Tacho Lycos

2025 NASA Student Launch

Proposal

High-Powered Rocketry Club at NC State University
1840 Entrepreneur Drive
Raleigh, NC 27606

September 11, 2024

Common Abbreviations and Nomenclature

AGL	=	Above Ground Level
AIAA	=	American Institute of Aeronautics and Astronautics
APCP	=	Ammonium Perchlorate Composite Propellant
APRS	=	Automatic Packet Reporting System
ASME	=	American Society of Mechanical Engineers
AV	=	Avionics
AVAB	=	Avionics and Air Brakes Bay
CAD	=	Computer Aided Design
CDR	=	Critical Design Review
CG	=	Center of Gravity
CNC	=	Computer Numerical Control
CP	=	Center of Pressure
FAA	=	Federal Aviation Administration
FMEA	=	Failure Modes and Effects Analysis
FRR	=	Flight Readiness Review
HPRC	=	High-Powered Rocketry Club
LRR	=	Launch Readiness Review
MAE	=	Mechanical & Aerospace Engineering
SDS	=	Safety Data Sheets
MSFC	=	Marshall Space Flight Center
NAR	=	National Association of Rocketry
NASA	=	National Aeronautics and Space Administration
NCSU	=	North Carolina State University
NFPA	=	National Fire Protection Association
PDR	=	Preliminary Design Review
PETG	=	Polyethylene Terephthalate Glycol
PLA	=	Polylactic Acid
PLAR	=	Post-Launch Assessment Review
PPE	=	Personal Protective Equipment
RMFS	=	Removable Modular Fin System
RSO	=	Range Safety Officer
SL	=	Student Launch
STEM	=	Science, Technology, Engineering, and Mathematics
STEMCRaFT	=	STEMnaut Capsule Radio Frequency Transmitter
STL	=	Stereolithography (File Format)
TAP	=	Technical Advisory Panel (TRA)
TRA	=	Tripoli Rocketry Association
WWE	=	WolfWorks Experimental

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1 General Information

1.1 Team Advisors and Mentors

i. Name: Dr. Felix Ewere

ii. Email: feewere@ncsu.edu

iii. Phone: (919) 515-8381

iv. Biography: Dr. Ewere is a teaching professor at North Carolina State University in the department of Mechanical and Aerospace Engineering. He is currently teaching the Aerospace Engineering Senior Design class and also acts as an advisor in the department of Aerospace Engineering. Dr. Ewere has a PhD in Mechanical Engineering and a Master's in Aerospace Engineering, both of which are from the University of Alabama in Huntsville. His research interests include the science and technology necessary for aerodynamics, structural mechanics, energy and smart materials. Recent works of his have focused on exploiting aeroelastic instabilities on piezoelectric structures used in engineering applications. His educational research interests are engineering design education and improving diversity and collaboration within disciplines. Dr. Ewere is also a senior member of AIAA and an ASME member.

i. Name: James "Jim" Livingston

ii. Email: livingston@ec.rr.com

iii. Phone: (910) 612-5858

iv. TRA Flyer Number: 02204

v. Biography: Jim Livingston will be the team mentor for the club in the 2025 NASA Student Launch Competition. Livingston joined TRA in 1993 and earned his Level 3 Certification with TRA in 1997. He has personally supervised more than 20 TRA members in earning their Level 3 Certification. Since 1998, he has served as a member of the TRA Technical Advisory Panel (TAP), which is responsible for advising the TRA board of directors on the technical aspects of propellants, construction materials, and recovery techniques. Livingston has also been involved in Tripoli motor research since 1997, and manufactured all of the motors he flew of sizes I through N for 25 years.

1.2 High-Powered Rocketry Club

The High-Powered Rocketry Club, also known by the team name "Tacho Lycos", is an interdisciplinary student organization within the Department of Mechanical and Aerospace Engineering at North Carolina State University. The club aims to stimulate interest in rocketry by designing and building high-powered rockets and competing in the NASA Student Launch (SL) Competition. Established in 2009, the club has provided an opportunity for students to gain real-world engineering experience through the annual NASA SL Competition, hosted by NASA's Marshall Space Flight Center (MSFC) in Huntsville, Alabama. Approximately 50 club members are involved in the design and construction of the SL Competition rocket and payload, who are led by a team of Aerospace Engineering Seniors, defined in Section 1.5. These seniors have elected to participate in the SL Competition to satisfy their senior design capstone project requirement. The final grade the Senior Design Team receives corresponds to the final SL Competition score given to the NC State University team. The club officers, defined in Section 1.6, oversee other club operations such as STEM Engagement events, regulation of club funds, and the club's social media platforms. The Senior Design Team and Officer Team regularly communicate with the team mentors, defined in Section 1.1, regarding research, planning, design, construction, testing, and launching of high-powered rockets. In addition to the SL Competition, the High-Powered Rocketry Club has a subsystem led by the Vice President that conducts experimental projects such as Air Brakes, imaging systems, and rover prototypes.

1.3 Student Team Leader

i. Name: Katelyn Yount

ii. Email: kvyount@ncsu.edu

iii. Phone: (980) 258-2628

iv. Responsibilities: Katelyn will act as the NC State University Student Team Lead for the 2025 NASA SL Competition. She will serve as both Team Lead of the Senior Design Team, as identified in Section 1.5, and President of the High-Powered Rocketry Club. As Senior Design Team Lead, Katelyn is responsible for managing each subsystem, as defined in Section 1.7, overseeing vehicle and payload design, ensuring all documentation is professional and cohesive, and creating and following a project schedule. Katelyn's responsibilities as president are detailed in Section 1.6.

1.4 Safety Officer

i. Name: Megan Rink

ii. Email: mdrink@ncsu.edu

iii. Responsibilities: Megan is responsible for ensuring the safe operation of lab tools and materials. This includes, but is not limited to, drill presses, hand tools, band saws, miter saws, power tools, dremels, flammable items, and hazardous materials. Megan is required to be present to ensure safety during the construction, assembly, and testing of the launch vehicle, payload, and other associated components. Megan must also be present at all club launches to ensure the club follows a launch day safety checklist and abides by the guidance of the local rocketry club's RSO, regardless of their relation to the NASA SL Competition. Prior to club launches, Megan is required to give a briefing on proper launch day safety practices, possible hazards, and personal checklist assignments to ensure the safety of club members. Additionally, Megan is responsible for maintaining the lab space and equipment to exceed NASA, MAE, and Environment Health and Safety standards. This includes, but is not limited to: displaying proper safety information and documentation, maintaining safe operation of the flame and hazardous materials cabinet, stocking the first aid kit, ensuring the proper use of PPE, and educating members on the proper operation of lab equipment. Megan must also manage and maintain documentation of the team's hazard analyses, failure mode analyses, and SDS chemical inventory data. Furthermore, Megan is responsible for ensuring that STEM Engagement Activities are conducted in a safe manner. In the event that Megan is not present in the lab or launch field during club events, a qualified team member trained by Megan will be appointed to perform all Safety Officer responsibilities.

1.5 Senior Design Team

The Senior Design Team, as shown below in Figure 1.1, consists of the Student Team Lead, as defined in Section 1.3, and seven Aerospace Engineering seniors who are using the NASA SL Competition as their senior capstone project. These seniors are responsible for the completion of all projects related to the NASA SL Competition. The roles and responsibilities of each of the Senior Design Team members are defined below, in the order they appear from left to right. The subsystems that each Senior Design member will be responsible for are defined in Section 1.7.

Figure 1.1: 2024-2025 Senior Design Team.

i. Name: Samuel Patterson

ii. Subsystem: Payload Electronics

iii. Previous years of club involvement: 1

iv. Biography and Responsibilities: Sam is a senior in Aerospace Engineering who enjoys aviation and the outdoors. This year he will be the Payload Electronics Team Lead, and he hopes to get first place. He has previously worked on the High-Powered Rocketry Club's Air Brakes projects, which he will help to integrate into this year's Student Launch rocket. In his free time, he enjoys going sailing and spending time with his friends.

i. Name: Trent Couse

ii. Subsystem: Recovery

iii. Previous years of club involvement: 5

iv. Biography and Responsibilities: Trent is a 6th-year student and will be the Recovery Lead. He is studying Aerospace Engineering with minors in Physics and Outdoor Education. He is enthusiastic about this year's payload challenge and implementing Air Brakes into our competition rocket. Outside of HPRC, he has worked as an Astrophysics Undergraduate Research Assistant and completed five rotations as a NASA Pathways Intern at Johnson Space Center. In his free time, he loves hiking, climbing, and mountaineering.

i. Name: Ryan Keever

ii. Subsystem: Payload Structural Integration

iii. Previous years of club involvement: 1

iv. Biography and Responsibilities: Ryan is a senior in Aerospace Engineering and is the Structural Integration Payload Lead. He is responsible for the design and development of this year's payload system, aiming to create an innovative payload that excels at the SL Competition. Over the past summer, he interned at NASA Langley Research Center, designing and prototyping hardware for the robotic assembly of structures on the Moon. In his free time, he enjoys playing soccer, watching movies, and he loves cats.

i. Name: Abigail Kuppler

ii. Subsystem: Integration

iii. Previous years of club involvement: 1

iv. Biography and Responsibilities: Abigail is a senior majoring in Aerospace Engineering. She is an active member of HPRC, where she serves as the Integration Lead for this year's Senior Design Team. Within her role, Abigail is responsible for integrating payloads and new structural components into the launch vehicle. She also facilitates effective communication between various subsystems and assists the Team Lead with project management and documentation. Abigail is a Brooke Owens Fellow, Class of 2024, and has recently completed an internship at Stratolaunch where she focused on payload integration and structural design.

i. Name: James Holley

ii. Subsystem: Structures

iii. Previous years of club involvement: 1

iv. Biography and Responsibilities: James is an Aerospace Engineering senior, and is responsible for the structural analysis, testing, and construction of the launch vehicles and component hardware. This year James aims to lead the creation of safe, effective, and elegant SL competition rockets by innovating and refining successful past team designs and techniques. James has been involved with rocketry since childhood and holds a Level 2 High-Powered Certification through the Tripoli Rocketry Association. He is passionate about space exploration and all manner of air and spaceflight.

i. Name: Aubri Sprouse

ii. Subsystem: Aerodynamics

iii. Previous years of club involvement: 2

iv. Aubri is a senior in Aerospace Engineering and has completed a minor in Graphic Communications. This year she in charge of the aerodynamic design of the rocket. This entails designing the primary structure, optimizing mass, ensuring flight stability, and implementing an Air Brakes system to meet the altitude challenge given by the NASA SL Competition. She previously interned at United Launch Alliance, where she worked in systems and design. Aubri also currently leads the SolidWorks User Group at NC State and enjoys watching and playing sports.

i. Name: Connor Swanson

ii. Subsystem: Payload Systems

iii. Previous years of club involvement: 2

iv. Biography and Responsibilities: Connor is a senior majoring in Aerospace Engineering with minors in Business Administration and Computer Programming. As Payload Systems Lead, his responsibilities include designing, developing, and testing the various systems involved in the rocket's payload. This year, he is looking forward to working on a successful and exciting payload design. He has previously completed a co-op at Altec as a manufacturing engineer, where he designed and implemented improvements to manufacturing processes. Outside of engineering, he enjoys playing and listening to music, watching football, and playing board games.

1.6 Leadership Team Organization

For the 2024-2025 school year, the club leadership team consists of two primary groups: the Senior Design Team and the Officer Team. While each of the teams are responsible for different aspects of the team's operation, both teams share responsibility for leading approximately 50 students through the SL competition and other high-powered rocketry related projects. The Senior Design Team is outlined in Section 1.5, and the Officer Team and their respective roles and responsibilities are outlined below, in order as they appear from left to right in Figure 1.2.

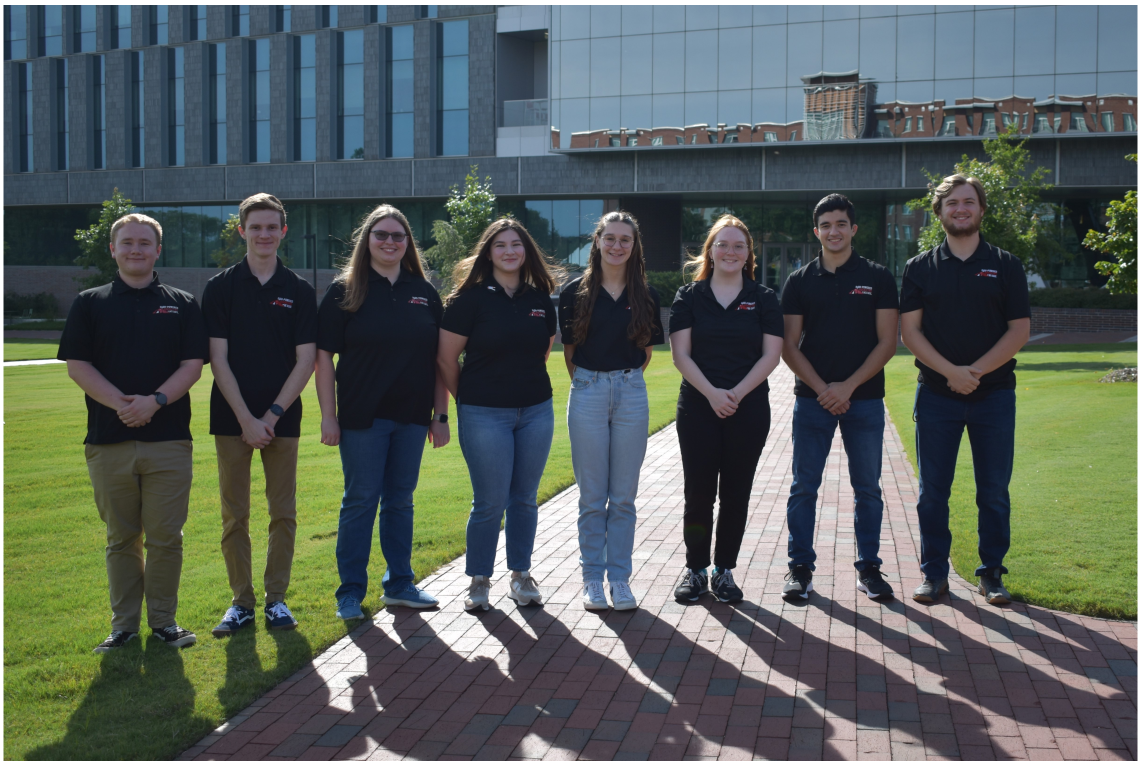


Figure 1.2: 2024-2025 Officer Team.

i. Name: James Garmon

ii. Position: Social Media Officer

iii. Previous years of club involvement: 1

iv. Biography and Responsibilities: James is a junior majoring in Aerospace Engineering and is responsible for managing all of HPRC's social media platforms. His goal is to use these platforms to increase engagement as well as document the club's progress throughout the academic year. He plans to utilize all available platforms including Instagram, LinkedIn, Facebook, X, Tiktok, and YouTube. James joined HPRC in his sophomore year and already holds his Level 1 certification. He is planning to earn his Level 2 certification this year. In his free time, James enjoys hanging out with friends, watching movies, and playing disc golf.

i. Name: Donald Gemmel

ii. Position: Vice President

iii. Previous years of club involvement: 2

iv. Biography and Responsibilities: Donald is a junior in Aerospace Engineering. This year he will be leading the WolfWorks Experimental (WWE) team in developing new student designs for tested high-power rockets. This will be Donald's fifth year working on amateur high-power rockets, and he holds a Level 2 certification through the National Association of Rocketry. Outside of HPRC, he enjoys mountain biking around campus and on local trails, and he conducts research in the NC State Turbulent Shear Flow Laboratory.

i. Name: Emily Cates

ii. Position: Webmaster

iii. Previous years of club involvement: 1

iv. Biography and Responsibilities: Emily is a junior in Aerospace Engineering. This year, she is responsible for keeping the club's website informative, up-to-date, and looking awesome. She is excited to work with the senior design team to build this year's rockets and payload, and she also hopes to get her Level 1 certification this fall. In her free time, Emily loves to travel and build Lego sets, and is a big fan of Dodgers baseball.

i. Name: Megan Rink

ii. Position: Safety Officer

iii. Previous years of club involvement: 3

iv. Biography and Responsibilities: Megan is a senior majoring in History with a concentration in Technological History. In addition to maximizing NASA safety score, she hopes to create a fun and safe environment this year and enhance the overall safety awareness of the club. In addition to rocketry, Megan has worked as a Museum Content and Collections Intern at the NASCAR Hall of Fame. She is a massive audiophile, an avid record collector, and enjoys NC State sporting events of all kinds.

i. Name: Katelyn Yount

ii. Position: President

iii. Previous years of club involvement: 3

iv: Biography and Responsibilities: Katelyn is a senior in Aerospace Engineering with a minor in Mathematics. As Team Lead and Club President, she is responsible for leading the Senior Design Team and managing the club. This year, Katelyn aims to guide the club to excel in the 2025 NASA Student Launch Competition and create a welcoming environment for all members. Katelyn has previously served as Vice President and Outreach Lead for the club and holds her Level 1 High-Powered Rocketry Certification. She has also worked as a research assistant in the Engineering Mechanics and Space Systems Lab on an amphibious rover. In her free time enjoys swimming.

i. Name: Sofia Antinozzi

ii. Position: Secretary

iii. Previous years of club involvement: 3

iv. Biography and Responsibilities: Sofia is a senior in Material Science and Engineering with a minor in Data Science. She plans to keep the club on track by communicating with club members and outside organizations as HPRC's primary point of contact. She is the president of NC State's Material Advantage Chapter and works as an undergraduate researcher in the Corrosion and Advanced Materials Lab at NC State.

i. Name: Tyler Perez

ii. Position: Treasurer

iii. Previous years of club involvement: 1

iv. Biography and Responsibilities: Tyler is a junior in Mechanical Engineering with a minor in Business Entrepreneurship. Tyler's responsibilities include maintaining the budget across the multiple subsections of the club and ensuring that sufficient funding is provided throughout the school year. He is also in charge of fundraising and merchandise-related activities. Outside of rocketry, Tyler is the student recruitment lead for the Society of Sales Engineers and enjoys motor-sports in his free time.

i. Name: Ben Radspinner

ii. Position: Outreach Lead

iii. Previous years of club involvement: 1

iv. Biography and Responsibilities: Ben is a junior in Aerospace Engineering. He is responsible for hosting outreach events with organizations outside of the University to teach others about rocketry. This year he will be working on networking with new schools and creating more fun activities so that kids of all ages can learn about HPRC's projects. In his free time he enjoys playing tennis with friends and listening to new music.

1.7 Subsystem Definition

For the Student Launch Competition the team is divided into several subsystems, each responsible for a different aspect of the project. The subsystems and the responsibilities of each subsystem are defined below. Each subsystem is led by a member the Senior Design Team or the Safety Officer, as identified in Sections 1.5 and 1.4 respectively. Each subsystem is also responsible for the incorporation and verification of a subset of requirements, defined in the "Subsystem Allocation" column of all requirement tables. The subsystems are:

- Project Management
- Safety
- Integration
- Aerodynamics
- Structures
- Recovery
- Payload Systems
- Payload Electronics
- Payload Structural Integration

The Project Management Team, led by Katelyn Yount, is responsible for creating and managing the team's schedule, including organizing launches and communicating with NASA, NAR, and TRA. The Project Management Team is also responsible for organizing documentation, mitigating conflicts that arise between subsystems, and delegating responsibilities. The Safety Team, led by Megan Rink, is responsible for ensuring safety during project construction, testing, and launching, through the implementation of risk mitigation procedures. The Safety Team is also responsible for documentation of lab space equipment and SL projects. The Integration Team, led by Abigail Kuppler, is responsible for system-level integration of payload and structural components into the launch vehicle. The Aerodynamics Team, led by Aubri Sprouse, is responsible for launch vehicle flight simulations, motor selection, apogee prediction, fin and Nose Cone design, and stability management. The Structures Team, led by James Holley, is responsible for the construction of the subscale and full-scale launch vehicles. The Structures Team is also responsible for vehicle material selection and structural verification testing. The Recovery Team, led by Trent Couse, is responsible for the launch vehicle recovery system, including parachute selection, altimeter selection, GPS selection, black powder charge determination, and ejection testing. The Payload Team is divided into three subsections including the Payload Systems Team, the Payload Electronics Team, and the Payload Structural Integration Team. The Payload Systems Team, led by Connor Swanson, is responsible for the design, testing, and implementation of the software required for the collection of rocket and landing site data, and transmission of this data via radio frequency to the NASA receiver. The Payload Electronics Team, led by Samuel Patterson, is responsible for the construction, configuration, and verification of the electrical hardware required for the collection and transmission of data for the payload challenge. Finally, the Payload Structural Integration Team, led by Ryan Keever, is responsible for the designing, building, and testing of the STEMnaut flight capsule that safely retains STEMnauts and houses the electronics required for the payload challenge. The Payload Structural Integration Team is also responsible for successful integration of the structural and electrical components required for the payload system.

1.8 Local NAR/TRA Chapter Information

The NC State University High-Powered Rocketry Club will be working with the Tripoli East NC prefecture (TRA Prefecture 65). The prefect for this chapter is currently Kurt Hessee. The club's mentor, Jim Livingston, is responsible for the purchase and storage of all motors bought for SL launches throughout the competition. Livingston's qualifications are listed in Section 1.1. Such motors are bought under his supervision and approval, and stored according to his specific safety requirements. For launches, all motors are assembled under Livingston's supervision. Livingston will also review designs and documents for the High-Powered Rocketry Club throughout the competition.

