NC STATE UNIVERSITY

Tacho Lycos
2026 NASA Student Launch
Proposal

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

September 22, 2025

Common Abbreviations and Nomenclature

AIAA	=	American Institute of Aeronautics and Astronautics
APCP	=	Ammonium Perchlorate Composite Propellant
ARC	=	Aerial Robotics Club
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
ECE	=	Electrical and Computer Engineering
ETF	=	Educational and Technology Fee
EYE	=	Engineer Your Experience
FAA	=	Federal Aviation Administration
FMEA	=	Failure Modes and Effects Analysis
FRR	=	Flight Readiness Review
HAUS	=	Habitat for Agricultural Utilization Study
HPRC	=	High-Powered Rocketry Club
LRR	=	Launch Readiness Review
MAE	=	Mechanical & Aerospace Engineering
SDS	=	Safety Data Sheets
NAR	=	National Association of Rocketry
NASA	=	National Aeronautics and Space Administration
NCSG	=	North Carolina Space Grant
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
RSO	=	Range Safety Officer
SGA	=	Student Government Association
SL	=	Student Launch
STEM	=	Science, Technology, Engineering, and Mathematics
STL	=	Stereolithography (File Format)
TAP	=	Technical Advisory Panel
TRA	=	Tripoli Rocketry Association
WWE	=	WolfWorks Experimental

Contents

List of Tables

List of Figures

1 General Information

1.1 High-Powered Rocketry Club

The High-Powered Rocketry Club at North Carolina State University, colloquially known as Tacho Lycos, offers students from all backgrounds and majors hands-on experience in the research, design, testing, and launching of high-powered rockets. The club has been competing in the NASA Student Launch (SL) Competition annually since its formation in 2009. In 2013, the Department of Mechanical and Aerospace Engineering at North Carolina State University partnered with the club to form a new capstone Senior Design project focused on competing in NASA SL. The club continues this tradition with its primary goal to design and fabricate a subscale, full-scale, and payload for NASA SL each year. In addition to the Senior Design project, the club also has an experimental subteam led by the Vice President, named WolfWorks Experimental. This group was the first developer of the club's Air Brakes system in the past years, and this year they will work towards a custom on-board flight computer, among other projects. The club's Faculty Advisor, detailed in Section 1.2, teaches the Capstone Senior Design Team and advocates for the club on university matters. Technical mentorship is provided by another individual, documented in Section 1.2. Throughout the year, the Senior Design Team and the Officer team keep close contact with these individuals for guidance, as well as for design and fabrication auditing. Each year, a member is elected as both the President of the club and the Team Lead for the Capstone Senior Design team and oversees operations of the entire club. NASA SL efforts and deliverables are led by the 8 members of the Capstone Senior Design team, detailed in Section 1.4, while Club affairs are overseen by a team of 8 officers, detailed in Section 1.5. These leadership bodies preside over approximately 50 active club members.

1.2 Team Advisors and Mentors

Faculty Advisor

i. **Name:** Dr. Felix Ewere

ii. **Email:** feewere@ncsu.edu

iii. **Phone:** (919) 515-8381

iv. **Biography:** Dr. Ewere is a teaching professor in NC State's Mechanical and Aerospace Engineering Department and serves as an advisor for the Aerospace Engineering Senior Design course. He holds a PhD in Mechanical Engineering and a Master's in Aerospace Engineering from the University of Alabama in Huntsville. His research spans aerodynamics, structural mechanics, energy systems, and smart materials, with recent projects investigating the use of piezoelectric structures to exploit aeroelastic instabilities. In addition to his technical work, Dr. Ewere is interested in advancing engineering design education and promoting diversity and interdisciplinary collaboration. He is a senior member of AIAA and ASME.

Team Mentor

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 mentor the team for the 2025 NASA Student Launch Competition. A long-time member of Tripoli Rocketry Association (TRA), he earned his Level 3 Certification in 1997 and has since guided over 20 members to achieve the same. Since 1998, Jim has contributed his expertise on the TRA Technical Advisory Panel, providing guidance on propellant selection, materials, and recovery systems. He has also been active in Tripoli motor research for decades, personally producing motors from sizes I through N for more than 25 years.

1.3 Subteam Organization

Tasks for NASA SL deliverables are split into nine different subteams to improve efficiency. Eight of these subteams are run by a member of the Senior Design Team, while the Safety subteam is run by the Club's Safety Officer. A breakdown of the specific subteam names, followed by what club role leads the team, can be seen below. The Payload team includes the Payload Systems, Payload Electronics, and Payload Structures leads, and will sometimes be referred to as the Payload subteam instead of their specific roles.. For more information on the responsibilities of each of the Senior Design-led subteams, see Section 1.4. For more information on the responsibilities of the Safety subteam, see Section 1.5.

i. **Project Management:** Senior Design Team Lead
ii. **Safety:** Club Safety Officer
iii. **Integration:** Senior Design Integration Lead
iv. **Aerodynamics:** Senior Design Aerodynamics Lead
v. **Structures:** Senior Design Structures Lead
vi. **Recovery:** Senior Design Recovery Lead
vii. **Payload Systems:** Senior Design Payload Systems Lead
viii. **Payload Electronics:** Senior Design Payload Electronics Lead
ix. **Payload Structures:** Senior Design Payload Structures Lead

1.4 Senior Design Team

The Senior Design Team associated with the High-Powered Rocketry Club at NC State University will lead the design, fabrication, testing, and launching of both a subscale and full-scale rocket with a scientific payload for the NASA SL Competition. They have chosen the NASA SL project to count as their capstone senior design project, and are supported in this decision by the Department of Mechanical and Aerospace Engineering at NC State University. Their performance on all deliverables of the NASA SL challenge will influence their grade for their capstone project. Each Senior Design member is a lead of their own subteam, in addition to the Safety Officer. The outline of these subteams can be found in Section 1.3. Figure 1.1 captures the 2025-2026 Senior Design team, with each member detailed in Section 1.4.1 following the left to right order of the image.

1.4.1 Senior Design Members and Responsibilities

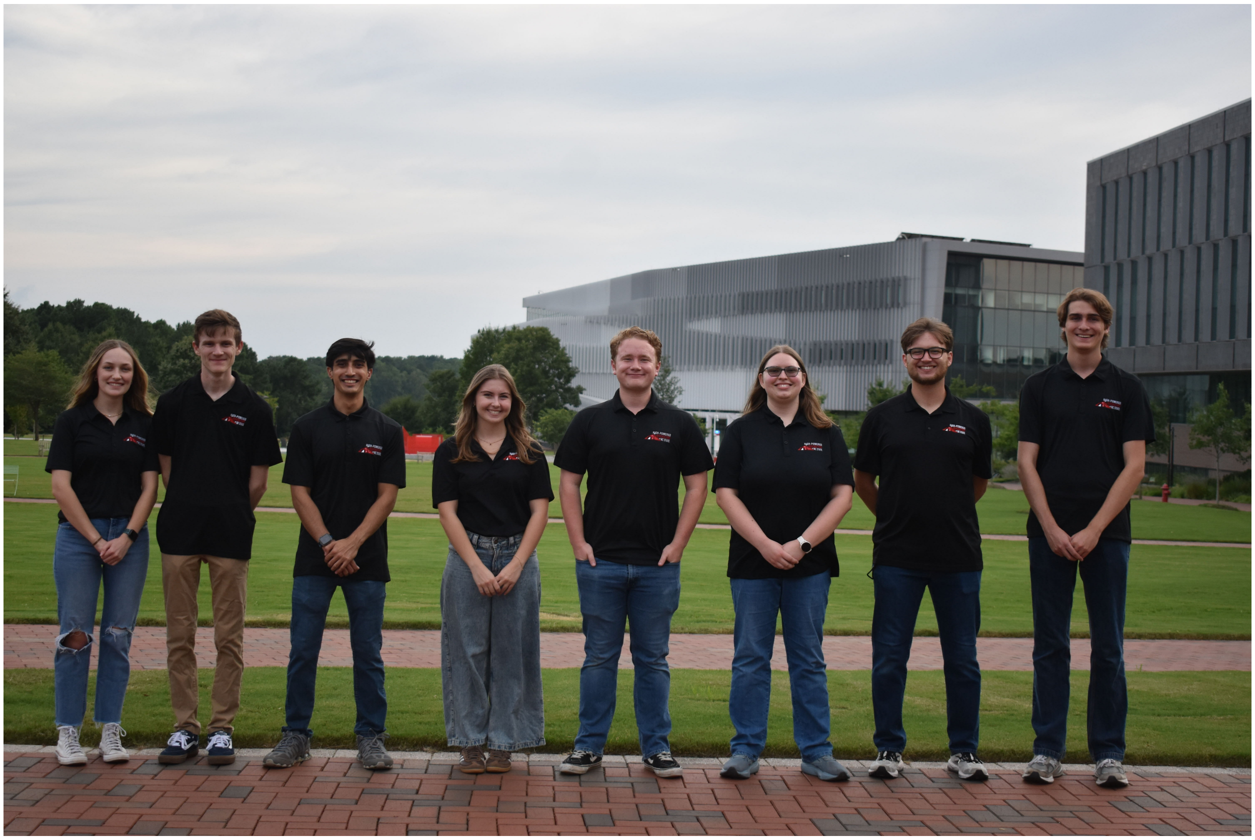

Figure 1.1: 2025-2026 High-Powered Rocketry Club Senior Design Team

Recovery

i. **Name:** Lauren Wilkie

ii. **Contact:** lewilki3@ncsu.edu

iii. **Responsibilities and Biography:** As Recovery Lead, Lauren is responsible for the design, fabrication, and testing of the launch vehicle's recovery system. Her work includes parachute selection, black powder charge determination, ejection testing, and integration of altimeters and GPS systems. Lauren is focused on making recovery more hands-on for new members while experimenting with new methods, such as cable cutters and hand-sewn parachutes. Outside of rocketry, she conducts computational and experimental research on liquid jet behavior in cross-flow, and enjoys running, hiking, and baking.

Structures

i. **Name:** Donald Gemmel

ii. **Contact:** dagemmel@ncsu.edu

iii. **Responsibilities and Biography:** As Structures Lead, Donald leads the construction of both the subscale and full-scale launch vehicles, as well as vehicle material selection, structural verification, and testing. This year, Donald is excited to increase the number of in-house fabricated components, including rolling custom airframes, producing sandwich composite plates, and experimenting with new fabrication methods for large nose cones. He is passionate about expanding the team's capabilities with advanced composites and pushing the boundaries of in-house manufacturing. Outside of countless personal rocket projects, Donald enjoys mountain biking and biking around campus.

Aerodynamics

i. **Name:** Aditya Chadha

ii. **Contact:** amchadha@ncsu.edu

iii. **Responsibilities and Biography:** As Aerodynamics Lead, Aditya is responsible for conducting vehicle flight simulations, motor selection, apogee prediction, fin and nose cone design, and stability management. His role also includes redesigning and integrating Air Brakes technology, improving simulation accuracy, and applying aerodynamic theory to enhance performance. This year Aditya is excited to implement improved post-processing and simulations for the Air Brakes roll system. In his free time, Aditya conducts research related to computational fluid dynamics (CFD).

Team Lead

i. **Name:** Elizabeth Bruner

ii. **Email:** eabruner@ncsu.edu

iii. **Phone:** (984)-209-9028

iv. **Responsibilities and Biography:** As Team Lead, Elizabeth is responsible for making and implementing schedules pertaining to designing, building, and testing the competition rocket and all subsystems. She is also responsible for outlining, organizing, and proofreading all documentation, while serving as the primary liaison between the Senior Design Team, the NASA SL program and North Carolina State University's Senior Design Program. She manages all subteams, oversees every design decision, and ensures all team members have the resources they need to succeed. Elizabeth's additional role as club President is further detailed in Section 1.5. In her free time, Elizabeth enjoys kayaking, reading a long book, and crocheting.

Integration

i. **Name:** James Garmon

ii. **Contact:** jwgarmo2@ncsu.edu

iii. **Responsibilities and Biography:** As Integration Lead, James Garmon is responsible for facilitating communication and collaboration among all subteams. He will ensure that the payload and vehicle designs are seamlessly combined. James also assists with documentation and leads weekly integration meetings. This year he will focus on working closely with the Safety Officer, Aidan McCloskey, to develop and maintain accurate safety documentation while also collaborating with all other subteam leads to define and verify requirements. James enjoys building personal rockets in his free time, and spends time outside of the lab cooking and camping.

Payload Structures

i. **Name:** Emily Cates

ii. **Contact:** eccates@ncsu.edu

iii. **Responsibilities and Biography:** As Payload Structures Lead, Emily is responsible for the 3D modeling, fabrication, and testing of the STEMnaut Habitat for Agricultural Utilization Study (HAUS) and any other payload structures. Her designs must protect the STEMnauts while supporting soil testing experiments and bearing structural loads during launch and landing. Emily is excited to apply her experience with 3D printing and composites to learn how to use new materials in the payload's design and construction. She is Level 1 high-power certified, and outside of the club enjoys traveling, building Lego sets, and supporting the Dodgers.

Payload Electronics

i. **Name:** Ben Radspinner

ii. **Contact:** brradspi@ncsu.edu

iii. **Responsibilities and Biography:** As Payload Electronics Lead, Ben is responsible for the design, construction, and verification of all electrical hardware necessary to meet payload requirements. This year, he will be focused on implementing sensors for the STEMnaut HAUS. His work will include soldering, configuring circuits, and implementing systems for data collection and transmission. In his free time, Ben enjoys listening to new music and playing action-adventure video games.

Payload Systems

i. **Name:** Mason Meyer

ii. **Contact:** mhmeyer@ncsu.edu

iii. **Responsibilities and Biography:** As Payload Systems Lead, Mason is tasked with developing all software required for the operation of the payload. His responsibilities include programming sensors for soil analysis within the STEMnaut HAUS, writing software for data transmission, and programming any moving components. In his free time, Mason runs a club devoted to the exploration and development of space, and he also enjoys playing Kerbal Space Program.

1.5 Officer Team

The Officer Team supports the non-technical aspects of NASA SL, as well as managing other general club affairs. The Safety Officer is also the lead of the Safety subteam; the full subteam breakdown can be seen in Section 1.3. Figure 1.2 depicts the 2025-2026 Officer team, and Section 1.5 highlights their respective roles, following the image order from left to right.

1.5.1 Officer Team Members and Responsibilities

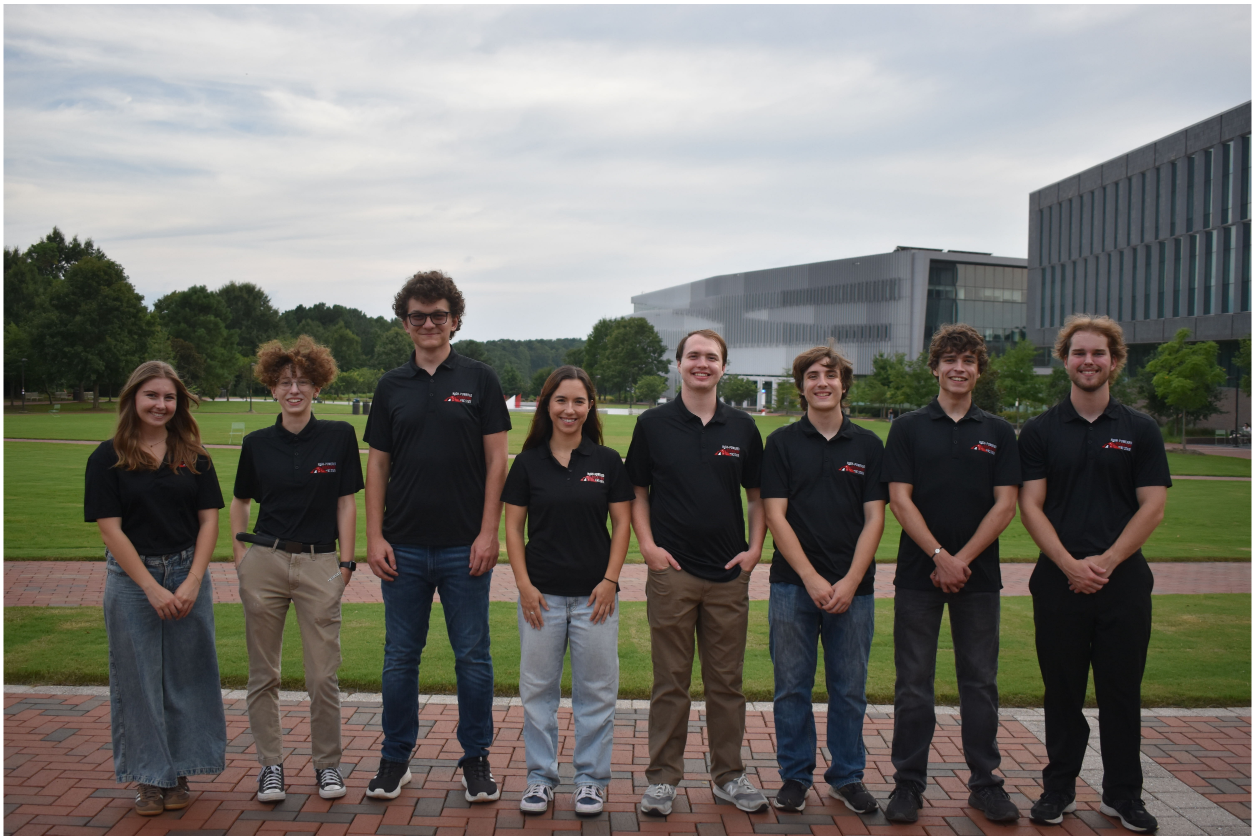

Figure 1.2: 2025-2026 High-Powered Rocketry Club Officer Team

President

i. **Name:** Elizabeth Bruner

ii. **Contact:** eabruner@ncsu.edu

iii. **Responsibilities and Biography:** The President of the club will preside over all general club meetings and meetings with the officer team. The position is to be an advocate for the club when interacting with North Carolina State University and its governing bodies. Elizabeth shall act as a primary liaison between the club members and their mentors. When overseeing the officers, Elizabeth must ensure all positions are performing their responsibilities and that they comply with the NASA SL guidelines for social media, safety, and outreach. Along with the rest of the officer team, the President will plan the logistics behind social events and launches for the rest of the club. Elizabeth is excited to grow the position this year by planning tours and networking events for club members with aerospace engineering companies.

