Rose Rocketry

NASA Student Launch Proposal

Project Kirkpatrick

Rose-Hulman Institute of Technology

Sept. 19, 2022

5500 Wabash Ave, Terre Haute, IN 47803

Contents

Table of Acronyms

Acronym	Definition
RR-SL	Rose Rocketry - Student Launch
BIC	Branam Innovation Center
KIC	Kremer Innovation Center
SL	Student Launch
NASA	National Aeronautics and Space Administration
FAA	Federal Aviation Administration
NAR	National Association of Rocketry
HPR	High Powered Rocketry
PPE	Personal Protection Equipment
PDR	Preliminary Design Review
TRA	Tripoli Rocket Association
LRR	Launch Readiness Review
FRR	Flight Readiness Review
CDR	Critical Design Review
CG	Center of Gravity
CP	Center of Pressure
RF	Radio Frequency
AGL	Above Ground Level
STEM	Science Technology Engineering and Math
SGA	Student Government Association
RSO	Range Safety Officer
GPS	Global Positioning System
IMU	Inertial Measurement Unit
APCP	Ammonium Perchlorate Composite Propellant
FIRST	For Inspiration and Recognition of Science and Technology
FRC	FIRST Robotics Competition
OTFR	One Time Funding Request
SBC	Single Board Computer
LiPo	Lithium Polymer Battery
APRS	Automatic Packet Reporting System
SDR	Software Defined Radio

1. General Information

1.1. Team Summary

Rose Rocketry houses a collegiate competition team, a research organization, and an enthusiast's hub with the aim to prepare students for a career in the aerospace industry. We compete in NASA Student Launch (SL), are developing research in space science, and provide members resources to complete their high-powered rocketry certification. The Rose Rocketry Club aims to provide students with hands-on technical experience in order to propel Rose's reputation among industry leaders and other universities.

The team has dedicated our project to our former advisor, Dr. Scott Kirkpatrick. Dr. Kirkpatrick served as team advisor for the last two years and was instrumental to the formation of the Rose Rocketry Club and our NASA Student Launch team.

Table 1.1: Project Summary

Team Name	Rose Rocketry
Project Name	Project Kirkpatrick
Mailing Address	5500 Wabash Ave, Terre Haute, IN 47803
NAR/TRA Sections	Indiana Rocketry Group Tripoli #132 NAR Section #711
Mentor	Randy Milliken randy@milliken.org NAR#86429 - Level 3
Adult Educator	Elaine Kirkpatrick kirkpatr@rose-hulman.edu 812-841-3949
Student Leader	Sam Betts bettssr@rose-hulman.edu 330-835-8351

1.2. Student Leaders

The Rose Rocketry Student Launch (RR-SL) team operates within the Rose Rocketry Club on campus, which was approved by the institution's Student Government Association (SGA). The student officer positions outlined below will act as key project managers and technical personnel.

Table 1.2 Student Officer Positions

Position	Name	Contact
Club Advisor	Dr. Elaine Kirkpatrick	kirkpatr@rose-hulman.edu
President	Sam Betts	bettssr@rose-hulman.edu
Vice President	Chirag Sirigere	sirigecj@rose-hulman.edu
Safety Officer	Ben Graham	grahambd@rose-hulman.edu
Public Affairs Chair	Gabriel Woller	wollergf@rose-hulman.edu
Treasurer	Garret Hart	hartgl@rose-hulman.edu
Secretary	Everest Zang	zangs1@rose-hulman.edu

