquad \text{Equation [4.4]}$$

To meet kinetic energy requirements, each separate section of the the vehicle must posses a kinetic energy less than 75 ft*lbf upon landing.

The various parachute designs under consideration for the drogue and the main parachute are shown in the table below:

Chute Type	Measure Type	Stability	C_d	Cost	Use
Cruciform	Across Chute	Good at any speed	Low – 0.4	Medium	High speed drogue or main chute
Flat Sheet	Across Chute	Ok at low speed, poor at high speed	Low – 0.7	Low	Main or Drogue chute
Panel Style	Across top panels, usually on diagonal	Good vertical stability, can rotate or spin	Med – 1.1	Medium	Mostly as a Main
Elliptical	Protected frontal area	Medium high speed, Good low speed	Med – 1.6	Medium	Main or Drogue chute
Toroidal	Protected frontal area	Good low speed	High – 2.2	High	High performance main chute. Best performance vs. weight

[2]

Table 9.1 : Different Parachute Types

There are mainly 4 parameters that has been chosen to select the appropriate parachute for the vehicle. They are drag, stability, and cost. We are currently researching and testing 3 different parachutes for both drogue and main deployment.

A sample calculation is shown below:

Assumptions for low fidelity model:

i) Streamer Recovery (one parachute tethered to entire vehicle)

ii) Simplified Drag Forces (only drag from the main parachute is considered - no drag forces generated by vehicle body)

iii) Constant air density (0.0023769 slug/ft^3)

iv) Mass of the heaviest individual vehicle component (0.614 slugs)

[2] Gene Engelgau, Rocketry Recovery Technology, 2013
Retrieved from https://fruitychutes.com/files/blog/NARCON%202013%20-%20Rocket%20 Recover%20 Technology.pdf

$$D_o = \sqrt{\frac{4m^2g}{K.E.\,\rho\pi C_d}} = \sqrt{\frac{4(0.614\ slugs)^2(32.2\ ft/s^2)}{(75\ lbf\ ft)(0.0023769\ slug/ft^3)(\pi)(2.2)}} = 6.3\ ft \quad \text{Equation [4.5]}$$

Parachute Type	C_D	D_O [ft]	D_C [in]	Cost [USD]
Annular/Toroid	2.2	6.33	84	276
Elliptical	1.6	7.42	84	245
Panel Style	1.1	8.95	108	125
Flat Sheet	0.7	11.22	N/A	N/A

Table 10: Nominal diameters for various parachutes

Some of the parachutes designs are Recovery is considering are discussed below. Major concerns for our design were the availability and cost of the existing commercial, off-the-shelf parachutes. Our initial candidate is the Panel Style parachute annular/toroid chute because of its simplicity of packing and deployment. Although it is more expensive, this type has the highest C_D, and therefore the smallest diameter, which reduces the weight and volume of the parachute. The preliminary selection is the Iris Ultra 84" Standard Parachute for the main chute, and the 2ft Pro-Experimental 1.9 Low-Porosity Ripstop Parachute.

A higher fidelity model will be developed to model the deployment sequence. This model will take into consideration multiple factors including the drag forces generated by the vehicle during recovery, drogue parachute drag, optimization of the altitude for main deployment, different weather parameters, and CFD modeling of the airflow around the parachutes. Using the data gleaned from this higher fidelity model, the dimensions and shape of the drogue and primary parachutes will be optimized. This research will enable a more robust and accurate model of how current parameters affect the kinetic energy and drift of the vehicle during the recovery phase. Physical testing on the ground will be done to verify the parachute drag coefficients, and other simulated parameters. These simulations and tests will be finished prior to the subscale and full-scale test launches.

Shock cords and launch configuration

The purpose of the shock cord is to keep the rocket "attached" during separation. The shock cord will prevent segments of the rocket from being discarded in multiple directions during descent. Because of our dual deployment system, two shock cords will be required. Ideally, each cord will be capable of withstanding the weight of the whole rocket. Since there is no predictable way the rocket will fall during launch, the shock cords must be strong and durable.

The material selection must match the requirements stated above. The selection can be narrowed down to two possible candidates: Kevlar or nylon. Kevlar not only has higher tensile strength, but it also possesses a higher melting point than nylon. The higher melting point grants Kevlar higher resistance to the temperature the ejection charges will reach in order to separate the rocket. As such, Kevlar is an excellent material to use for the shock cords.

Two sets of shock cords will be used in the rocket: one attached to the nose cone and another attached to the base of the rocket. Further research and experimentation will be done to finalize the exact dimensions of the cord, as it is important that the cord not only withstands the stress of carrying the descending rocket, but that is also prevents segments of the separated body from hitting each other. Regardless of the length selected, the shock cord will also be bundled into separate and equal lengths in order to dissipate the momentum of descent.

The launch configuration of the rocket will consist of the drogue parachute located at the base of the nose cone and the main parachute located towards the rocket. Configuration #3 is the most suitable recovery hardware configuration for our rocket (as illustrated in the supplement Counterpart Documents) , as it provides the most room and flexibility for the selected payload in the nose cone.

Shear Pins and Ejection Charges

Even though the rocket must be strong enough to withstand several external forces during flight, it must be able to separate into segments in order to ensure a safe landing. However, in order for the rocket to deploy the parachutes necessary, the correct amount of ignition charges must be separated in order to successfully disconnect the shear pins that have allowed the rocket to reach apogee. The selection of shear pins and quantity of black powder must be done simultaneously due to this unique relationship.

Our selection of shear pins will be based upon the forces acting on the rocket. On the ground, the inside of the rocket and the surrounding environment are both exposed to the same pressure. During flight, however, the increase in altitude will cause a decrease in the outside pressure whereas the inside pressure of the rocket will remain constant. This pressure difference will be cause the rocket to separate if the shear pins are improperly selected. As a result, the first phase of recovery will be determining the forces pulling the rocket apart. Once these forces are calculated, the next phase will encompass shear pin selection. The final phase will be calculating how much black powder is required to break apart the rocket to deploy the parachutes.

The pressure differential between the inside and outside of the rocket will be the primary driver of rocket separation. As such, the maximum pressure differential will be calculated in order to ensure the rocket reaches its targeted altitude. Assuming a temperature of 15°C, the pressure at 5,500 feet is 12.0 psi. The resulting pressure difference, ΔP, will be 12.7 psi. Stress analysis can be used to determine the force acting on the rocket by using the following equation:

$$\Delta P = \frac{F}{A} \qquad \text{Equation [4.6]}$$

where:

F = force [lbf]

A = cross sectional area [in^2]

The cross sectional area of a cylinder is a circle, so substituting that into Equation [4.6] results in:

$$F = \frac{\Delta P \pi D^2}{4} \qquad \text{Equation [4.7]}$$

where:

D = diameter of the rocket [in^2]

The rocket will incorporate multiple shear pins in order to distribute the forces. Adding the number of shear pins, N, to the equation results in the following equation:

$$F_{min} \geq \frac{\Delta P \pi D^2}{4N} \qquad \text{Equation [4.8]}$$

This equation calculates the minimum force needed to break apart the rocket. As a result, this describes the worst case scenario for preventing shear stress.