Vice President

i. **Name:** Alex Key

ii. **Contact:** arkey@ncsu.edu

iii. **Responsibilities and Biography:** The Vice President of the club, Alex, will lead an experimental team, known as WolfWorks Experimental. He will be responsible for integrating new members into the club by leading a month-long project at the start of the school year, which will culminate in a group launch. After this, the member in the position will lead experimental projects that will support the growth of the club. If the President is not able to perform their duties, the Vice President will take over. Alex is a Level 2 Tripoli certified, and works on a Gas Atomizer and Powder Bed Fusion printers in NC State's metal additive manufacturing lab. Aside from the club and building personal rockets, he enjoys drawing/painting, playing video games, and watching horror movies.

Treasurer

i. **Name:** David Chrostowski

ii. **Contact:** dchrost@ncsu.edu

iii. **Responsibilities and Biography:** As club Treasurer, David will document all funding and spending through documentation and spreadsheets. He shall order materials for both NASA SL and WolfWorks Experimental, keeping a budget in mind. David will also be in charge of applying for grants through the university and external sources. He is also responsible for making, ordering, and keeping track of any merchandise created for club members. In this position, David is excited to source more funding for the club. David enjoys working on cars in his free time, and is currently restoring a 1970 Ford Mustang.

Secretary

i. **Name:** Gabriela Santiago

ii. **Contact:** gdsanti2@ncsu.edu

iii. **Responsibilities and Biography:** As secretary of the club, Gabriela will send updates to the general members of the club in the form of weekly emails. She is responsible for communicating any pertinent information to the rest of the club. Gabriela must also represent the club at student fairs throughout the school year, and help with membership gain and retention. In her free time, Gabriela likes to dance, and performs for an NC State club dance team.

Safety

i. **Name:** Aidan McCloskey

ii. **Email:** abmcclos@ncsu.edu

iii. **Phone:** (252)-571-8791

iv. **Responsibilities and Biography:** As Safety Officer, Aidan is responsible for ensuring that all club activities are conducted in accordance with NASA SL and NC State Environmental Health and Safety standards. He will maintain and display proper safety documentation, including Safety Data Sheets (SDS) and hazard analyses, and will oversee the safe operation of lab tools such as the drill press, band saw, miter saw, and other hand and power tools. Aidan is in charge of monitoring personal protective equipment (PPE) use, keeping the first aid kit stocked, and managing the hazardous materials. During launches, Aidan will be present to enforce Range Safety Officer (RSO) guidelines, complete launch day checklists and brief members on safety procedures. He will also provide a safety training at the beginning of each semester which members are required to take, and pass, a quiz on. Aidan is looking forward to improving the lab organization and wants to put a special focus on preventative safety measures this year, as well as creating standard operating procedures. In his free time, Aidan enjoys camping, board games, and spending time with friends.

Outreach

i. **Name:** Peter Tolman

ii. **Contact:** pjtolman@ncsu.edu

iii. **Responsibilities and Biography:** As Outreach Officer, Peter is responsible for coordinating and conducting STEM engagement events at local schools and community centers, teaching key topics in rocketry and engineering. Peter will maintain connections with schools and community groups the club has previously partnered with, while also seeking opportunities to expand the club's programs. Peter is looking forward to going to events and spreading his love of STEM and rocketry with the younger generation. This year, he is going to increase the number of outreach events the club leads, as well as add new and more complex activities to the events. In his free time, Peter likes to go backpacking and play strategy board games.

Webmaster

i. **Name:** Jackson Elia

ii. **Contact:** jgelia@ncsu.edu

iii. **Responsibilities and Biography:** Jackson is tasked with maintaining and updating the club's website and university club page to ensure they contain accurate and up-to-date information. He will keep the club's constitution current on both platforms, as well as upload official NASA SL documentation, once they have been submitted by the Senior Design team. In this role, Jackson is excited to modernize the website and build a compelling online presence to attract potential sponsors. Jackson enjoys hiking and working on experimental rocketry projects in his free time.

Social Media

i. **Name:** Seth Olanovich

ii. **Contact:** scolanov@ncsu.edu

iii. **Responsibilities and Biography:** The social media officer is responsible for keeping the club's online presence active and engaging across multiple platforms, including Instagram, Facebook, X (Twitter), TikTok, and LinkedIn. Seth will post regular updates on club activities and share important information. This year, Seth is excited to grow the club's social media presence by posting more funny and relatable content.

1.6 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 Mike Nay. 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 1.2. 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.

2 Facilities and Equipment

2.1 Description

The High-Powered Rocketry Club conducts its main activities in the MAE Student Fabrication Lab, located in Room 2003 of Engineering Building III on NC State University's campus. Commonly known as the "Rocketry Lab," this space provides a variety of tools for hands on work, including a drill press, belt sander, band saw, scroll saw, miter saw, vise, 3-D printer, and a collection of handheld power tools.

For members who have completed specialized training, additional workspace is available in the Entrepreneurship Initiative Garage of the Partners 1 Building. This facility offers advanced equipment, such as a laser cutter, multiple 3-D printers, and a range of hand tools. The club mostly utilizes the Entrepreneurship Initiative Garage for access to a laser cutter, as the club's 3-D printers and hand tools are more easily accessible in the Rocketry Lab.

Another space the club is able to utilize is the EB2 Makerspace located in Engineering Building II rooms 1003A and 1004. This space offers many different tool and equipment, including but not limited to a wood cutting ShopBot CNC router, WAZER waterjet cutter, and PCB mills. The Makerspace is coordinated by Dzung Nguyen. Online training is needed for both the Makerspace and select tools available for use in the Makerspaces.

The club also utilizes a high precision machine shop in Engineering Building III for metal and wood machining projects. Gary Lofton supervises the Senior Design Shop, while J. Steve Cameron manages the Research Shop. Both supervisors handle machining requests, generally returning finished components within a week. The shop includes mills, lathes, drill presses, metal and wood saws, a water jet, and welding stations. The Senior Design Team members, listed in Section 1.4, gain access to this facility after completing the required training under Gary Lofton's guidance.

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 ECE Makerspace is open to all trained NC State University students from:

Sunday - Saturday: All Day

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

All activities involving construction or testing in the Rocketry Lab require the presence of the club's Safety Officer, Aidan McCloskey, or another trained member of the Safety Team. All launch day activities and pre-launch checks will also be overseen by Aidan McCloskey. Use of the Aerospace Vehicle Structures Lab must be supervised by the MAE Lab Director and Supervisor, Dr. Jaideep Pandit. Similarly, any work in the high-precision machine shop requires oversight from the Research Fabrication Facility Supervisor, J. Steve Cameron.

2.4 Available Equipment

Members of the High-Powered Rocketry Club have the ability to work with a wide range of equipment across several campus facilities, including the Rocketry Lab, the Entrepreneurship Initiative Garage, the Aerospace Vehicle Structures Lab, and the high-precision machine shop. In the Rocketry Lab, the team can utilize a drill press with 12 inches of travel, a scroll saw, band saw, belt sander, and a miter saw. The lab also contains a variety of handheld tools, including a DeWalt 18V drill, DeWalt jigsaw, Dremel 4300 rotary tool, rigid oscillating cutter, and a Wagner heat gun. To ensure safety, these tools remain in the lab and may only be used by members who have completed the required training established by the Safety Officer. The Rocketry Lab is also outfitted with compressed air lines, which support vacuum sealing for composite layups.

Beyond the Rocketry Lab, club members have access to additional equipment in other workspaces. This includes laser cutters, multiple 3-D printers, tensile testing machines, and high-precision machining tools such as metal and wood saws, drill presses, mills, lathes, water jets, and welding stations.

2.5 Supplies Required

A proposed supplies list for the construction, launching, and testing of a subscale, full-scale, and payload can be found in Table 6.1. The subscale and full-scale body tubes will be built using custom composites, so pre-made airframe sections are not required for this year's structure. The club also has retained materials from previous years, including motor casings, balsa wood, and PLA filament. The other required materials that must be purchased for the rocket structure can be found in the Subscale Structure and Full Scale Structure section of Table 6.1. Various electronics for payload and recovery use, including an Adafruit Feather, Arduinos, antenna, BMP180 Digital Barometric Pressure sensor, BNo055 9 axis absolute orientation sensor, MPL 3115A2 altimeter, MPM3610 Voltage Regulator, Nooelec NESDR SMart reciever, and Rasberry Pis are already owned by the club. Due to the payload challenge requiring soil testing, new sensors must be purchased. These, and other required materials for payload, are outline in the Payload section of Table 6.1. The club has also retained materials for recovery and avionics use, including Eggtimer Quasar altimeters, Stratalogger altimiters, RRC3 altimiters, and quick links. This year, the team will be making custom parachutes, so parachutes will not be purchased. Materials to make the parachutes, and additional recovery materials required, can be seen in the Recovery and Avionics section of Table 6.1. The club also owns reusable PPE, such as safety glasses and particle masks, and non-reusable PPE, such as wipes, paper towels, and nitrile gloves. These non-reusable PPE will have to be restocked during the building process, and are included as incidentals in the Miscellaneous section of Table 6.1.

Beyond physical resources, the club relies on a range of software tools during the competition year. Through NC State University's licensing, the team is able to use Microsoft Office Suite, SolidWorks, ANSYS, and MATLAB. In addition, the club employs OpenRocket, an open-source program for rocketry design and simulation. To further support launch vehicle modeling, the Senior Design Team has independently purchased a RockSim license.

3 Safety

3.1 Safety Requirements

Table 3.1 below contains the safety requirements outlined and provided in the 2026 NASA SL Handbook.

Table 3.1: 2025-2026 Safety Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
5.1	The final checklists SHALL be included in the FRR report and used during the Launch Readiness Review (LRR) and any Launch Day operations.	The Project Management Lead, alongside the Integration Lead and Safety Office,r will write a final checklist for launch operations to be used during launch days. This Checklist will be included in the FRR report, presented during the LRR, and during any Launch Day operations.	Inspection	Project Manage-ment, Integration, Safety
5.2	Each team SHALL identify a student safety officer. See rule 5.2 for all guidelines pertaining to the student safety officer.	The team will democratically elect a Safety Officer. The Safety Officer will follow all rules in the NASA SL Handbook rule 5.2.	Inspection	Project Manage-ment

3.2 Safety Plan

3.2.1 Students Responsible

Aidan McCloskey is the elected Safety Officer for the 2025-26 competition year. He is responsible for ensuring that a culture of safety is present within the club. This includes, but is not limited to, ensuring all lab safety procedures are observed at all times. Aidan is also responsible for ensuring the Rocketry Lab's first aid kit and any PPE equipment are well stocked throughout the year. Members must be informed of all safety protocol via a lab safety quiz at the beginning of the school year, created by Aidan outlined in Section 3.4. Other duties include overseeing all ejection testing that occurs in the club, enforcing the use of launch day checklists for all club rockets as well as encouraging safety protocols be met for personal launches, and delivering a safety briefing before any launches the team plans to attend.

Aidan will also lead the safety team. This team represents members who are equipped with safety protocol, launch procedures, and safety training. Aidan will lead monthly Safety Team meetings. During launches, members of the Safety team will be responsible for assisting in leading launch day checklists for WolfWorks Experimental launches. Safety Team members will also be responsible for ensuring that all safety protocols are followed during design, fabrication, storage, and launches, should Aidan be unable to attend the meeting or launch.

Safety documentation will be led by the Integration Lead, James Garmon. James will be responsible for keeping and maintaining all required Safety Data Sheets (SDS), Failure Mode and Effects Analysis (FMEA), and other pertinent safety documentation. Aidan will work with James to assist in documentation writing, fulfilling NASA Requirement 5.2.

3.2.2 Hazards Analysis and Mitigation

Throughout the competition year, FMEA tables will be completed. These will identify hazards within the project plan, subsystems, personnel, and environment. After being identified, hazards will be dissected to understand their likelihood and severity, causes and effects, and methods of mitigation. All identified hazards will be documented using FMEA tables alongside likelihood and severity (LS) matrices to better visualize the effectiveness of mitigation efforts.

In addition to FMEA tables and LS Matrices, high level Fault-Tree Analyses will be performed once payload and vehicle designs are more finalized.

Table 3.2 below shows an example of an LS matrix that the Safety Team will utilize to show how hazards are ranked based on how likely and severe the hazard is. Table 3.3 and Table 3.4 show keys for Level of Severity and Likelihood of Occurrence, respectively.

Table 3.2: FMEA LS Matrix

		Level of Severity			
		1 Negligible Harm	2 Minor Harm	3 Moderate Harm	4 Major Harm
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

Table 3.3: FMEA Severity Key

Level of Severity			
1 Negligible Harm	2 Minor Harm	3 Moderate Harm	4 Major Harm
Launch vehicle experiences negligible damage; personnel and environment remain unaffected.	Launch vehicle sustains minor damage; personnel treated with first aid; environment only slightly affected.	Launch vehicle sustains moderate damage; personnel need intensive first aid or professional medical care; environment experiences moderate impact.	Launch vehicle cannot be repaired; personnel need urgent medical care or may die; environment severely damaged.

Table 3.4: FMEA Likelihood Key

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

3.2.3 Facilities and Hazardous Materials: Handling, Operations, and Risk Assessment

The club has a dedicated lab space that they share with another MAE-affiliated club, Aerial Robotics Club (ARC). The Rocketry lab is located in EB3 room 2003 on NC State's Centennial Campus. Club members are instructed on the proper use of all machinery and tools in the Rocketry Lab before use. Tooling and equipment to be used along with safety mitigation measures, are shown in Table 3.5. Here, mitigation measures are defined as the proper handling of equipment and the use of PPE.

For all hazardous materials, club members are informed on the risks, storage, and handling of the materials. Proper use of PPE will also be taught and enforced. All potentially combustible or volatile materials, including black powder, acetone, and epoxy are stored in a flame cabinet located in the Rocketry Lab. Club members are encouraged to minimize the use of the cabinet unless necessary to maintain a cool and dry environment. All potentially hazardous materials, as well as their safety mitigation measures are shown in Table 3.6. Here, mitigation measures are defined as the proper storage, handling, and use of PPE for each hazardous material. All usage and storage of hazardous materials will follow guidelines outlined in their respective SDS, which are shown in Section 3.2.4. As part of the Rocketry Lab Safety Plan, all injuries within the lab are kept recorded indefinitely.

Other spaces available to the team to utilize include the MAE Senior Design Lab (EB3 room 1224), the Albright Entrepreneurship Garage (Partners I room 1650), the ECE Makerspace (EB2 rooms 1003A and 1004) and the Hill Makerspace (D. H. Hill Jr. Library room 1222). Each of these additional spaces require safety training and certification provided by NC State to be able to access.

Table 3.5: Hazardous Tools, Equipment and Mitigation

Equipment	Location	PPE	Handling
Dremel	Tool Cabinet	Safety glasses, particle mask	Use both hands, secure material with a vise, and don't apply excessive pressure.
Orbital Sander	Tool Cabinet	Safety glasses, particle mask	Use both hands, keep the pad flat against the workpiece, and move in a slow, steady motion.
Heat Gun	Tool Cabinet	Safety glasses	Keep the nozzle away from flammable materials and do not touch the tip after use.
Drill	Tool Cabinet	Safety glasses, particle mask	Use both hands, secure the material, and make sure the bit is tight before use.
Jigsaw	Tool Cabinet	Safety glasses	Hold firmly with both hands, keep the base plate flat against the material, and let the blade do the cutting.
Shop-Vac	Tool Island	N/A	Empty the canister regularly and ensure the filters are clean.
Drill Press	Tool Island	Safety glasses	Secure the workpiece with a vise or clamp, and ensure the drill bit is properly secured.
Belt Sander	Tool Island	Safety glasses	Stand to the side of the machine, feed the material slowly, and avoid applying too much pressure.
Miter Saw	Tool Island	Safety glasses	Ensure the material is clamped down, use a firm grip, and allow the blade to come to a complete stop before moving the material.
Scroll Saw	Tool Island	Safety glasses	Feed the material slowly and keep your fingers a safe distance from the blade.
Band Saw	Tool Island	Safety glasses	Stand to the side of the blade, ensure the blade guard is in place, and use a push stick for small pieces.
Vise	Tool Island	N/A	Ensure the workpiece is securely clamped before performing any work.

Table 3.5: Hazardous Tools, Equipment and Mitigation

Equipment	Location	PPE	Handling
Compressed Air	Tool Island	Safety glasses	Never point the nozzle at yourself or others; use a regulated nozzle to prevent high-pressure injuries.
Hot Glue Gun	Electronics Bench	N/A	Do not touch the tip or hot glue, and unplug the gun when not in use.
Soldering Iron	Electronics Bench	Safety glasses, particle mask	Use in a well-ventilated area or with the addition of a fume extractor, use a stand for the iron, and do not touch the tip.
Power Supply	Electronics Bench	N/A	Ensure connections are secure and polarity is correct before turning on.
LiPo Charging Station	Electronics Bench	N/A	Charge LiPo batteries in designated fire-safe bags and never leave them unattended while charging.
3D Printer	Electronics Bench	N/A	Use in a well-ventilated area for some filament types and avoid touching the hot nozzle or heated bed.

Table 3.6: Hazardous Materials and Mitigation

Hazardous Material	Manufacturer	Hazard Type	PPE	Storage	Handling
High Power Rocket Motors	Aerotech	Explosive, Flammable	Safety glasses, gloves	Store in a dry location, away from open flames and other heat sources. Do not store near acids.	Handle with care, when assembling the motor, keep away from heat/spark-s/open flames/hot surfaces.
Motor Ignitor	Aerotech	Explosive, Flammable	Safety glasses	Store in a dry location, away from open flames and other heat sources. Do not store near acids.	Keep away from flames and other sources of heat. Do not smoke within 25 feet of the product. Do not ingest. Do not breathe exhaust fumes. Keep in original packaging until ready for use.

Table 3.6: Hazardous Materials and Mitigation

Hazardous Material	Manufacturer	Hazard Type	PPE	Storage	Handling
Kevlar	DuPont	Dust formation may form in the air	Safety glasses	Keep away from direct sunlight	Avoid dust formation. Avoid breathing dust. Clean up dust and fiber with a HEPA filtered vacuum or by wet cleaning. Do not touch moving thread-lines, as entanglement can severely cut or sever fingers.
Estes Motors	Estes	Explosive, Flammable	Safety glasses, gloves	Storage area should be dry and well-ventilated. Keep away from extreme heat, ignition sources, or open flames.	Keep out of reach of small children. Handle with care. Keep ignition sources away.
Polyester Glazing Putty	Fibre Glass-Evercoat	Flammable liquid and vapor, Causes eye, skin, nose, and throat irritation, Carcinogen	Safety glasses, gloves, protective mask	Store in a cool, well-ventilated area. Do not use or store near heat, sparks, or open flames.	Use only with adequate ventilation. Avoid contact with eyes, skin, and clothing. Do not breathe sanding dust, vapors, or spray mist. Close the container after each use.
Black Powder	Hodgdon	Flammable, Explosive, toxic, eye irritant	Safety glasses, gloves	Store in a dry, cool, and well ventilated place. Keep in the original Container when not in use. Keep away from heat, hot surfaces, sparks, open flames, and other ignition sources.	Avoid friction, grinding, or shock. Do not eat, drink, or smoke when using. Wash hands and forearms after handling.