Table 1.3 Student Size and working hours

Number of Students	30
Number of Hours on Proposal	290

1.3. Team Organization

The RR-SL team consists of 20 new students and 10 returning for the 2022-2023 season. The Rose Rocketry Club President is the competition project manager and is responsible for creating and maintaining a project plan throughout the season. The Rose Rocketry Club Vice President is the lead technical manager for the competition. The Vice President is responsible for ensuring each team member has meaningful work and each subteam has the resources they need to be successful. The Treasurer is responsible for tracking the team budget and project plans, and will communicate current project status to the President. The Safety Officer will be responsible for maintaining and enforcing the safety plan and prosiding over all team launches. Subteam leads will be appointed by the Vice President and will be responsible for creating and maintaining project plans for their individual subteams. Subteam leads will be responsible for communicating with the Rose Rocketry Club officers, specifically the Treasurer, to ensure they are meeting mission cost and time constraints. Subteams will be officially formed, and a lead appointed, according to the project plan in Section 6**.** Below in Figure 1.1 is a diagram of key team personnel and structure. Other student officer positions not mentioned have key roles in the club, but no official role in the NASA SL team.

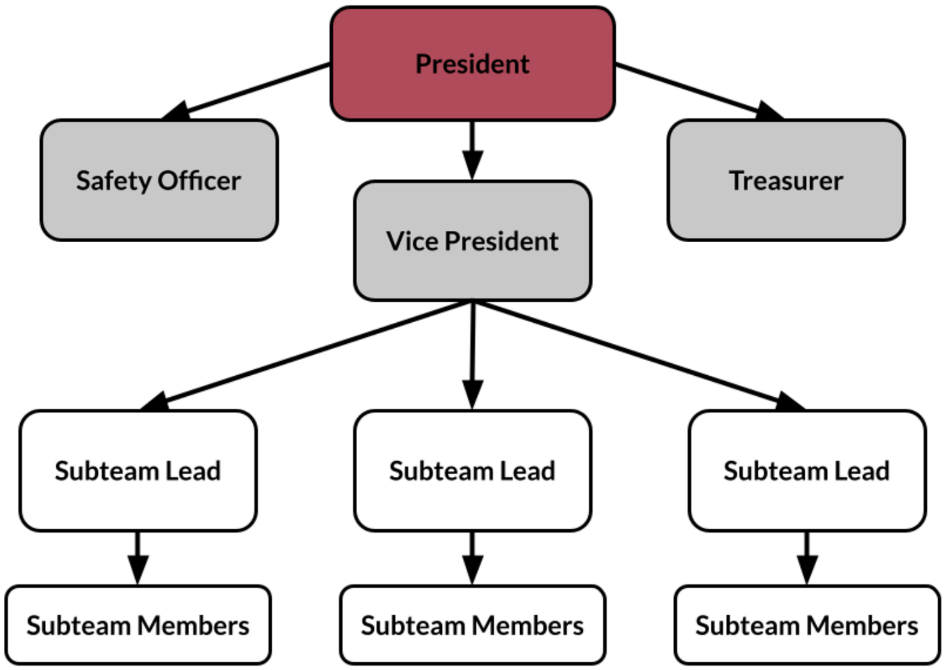

Figure 1.1: Team Organization

2. Facilities/Equipment

The RR-SL team has a dedicated workspace in the Branam Innovation Center (BIC) shown in Figure 2.1. The Branam and Kremer Innovation Centers (KIC) are two state-of-the-art workspace facilities that provide the resources necessary to support individual engineering projects, large-scale engineering competition teams, and senior capstone projects.

The workspace is 18 by 13 ft and contains storage shelves, tool shelves, workbenches, and movable tables. The team has standard power tools and hand tools as well as raw materials and a soldering station. More general tools and materials including routers, pipe cutters, and sandpaper are provided for community use by the BIC and KIC.

Figure 2.1: Rose Rocketry Workspace

The BIC and KIC are managed and maintained by dedicated employees of the university, who impose a standard set of rules regarding health and human safety. All students are required to wear PPE including safety glasses, closed-toed shoes, and long pants while in a workspace. To obtain access to the BIC/KIC, each student must pass a safety training course which covers basic operational safety, environmental health & safety practices, and 5S practices. Supervised access hours are limited to 8 A.M-12 A.M during the week and 10 A.M - 12 A.M on weekends. Additional training enables students 24-hour unsupervised access to the main work spaces in BIC/KIC. This training focuses on liability and safety. Between the BIC and KIC, there are two machine shops: one for metal and one for wood. To gain metal machine shop access, students are required to complete a scheduled 12-hour training program with an expert instructor. Upon completion, students gain access to machine shop equipment, including lathes, drill presses, mills, and other machinery. The wood shop has a 4-hour training program of similar structure. All machine shop use requires partner work and can only be accessed during supervised hours. Machine shop and power tool use, with the exception of hand drills, are strictly forbidden during unsupervised hours for students with 24/7 access. This information is summarized in **Table 2.1**.