The maximum shear force, F_{max} , occurs when the ejection charge fails to separate the rocket:

$$F_{req} = K \times N \times F_{max} \qquad \text{Equation [4.9]}$$

where:

K = safety factor

Since force is related to the pressure and cross sectional area, the equation can be rearranged to calculate the required pressure to break the shear pins and separate the rocket:

$$P_{req} = \frac{F_{max}}{F_{min}}(K \times N \times \Delta P) \qquad \text{Equation [4.10]}$$

The use of this equation will help narrow down the scope of shear pins that can be used. Other factors such as area, cost, and length will be considered alongside the pressure required to shear before purchase. The rocket will incorporate eight shear pins overall, with four used on each side of the coupler.

A balance must be struck with the amount of black powder used. There are two undesirable outcomes that can result from improperly calculating the amount of black powder. In one situation, the rocket does not separate fully and the parachute cannot deploy due to a lower mass of ejection charge used. At the other extreme case, the ejection causes more damage to the rocket then intended, preventing reusability. These two situations alongside the obvious safety concerns associated with combustible material demonstrate the importance of proper selection of ejection charges.

The amount of ejection charge can be derived from the ideal gas law:

$$PV = mRT \quad \text{Equation[4.11]}$$

where:

V = volume [in^3]
m = mass [lbf]
T = temperature [°R]
$R = 266 \ \frac{in\ lbf}{lbm\ °R}$

Since the pressure has been calculated in Equation [4.11] and the volume of a cylinder is just the area of a circle multiplied by length L, the equation can be placed in the form of pounds per unit length:

$$\frac{m}{L} = D^2\left(\frac{P_{req}\pi}{4RT}\right)\left(454\frac{g}{lbf}\right) \quad \text{Equation [4.12]}$$

Since the acceptable format of mass is in grams, a conversion factor must be applied. Since the equation above represents mostly constants, a variable C can be introduced as the following:

$$C = \frac{P_{req}\pi}{4RT} \quad \text{Equation [4.13]}$$

The final equation can be represented as:

$$m = CD^2L \quad \text{Equation [4.14]}$$

With Equation [4.13] and Equation [4.14], we can determine the shear pins and the amount of black powder, respectively. Even though these equations will be helpful, they are no substitute for performing ground tests which can simulate flight behaviour without requiring the launch of the entire rocket. Once equipment selection is made, ground tests can be designed and planned in order to ensure the effectiveness of the purchased materials. Any other materials crucial to the recovery system, such as the shear pins, quick links, shock cords, and eye bolts, are specified later in the document under Project Plan with the source, cost, and quantity.

Avionics & Electronics

Altimeters

The altimeter pair on the rocket will consist of two PerfectFlite StratoLoggerCF altimeters as per Recovery System Requirement (RSR) 3.6 of the launch handbook (Figure 26). One of the two altimeters will serve as a backup ejection system in the case that the first altimeter fails to ignite ejection charges. Each altimeter will be powered by a commercially available battery as per RSR 3.5. The altimeters and their power supplies will be isolated in the avionics bay of the rocket at a sufficiently far distance from any electromagnetic transmitters. This will prevent accidental ignition of ejection charges and any other type of interference with the recovery procedure.

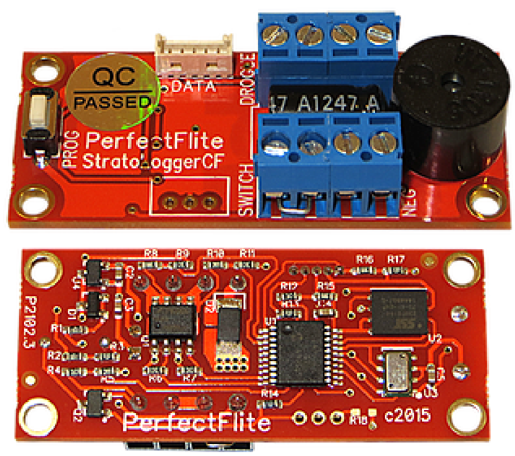


Figure 11.1.1: PerfectFlite StratoLoggerCF Altimeter

As soon as the altimeter pressure sensors sense that apogee (the official launch day target altitude) has been reached, they will send a signal through igniter leads to electric matches. The black powder in the ejection canister caps will ignite, separating the rocket sections and releasing the drogue parachute. A similar event will occur for the main parachute. The altimeters used on the rocket are simple to program, perform up to 100,000 ft Mean Sea Level (MSL), and contains sensors that perform with 0.1% accuracy.

Vehicle requirement 2.4 of the student launch handbook states that a dedicated arming switch will be available on the outside of the airframe and accessible from launch configuration. The team plans to use a keylock switch to meet this requirement. Having a key to arm and disarm the avionics bay is helpful in confirming the state of the altimeters because a key-lock mechanism provides a simple interface, reassuring the team that avionics are/are not ready for flight.

Telemetry

Since the rocket must be located after a successful landing, it is necessary to have a method of efficiently retrieving it. For this purpose, a BigRedBee BRB900 unit will be employed (Figure 27). The unit is capable of transmitting the rocket's coordinates to a receiver/ground station. The station will most likely be provided by BigRedBee, LLC as well, as it has been designed for the specified transmitter. Additionally, no licensing is required for the 900 Mhz RF transmitter because the device has been FCC approved. The transmitter makes use of the u-blox MAX-7 or MAX-8 GPS module. Built-in memory will allow for post-flight assessment of GPS data in Google Maps, allowing for simple presentation and assessment of flight characteristics. The transmitter unit will be placed in a bay near the nose cone at a sufficiently far distance so as to not interfere with the avionics bay, as per RSR 3.12.1-4.

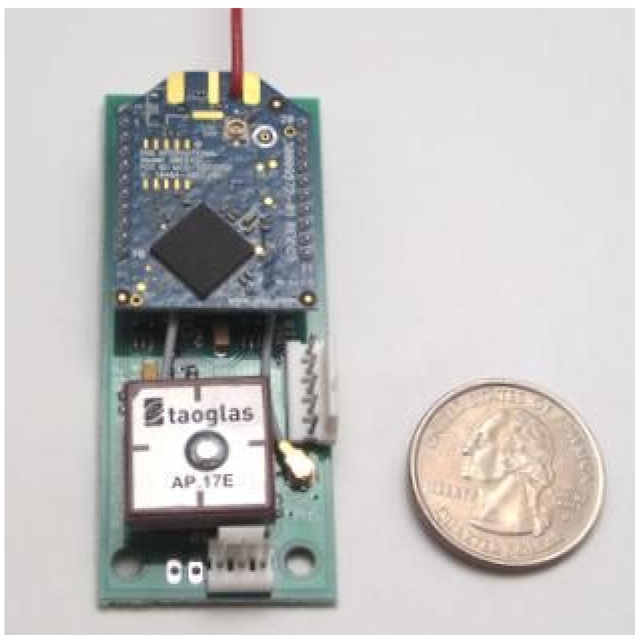


Figure 11.1.2 : BRB900 Transmitter

Design Requirements

Kinetic energy of impact

The kinetic energy of a individual rocket section on impact can be determined via the formula for kinetic energy:

$$KE = \frac{1}{2} m v^2 \qquad \text{Equation [5.1]}$$

Here, the velocity is the terminal velocity of each part which can be written as.