Table 3.6: Hazardous Materials and Mitigation

Hazardous Material	Manufacturer	Hazard Type	PPE	Storage	Handling
Acetone	Klean Strip	Flammable, toxic, eye, skin, and respiratory irritant	Safety glasses, protective mask	Store in a cool, dry place. Keep the container tightly closed when not in use. Keep away from heat or flame, or any other ignition sources. Do not reuse the container.	Use non-sparking tools. Wash hands thoroughly after handling. Avoid breathing vapors. Use only outdoors or in a well-ventilated area.
Firewire Initiator	MJG Technologies Inc	Fire Hazard, Toxic	Safety glasses, gloves	Keep in a cool, dry, well ventilated area. Keep containers tightly closed.	Keep away from heat, sparks, and open flame. Take precautionary measures against static discharges when there is a risk of dust explosion.
Isopropyl Alcohol	Research Solutions	Flammable, toxic, eye damage and irritant	Safety glasses, protective mask	Store in a cool, dry place. Keep the container tightly closed when not in use. Keep away from heat or flame, or any other ignition sources. Do not reuse the container.	Use explosion-proof electrical/venti-lating/lighting equipment. Use only non-sparking tools. Avoid prolonged breathing of mist or vapor. Wash thoroughly after handling.
Partell Paste #2	Rexco	May be fatal if swallowed and enters airways	Safety glasses, gloves	Store in a cool, dry location and away from open flames, heat, and sparks. Keep the container tightly closed when not in use.	Do not eat, drink, or smoke in the application area. Wash hands before breaks and at the end of the working period. Keep work areas free of hot surfaces and other ignition sources.

Table 3.6: Hazardous Materials and Mitigation

Hazardous Material	Manufacturer	Hazard Type	PPE	Storage	Handling
No Clean Solder Wire	RS Components	May Cause allergic skin reaction	Safety glasses, fume extractor	Keep in a cool, dry, well ventilated area. Keep containers tightly closed.	Avoid breathing dust/fume/-gas/mist/va-pors/spray. Avoid contact during pregnancy/while nursing. Wash thoroughly after handling. Do not eat, drink, or smoke when using this product.
Mold Release Paste Wax	Stoner Molding solutions	Flammable Solid, May cause an allergic skin reaction, May cause drowsiness or dizziness	Safety glasses, gloves, protective mask	Store in a well-ventilated place. Keep container tightly closed. Store away from heat, acids, strong bases, and strong oxidizing agents.	Keep away from heat/spark-s/open flames/hot surfaces. Avoid breathing dust/-fume/gas/mist/-vapors/spray. Use only outdoors or in a well-ventilated area.
635 Thin Epoxy Resin	US Composites	Skin corrosion/irri-tation, eye damage/irri-tation, toxic	Safety glasses, gloves	Store in original container protected from direct sunlight in a dry, cool, and well-ventilated area. Keep in either the original container or an approved substitute. Do not reuse the container.	Use only outdoors or in a well-ventilated area. Avoid breathing vapor. Wash hands thoroughly after handling.
Fiberglass	US Composites	Skin irritation, serious eye irritation, respiratory irritation	Safety glasses, gloves, protective mask	Store at or below 25deg C (77deg F) and relative humidity less than 65% for optimum performance. It is not an electrical conductor and may accumulate a static charge.	Avoid breathing dust. Wash face, hands, and any exposed skin thoroughly after handling. Ensure good ventila-tion/exhaustion at the workplace. Use vacuuming or wet sweeping methods instead of dry sweeping.

Table 3.6: Hazardous Materials and Mitigation

Hazardous Material	Manufacturer	Hazard Type	PPE	Storage	Handling
Carbon Fiber	US Composites	Skin irritation, serious eye irritation, and respiratory irritation. Fibers are electrically conductive	Safety glasses, gloves, protective mask	Store in a cool, dry place. Maintain sealed against contamination from dirt and moisture.	Avoid eye and skin contact. Do not rub or scratch irritated areas to prevent fibers from forcing into the skin. Use local exhaust ventilation to control vapor, fumes, or dust. Vacuum equipment is recommended to remove fibers and dust from clothing and work areas. Compressed air is not recommended.
Peel Ply	US Composites	None	Safety glasses	Keep in a dry and well-ventilated place.	Be careful of static while unwinding. Use normal personal hygiene and good housekeeping.
Breather/Bleeder Absorber Cloth	US Composites	None	Safety glasses	Store in dry areas away from sources of ignition.	Avoid excessive contact with the material.
556 2:1 Epoxy Hardener	US Composites	Eye, Skin, and Respiratory irritant/damage. Toxic if ingested.	Safety glasses, gloves	Store in a cool, dry place away from high temperatures and moisture. Keep container tightly closed. Store in a locked area.	Do not breathe vapors or mists from heated material. Avoid skin and eye contact. Wash hands thoroughly after handling.

Table 3.6: Hazardous Materials and Mitigation

Hazardous Material	Manufacturer	Hazard Type	PPE	Storage	Handling
406 Colloidal Silica	West System	Eye and skin irritant. Respiratory irritant.	Safety glasses, protective mask	Store in a cool, dry place. Store in sealed containers to prevent moisture absorption.	Avoid dust formation. Avoid breathing dust. Wash after handling. Provide appropriate exhaust ventilation where dust can be generated.
404 High-Density Filler	West System	Eye and skin irritant. Respiratory irritant. Carcinogen.	Safety glasses, gloves, protective mask	Store in a cool, dry place. Store in sealed containers to prevent moisture absorption.	Avoid dust formation. Avoid breathing dust. Wash after handling. Provide appropriate exhaust ventilation where dust can be generated.
206 Epoxy Hardener	West System	Eye, Skin, and Respiratory irritant/damage. Toxic if ingested.	Safety glasses, gloves	Store in a cool, dry place away from high temperatures and moisture. Keep container tightly closed. Store in a locked area.	DO NOT spray, apply, or heat this product. Do not breathe vapors or mists from heated material. Avoid skin and eye contact. Wash hands thoroughly after handling.
105 Epoxy Resin	West System	Skin and eye irritant. May cause allergic skin reaction.	Safety glasses, gloves	Store in a cool, dry place. Store in tightly sealed containers to prevent moisture absorption and loss of volatiles	Avoid all skin and eye contact. Wash thoroughly after handling. Launder contaminated clothing before reuse. Avoid inhalation of vapors from heated product.

3.2.4 SDS Sheets

A preliminary list of Safety Data Sheets for the materials and chemicals the team anticipates using for the design and fabrication of the launch vehicle and payload has been compiled. To maintain easy accessibility of these documents, a dedicated Google Drive storage folder will be used. This folder will be automatically updated as the project progresses and materials are identified.

The full set of SDS documents are stored here: NCSU High Powered Rocketry Safety Data Sheets

3.2.5 Storage and Handling of Energetics

Identified in Section 1.2, Jim Livingston is the team's designated mentor, associated with TRA. All motors purchased will be of appropriate certification levels and made under Livingston's TRA member number. Livingston will be considered the owner of the launch vehicle, and present to supervise all motor assemblies, installations and other activities involving energetic devices. He also serves as a source of guidance for the team in the design of the launch vehicle, documentation, and personal rocketry pursuits.

3.3 Preliminary Hazards Analysis

Table 3.7 provides an example of a FMEA table.

Table 3.7: FMEA Example

Label	Hazard	Cause	Effect	LS Pre-Mitigation	Mitigation	LS Post-Mitigation	Verification
HZ.1	Epoxy Contact with skin	Working closely with epoxy for Layups, Fillets, etc.	Skin irritation, possible allergic reaction	2D	Team members are trained to work with epoxy so that contact with skin is avoided. Gloves and other proper PPE are required for all team members who work with epoxy.	2B	Demonstration.
HZ.2	Insect sting/bite	Extended exposure outdoors during launch days	Itchiness, rash, swelling, and/or anaphylaxis	4B	Bug spray will be provided to team members who attend launches. An EpiPen will be on the launch site for anyone who may have an allergic reaction.	2A	Demonstration.

3.4 Briefing Plan for Accident Avoidance

At the beginning of the year, the Safety Officer will give a Safety Presentation. This will include, but is not limited to, proper handling of equipment and tools, proper PPE for tools and hazardous materials, and location of pertinent PPE in the lab (Safety Cabinet, Flame Cabinet, Fire Extinguisher, etc). Before club members are allowed to work on the fabrication of the launch vehicle, team members are required to pass a Lab Safety Quiz with a 100% score by the Safety Officer. This quiz covers Rocketry Club safety protocols, including proper PPE usage, tool usage, and other pertinent safety materials.

During a club meeting before each launch, the safety officer will brief all team members who are who plan to attend the launch. This briefing will include, but is not limited to, expectations at the the launch field, weather forecast, expected hazards, checklist assignments, and any other important safety information about the upcoming launch. If a team member is unable to attend this briefing, they will not be permitted to attend the launch unless they are briefed one-on-one with the safety officer before the launch day.

3.5 Lab Safety Handbook

3.5.1 Federal, State, and Local Law Compliance Plan

All team members and mentors are dedicated to adhering to all applicable federal, state, and local laws throughout the design, fabrication, construction, and launching of all high-powered rockets, as well as during any club activities. The team will follow the guidance and instruction of any TRA or NAR launch personnel on launch days to ensure full legal compliance.

3.5.2 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 adhere to all applicable FAA regulations and will refrain from launching a high-power rocket under any of the following 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.

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

In accordance with Code of Federal Regulation 27 Part 55, the team will purchase hobby rocket motors only under the appropriate licensing requirements.

3.5.4 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.

3.6 Safety Agreement

The following safety agreement affirms that all team members agree to comply with the safety regulations set by the NASA SL and the Safety Officer.

2025-26 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. Compliance with NAR High Power Rocket Safety Code.

v. 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.

2025-26 NCSU HPRC Safety Acknowledgement

Leadership Team:

Elizabeth Bruner	[illegible]	9/8/2025
Aidan McCloskey	[illegible]	9/8/2025
James Garmon	[illegible]	9/8/2025
Donald Gemmel	Donald Gemmel	9/8/25
Lauren Wilkie	[illegible]	9/8/2025
Aditya Chadha	[illegible]	9/8/2025
Ben Radspinner	[illegible]	9/8/2025
Emily Cates	[illegible]	9/8/2025
Mason Meyer	[illegible]	9/8/2025
Alex Key	[illegible]	9/08/2025
David Chrostowski	David Chrostowski	9/8/2025
Gabriela Santiago	[illegible]	9/9/2025
Jackson Elia	Jack Eli[illegible]	9/9/2025
Peter Tolman	[illegible]	9/8/2025
Seth Olanovich	[illegible]	9/8/2025

2025-26 NCSU HPRC Safety Acknowledgement

Team Members:

Harshil Mehta	[illegible] 9/8/2025
Auston Parker	9/8/25 [illegible]
Kensley Johnson	Kensley Johnson 9/8/25
Cody Bell	[illegible] 9/8/25
Seth Grady	[illegible]
Natalie Plyler	[illegible]
Mickayla Belus	[illegible]
Nicks Cox	[illegible]
John Coyne	John Coyne 9/8/25
Kwame Dankwa	[illegible] 9/8/25
Luis Martinez Martinez	[illegible] 9/8/25
Kevin Wu	[illegible]
Kaylie Hoffmann	[illegible]
Dilun Dusanayaka	[illegible]
Alan Garcia	[illegible] 9-8-25
Zack Cash	[illegible] 9-8-25
Ari Seran	[illegible] 9-8-25
Bryce Holbrook	[illegible] 9-8-25
Yariel Hernandez - Jaramillo	[illegible]
Timothy Moon	Timothy Moon
Scott Cooper	[illegible]
Kevin Pham	[illegible] 9/8/25

2025-26 NCSU HPRC Safety Acknowledgement

Will Sanderson	[illegible]	9/8/25
James Blain	[illegible]	
Vishant Patel	[illegible]	Sept/08/2025
Amir Maksutov	[illegible]	9/9/2025
Nathan McIntire	[illegible]	
Isaac Hammons	[illegible]	9/9/2025
Andrew Gunter	[illegible]	9-9-25
Jason Kim	[illegible]	9/9/25
Aidan Pardo	[illegible]	9/9/25
Adelaide Stressman	Adelaide [illegible]	
Craig Abell	[illegible]	9/9/25
Austin Hart	[illegible]	9/9/25
Pranit Lokineni	[illegible]	9/9/25
Gavin Draper	[illegible]	9/10/25
Robert Gould	Robert Gould	9/10/25
Jake Garry	[illegible]	9/10/25
Yahir Villa-Rodiles	Yahir Villa-Rodiles	9/10/25
Adarsh Thakur	[illegible]	9/10/25
Rishi Pantala	[illegible]	9/10/2025
Charlie Putney	[illegible]	9/10/25
Isabel Baker	Isabel Baker	9/10/2025
Christopher Shaffer	[illegible]	9/10/2025
Andrew Bostic	[illegible]	9/10/2025

2025-26 NCSU HPRC Safety Acknowledgement

Joseph Alonso	[illegible]	9/11/2025
Benjamin Roylance	[illegible]	9/11/2025
William Selby	Wm L Selby	9/11/2025
Luke Serfontein	[illegible]	9/11/2025
Andrew Mae	[illegible]	9/11/2025
Jimmy Le	Jimmy [illegible]	9/11/2025
Yarilyn Vasquez	[illegible]	9/11/2025
Andrew Gunter	Andrew Gunter	9/11/2025
Morgan Kropiewnicki	Morgan Kropiewnicki	9/11/2025
Jon Ahern	Jonathan Ahern	9/11/2025
Eliana Wallace	E. Wallace	9/11/25

4 Technical Design

4.1 General Requirements

Table 4.1 below contains the general requirements outlined and provided in the 2026 NASA SL Handbook.

Table 4.1: 2025-2026 General Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
1.1	Teams SHALL engage with their communities in the STEM industry or STEM education. To satisfy this requirement, teams SHALL complete either a STEM Industry Engagement Plan and Summary OR a Community STEM Engagement Plan and Summary. Requirements for each can be found in the Engagement section, pages 38–40.	The elected Outreach Lead, identified in Section 1.5, will create a plan where they identify local organizations to visit, activities to implement, and potential dates and/or schedules to engage communities throughout the fall and spring semesters. They will keep a record of communication, counts of individuals impacted, and photos of events to be shared with the Team Lead before and after the event.	Inspection	Project Management
1.2	The team SHALL establish and maintain a social media presence to inform the public about team activities	The elected Social Media officer, identified in Section 1.5, will maintain and use the team's social media platforms to document progress and events. Platforms include but are not limited to Instagram, Facebook, and LinkedIn.	Inspection	Project Management
1.3	Each team SHALL identify a "mentor." A mentor is defined as an adult who is included as a team member, supports 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 must adhere to the following requirements:	The team lead will identify a mentor who is not affiliated with the team's school.	Inspection	Project Management
1.3.1	The mentor SHALL maintain a current certification and be in good standing with the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse class the team intends to use.	The chosen mentor will maintain both good standing with either the Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) as well as certification for the motor impulse class that the Aerodynamics lead decides to use.	Inspection	Project Management

Table 4.1: 2025-2026 General Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
1.3.2	The mentor SHALL have flown and successfully recovered (using electronic, staged recovery) a minimum of two flights in the motor impulse class (or higher) the team intends to use, prior to PDR.	The chosen mentor will have either flown or have provided logs of at least two successful flights utilizing electronic staged recovery in the motor class that the team intends to use.	Demonstration	Project Management
1.3.3	The mentor must attend all team launches throughout the project year, including launch week, as the mentor is designated the individual owner of the rocket for insurance and liability purposes.	The chosen mentor will attend all team launches, including the competition launch, throughout the year as the flyer of record.	Demonstration	Project Management

4.1.1 Launch Vehicle Requirements

Table 4.2 below contains the launch vehicle requirements outlined and provided in the 2026 NASA SL Handbook.