In contrast to the 2021-2022 season, we are starting the year with all necessary tools and equipment. The team is starting the season with some raw stock and materials on hand from last season. We have already ordered and received many consumables needed for the entire season such as assorted wire, G10 fiberglass sheets, nylon screws, common electronic sensors, plywood, etc. Generally, due to experiences from last season and the increased scarcity of parts, the team is prioritizing ordering parts earlier in the season.

Table 2.1: BIC and KIC General Overview

Hours of Operation	Weekdays: 8 AM - 12 AM Weekends: 10 AM - 12 AM
Required Personnel	One BIC/KIC service desk attendant and one additional team member
Necessary Equipment	Drill press, table saw, band saw, lathe, milling machine, sanding and painting ventilation booth, electronics lab, wind tunnel, 3D printers, common hand tools, common power tools, waterjet,
Safety Precautions	Entry level safety program, proper PPE usage, 5S training program, on duty BIC/KIC supervisor
General Use	All vehicle/payload manufacturing and assembly, in-person update meetings

3. Safety

The RR-SL team's top priority is the safety and well-being of our members. All the safety protocols of the BIC/KIC facilities and the campus-wide policies are used to ensure student health and safety are kept at top priority. This includes the current policies for COVID-19.

3.1 Safety Plan

3.1.1 COVID-19

We follow the university's guidelines for COVID-19. The document Rose-Hulman created outlines advice for preventing illness and the campus policies for what to do if you do test positive for COVID-19. All information on these guidelines is found on Rose-Hulman's Rose-Ready website:
https://www.rose-hulman.edu/about-us/community-and-public-services/health/Rose-Ready.pdf.

3.1.2 Materials Safety

The risk posed by the materials used throughout the season will be evaluated utilizing the risk assessment matrix detailed in the sections below. All handling of materials associated with the rocket will occur within the designated work areas inside the BIC/KIC and with the necessary supervision. Additionally, we will make use of the resources provided by the BIC/KIC for the handling and storage of hazardous materials. This includes the use of a designated chemical storage cabinet, a fire cabinet, a ventilated paint booth, and a ventilated sanding booth. We utilize gloves and masks for any materials that can cause short- or long-term harm. Safety training is offered to members beforehand to ensure that new members are aware of the safety statement before proceeding forward. The safety chair will be responsible for briefing all team members on any and all potential material hazards. Additionally, the safety officer will conduct training presentations at the start of each year, as well as additional sessions as necessary for any students who join the team mid-season, to ensure that all members understand the dangers presented by materials before working with them.

3.1.3 Facility Safety

All team members must complete safety training before their student ID card will allow them access to our workspace (the BIC and KIC). Additionally training courses, taught by expert instructors, must be taken before a student's ID card will allow them into any of the machine shops. Additionally, the BIC and KIC are supervised 8AM to midnight on weekdays and 10AM to midnight by either adult supervisors, trained student workers, or both. See section 2.0 for a detailed description of the safety and usage of the BIC and KIC.

3.1.4 Safety Officer

Ben Graham has been designated as the safety officer for the 2022-23 academic year. This position is strongly encouraged to be L2 certified with NAR, which Ben is. The safety officer is responsible for holding all team members accountable for the safety measures listed in this section. In support of this, the safety officer will be responsible for updating and maintaining all safety rules and documentation, training new members on safe construction techniques, and overseeing all ground-testing and launches. The safety officer (or an equally knowledgeable member under guidance of the officer) must be present at any meetings involving fabrication and will both conduct a team safety briefing as well as audit the fabrication process to ensure compliance with the designated safety practices for the task.