$$v_{terminal} = \sqrt{\frac{2\,m\,g}{C_d\,\rho_{air}\,(\pi/4)\,D_C^{\,2}}} \qquad \text{Equation [5.2]}$$

A sample calculation with the toroidal parachute for the payload compartment is shown below:

$$v_{terminal} = \sqrt{\frac{2\,(0.614\ slugs)\,(32.2\,ft/s^2)}{2.2\,(0.0023769\ slug/ft^3)\,(\pi/4)\,(8\,ft)^2}} = 46.9624\,ft/s \qquad \text{Equation [5.3]}$$

Tethered Section	Mass [oz]	kinetic energy [ft*lbf]
Nose Cone + Payload Bay + Drogue Bay	316.00	46.9624
Avionics Bay	131.97	19.6172
Booster and Main Parachute Bay	299.97	44.5846

Table 11: Section Mass and Kinetic Energy

Maximum Drift

To calculate the drift of the rocket, a simulated launch vehicle was created and modeled in OpenRocket. In the model, an a worst case scenario with an eastward wind with a speed of 20 mph was simulated. Launch results showed a final lateral drift of 175.94 m from the launch site, below the maximum 2,500 ft. Further improvements to the design can be made to decrease the amount of drift. In addition, the total simulated flight time from apogee to landing is less than the maximum time of 90 seconds.

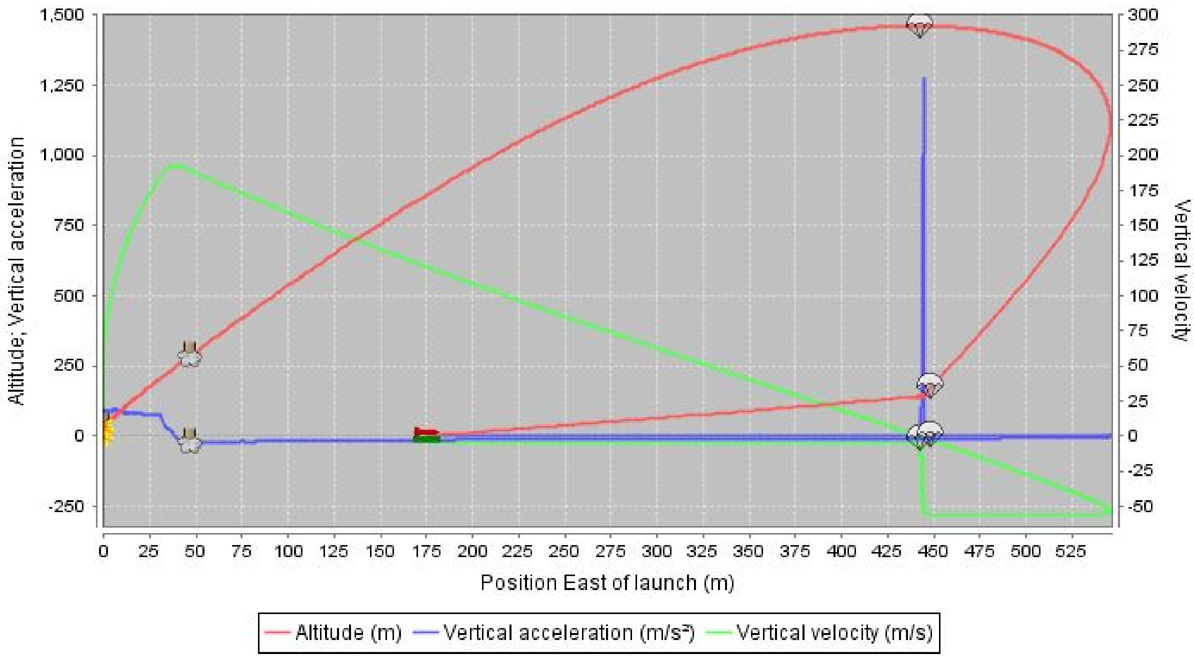


Figure 11.2.1: Drift with 20 mph Winds

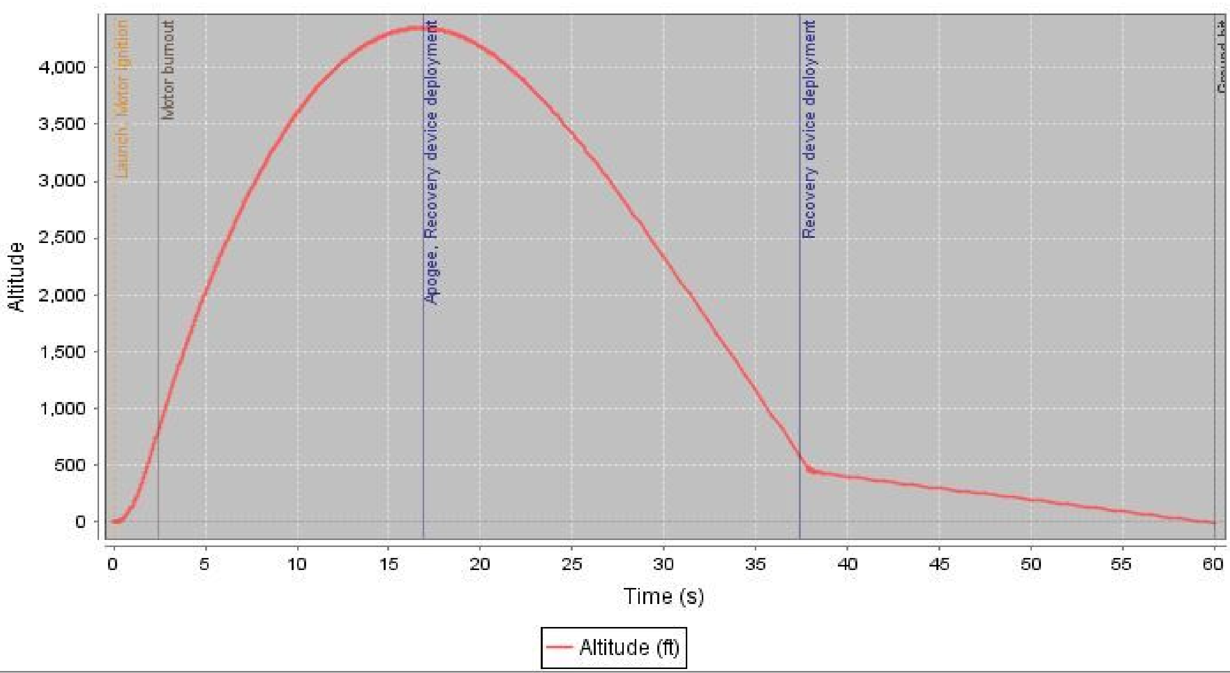


Figure 11.2.2: Plot of Altitude vs. Time

Payload

Payload Requirements

A drone that will deliver a navigational beacon has been chosen for the payload. The drone will be designed to meet the following requirements (from the launch handbook):

1. The drone will deploy from the internal structure of the launch vehicle.
2. The drone will be powered off until the rocket has safely landed on the ground and is capable of being powered on remotely after landing.
3. The drone will be retained within the vehicle utilizing a fail-safe active retention system. The retention system will be robust enough to retain the drone if atypical flight forces are experienced.
4. At landing, and under the supervision of the Remote Deployment Officer, the team will remotely activate a trigger to deploy the drone from the rocket.
5. After deployment and from a position on the ground, the drone will take off and fly to a NASA specified location, called the Future Excursion Area.
6. The drone will place a navigational beacon on the Future Excursion Area.
7. The drone battery will be sufficiently protected from impact with the ground.
8. The batteries powering the drone will be brightly colored and clearly marked as a fire hazard.