Table 4.2: 2025-2026 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 will receive zero altitude points towards their overall project score and will not be eligible for the Altitude Award.	The Structures and Aerodynamics leads will design the full launch vehicle to be capable of delivering the payload to an apogee between 4,000 ft and 6,000 ft AGL. The Structures lead will facilitate the manufacturing and testing of the launch vehicle with the team.	Analysis, Demonstration	Aerodynamics, Structures
2.2	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 Recovery lead and Payload team will use batteries that have a large enough capacity that they can power all avionic and payload electronics for a minimum of 3 hours without losing the capability of any critical components. The Integration lead will verify the batteries have full functionality before launch.	Demonstration	Integration, Payload, Recovery
2.3	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 simulations based on the designed launch vehicle and determine a target altitude specified in the CDR Report.	Analysis	Aerodynamics
2.4	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 will construct a vehicle capable of withstanding the launch loads expected and the Recovery lead will design a recovery system that will safely bring the launch vehicle to the ground, with the vehicle being able to launch again with minimal repairs within the same day.	Analysis, Demonstration	Recovery, Structures
2.5	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 Structures lead and Recovery lead will design the separating points of the rocket for recovery such that there is a maximum of four (4) independent sections, those being defined by NASA Req. 2.5.	Inspection	Recovery, Structures

Table 4.2: 2025-2026 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.5.1	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).	Structures lead will manufacture the launch vehicle such that any Coupler/Airframe shoulders at in-flight separation points will be at least two airframe diameters in length.	Inspection	Structures
2.5.2	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.)	Structures lead SHALL Manufacture the launch vehicle such that any Coupler/Airframe shoulders at in-flight separation points SHALL be at least 1.5 airframe diameters in length.	Inspection	Structures
2.5.3	Nosecone shoulders SHALL be at least ½ body diameter in length.	Structures lead will manufacture the Nosecone such that its shoulder will be at least ½ body diameter in length.	Inspection	Structures
2.6	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 Aerodynamics lead will select a motor igniter that is capable of being launched using the NASA-designated 12-volt direct firing system.	Demonstration	Aerodynamics
2.6.1	Each team SHALL use commercially available ematches or igniters. Hand-dipped igniters SHALL not be permitted.	The Aerodynamics and Recovery leads will use commercially available ematches for all pyrotechnic initiations.	Inspection	Aerodynamics, Recovery
2.7	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 motor that uses ammonium perchlorate composite propellant certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR)	Inspection	Aerodynamics
2.8	The launch vehicle SHALL be limited to a single motor propulsion system.	The Aerodynamics and Structures lead will design the launch vehicle such that it utilizes a single motor propulsion.	Inspection	Aerodynamics, Structures
2.9	The total impulse provided by a College or University launch vehicle SHALL not exceed 5,120 Newton-seconds (L-class).	The Aerodynamics will select a motor that does not exceed 5120 Newton-seconds of impulse.	Inspection	Aerodynamics

Table 4.2: 2025-2026 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.10	Pressure vessels on the vehicle must be approved by the RSO and SHALL meet the following criteria:	The Team lead will inform the RSO of any and all pressure vessels onboard the launch vehicle.	Demonstration	Project Management
2.10.1	The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews.	The Structures lead and Safety team will verify that any and all pressure vessels are designed with a factor of safety of 4:1.	Inspection	Structures, Safety
2.10.2	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 Recovery lead will design the recovery system such that every pressure vessel will include a pressure relief valves that see the pressure of the tank and will be capable of withstanding the maximum pressure and flow rate of the tank.	Inspection	Recovery
2.10.3	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 will 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 Safety Team will work with the Recovery team to document all pressure vessels, including the number of pressure cycles, dates of pressurization/depressurization, and the name of the person/entity administering each pressure event.	Inspection	Recovery, Safety
2.11	The launch vehicle SHALL have a minimum static stability margin of 2.0 while sitting on the pad.	The Aerodynamics lead will design the launch vehicle such that it will have a minimum static stability margin of 2.0 while on the pad.	Analysis	Aerodynamics
2.12	The launch vehicle SHALL have a minimum thrust to weight ratio of 5.0:1.0.	The Aerodynamics Lead and Structures lead will design the launch vehicle to have a minimum thrust to weight ratio of 5.0:1.0.	Analysis	Aerodynamics, Structures
2.13	Any structural protuberance on the rocket SHALL be located aft of the burnout center of gravity. Camera housings will be exempted, provided the team can show that the housing(s) cause minimal aerodynamic effect on the rocket's stability.	The Aerodynamics Lead will ensure that any systems that any structural protuberances are located aft of the center of gravity of the launch vehicle, as well as confirm that any necessary cameras that violate this requirement will cause minimal aerodynamic effect to the launch vehicle's stability.	Inspection, Analysis	Aerodynamics

Table 4.2: 2025-2026 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.14	The launch vehicle SHALL accelerate to a minimum velocity of 52 fps at rail exit.	The Aerodynamics Lead will select a commercially available motor that provides enough thrust that the velocity of the launch vehicle at the exit of the rail is at a minimum of 52 fps.	Analysis	Aerodynamics
2.15	Subscale rockets are required to use a minimum motor impulse class of E (mid-power motor).	The Aerodynamics Lead will select a Motor with a minimum motor impulse class of E for the subscale launch vehicle.	Inspection	Aerodynamics
2.16	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 Aerodynamic Lead and Structures lead will design the subscale launch vehicle to not exceed 75% of the dimensions of the full-scale launch vehicle.	Inspection	Aerodynamics and Structures
2.18	Vehicle Demonstration Flight—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.).	Project Management will ensure that the launch Vehicle Performs a Vehicle Demonstration flight, wherein all subsystems (Recovery, Structures, Payload, etc) perform as intended and in the same configuration as the Competition Prior to the FRR Deadline.	Demonstration	Project Management
2.19	All Lithium Polymer batteries SHALL be sufficiently protected from impact with the ground and will be brightly colored, clearly marked as a fire hazard, and easily distinguishable from other payload hardware.	All Lithium Polymer Batteries used in the launch vehicle will be designed to have adequate housing and labeling to ensure that they are protected from impact as well as identifiable from payload hardware. The Safety team and Integration lead will ensure that housings meet these requirements.	Inspection, Demonstration	Integration, Safety
2.20.1	The launch vehicle SHALL not utilize forward firing motors.	The Aerodynamics Lead will design the rocket such that it will not utilize forward firing motors.	Inspection	Aerodynamics

Table 4.2: 2025-2026 Launch Vehicle Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
2.20.2	The launch vehicle SHALL not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)	The Aerodynamics Lead will design the rocket such that it will not utilize motors that expel titanium sponges.	Inspection	Aerodynamics
2.20.3	The launch vehicle SHALL not utilize hybrid motors.	The Aerodynamics Lead will design the rocket such that it will not utilize hybrid motors.	Inspection	Aerodynamics
2.20.4	The launch vehicle SHALL not utilize a cluster of motors.	The Aerodynamics Lead will design the rocket such that it will not utilize a cluster of motors.	Inspection	Aerodynamics
2.20.5	The launch vehicle SHALL not utilize friction fitting for motors.	The Structures lead will design a motor retention system that does not utilize a friction fitting for the selected motor.	Inspection	Structures
2.20.6	The launch vehicle SHALL not exceed Mach 1 at any point during flight.	The Aerodynamics Lead will select a motor such that the designed launch vehicle does not exceed Mach 1 at any point during its flight.	Analysis	Aerodynamics
2.20.7	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 un-ballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).	The Aerodynamics Lead and Structures Lead will design the Rocket such that any and all potential ballast needed will not exceed 10% of the total launch vehicle's un-ballasted weight.	Analysis	Aerodynamics, Structures
2.20.7.2	Ballast must be mechanically retained. Friction fit is not a permissible form of retention.	The Structures lead will ensure that any ballast needed will be mechanically retained without the use of friction fitting.	Inspection	Structures
2.20.7.3	Ballast SHALL be removable.	The Structures lead will ensure that any and all ballast needed will be removable.	Inspection	Structures
2.20.7.4	All requirements found in sections 1 through 5 of this handbook SHALL be met in both the minimum and maximum design ballast configurations. Where applicable, teams are expected to present calculations and performance metrics for both minimum and maximum design ballast configurations.	The Aerodynamics lead will calculate performance metrics for both the minimum and maximum Ballast designed to be on the final launch vehicle configurations.	Analysis	Aerodynamics
2.20.8	Transmissions from on-board transmitters, which are active at any point prior to landing, SHALL not exceed 250 mW of power (per transmitter).	The Recovery Lead, Payload Team, and Integration lead will ensure that any Transmissions from on-board transmitters will not exceed 250 mW of power.	Inspection	Integration, Payload, Recovery

4.2 Launch Vehicle Design

4.2.1 Launch Vehicle Dimensions

The preliminary launch vehicle design utilizes fiberglass airframe components with a 6.15” outer diameter. The airframe is constructed from hand-rolled two-dimensional fiberglass cloth for constant diameter laminates and three-dimensional fiberglass sleeves for the varying diameter nose cone laminate. The vehicle measures 110” from the aft of the motor retainer to the blunted nose cone tip, and has a launch pad weight of 40.9 lbs, Figure 4.1 and 4.2.

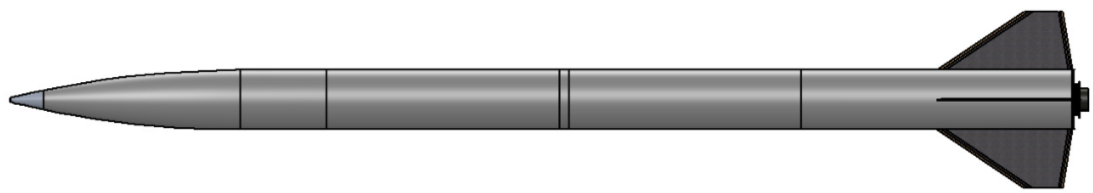

Figure 4.1: Rocket Assembly

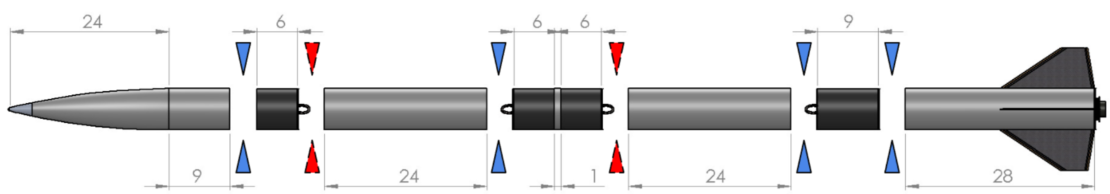

Figure 4.2: Dimensioned Rocket Sections [in]. In-flight Separation points (red and dashed). Non-in-flight separation points (blue and solid)

Nose Cone/Payload Bay

The nose cone body will be constructed of three-dimensional fiberglass sleeves to extend and contract throughout the length. The tip of the nose cone will be machined from a 6061 aluminum rod, following the construction and processing of the nose cone body. The nose cone is an ogive shape with a 4 to 1 length to outer-diameter ratio. The overall length will be minimally shorter than the 4x diameter due to a blunted aluminum tip. The aft of the nose cone will feature an over-sized matching body diameter 9” long section. The increased length along with a nose cone shoulder extending 3” out of the nose cone, will allow for ample payload volume. The nose cone shoulder will be fixed in the nose cone via PEM nuts and screws described in **Non-in-flight Separation Points** for a removable assembly with 3” of coupling length internal to the nose cone. The aft end of the shoulder will feature a stepped bulkhead with the forward recovery attachment for the main parachute recovery system. The stepped bulkhead will be removable with the load transfer through the payload system’s structure.

Main Parachute Bay

The forward airframe section will couple the nose cone, shoulder, and the forward end of the avionics bay with a 24” section of tubing to additionally house the main parachute recovery system. The forward end of the main parachute bay will be an in-flight separation point fixed via shear pins on ascent and descent until the specified main parachute separation charge. The aft end of the main parachute bay will be fixed via PEM nuts and screws to the forward end of the avionics bay coupler.

Avionics Bay

The avionics bay houses the rocket’s altimeters and tracking systems to ensure the deployment of the vehicle’s recovery systems. The avionics bay is 13” of coupler tubing with a 1” switchband centered on the coupler with access ports for arming switches and vent ports. Forward bay retention is mentioned in **Main Parachute Bay**, aft bay separation is mentioned in **Drogue Parachute Bay**. The recovery attachment points on both ends of the avionics bay will function via stepped bulkheads with U-bolts facing toward their respective airframe sections. The bulkheads will be connected through two 6061 aluminum threaded rods tightened with nuts. The U-bolts will be offset radially to the threaded rods for decreased load concentration. The avionics will be mounted to the threaded rods with a 3D printed avionics sled, further described in **Avionics Bay Design**.

Drogue Parachute Bay

The drogue parachute bay will couple the aft end of the avionics bay and the forward end of the air brakes bay with a 24” section of airframe tubing. The drogue parachute recovery system will be housed in the bay. An in-flight separation point is at the coupling of the avionics bay, where shear pins will fix the sections until the specified drogue parachute separation charge. The bay’s aft recovery retention is specified in **Air Brakes System**.

Air Brakes System

The Air Brakes bay will couple the fin can and the drogue parachute bay. The avionics bay will use a 9” coupler centered between the airframe sections. Both ends of the coupler will be fixed with PEM nuts and screws. The recovery attachment points on both ends of the air brakes bay will function via stepped bulkheads with U-bolts facing toward their respective airframe sections. The bulkheads will be connected through four 6061 aluminum rods with threaded ends and tightened nuts. The Air Brakes system is situated as such to ensure meeting structural requirement 2.13.

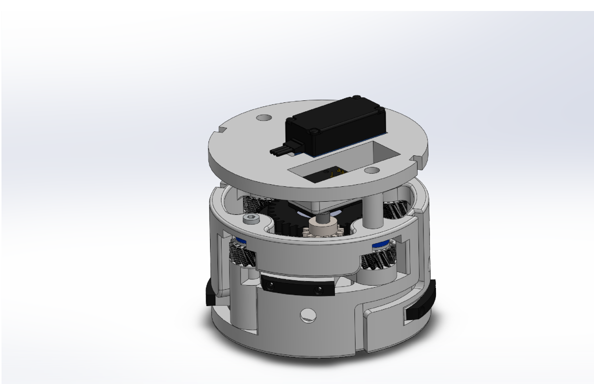

Figure 4.3: Air Brakes Assembly Isometric View

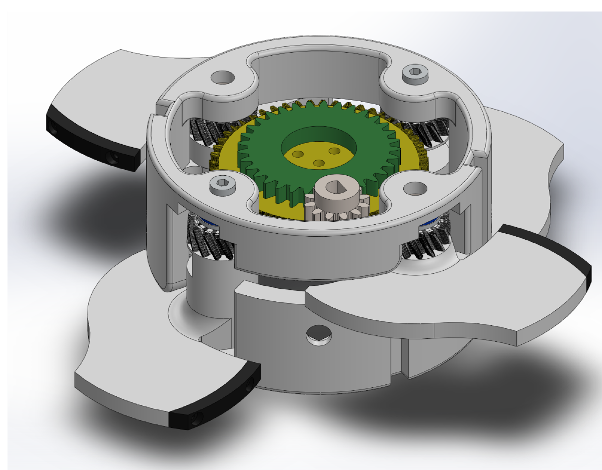

Figure 4.4: Air Brakes Assembly Fully Extended

Air Brakes is a set of 4 deployable fins which will be situated in the Air Brakes Coupler as aforementioned. The fins extend into the freestream airflow around the rocket during the coast phase to induce drag onto the Launch vehicle. This allows greater control for apogee on launch day. The assembly works through a servo motor driving a central helical gear as seen in Figure 4.5, to deploy all four fins simultaneously.

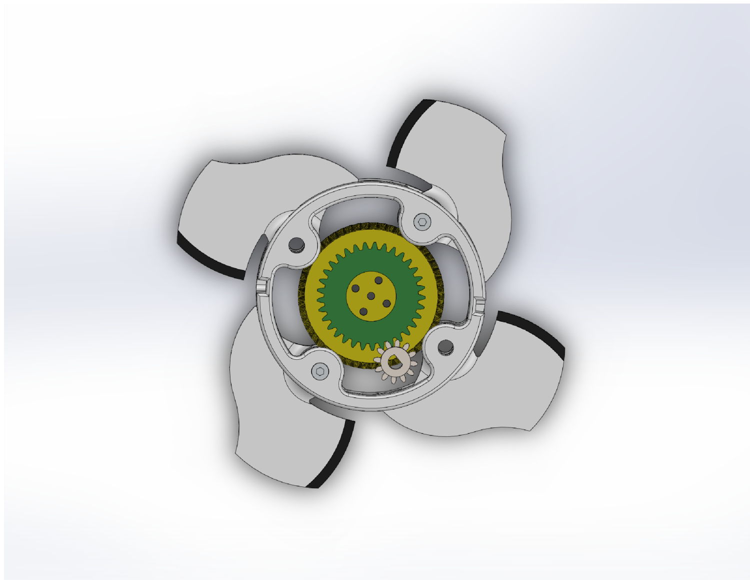

Figure 4.5: Air Brakes Assembly Top Down View

The assembly is controlled through a Raspberry Pi 5 acting as the central flight computer. The fins are hinged to the assembly through 4 screws running through the central housing, with each fin mounted on a bearing to reduce the friction experienced by the gears. The assembly, along with the fully retracted and deployed states, is shown in Figures 4.3 and 4.4 respectively.

Bulkhead Design

Bulkheads will be constructed of two different diameter circular plates with concentric alignment to provide a stepped appearance. The bulkheads will use sandwich fiberglass and long-grain balsa wood composite plates to provide a lightweight but high-strength structure. Recovery attachment will utilize 5/16" stainless steel round U-bolt with mounting plates for load distribution centered on the bulkhead. Bolt placement will be 90 degrees offset from the avionics bay threaded rods. Inline connection lever terminals will be super-glued to holes drilled through the bulkhead. Inline terminals allow access to black powder charge wiring aft and forward of the bulkhead without the need for wires to be slotted through during assembly.

4.2.2 Fin Can

The fin can will be constructed with a 28" long airframe tubing section with slots cut from the aft end to the forward end of the fin tabs. The fin can assembly will use a 12" motor tube with a 3.08" outer diameter to house the rocket motor with three centering rings at the forward, middle, and aft end constructed from a sandwich composite of balsa wood and carbon fiber laminates. The aft centering ring will have a stepped design to act as a thrust plate and a motor retainer mounting point. The motor retainer will be a 6061 aluminum plate with mounting holes for screws to interface the retainer to the aft centering ring.

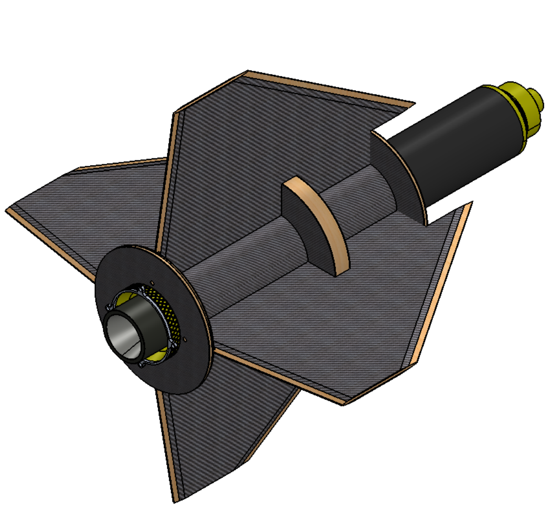

Figure 4.6: Fin Can Isometric View

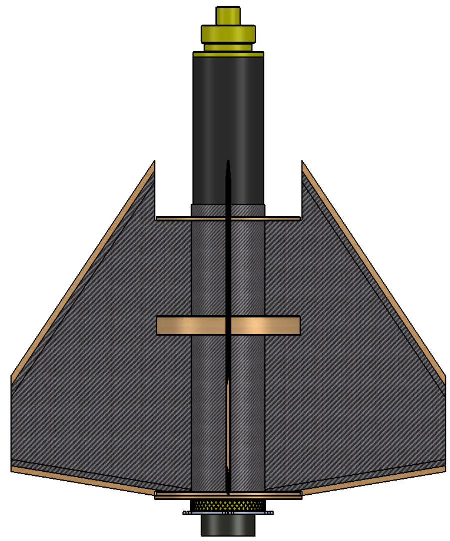

Figure 4.7: Fin Can Side View

Fixed Fin Design

A "through-the-wall" fin can design will be implemented for the vehicle design found commonly among high-power rocketry building techniques, Figure 4.6 and 4.7. A strong two-part epoxy adhesive will be used to bond the fins, centering rings, motor mount tube, and airframe into a rigid assembly. Fins will include tabs extending from the outer diameter of the airframe to the outer diameter of the motor tube. The fin tabs will follow slots cut in the airframe. Three centering rings will be bonded to the motor tube located at the forward, aft, and middle sections of the motor tube. The central centering ring will have matching slots in the fins to allow for even placement radially and perpendicular to the motor tube.