1.9 Time Spent on Proposal

Approximately 257 hours were spent on this proposal across all Senior Design Team members. This includes time spent brainstorming, attending meetings, creating schedules, and writing the document itself.

2 Facilities and Equipment

2.1 Description

The High-Powered Rocketry Club uses the MAE Student Fabrication Lab in Room 2003 of Engineering Building III on NC State University's Centennial Campus, informally referred to as the ”Rocketry Lab”. This workspace is equipped with a small drill press, belt sander, band saw, scroll saw, miter saw, vise, 3-D printer, and handheld power tools. Club members who have completed additional specialized training also have access to the Entrepreneurship Initiative Garage located in the Partners 1 Building on NC State University's Centennial Campus. This workspace is equipped with a laser cutter, 3-D printers, and multiple handheld power tools.

In addition to these work spaces, the High-Powered Rocketry Club members also have access to a high-precision machine shop in Engineering Building III. The Senior Design shop supervisor is Amos Tucker and the Research shop supervisor is J. Steve Cameron. The shop supervisors take machining requests then returns the product in approximately one week. The machine shop is equipped with metal saws, wood saws, drill presses, mills, lathes, a water jet, and welding equipment. Members of the Senior Design Team, listed in Section 1.5, have access to the NC State MAE Senior Design Machining Lab after completing required training led by Amos Tucker. Members of the Senior Design Team also have access to the Aerospace Engineering Senior Design Space Lab in Room 1224 of Engineering Building III, supervised by Felix Ewere. Additionally, members of the High-Powered Rocketry Club have supervised access to the Aerospace Vehicle Structures Lab in Room 2208 of Engineering Building III. This workspace is equipped with a Universal Testing Machine, capable of providing tensile and compressive loads for structural testing.

2.2 Hours of Accessibility

The Rocketry Lab in Room 2003 is open to the Officer Team and Senior Design Team from:

Monday - Sunday: 6:00 AM - 12:00 AM

The Entrepreneurship Initiative Garage is open to all trained NC State University students from:

Monday - Wednesday: 8:30 AM - 4:30 PM

Thursday - Friday: 10:00 AM - 4:00 PM

The NC State MAE Senior Design Machining Lab is open to all trained members of the Senior Design Team from:

Monday - Thursday: 8:00 AM - 5:00 PM

Friday: 10:00 AM - 4:00 PM

The Aerospace Engineering Senior Design Space Lab is open to the Senior Design Team from:

Monday - Friday: 7:00 AM - 10:00 PM

All other facilities listed in Section 2.1 require approval from a supervisor and a scheduled appointment for use.

2.3 Necessary Personnel

The club Safety Officer, Megan Rink identified in Section 1.4, or a qualified individual from the Safety Team, must be present for all construction and testing conducted in the Rocketry Lab. The MAE Lab Director and Supervisor, Dr. Jaideep Pandit, must be present for any use of the Aerospace Vehicle Structures Lab. Research Fabrication Facility Supervisor, J. Steve Cameron, must be present for any use of the high-precision machine shop.

2.4 Available Equipment

High-Powered Rocketry Club members have access to a variety of tools in the Rocketry Lab, Entrepreneurship Initiative Garage, Aerospace Vehicle Structures Lab, and machine shop. Within the Rocketry Lab, the team has access to a drill press with 12 in. of travel, a scroll saw, a band saw, belt sander, and miter saw. The Rocketry Lab is also equipped with handheld tools including a DeWalt 18V drill, DeWalt jigsaw, Dremel 4300 Rotary tool, rigid oscillating cutting tool, and Wagner heat gun. Each of these tools are kept in the lab to prevent unauthorized use and members must be trained on on these tools before they are permitted to use them. Additionally, the Rocketry Lab is equipped with compressed air lines, which are used to create vacuum seals for composite layups.

As detailed in Section 2.1, the team also has access to additional equipment in various work-spaces. This includes laser cutters, 3-D printers, tensile testing machines, and high-precision machining equipment like metal saws, wood saws, drill presses, mills, lathes, water jets, and welding equipment.

2.5 Supplies Required

A preliminary list of materials required for the building, designing, and launching of the SL rocket and payload is detailed in Section 6.2. However, it is worth noting that HPRC owns building materials accumulated from previous years. This includes recovery materials such as parachutes, quick links, and altimeters of various types: Eggtimer Quasars, Strataloggers, and RRC3s. The club also owns electronics including Raspberry Pis, Arduinos, an Adafruit Feather, BMP180 Digital Barometric Pressure Sensor, MPM3610 Voltage Regulator, BNO055 9-axis absolute orientation sensor, MPL 3115A2 altimiter, Nooelec NESDR SMArt reciever, and various antenna. The club may also require new electronics for this year's payload challenge, as detailed in Section 4.6. Additionally, the club owns vehicle materials including Aircraft Grade Plywood and various motor casings. The team also requires non-reusable PPE including nitrile gloves, wipes, masks, and paper towels. In addition to these necessary materials, the team owns PPE from previous years including safety glasses and particle masks.

In addition to physical materials, HPRC requires various software packages for use throughout the competition. HPRC has access to Microsoft Office Suite, SolidWorks, ANSYS, and MATLAB, all acquired through NC State University's license. HPRC also has access to Asana, a Kanban board and task management application through the use of NC State University's license. HPRC has access to OpenRocket which is an open source software. Finally, the Senior Design Team has purchased a license to RockSim, used for launch vehicle flight simulations.

3 Safety

3.1 Safety Requirements

Table 3.1 below contains the safety requirements outlined and provided in the 2025 NASA SL Handbook.

Table 3.1: 2024-2025 Safety Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
5.1	Each team shall use a launch and safety checklist. The final checklists shall be included in the FRR report and used during the LRR and any Launch Day operations.	The Safety Officer will create a launch and safety checklist. All team members will use this checklist during launch day activities and rocket/payload construction. The final checklist will be included in the FRR report and used during LRR.	Validation of Records	All Subsystems
5.2	Each team shall identify a student Safety Officer who will be responsible for all items in Section 5.3.	The team will democratically nominate a student safety officer who will be responsible for all items in Section 5.3. The designated Safety Officer is identified in Section 1.4.	Validations of Records	Safety
5.3.1.1	The designated Safety Officer SHALL monitor team activities with an emphasis on safety during design of vehicle and payload.	The Safety Officer will attend team activities that focus on the design of the vehicle and payload to enforce proper safety protocols.	Demonstration	Safety
5.3.1.2	The designated Safety Officer SHALL monitor team activities with an emphasis on safety during the construction of vehicle and payload components.	The Safety Officer will attend team activities that focus on the construction of vehicle and payload components to enforce proper safety protocols.	Demonstration	Safety
5.3.1.3	The designated Safety Officer SHALL monitor team activities with an emphasis on safety during the assembly of vehicle and payload	The Safety Officer will enforce proper safety protocols during the assembly of the vehicle and payload.	Demonstration	Safety
5.3.1.4	The designated Safety Officer SHALL monitor team activities with an emphasis on safety during the ground testing of vehicle and payload.	The Safety Officer will attend and enforce proper safety protocols during the ground testing of the vehicle and payload.	Demonstration	Safety
5.3.1.5	The designated Safety Officer SHALL monitor team activities with an emphasis on safety during the subscale launch test(s).	The Safety Officer will attend the subscale launch test(s) and ensure that the team follows the written safety protocols and checklists.	Demonstration	Safety
5.3.1.6	The designated Safety Officer SHALL monitor team activities with an emphasis on safety during the full-scale launch test(s).	The Safety Officer will attend the full-scale launch test(s) and ensure that the team follows the written safety protocols and checklists.	Demonstration	Safety

Table 3.1: 2024-2025 Safety Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
5.3.1.7	The designated Safety Officer SHALL monitor team activities with an emphasis on safety during the competition launch.	The Safety Officer will attend the competition launch and ensure that the team follows the written safety protocols and checklists.	Demonstration	Safety
5.3.1.8	The designated Safety Officer SHALL monitor team activities with an emphasis on safety during recovery activities.	The Safety Officer will be present and enforce safety protocols during launch vehicle recovery activities.	Demonstration	Safety
5.3.1.9	The designated Safety Officer SHALL monitor team activities with an emphasis on safety during STEM engagement activities.	The Safety Officer will attend STEM engagement activities and ensure all participants are following proper safety protocols.	Demonstration	Safety
5.3.2	The designated Safety Officer SHALL implement procedures developed by the team for construction, assembly, launch, and recovery activities.	The Safety Officer will implement and verify all procedures developed by the team for construction, assembly, launch, and recovery activities.	Demonstration	Safety
5.3.3	The designated Safety Officer SHALL manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and SDS/chemical inventory data.	The Safety Officer will manage and maintain the team's hazard analyses, failure modes analyses, procedures, and SDS/chemical inventory data.	Inspection	Safety
5.3.4	The designated Safety Officer SHALL assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.	The Safety Officer will assist the team in the creation of the team's hazard analyses, failure modes analyses, and procedures to maintain a safe laboratory space.	Demonstration	Safety
5.4	During test flights, teams SHALL abide by the rules and guidance of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch does not give explicit or implicit authority for teams to fly those vehicle configurations and/or payloads at other club launches. Teams SHALL communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.	The Safety Officer will verify that the team abides by all local rocketry club rules and regulations.	Demonstration	Safety
5.5	Teams SHALL abide by all rules set forth by the FAA.	The Safety Officer will train the team on all appropriate safety protocols and rules. The Safety Officer will ensure that the team follows all rules set forth by the FAA.	Validation of Records	All Subsystems

3.2 Safety Plan

3.2.1 Students Responsible

Megan Rink is the elected Safety Officer for the 2024-25 competition year. She is responsible for leading the Safety Team as well as creating and upholding a culture of safety within the club. She will be primarily responsible for safety documentation, including hazard mitigation, and maintaining first aid and PPE supplies for the lab.

”Safety Sheriffs” will be trained, tested, and appointed by the Safety Officer to assist with the supervision of construction activities and with upholding compliance with safety guidelines and practices both with and without the presence of the Safety Officer. Before they are appointed, potential Safety Sheriffs will be required to pass a quiz on lab safety procedures and will be familiarized with common first aid practices.

3.2.2 Facilities/Hazardous Materials Involved and Risk Assessment

The main fabrication and lab space utilized will be EB3 room 2003 on NC State’s Centennial Campus. This is a dedicated space for HPRC that is shared with another MAE-affiliated club, Aerial Robotics Club (ARC). Other utalized spaces include the MAE Senior Design Lab (EB3 room 1224), the Albright Entrepreneurship Garage (Partners I room 1650), and the Makerspace (D. H. Hill Jr. Library room 1222). Each of these spaces requires a separate safety quiz and has dedicated staff to assist students.

All hazardous materials are stored in a flame cabinet located in EB3 room 2003. Club members are encouraged to minimize opening and closing the cabinet to maintain a cool and dry environment for materials.

Club members are instructed on the proper use of all machinery and tools before use. As a part of the Lab Safety Plan, all injuries within the lab are physically and digitally reported and records are kept indefinitely.

Table 3.2: Hazardous Materials and Mitigation

Hazardous Material	Manufacturer	Hazard Type	Storage
Black Powder	Hodgden	Flammable, Explosive	Store in a cool, dry place. Handle with care. Keep out of reach of children.
105 Epoxy Resin	West System	Skin, lung, and eye irritant; Carcinogen; Toxic if ingensted	Store in a cool, dry place. Keep well-ventilated.
205 Epoxy Hardener	West System	Eye, skin irritant; Harmful if swallowed.	Store at room temperature. Keep containers closed to prevent contamination.
206 Epoxy Hardener	West System	Skin, lung, and eye irritant; Carcinogen; Toxic if ingested.	Store in a cool, dry place. Keep well-ventilated
406 Colloidal Silica	West System	Skin, lung, and eye irritant; Carcinogen; Toxic if ingested.	Store in a cool, dry place. Keep away from flames, fire starters, and heat.

Table 3.3: Hazardous Tools, Equipment and Mitigation

Tool	Location	Required PPE
Band Saw	Tool Island	Safety glasses, particle mask
Belt Sander	Tool Island	Safety glasses, particle mask
Drill Press	Tool Island	Safety glasses, particle mask
Miter Saw	Tool Island	Safety glasses
Dremel	Tool Cabinet	Safety glasses, particle mask
Soldering Iron	Electronics Bench	Safety glasses
3D Printer	Electronics Bench	n/a

3.3 NAR/TRA Personnel Procurement and Performance Plan

3.3.1 NAR High-Power Rocket Safety Code

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.
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.
3. **Motors.** I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 ft. of these 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.
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.
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 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 of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.
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.
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.
10. **Launch Site.** I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 ft., whichever is greater, or 1000 ft. 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 ft.).
11. **Launcher Location.** My launcher will be 1500 ft. 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.

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.
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.

3.3.2 Hazardous Materials Handling and Operations

As required by the HPRC Lab Safety Agreement, all team members will be required to follow specific handling/PPE standards while using hazardous materials in fabrication. Detailed below are PPE requirements for commonly used materials.

Table 3.4: Hazardous Materials Handling and Operations

Hazardous Material	Required PPE	Basic Handling Procedures
Black Powder	Safety glasses, gloves	Avoid impact, friction, heat, sparks, or flame while handling, wear appropriate PPE
105 Epoxy Resin	Gloves	Use in a well-ventilated area, wear appropriate PPE, avoid contact with skin, do not ingest
205 Epoxy Hardener	Gloves	Use in a well-ventilated area, wear appropriate PPE, avoid contact with skin, do not ingest
206 Epoxy Hardener	Gloves	Use in a well-ventilated area, wear appropriate PPE, avoid contact with skin, do not ingest
406 Colloidal Silica	Safety glasses, gloves, particle mask/respirator	Use in a well-ventilated area, wear appropriate PPE, avoid contact with skin, do not ingest, inform others within a general vicinity of use

3.4 Briefing Plan for Accident Avoidance

Before being allowed to participate in any construction or fabrication activities, all team members are required to pass a Lab Safety Quiz. The Safety Officer will give all club members a presentation that covers all lab safety rules and PPE guidelines on which they will be tested. Team members must achieve a perfect score to participate in HPRC lab activities.

Ahead of all launch activities, the Safety Officer will conduct a safety briefing at a General Body Meeting that outlines expectations for team members, weather forecasts, expected hazards, checklist assignments, and any other applicable notices for a given launch window. Any and all team members who plan on attending a launch will be expected to be present for the brief, either in person or via a video communication call. If a team member is not present either in person or online, they are ineligible to attend the launch.

3.5 Including Safety in Documentation

Throughout this competition year, thorough safety and hazard analyses will be completed. Failure Mode and Effects Analysis (FMEA) risk assessment tables will be the primary method of analysis utilized. Once a final payload and vehicle design are chosen, high-level Fault-Tree Analysis will be performed. In future documents, the FMEA tables will be accompanied by likelihood-severity (LS) matrices to make the graphics more clear. Table 3.5 below shows the definition of the LS matrices that the Safety Team will utilize. Table 3.6 defines level of severity and Table 3.7 defines likelihood of occurrence. Table 3.8 also provides an example of a FMEA table.

3.5.1 FMEA Likelihood/Severity

Table 3.5: FMEA LS Matrix

		Level of Severity			
		1 Low Risk	2 Medium Risk	3 High Risk	4 Severe Risk
Likelihood of Occurrence	A Very Unlikely	1A	2A	3A	4A
	B Unlikely	1B	2B	3B	4B
	C Likely	1C	2C	3C	4C
	D Very Likely	1D	2D	3D	4D

3.5.2 FMEA Severity/Likelihood Key

Table 3.6: FMEA Severity Key

Level of Severity			
1 Low Risk	2 Medium Risk	3 High Risk	4 Severe Risk
Negligible damage to vehicle, personnel and environment unharmed	Minimal damage to vehicle, personnel can be easily treated with first aid, environment is minimally harmed	Moderate damage to vehicle, personnel require intensive first aid or eventual treatment by a medical professional, environment has moderate damage	Irreparable damage to vehicle, personnel require immediate medical attention, personnel death, environment is destroyed

Table 3.7: FMEA Likelihood Key

Level of Severity			
A Very Unlikely	B Unlikely	C Likely	D Very Likely
1-25% Occurrence	26-50% Occurrence	51-75% Occurrence	76-100% Occurrence

3.5.3 FMEA Example

Table 3.8: FMEA Example

Label	Hazard	Cause	Effect	LS Before	Mitigation	LS After
Ex.A.1	Slips, trips, and falls	Material spills around the lab	Skin abrasion, bruising	3B	After handling liquid/powder materials, lab floors will be inspected for spills	2A
		Wet/uneven launch field conditions			Only required and listed personnel are allowed on launch field for recovery; closed toe shoes required	
Ex.A.2	Bug sting/bite	Prolonged exposure to wildlife during launch	Itchiness, rash, and/or anaphylaxis	4A	Bug spray is provided to team members at the launch site	1A

3.6 Lab Safety Handbook

3.6.1 Federal, State, and Local Law Compliance Plan

All team members and mentors will be committed to upholding all federal, state, and local laws during the construction and flight of high-powered rockets as well as during any and all club activities. The team will follow the instructions of TRA/NAR personnel during launch day activities to ensure compliance with all laws.

3.6.2 Federal Aviation Regulations 14 CFR, Subchapter F, Part 101, Subpart C

The sub-parts of the Federal Aviation Regulations concerning general operating limitations of the launch of high-power rockets details where and when high-power rocket launches can take place, and how they should be operated. The team will comply with all general FAA operating regulations and will not fly a high-power rocket under such conditions:

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

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

(c) Into any cloud;

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

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

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

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

    i. Not less than one-quarter the maximum expected altitude;

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

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

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

3.6.3 Code of Federal Regulation 27 Part 55: Commerce in Explosives

In compliance with the Code of Federal Regulation 27 Part 55: Commerce in Explosives, the team will only purchase hobby rocket motors utilizing an appropriate license.

3.6.4 NFPA 1127 Code for High-Power Rocketry

The NFPA 1127 Code for High-Power Rocketry establishes guidelines for the safe operation of high-power rockets. These codes are put in place to protect users as well as the general public and to minimize injury and deaths related to high-power rocketry. Topics such as certification, pre-flight inspection, motor installation and components, payloads, and others are covered in this document. The team will comply with the guidelines listed in this document during all launch activities.

3.7 Motor and Energetics Management

All motor purchases will be made using the member numbers of the club's TRA mentor with appropriate certification levels, as detailed in Section 1.1. At launches, all motors will be assembled and installed under the supervision of mentor Jim Livingston. Livingston will also supervise the storage, assembly, and installation of motors. He will also serve as a mentor and review designs and documents for the NC State University team.

3.8 Safety Agreement

The safety agreement below contains a written statement that all team members understand and will abide by the safety regulations outlined by the 2025 NASA SL Handbook and by the HPRC Safety Officer.

2024-25 NCSU HPRC Safety Acknowledgement

NASA SLI Safety Acknowledgement

i. Range safety inspections will be conducted on each rocket before it is flown. Each team shall comply with the determination of the safety inspection or 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 launch of any rocket for safety reasons.

iii. The team mentor is ultimately responsible for the safe flight and recovery of the team's rocket. Therefore, a team shall not fly a rocket until the mentor has reviewed the design, examined the build, and is satisfied the rocket meets established amateur rocketry design and safety guidelines.

iv. Any team that does not comply with the safety requirements shall not be allowed to launch their rocket.

NCSU HPRC Lab Safety Acknowledgement

i. I agree to follow all posted safety rules and regulations in and around the designated HPRC lab space (EBIII room 2003) in accordance with NCSU policies.

ii. I agree to follow all safety guidelines as determined by the Safety Officer during any and all HPRC activities.

iii. I agree to follow all procedural checklists during launch day activities.

iv. I agree to uphold both club and university standards during outreach and competition activities.

By signing and dating below, I agree that I have read, understand, and agree to follow the safety guidelines as outlined above.