Multiple design ideas were considered for accomplishing the task of ensuring the proper orientation prior to drone deployment. Eventually, our team converged on the idea of using a rotating mechanism that will control an aluminum rod attached to a lead screw. This is the Drone Reorientation and Existing System, or DRES for short. For the drone, we converged into an idea of building a foldable drone so that the drone will be able to fit inside a small confined 6 inch tube.

Parts List

- Brushless motors with 2300KV
- 6 in propeller blades
- 4 in 1 electronic speed controller
- Pixhawk flight controller
- 3D printed gripper mechanism
- TowerPro micro servo for gripper
- 2200 mAh lithium polymer battery
- RunCam Nano FPV Camera
- Radiolink M8N SE100 Mini GPS System

- FlySky FS-i6 2.4G 6ch AFHDS RC Transmitter with FS-iA6B Receiver
- AKK X1P 5.8Ghz Video Transmitter

Drone Mechanical Aspects

The primary challenge in creating this drone is that it will have to fit in a compact cylindrical tube of 6 inch outer diameter. To ensure stability of the drone under light wind and weight of its various components, the drone must be sufficiently big enough. Thus, we have decided to make the drone arms folding. The folding mechanism will utilize a simple worm and worm gear system. This design was chosen because pair will create a locking mechanism ensuring that the arms will not swivel during flight. The motor that will spin the worm will be located at the drone base separate from the drone. Upon drone exit from the payload compartment, the motor will be actuated to unfold the arms, then the motor shaft will disengage from the worm. Separating the motor from the drone will help reduce the weight of the drone. The preliminary drone model is shown on Figure 12.1.1

To satisfy payload requirement 7, a 3D printed battery housing will be created to absorb the shock from potential impact. This compartment will also house the gear mechanism responsible for the folding arms. An electronics housing will also be used to house the internal electronics for added safety.

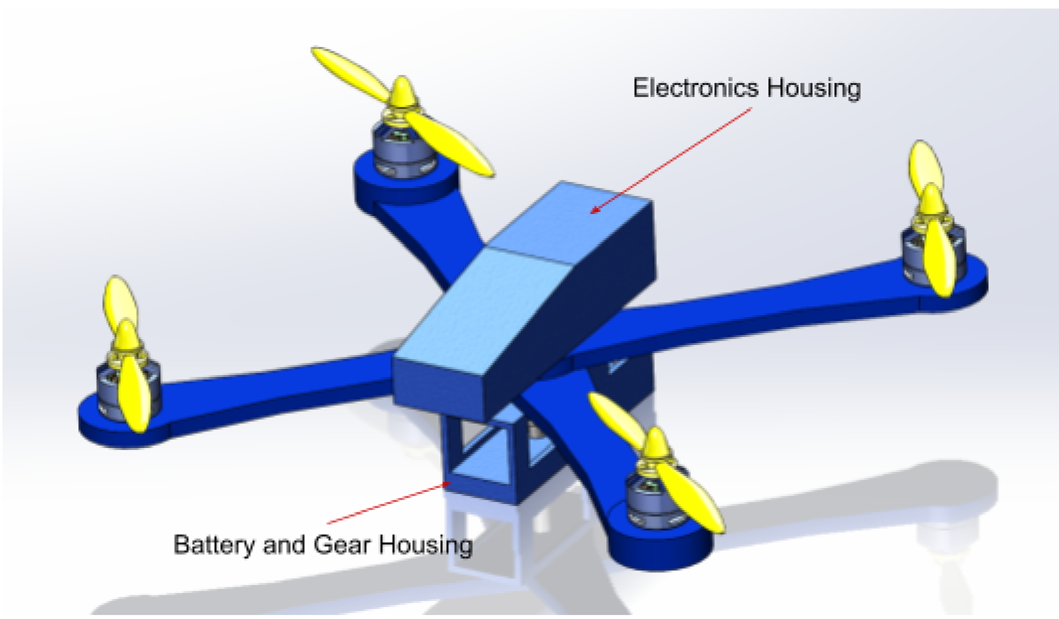


Figure 12.1.1: Drone

The gripper mechanism will primarily be 3D printed. It will have spur gear pattern on both arms such that if one arm moves, the other will move. A servo will actuate one of the arms for the gripping motion. A mechanism commercially available using the same concept is shown in (Figure 12.2.1)

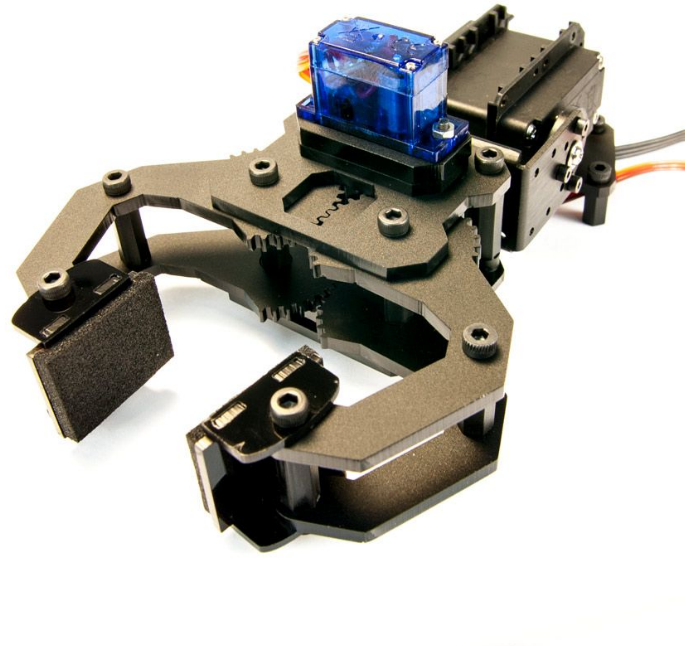


Figure 12.2.1: Gripper Mechanism

Drone Electronics and Block Diagram

The block diagram shown on Figure 12.3.1 portrays the various components and their interactions within the drone.