3.2 Hazards Assessment

The risks involved in this project are assessed along two axes: the probability of an event occurring and the severity of the given event. These are tabulated in **Table 3.1**, **Table 3.2, and Table 3.3**, where Table 3.3 displays the combined data from Table 3.1 and Table 3.2 to provide a proper risk assessment matrix.

Table 3.1: Probability of Event

Category	Value	Description
Improbable	1	Less than 10% chance
Unlikely	2	10-35% chance
Possible	3	35-65% chance
Likely	4	65-90% chance
Probable	5	Greater than 90% chance

Table 3.2: Severity of Event

Category	Value	Human Impact	Equipment Impact	Mission Impact
Negligible	1	Minor or none	Minor or none	No disruption
Marginal	2	Minor injury	Minor damage	Proceed with caution
Moderate	3	Moderate injury	Repairable equipment failure	Flight delayed until event resolved
Critical	4	Serious injury	Partially irreparable equipment failure	Flight does not proceed until system replaced
Catastrophic	5	Life threatening or debilitating injuries	Failure resulting in total loss of system or equipment	Flight canceled or destroyed

Table 3.3: Mapped Risk Assessment Matrix

		Severity				
		Negligible	Marginal	Moderate	Critical	Catastrophic
Probability	Improbable	1	2	3	4	5
	Unlikely	2	4	6	8	10
	Possible	3	6	9	12	15
	Likely	4	8	12	16	20
	Probable	5	10	15	20	25

3.2.1 Materials and Fabrication Hazards

Table 3.4 shows the analysis of the risks to personnel associated with fabricating the launch vehicle before mitigation, as well as the plan for mitigating each hazard. The risks are assessed as described in **Section 3.5** based on their likelihood and the severity of their consequences.

Table 3.4: Materials Hazard Risk Assessment Matrix

Hazard	Probability	Severity	Risk	Mitigation
Entanglement with machines	3 (Improper use of machinery, machinery failure)	5 (Severe lacerations, fatal injuries)	15	Use PPE, follow dress codes in machine shops, safety training
Eye irritation	3 (Solder and epoxy fumes, flying debris, airborne particles)	4 (Possible temporary vision loss, blindness)	12	Wear proper PPE, limit exposure time to epoxies and chemicals, work in BIC ventilation both when necessary
Fumes	4 (Working with inadequate ventilation, epoxy handling, other BIC/KIC)	3 (eye irritation, lung irritation, lightheadedness, shortness of breath, and nausea, possible nerve damage)	12	Maintain proper PPE when working with fuming materials or maintain a safe distance from fuming materials in a well-ventilated environment
Improper use of tools	3 (Use of BIC/KIC machine shop, soldering irons)	4 (Damage to equipment, deep lacerations, burns, amputations)	12	Members could either ask BIC/KIC personnel or the team Safety Officer before using high-risk tools, or attend BIC safety training. Members are expected to adhere to BIC guidelines for tool safety and certification;
Fire	2 (flammable substance, mishandling of equipment, improper wiring)	5 (Severe burns, loss of part or project)	10	Store flammable substances in flammables cabinet, fire extinguisher placed nearby, test circuitry before use.
Airborne particles and chemicals	3 (sanding dust, metal shavings, paint, aerosols, etc)	3 (Skin laceration or irritation, eye damage, particle inhalation)	9	Proper use of PPE and safety training, use workspace ventilation as needed.
Fiberglass	3 (Air borne particles created during fabrication)	3 (Respiratory issues, skin irritation, splinters)	9	Wear N95 respirators during fabrication, work in a well-ventilated space
Hearing Damage	3 (Use of BIC/KIC machine shop, loud power tools, other BIC/KIC teams)	3 (Increased rate of higher frequency hearing damage)	9	Use proper PPE, maintain a safe distance from active machinery