2024-25 NCSU HPRC Safety Acknowledgement

Leadership Team:

Katelyn Yount		8/22/24
Megan Rink		8/22/24
James Holley		8/22/24
Aubri Sprouse		8/22/24
Trent Couse		8/23/24
Connor Swanson		8/22/24
Ryan Keever		8/22/24
Sam Patterson		8/22/24
Abby Kuppler		8/22/24
Donald Gemmel		8/22/24
Tyler Perez		8/22/2024
Sofia Antinozzi		8/22/2024
Ben Radspinner		8/22/2024
James Garmon		8/22/2024
Emily Cates		8/22/24

Team Members:

Craig Abell		8/22/24
Peter Tolman		8/22/24
Alex Key		8/22/24
Willard Sheats		8/22/24
Nathan Meyer		8/22/24

2024-25 NCSU HPRC Safety Acknowledgement

Aidan McCloskey	[illegible]	8/22/24
Andrew Simon	Andrew Simon	8/22/24
Zane Andersen	[illegible]	8/23/24
Sailor Koeplinger	[illegible]	8/23/24
Lauren Wilkie	[illegible]	8/26/24
Aditya Chauhan	[illegible]	8/26/24
Benjamin Jorgensen	[illegible]	8/26/24
Tony Ugorji	[illegible]	8/26/24
Lauren Hullender	Lauren Hullender	9/3/24
Will Sanderson	[illegible]	9/3/24
Jack Dubois	Jack Dubois	9/3/24
Valeriya Taylor	[illegible]	9/5/24
Harshil Mehta	[illegible]	9/5/24
Matthew Wheeler	Matthew Wheeler	9/5/24
Nate Orbanski	[illegible]	9/5/24
Kevin Pham	[illegible]	9/5/24
Alex Chandler	[illegible]	9/8/24
Abhi Chandra	[illegible]	9/5/24
Gabriela Santiago	[illegible]	9/5/24
Austin Hoke	Austin Hoke	9/5/24
[illegible]	[illegible]	9/5/24
Sam Hong	[illegible]	9/5/24
Hunter Power	[illegible]	09/05/2024

2024-25 NCSU HPRC Safety Acknowledgement

Lydia Ball	Lydia Ball	9/5/24
Prathika Ponnusamy	[illegible]	9/5/24
Maddie McDaniel	[illegible]	5 Sep 24
Josh Clodfelter	J Clodfelter	9/5/24
Stuart Robinson	Stuart Robinson	9/5/24
Tarik Junuzovic	[illegible]	9/5/24
Aidan Pardo	[illegible]	9/5/24
Delali Dodor	[illegible]	9/5/24
Kenneth Nguyen	Kenneth Nguyen	9/5/24
John Coyne	John Coyne	9/5/24
Liam Silver	[illegible]	9/5/24
Yong-Joon Kim	[illegible]	9/5/24

4 Technical Design

4.1 General Requirements

Table 4.1 below contains the general requirements outlined and provided in the 2025 NASA SL Handbook.

Table 4.1: 2024-2025 General Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
1.1	Students on the team SHALL do 100% of the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder or any variant of ejection charges, or preparing and installing electric matches (to be done by the team's mentor). Student team members SHALL only be a part of one team in any capacity. Teams SHALL submit new work. Excessive use of past work SHALL merit penalties.	The team members of the NC State's High-Powered Rocketry Club will design, build, and document a completely original work as a solution to the challenge and vehicle requirements outlined in the NASA SL Handbook.	Inspection	Project Management
1.2	The team SHALL provide and maintain a project plan to include, but not limited to, the following items: project milestones, budget and community support, checklists, personnel assignments, STEM engagement events, and risks and mitigations.	The Team Lead, Vice President, Outreach Officer, Safety Officer, Treasurer, and Webmaster will develop a project plan and adhere to it. This plan will include deadlines and expectationfs for project milestones, budget and community support, checklists, personnel assignments, STEM engagement events, and risks and mitigations.	Inspection	Project Management
1.3	Team members who will travel to the Huntsville Launch SHALL have fully completed registration in the NASA Gateway system before the roster deadline.	The Team Lead will ensure all team members who shall travel to the Huntsville Launch have completed in the NASA Gateway system before the roster deadline or by Nov. 29th, 2024.	Inspection	Project Management
1.3.1	Team members who will travel to the Huntsville Launch SHALL include students actively engaged in the project throughout the entire year.	The Team Lead will only select team members who have actively engaged in the project throughout the year to travel to the Huntsville Launch.	Inspection	Project Management

Table 4.1: 2024-2025 General Requirements

NASA Req. No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
1.3.2	Team members who will travel to the Huntsville Launch SHALL include one mentor (see Requirement 1.13);	The Team Lead will invite the mentor(s) identified in Section 1.1 to the Huntsville Launch competition. A notice of the Huntsville Launch dates will be sent to the mentor(s) once NCSU HPRC is officially accepted into the competition	Inspection	Project Management
1.3.3	Team members who will travel to the Huntsville Launch SHALL include no more than two adult educators.	The Team Lead will invite the adult educator(s) identified in Section 1.1 to the Huntsville Launch competition. A notice of the Huntsville Launch dates will be sent to the adult educator(s) once NCSU HPRC is officially accepted into the competition.	Inspection	Project Management
1.4	Teams SHALL engage a minimum of 250 participants in Educational Direct Engagement STEM activities. These activities can be conducted in-person or virtually. To satisfy this requirement, all events SHALL occur between project acceptance and the FRR addendum due date. A template of the STEM Engagement Activity Report can be found on pages 40 – 43.	The Outreach Lead, identified in Section 1.6, will organize multiple events across the fall and spring semesters at local schools, organizations, etc. The Outreach Lead will keep a talley of all participants and a record of proof, consisting of photos and email confirmations. All information will be shared with the Team Lead before and after the event.	Inspection	Project Management
1.5	The team SHALL establish and maintain a social media presence to inform the public about team activities.	The Social Media Officer, identified in Section 1.6, will document club progress and events across multiple social media platforms. Platforms consist of Instagram, Facebook, X, TikTok, and LinkedIn.	Inspection	Project Management

Table 4.1: 2024-2025 General Requirements

NASA Req. No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
1.6	Teams SHALL email all deliverables to the NASA project management team by the deadline specified in the handbook for each milestone. In the event that a deliverable is too large to attach to an email, inclusion of a link to download the file SHALL be sufficient. Late submissions of PDR, CDR, or FRR milestone documents will NOT be accepted. Teams that fail to submit the PDR, CDR, or FRR milestone documents SHALL be eliminated from the project.	The Team Lead will email all deliverables to the NASA project management team by the deadline specified in the NASA SL handbook. The Webmaster, identified in Section 1.6, will receive the deliverables and upload it to the NCSU HPRC's website by the specified deadline.	Inspection	Project Management
1.7	Teams who do not satisfactorily complete each milestone review (PDR, CDR, FRR) SHALL be provided action items to be completed following their review and SHALL be required to address action items in a delta review session. After the delta session, the NASA management panel will meet to determine the teams' status in the program, and the teams SHALL be notified shortly thereafter.	Team members will complete all milestone review documents and submit before the provided deadline. In the event that NASA determines a document is not satisfactorily completed, the team will address the action items in a delta review session.	Inspection	Project Management
1.8	All deliverables SHALL be in PDF format.	The Team Lead will send all deliverables to the NASA project management team in PDF format.	Inspection	Project Management
1.9	In every report, teams SHALL provide a table of contents, including major sections and their respective subsections.	The Team Lead will organize the report documents to include and follow a table of contents.	Inspection	Project Management
1.10	In every report, the team SHALL include the page number at the bottom of the page.	The Team Lead will ensure that a page number is included at the bottom of every page in the report document.	Inspection	Project Management

Table 4.1: 2024-2025 General Requirements

NASA Req. No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
1.11	The team SHALL provide any computer equipment necessary to perform a video teleconference with the review panel. This includes, but is not limited to: a computer system, video camera, speaker telephone, and a sufficient Internet connection. Cellular phones should be used for speakerphone capability only as a last resort.	The Team Lead will provide and set-up all computer equipment necessary for video teleconference presentations/meetings in advance. The Team Lead will only use cellular phones for meetings and presentations as a last resort after all other avenues have been attempted.	Inspection	Project Management
1.12	All teams attending Launch Week SHALL be required to use the launch pads provided by Student Launch's launch services provider. No custom pads SHALL be permitted at the NASA Launch Complex. At launch, 8-foot 1010 rails and 12-foot 1515 rails will be provided. The launch rails SHALL be canted 5 – 10 degrees away from the crowd on Launch Day. The exact cant SHALL depend on Launch Day wind conditions.	The Aerodynamics Lead and Structures Lead will ensure and construct a launch vehicle that can use the launch pads provided by the NASA SL's launch services provider. The Aerodynamics Lead and Structures Lead will consider the launch rail cant and dimensions when designing/constructing the launch vehicle.	Inspection	Aerodynamics, Structures

Table 4.1: 2024-2025 General Requirements

NASA Req. No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
1.13	Each team SHALL identify a "mentor." A mentor is defined as an adult who is included as a team member, who will be supporting the team (or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization. The team mentor SHALL not be a student team member. The mentor SHALL maintain a current certification, and be in good standing, through the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle and must have flown and successfully recovered (using electronic, staged recovery) a minimum of two flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to Launch Week. One travel stipend SHALL be provided per mentor regardless of the number of teams he or she supports. The stipend SHALL only be provided if the team passes FRR and the team and mentor attend Launch Week in April.	The Team Lead will identify a mentor according to NASA Regulation 1.13 and include the mentors information in all NASA documentation. The Treasurer and Team Lead will provide a travel stipend to the mentor(s) to travel to the Huntsville Launch.	Inspection	Project Management
1.14	Teams SHALL track and report the number of hours spent working on each milestone.	The Team Lead and Integration Lead will record the hours worked by all sub-teams at the end of every week. The Team Lead will ensure the number of hours spent working on each milestone is compiled for each milestone and is included in the respective document.	Inspection	Integration, Project Management

4.1.1 Launch Vehicle Requirements

Table 4.2 below contains the launch vehicle requirements outlined and provided in the 2025 NASA SL Handbook.

Table 4.2: 2024-2025 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.1	The vehicle SHALL deliver the payload to an apogee altitude between 4,000 and 6,000 feet above ground level (AGL). Teams flying below 3,500 feet or above 6,500 feet on their competition launch SHALL receive zero altitude points towards their overall project score and SHALL not be eligible for the Altitude Award.	The Aerodynamics Lead will design a launch vehicle that reaches an apogee between 4,000 and 6,000 ft. AGL. The Structures Lead will organize and facilitate the construction of the launch vehicle with the rest of the team.	Analysis, Demonstration	Aerodynamics, Structures
2.2	Teams SHALL declare their target altitude goal at the CDR milestone. The declared target altitude SHALL be used to determine the team's altitude score.	The Aerodynamics Lead will perform multiple simulations to determine the approximate apogee for the full-scale rocket and include the target altitude in the CDR milestone.	Inspection	Aerodynamics
2.3	The launch vehicle SHALL be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.	The Structures Lead and Recovery Lead will design a recovery system that allows the launch vehicle to be recovered and re-used upon ground impact. The rocket will sustain minimal damage and have the ability to launch twice in the same day without repairs or needed modifications.	Demonstration	Recovery, Structures
2.4	The launch vehicle SHALL have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute.	The Aerodynamics Lead and Recovery Lead will design a launch vehicle and recovery system that has a maximum of four indpendent sections.	Inspection	Aerodynamics, Recovery
2.4.1	Coupler/airframe shoulders which are located at in-flight separation points SHALL be at least two airframe diameters in length. (One body diameter of surface contact with each airframe section).	The Aerodynamics Lead will design the coupler/airframe shoulders to be at least 2 airframe diameters in length. The Structures lead shall build the coupler/airframe shoulders per the Aerodynamics Leads design.	Inspection	Aerodynamics, Structures

Table 4.2: 2024-2025 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.4.2	Coupler/airframe shoulders which are located at non-in-flight separation points SHALL be at least 1.5 airframe diameters in length. (0.75 body diameter of surface contact with each airframe section.)	The Aerodynamics Lead will design the coupler/airframe shoulders to be at least 1.5 airframe diameters in length. The Structures Lead shall build the coupler/airframe shoulders per the Aerodynamics Leads design.	Inspection	Aerodynamics, Structures
2.4.3	Nosecone shoulders which are located at in-flight separation points SHALL be at least ½ body diameter in length.	The Aerodynamics Lead will design the nosecone shoulders to be at least 0.5 body diameter in length. The Structures Lead will construct the nosecone shoulders per the Aerodynamics Leads design.	Inspection	Aerodynamics, Structures
2.5	The launch vehicle SHALL be capable of being prepared for flight at the launch site within 2 hours of the time the Federal Aviation Administration flight waiver opens.	The Team Lead, Integration Lead, and Safety Officer will develop launch day checklists that can be performed within 2 hours of the time the FAA flight waiver opens.	Demonstration	Integration, Project Management, Safety
2.6	The launch vehicle and payload SHALL be capable of remaining in launch-ready configuration on the pad for a minimum of 3 hours without losing the functionality of any critical on-board components, although the capability to withstand longer delays is highly encouraged.	The Team Lead, Integration Lead, and Safety Officer will monitor and ensure that the launch vehicle is able to remain in launch-ready configuration on the launch pad for a minimum of 3 hours without losing any critical components. The Team Lead and Safety Officer will ensure the safety of the launch vehicle during this time.	Demonstration	Project Management, Safety
2.7	The launch vehicle SHALL be capable of being launched by a standard 12-volt direct current firing system. The firing system SHALL be provided by the NASA-designated launch services provider.	The Team Lead and Aerodynamics Lead will select a motor ignitor that is capable of being launched by a 12-volt direct current firing system.	Demonstration	Project Management, Aerodynamics
2.8	The launch vehicle SHALL require no external circuitry or special ground support equipment to initiate launch (other than what is provided by the launch services provider).	The Structures Lead will build the launch vehicle to require no external circuitry or special ground support equipment to initiate launch. The Team Lead will verify this during launch tests.	Demonstration	Project Management, Structures

Table 4.2: 2024-2025 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.9	Each team SHALL use commercially available ematches or igniters. Hand-dipped igniters SHALL not be permitted.	The Team Lead and Safety Officer will ensure that all emaches and igniters used are commercially available and that the launch vehicle does not use hand-dipped igniters.	Inspection	Project Management, Safety
2.10	The launch vehicle SHALL use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).	The Aerodynamics Lead will select a commercially available solid motor propulsion system that uses APCP and is approved by NAR, TRA, and/or CAR for the launch vehicle. The Team Lead will verify the motor selection.	Inspection	Aerodynamics, Project Management
2.10.1	Final motor choice SHALL be declared by the Preliminary Design Review (PDR) milestone.	The Aerodynamics Lead will declare the final motor choice in the PDR milestone.	Inspection	Aerodynamics
2.10.2	Any motor change after PDR SHALL be approved by the NASA management team or NASA Range Safety Officer (RSO). Changes for the sole purpose of altitude adjustment SHALL not be approved. A scoring adjustment against the team's overall score SHALL be incurred when a motor change is made after the PDR milestone. The only exception is teams switching to their secondary motor choice provided the primary motor choice is unavailable due to a motor shortage.	The Team Lead will request the NASA mangement team or NASA RSO for approval for motor changes following the PDR milestone.	Inspection	Project Management
2.11	The launch vehicle SHALL be limited to a single motor propulsion system.	The Aerodynamics Lead will design the launch vehicle to be a single motor propulsion vehicle.	Inspection	Aerodynamics
2.12	The total impulse provided by a College or University launch vehicle SHALL not exceed 5,120 Newton seconds (L-class).	The Aerodynamics Lead will select a motor for the launch vehicle that will not exceed a total impulse of 5,120 Newton seconds.	Inspection	Aerodynamics
2.13	Pressure vessels on the vehicle SHALL be approved by the RSO.	The Structures Lead and Team Lead will provide all necessary information regarding any on-board pressure vessels for RSO approval.	Inspection	Project Management, Structures

Table 4.2: 2024-2025 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.13.1	The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) SHALL be 4:1 with supporting design documentation included in all milestone reviews.	The Aerodynamics Lead and Structures Lead will design and construct a launch vehicle with a minimum factor of safety of 4:1. Supporting design documentation will be included in all milestone documents and reviews.	Analysis, Inspection	Aerodynamics, Structures
2.13.2	Each pressure vessel SHALL include a pressure relief valve that sees the full pressure of the tank and is capable of withstanding the maximum pressure and flow rate of the tank.	The Structures Lead will construct and select all on-board pressure vessels to include a pressure relief valve that is capable of withstanding the maximum pressure and flow rate of the tank.	Analysis, Inspection	Structures
2.13.3	The full pedigree of the tank SHALL be described, including the application for which the tank was designed and the history of the tank. This SHALL include the number of pressure cycles put on the tank, the dates of pressurization/depressurization, and the name of the person or entity administering each pressure event.	The Structures Lead will keep full documentation of each pressure vessel on-board the launch vehicle. The information collected and stored will include the application of the pressure vessel/tank, the number of pressure cycles, the dates of pressurization/depressurization, and the names of each person or entity administering the pressure events.	Inspection	Structures
2.14	The launch vehicle SHALL have a minimum static stability margin of 2.0 at the point of rail exit. Rail exit is defined at the point where the forward rail button loses contact with the rail.	The Aerodynamics Lead will design the launch vehicle to have a minimum static stability margin of 2.0 at the point of rail exit.	Analysis	Aerodynamics
2.15	The launch vehicle SHALL have a minimum thrust to weight ratio of 5.0:1.0.	The Aerodynamics Lead will design the launch vehicle to have a minimum thrust to weight ratio of 5.0:1.0.	Analysis, Inspection	Aerodynamics
2.16	Any structural protuberance on the rocket SHALL be located aft of the burnout center of gravity. Camera housings SHALL be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.	The Aerodynamics Lead will design the launch vehicle to only have structural protuberance aft of the burnout center of gravity on the rocket.	Analysis, Inspection	Aerodynamics
2.17	The launch vehicle SHALL accelerate to a minimum velocity of 52 fps at rail exit.	The Aerodynamics Lead will design the launch vehicle and select the appropriate motor to have a minimum velocity of 52 fps at rail exit.	Analysis	Aerodynamics

Table 4.2: 2024-2025 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.18	All teams SHALL successfully launch and recover a subscale model of their rocket. Success of the subscale is at the sole discretion of the NASA review panel. The subscale flight may be conducted at any time between proposal award and the CDR submission deadline. Subscale flight data SHALL be reported in the CDR report and presentation at the CDR milestone. Subscales are required to use a minimum motor impulse class of E (Mid Power motor).	The team will successfully launch and recover a subscale model of their intended launch vehicle. The Team Lead will ensure that the subscale flight data is reported and presented in the CDR milestone. The Aerodynamics Lead will ensure that the subscale uses a minimum motor impulse class of E.	Demonstration	Aerodynamics, Project Management
2.18.1	The subscale model SHALL resemble and perform as similarly as possible to the full-scale model; however, the full-scale SHALL not be used as the subscale model.	The Aerodynamics Lead and Structures Lead will design and construct a subscale launch vehicle that will resemble and perform as similarly as possible to the full-scale launch vehicle. The subscale model will not be used as the full-scale model.	Inspection	Aerodynamics, Structures
2.18.2	The subscale model SHALL carry an altimeter capable of recording the model's apogee altitude.	The Recovery Lead will install an altimeter capable of recording the subscale model's apogee altitude into the launch vehicle.	Inspection	Recovery
2.18.3	The subscale rocket SHALL be a newly constructed rocket, designed and built specifically for this year's project.	The Aerodynamics Lead and Structures Lead will facilitate the design and construction of a unique subscale rocket, built for the purpose of this years NASA SL challenge.	Inspection	Aerodynamics, Structures
2.18.4	Proof of a successful flight SHALL be supplied in the CDR report.	The team will include proof of a successful flight in the CDR report. The Team Lead will verify this information and formatting.	Inspection	Project Management
2.18.4.1	Altimeter flight profile graph(s) OR a quality video showing successful launch, recovery events, and landing as deemed by the NASA management panel are acceptable methods of proof. Altimeter flight profile graph(s) that are not complete (liftoff through landing) SHALL not be accepted.	The Recovery Lead will process altimeter flight data and include altimeter flight profile graphs in the CDR report. If altimieter flight profile graphs are not avialable, the Recovery Lead will submit a quality photo showing successful launch, recovery events, and landing events as proof for a successful flight.	Analysis	Recovery

Table 4.2: 2024-2025 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.18.4.2	Quality pictures of the as landed configuration of all sections of the launch vehicle SHALL be included in the CDR report. This includes, but is not limited to: nosecone, recovery system, airframe, and booster.	The Recovery Lead will take quality photos of all sections of the launch vehicle in its landed configuration. The Team Lead will include the photos in the CDR report.	Analysis, Demonstration	Project Management, Recovery
2.18.5	The subscale rocket SHALL not exceed 75% of the dimensions (length and diameter) of your designed full-scale rocket. For example, if your full-scale rocket is a 4” diameter, 100” length rocket, your subscale SHALL not exceed 3” diameter and 75” in length.	The Aerodynamics Lead and Structures Lead will design and construct a subscale rocket that does not exceed 75% of the dimensions for the designed full-scale rocket.	Inspection	Structures
2.19.1	Vehicle Demonstration Flight—All teams SHALL successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown SHALL be the same rocket to be flown for their competition launch. The purpose of the Vehicle Demonstration Flight is to validate the launch vehicle’s stability, structural integrity, recovery systems, and the team’s ability to prepare the launch vehicle for flight. A successful flight is defined as a launch in which all hardware is functioning properly (drogue chute at apogee, main chute at the intended lower altitude, functioning tracking devices, etc.). Requirements 2.19.1.1-9 SHALL be met during the full-scale demonstration flight:	The team will successfully launch and recover their designed full-scale launch vehicle prior to FRR in its final flight configuration. The team will validate all aspects of the launch vehicle during this flight and meet NASA requirements 2.19.1.1-9.	Demonstration	Project Management
2.19.1.1	The vehicle and recovery system SHALL have functioned as designed.	The Integration Lead and Team Lead will verify that the vehicle and payload system functioned as it was designed.	Demonstration	Integration, Project Management
2.19.1.2	The full-scale rocket SHALL be a newly constructed rocket, designed and built specifically for this year’s project.	The Aerodynamics Lead and Structures Lead will facilitate the design and construction of a new full-scale rocket, built for the purpose of this years NASA SL Challenge.	Inspection	Aerodynamics, Structures