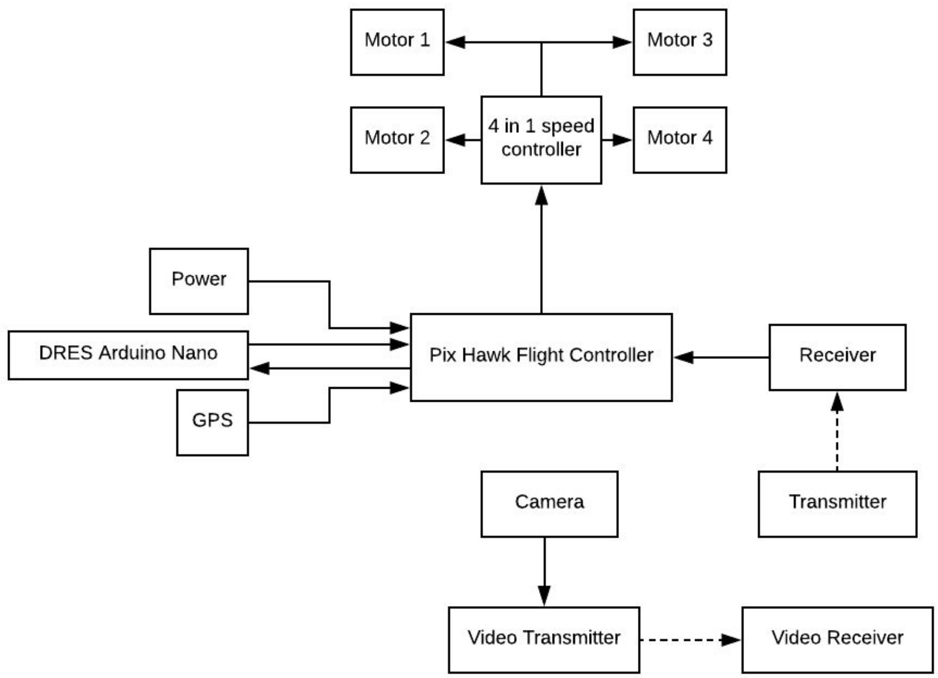


Figure 12.3.2: Drone Electronics Diagram

Drone Transmitter Selection

The AKK X1P 5.8Ghz 200mV video transmitter has been selected for its light weight and sufficient power.

Figure 12.4.1: AKK X1P 5.8Ghz

Drone Motor Selection

Brushless motors offer several advantages over brushed DC motors, which include high torque to weight ratio, more torque per watt, higher reliability, and reduction of electromagnetic interference. The key advantage that made brushless stood out was its high torque to weight ratio, which is an important criteria in keeping the drone light.

Figure 12.4.2: 2300 KV brushless motor

Electronic Speed Controller Selection

A 4 in 1 ESC has been selected to control the speed of the brushless motors. This ESC has a capacitance of 2200 μF offering higher accuracy, less drift, and smoothness. This component is also capable of both voltage and current monitoring for safety.

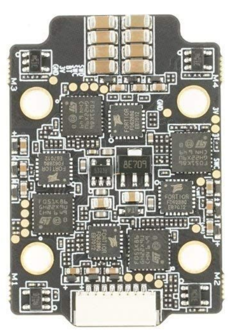


Figure 12.4.3: 4 in 1 BLHeli 32 electronic speed controller

Flight Controller Selection

Pixhawk autopilot is an open source autopilot system oriented toward inexpensive drones. The Readytosky Pixhawk PX4 has been chosen for its high performance and redundancy. When the primary controller fails, the controller can fall over to the backup control.

Figure 12.4.4: Pixhawk flight controller

Microcontroller Selection

The Arduino Nano is a 32-bit microcontroller. This microcontroller has been selected for its small size. Two Arduino Nano's will be used; one for the drone and the other for the DRES.

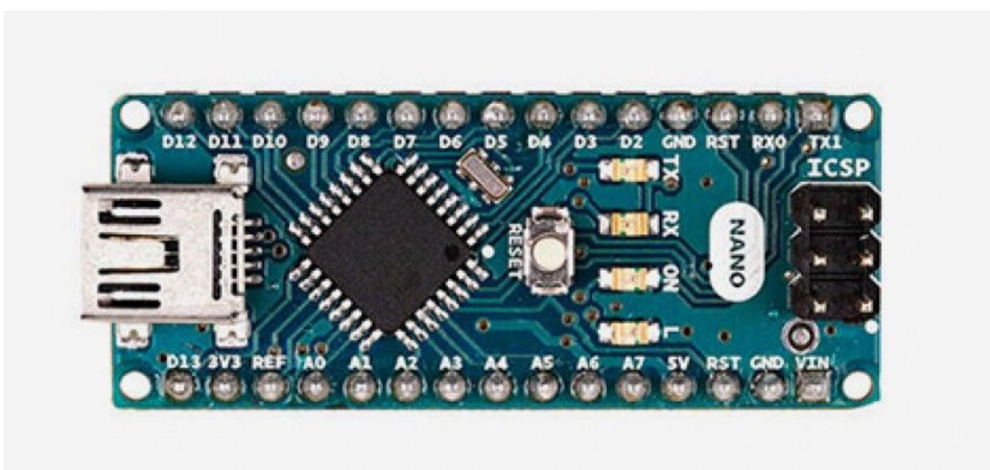


Figure 12.4.5: Arduino Nano

Servo Selection

This servo will be used to grip the navigational beacon. The reason for choosing this component was for its small size and weight, with a torque of 80 Nmm to drive the gripper.

Figure 12.4.6: Towerpro SG51R Micro Servo

Drone Battery Selection

While researching for components to buy, it was decided that a rather high discharge rate and capacity for a battery was needed just in case other electronic components were going to be placed on the drone. The chosen battery is capable of powering 4 motors and would be able to power other devices like the camera and potential servos.

Figure 12.4.7: 2200mAh LiPo Battery

GPS Selection

Radiolink M8N SE100 Mini GPS System Module was chosen for its low cost, high precision and compatibility with the pixhawk controller.

Figure 12.4.8: Radiolink M8N SE100 Mini GPS System Module

Transmitter and Receiver Selection

The FlySky FS-i6 2.4G 6CH AFHDS RC Transmitter With FS-iA6B Receiver was selected for its basic capabilities and its 6 channel control.

Figure 12.4.9: FlySky FS-i6 Transmitter with FS-iA6B Receiver

Drone Camera Selection

The RunCam Nano Camera has been selected for its small size. Although the resolution is low at 650TVL (640x480), it should be sufficient to spot the Future Excursion Area.

Figure 12.4.10: RunCam Nano FPV Camera

Drone Reorientation and Exit System

The mechanical workings of the DRES system is as follows Figure 12.5.1. The steel mounting plate that will mount the stepper motor and the counterweight will be fixed to the aluminum slider such that it will rotate with the rod. The bottom part of the rod will be supported by two thrust bearings affixed to two separate flanges. The top part of the rod during flight, will be supported by an interference fit with the nose cone. This interference fit will help support the rod during flight. Upon landing and nose cone discharge, the lead screw will spin to carry the drone out of the payload compartment for flight. Thus, satisfying payload requirement 1. The counterweight will help balance the weight from the stepper motor and lead screw.