Fin Can Assembly

The fin can will be assembled by bonding the motor tube, fins, and two forward centering rings together before installation in the airframe. The forward and middle centering rings, motor tube, and four fins will be bonded simultaneously, allowing full access for forming structural fillets at the fin tab roots to ensure proper load transfer. Vertical and radial fin alignment will be maintained by the middle centering ring, which is manufactured with fin slots, eliminating the need for a separate alignment jig.

The cured initial assembly will then be bonded to the airframe tube. Epoxy will be smeared just aft of the forward-most centering ring resting position in the airframe to allow for the epoxy to be pushed into place when assembled, forming a forward fillet. With aft access to the middle centering ring, an additional fillet can be made to the centering ring. To construct a fillet on the forward end of the middle centering ring and on the aft end of the forward centering ring, two holes will be drilled between the centering rings, with one on each side of the interior. One cure cycle at a time, low viscosity epoxy will be squeezed into the holes. The fin can assembly will slowly be spun at an angle to spread a fillet at the desired interface. Epoxy from each operation will be used to cover the drilled hole. The aft centering ring is a multi-purpose centering ring, thrust plate, and motor retainer mount. The aft centering ring will be a stepped interface with a similar interface mentioned in the bulkhead design to match the outer and inner diameter of the airframe tube. The centering ring will have four through holes with PEM nuts epoxied on the aft end for interfacing the custom motor retainer. The custom motor retainer will be removable via screws.

Fin Design

The vehicle's passive stability will be driven by 4 trapezoidal fins with an aft bias. The semi-span of the fins matches 1x the inner diameter of the airframe tube with a 14" root chord, 4" tip chord, 9" sweep length, and a .205" overall sandwich composite thickness, Figure 4.8. The design focuses on providing a tip chord with no sweep aft of the root chord of the fin to increase the flutter resistance of the fins and to reduce the point force generated by off-axial landing angles. The fin tab extending towards the motor tube allows for the central centering ring to slot into the fin. The forward and aft ends of the tab are to be attached to the respective centering rings for additional bond length farther from the fin's center of pressure.

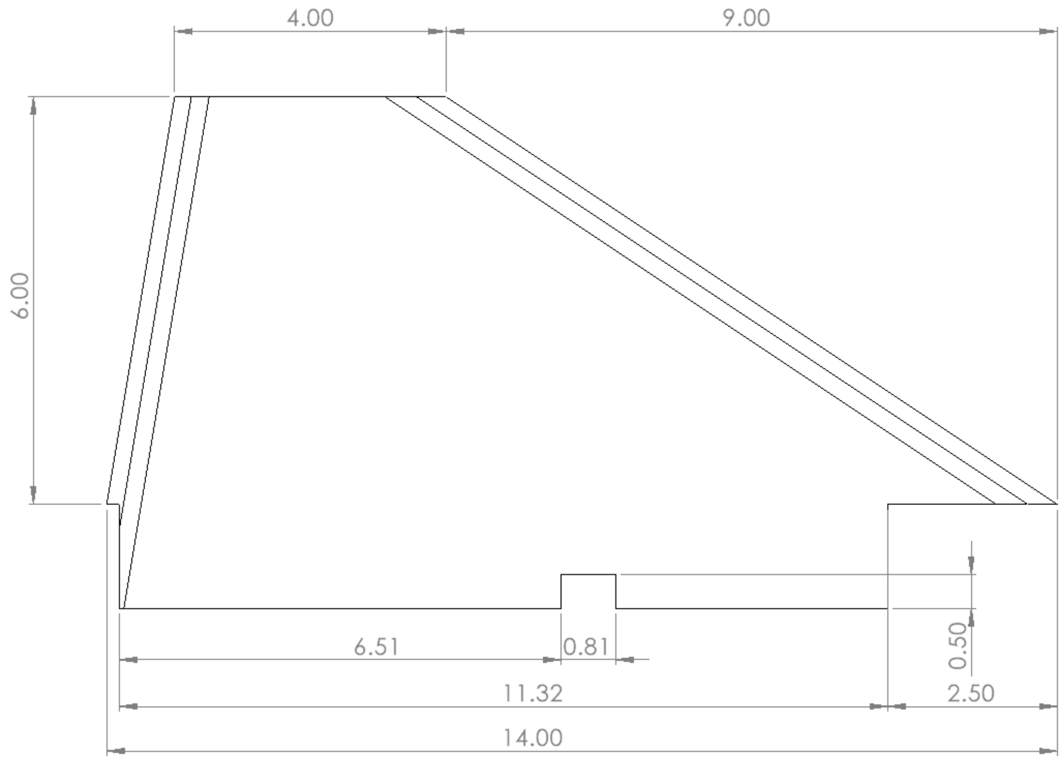

Figure 4.8: Dimensioned Fin [in]

All aerodynamic simulations will be done through advanced 3D, CFD, ANSYS Fluent 3D. All post processing will be done through a combination of ANSYS Fluent 3D, TecPlot 360 EX, and custom MATLAB scripts. Fin will be further optimized for greater control of the rocket.

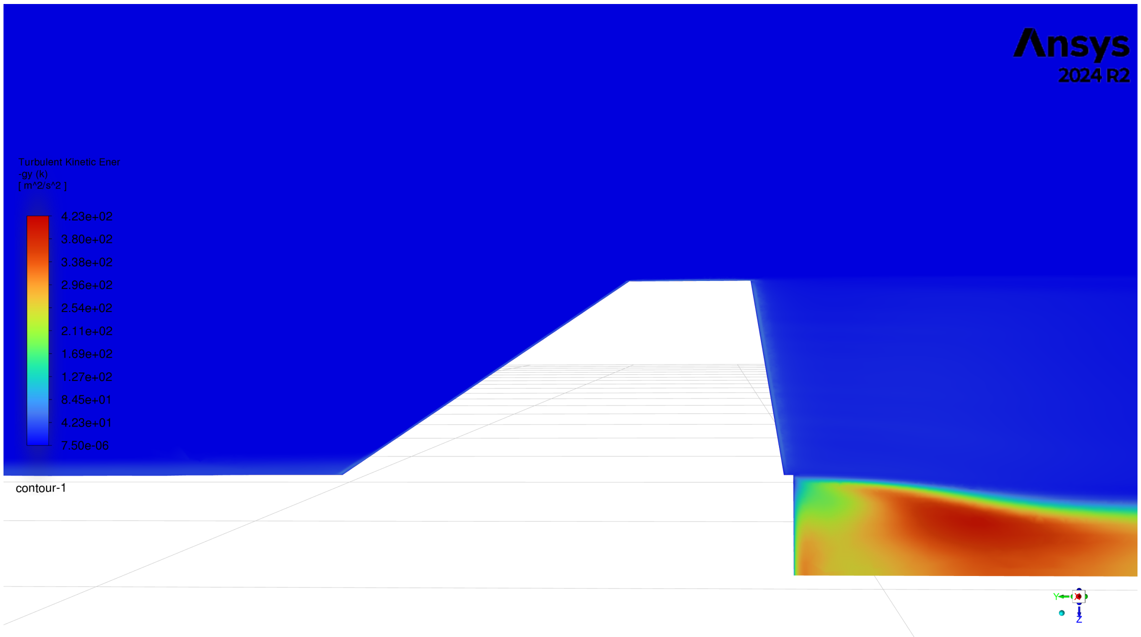

Figure 4.9: Contour Of Turbulent Energy Around the Fin at 102 m/s

Above, in Figure 4.9 is a preliminary CFD simulation of airflow around the fin. Airflow around the leading edge and trailing edge of the fin is laminar due to the low Turbulent energy shown in Figure 4.9. This design will be further refined along with the rest of the launch vehicle to make it as streamline as possible to reduce the drag experienced during flight.

4.2.3 Airframe Material Selection

Composite Materials

Composite cloths offer a high-strength, waterproof alternative to paper-derived materials and components commonly used in high-power rocketry. Composite materials are derived from a cloth of strands of filament of petroleum or silicon base, then saturated in a two-part laminating epoxy. The resulting composite cures at the epoxy manufacturer's specifications, providing a complete laminate. Composite materials are brittle and highly anisotropic with large variations in manufactured properties due to voids and excess mix ratios. Composite filaments benefit from loadings following the length of the strands, allowing design to focus material in the direction of anticipated loading. Table 4.3 has been provided with typical unidirectional cloth material properties. An additional table has been provided with composite laminate strengths for unidirectional and plain weave laminates, Table 4.4

Table 4.3: Material Properties of Unidirectional Composite Fabrics [2, 6, 1]

Name	Tensile Strength [ksi]	Tensile Modulus [Msi]	Density [lb/in^3]
Toray T300	512	33.4	0.0636
Toray T700S	711	33.4	0.0650
Toray T700S	711	34.8	0.0650
Hexcel AS4	650	33.5	0.0646
Hexcel AS4C	675	33.5	0.0643
Hexcel IM2C	830	43.0	0.0643
JPS E-Glass Fiberglass	490	10.4	0.0918
JPS S-Glass Fiberglass	670	12.9	0.0914

Woven E-glass Fiberglass

Fiberglass is made of glass filaments using silicon, sodium carbonate, and calcium carbonate at high temperatures. “E-glass,” also known as electrical fiberglass, is a general-purpose, lower-cost fiber commonly found in marine construction. The filaments are most commonly woven into a plain weave style with interlocking 0 and 90 degree patterns. When epoxy is applied and cured into a dry woven fiberglass cloth, the composite laminate is a high-strength and lightweight construction material. Woven E-glass is used in high-power rocketry for its higher tensile and bending strength compared to paper-derived airframe materials of the same sizing. Fiberglass airframes are higher-density than paper-derived sources, but are waterproof following a completed cure cycle.

Woven S2-glass Fiberglass

Interwoven S2-glass cloth is manufactured similarly to E-glass, but with a higher silicon content. The variation in construction provides up to a 30% increase in breaking strength compared to E-glass, but at an increased cost. The higher-strength S2-glass will be used as the primary construction material for body tubes, couplers, nosecone, and sandwich layups close in proximity to radio wave-emitting devices.

Woven Carbon Fiber

Carbon fiber filaments are drawn from petroleum-based materials and extruded at higher temperatures than glass filaments. Carbon fiber filaments are constructed into various weave patterns to provide differing working qualities with slight strength variations. Carbon fiber cloths benefit from higher strength and lower densities, but face higher costs and are electrically conductive surfaces, removing the ability to transmit radio waves found commonly in GPS trackers. Carbon fiber will be used in the aft portion of the rocket for the centering rings, motor tube, and fins for higher strength, lower density, and ample distance from radio wave emissions.

Table 4.4: Typical Composite Laminate Strengths [3]. *Plain Weave 60% v_f. ** Unidirectional 50 % v_f.

Name	Tensile Strength [ksi]	Shear Strength [ksi]	Density [lb/in^3]
E-Glass Fiberglass*	64.0	5.8	0.0686
Carbon Fiber*	87.0	13.1	0.0578
E-Glass Fiberglass**	145.0	5.8	0.0686
Carbon Fiber**	217.6	10.2	0.0578

Paper-Derived

High-power rockets commonly utilize paper-based body tube materials with low density, good compressive strength, and low costs. Paper-based sources typically fall short in dimensional stability with humidity and temperature affecting tolerancing, especially when launching in highly variant launch conditions. These airframe materials are also not water-proof and can require the complete reconstruction of a body tube should it soak in water or a puddle during recovery. Paper-derived body tube materials will not be used for the subscale or full-scale vehicles due to the aforementioned downsides. The launch field that the club most commonly launches at often has drainage ditches with water, snow on the ground at launch, 50°F differences in temperature, and humidity changes throughout the year due to the proximity to the ocean.

Balsa wood will be used for the sandwich composite plates that will be constructed. Balsa wood is a high strength to density material that is common in low power rocketry construction on its own. Sheets of balsa wood will be used for sandwich material as the core material due to the low loads received when in a sandwich composite with multiple layers of composite laminate on forward and aft faces, far from the neutral bending line.

Fasteners

All vehicle fasteners and recovery hardware will utilize 18-8 or 316 stainless steel. Stainless steel was chosen for its high strength and corrosion resistance compared to plated steel in high humidity environments and anticipation of scratching during vehicle launches. All fasteners will also utilize imperial sizing with hex key ports for loosening and tightening. Stainless steel components are common and only experience a small price increase compared to their steel-plated counterparts.

The threaded rod assembly for the avionics bay is the only exception to the stainless steel material requirement. The threaded rods and associated nuts will use aluminum 6061 for a higher strength to density material.

4.2.4 Construction Methods

Fins

Fins will be cut out of an in-house sandwich carbon fiber and balsa wood composite plate. A wet lay vacuum process will be used to fabricate the plate with up to 5 layers of 3K carbon fiber cloth on each side of the plate with laminating epoxy. The plate will then undergo a vacuum with two caul plates to provide a smooth and flat surface. Breather fabric and peel-ply will be utilized to absorb excess epoxy while providing a surface to release the sandwich plate from the caul plates. Once cured, it is anticipated that pinholes will be present in the layup. A secondary coat of epoxy will be spread on both sides of the plates with additional release film to provide a smooth final surface with minimal sanding.

Following the plate fabrication, the fins will be rough cut with a wet tile saw before being clamped together on a belt sander for a geometry consistent with all four fins. Fins will be beveled at the leading and trailing edges on a Dremel router jig with a 15-degree chamfer bit, and further rounded at the edges via hand sanding. After smoothening the leading and trailing edges, a strip of carbon fiber tape and epoxy will be applied to cover the exposed balsa wood, extending a quarter inch into the un-beveled portions of the fin to improve impact resistance and decrease the causes of delamination.

Bulkheads

Bulkheads will be cut from 1/8” balsa wood on a ShopBot CNC router to provide repeatable and accurate diameter circles. Hardware mounting points will additionally be routed out during the CNC process. The hardware mounting points will be used as centering locations for the composite bond process for proper alignment.

Stepped bulkheads for avionics and the multi-purpose thrust plate will follow the same construction process, but with differences in fabric. Fiberglass will be used for avionics bulkheads due to the proximity to transmitting electronics, and carbon fiber for the thrust plate. Up to five layers of composite fabric will be on the exposed forward and aft portions of the combined stepped bulkhead. A single layer of composite fabric will interface the balsa plies to provide a fiberglass-to-fiberglass connection between the bulkheads and coupler or airframe contacts. Before the vacuum process, the wet composite cloth will be trimmed to reduce the post-processing after the cure process completes. The vacuum process will utilize a single caul plate with peel ply and breather on both ends of the bulkhead to minimize the weight, as a smooth surface with an epoxy wash is not necessary for interior and non-aerodynamic components.

Centering Rings

The centering ring manufacturing process will mimic the bulkheads. A CNC router will be used to cut out the 1/8” balsa wood, with a sandwich composite layup following the same method used for the bulkheads.

Airframe Tubing

The body tubes and coupling tubes will be fabricated via a roll-wrapped airframe with S2-glass. The fabricated airframe will extend beyond the design to account for fraying at the ends. Cloth will be wet out and rolled over a mylar-covered mandrel. The cloth will be wrapped with weight, pulling the fibers in tension to increase the fiber volume fraction. Heat-shrink tape will be spiral-wound around the airframe with overlapping segments. Compression applied by heating the shrink tape will squeeze excess epoxy from the laminate and provide a smooth surface with minimal sanding. Should surface pinholes be present following the roll-wrapping process, an epoxy coat will be applied to the outer surface of the tube and sanded smooth. Once cured, tubes will be cut with a carbide-tipped blade on a miter saw.

Nosecone

The nosecone will be constructed using a 3D fiberglass sleeve material. The mandrel will be 3D printed in PLA. The mandrel will be sanded to high grit before being covered in mold release wax, following the manufacturer's recommendations for application. Should the part not release, the PLA mandrel allows for a destructive mandrel removal with elevated temperatures not to exceed the deflection temperature of the epoxy used in the laminate. Due to the contoured surface, the outer surface will not receive peel-ply or heat-shrink following the layup process. The smooth surface will be generated with an epoxy coat and sanding process.

Surface Preparation Standard

All components that interface with epoxy will follow a standard to ensure a surface with high surface energy ready for the bonding process.

Composites

1. Wear proper PPE with gloves free of dust or oils.
2. Clean surface with a minimum of 70% isopropyl alcohol using lint-free and clean towels.
3. Sand in various directions of bond surface for a minimum of 10 seconds per in^2.
4. Sand with grit between 175 and 275.
5. Clean surface with a minimum of 70% isopropyl alcohol until all debris has been removed.
6. Do not contaminate surface with dirty gloves or oils until bond is finished and cured.

Paper-Derived

1. Wear proper PPE with gloves free of dust or oils.
2. Clean surface with a lint-free and clean towel.
3. Sand in various directions of bond surface for a minimum of 10 seconds per in^2.
4. Sand with grit between 120 and 180.
5. Clean surface with a lint-free and clean towel until all debris is removed.
6. Do not contaminate surface with dirty gloves or oils until bond is finished and cured.

Non-in-flight Separation Points

For sections of the rocket that require separation, but not during flight, PEM nuts with countersink screws will be used to fasten sections together. Four Holes will be drilled with even separation radially about the middle of the coupling section through both airframes. The PEM nuts will then be press-fit into the coupler with the larger diameter side facing in to the center of the tube. The PEM nuts will be further epoxied to the inside of the coupler as a backup to the press-fit placement. The outer airframe will be countersunk to create a flush surface that perfectly matches the countersink screws.

4.3 Projected Altitude

Projected Altitude

The launch vehicle's target apogee will be 4600 ft. This was selected to meet recovery requirements 3.3, 3.10, and 3.11, the predicted mass of the rocket, and available motor casings for purchase. Current simulations have been done through OpenRocket, using the AeroTech L1520T, but other software will be used to cross verify apogee. The aforementioned motor, along with the AeroTech L1390G and L1150R, are the only motors that will work with the given launch vehicle configuration, and keep the rocket within the given altitude range. Figure 4.10 shows the trajectory profile for the ascent phase of the vehicle for all motors mentioned. Further discussion and rationale for motor selection is discussed in Section 4.5.