Table 4.2: 2024-2025 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.19.1.3.1	During Vehicle Demonstration Flight - If the payload is not flown, mass simulators SHALL be used to simulate the payload mass.	The Payload Team and Structures Lead will use a mass simulator to simulate the payload mass if the payload is not flown during the Vehicle Demonstration Flight.	Inspection	Payload Team, Structures
2.19.1.3.2	The mass simulators SHALL be located in the same approximate location on the rocket as the missing payload mass.	The Structures Lead will place the mass simulators in the same approximate location in the launch vehicle as the missing payload mass.	Inspection	Structures
2.19.1.4	If the payload changes the external surfaces of the rocket (such as camera housings or external probes) or manages the total energy of the vehicle, those systems SHALL be active during the full-scale Vehicle Demonstration Flight.	If the payload changes the external surfaces or manages the total energy of the vehicle, the Payload Team and Team Lead will ensure that those systems are active during the Vehicle Demonstration Flight.	Inspection	Payload Team, Project Management
2.19.1.5	Teams SHALL fly the competition launch motor for the Vehicle Demonstration Flight. The team may request a waiver for the use of an alternative motor in advance if the home launch field cannot support the full impulse of the competition launch motor or in other extenuating circumstances.	The Aerodynamics Lead and Team Lead will ensure that the competition launch motor is used for the Vehicle Demonstration Flight. If unable, the Team Lead will request a waiver for the use of an alternative motor from NASA in advance.	Inspection	Aerodynamics, Project Management
2.19.1.6	The vehicle SHALL be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the maximum amount of ballast that will be flown during the competition launch flight. Additional ballast SHALL not be added without a re-flight of the full-scale launch vehicle.	The Aerodynamics Lead and Team Lead will ensure that the full-scale launch vehicle is flown in its fully ballasted configuration during the Vehicle Demonstration Flight. The Aerodynamics Lead will not add additional ballast without a re-flight of the full-scale launch vehicle.	Inspection	Aerodynamics, Project Management
2.19.1.7	After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components SHALL not be modified without the concurrence of the NASA management team or Range Safety Officer (RSO).	The team will not modify the launch vehicle or any of its components after completing the full-scale demonstration flight without the approval of the NASA management team or RSO.	Inspection	Project Management
2.19.1.8	Proof of a successful flight SHALL be supplied in the FRR report.	The Team Lead will ensure that proof of a successful full-scale demonstration flight is supplied in the FRR report.	Inspection	Project Management

Table 4.2: 2024-2025 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.19.1.8.1	Altimeter flight profile data output with accompanying altitude and velocity versus time plots is required to meet Requirement 2.19.8. Altimeter flight profile graph(s) that are not complete (liftoff through landing) SHALL not be accepted.	The Recovery Lead will include altimeter flight profile data with accompanying altitude and velocity versus time plots in the FRR report for the full-scale launch vehicle.	Inspection	Recovery
2.19.1.8.2	Quality pictures of the as landed configuration of all sections of the launch vehicle SHALL be included in the FRR report. This includes, but is not limited to: nosecone, recovery system, airframe, and booster.	The Recovery Lead and Team Lead will include quality photos of the landing configurations for all parts of the launch vehicle in the FRR report.	Inspection	Project Management, Recovery
2.19.1.8.3	Raw altimeter data SHALL be submitted in .csv or .xlsx format.	The Recovery and Team Lead will submit all raw altimeter data in .csv or .xlsx format.	Inspection	Project Management, Recovery
2.19.1.9	Vehicle Demonstration flights SHALL be completed by the FRR submission deadline. No exceptions SHALL be made. If the Student Launch office determines that a Vehicle Demonstration Re-flight is necessary, then an extension may be granted. THIS EXTENSION IS ONLY VALID FOR RE-FLIGHTS, NOT FIRST TIME FLIGHTS. Teams completing a required re-flight SHALL submit an FRR Addendum by the FRR Addendum deadline.	The team will complete the Vehicle Demonstration flights by the FRR submission deadline.	Inspection	Project Management

Table 4.2: 2024-2025 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.19.2	Payload Demonstration Flight—All teams SHALL successfully launch and recover their full-scale rocket containing the completed payload prior to the Payload Demonstration Flight deadline. The rocket flown SHALL be the same rocket to be flown as their competition launch. The purpose of the Payload Demonstration Flight is to prove the launch vehicle's ability to safely retain the constructed payload during flight and to show that all aspects of the payload perform as designed. A successful flight is defined as a launch in which the rocket experiences stable ascent and the payload is fully retained until it is deployed (if applicable) as designed. Requirements 2.19.2.1-4 SHALL be met during the Payload Demonstration Flight.	The team will launch and recover their full-scale rocket containing the completed payload prior to the Payload Demonstration Flight deadline. The Payload Team and Structures Team will ensure that the launch vehicle and payload flown are to be flown the exact same as their competition launch.	Inspection	Payload, Project Management, Structures
2.19.2.1	The payload shall be fully retained until the intended point of deployment (if applicable), all retention mechanisms shall function as designed, and the retention mechanism shall not sustain damage requiring repair.	The Payload Team and Integration Lead will ensure that the payload is capable of remaining fully retained until its intended point of deployment and functions as its designed without sustaining damage.	Inspection	Integration, Payload
2.19.2.2	The payload flown shall be the final, active version.	The Payload Team and Team Lead will ensure that the payload flown during the Payload Demonstration Flight is the final, active version of the payload.	Inspection	Payload, Project Management
2.19.2.3	If Requirements 2.19.2.1-2 are met during the original Vehicle Demonstration Flight, occurring prior to the FRR deadline and the information is included in the FRR package, the additional flight and FRR Addendum SHALL not be required.	The team will adhere to and meet NASA Requirements 2.19.2.1-2. The Team Lead will ensure all criteria for the VDF are complete and submitted before the FRR deadline. If the criteria is not properly met, the team will submit an additional flight and an FRR Addendum.	Inspection	Project Management
2.19.2.4	Payload Demonstration Flights SHALL be completed by the FRR Addendum deadline. NO EXTENSIONS SHALL BE GRANTED.	The team will complete the Payload Demonstration Flights by the FRR Addendum deadline.	Inspection	Project Management

Table 4.2: 2024-2025 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.20	An FRR Addendum SHALL be required for any team completing a Payload Demonstration Flight or NASA required Vehicle Demonstration Re-flight after the submission of the FRR Report.	The team will submit an FRR Addendum if the team needs to complete a Payload Demonstration Flight or a NASA required Vehicle Demonstration Re-flight after the FRR Report.	Inspection	Project Management
2.20.1	Teams required to complete a Vehicle Demonstration Re-Flight and failing to submit the FRR Addendum by the deadline SHALL not be permitted to fly a final competition launch.	The team will complete a Vehicle Demonstration Re-Flight, if required, and submit it by the FRR Addendum deadline.	Inspection	Project Management
2.20.2	Teams who complete a Payload Demonstration Flight which is not fully successful may petition the NASA RSO for permission to fly the payload during launch week. Permission SHALL not be granted if the RSO or the Review Panel have any safety concerns.	The team will petition the NASA RSO for permission to fly the payload during launch week if the Payload Demonstration Flight is not fully successful.	Demonstration	Project Management
2.21	The team's name and Launch Day contact information SHALL be in or on the rocket airframe as well as in or on any section of the vehicle that separates during flight and is not tethered to the main airframe. This information SHALL be included in a manner that allows the information to be retrieved without the need to open or separate the vehicle.	The Team Lead will verify that the team's name and contact information is in the rocket airframe and any section of the launch vehicle that separates during flight and is not tethered to the main airframe.	Inspection	Project Management
2.22	All Lithium Polymer batteries SHALL be sufficiently protected from impact with the ground and SHALL be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other payload hardware.	The Team Lead and Safety Officer will ensure that all Lithium Polymer batteries are sufficiently protected from impact with the ground. All Lithium Polymer batteries will be brightly colored and clearly marked to make it distinguishable from other payload hardware.	Analysis, Inspection	Project Management, Safety
2.23.1	The launch vehicle SHALL not utilize forward firing motors.	The Aerodynamics Lead will design the launch vehicle to not utilize forward firing motors.	Inspection	Aerodynamics
2.23.2	The launch vehicle SHALL not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)	The Aerodynamics Lead will design the launch vehicle to not utilize motors that expel titanium sponges.	Inspection	Aerodynamics
2.23.3	The launch vehicle SHALL not utilize hybrid motors.	The Aerodynamics Lead will design the launch vehicle to not utilize hybrid motors.	Inspection	Aerodynamics

Table 4.2: 2024-2025 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.23.4	The launch vehicle SHALL not utilize a cluster of motors.	The Aerodynamics Lead will design the launch vehicle to not use a cluster of motors.	Inspection	Aerodynamics
2.23.5	The launch vehicle SHALL not utilize friction fitting for motors.	The Structures Lead will construct the launch vehicle to not utilize friction fitting for motors. A reusable casing mechanism will be designed to house a motor.	Inspection	Structures
2.23.6	The launch vehicle SHALL not exceed Mach 1 at any point during flight.	The Aerodynamics Lead will design the launch vehicle and select a motor such that Mach 1 is not exceeded at any point during the flight.	Analysis	Aerodynamics
2.23.7	Vehicle ballast SHALL not exceed 10% of the total un-ballasted weight of the rocket, as it would sit on the pad (i.e., a rocket with an unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).	The Aerodynamics Lead will design the launch vehicle such that the vehicle ballast does not exceed 10% of the total un-ballasted weight of the rocket.	Analysis, Inspection	Aerodynamics
2.23.8	Transmissions from on-board transmitters, which are active at any point prior to landing, SHALL not exceed 250 mW of power (per transmitter).	The Payload Team and Recovery Lead will verify that any transmission from on-board transmitters will not exceed 250 mW of power (per transmitter) prior to the landing of the launch vehicle.	Analysis	Payload, Recovery
2.23.9	Transmitters SHALL not create excessive interference. Teams SHALL utilize unique frequencies, handshake/passcode systems, or other means to mitigate interference caused to or received from other teams.	The Payload Team and Recovery Lead will verify that all transmitters used will not create excessive interference. All information being transmitted shall use unique frequencies, passcode systems, or other relevant systems to reduce interference.	Analysis, Demonstration	Payload, Recovery
2.23.10	Excessive and/or dense metal SHALL not be utilized in the construction of the vehicle. Use of lightweight metal SHALL be permitted but limited to the amount necessary to ensure structural integrity of the airframe under the expected operating stresses.	The Structures Lead will not use excessive and/or dense metal in the construction of the launch vehicle. Only the use of lightweight metal will be allowed into the design and construction of the launch vehicle.	Inspection	Structures

4.2 Launch Vehicle Design

4.2.1 Launch Vehicle Dimensions

The preliminary launch vehicle design consists of a 6 in. maximum body diameter rocket with four sections and two in-flight separation points. The current overall vehicle length is 97 in. and the vehicle has a dry mass of 30.625 lb, including a simulated payload mass. All airframe and coupler sections will be constructed from commercially available 6 in. diameter G12 wound fiberglass tubes, specifically designed for high-powered rocketry.

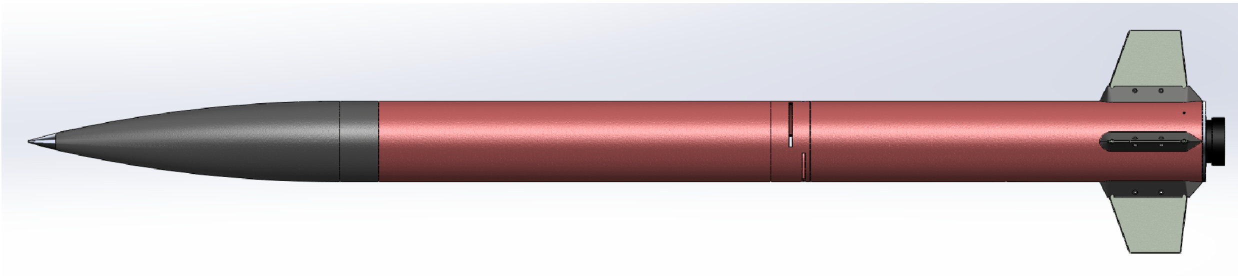


Figure 4.1: Assembled launch vehicle.

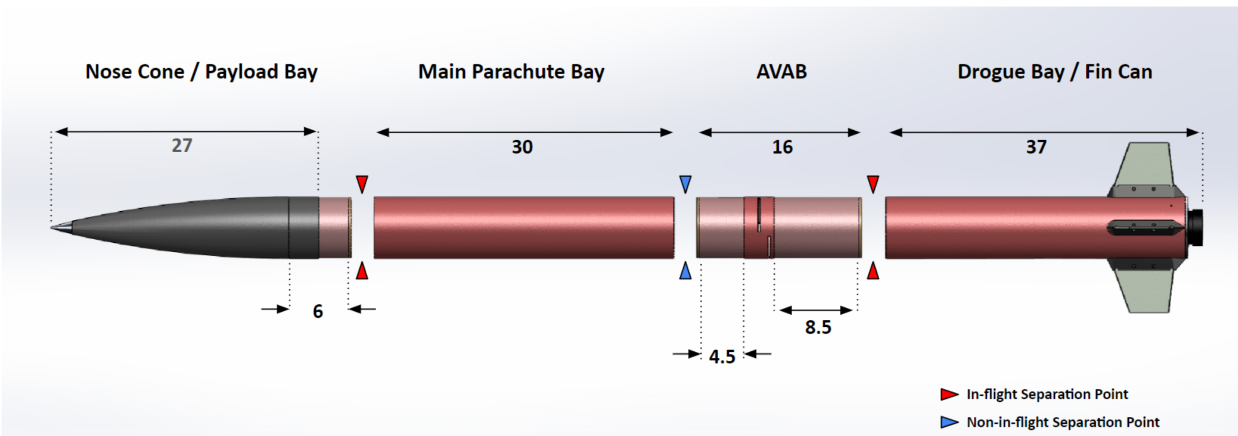


Figure 4.2: Preliminary vehicle section dimensions [in.].

Nose Cone/Payload Bay

The Nose Cone of the vehicle will be constructed of a commercially available wound G12 fiberglass Nose Cone with an anodized aluminum tip. The shape of the Nose Cone will be a 4:1 tangent ogive, with a base diameter of 6 in. The Nose Cone shoulder will consist of a 6 in. length coupler section adhered 3 in. into the Nose Cone, with the remaining 3 in. coupler mated to the main parachute bay. This connection will be an in-flight separation point, meeting Requirement 2.4.3, and will be secured with nylon shear pins.

The internal volume of the Nose Cone and shoulder will serve as the payload bay. The rear closure of the bay will be a removable bulkhead fitted to the end of the Nose Cone shoulder. This will allow access to the electronics payload and STEMnaut crew compartment. This bulkhead will be secured to the Nose Cone via ¼ in. threaded rods connected to a ring bulkhead adhered further into the Nose Cone. These threaded rods will also be the structural attachment point for all payload elements and any required ballast.

Main Parachute Bay

The main parachute bay will be a 30 in. long section of airframe housing the main parachute and recovery hardware. The aft end of the bay will mate to the forward coupler section of the Avionics/Air Brakes Bay and will be a non-in-flight separation point. This connection will be secured using nylon push rivets through the overlapping coupler and airframe sections.

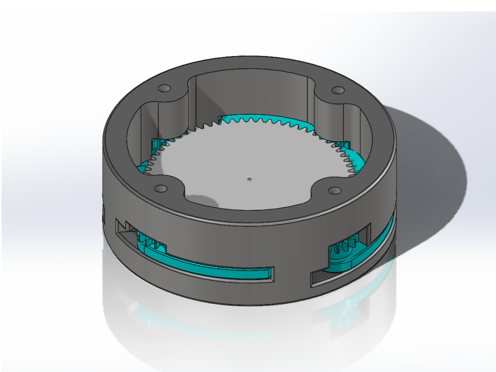
Avionics/Air Brakes (AVAB) Bay

The Avionics and Air Brakes Bay, hereafter 'AVAB', will consist of a 16 in. length of coupler with a 3 in. sleeve of airframe material adhered 4.5 in. from the forward edge of the coupler tube. This will allow the required 4.5 in. of surface contact between the main parachute bay and the AVAB (Requirement 2.4.2). The outer 3 in. airframe sleeve will feature two pairs of mirrored, offset slots cut through both the airframe and coupler wall, allowing the deployment of four drag fins into the airstream during the coast phase. A small portion of the outer airframe sleeve, forward of the Air Brake slots, will serve as a switch-band for arming recovery altimeters. A solid bulkhead located internally between the Air Brake slots and switch-band portion will partition the AVAB into two-compartments (Requirement 3.14.1). The forward compartment will house the recovery altimeters and associated components, and the aft compartment will house the Air Brakes system. More information about the Avionics Bay design can be found in section 4.4.2. Pressure port holes for the recovery altimeters will be drilled through the Main Parachute Bay and the forward AVAB compartment. The holes will be drilled far enough forward of the Air Brakes slots such that the altimeters are not impacted by the pressure changes due to the airflow impinging on the drag fins. Removable bulkheads will serve as the forward and aft closures of the respective compartments, and will be secured with ¼ in. threaded rods running through the entire AVAB, also serving as the structural attachment points for internal components.

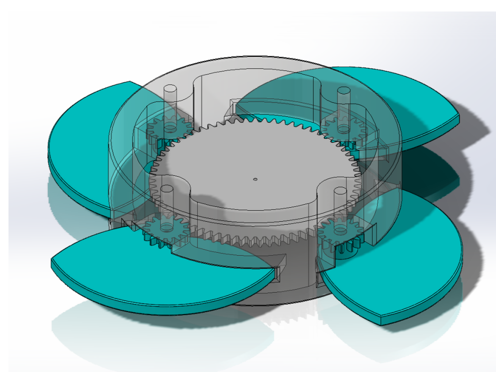
The remaining 8.5 in. of coupler section aft of the airframe sleeve will mate to the Fin Can and will be an in-flight separation point, fastened with nylon shear pins. This length exceeds Requirement 2.4.1, however is deemed necessary to accommodate the Air Brakes system in the aft AVAB compartment. It will position the airbrake protuberances aft of the vehicle CG at burnout, per Requirement 2.16.

Air Brakes System

The Air Brakes system deploys four autonomously controlled fins that rotate from inside of the AVAB into the airstream during the coast phase. The system is designed to selectively increase drag force on the vehicle in a controlled manner to achieve the declared apogee, defined in Section 4.3. The fins are actuated via a servo motor commanded by an inertial flight computer. The four fins deploy and retract simultaneously via a central gear, and are retained within a housing section inside the aft AVAB compartment. The fins hinge upon the same threaded rods providing the internal support structure for the AVAB components. The drag fins, housing, and gears will be fabricated out of 3D-printed PETG filament (4.2.2).



(a) Drag fins retracted.



(b) Drag fins deployed.

Figure 4.3: Air brakes deployment mechanism.

Fin Can/Drogue Parachute Bay

The Fin Can airframe will be 36 in. in length and will mate with the aft AVAB coupler at an in-flight separation point. The forward volume of the Fin Can will also serve as the Drogue Parachute Bay. A permanent bulkhead will be adhered into the Fin Can forward of the motor casing to attach recovery hardware. Four fins constructed of G10 fiberglass will be attached in either a fixed permanent configuration (i) or as part of a removable, modular fin system (ii). For both configurations, the aft closure of the Fin Can will consist of a thrust bulkhead, and an Aero Pack 75mm motor retainer, bringing the overall Fin Can length to 37 in.

i. Fixed Fin Design

A fixed, "through-wall" fin design is a commonly used construction method in model and high-powered rocketry that can produce strong adhesive bonds between the fins, centering rings, motor mount tube, and airframe. Centering rings are adhered to the motor mount tube then inserted into the airframe. Fin tabs protrude through slots in the airframe and sit flush with the motor mount tube. The forward and aft edges of the fin tabs are bracketed by the centering rings and are adhered along all points of contact with both the centering rings and the motor mount tube. Outside of the airframe, adhesive fillets are applied in the grooves formed with the root chord of the fins and the airframe body. While this method has been used successfully by the team in the past and results in a structurally strong assembly, it has high time and labor cost for fabrication, modification, repair, or total replacement in the event of structural damage to any sub-component. For this reason, in more recent years the club has pivoted to implementing removable fin system designs.

ii. Removable Modular Fin System Design (RMFS)

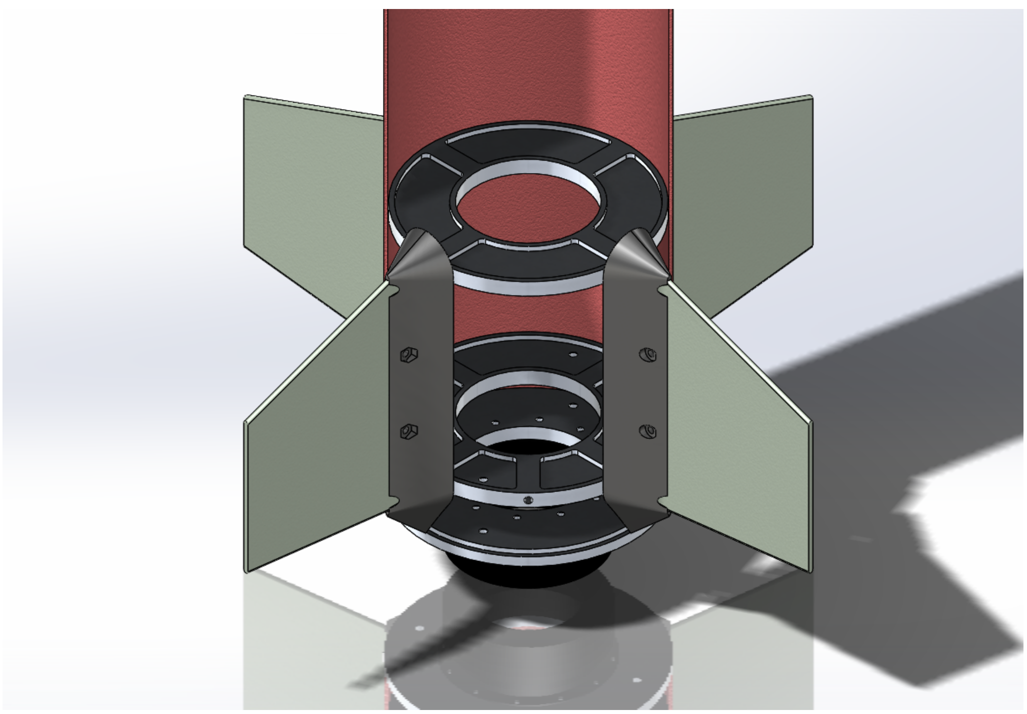


Figure 4.4: RMFS partial section view, without motor casing or fasteners.