Electric Shock	2 (Improper wiring, device failure, test equipment misuse)	4 (Part damage, mission delays, personal injury)	8	Members will never work alone and must be trained on electrical equipment
Epoxy Contact	4 (environmental contamination, broken PPE, resin spill)	2 (skin irritation, eye irritation, burns)	8	Discard broken PPE, limit exposure, wear proper PPE, train new members on epoxy handling
Falling tools or materials	2 (Mounting failure, improper use of storage racks)	4 (Tool damage, storage rack damage, personal injury)	8	Store frequently used tools in easy to access locations, adhere to 5S
Flying debris	2 (Improper use of machinery, machinery failure)	4 (Blunt force trauma, lacerations)	8	Maintain a safe distance from machines under operation, wear proper PPE, ensure those working on machinery are properly certified by the BIC
Soldering burn	4 (Lack of attention, improper procedure of safety before soldering)	2 (Low temperature solder is most often used, leading to minor burns only)	8	Perform soldering only on stable surfaces and in proper lighting; use tweezers or "helping hands" to hold components; ask assistance from BIC personal before soldering
Hazardous Waste	2 (Improper handling of chemicals, spills)	3 (Abrasion, moderate skin burn)	6	Ensure proper use of chemical handling equipment (chemical storage cabinets, containers, etc.)
Tripping Hazard	2 (Items left in walkway, electrical cords loose, uneven terrain)	3 (Injury from collision with other workspace items, damage to equipment)	6	Keep walkways clear of obstacles; avoid placing cords across walkways and securely tape down any that must; make all members aware of field conditions for launch events

3.2.2 Operational Hazards

Table 3.5 shows the analysis of the risks to personnel and the project associated with launching the rocket, as well as the plan for mitigating them. Similar to **Table 3.4**, the risks are assessed based on their likelihood and consequences.

Table 3.5: Operational Hazard Risk Assessment Matrix

Hazard	Probability	Severity	Risk	Mitigation
Unsuccessful Staging	3 (Improper rocket assembly, improper component packing)	5 (Partial or complete destruction of the vehicle and/or payload)	15	Inspect vehicle construction and component packing before launch
Catastrophic Misfire	2 (Structural weakness in the motor, tipped during launch)	5 (Complete destruction of the vehicle and payload)	10	Examine motor before vehicle launch, ensure proper setup of vehicle before launch
Loss of Control	2 (Broken or damaged fins)	5 (Partial or complete destruction of the vehicle and/or payload)	10	Inspect flight control components before vehicle launch
Recovery System Failure	2 (Improper assembly of recovery devices, parachute entanglement)	5 (Partial or complete destruction of the vehicle and/or payload)	10	Inspect construction of recovery devices before launch
Airborne Debris	3 (High wind speeds, systems on the rocket breaking mid-flight)	3 (Blunt force trauma, lacerations)	9	Maintain a reasonable and safe distance from energetic devices
Dehydration	3 (failure to drink enough fluids, prolonged exertion)	3 (Thirst, dry mouth, headache, muscle cramps, fatigue, fainting)	9	Ensure all team members are properly hydrated, distribute water to team members at launch events
Heat Stroke	3 (Prolonged exposure in a high-temperature environment)	3 (Possible hospitalization)	9	Ensure team members limit exposure to dangerously high temperatures
Safe Misfire	2 (Improper motor construction, motor casing flaw)	4 (Partial destruction of the vehicle and/or payload)	8	Mentor will perform motor reloading cautiously
Radio Telemetry Failure	2 (Interference, electronic failure)	2 (Reduced possible methods of payload locating)	8	Thoroughly test transmission equipment prior to flight