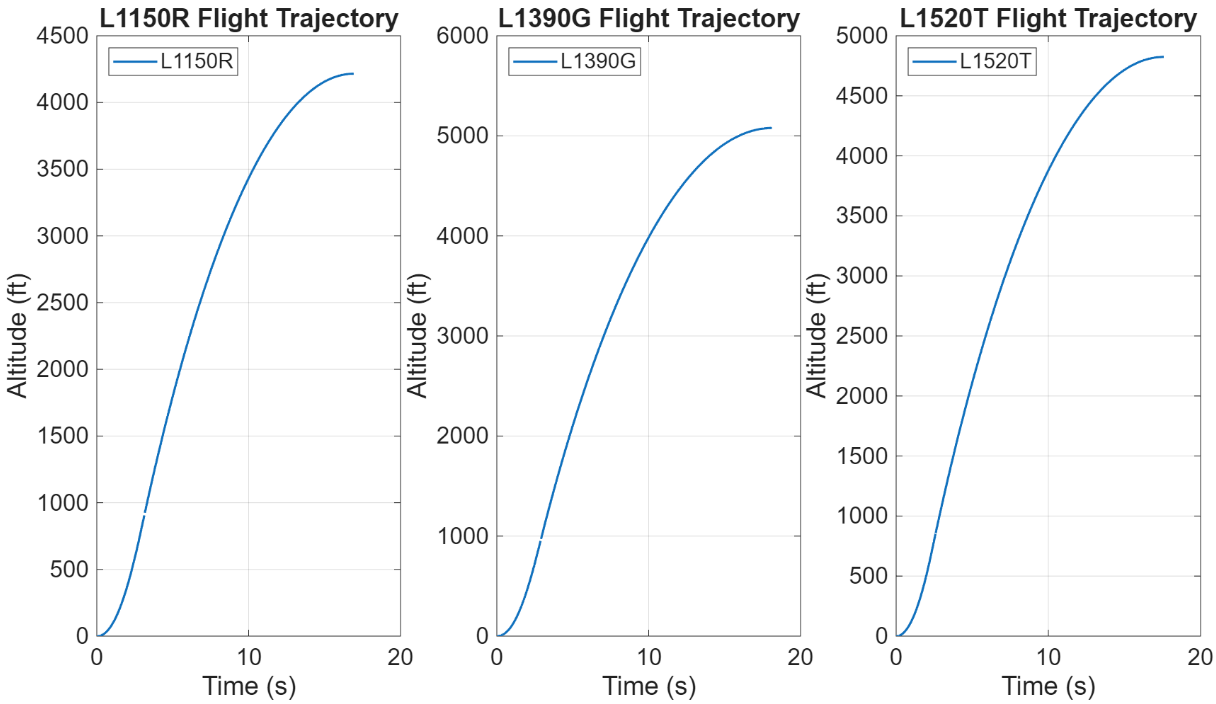

Figure 4.10: Trajectory Analysis for Target Apogee Without Air Brakes

4.3.1 Air Brakes

Air Brakes Control

The Launch Vehicle will have an Air Brakes system to control apogee on launch day. By simulating a rocket that will overshoot the target apogee, the Air Brakes system will employ its apogee predictor algorithm through a bang-bang control scheme to increase the drag on the launch vehicle during the coast phase to reach 4600 ft. From past launches, the system has been proven to take off 200 to 600 ft, depending on vehicle configuration and launch day conditions. For launch day, the Air Brakes system will aim to take off 200 ft.

OpenRocket Plugin

To ensure flight trajectory analysis is accurate with the Air Brakes System, flight simulations must be run with and without Air Brakes deploying. The current system employed in OpenRocket does not natively support Air Brakes, and the current control algorithm relies on custom code to detect apogee in real time during the flight. OpenRocket supports plugins that influence the simulation through custom code and methods, therefore a custom plugin will be implemented that runs the custom apogee predictor and control system through OpenRocket to best simulate flights for launch day.

4.4 Launch Vehicle Recovery Specifications

The launch vehicle will utilize a dual deployment recovery system, including a drogue parachute and a larger main parachute, satisfying NASA requirement 3.1. Two independent, commercially available altimeters will manage the deployments by activating four distinct black powder charges. The primary altimeter will initiate the drogue parachute release at apogee and the main parachute at 550 ft. The secondary altimeter serves as a backup, deploying the drogue parachute one second after apogee and the main parachute at 500 ft. Additionally, the avionics bay will include a GPS unit to track the vehicle's location after landing.

4.4.1 Recovery System Requirements

Table 4.5 includes the recovery system requirements created by NASA, the Senior Design Team's plan of action to meet these requirements, and the verification method that will be used to ensure the requirements are met.

Table 4.5: 2025-2026 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 recovery system such that the drogue parachute is deployed at apogee and the main parachute is deployed at a lower altitude.	Demonstration	Recovery
3.1.1	The main parachute SHALL be deployed no lower than 500 feet.	The Recovery Lead will design the recovery system such that the main parachute is deployed at no lower than 500 feet.	Demonstration	Recovery
3.1.2	The apogee event SHALL contain a delay of no more than 2 seconds.	The Recovery Lead will design the recovery system such that the drogue will even contain a delay of no more than 2 seconds.	Demonstration	Recovery
3.1.3	Motor ejection is not a permissible form of primary or secondary deployment.	The Recovery will not utilize motor ejection for any deployment events in the recovery system.	Demonstration	Recovery
3.2	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 select or manufacture parachutes such that each independent section will have a maximum kinetic energy of 75 ft-lbf at landing.	Analysis	Recovery

Table 4.5: 2025-2026 Recovery Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
3.3	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 the Recovery system such that they utilize commercially available barometric altimeters for the initiation of rocketry recovery events.	Inspection	Recovery
3.4	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 Avionics system for the recovery system such that each altimeter has a dedicated power supply utilizing commercially available batteries.	Inspection	Recovery
3.5	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 it may be armed using mechanical arming switches that are accessible from the exterior of the launch vehicle while it is on the launch pad.	Demonstration	Recovery
3.6	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 utilize arming switches such that they are capable of being locked in the on position regardless of flight forces experienced during the launch.	Demonstration	Recovery
3.7	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 any and all Avionics used in the system are completely independent of any and all Payload electrical circuits.	Inspection	Recovery
3.8	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 such that Shear pins will be used for both main and drogue compartments. The Structures lead will ensure the launch vehicle is designed such that Shear pins will be used.	Inspection	Recovery, Structures
3.9	Bent eyebolts SHALL not be permitted in the recovery subsystem.	The Structures lead will ensure that any connection points between shock cord and structural elements of the launch Vehicle (Bulkheads) will not utilize bent eyebolts.	Inspection	Structures

Table 4.5: 2025-2026 Recovery Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
3.10	The recovery area SHALL be limited to a 2,500 ft. radius from the launch pads.	The Recovery Lead will select appropriately sized parachutes to be used for the recovery system such that the launch vehicle does not drift more than 2,500 ft from the Launch Pads.	Analysis, Demonstration	Recovery
3.11	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 select appropriately sized parachutes to be used for the recovery system such that the launch vehicle's descent time is not more than 90 seconds.	Analysis, Demonstration	Recovery
3.12	Electronic GPS Tracking device(s) SHALL be installed in the launch vehicle and will transmit the position of the tethered vehicle and any independent section(s) to a ground receiver.	The Recovery Lead will utilize Electronic GPS tracking devices in every independent section of the launch vehicle that are capable of transmitting the position of the section to a ground receiver.	Inspection, Demonstration	Recovery
3.13.1	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 Avionics system such that any altimeters used will be physically separated from any radio frequency transmitting device or magnetic wave producing device.	Inspection	Recovery
3.13.2	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 Avionics system such that any recovery electronics used will be shielded from any transmitting devices.	Inspection	Recovery
3.13.3	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 Avionics system such that any recovery electronics are shielded from any magnetic wave producing devices.	Inspection	Recovery
3.13.4	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 avionics system such that any recovery electronics are shielded from any devices on the launch vehicle that may affect the proper operations of the recovery system electronics.	Inspection	Recovery

4.4.2 Recovery Events

The recovery system contains two individual recovery events. The first event will occur at apogee, when the drogue parachute is deployed. The primary altimeter will ignite the primary drogue black powder charge, positioned aft of the avionic bay. One second after apogee, the secondary altimeter will initiate the secondary drogue black powder charge, also located aft of the avionics bay for redundancy. The pressure created inside the drogue bay by the black powder charges will break the shear pins connecting the drogue bay to the fin can, allowing the launch vehicle to separate and release the drogue parachute. The vehicle will descend under the drogue parachute until the second recovery event.

The second recovery event will occur at 550 ft. The primary altimeter will ignite the primary main black powder charge, located forward of the avionics bay. For the sake of redundancy, a secondary altimeter will ignite the secondary main black powder charge at 500 ft. The main black powder charges will pressurize the main bay, breaking the shear pins connecting the nose cone to the avionic bay. This will allow the launch vehicle to separate and release the main parachute. The launch vehicle will descend under the main parachute until it reaches the ground.

4.4.3 Avionics Bay Design

The avionics bay will be housed in a coupler located directly aft of the nose cone. An avionics sled, designed in SolidWorks and 3D printed, will serve as the mounting platform for all avionics components. The sled will be secured to bulkheads at each end of the coupler using two threaded rods running axially through the bay.

The avionics bay will be designed to operate independently of the payload and Air Brakes systems to ensure no interference with recovery devices. To meet Requirement 3.13, all avionics will be isolated in their own dedicated coupler, separate from other electronics.

The sled will accommodate two altimeters, two LiPo batteries, one GPS unit, and two mechanical pull-pin switches. In compliance with NASA Requirement 3.7, each altimeter will be powered by a dedicated LiPo battery on an independent circuit, separate from payload and Air Brakes electronics. Two access holes in the switch band will allow external arming of the pull-pin switches, satisfying Requirement 3.5. Pressure port holes will also be integrated into the switchband to equalize internal pressure with atmospheric conditions.

Each bulkhead enclosing the avionics bay will have U-bolts mounted on the outer side, which will serve as recovery attachment points. Kevlar shock cord will be used to connect the vehicle to both the drogue and main parachutes. Additionally, two 3D-printed black powder charge canisters, hereafter referred to as blast caps, will be mounted externally on the bulkheads. A hole will be drilled in each bulkhead to route an e-match into the corresponding blast cap, ensuring the match sits securely within the charge. The e-matches will then be wired to their respective altimeters for deployment initiation.

4.4.4 Recovery Avionics

The avionics bay will house one PerfectFlite StrattologgerCF, one Altus Metrum EasyMini, one Eggfinder Mini, and three 7.4V 800mAh LiPo batteries. The StrattologgerCF will serve as the primary altimeter, operating on an independent circuit powered by one of the three batteries and controlled through a dedicated pull-pin switch. The EasyMini will function as the secondary altimeter, also on an independent circuit with its own battery and pull-pin switch. Both switches will be externally accessible through holes in the switch band. Removal of the pull-pin arms the corresponding device, locking the altimeter in the "on" state for the duration of flight. This configuration ensures compliance with requirements 3.3, 3.4, 3.5, 3.6, and 3.7.

Prior to each test flight, the altimeters will undergo verification in a vacuum chamber to confirm proper functionality. For these tests, each altimeter will be connected to a circuit board equipped with light-emitting diode (LED) indicators in place of e-matches. LEDs of distinct colors will provide clear visual confirmation of device operation. Pressure within the chamber will be gradually decreased to simulate ascent, then increased to represent apogee and descent. Data recorded during testing will be plotted to verify that the simulated events align with expected behavior.

4.4.5 Ejection Charges

Each blast cap will be filled with FFFG granular black powder and initiated by an e-match. Ignition of the charge will pressurize the designated parachute bay and break the shear pins, permitting separation of the sections and subsequent parachute deployment. Primary and secondary black powder charges will be implemented for both drogue and main deployments. The force required to separate a section will be determined from the tensile strength and number of shear pins employed, together with the parachute bay volume and internal pressure generated during ignition. The mass of each primary black powder charge will be calculated using the following equation,

$$m_{BP} = \frac{Fl}{RT_C} \tag{1}$$

where m_{BP} is the mass of black powder, F is the force required to break the shear pins, l is the length of the parachute bay, R is the ideal gas constant, and T_C is the combustion temperature of the black powder. These calculations will also be verified by Chuck Pierce's Ejection Charge Calculator [4]. The mass of each secondary black powder charge will be calculated by adding 0.5 oz to the mass of the respective primary charge. Any remaining volume within the blast cap not occupied by black powder will be filled with biodegradable recovery wadding and sealed with blue tape to prevent leakage. Prior to each test launch, the launch vehicle will be fully assembled in its flight configuration, and ground ejection tests will be conducted to validate each recovery event.

4.4.6 Parachute Design

The recovery system will employ two parachutes, a small drogue parachute and a larger main parachute. Parachute sizing is determined based on descent time and kinetic energy requirements established by NASA. To optimize launch vehicle performance, the system will be designed to achieve ground impact in under 80 seconds while maintaining a maximum kinetic energy of 65 ft-lbf for the heaviest section of the vehicle. Based on these requirements, an 18 in hemispherical drogue parachute and a 120 in toroidal main parachute have been selected.

Fabrication will utilize Chutemaker templates for both parachutes [5]. Each parachute will be constructed from ripstop nylon and sewn with Kevlar or nylon thread for strength and durability. Before all test flights, the parachutes will undergo drop testing from a known height. The drag coefficient, C_d, will then be calculated and compared to the theoretical value using the following equation,

$$C_d = \frac{D}{\frac{1}{2}\rho V^2 A} \tag{2}$$

where D is the drag force, ρ is air density, V is object velocity, and A is the projected parachute area.

4.4.7 Parachute Calculations

The predicted descent velocity of the vehicle was calculated using the following formula,

$$v_{desc} = \sqrt{\frac{2mg}{\rho A C_d}} \tag{3}$$

where v_{desc} is the descent velocity, m is the mass of the vehicle, g is gravitational acceleration, ρ is air density, A is the projected area of the parachute, and C_d is the drag coefficient of the parachute.

The selected drogue parachute is a 18 in hemispherical parachute. This parachute has a projected area of 1.77 ft^2 and a C_d of 0.75. Given that the dry mass of the launch vehicle is 37.1 lb, the descent rate under the drogue parachute is calculated to be 108.46 fps. The main parachute chosen for the vehicle is a 120 in toroidal parachute, which has a projected area of 76.11 ft^2 and a C_d of 2.2. This will result in a main descent rate of 13.66 fps.

After obtaining the launch vehicle descent velocity, the kinetic energy of the heaviest section can be calculated using the following equation,

$$K = \frac{1}{2} m v_m^2 \tag{4}$$

where K is the maximum kinetic energy, m is the mass of the heaviest section, and v_m is the descent velocity under the main parachute. Using a descent velocity of 13.66 fps and a mass of 18.8 lb, the maximum kinetic energy of the launch vehicle is calculated to be 54.47 ft-lbf.

The total descent time of the launch vehicle is calculated using the following equation,

$$t_d = \frac{r_a - r_m}{v_d} + \frac{r_m}{v_m} \tag{5}$$

where t_d is descent time, r_a is the altitude of apogee, r_m is the main parachute deployment altitude, v_d is the drogue descent velocity, and v_m is the main descent velocity. Assuming the drogue deployment occurs at an apogee of 4600 ft and the main deployment occurs at 550 ft, this results in a descent time of 77.61 seconds, which satisfies NASA Requirement 3.11.

Table 4.6 presents the variation in drift distance of the launch vehicle with wind speeds ranging from 0 mph to 20 mph. The analysis assumes the vehicle reaches apogee directly above the launch pad and drifts at a constant rate with the wind. As these calculations are based on a worst-case scenario, specifically, constant wind conditions, the resulting values represent an upper bound on drift distance, satisfying NASA Requirement 3.10.

Table 4.6: Wind Drift Distance

Wind Speed (mph)	Drift Distance (ft)
0	0
5	569.16
10	1138.32
15	1707.48
20	2276.64

4.5 Motor Brand and Class

Motor selection for the launch vehicle is based on a variety of factors, including team experience, mentor suggestions, brand reliability, and commercial availability. The team has used AeroTech rocket motors for years and is very familiar with their performance and reliability, coupled with the brand's motors being commercially available. The launch vehicle will utilize an AeroTech motor for all 2026 NASA SL Competition flights.

To select a motor, basic kinematic principles and flight trajectory software must be employed for analysis. This grounds the simulation with kinematic derived equations to best check results from the simulation software. The kinematic process can be achieved through a simplified model of the launch vehicle. Drag forces and air resistance are neglected for this model.

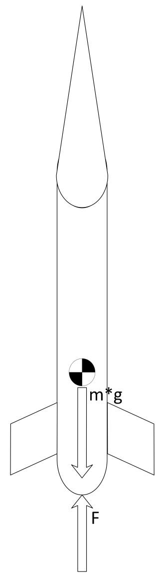

Figure 4.11: Simplified Model of a Rocket Free Body Diagram

Using a free body diagram in Figure 4.11 and kinematic equations, the following equations can be derived:

$$t = \frac{I_{total}}{F_{avg}} \tag{6}$$

$$\ddot{x} = \frac{F_{avg}}{m_{total}} - g \tag{7}$$

$$x_{burnout} = \frac{1}{2}(\frac{F_{avg}}{m_{total}} - g)t^2 \tag{8}$$

$$x_{apogee} = \frac{F_{avg} \cdot x_{burnout}}{g \cdot m_{burnout}} \tag{9}$$

Using equations 6 through 9, a simplified impulse against thrust curve can be created. This shows the requirements for the launch vehicle at a given weight for what impulse is necessary to reach the target apogee, as mentioned in Section 4.3. The performance curve is shown in Figure 4.12, where it is assumed that 10% of the mass of the launch vehicle is propellant mass.