The team will implement a Removable Modular Fin System (RMFS) as the preferred design. This system forgoes use of a motor mount tube. Instead, two ⅜ in. centering rings and one ⅜ in. thrust bulkhead are machined from 6061-T6 aluminum stock to center the motor casing in the airframe. The fins will each slot into individual, 3D-printed PETG brackets, and will be secured using #8 zinc-plated steel machine screws with hex nuts through holes in the fin tabs and brackets. Each fin bracket will sit flush against the exterior surface of the airframe, and will in turn be fastened to the airframe and centering rings via machine screws into threaded holes in the centering rings. The fins brackets will be oriented radially in 90-degree increments. One additional threaded hole will be present in the aft centering ring at a 45-degree offset between existing holes to affix the rear rail guide. This fin attachment method requires only 9 small holes in the airframe, and completely removes the need to cut long slots along the Fin Can as with previous removable fin system designs.

The purpose of the thrust bulkhead is to evenly transfer the thrust force from the motor casing to the aft circumference of the Fin Can. Thus, ¼ in. of the bulkhead thickness will be a lip that matches the outer diameter of the airframe and be positioned flush against the end of the airframe.The forward ⅛ in. of the bulkhead will be sized to fit inside the airframe to center it. The Aero Pack 75mm flanged motor retainer will be fastened to the thrust plate with machine screws and threaded holes. The thrust plate will be held in place with additional machine screws running through the plate and into threaded holes in the aft centering ring.

The RMFS improves upon previous designs by eliminating the need for composite layups, reducing part count, preserving airframe integrity, and providing increased modularity. In the event of a mishap that compromises any part of the system other than the motor casing or airframe, individual components can be swapped out for spares in minutes.

Fin Design

As described above, the launch vehicle will feature four fins constructed of ⅛ in. G10 fiberglass, mounted into 3D printed PETG fin brackets affixed to the Fin Can.

i. Geometry

The fins and fin brackets both incorporate a trapezoidal shape with backward-swept leading edges and forward-swept trailing edges depicted in Figure 4.5. This geometry provides balance between aerodynamic and structural performance. Trapezoidal fins have lower induced drag than fin geometries with straight trailing edges, and have the structural benefit of keeping the trailing edge of the fins forward of the aft structure of the Fin Can, decreasing the chance of direct impact upon recovery. This fin shape will also be easier to fabricate than a more complex geometry.

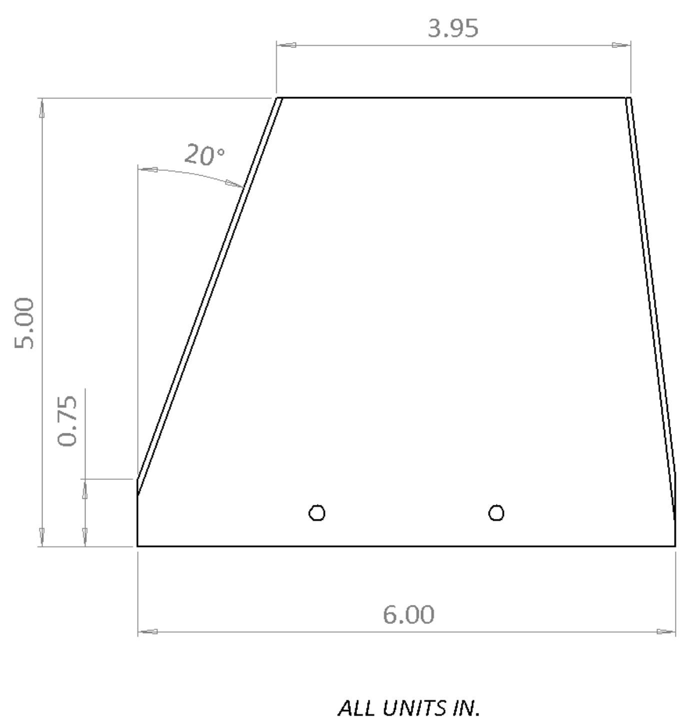


Figure 4.5: Preliminary fin geometry [in.].

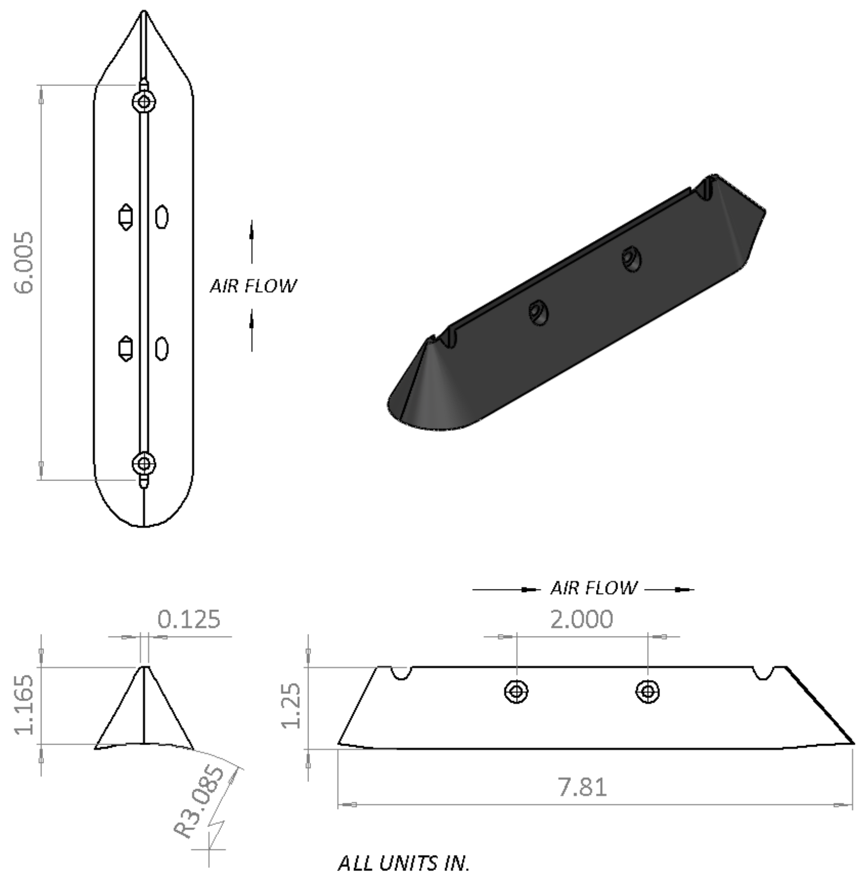


Figure 4.6: Preliminary fin bracket geometry 3-view [in.].

ii. Simulation

An initial aerodynamics simulation to show fin performance was completed using SolidWorks Flow Simulation. The fin and bracket shape will be optimized for more advanced aerodynamic performance. Additionally, future simulations will be performed in a more advanced software, ANSYS Fluent 3D. The turbulent energy profile shown in Figure 4.7 shows that the flow over the fin is laminar, allowing for high control. Turbulence along the bracket will be improved with a more aerodynamic design iteration. This will also reduce turbulent energy along the fin. The design of the bracket may influence fin design further.

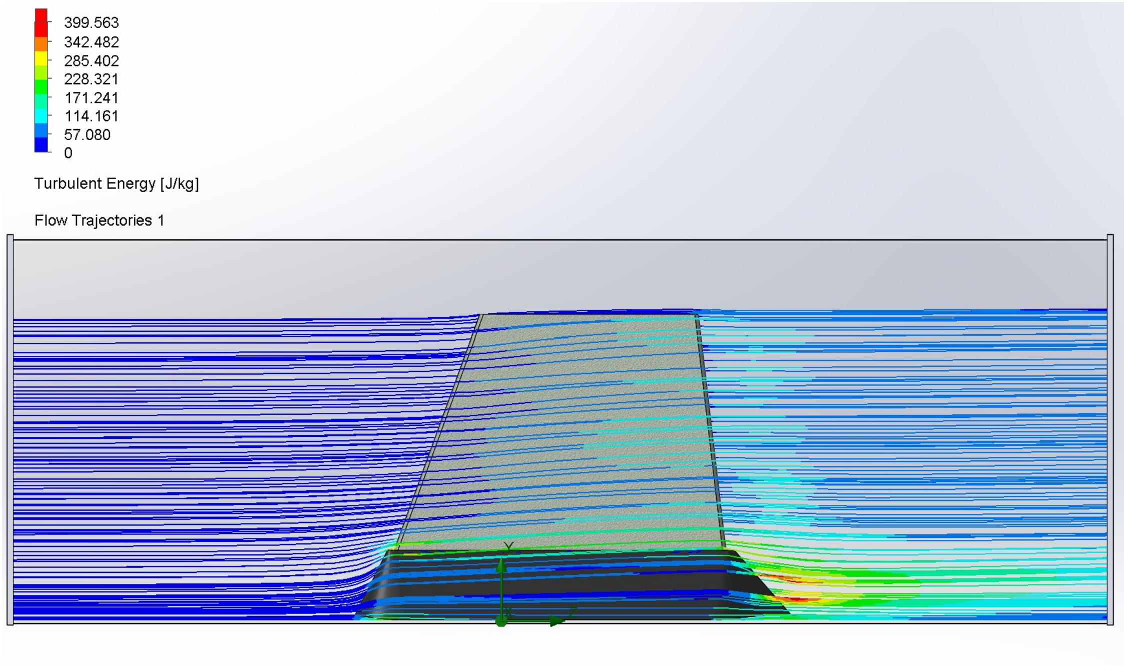


Figure 4.7: Turbulent Energy of Fin Bracket and Fin at 180 m/s.

Bulkhead Design

All bulkheads excluding the thrust and AVAB partition bulkheads will be constructed out of Baltic birch plywood, either ½ or ¾ in. in total thickness depending on predicted loading. Removable bulkheads will have a smaller inner diameter to allow centering within coupler sections, and a lip for the larger diameter to sit flush against the outer circumference of the coupler section. This lip will make up at least half of the total thickness of each removable bulkhead. The bulkhead to bulkhead fabrication process is detailed below in Section 4.2.1.

Rounded ¼ in. zinc-plated steel U-bolts will be mounted to the removable bulkheads on the AVAB and payload bay as well as the permanent Fin Can bulkhead. These U-bolts will serve as the attachment points for recovery hardware, therefore the bulkheads must be sufficiently strong to withstand the forces encountered during recovery system deployment events. The U-bolts will be backed with plate washers to provide the largest possible surface area over which forces are applied, helping to reduce internal stresses in the bulkheads. The forward and aft removable bulkheads on the AVAB will also be used to mount terminal blocks and charge wells for recovery system energetics.

4.2.2 Material Selection

There are many properties to consider when selecting appropriate materials for aerospace components such as weight, strength, ductility/brittleness, thermal resilience, heat and electrical conductivity, and corrosion resistance. Ease of fabrication, environmental hazards, and cost are other non-mechanical properties which must be factored into material selection. For this challenge our primary criteria for material selection are weight, cost, and reusability. The reusability factor will be a combination of material strength and resilience under predicted conditions.

Phenolic Tubing and Blue Tube

Phenolic Tubing and Blue Tube are both commercially available spiral wound paper fiber based tubes commonly used in hobby rocketry. Phenolic tubing is resin-impregnated which greatly increases compressive strength yet also increases brittleness and decreases impact resistance. Phenolic tubing is also heat resistant, low cost, and lightweight.

Blue Tube is a proprietary, spiral wound, high-density paper fiber tube that is much more impact resistant and generally durable than Phenolic tubing. However, it is slightly heavier and more costly than Phenolic Tubing (Table 4.3). The primary disadvantage of both of these materials for the vehicle airframe is vulnerability to water damage, which is a significant recovery hazard at our home launch field, which features many wide irrigation ditches. As such, they are considered to have a low reusability factor and are not considered suitable for the full- scale launch vehicle.

Carbon Fiber

Carbon fiber resin composite tubing is the premium material for airframe strength, durability, and weight. Unlike paper fiber based tubes, it is also waterproof, which contributes to a high reusability factor. The primary disadvantage of carbon fiber tubing is price, which is by far the most costly material to use. Additionally, it poses inhalation, irritant, and abrasion hazards during the fabrication process. However, these hazards are mitigated through proper use of PPE and airborne debris management.

G12 Fiberglass

Wound G12 glass fiber tubing is another strong, impact resistant, and waterproof composite material. For 6 in. diameter body tubes, it is approximately 33 percent heavier than carbon fiber tubing. However, it is approximately half the cost with the same high reusability factor (Table 4.3). Working with the material poses similar risks as carbon fiber, but can be mitigated through the same protective measures. For these reasons G12 fiberglass tubing will be the material of choice for airframe construction.

Table 4.3: Material Selection Data For 6 in. Diameter Airframe

Material	Mass per inch [oz.]	Cost per inch [USD]	Reusability Factor
Phenolic Tubing	0.77	$1.24	Low
Blue Tube	0.87	$1.61	Low
Carbon Fiber	1.53	$9.68	High
G12 Fiberglass	2.00	$4.68	High

G10 Fiberglass

G10 fiberglass is another strong, durable fiberglass composite widely used in model and high-powered rocketry. It differs from G12 fiberglass in that G12 composite is manufactured by winding glass fiber filament and resin coating on a mandrel to form the composite matrix, while G10 fiberglass consists of layers of glass fiber cloth that are laminated together with resin. As a result, G10 fiberglass is well suited for applications requiring flat surface areas, such as fins and bulkheads. G10 fiberglass is heavier and more costly than plywood, at $45 per 1 ft^2. The fins made using this material can be cut and finished at the required thickness without the need for additional layups or reinforcement, as would be required for equally strong fins made of plywood. For this reason G10 will be the material used to fabricate the launch vehicle fins.

Aviation-Grade Plywood

Aviation grade plywood is a lightweight plywood manufactured to stringent quality standards. Historically the team has used aviation grade birch plywood to construct launch vehicle bulkheads, centering rings, fins, and internal fin runners. It costs $41.90 USD per sheet of ⅛ in. plywood, and multiple sheets are typically required to cut all the required layers for vehicle components. Additional costs incurred during the fabrication process must also be considered which is detailed in Section 4.2.3.

Baltic Birch Plywood

Baltic Birch plywood is higher quality than construction grade birch plywood in that it is free of any voids between the plies which could create unanticipated stress concentrations under load. Based on previous team finite element analysis of bulkheads on similar or greater mass launch vehicles, ½ in. or ¾ in. plywood is well suited for bulkhead construction. A ½ in. thick sheet of Baltic birch plywood costs $25 USD and a ¾ in. thick sheet costs $35 USD. A single sheet of either thickness would be sufficient size to manufacture all plywood components for the launch vehicle, with no additional monetary cost. For this reason, the team will use Baltic birch plywood to fabricate the permanent and removable bulkheads for the launch vehicle. As with all newly implemented materials and fabrication methods, further testing and analysis will be used to validate material suitability.

6061 Aluminum

6061 Aluminum is an aluminum alloy with extensive use in aerospace applications. It is ductile, lightweight, strong, thermally resistant, and easily machined, making it the material of choice for the RMFS centering rings and thrust plate. One benefit of using aluminum over wooden components, besides strength, is the ability to tap threaded holes for removable fasteners directly into the material without the need for metal inserts. This will allow for thinner overall material requirements around the attachment points. 6061 aluminum plates of the required ⅜ in. thickness are widely available from a variety of vendors, and the size required to machine all aluminum components would cost approximately $78 USD.

Epoxy Resin

West System 105 Epoxy Resin paired with West System 206 Slow Hardener curing agent has been the epoxy used by the team for years with great success. With proper surface preparation, it yields high-strength adhesion between critical airframe components. The reported ultimate tensile strength of the fully cured resin is 7300 psi. The main downsides to using this epoxy are cost and cure time, with cost of around $1.04 per fluid oz. of epoxy (with curing agent included) and a minimum cure time of 24-hours. Regardless, the strength and reliability of the resulting bonds are assessed to be worth the trade-off. The team will continue to use this epoxy system to permanently bond coupler and airframe sections together, as well as bond permanent bulkheads into the airframe. For the latter application, West System 406 Colloidal Silica adhesive filler will also be added to the epoxy and hardener mix to enable application of thick, reinforcing fillets at joints between the airframe and bulkheads.

PLA

Polylactic acid (PLA) is a widely used polymer for material extrusion 3D-printing. It is easy to print with low warping characteristics. Tensile strength of 3D printed polymer depends on multiple variables, however 7,250 psi is on the higher end of reported values. PLA has poor impact resistance, however, and is subject to embrittlement under high loading or prolonged UV exposure. Additionally, it has a low glass transition temperature of around 130 °F. PLA is not recommended for any structural components, however may be used for internal, non-structural elements. It will be used to create mock-ups to aid in the design process, as well as custom tube marking jigs discussed in Section 4.2.3.

PETG

Polyethylene terephthalate glycol (PETG) is another commonly used 3D printing polymer. It has similar ease of printing and tensile strength as PLA, however, has superior impact resistance, higher glass transition temperature of around 185 °F, UV resistance, and greater flexibility. Thus making it an overall better choice for our structural applications, such as the fin brackets.

The mechanical properties of any 3D printed components can vary greatly depending on numerous parameters such as part geometry, infill percentage, layer line orientation, print speed, and heatbed/nozzle temperatures. Thorough real-world testing and evaluation will be conducted on any 3D printed components to ensure suitability for use on the launch vehicle.

Fasteners

With the introduction of threaded aluminum components, close attention must be paid to the types of fasteners used to assemble the RMFS components. Standard metal machine screws are typically made of steel, with two common varieties being stainless steel and zinc-plated steel. Stainless steel screws are prone to thread deformation under high stresses. Due to stainless steel and aluminum being relatively soft metals, this chance of thread deformation is increased, which can cause fasteners to seize or fail. Furthermore, aluminum and stainless steel are galvanically dissimilar metals and will be prone to galvanic corrosion when they remain in contact. Zinc however, is a similar metal to aluminum in the galvanic series and prevents this issue. For these reasons, zinc-plated steel machine screws and associated hardware shall be the only type of fasteners used for securing RMFS components.

4.2.3 Construction Methods

Bulkheads

Historically the team has manufactured bulkheads using layered ⅛ in. plies of laser-cut aviation grade plywood, which are adhered together with West System epoxy resin in a vacuum layup process. This method produces strong, reliable bulkheads. However it uses expensive materials, is time-consuming, and generates unnecessary waste. It requires the use of many other consumables such as mixing cups, alignment dowels, nitrile gloves, peel-ply, vacuum-seal tape, plastic sheeting, sandpaper, and acetone. This year the team will evaluate CNC milling as an alternative process of bulkhead fabrication. This should streamline the fabrication process and lead to reduced overall cost and waste.

The process will begin with generation of simple CAD models of each bulkhead in SolidWorks. Drawing files derived from these models will be exported and transferred into VCarve Pro software where tooling instructions for a ShopBot CNC router will be programmed. The ShopBot CNC router will be used to mill multiple bulkheads simultaneously out of a single Baltic birch plywood sheet of the desired thickness. Any hardware mounting holes too small to be cut by the router head, or any that need to be added afterwards will be drilled out using a drill press.

Centering Rings and Thrust Bulkhead

Similar to the plywood bulkheads, the 6061 Aluminum centering rings and thrust plate will also be machined out of flat stock. However they will either be cut on a CNC water jet cutting machine or via a CNC mill in the NC State Machine Shop. Fastener hole drilling and threading will be either completed by the machine shop, or in the team lab by hand using a drill press and a tap and die set.

To further enhance the durability of the aluminum parts, the team should consider anodizing them post-machining. This is an electrochemical process which thickens the natural oxide layer on the surface of the parts, providing additional corrosion and wear resistance. This would be especially beneficial on the thrust bulkhead, which will be in close proximity to motor exhaust during takeoff/flight and directly exposed to ground contact during recovery.