To satisfy payload requirement 3, various measures will be taken. This includes, using an aluminum rod thick enough to sufficiently support the reorientation mechanism under 5 G-forces along with sufficient supports at the bottom and top of the rod as mentioned. In the event of a failure, the drone should be firmly attached to the DRES to minimize debris. Thus, a higher safety factor 2.5 will be used for the parts critical to the structure of the DRES.

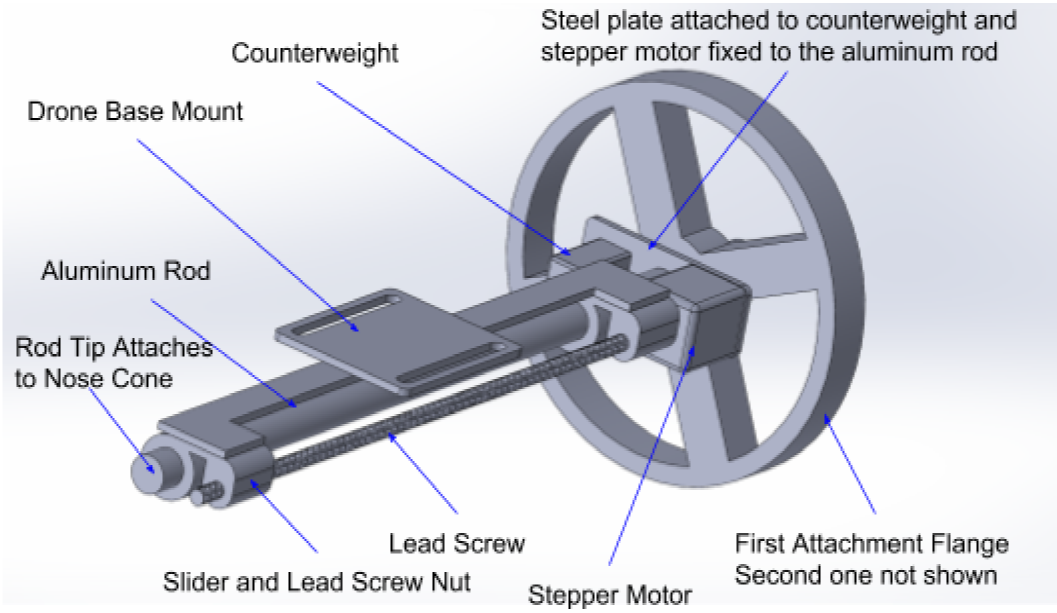


Figure 12.5.1: DRES System

Parts List

- Aluminum rod
- Lead screw
- Attachment flange
- Thrust bearings
- NEMA 11 stepper motor for lead screw
- DC motor and spur gear pair for orienting the aluminum rod.
- Arduino Nano Microcontroller
- Counterweight
- Drone base mount
- MPU-6050 gyroscope and accelerometer
- Uxcell Double Shaft Worm Gear Motor DC 12V 40RPM

DRES Electronics and Block Diagram

The block diagram shown on Figure 12.5.2 portrays the various components and their interactions for the the drone reorientation and exit system.

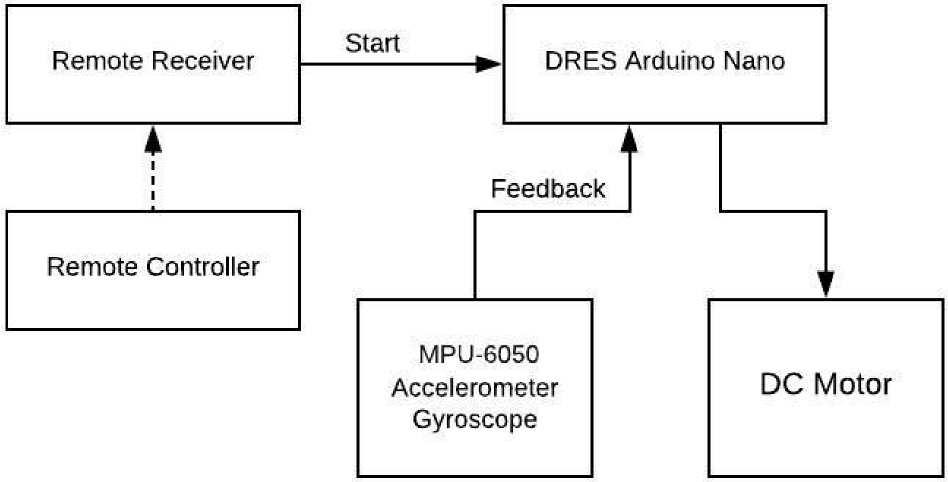


Figure 12.5.2: DRES Electronics Block Diagram

Remote Controller Selection

To satisfy payload requirement 1, the remote control will start the drone reorientation process, after which is complete, the drone will exit the payload compartment and fly. The Long Range 2000M was selected for having a working distance of 2000 meters with a magnetic antenna mount.

Figure 12.5.3: Long Range 2000M Remote Control Kit

Microcontroller Selection

The Arduino Nano has been selected for its compact size. The Arduino will control the DC motor to reorient the drone and the stepper motor for drone exit. Upon drone exit, the Arduino will send the signal to the drone flight controller for take off. This component is also used for the drone to control the navigational beacon clamp; thus also listed on the Drone Electronics Section.

IMU Selection

The MPU-6050 will feed the orientation data to the Arduino microcontroller.

Figure 12.5.4: IMU

Stepper Motor Selection

A stepper motor was selected for its ease of precise maneuverability. The Nema 11 size was chosen for its compactness. Based on comparisons, a Nema 11 can be purchased with a torque rating of 10 Ncm, which should be sufficient for the lead screw mechanism.

Figure 12.5.5: Nema 11

DC Motor Selection

The Uxcell Double Shaft Worm Gear Motor motor has been selected. This 1 Nm motor will have enough torque to reorient the aluminum rod and to keep it from rotating after reorientation. The motor shaft will be attached to a spur gear meshing with another spur gear attached to the aluminum rod.

Figure 12.5.6: Uxcell worm gear motor

Future Considerations

Among the primary challenges for the drone is the drone exit method. There are many variables that can negatively impact the drone exit. These issues could potentially be but are not limited to, parachute or long grass getting in the way of the drone, uneven terrain making drone maneuverability difficult on take off, drone becoming stuck while exiting. To address these issues, the design will likely need fine tuning and changes to ensure that the drone performs without mishaps. Another primary challenge is the drone folding mechanism. One of the issues with the current folding design is that a separate motor is needed to unfold the mechanism. It could be much more simpler by using a torsional spring; however, using a torsional spring will require a locking mechanism to prevent the drone arms from swivel. Thus, more designs are to be considered with several viable prototypes for folding.

STEM Engagement

Engagement Through AIAA-SBU

The primary method that the Seawolves team will take to engage with the community will be through the AIAA-SBU organization. Since there has been virtually no aerospace presence on the SBU campus until the reinstatement of AIAA-SBU in Fall 2016, this project is a perfect way to engage the community of students that are interested in aerospace. One of the biggest goals of AIAA-SBU is to inspire younger students to participate in activities similar to this competition, following the completion of this year’s activities.