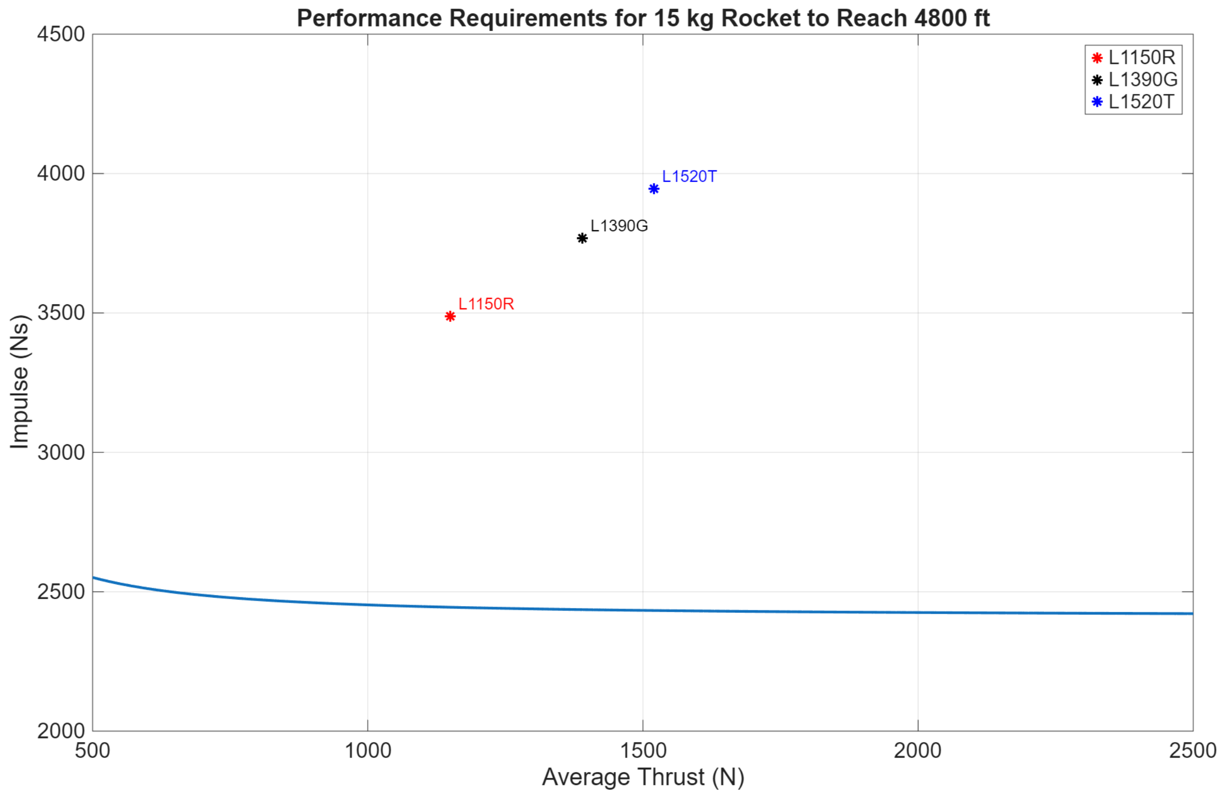

Figure 4.12: Performance Curve: Impulse vs Thrust

Each motor displayed in Figure 4.12 meets requirements 2.10.1 through 2.10.4, and the length restrictions due to the Air Brakes assembly sitting 4.5 in deep into the top of the fin can. Furthermore, it is clear from figures 4.10 and 4.12 that the two motors suited for use will be either the AeroTech L1390G or AeroTech L1520T. Both motors let the launch vehicle overshoot the target apogee by 200 ft or more for Air Brakes to have tolerance for deployment.

More robust simulations will be done in OpenRocket, which accounts for drag, air resistance, orientation, and other factors that the simple model can not. These will give a better understanding of the motor performance for the launch vehicle and ultimately final motor selection.

4.6 Payload Design

4.6.1 Payload Requirements

Table 4.7: 2025-2026 Payload Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
4.1	After landing, teams SHALL autonomously collect and retain a soil sample of at least 50 milliliters.	The Payload team will design a payload that can autonomously collect 50 mL of soil from the landing site.	Demonstration	Payload Team
4.1.1	All soil collection and analysis must be completed within 15 minutes of landing.	The Payload team will design the payload such that it will collect the soil sample within 15 minutes of the launch vehicle landing.	Demonstration	Payload Team
4.2	Teams SHALL autonomously test the collected sample for at least one of the following: Nitrate-Nitrogen content, pH level, or electrical conductivity	The Payload team will design the Payload such that it is able to autonomously test the soil sample for its Nitrate-Nitrogen content, pH level, and Electrical Conductivity,	Demonstration	Payload Team
4.2.1	Analysis results SHALL include time stamps for verification.	The Payload will be programmed such that it includes timestamps for every important Analysis result.	Demonstration	Payload Systems lead
4.2.2	The results of these tests SHALL be included in the PLAR. Preliminary results SHALL be made available for confirmation by the NASA Student Launch management team at the competition launch.	The Payload team will extract and document all analysis from any tests conducted by the payload in the PLAR Document.	Demonstration	Payload Team

Table 4.7: 2025-2026 Payload Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
4.4	The HAUS's structure SHALL include an atmosphere isolated compartment to serve as living quarters for 4 STEMnauts. The compartment SHALL be enclosed and separated from the external atmosphere; No additional requirements for "living conditions" are included, but teams are encouraged to consider appropriate accommodations the STEMnauts may need for an extended excursion on a lunar or planetary body. STEMnauts are assumed to have all the qualities typical of astronauts. It is up to teams to be creative in how to depict their four STEMnauts in the HAUS design. "Atmosphere isolated compartment" means the living quarters must be enclosed and separated from the external atmosphere. Pressure equalization holes are exempt from this isolation requirement.	The Payload Structures Lead will design a HAUS enclosure to serve as living quarters for 4 STEMnauts. The HAUS enclosure will be separate from the external atmosphere, with a hole to equalize pressure if deemed necessary.	Inspection	Payload Structures
4.4.1	The HAUS enclosure SHALL not incorporate or rely on the structural airframe (including couplers) of the launch vehicle to meet requirement 4.4.	The Payload Structures Lead will design the HAUS enclosure such that it does not incorporate or rely on any structural components of the launch vehicle.	Inspection	Payload Structures
4.5	The STEMnauts SHALL be safely retained within the HAUS during flight (no alternative launch seating or location is permitted).	The Payload Structures Lead will design the HAUS enclosure such that all STEMnauts are safely retained during the flight.	Inspection	Payload Structures
4.6	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 Structures Lead will design the Payload such that there are no protrusions that extend more than a quarter inch outside the exterior of the airframe.	Demonstration	Payload Structures
4.7.1	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 team will design the Payload such that it does not use Black Powder or any other similar energetics for any surface operations of the Payload.	Inspection	Payload Team

Table 4.7: 2025-2026 Payload Requirements

NASA Req No.	Requirement Statement	Planned Action	Verification Method	Subsystem Allocation
4.7.2	Any UAS weighing more than .55 lbs. SHALL be registered with the FAA and the registration number marked on the vehicle.	The Payload team will register any UAS that weighs more than .55 lb with the FAA and will follow all rules and regulations set by the FAA, including labeling and markings on the UAS.	Inspection	Payload Team

4.6.2 Projected Designs

Deploying Driller

The Deploying Driller payload design is a fully deployable craft that will orient itself after landing. It will use a set of four extending legs on the sides of the craft, connected to and deployed by a linkage and collar assembly, to go from a horizontal to a vertical orientation, allowing the payload to drill straight down out of an opening in the base of the craft. The STEMnauts will be seated in an atmosphere-isolated compartment at the top of the payload.

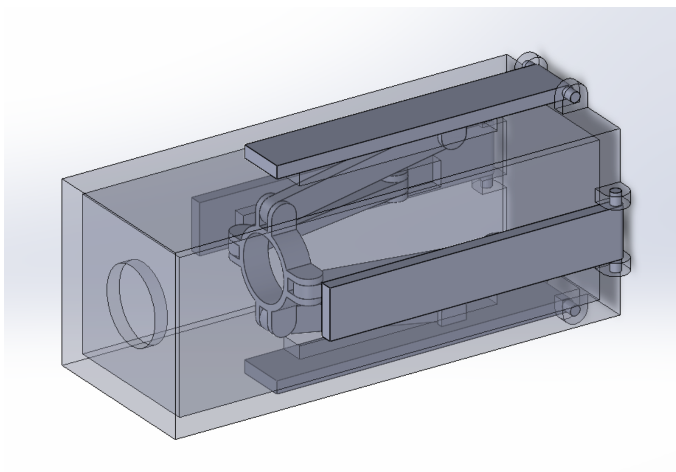

Figure 4.13: CAD Model of Deploying Driller in Initial Landed Configuration

The payload will separate from the rocket at the main parachute deployment and will descend under its own parachute. After landing, the payload will be assumed to be resting on one of its sides, with the drill pointed parallel to the ground, as seen in Figure 4.13. Four legs will fold out, hinging from the base of the craft, and push the craft upright until the legs are parallel to the base of the craft and flat against the ground, as shown in Figure 4.14. Once this process is complete, the payload will be fully upright and can proceed with drilling operations.

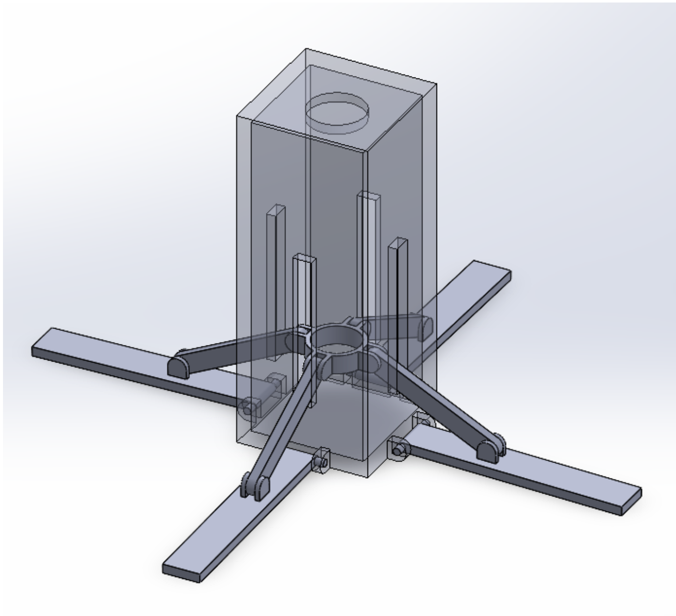

Figure 4.14: CAD Model of Deploying Driller in Upright Drilling Configuration

Mounted Nosecone Design

The Mounted Nosecone design remains inside the rocket after landing. Similar to the design above, the mounted nosecone payload uses a drill to collect soil samples. The rotating section containing the drill will be placed inside the nosecone for space and weight efficiency. The STEMnauts will be sealed in an atmosphere-isolated compartment at the top of this payload forward of the electronics. To ensure the drill is pointed at the ground, part of the payload will be rotated using an electric motor connected to a gear. The rotating portion will be placed on paired thrust bearings to minimize friction. The rotating section is positioned on the opposite side of the coupler section from the nosecone. This means it will be exposed after separation and remain exposed on the ground. After landing, an accelerometer and magnetometer will be used to detect the "down" direction, and the motor will rotate the payload accordingly. A drill will then be deployed through a pre-cut hole in the payload structure.

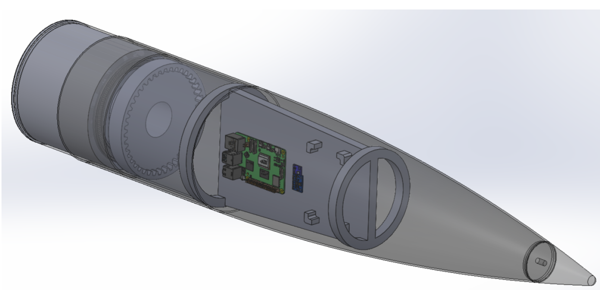

Figure 4.15: Mounted Driller Isometric View

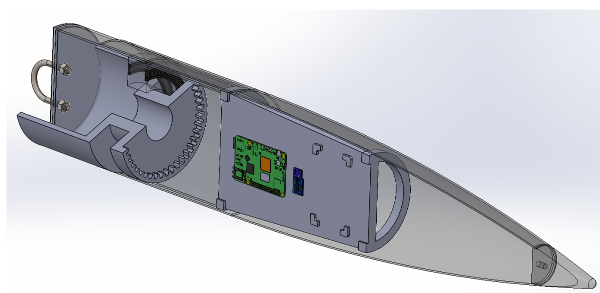

Figure 4.16: Mounted Driller Section View

Drill Design

Regardless of which design is used, a similar drill concept will be incorporated. The drill will consist of two parts: a tube and a screw. The tube will be used to hold loose soil on the screw as the screw rotates to collect soil inside the payload. The tube will also rotate, allowing serrated teeth on the bottom of the tube to cut into hard dirt, loosening it and allowing easier collection for the screw.

At the top of the screw is a fixed wall that funnels dirt into a designated container. The soil sampling sensor will already be positioned in the container to be covered with dirt. This allows for simple and consistent testing of pH, nitrate-nitrogen content, and electrical conductivity.

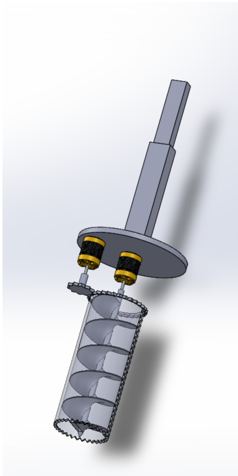

Figure 4.17: Deployable Drill with Linear Actuator

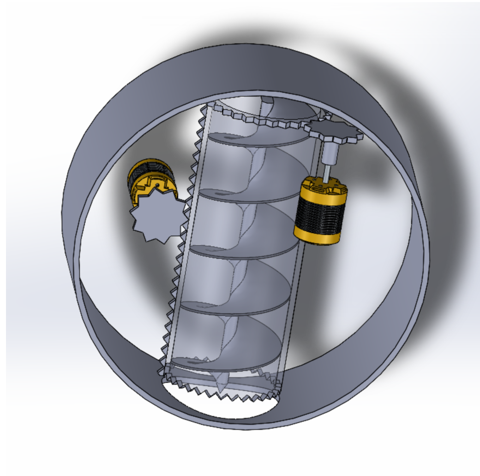

Figure 4.18: Mounted Drill in Body Tube

The Deployable Driller payload will use the drill in the configuration shown in Figure 4.17. A linear actuator at the top will extend the entire drill assembly down. This will include a motor to spin the drill and a motor to spin the tube.

The Nosecone Mounted payload will use the drill in the configuration, as seen in Figure 4.18. This design incorporates a motor to extend the drill out of a hole in the body tube. Another motor will rotate the drill tube and screw as one.

Payload Electronics Design

The payload will use launch and landing detection to automatically begin the dirt sampling process. To detect landing, a barometer, accelerometer, and magnetometer will be added to the electronics sled. This is to determine the altitude and orientation of the payload post-launch. To measure the properties of the soil, the payload will utilize a probe sensor, shown in Figure 4.19, that will be covered in the soil for measurement. The sensor will measure nitrogen levels, pH, and electrical conductivity. Having the probe measure all of the target properties is advantageous because it will reduce the form factor of the sensing equipment.

Figure 4.19: Crisis 7-in-1 Soil Tester

For dirt collection, a stepper motor will be used to control the drilling process, while a servo will control the raising and lowering of the drill head. For the Deploying Driller design, a linear actuator would control the position of the legs. Alternatively, the Mounted Nosecone design would have a servo control the rotation of the drill head so it points in the correct direction before drilling. All sensors and motors will interface with a Raspberry Pi 5 that will handle all of the on-board processing.

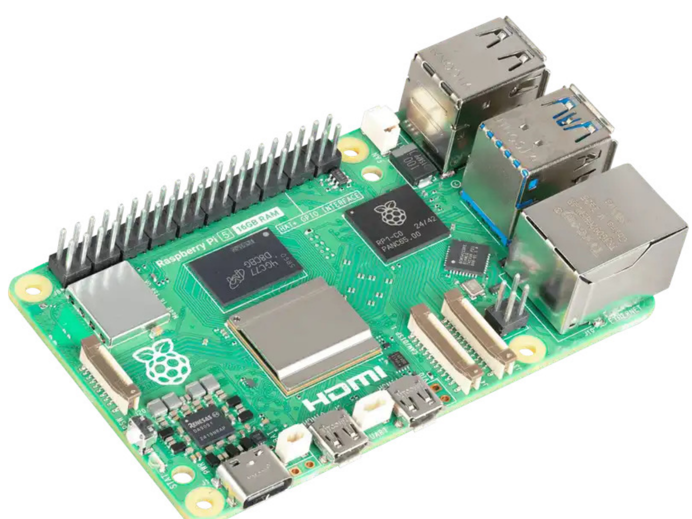

Figure 4.20: Raspberry Pi 5

Figure 4.21 details how all of the electronic components will interact with the Raspberry Pi on board the payload. All processes on the field will be designed to be fully automated, and data will be stored on the Raspberry Pi for analysis.

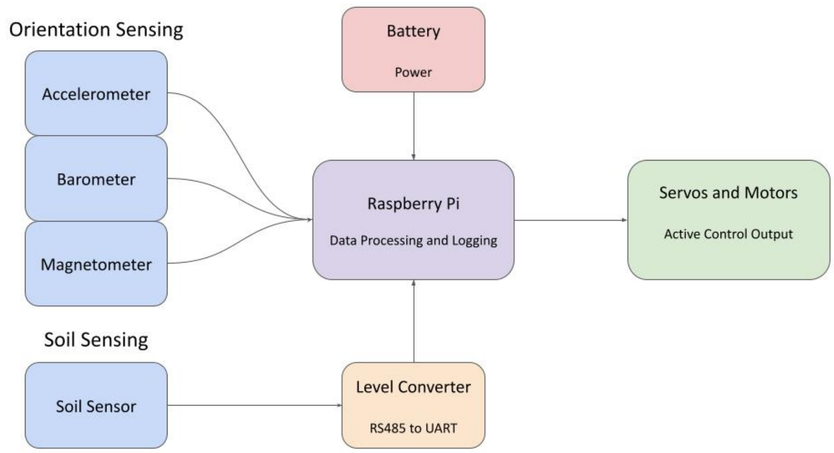

Figure 4.21: Diagram of Electronics Interfacing with Raspberry Pi 5

Alternative Design Solutions

An alternative solution is to have the payload deploy on the ground, either partially or fully. A fully deployed payload will function similarly to the lander concept above, but will remove the necessity for a parachute. The payload will be fixed to a threaded rod, which will be rotated to push the payload out of the rocket. Once fully separated, the legs will be deployed to self-right the craft. Drilling will then commence from this upright state.