Fins

Fin templates will be traced onto G10 fiberglass sheet stock and then roughly cut using a miter saw with a carbide blade or a handheld rotary cutting tool such as a Dremel. The fin mounting holes will be drilled into the rough cut fins using a drill press and the hole area will be covered with masking tape to minimize any surface delamination. Next, all four fins will be clamped together and sanded down to final dimensions as a single unit to ensure consistent size. The leading and trailing edges of each fin will then be rounded off using a belt sander. The finished fins will be cleaned with acetone to remove any contaminants. Finally, the fins will be test fitted and secured into the fin brackets.

Due to the hazardous nature of fiberglass dust and splinters, vacuum suction will be applied in proximity to the cutting tools during all steps that involve material removal. Additionally, these processes will be completed outdoors or in the ventilation booth of the NC State Senior Design Lab whenever possible.

Fin Brackets

The fin brackets will be 3D printed out of PETG filament using the material extrusion printing method. The fin bracket CAD model will be generated in SolidWorks then exported as an STL file. The STL file will be imported into PrusaSlicer software, which generates the toolpath and other control code for the printer. Print parameters discussed in material selection (Section 4.2.2) will be tuned for sufficient print quality and part strength. The output binary geometric code generated by the slicing software will then be transferred to the team's Prusa Mk4 printer for printing.

Airframe and Coupler Cutting

Fiberglass body tube and coupler cutting, poses the hazards previously outlined in Section 4.2.2 and fin construction section above. Due to these hazards, airframe and coupler cutting will only be performed by trained and properly equipped team members or NC State machine shop staff. Fiberglass tube sections will first be inspected for irregularities and test fit by team members. Next, tubes will be marked to the specified dimensions then cut using a wet saw, band saw, or rotary hand tool with an appropriate blade. Cut edges will be hand sanded to remove any stray glass fibers. Then the entire tube will be cleaned of dust and debris via a vacuum, then wiped with isopropyl alcohol.

A similar procedure will be followed for drilling holes; however masking tape will be added to the inside of the tube to help prevent fiber delamination when the drill bit exits the material surface. Holes that require very accurate placement, such as those for the fin brackets, will be marked with the aid of 3D-printed markup jigs to ensure precise and symmetric placement around the circumference of the body tube. Holes will be drilled using a drill press with the tubes supported by and clamped to a wood positioning jig.

Airframe and Coupler Adhesion

Proper airframe and coupler adhesion is critical to the overall integrity of the launch vehicle sections. Thus, care must be taken to ensure the best possible mechanical and chemical bond is achieved when sections are epoxied together. First both sections will again be inspected and test fit, then cleaned to remove any surface contamination. The coupler section will be marked to ensure exact placement within the airframe, then the desired contact areas of both sections will be lightly sanded with medium-grit sandpaper to promote mechanical bonding. Next, the surface is again cleaned and wiped with acetone to promote chemical bonding. After the acetone dries from the surface, a light coat of epoxy resin will be applied to the contact surfaces and the sections will be joined. Excess epoxy will be wiped away and the joined sections will be secured together for 24 hours during the curing process. After curing, any stray epoxy will be spot cleaned from the assembly using acetone.

Ballast

Ballast may be required to improve vehicle stability by shifting the overall CG forward. In this case, ballast shall consist of the appropriate mass and density. Solid material will be securely mounted to structural elements in the Nose Cone/Payload Bay, as far forward as possible to minimize the mass required. In the unlikely circumstance that ballast is required to shift the vehicle CG aft, it will be secured to the aft centering ring within the RMFS using the original fasteners or extended versions of the fasteners.

Safety Standards

All team members shall be trained on the appropriate safety procedures put in place by the club and the designated Safety Officer. All team members shall be required to follow all safety procedures, while operating in the clubs laboratory space or performing club activities. These regulations include, but are not limited to:

- Team members shall wear the proper PPE for what task they are performing at all times.
- Team members shall be trained on equipment by an individual certified by the Safety Officer prior to use.
- Team members shall follow and adhere to all instructions and safety procedures given by the Safety Officer at all times.

Further safety precautions and procedures are detailed in Section 3.

4.3 Projected Altitude

The launch vehicle's target apogee is 5000 ft. This has been selected due to the predicted mass of the vehicle, available motor options, and recovery Requirements 3.3, 3.11, and 3.12. Based on the mass distribution of the vehicle and the motor casing being utilized, the motors that will keep the vehicle in the required altitude are the AeroTech motors L1520T, L1940X, and L1390G. Simulations with these motors in OpenRocket provide the ascent profiles shown in Figure 4.8. The projected altitude takes these curves, as well as the implementation of Air Brakes into account, yielding an altitude target of 5000 ft. This utilized the L1390G motor. Motor selection will be discussed further in Section 4.5.

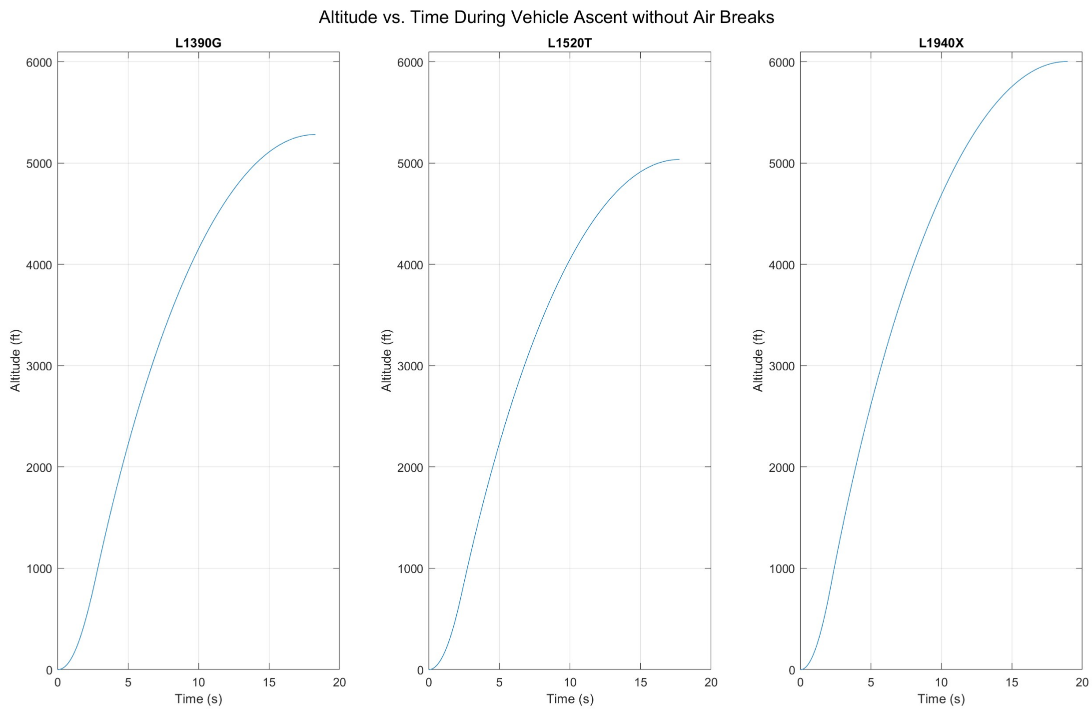


Figure 4.8: Altitude vs. Time for Each Motor.

4.3.1 Air Brakes

The launch vehicle will contain an Air Brakes system. This will allow for increased control of apogee on launch day. By slightly overshooting our target apogee, the Air Brakes System will slow the rocket using a predictive algorithm to reach 5000 ft. This system should be able to decrease the apogee by up to 300 ft. On launch day, the Air Brakes system should have to decrease the apogee by approximately 200 ft.

4.4 Launch Vehicle Recovery Specifications

As per NASA Requirement 3.1, the launch vehicle will employ a dual deployment recovery system with one drogue parachute and one larger main parachute. These parachute deployments will be controlled by two independent altimeters that ignite four separate black powder charges. The primary altimeter will trigger the drogue parachute deployment at apogee and the main parachute deployment at 550 ft. The secondary altimeter will act as a backup for the primary altimeter, triggering the drogue parachute deployment 1 second after apogee and the main parachute deployment at 500 ft. The avionics bay will also contain an electronic GPS to locate the launch vehicle after descent.

4.4.1 Recovery System Requirements

Table 4.4 below outlines the given NASA requirements pertaining to the recovery system, the planned action the Senior Design Team plans to take to meet these requirements, and the methods the team will use to verify these requirements are being met.

Table 4.4: 2024-2025 Recovery Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
3.1	The full-scale launch vehicle SHALL stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee, and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue stage descent is reasonable, as deemed by the RSO.	The Recovery Lead will design a dual deploy recovery system using two altimeters, one serving as a primary altimeter and one serving as a secondary backup altimeter, with a drogue shoot deployed at apogee and a main parachute deployed above 500 ft.	Demonstration	Recovery
3.1.1	The main parachute SHALL be deployed no lower than 500 feet.	The Recovery Lead will program the primary altimeter to deploy the main parachute at 550 ft and the secondary altimeter to deploy the main parachute at 500 ft.	Demonstration	Recovery
3.1.2	The apogee event SHALL contain a delay of no more than 2 seconds.	The Recovery Lead will program the primary altimeter to deploy the drogue parachute with a 0 second delay from apogee and the secondary altimeter deploy the drogue parachute 1 second after apogee.	Demonstration	Recovery
3.1.3	Motor ejection is not a permissible form of primary or secondary deployment.	The Recovery Lead will design a dual deploy recovery system controlled by two altimeters, not motor ejection.	Inspection	Recovery
3.2	Each team shall perform a successful ground ejection test for all electronically initiated recovery events prior to the initial flights of the subscale and full-scale vehicles.	The Recovery Lead will perform ground ejection tests prior to every vehicle launch.	Demonstration	Recovery
3.3	Each independent section of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf at landing. Teams whose heaviest section of their launch vehicle, as verified by vehicle demonstration flight data, stays under 65 ft-lbf will be awarded bonus points.	The Recovery Lead will design a recovery system to use parachutes large enough such that the heaviest section of the launch vehicle's kinetic energy does not exceed 75 ft-lbf.	Analysis	Recovery

Table 4.4: 2024-2025 Recovery Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
3.4	The recovery system SHALL contain redundant, commercially available barometric altimeters that are specifically designed for initiation of rocketry recovery events. The term “altimeters” includes both simple altimeters and more sophisticated flight computers.	The Recovery Lead will design a recovery system that uses two separate commercially available barometric altimeters designed for rocketry recovery events that function on two separate electronic circuits.	Inspection	Recovery
3.5	Each altimeter SHALL have a dedicated power supply, and all recovery electronics SHALL be powered by commercially available batteries.	The Recovery Lead will design the recovery system such that each of the altimeters have their own independent commercially available batteries that function on separate circuits.	Inspection	Recovery
3.6	Each altimeter SHALL be armed by a dedicated mechanical arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	The Recovery Lead will design the recovery system such that each of the altimeters are armed using pull pin switches which may be accessed from the exterior of the launch vehicle’s airframe.	Inspection	Recovery
3.7	Each arming switch SHALL be capable of being locked in the ON position for launch (i.e., cannot be disarmed due to flight forces).	The Recovery Lead will choose arming switches that are locking in the on position for the entirety of the flight.	Inspection	Recovery
3.8	The recovery system, GPS and altimeters, and electrical circuits SHALL be completely independent of any payload electrical circuits.	The Recovery Lead will design the recovery system such that both altimeters and the GPS function on circuits independent from any payload electrical circuits.	Inspection	Recovery
3.9	Removable shear pins SHALL be used for both the main parachute compartment and the drogue parachute compartment.	The Recovery Lead will design the recovery system to utilize shear pins on the connection points for the main parachute compartment and the drogue parachute compartment.	Inspection	Recovery
3.10	Bent eyebolts SHALL not be permitted in the recovery subsystem.	The Recovery Lead shall confirm that no bent eyebolts are utilized anywhere within the recovery subsystem.	Inspection	Recovery
3.11	The recovery area SHALL be limited to a 2,500 ft. radius from the launch pads.	The Recovery Lead will design the recovery system to utilize parachutes appropriately sized to ensure that the launch vehicle does not drift more than 2,500 ft. from the launch pads during descent.	Analysis	Recovery

Table 4.4: 2024-2025 Recovery Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
3.12	Descent time of the launch vehicle SHALL be limited to 90 seconds (apogee to touch down). Teams whose launch vehicle descent, as verified by vehicle demonstration flight data, stays under 80 seconds will be awarded bonus points.	The Recovery Lead will design the recovery system to utilize parachutes appropriately sized to ensure that the launch vehicle descends to the ground in under 90 seconds.	Analysis	Recovery
3.13	An electronic GPS tracking device SHALL be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver.	The Recovery Lead will design the recovery system to utilize an electronic GPS in each separating section of the launch vehicle.	Inspection	Recovery
3.13.1	Any rocket section or payload component, which lands untethered to the launch vehicle, SHALL contain an active electronic GPS tracking device.	The Recovery Lead will utilize an electronic GPS in each separation section of the launch vehicle.	Inspection	Recovery
3.13.2	The electronic GPS tracking device(s) SHALL be fully functional during the official competition launch.	The Recovery Lead will test all electronic GPS tracking device(s) after the vehicle is fully assembled before every launch.	Demonstration	Recovery
3.14	The recovery system electronics SHALL not be adversely affected by any other on-board electronic devices during flight (from launch until landing).	The Recovery Lead will design the recovery system such that none of the recovery system electronics are influenced by other on-board electronic devices.	Demonstration	Recovery
3.14.1	The recovery system altimeters SHALL be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.	The Recovery Lead will design the recovery system such that all altimeters are physically located in a separate compartment from all other non-recovery on-board electronics.	Inspection	Recovery
3.14.2	The recovery system electronics SHALL be shielded from all on-board transmitting devices to avoid inadvertent excitation of the recovery system electronics.	The Recovery Lead will design the recovery system such that the recovery system electronics are shielded from all on-board transmitting devices.	Inspection	Recovery
3.14.3	The recovery system electronics SHALL be shielded from all on-board devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.	The Recovery Lead will design the recovery system such that the recovery system electronics are shielded from all on-board magnetic wave generating devices.	Inspection	Recovery

Table 4.4: 2024-2025 Recovery Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
3.14.4	The recovery system electronics SHALL be shielded from any other on-board devices which may adversely affect the proper operation of the recovery system electronics.	The Recovery Lead will design the recovery system such that the recovery system electronics are shielded from all on-board devices which may adversely affect the proper operation of the recovery system electronics.	Inspection	Recovery

4.4.2 Avionics Bay Design

The forward section of the AVAB is the Avionics (AV) bay. Contained within the AV bay are two altimeters, two batteries, and one GPS. Each of the altimeters will be powered by separate LiPo batteries on independent circuits separated from all other payload and Air Brakes electronics.

All AV electronic devices will be secured to a custom made AV Sled designed in SOLIDWORKS and 3D printed. This AV Sled will rest on two threaded rods that run through the entirety of the AV bay and through the bulkheads mounted on each end as described in Section 4.2.1. Also mounted to this AV sled will be two mechanical pull pin switches used to arm and disarm the altimeters. Two holes will be drilled through the AVAB switch band to allow the pull pin switches to be armed from the exterior of the launch vehicle while on the launch pad. There will also be pressure port holes drilled along the switch band in order to ensure a consistent pressure between the interior of the AV bay and the outside atmospheric pressure.

On the exterior side of both bulkheads surrounding the AVAB are two PVC pipe ends and one U-bolt. These two PVC pipe ends will furthermore be referred to as blast caps. Two small holes will be drilled through each of the bulkheads to allow the e-matches to rest inside of the blast caps and connect back into the altimeters. The drogue and main parachutes will be connected back to the rocket with Kevlar Shock Cord.

As per NASA Requirement 3.14, the AV bay is designed such that no electronic devices have adverse effects on the recovery electronics. Within the AVAB, the Air Brakes bay and avionics bay will be separated by a bulkhead padded with an insulating material to block magnetic waves.

4.4.3 Ejection Charges

Each of the blast caps will be filled with FFFG Granular Black Powder that is ignited by the e-matches to pressurize the respective parachute bays in order to separate the sections of the launch vehicle and deploy the parachutes. In total, there will be four black powder charges: the primary drogue parachute ejection charge, the secondary drogue parachute ejection charge, the primary main parachute ejection charge and the secondary main parachute ejection charge.

The size of the primary ejection charges will be calculated using Chuck Pierce's Ejection Charge Calculator and verified by hand calculations. For redundancy, the secondary charges will be calculated by adding 0.5 oz. to the primary charges to ensure separation. Any volume of the blast caps not filled by blast powder will be filled with paper towel and the tops of all the blast caps will be wrapped with blue tape to ensure no black powder leakage. Prior to each launch, the launch vehicle will be assembled in its launch day configuration and ground ejection testing will be performed on each of these recovery events.

4.4.4 Recovery Events

The recovery system is designed with two recovery events, one for drogue parachute deployment and one for main parachute deployment.

The first recovery event occurs at apogee when the primary altimeter ignites the primary drogue black powder charge on the aft end of the AVAB. One second later, the secondary altimeter will ignite the secondary drogue black powder charge on the aft end of the AVAB for redundancy. These black powder charges ignite and create a pressure buildup in the Drogue Bay, breaking the shear pins that connect the AVAB to the Drogue Bay, and separating the sections to deploy the drogue parachute. The launch vehicle then falls under drogue parachute until the second recovery event.

The second recovery event occurs at 550 ft. when the primary altimeter ignites the primary main black powder charge on the forward end of the AVAB. At 500 ft, the secondary altimeter will ignite the secondary main black powder charge on the forward end of the AVAB for redundancy. These black powder charges ignite and create a pressure buildup in the Main Parachute Bay and Nose Cone. This breaks the shear pins that connect the Main Parachute Bay to the Nose Cone and separates the sections to deploy the main parachute. The launch vehicle then falls under main parachute for the remainder of the descent.

4.4.5 Parachute Calculations

The descent velocity of the launch vehicle was calculated using the equation

$$v_D = \sqrt{\frac{2mg}{\rho A C_d}} \tag{1}$$

where v_D is the descent velocity, m is the mass of the vehicle, ρ is air density, A is the canopy area of the parachute, and C_d is the coefficient of drag of the parachute.

The drogue parachute selected for the launch vehicle is the Fruity Chutes 18" Elliptical Parachute. This parachute has an area canopy of 3.0197 ft^2 and a coefficient of drag of 0.8427, resulting in a descent velocity of 100.61 fps under drogue. The main parachute selected for the launch vehicle is the Fruity Chutes Iris 120" Ultralight Parachute. This parachute has an area canopy of 135.4703 ft^2 and a coefficient of drag of 1.236, resulting in a descent velocity of 12.403 fps.

With the descent velocity, the maximum kinetic energy at landing can be calculated with

$$K = \frac{1}{2} m {v_d}^2 \tag{2}$$

where K is the maximum kinetic energy. Using the a descent velocity of 12.403 fps and an estimated mass of 30.625 lbm, the maximum kinetic energy of the launch vehicle was calculated to be 73.22 ft-lbf, satisfying NASA Requirement 3.3.

With descent velocity for the drogue and main parachutes, the total descent time was calculated using the equation

$$t_d = \frac{r_a - r_m}{v_d} + \frac{r_m}{v_m} \tag{3}$$

where t_d is the descent time, r_a is the apogee, r_m is the main parachute deployment deployment altitude, v_d is the drogue descent velocity, and v_m is the main descent velocity. Assuming a drogue deployment at an apogee of 5000 ft, and a main deployment at 500 ft, the total descent time was calculated to be 85.04 seconds, satisfying NASA Requirement 3.12.

Table 4.5 shows how the drift distance of the launch vehicle from the launch pads will vary with wind speed up to a maximum of 20 mph.

Table 4.5: Wind Drift Distance

Wind Speed (mph)	Drift Distance (ft)
0	0
5	623.60
10	1247.21
15	1870.81
20	2494.41

For drift distance calculations, it was assumed that the launch vehicle would constantly drift with the wind and would reach apogee directly above the launch pad. Since the launch vehicle will fly into the wind and the winds will not be constantly blowing, these calculations are an upper bound for maximum drift distance, satisfying NASA Requirement 3.11.

4.4.6 Recovery Avionics

The AV bay will contain one PerfectFlite StratoLoggerCF, one Eggtimer Quasar, two 7.4V 800mAh LiPo batteries, and two Lab Rat Rocketry pull pin switches. The StratoLoggerCF will act as the primary altimeter and be on an independent circuit with one of the batteries and pull pin switches. The Quasar will be on a second independent circuit with a different battery and a different pull pin switch. Both of these pull pin switches will be accessible via a hole drilled into the switch band of the AVAB bay. Once the pull pin is removed from the pull pin switch, the switch becomes locked in the on position, leaving the altimeters functioning for the duration of the flight. This configuration satisfies NASA Requirements 3.4, 3.5, 3.6, 3.7, and 3.8.

Before flight each of the altimeters will be configured and tested in a vacuum chamber. To test the altimeters, they will be placed inside of a vacuum chamber connected to a circuit board with indicator lights instead of e-matches. Pressure will slowly be removed from the chamber mimicking a rise in altitude and then slowly increased to mimic apogee and descent. The indicator lights for each of the charges will be different colors to more easily verify proper functionality of the altimeters. Upon completion of the testing, the altimeter data will be plotted to ensure that the visualized events occurred at the expected simulated altitudes.