Arduino Workshop

One of the numerous events that AIAA-SBU will be participating in is an Arduino workshop. This event is a collaborative effort, hosted by SBU's Robotics Team and a few other participating organizations. The purpose of this event is to teach students, particularly lowerclassmen with little experience, about the basics of Arduino. This workshop will be particularly helpful to first-year mechanical engineering students, as the introductory course in mechanical engineering requires the completion of a robot project controlled by an Arduino Uno. This event will take place on October 24, from 5:30-7:00 pm. The anticipated attendance for this event is 30 students.

Company Tours

AIAA-SBU is really focused on getting its members involved with the local industry. One of the ways we intend to do this is through company tours; we are currently in the process of setting up a tour with Orbital ATK/Northrop Grumman in late October (pending approval from AIAA-SBU's company contact). While this company is the closest to being confirmed for a tour, AIAA-SBU also intends to reach out to other local companies, including but not limited to GE Aviation, Rockwell Collins, Cobham, Dayton T. Brown, and Telephonics. Hopefully students will have the chance to visit multiple companies throughout the year as a result of our efforts. Depending on the company, an estimation of 15-25 students can be used as a tentative approximation for each tour.

Professional Development Events

While competitions, industry engagement, and workshops are imperative to the mission of AIAA-SBU, professional development is also a top priority of the organization. AIAA is a professional organization, so there is a responsibility of SBU's chapter to prepare members for their ultimate entry into the workforce. AIAA-SBU plans to participate in a few of these events throughout the year, with the main event being a collaboration for a pre-conference workshop, hosted by SBU's chapter for the Society of Asian Scientists and Engineers (SASE). This is an annual event, and SASE usually anticipates great attendance (approximately 60-75 students). The lessons learned for this event are imperative to develop the networking skills required to make strong connections in the STEM field.

With the combination of this event, along with AIAA-SBU's participation in resume reviews, mock interview sessions, and more, it can be estimated that this form of engagement will extend to roughly 120 students throughout the year.

Industry Calls/Informational Interviews

Throughout the past year, the president of AIAA-SBU, CJ Liopyros, has been developing an extensive network of contacts in the aerospace industry. CJ reaches out to industry professionals to conduct informational interviews and find out more about their careers, as he is undecided about his specific career path. However, he recently brought the idea to the rest of the AIAA-SBU E-Board; as a result, AIAA-SBU is planning on contacting some of his most interesting contacts to see if they would be open to an informational interview session with a group of students (members from AIAA-SBU and any other collaborating organizations). Many students are probably in the same position as CJ, and would be interested in hearing about some prospective career paths in aerospace. If properly advertised, as this is a unique event, an anticipated attendance of 20-25 students could be accounted for, for each call.

Engagement Summary

The table content below provides an estimation of the current plans and hopes for AIAA-SBU's STEM engagement activities throughout the academic year.

Event	**Estimated Date(s)**	**Anticipated Attendance**
Arduino Workshop	10/24/18	30
Company Tours	10/18; 12/18; 3/19	60
Professional Development Events	09/26/18, 10/18; 2/19	120
Industry Calls/Informational Interviews	11/18; 2/19	45
		Total: 255

Table 12: Current plan summary

Project Plan

Budget

Subsystem Team Budgets

Structures, Aerodynamics, and Propulsion (SAP) Budget					
Item Name	**Manufacturer**	**Part Number (Link)**	**Quantity**	**Price (US$)**	**Item Total (US$)**
L2200G	Aerotech	L2200G	1	$259.99	$259.99
PLA Spool	HATCHBOX	N/A	2	$20.00	$40.00
Primer	McMaster-Carr	N/A	1	$33.94	$33.94
Paint	McMaster-Carr	N/A	1	$38.75	$38.75
Epoxy	McMaster-Carr	N/A	5	$80.48	$402.40
Sand Paper	McMaster-Carr	N/A	1	$49.74	$49.74
Threaded Rods	McMaster-Carr	N/A	20	$0.00	$0.00
Hex nuts	McMaster-Carr	N/A	74	$0.00	$0.00
Fiberglass Tubing	N/A	N/A	3	$184.99	$554.97
Flathead Screws	N/A	N/A	N/A	N/A	N/A
Fiberglass Plates	Madcow Rocketry	FG-PL-125-VS	4	$0.00	$0.00
Eye-Bolt	N/A	N/A	N/A	N/A	N/A
Wooden Plates	N/A	N/A	6	$0.00	$249.60
PVC Canister (one 1" x 10 ft section)	Home Depot	193755	4	$41.60	$166.40
Total SAP System Projected Cost:				**$1,629.39**	

Payload Budget

Item Name	Manufacturer	Part Number	Quantity	Price (US$)	Item Total (US$)
4 Brushless motors with 2300KV	Woafly	B01KFD3WBU	1 (4 motors included)	$30.00	$30.00
6in propeller blades	Master Airscrew	RS Series 6045	1 (4 propellers included)	$5.00	$5.00
4 in 1 ESC	Rcharlance	B07CQKBQW2	1	$55.00	$55.00
Pixhawk flight controller	ReadyToSky	B07CHQ7SZ4	1	$72.00	$72.00
TowerPro micro servo	Adafruit	485169	1	$5.00	$5.00
2200mAh LiPo Battery	Gens Ace	GA-B-25C-2200-3S1P	1	$27.00	$27.00
RunCam Nano FPV Camera	getFPV	7875	1	$20.00	$20.00
Radiolink M8N SE100 Mini GPS System	Radiolink	B07FQ66W9F	1	$23.00	$23.00
FlySky FS-i6 2.4G 6ch AFHDS RC Transmitter with FS-iA6B Receiver	Banggood	983537	1	$49.00	$49.00
AKK X1P 5.8Ghz Video Transmitter	Akk	KK-X1P	1	$14.00	$14.00
Nema 11 Bipolar Stepper Motor	Osmtec	11HS18-0674S	1	$18.90	$18.90
DC 12V 40RPM Worm Gear Motor	Uxcell	a17022400ux0506	1	$35.61	$35.61
MPU-6050	Adafruit	485-2019	1	$7.95	$7.95
Total Payload System Electronics Projected Cost:				**$362.46**	

Recovery & Navigation Budget					
Item Name	Manufacturer	Part Number (Link)	Quantity	Price (US$)	Item Total (US$)
Main Parachute	Iris Ultra 84" Standard Parachute	IFC-84	1	$276.00	$276.00
Drogue Parachute	Pro-Experimental 1.9 Low-Porosity Ripstop Parachutes	Pro 2ft CHUTE	1	$43.00	$43.00

Altimeter(s)	PerfectFlite	StrattoLoggerCF	2	$54.95	$109.90
Shear Pins	McMaster-Carr	98372A450	1	$12.35	$12.35
GPS/RF Unit	BigRedBee	BRB900	1	$367.00	$367.00
Eyebolts	McMaster-Carr	3014T45	4	$3.01	$12.04
Shock Cords	Apogee Components	30327	30	$0.97	$29.10
Batteries	McMaster-Carr	71455K56	3	$4.85	$14.55
Switches	McMaster-Carr	7188K22	1	$19.43	$19.43
Connecting Links	McMaster-Carr	8947T25	4	$2.56	$10.24
Total Recovery & Navigation System Projected Cost:				**$893.61**	