Another solution is to have the payload partially deploy after landing. During flight, the entire payload is situated within or behind the nosecone coupler, but after landing, the section containing the drill is extended outside the rocket. This is more similar functionally to the rotating retained payload. A motor and a threaded rod will be used to achieve the extension. The motor will be programmed to turn a set number of rotations to ensure the drill section is free, then stop and take an accelerometer reading. The drill will make one final rotation, of varying angular length, to position the drill facing downward. Once the soil is collected, the payload will rotate an additional half rotation so the hole is pointed upward. This will collect the soil on the opposite side of the payload, where it will come into contact with the sensor for analysis.

Other methods for collecting soil were also considered before selecting the drill. These ideas mainly involved using rotating scoops or buckets to bring the soil into a central container. A scoop-based design was not pursued due to the increased reliability and versatility of the drill design across multiple soil conditions, ranging from dry to muddy soil.

4.7 Payload Technical Challenges

4.7.1 Challenges with Deploying Driller Design

One of the main challenges with the Deploying Driller design is a reduced capability to counteract the torque from the drill on the craft itself. Since this design is freestanding from the rocket and must be compact to fit within the rocket for deployment, it will have much less weight behind it than a design that would remain in the vehicle. This may cause the craft to spin around the drill while the payload is drilling into the soil, especially if the soil is muddy or hard. Potential solutions to this problem include adding anchoring methods to the legs or body to counteract the torque.

Another challenge is that the parachute may inflate in the wind after landing, causing the craft to drag along the ground. Ideas to remedy this include reeling in the parachute after landing, detaching a riser after landing so the parachute cannot inflate as easily, and utilizing anchoring methods.

This design will also be larger than the other designs. Space and mass are required for parachute attachments, legs, and additional infrastructure unique to this design. This problem is also present in the design that fully deploys on the ground.

4.7.2 Challenges with Mounted Nosecone Design

The primary challenge with the Mounted Nosecone design is the limited length of the drill. The drill will be perpendicular to the length of the rocket, so the diameter of the payload constrains the length. The body tube, the coupler, the bearing, and the payload structure will all reduce the usable length. A shorter drill would mean less soil can be collected, making it more difficult to achieve the goal of 50 mL. Part of the drill length will also be unused while it sits between the interior of the payload and the ground. This may limit the length of the drill in the ground to two or three inches. Such a drill would have to be very wide to harvest the needed amount of soil. Alternatively, a shorter drill design could rely on repeated extensions into the soil. If the soil is not tightly packed or overly damp, soil may collect at the bottom of a drilled hole. The screw could extend and collect this new soil. This method is not as reliable as a longer drill.

This design may also run into problems with friction between the ground and the rotating section of the payload. If the payload structure is in contact with the ground, it will require increased torque to rotate. This may lead to inaccurate measurements of rotational distance and problems with the deployment mechanism. This issue is also present in the full- and partially-deploying alternate designs.

5 STEM Engagement

5.1 Purpose and Description of STEM Engagement

STEM Engagement or Outreach events are designed to promote new concepts in engineering and STEM to K-12 students with a particular emphasis on aerospace. Teaching K-12 students about STEM provides a valuable opportunity for the club to be involved with the local community and expand the learning opportunities of K-12 students in the area with hands-on learning and presentations. STEM participation allows these students to have a real-world engineering experience and may inspire them to pursue STEM in the future.

For each STEM-related activity event, the club contacts local parks, schools, and other organizations involved in primary education to plan and participate in events. By the end of the event, the club will teach students at least one concept involved in a STEM education. These include, but are not limited to, Newton's laws of motion, composite manufacturing, the engineering design cycle, and aerodynamics. After STEM concepts are taught, the club will follow up with hands-on activities and examples to reinforce learning objectives. For high school students, the club may also help the group launch low powered rockets.

5.2 Community STEM Engagement Plan

Last year, the club engaged with 2,108 students across 18 outreach events planned over the course of the year. This year, the club intends to engage with over 2,200 students while increasing the diversity of educational topics taught to include more topics related to engineering. In order to achieve this target the club will reach out to institutions that the club has had previous relationships with. To increase the diversity of events, the club will be working directly with school teachers and high school clubs in order to achieve desired learning targets. In the fall, the club already has 10 outreach events planned, with a similar amount planned in the spring.

5.2.1 Jordan High School

The club plans to host an event at Jordan High School on October 10th. At this event, the club will be launching bottle rockets and teaching physics students about Newton's third law of motion. After launching the bottle rockets, students will complete a lab in which they calculate the velocity of the fuel (water) using Newton's third law. Students will also be shown a presentation on NASA student launch and high-powered rocketry. The projected attendance for this event is 30 students.

5.2.2 Astronomy Days

Astronomy Days is a two day event in January run by the North Carolina Museum of Natural Science. The club will co-host a table with the Tripoli Rocketry Association, where K-12 students can create straw rockets while learning about STEM concepts, such as aerodynamics and Newton's laws of motion. Along with STEM concepts, the club will talk to students about NASA SL, and how the club uses the engineering design cycle over the course of the year. The projected attendance for this event is 500 students.

TACHO LYCOS

2025-26 Outreach Engagment Timeline

	Aug				Sep				Oct				Nov					Dec			Jan				Feb				Mar					Apr				May			
Event type	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	W41
School Engagment Event										3			5	7				8					9	11			13		15		18										
Muesum Engagment Event																							10						16		19										
Lab Tour					1																						14														
Organization Engagment Event							2																																		
Other													4,6													12				17					20						

Figure 5.1: 2025-2026 Outreach Engagement Timeline

6 Project Plan

Figure 6.1 displays the schedule for the development of the rocket in a Gantt chart style format. This chart includes a subscale launch on November 1st, and a full-scale VDF and PDF on February 21st, 2026. It should be noted that there are backup subscale launch dates on November 15th, 2025, and December 13th, 2025. There are also backup full-scale launches on March 14th, 2026 and March 28th, 2026. The first few weeks of the design cycle were spent solidifying the designs for the payload and vehicle for the Proposal document. Subscale manufacturing will begin after proposal submission, and will be completed two weeks before the launch on November 1st. Payload fabrication will begin in October and will be completed three weeks before the VDF on February 21st. Full-scale manufacturing will begin two weeks after the subscale launch. Full-scale vehicle manufacturing, as well as parachute manufacturing, will also be completed three weeks before VDF to allow adequate time for testing of both systems. The club will work towards vehicle and payload design and construction during established weekly meetings throughout both semesters. Figure 6.2 displays a schedule for completing NASA SL deliverables in the form of a Gantt chart. Documentation will be completed by the Senior Design team members and the Safety Officers during established weekly Senior Design meetings, as well as in their free time. The club will complete the final deliverable by competing in the NASA SL competition in person in Huntsville, Alabama, from April 22, 2026, to April 26, 2026.

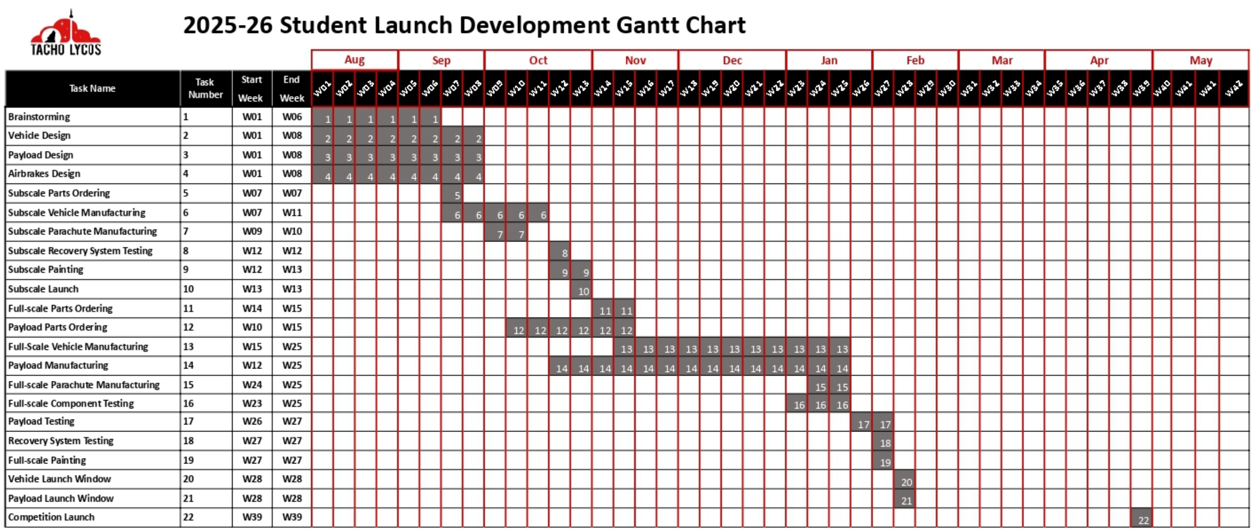

Figure 6.1: Development Gantt Chart

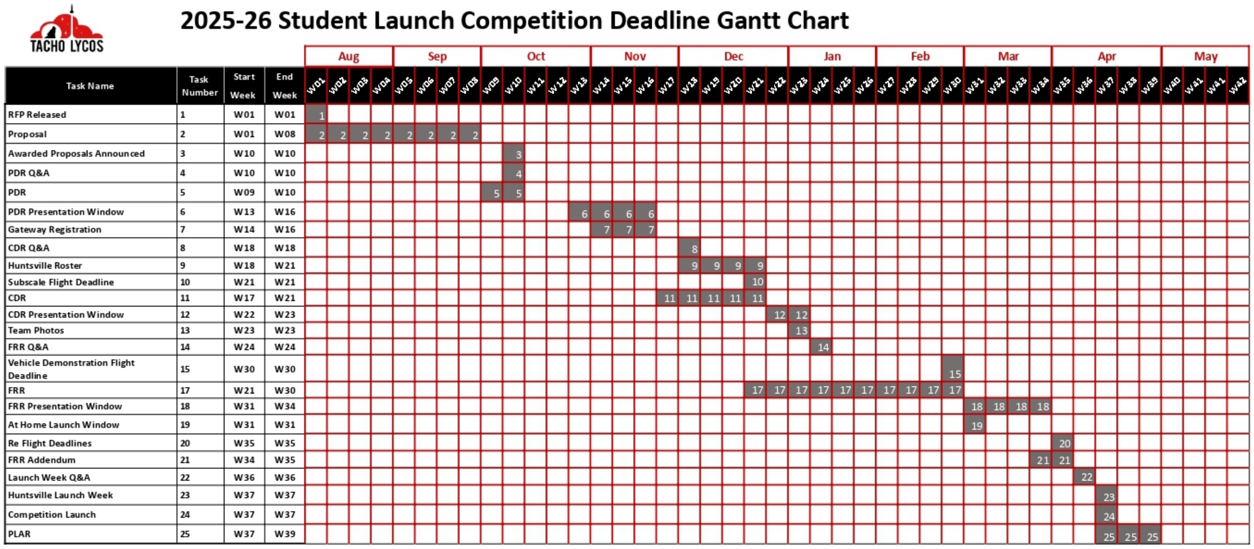

Figure 6.2: Deliverables Gantt Chart

6.1 Budget

Table 6.1 shows HPRC's year-long budget plan for the 2025-2026 academic school year. The table is organized in columns of Item, Vendor, Quantity, Price Per Unit, and Total Item Price. The rows are also grouped according to the club's seven major categories of spending. Highlighted in light gray at the end of each section is the summed total of all the prices for that category. At the bottom of the table, the total for the expenses of the club throughout the year is highlighted in dark gray. All of the items and prices are based on estimates made by the subteam leads and officers regarding what they believe they need for this year's competition vehicle. It is important to note that both the listed items and their prices may change slightly as the design for our rocket is finalized throughout this year. Any changes made could result in alterations to the items needed, the vendors used, and the total amount spent throughout the year.

Table 6.1: 2025-2026 NASA Student Launch Competition Budget

	Item	Vendor	Quantity	Price Per Unit	Item Total
Subscale Structure	8.9 oz/yd^2 S2 Fiberglass Cloth	US Composites	10	$ 9.50	$ 95.00
	5.7 oz/yd^2 Carbon Fiber Cloth	US Composites	5	$ 18.50	$ 92.50
	4 in Light Fiberglass Sleeve	Soller Composites	15	$ 2.50	$ 37.50
	Subscale Motor	Aerotech	2	$ 95.99	$ 191.98
	1/8 in x 6 x 12 Aluminum Plate	McMaster	1	$ 19.16	$ 19.16
	Motor Casing	Aerotech	1	$ 98.86	$ 98.86
	Rail Button	Apogee Rockets	2	$ 4.25	$ 8.50
	1/8 in x 6 x 24 Balsa Wood	Hobby Lobby	2	$ 5.99	$ 11.98
	U-Bolts	McMaster	4	$ 2.50	$ 10.00
	Screws	McMaster	4	$ 5.23	$ 20.92
	PLA Filament	Bambu	2	$ 15.99	$ 31.98
				Subtotal:	**$ 618.38**
Full Scale Structure	6 in. Nosecone 4:1	PH	1	$ 159.99	$ 159.99
	8.9 oz/yd^2 S2 Fiberglass Cloth	US Composites	25	$ 9.50	$ 237.50
	Full-scale Motor	Aerotech	3	$ 272.68	$ 818.04
	1/8 in x 6 x 12 Aluminum Plate	McMaster	1	$ 19.16	$ 19.16
	Motor Casing	Aerotech	1	$ 526.45	$ 526.45
	Large Rail Button -1515	Apogee Rockets	2	$ 4.25	$ 8.50
	U-Bolts	McMaster	4	$ 6.50	$ 26.00
	Double Pull Pin Switch	Apogee Rockets	1	$ 20.35	$ 20.35
				Subtotal:	**$ 1815.99**
Payload	Barometric Pressure Sensor	Adafruit	2	$ 6.95	$ 13.90
	Magnetometer	Adafruit	2	$ 5.95	$ 11.90
	NPK Sensor	DFRobot	1	$ 59.00	$ 59.00
	pH & Electrical Conductivity Sensor	DFRobot	1	$ 62.00	$ 62.00
	Milling Aluminum	General	1	$ 19.99	$ 19.99
	Thrust Bearings	General	4	$ 24.99	$ 99.96
	Servo Motor	Amain Hobbies	3	$ 54.99	$ 164.97
	Linear Actuator	Vevor	1	$ 25.56	$ 25.56
	Raspberry Pi 5	Sparkfun Electronics	1	$ 88.00	$ 88.00
	PETG Filament	Bambu	1	$ 29.99	$ 29.99
	Structural/Housing Materials	General	1	$ 300.00	$ 300.00
				Subtotal:	**$ 875.27**

Table 6.1: 2025-2026 NASA Student Launch Competition Budget

	Item	Vendor	Quantity	Price Per Unit	Item Total
Recovery and Avionics	1 yd Ripstop Nylon	Emma Kites	15	$ 7.95	$ 119.25
	6 in. Deployment Bag	Fruity Chutes	1	$ 54.40	$ 54.40
	4 in. Deployment Bag	Fruity Chutes	1	$ 47.30	$ 47.30
	18 in. Nomex Chute Protector	Wildman Rocketry	1	$ 10.95	$ 10.95
	12 in. Nomex Chute Protector	Wildman Rocketry	1	$ 8.95	$ 8.95
	Kevlar Shock Cord	Chris' Rocketry	25	$ 1.30	$ 32.50
	Quick Links	McMaster-Carr	6	$ 8.28	$ 49.68
	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
	WAGO Lever Wire Connector	Grainger	50	$ 0.67	$ 33.50
				Subtotal:	**$ 425.73**
Miscellaneous	Paint	Krylon	6	$ 20.00	$ 120.00
	Birch Plywood 1/8 in.x2x2n	Rockler	6	$ 14.82	$ 88.92
	635 Epoxy Resin	US Composites	1	$ 185.30	$ 185.30
	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
	Estimated Shipping				$ 1,000.00
	Incidentals (replacement tools, hardware, safety equipment, etc.)				$ 1,500.00
				Subtotal:	**$ 3,049.07**
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	$ 20.00	$ 1000.00
	Polos	Core365	20	$ 26.00	$ 520.00
				Subtotal:	**$ 1,520.00**
				Total Expenses:	**$ 18,998.10**

6.2 Funding Plan

The High-Powered Rocketry Club receives financial support from several NC State University resources as well as from the North Carolina Space Grant (NCSG). Each source contributes in different ways, and together they provide the foundation for the team's budget during the 2025–2026 academic year.

NC State's Student Government Association (SGA) allocates funding to more than 600 student organizations, including the club. At the start of each semester, the club submits an application outlining anticipated expenses, and SGA distributes funds based on those requests. For this academic year, the club will apply for $2,000 in both the fall and spring semesters. Despite these requests, the team expects to receive about $796 per semester, consistent with previous years. In the fall, these funds are typically devoted almost entirely to the subscale rocket, with little left over for full-scale materials. During the spring semester, SGA allocations usually support the purchase of remaining materials.

Additional funding comes from the College of Engineering Enhancement Funds through the Engineer Your Experience (EYE) department, which primarily supports engineering-related travel. All student travel expenses to Huntsville will be covered by this source. Based on the previous year's costs, the club estimates receiving approximately $8,500 this year to cover travel.

The Educational and Technology Fee (ETF) also provides funding aimed at enhancing academic experiences through student organizations. For the 2025–2026 academic year, the club expects to receive $3,500. These funds will be used for lab and safety equipment, as well as for covering the travel and lodging expenses of the team's faculty advisors during the Huntsville trip.

Beyond university sources, the North Carolina Space Grant (NCSG) provides a significant share of the team's resources. The club must apply in the fall semester for up to $5,000 in funding to support participation in the NASA SL Competition. The club has consistently received the maximum award in previous years, and the same outcome is expected for 2025–2026. These funds, typically available in November, are used primarily for the construction of the full-scale rocket and payload.

Sponsorships also supplement the team's budget. In the past, the club has received support from companies such as Collins Aerospace, Jolly Logic, and Fruity Chutes. The team continues to reach out to both new and past sponsors, though contributions are more commonly offered in the form of in-kind donations or discounts rather than direct financial support. For this academic year, the team anticipates receiving approximately $500 in goods and discounts, with the possibility of additional support as more sponsorships are secured.

All projected funding sources and allocations are summarized in Table 6.2, which provides a full overview of the expected revenue and expenditures for the 2025–2026 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	$8,500	$8,500
Educational and Technology Fee	$3,500	$0	$3,500
Sponsorship	$250	$250	$500
Total Funding:			**$19,092.00**
Total Expenses:			**$18,998.10**
Difference:			**$93.90**

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