4.5 Motor Brand and Class

Motor selection is based on a variety of factors. Brand is based on team experience, mentor advice, and commercial availability. AeroTech solid rocket motors are commercially available and very reliable. The team has used AeroTech rocket motors for years and is very familiar with their performance. The launch vehicle will utilize an AeroTech motor for all 2025 NASA SL Competition flights.

In order to select a motor class, basic kinematic principles and results from simulation software are utilized. This allows for a check of the simulation results to ensure that they are reasonable. The kinematic process is possible through a simplified vehicle model and by neglecting drag forces.

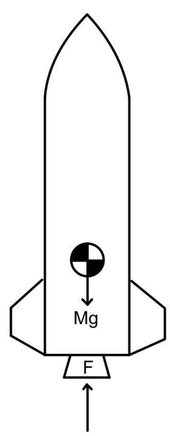


Figure 4.9: Simple Free Body Diagram for Motor Estimation.

Using the free body diagram in Figure 4.9 and kinematic equations, the following equations can be derived:

$$t = \frac{I_{total}}{F_{avg.}} \tag{4}$$

$$\ddot{x} = \frac{F_{avg.}}{m_{total}} - g \tag{5}$$

$$x_{burnout} = \frac{1}{2}\left(\frac{F_{avg}}{m_{total}} - g\right)t^2 \tag{6}$$

$$x_{apogee} = \frac{F_{avg.}x_{burnout}}{m_{burnout}g} \tag{7}$$

Using equations 4, 5, 6, and 7, a curve of impulse against thrust can be created. This provides a range of required impulse for the launch vehicle. This curve assumes that the propellant is an estimated 10% of the mass, neglects air resistance, and that the vehicle goes directly vertical off of the launch rail. This curve is shown below in Figure 4.10.

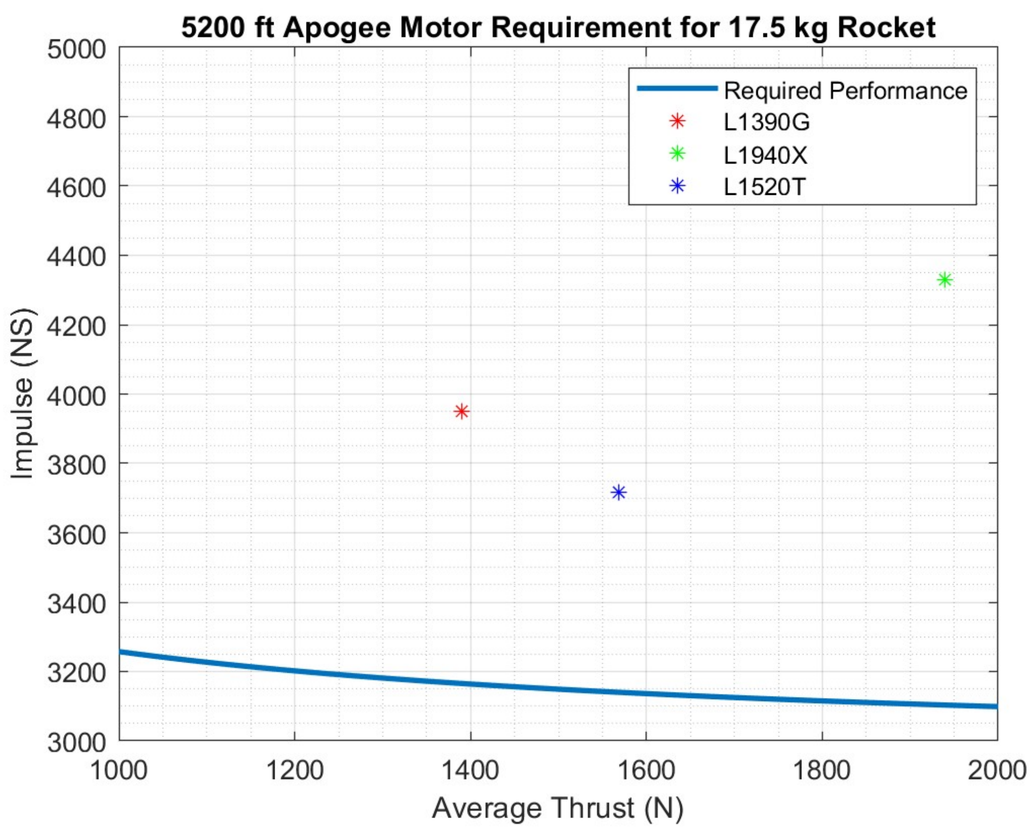


Figure 4.10: Requirements and Motors for 5000 ft Apogee.

For the apogee target of 5200 ft. without Air Brakes, a motor that fits above the curve will fall within an L class and satisfy the altitude need. L class motors fall between 2,560-5,120 Ns and satisfy the vehicle Requirement 2.12. The motors in consideration, L1520T, L1940X, and L1390G, all sit above the curve and should provide the necessary thrust and impulse to reach altitude.

Utilizing the OpenRocket model, the three motors were selected. OpenRocket is able to produce results of higher accuracy, as it is a six degree of freedom simulator. Currently, the L1390G AeroTech motor will approach 5200 ft, and Air Brakes will be implemented to target 5000 ft. This motor has a total impulse of 3,949 Ns.

4.6 Payload Design

4.6.1 Payload Requirements

The following is a passage from the 2025 NASA SL Handbook that defines the payload challenge: ”Teams are tasked with designing, building, and flying a STEMnaut flight capsule capable of safely retaining four STEMnauts and transmitting, via radio frequency, relevant rocket and STEMnaut landing site data to a NASA-owned receiver located at the launch site. STEMnauts are physical representations of the crew on-board the rocket. The method(s)/design(s) utilized to complete the payload mission shall be at the team’s discretion and will be permitted so long as the designs are deemed safe, obey FAA and legal requirements, and adhere to the intent of the challenge. NASA reserves the right to require modifications to a proposed payload.”

Table 4.6 below contains the payload requirements outlined and provided in the 2025 NASA SL Handbook.

Table 4.6: 2024-2025 Payload Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
4.1	USLI PAYLOAD MISSION OBJECTIVE- College/University Division teams SHALL design, build, and fly a STEMnaut flight capsule capable of safely retaining four STEMnauts and transmitting, via radio frequency, relevant rocket and STEMnaut landing site data to a NASA-owned receiver located at the launch site. STEMnauts SHALL be physical representations of the crew onboard the rocket. The method(s) and design(s) utilized to complete the payload mission SHALL be at the team’s discretion, permitted so long as the designs are deemed safe, comply with FAA and legal requirements, and adhere to the intent of the challenge. NASA reserves the right to require modifications to any proposed payload.	The team will design a flight capsule that meets size, weight, and structural requirements to safely house four STEMnauts, using physical models to represent the crew. A microcontroller with sensors will collect and store data for transmission upon landing. The design process will adhere to all FAA and NAR rules. Safety reviews will be conducted, and any necessary modifications will be implemented according to feedback from NASA.	Demonstration	Payload Team

Table 4.6: 2024-2025 Payload Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
4.2.1	Teams SHALL choose a minimum of 3 pieces of data from the below list to a maximum of 8 to transmit to the NASA receiver. • Time of landing • Maximum velocity • Landing velocity, G-forces sustained • Calculated STEMnaut crew survivability • Temperature of landing site • Apogee reached • Battery check/power status • Orientation of on-board STEMnauts	The team will transmit the following data: • Time of landing • Maximum velocity • Landing velocity, G-forces sustained • Calculated STEMnaut crew survivability • Temperature of landing site • Apogee reached • Battery check/power status • Orientation of on-board STEMnauts Sensors and data logging systems will be installed in the capsule to measure these parameters. All data will be transmitted to the NASA receiver upon landing.	Inspection	Payload Team
4.2.2	The payload SHALL not have any protrusions from the vehicle prior to apogee that extend beyond a quarter inch exterior to the airframe.	The Payload Structural Integration lead will design the STEMCRaFT such that it does not have any protrusions extending beyond a quater in. of the airframe prior to apogee.	Inspection	Payload Structural Integration
4.2.3	Payload SHALL transmit on the 2-M band. A specific frequency SHALL be given to the teams later. NASA SHALL use the FTM-300DR transceiver.	The Payload Team will design the STEMCRaFT such that transmissions will be sent to the FTM-300DR receiver on the 2-M band using a specific frequency stated by NASA.	Inspection	Payload Electronics, Payload Structural Integra-tion,Pay-load Systems
4.2.4	All transmissions SHALL start and stop with team member call sign.	The transmission system will be programmed to initiate and terminate all transmissions with the designated team member call sign, ensuring compliance with communication protocol.	Demonstration	Payload Systems
4.2.5	Teams SHALL submit a list of what data they will attempt to transmit by NASA receiver by March 17.	The team will prepare and submit a list of selected data points to NASA before the March 17 deadline.	Demonstration	Payload Team
4.2.6	Teams SHALL transmit with a maximum of 5W and transmissions SHALL not occur prior to landing.	The Payload Team ensure that no transmissions begin prior to the launch vehicle landing, and that the transmission does not exceed 5W of power.	Demonstration	Payload Electronics, Payload Systems

Table 4.6: 2024-2025 Payload Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
4.2.6.1	Teams SHALL not transmit on the specified NASA frequency on launch day prior to landing.	The Payload Team ensures that no transmission are sent on the NASA specified frequency prior to the launch vehicle landing.	Demonstration	Payload Electronics, Payload Systems
4.3.1	Black powder and/or similar energetics are only permitted for deployment of in-flight recovery systems. Energetics will not be permitted for any surface operations.	The Payload, Recovery, and Integration Teams coordinate to ensure that no energetics are used outside of the deployment of in-flight recovery systems.	Inspection	Integration, Payload Structural Integration, Safety, Recovery
4.3.2	Teams SHALL abide by all FAA and NAR rules and regulations.	The Safety Team reviews all payload systems to ensure that the payload is compliant with all FAA and NAR regulations.	Inspection	Safety
4.3.3	Any payload experiment element that is jettisoned during the recovery phase SHALL receive real-time RSO permission prior to initiating the jettison event, unless exempted from the requirement by the RSO or NASA.	The Payload and Safety Teams ensures that no element of the payload is jettisoned unless the jettison event is triggered manually, and after recieving RSO authorization.	Demonstration	Payload Systems, Safety
4.3.4	Unmanned aircraft system (UAS) payloads, if designed to be deployed during descent, SHALL be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given permission to release the UAS.	The Payload and Safety Teams ensures that any UAS payloads deployed during the flight remains tethered to the launch vehicle prior to recieving RSO authorization.	Demonstration	Payload Systems, Safety
4.3.5	Teams flying UASs SHALL abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112–95 Section 336; see https://www.faa.gov/uas/faqs).	The Payload and Safety Teams coordinate to ensure that any UAS payloads developed are compliant with all FAA rules and regulations.	Inspection	Safety
4.3.6	Any UAS weighing more than .55 lbs. SHALL be registered with the FAA and the registration number marked on the vehicle.	The team will register any UAS exceeding .55 lbs with the FAA and ensure the registration number is clearly marked on the UAS, meeting FAA requirements.	Inspection	Payload Team

4.6.2 Projected Designs

Nose Cone Mounted STEMCRaFT

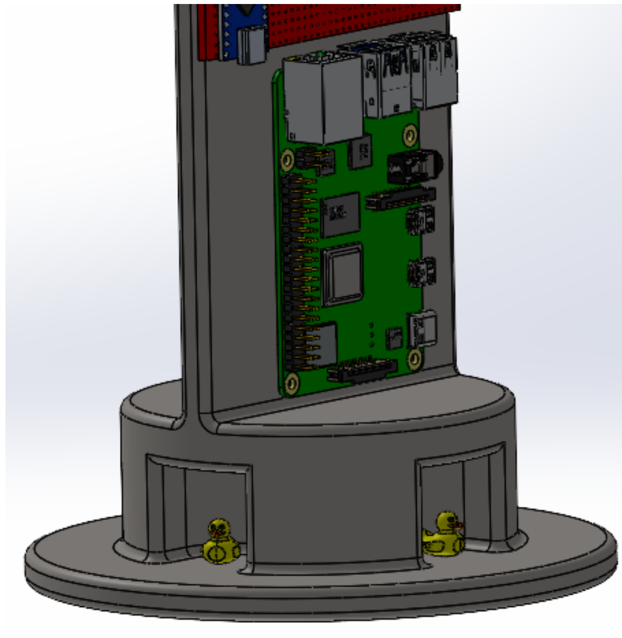


Figure 4.11: CAD model of Nose Cone mounted STEMCRaFT showing STEMnaut housing and electronics sled.

As depicted in Fig. 4.11, the STEMCRaFT module will house 4 STEMnauts represented by plastic ducks. The STEMnauts will be secured in the housing for safe and comfortable travel throughout the mission. Onboard the STEMCRaFT will be electronics for gathering telemetry data and transmitting data. These electronics will include a microcontroller such as the Raspberry Pi or Arduino and sensors including an altimeter, inertial measurement unit, temperature sensor, and humidity sensor. Based on the data gathered throughout the flight, the microcontrollers will be able to estimate the crew's survivability upon impact. Following the landing of the launch vehicle, key pieces of data will be processed, encoded, and transmitted to a ground station.

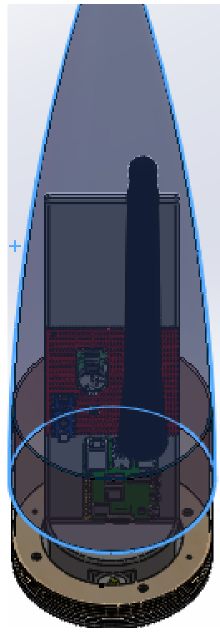


Figure 4.12: CAD of STEMCRaFT secured in Nose Cone.

Figure 4.12 shows the STEMCRaFT secured in the Nose Cone. The STEMCRaFT is fastened to a ring mounted at the open end of the Nose Cone. This configuration will minimize the complexity of the recovery process and allow for a simple integration into the rocket as a whole.

STEMCRaFT Lander

This design utilizes a lander that will jettison from the launch vehicle. The STEMCRaFT Lander uses a parachute to reduce the descent velocity and safely land the STEMnauts within survivable limits.

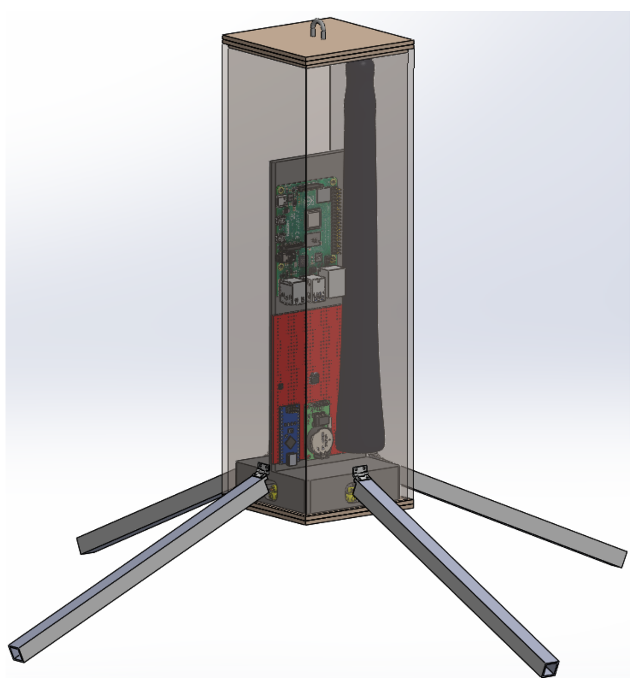


Figure 4.13: CAD model of STEMCRaFT Lander in the deployed state.

As seen in Fig. 4.13, four legs are attached to the body of the lander, which will deploy using spring hinges. These legs fold out to create a wide base that will help the lander to remain upright as it lands. Since the landing orientation will be known, the antenna can be pre-positioned inside the lander to ensure communication with the receiver. Similar to the Nose Cone Mounted STEMCRaFT design, the STEMnauts and electronics will be housed in separate compartments inside the lander housing. The electronics will also be similar to those described in Section 4.6.2 and are discussed in further detail below.

Projected Electronics

In order to accomplish this year's payload technical challenge, the payload electronics must be capable of recording, processing, and transmitting data through the specified 2M band. The front-runner payload design utilizes a Raspberry Pi as the central processing unit. This will ensure that the payload has sufficient computing power and storage capacity, while also allowing for a large variety of sensors that may be utilized. Additionally, it allows for flexibility in what hardware is used throughout the encoding and transmission process.

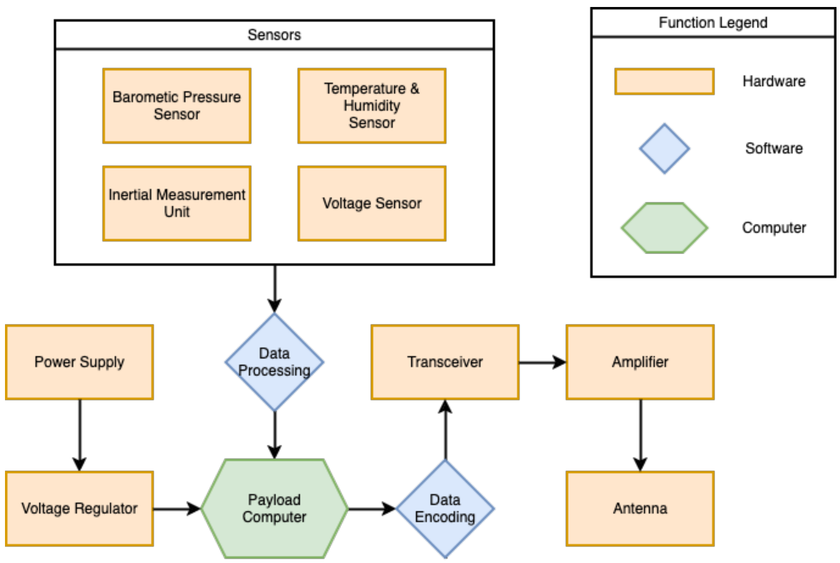


Figure 4.14: Initial Payload Electronics Functional Block Diagram.

In this design, the Raspberry Pi is responsible for all computations required to convert and store the raw data collected from the sensors. This is accomplished by having the onboard sensors interface directly with the Raspberry Pi. Once data from the sensors is received, the system will perform the computations necessary to convert the raw data into the appropriate units. The processed data will then be stored onboard where it may be accessed for transmission and post-recovery analysis.

While the data is being logged locally, the central processing unit will also manage the encoding of data to be transmitted upon landing. Once the onboard sensors detect landing, the system will initiate the transmission process. This is when the system will begin analyzing the flight data, and encoding data for transmission. After encoding the data using the appropriate communication protocol, it will be routed to the transmitter, relayed to the amplifier, and finally sent to the antenna for transmission to the NASA receiver.

Alternative Design Solutions

Multiple central processing units have been considered in the initial design phases. A more lightweight Arduino-based design is being considered, but is less ideal than the more heavyweight Raspberry Pi, due to the limited computing power. Custom electronics based around the STM32 microcontroller are also being considered, however, there are still significant questions about the practicality of custom electronics given their development timeline.

Several methods for encoding data prior to transmission have been evaluated for use in the payload. APRS has emerged as the leading option due to its ease of use and ability to meet the payload's objectives. Other methods, such as text-to-speech transmission on the 2M band and AX.25 packet radio, were also considered but deemed less optimal due to their limited support compared to APRS and their reduced compatibility with a wide range of receivers.

4.7 Payload Technical Challenges

4.7.1 Nose Cone Mounted STEMCRaFT

A Nose Cone mounted STEMCRaFT introduces many challenges. The nosecone offers limited space for electronics, especially for the antenna. The challenge of transmitting on the 2M band means antenna size and orientation is important. Creating an effective system that requires significant space in such a restricted space is one of the drawbacks of pursuing a Nose Cone mounted STEMCRaFT.

4.7.2 Challenges with STEMCRaFT Lander

A prominent challenge with the STEMCRaFT Lander is the added complexity of jettisoning it from the launch vehicle. Additionally, the parachute for the STEMCRaFT Lander introduces another potential point of failure in the system. There are also concerns that the lander could tip due to horizontal velocity during landing. While extending the legs could improve the lander's stability, this would also increase its weight and stowed volume.

4.7.3 Challenges with Projected Electronics

One of the key technical challenges is developing an effective algorithm to assess the survivability of the STEMnauts. Our current plan involves calculating survivability by combining data collected from various sensors on the payload. By assigning different weights to each type of sensor data, we aim to create an algorithm capable of generating a reliable survivability metric, which will be transmitted to the NASA transceiver.

Another challenge under consideration is determining the optimal method for initiating payload transmission to the NASA transceiver. The leading solution involves using the onboard computer and available sensors to automatically detect when the launch vehicle has landed. The primary risk with this approach is that fully autonomous transmission could either activate prematurely or fail to transmit completely. Despite this risk, this method is preferable due to the reduced complexity in terms of the payload hardware.

Alternatively, a manually triggered transmission system would increase the payload's complexity in terms of hardware, as it would require both receiving and transmitting capabilities, rather than just transmitting. While this method would offer more reliable transmission with less risk of malfunction, it also introduces the potential for human error. Both approaches offer distinct advantages and challenges, which must be carefully weighed to determine the most viable solution moving forwards.