Launchpad Fire	2 (flammable debris blown across launch pad, flammable fuel spilled)	3 (Heat damage to parachute, motor, electronics)	6	Remove brush, dry debris, and other flammables around the launch pad area and have a fire extinguisher on hand
Hypothermia & Frostbite	2 (Failure to wear appropriate clothing)	3 (Possible hospitalization)	6	Ensure team members limit exposure to dangerously low temperatures; check weather forecasts ahead of launches if low temperatures are predicted
Injury from Falling Objects	1 (faulty parachute ejection, severe winds	5 (Blunt damage to the rocket or payload, concussion, fractured skull, death)	5	Keep a close eye on the vehicle or have someone spot the vehicle for those who are unable
Personnel Injury from Terrain	2 (Uneven footing, potholes, nails, etc.)	2 (Sprained or broken ankles, small puncture wounds)	4	Watch footing around terrain, travel with at least one person
Contact Burns	1 (Contact with motor after flight, standing too close to the launchpad)	4 (Mild to severe burns)	4	Proper handling of the rocket will be used

3.2.3 Project Hazards

Table 3.6 shows the general risks to the success of the project.

Table 3.6: Project Hazard Risk Assessment Matrix

Hazard	Probability	Severity	Risk	Mitigation
Testing Failure	4 (faulty part, improper rocket construction)	5 (major project delay, increased cost, possible disqualification from incomplete flight)	20	Careful design and consideration of every configuration that flies, only fly previously tested or extensively analyze rocket configurations
Failure to receive parts	3 (shipping delays, failure to order parts on time)	5 (major project delays, cannot continue fabrication)	15	Treasurer shall ensure orders are purchased in a timely manner; team leaders will ensure that alternate suppliers are available for crucial parts when possible
COVID-19	2 (Over 90% vaccination rate	3 (Isolation limiting access to	6	All members must follow the Rose Ready document.

	between students and faculty)	facilities, restrictions on travel)		
Loss of BIC/KIC space	1 (Revoked club privileges)	4 (fabrication difficulties, loss of member interest and school support)	4	Adhere to all guidelines set by the BIC/KIC
Inadequate funds	1 (BIC/KIC decides to cut funding, Rose decreases BIC/KIC budget)	4 (limited funds for spare or quality parts, fewer students can travel to launches)	4	Fundraise additional capital, apply for grants and sponsorships
Inadequate transportation	1 (shortage of team funds, not enough students willing to drive)	4 (project delays, limitation of personnel able to travel)	4	Prepare logistics and scout drivers ahead of time
Major Equipment Failure	1 (equipment part failure, student misuse)	4 (large project delays, person injury)	4	Students are required to follow equipment maintenance if necessary. Students can ask veteran members or ask BIC personnel for assistance.

3.3 NAR/TRA Protocols and Motor Handling

The rocket motors used for the NASA-SL competition will only be handled by mentors holding the necessary Level 2 NAR certification. The restriction includes motor purchasing, storage, assembly, lighting, and ignition. Additionally, the team mentor will be responsible for the purchase and packing of the black powder charges used in the rocket recovery systems. All rocket motors used by the club are stored in a fireproof cabinet in the BIC space with a nearby fire extinguisher. The Rose-Hulman BIC director, public safety office, and team's advisor each have a key to the cabinet.

3.4 Hazard Recognition and Accident Avoidance

The team safety officer is responsible for briefing students on common hazards, procedures, and avoidance techniques. These briefings are to be presented prior to working with or around hazardous materials and situations. For example, the Safety Officer will present a briefing to the entire team before beginning construction of the subscale or full scale rocket on the hazards of epoxy as well as before every launch.

Similarly, individual briefings will be provided to the subteam manufacturing the vehicle on the hazards of cutting and sanding fiberglass. Additionally, each team member must read and sign the team safety statement on page 19.

3.5 Document and Procedure Caution Statements

All team plans, procedures, checklists, and other working documents must be created using the team's document template. If the contents of the document will inform the reader, in any fashion, about material or conditions which require PPE or other precautions, the cover page must contain a bold, large font message, surrounded by a yellow border, listing the hazards. For example, the ground testing procedure document should include the following hazards on the cover page: LiPo batteries, black powder, PPE required, extra caution required. Following the cover page, the document will require an abstract summarizing the risk and precautions needed. And, inline warnings will be placed directly next to the line of the document requiring caution.