Total Budget

Estimated Total Expenses	
Item Name	**Item Total (US$)**
SAP	$1,629.39
PAY	$362.46
R&N	$893.61
Travel	$4,000.00
Total Projected Cost:	**$6,885.46**

Project Schedule

The project schedule was created using Google Sheets, a cloud-based spreadsheet software. The schedule updates cell colors based on the proximity of important dates, providing a real-time look on major student launch event dates. Below is an image of the schedule from September 19, 2018:

Timeline for NASA Student Launch					
Year	**Month**	**Date**	**Item/Event**	**Notes?**	**Days Until**
2018	August	08/22/2018	Request for Proposal (RFP) Released		-28

	September	09/19/2018	Electronic copy of completed proposal due	Submit to project office by **3 p.m. CDT (4 p.m. in New York)** to **Katie Wallace: katie.v.wallace@nasa.gov** **Fred Kepner: fred.kepner@nasa.gov** Receipt of all submissions will be confirmed via an email response. If you have attached a large file to your submission email and not received an email confirmation, it may not have been received.	0
	October	10/04/2018	Awarded proposals announced		15
		10/12/2018	Kickoff and PDR Q&A		23
		10/26/2018	Team social media presence established	Social media handle list sent to project office by **8:00 a.m. CDT (9:00 a.m. in New York)**	37
	November	11/02/2018	Preliminary Design Review (PDR) report, presentation slides, and flysheet due	Submit to NASA project management team by **8:00 a.m. CDT. (9:00 a.m. in New York)**	44
		11/05/2018	PDR video teleconferences	until 11/19/2018	47
		11/27/2018	CDR Q&A		69
2019	January	01/04/2019	Critical Design Review (CDR) report, presentation slides, and flysheet due	Submit to NASA project management team by **8:00 a.m. CST (9:00 a.m. in New York)**	107
		01/07/2019	CDR video teleconferences	until 01/22/2019	110
		01/25/2019	FRR Q&A		128
	March	03/04/2019	Vehicle Demonstration Flight deadline		166
		03/04/2019	Flight Readiness Review (FRR) report, presentation slides, and flysheet due	Submit to NASA project management team by **8:00 a.m. CST (9:00 a.m. in New York)**	166

		03/08/2019	FRR video teleconferences	until 03/21/2019	170
		03/25/2019	Payload Demonstration Flight and Vehicle Demonstration Re-flight deadlines		187
		03/25/2019	FRR Addendum due	Submit to NASA project management team by **8:00 a.m. CST (9:00 a.m. in New York)** (Teams completing additional Payload Demonstration Flights and Vehicle Demonstration Re-flights only)	187
	April	04/03/2019	Teams travel to Huntsville, AL		196
		04/03/2019	Launch Readiness Reviews (LRR) for teams arriving early	OPTIONAL	196
		04/04/2019	Official Launch Week Kickoff, **LRR**s, Launch Week Activities		197
		04/05/2019	Launch Week Activities		198
		04/06/2019	**Launch Day**		199
		04/06/2019	Awards Ceremony		199
		04/07/2019	Backup launch day		200
		04/26/2019	Post-Launch Assessment Review (PLAR) due	Submit to NASA project management team by **8:00 a.m. CDT (9:00 a.m. in New York)**	219

Table 13: Critical Project Deadlines

Funding

From preliminary budget estimates, this project requires a total of $6,885.46 to effectively execute. To successfully attain this funding, the Stony Brook team has reached out to three university organizations, a variety of local aerospace/mechanical engineering companies, alumni, and interested personel. The team has also requisitioned funds allocated for senior design teams working on the project.

One university organization that the team reached out to request funds from was the College of Engineering and Applied Sciences (CEAS). Student clubs and organizations on campus registered with CEAS are able to request funds through CEAS. AIAA-SBU applied for funding for the 2019-2019 year. AIAA-SBU has previously received funding for projects through CEAS. In total, $1500 was requested to pay for some structural supplies as well as pay for travel and outreach events. It is expected that a significant portion of this funding will be granted to the chapter.

The team also has access to funding through the Undergraduate Student Government (USG) at Stony Brook University because AIAA-SBU is an officially recognized university student organization. The AIAA-SBU chapter is due to receive a maximum of $600 in the Spring 2019 semester. In addition, AIAA-SBU has the ability to apply for up to $4000 in travel grants. AIAA-SBU chapter intends to reach out to them to request funding for travel.

CEAS also offers outreach programs for all of the clubs that they support. This includes a team that will help obtain third party sponsorship for any competition club. Since AIAA-SBU is registered as both a professional organization and a competition club they are able to use this outreach program to try to obtain funding from local and national companies. Currently the club has created a sponsorship packet is in the process of . Companies can benefit from this in many ways. Sponsorships are tax deductible and also provides opportunities for networking with students within the Stony Brook community for potential employment. In total the team estimates to obtain $2000 from outside sponsorship to use on the project. Another university department that the team reached out to request funds from was the Department of Mechanical Engineering. This department has previously sponsored design competition teams in the past, and the team expects to receive $500 from the department.

A final source of monetary resources is money allocated to the senior design teams to work on their senior design projects. Each student on a team is given $280 once their project is approved. In total there are 9 students who are working on this project as part of their senior design class meaning that $2,520 will be allocated to this project through those teams.

In total the proposed outreach will result in $11,120 distributed to the Stony Brook team. This is $4,234.54, which is good as the extra money would go to more supplies for testing and facilities for testing.

Sustainability Plan

Due to the relatively new presence of Stony Brook in this competition, creating a lasting plan so that this team will remain at Stony Brook is very important to the team. To do this a combination of outreach to the university community, especially the underclassmen, and the community and AIAA regional chapter will be done.

The outreach to the university community is most important to us as they will be the next generation of the Stony Brook team. Since most of our members are in their junior or senior years the team is looking to bring in young members by offering shadowing and workshops to teach the students technical skills required to participate in a project of this caliber, while at the same time having fun. Along with this after the successful completion of our launch we believe it will draw attention from the university students and faculty because nothing like this has been done at Stony Brook, or on Long Island in the last 10 years. The team hopes to build off this momentum and draw members, faculty, and sponsorship for funding to help support the project. Finally from the many events that the AIAA chapter plans to hold it is hoped that the team can educate the university and community on the importance of this work and how thrilling it can be.

Another way the to keep the team's presence known is through outreach to the community and to the regional AIAA chapter. To establish a presence in the community it is planned to constantly keep the sponsors we obtain updated with project milestone and try to bring them in when possible to view our project. Along with this it is hoped that after the first community outreach event, a better understanding of what the surrounding community wants can be established and a yearly event can be help at Stony Brook geared towards rocketry. Finally through the AIAA regional chapter it is hoped that through this competition Stony Brook will become more recognizable to them so that they may support this chapter with funding and manpower for events and ideas.

Due to the new presence of this Stony Brook team it is most important to establish a baseline of members and funding. This will be the focus of the sustainability plan and will mainly take place through the university. In years to come once the team is established more focus can be placed on student engagement and community outreach.