5 STEM Engagement

5.1 Purpose and Description of STEM Engagement

Outreach events are designed to introduce kids K-12 to new STEM concepts such as rocketry and the engineering design process. Teaching kids about these concepts allows the club to directly engage with their community and enhance the learning of students through hands-on demonstrations and educational presentations. Introducing Newton's laws of motion and other STEM concepts early in students education using engaging and fun activities can increase the students interest in STEM concepts and promote the pursuit of STEM topics later in their educational career.

For each STEM engagement event, the club will reach out to elementary, middle, and high schools and other community organizers to plan or participate in an event. At each event, the club will teach at least one STEM concept related to rocketry to the students and also inform them of club activities. This will normally be done with a presentation, but other methods are also used such as Q&A sessions. After the STEM concepts are taught, the club will follow up with a hands-on activity so that the students are more engaged. In the past the club has made bottle rockets or straw rockets with elementary and middle school students. For high school students the club has launched low powered rockets or looked at whatever project the students are working on and offered guidance. These procedures will be repeated for this year.

General Requirement 1.4 from the NASA USLI Student Handbook states that the Student Launch team shall engage with a minimum of 250 participants between the acceptance of the project and the FRR addendum deadline. The events described in Section 5.2 satisfy these requirements. The club has already begun working towards scheduling and outlining these events. Last year the club engaged with 1446 participants. The club plans to increase the amount of events that are held and is are working on new activities to further engage students in STEM concepts.

5.2 Planned STEM Engagement Events

5.2.1 Apex Friendship High School

The club plans to work with Apex Friendship High School to help supplement their rocketry unit. In the unit the students build their own model rockets. The club will do a presentation outlining the activities the club participates in and then will launch water bottle rockets with them as an activity afterwards. Since the event is at a high school, Team members will describe more in-depth what they are working on. Projected attendance for this event is 75 students.

5.2.2 Durham Parks and Recreation

For this event the club will go to Durham to work with kids interested in low-power rocketry. The park provides small Estes rocket kits for the students to build and launch. The team does a quick presentation on rocketry, Newton's laws of motion, general safety procedures for the activity, and a quick Q&A. Projected attendance for this event is 30 students.

5.2.3 Astronomy Days

Astronomy days is a 2 day event held by the North Carolina Museum of Natural Sciences. The club will co-host a booth with the Tripoli Rocketry Association where kids of all ages can create straw rockets while learning about simple STEM topics such as Newton's laws of motion. The club will also talk to students about the NASA Student Launch Challenge and how the club uses the engineering design process to solve problems posed by NASA. Projected attendance for this event can fluctuate but is expected to be around 500 kids.

5.2.4 Laurel Park STEAM Nights

This event is held in partnership with Laurel Park Elementary School. The school hosts multiple organizations and clubs to talk about many different topics in STEM and the arts. The team will do a presentation outlining the NASA SL Challenge and how the club uses the engineering design process to solve the challenge. As a hands-on activity, the team will build straw rockets with the kids and discuss with them how Newton's laws of motion apply to the rocket. Projected attendance for this event is around 50 students.

6 Project Plan

6.1 Development Schedule

Figure 6.1 below depicts the competition deadlines, as described in the 2025 NASA SL Handbook and Request for Proposal. Figure 6.2 below depicts the project development schedule. The first couple weeks of the competition will be dedicated to brainstorming, vehicle design, and payload design. During the rest of the 2024 year the subscale rocket will be constructed, tested, and launched before the CDR deadline. Simultaneously, the payload will be designed and developed. At the start of the 2025 year the full-scale rocket will be constructed, tested, and launched before the FRR deadline. During the beginning of the 2025 year the payload will also be manufactured. The payload will then be tested and launched before the FRR Addendum deadline. Finally, at the end of the competition, the team will travel to Huntsville, Alabama to participate in Huntsville launch week and complete the final competition launch.

2024-25 Student Launch Competition Gantt Chart

				Aug			Sep				Oct				Nov					Dec			Jan				Feb				Mar					Apr				May			
Task Name	Task Number	Start Week	End Week	W01	W02	W03	W04	W05	W06	W07	W08	W09	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25	W26	W27	W28	W29	W30	W31	W32	W33	W34	W35	W36	W37	W38	W39	W40
RFP Released	1	W01	W01	1																																							
Proposal	2	W01	W05	2	2	2	2	2																																			
Awarded Proposals Announced	3	W08	W08								3																																
PDR Q&A	4	W09	W09									4																															
PDR	5	W06	W12						5	5	5	5	5	5	5																												
PDR Presentation Window	6	W13	W16													6	6	6	6																								
Gateway Registration	7	W13	W16													7	7	7	7																								
CDR Q&A	8	W17	W17																	8																							
Huntsville Roster	9	W16	W19																9	9	9	9																					
CDR	10	W13	W21													10	10	10	10	10	10	10	10	10																			
CDR Presentation Window	11	W22	W25																						11	11	11	11															
Team Photos	12	W23	W26																							12	12	12	12														
FRR Q&A	13	W26	W26																										13														
FRR	14	W22	W31																						14	14	14	14	14	14	14	14	14	14									
FRR Presentation Window	15	W32	W34																																15	15	15						
At Home Launch Window	16	W33	W38																																	16	16	16	16	16	16		
FRR Addendum	17	W32	W35																																17	17	17	17					
Launch Week Q&A	18	W35	W35																																			18					
Huntsville Launch Week	19	W37	W37																																					19			
Competition Launch	20	W37	W37																																					20			
PLAR	21	W40	W40																																								21

Figure 6.1: 2025 SL Competition Deadlines.

2024-25 Student Launch Competition Development Gantt Chart

				Aug			Sep				Oct				Nov					Dec			Jan				Feb				Mar					Apr				May			
Task Name	Task Number	Start Week	End Week	W01	W02	W03	W04	W05	W06	W07	W08	W09	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25	W26	W27	W28	W29	W30	W31	W32	W33	W34	W35	W36	W37	W38	W39	W40
Brainstorming	1	W01	W05	1	1	1	1	1																																			
Vehicle Design	2	W05	W06					2	2																																		
Payload Design	3	W05	W16					3	3	3	3	3	3	3	3	3	3	3	3																								
Subscale Parts Ordering	4	W06	W06						4																																		
Subscale Manufacturing	5	W07	W09							5	5	5																															
Subscale Ejection Testing	6	W10	W10										6																														
Subscale Painting	7	W11	W12											7	7																												
Subscale Launch	8	W12	W12												8																												
Full-scale Parts Ordering	9	W14	W20														9	9	9	9	9	9	9																				
Payload Parts Ordering	10	W10	W20										10	10	10	10	10	10	10	10	10	10	10																				
Full-scale Manufacturing	11	W21	W26																					11	11	11	11	11	11														
Payload Manufacturing	12	W21	W31																					12	12	12	12	12	12	12	12	12	12	12									
Full-scale Component Testing	13	W25	W26																									13	13														
Recovery System Testing	14	W24	W26																								14	14	14														
Payload Testing	15	W28	W32																												15	15	15	15	15								
Vehicle Launch Window	16	W26	W30																										16	16	16	16	16										
Payload Launch Window	17	W26	W34																										17	17	17	17	17	17	17	17	17						
Competition Launch	18	W37	W37																																					18			

Figure 6.2: 2025 SL Competition Development Schedule.

6.2 Budget

Table 6.1 details the year long budget plan for the 2024 - 2025 academic school year. The table is organized in columns of Item, Vendor, Quantity, Price Per Unit, and Total Item Price. Highlighted in light gray at the end of each section is the summed total of all the prices. At the end of the budget section and highlighted in dark gray is the total expenses of the club throughout the year. All prices are based on both previous years recorded expense reports and the predicted expenses, based on the model rocket outlined in this proposal. It is important to note that these items may change slightly as the design for our rocket becomes more finalized throughout the year. This would lead to changes in items needed, vendors used, and the total amount spent throughout the year. Some vendor abbreviations used are as following: Always Ready Rocketry (ARR), Performance Hobbies (PH), Lab Rat Rocketry (LRR), and Radio Corporation of America (RCA).

Table 6.1: 2024-2025 NASA Student Launch Competition Budget

	Item	Vendor	Quantity	Price Per Unit	Item Total
Subscale Structure	Nosecone	ARR	1	$ 27.75	$ 27.75
	4 in. Airframe	ARR	2	$ 39.95	$ 79.90
	Airframe-Nosecone Transition	ARR	1	$ 27.75	$ 27.75
	Subscale Motor	Aerotech	2	$ 95.99	$ 191.98
	38mm Motor Retainer	Aerotech	1	$ 6.92	$ 6.92
	Motor Casing	Aerotech	1	$ 98.86	$ 98.86
	Rail Button	Apogee Rockets	2	$ 4.25	$ 8.50
	Fiberglass Fins	Apogee Rockets	4	$ 16.50	$ 66.00
	U-Bolts	Prime Line	4	$ 1.50	$ 6.00
	Screws	Everbilt	6	$ 1.18	$ 7.08
	Threaded Charge Canister	Additive Aerospace	1	$ 8.49	$ 8.49
				Subtotal:	**$ 603.48**
Full Scale Structure	6 in. Nosecone 4:1	PH	1	$ 159.99	$ 159.99
	6 in. G12 Fiberglass Tube (60 in.)	ARR	1	$ 259.00	$ 259.00
	6 in. G12 Fiberglass Tube (48 in.)	ARR	1	$ 207.20	$ 207.20
	6 in. G12 Fiberglass Coupler	ARR	4	$ 77.50	$ 310.00
	Full-scale Motor	Aerotech	2	$ 272.68	$ 545.36
	Motor Retainer	Aerotech	1	$ 59.50	$ 59.50
	Motor Casing	Aerotech	1	$ 526.45	$ 526.45
	Large Rail Button -1515	Apogee Rockets	2	$ 4.25	$ 8.50
	U-Bolts	Prime Line	8	$ 1.00	$ 8.00
	32mm Bore	goBILDA	2	$ 12.99	$ 25.98
	Double Pull Pin Switch	Apogee Rockets	1	$ 20.35	$ 20.35
				Subtotal:	**$ 2130.33**
Payload	Barometric Pressure Sensor	Adafruit	1	$ 9.99	$ 19.98
	Temp & Humidity Sensor	TempStick	1	$ 119.99	$ 119.99
	Inertial Measurement Unit	ALTA	1	$ 132.98	$ 132.98
	Voltage Sensor	Klein Tools	1	$ 19.99	$ 19.99
	Voltage Regulator	DROK	1	$ 29.99	$ 29.99
	Transceiver	DigiKey	2	$ 23.52	$ 47.04
	Amplifier	RCA	2	$ 28.48	$ 56.96
	RC Transmitter/Receiver	Radiolink	1	$ 19.99	$ 19.99
	Locking Collars	Eternity Collars	2	$ 9.99	$ 19.98
	Shock Absorbers	Bilstein	1	$ 13.99	$ 13.99
	Carbon Fiber PETG Filament	Bambu	1	$ 29.99	$ 29.99
	Structural/Housing Materials	General	1	$ 300.00	$ 300.00
				Subtotal:	**$ 810.88**

Table 6.1: 2024-2025 NASA Student Launch Competition Budget

	Item	Vendor	Quantity	Price Per Unit	Item Total
Recovery and Avionics	72 in. Standard Parachute	Fruity Chutes	1	$ 313.37	$ 313.37
	60 in. Standard Parachute	Fruity Chutes	1	$ 266.07	$ 266.07
	12 in. Elliptical Parachute	Fruity Chutes	1	$ 67.41	$ 67.41
	6 in. Deployment Bag	Fruity Chutes	1	$ 54.40	$ 54.40
	4 in. Deployment Bag	Fruity Chutes	1	$ 47.30	$ 47.30
	18 in. Cloth	Nomex	1	$ 26.40	$ 26.40
	13 in. Cloth	Nomex	1	$ 17.60	$ 17.60
	Kevlar Shock Cord	Huyett	25	$ 6.99	$ 174.75
	Quick Links	Huyett	14	$ 6.98	$ 97.72
	Electric Match	Firewire	16	$ 2.00	$ 32.00
	Ejection Charge	Aerotech	24	$ 1.25	$ 30.00
	Small Nylon Shear Pins	Essentra	40	$ 0.18	$ 7.20
				Subtotal:	**$ 1,134.22**
Miscellaneous	Paint	Krylon	6	$ 20.00	$ 120.00
	Birch Plywood 1/8 in.x2x2n	Rockler	6	$ 14.82	$ 88.92
	105 Epoxy Resin	West Systems	2	$ 109.99	$ 219.98
	206 Slow Hardener	West Systems	2	$ 62.99	$ 125.98
	Filament Spool	Atomic Filament	1	$ 26.00	$ 26.00
	Quick Dry 2-Part Epoxy	Clearweld	1	$ 20.28	$ 20.28
	Wood Glue	Gorilla	1	$ 7.98	$ 7.98
	Misc. Bolts	Everbilt	1	$ 20.00	$ 20.00
	Misc. Nuts	Everbilt	1	$ 10.00	$ 10.00
	Misc. Washers	Everbilt	1	$ 8.00	$ 8.00
	Tinned Copper Wire Kit	DX Engineering	1	$ 12.00	$ 12.00
	Zip Ties Pack	HMRope	1	$ 6.59	$ 6.59
	9V Battery Pack	ACDelco	2	$ 12.00	$ 24.00
	Misc. Tape	Scotch	1	$ 20.00	$ 20.00
	Liquid Bandages	Equate	1	$ 5.00	$ 5.00
	Estimated Shipping				$ 1,000.00
	Incidentals (replacement tools, hardware, safety equipment, etc.)				$ 1,500.00
				Subtotal:	**$ 3,214.73**
Travel	Student Hotel Rooms – 4 nights	Hilton Hotels	8	$ 898.45	$ 7,187.60
	Mentor Hotel Rooms – 4 nights	Hilton Hotels	2	$ 556.03	$ 1,112.06
	NCSU Van Rental (# Vans)	NCSU	3	$ 798.00	$ 2,394.00
				Subtotal:	**$ 10,693.66**
Promotion	T-Shirts	Core365	50	$ 15.00	$ 750.00
	Polos	Core365	20	$ 25.00	$ 500.00
	Stickers	CustomInk	500	$ 0.43	$ 215.00
				Subtotal:	**$ 1,465.00**
				Total Expenses:	**$ 20,251.20**

6.3 Funding Plan

HPRC receives funding from a variety of NC State University's resources as well as from the North Carolina Space Grant (NCSG). Below is a detailed breakdown of each different funding source, followed by the specific allocations of the funds.

NC State's Student Government Association (SGA) provides appropriations to over 600 clubs and organizations on campus, including HPRC. At the beginning of each semester, clubs submit application proposals outlining their anticipated expenses. Following submission, the clubs meet with SGA representatives in a fifteen-minute interview to discuss their activities, clarify budget details, and describe the overall value they bring to the university. Subsequently, SGA allocates money to each organization on campus. For the 2023-2024 academic year, HPRC received $1,592.00

from SGA - $796.00 in the fall semester and $796.00 in the spring semester. For this academic year, we requested $1,800 for the fall semester, with another $1,800 request for the spring semester. Although we are requesting this amount, it is predicted that the club will receive the same $796 per semester as in previous years. Student government funds in the fall are typically used almost entirely for the subscale rocket, with little revenue left for backup parts or full-scale materials. In the spring semester, Student Government funds will go to anything that is needed by the club, provided that all expenditures are tracked by receipts.

NC State's College of Engineering Enhancement Funds, provided by the "Engineer your Experience" (EYE) department supports engineering extracurricular activities typically related to travel. Student travel costs to Huntsville will be entirely covered by EYE. Based on last years expenses for Huntsville, it is estimated that HPRC will receive around $8,000 this year for travel costs.

The Educational and Technology Fee (ETF) is an NC State fund that allocates funding for academic enhancement through student organizations. In the 2023-2024 academic year, HPRC received $2,500 from ETF and the club anticipates to receive $2,500 for this academic year as well. This funding will be used exclusively to fund the team's faculty advisors' travel and hotel costs for the trip to Huntsville.

In addition to funding through multiple NC State University organizations, the North Carolina Space Grant (NCSG) is a significant source of HPRC's funds. The NCSG accepts funding proposals during the fall semester and teams can request up to $5,000 for participation in NASA competitions. They review the proposal submitted and inform the club of the amount rewarded. In previous academic years, we have received the maximum amount of $5,000, which will be available for use starting November, 2024. It is predicted that since we have received this amount in prior years we will be allocated the full $5,000 again this year.

Regarding sponsorships, HPRC has previously been sponsored by companies including Collins Aerospace, Jolly Logic, Fruity Chutes, and others. The club is currently seeking new sponsorships and reaching out to past sponsors. We have found that companies are more likely to donate gifts in-kind rather than provide monetary sponsorship. The team estimates to receive $3,200 in gifts of this kind during this academic year. However, we can expect this amount to increase if we hear back from any other companies regarding gifts or sponsorships.

All of these totals are listed in Table 6.2 below, which outlines the projected costs and incoming revenue for the 2024-2025 academic year.

Table 6.2: Projected Funding Sources

Organization	Fall Semester	Spring Semester	Academic Year
NC State Student Government	$796	$796	$1,592
North Carolina Space Grant	$5,000	$0	$5,000
Engineer Your Experience	$0	$8,000	$8,000
Educational and Technology Fee	$0	$2,500	$2,500
Sponsorship	$1,600	$1,600	$3,200
Total Funding:			**$20,292.00**
Total Expenses:			**$20,251.20**
Difference:			**$40.80**

6.4 Sustainability Plan

Since HPRC is a North Carolina State University student organization, the club's sustainability depends on the recruitment and retention of new members. The club takes many measures at the beginning of the academic year to gain the interest of new members such as attending university sponsored events, conducting interest meetings, and holding an Interest Launch for new members. Within the first month of the academic year, returning members of HPRC advertise the club through club fairs, fliers, and personal referrals. At club fairs, the club showcases past Student Launch rockets and payloads, along with past experimental projects, to gain the interest of new members and explain how they can get involved with the club. Additionally, the club provides new members with the club's Instagram, email list, and website address for them to stay informed about the progression of the club in the SL Competition and in WolfWorks Experimental (WWE). After club fairs, HPRC holds interest meetings that introduce new potential members to the subsystems of the club, outlined in Section 1.7, the Subsystem meeting times, the SL payload challenge, and experimental projects for the academic year. These interest meetings are typically attended by over 100 new potential members, half of which become actively engaged in the club. Finally, the club holds an Interest Launch about one month into the academic year. Interest launch is run by the Vice President of the club, and involves relaunching the SL rocket from the previous year. This launch is specifically designed for new members to get hands-on experience with high-powered rocketry.

In order to engage and retain new members, the club conducts enrichment opportunities for new members including technical workshops and experimental projects. In the past, technical workshops have included rocketry 101, Solidworks, OpenRocket, soldering, electronics, tool safety and operation, and history of rocketry, which will be conducted again this year. In these workshops, an HPRC member with experience in the subject gives a presentation, then leads a group through a demonstration on how to correctly do the activity. This allows students to apply what they have learned in classes and gain experience in what is not taught in the classroom. Additionally, after the completion of Interest Launch, the Vice President is responsible for an underclassman based experimental subsystem, called WolfWorks Experimental, or WWE. This subsystem designs, fabricates, tests, and launches experimental projects and rockets. In previous years, this team has worked on an Air Brakes system, an experimental rover, a supersonic rocket, and a custom fiberglass rocket. This year WWE will continue to pursue experimental projects chosen and constructed by underclassmen, separate from the NASA SL Competition. The club also holds events outside of weekly meetings for holidays and extracurricular activities that promote a feeling of community within the club.

Each year the Senior Design Team consists of 8 members, each of which have a different role in SL Competition, as defined in Section 1.5. When new members join HPRC who are majoring in Aerospace Engineering, they are informed that continued involvement in the club up to their Junior year could mean that they will be a member of the HPRC Design Team, which fulfills their aerospace engineering capstone project requirement. Members who are juniors in aerospace engineering are encouraged to pick a subsystem that they are interested in, and work with that subsystem lead throughout the year to learn how to successfully lead the subsystem. At the end of the year, elections for officer positions are carried out and the President is determined. The President is then responsible for choosing the Senior Design Team for the next Academic year, along with the assistance of the previous Senior Design Team members. This process ensures that each Senior Design position is filled by a qualified member of the club every year. In the case of there being less than eight members interested in being on the Senior Design Team, the remaining members are chosen by Dr. Ewere, the professor in charge of the Aerospace Engineering Senior Design class. These new members are then trained for the position through documentation written by previous subsystem leads.

The High-Powered Rocketry Club also focuses on creating and maintaining relations with industries and local communities. The club develops partnerships with local communities through outreach activities, as described in Section 5, by working with local schools, organizations, and museums to hold STEM engagement activities. Relationships are then maintained by holding such STEM engagement events annually. During launches at the East NC Tripoli Prefecture, club members assist with set-up and tear-down of launch systems. This also provides an opportunity for club members to interact with the community and learn from mentors who have significant experience in rocketry.

The High-Powered Rocketry Club is almost completely self-sufficient regarding funding and use of equipment. Manufacturing equipment used in the production of components for the SL launch vehicles are available onsite and described in detail in Section 2.4. If any additional equipment is required the team will communicate with the club mentors, who are listed in Section 1.1. Materials used in the construction of the SL launch vehicle and payload are acquired with funding from the sources detailed in Section 6.3. The allocation of these funds to subsystems is determined by the Treasurer, which ensures the sustainability of funds.