3.6 Regulatory Compliance and Use of Airspace

To comply with all federal, state, and local laws regarding unmanned rocket launches and motor handling, the team will only launch our rockets at approved NAR or Tripoli fields with the required personnel staffing the launch. The primary launch site for the team is Indiana Rocketry, NAR Section #711 and Tripoli #132. This was also the team's primary launch site during last year's competition. The site currently holds a 16,000 feet above ground level (AGL) flight waiver.

Team Safety Statement

The following statement will be electronically distributed for all team members to sign:

As a member of the Rose Rocketry Student Launch (RR-SL) team, I agree to:

1. Adhere to all guidelines outlined in the Rose-Ready document and maintain proper safety procedures to mitigate risk of spreading COVID-19.
2. Comply with all current local, state, and federal health mandates both inside and outside of team functions.
3. Adhere to all relevant local, state, and federal laws and regulations.
4. Adhere to the NAR High Power Rocket Safety Code.
5. Comply with all instructions given to me by the team mentor, the team Safety Officer, and by any Range Safety Officers.
6. I understand that range safety inspections will be conducted on each rocket before its flown.
7. I understand that the Range Safety Officer has the final say on all rocket safety issues.
8. I understand that the Range Safety Officer has the final say on all launch decisions.
9. I understand that no rocket should fly prior to team mentor approval.
10. Wear appropriate PPE for all team-related work.
11. Understand the hazards of each material or machine I plan to use or operate and take appropriate action to mitigate or eliminate said hazards to the best of my ability.
12. Never misuse the materials or equipment I will work with in this project for any reason.
13. Acknowledge that the team will not be permitted to fly a rocket until the team mentor has reviewed the design.
14. Recognize that the team is expected to comply with established amateur rocketry design and safety guidelines as supervised by the team's mentor.
15. Acknowledge that failure to comply with any of the aforementioned safety regulations is cause for expulsion from the team.
16. Acknowledge that any action deemed unsafe by the team's mentor, Range Safety Officer, and team advisor is also a cause for expulsion from the team.

By signing below, I am acknowledging that I understand and will comply with the rules listed above. I recognize that any violation of these rules may result in me being unable to participate in RR-SL operations.

Name____

Signature___________________________________ Date____________

4. Technical Design

4.1 Proposed Vehicle Specifications

The proposed rocket design will utilize epoxy-joined fiberglass construction and include a nose cone, adequate space for a drogue and main parachute, and four tail fins. The vehicle architecture has three sections: the Avionics Bay, Recovery System, and Mission Payload. The proposed vehicle specifications are listed below in **Table 4.1.** A rough schematic of the rocket is presented in **Figure 4.1**.

Table 4.1 Vehicle Specifications

Preliminary Apogee	5000 ft.
Motor	Cesaroni Technology K780BS
Rocket Length	102 in.
Airframe Diameter	4 in.
Dry Weight	17.3 lbm.
Gross Liftoff Mass	21.1 lbm.
Static Stability Margin	3.75 cal.
CG *	58.9 in.
CP *	73.9 in.

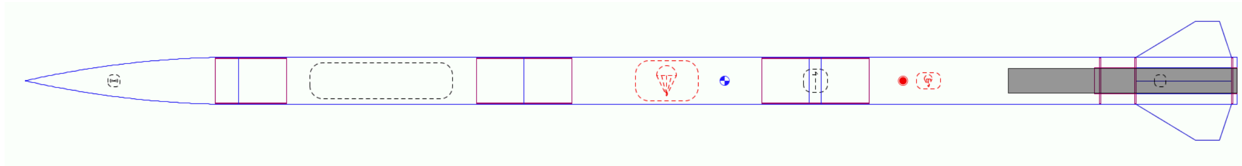

Figure 4.1 OpenRocket Vehicle Design

The fins will be designed such that the aftmost point of the fin does not extend beyond the aft end of the body tube (see **Figure 4.2**). The team has adopted this design restriction to avoid damage to the aerostructure during landing. Additionally, the fins will be designed with a long root edge and narrow span, which both decreases stress on fin attachment points and reduces risk of recovery entanglement.

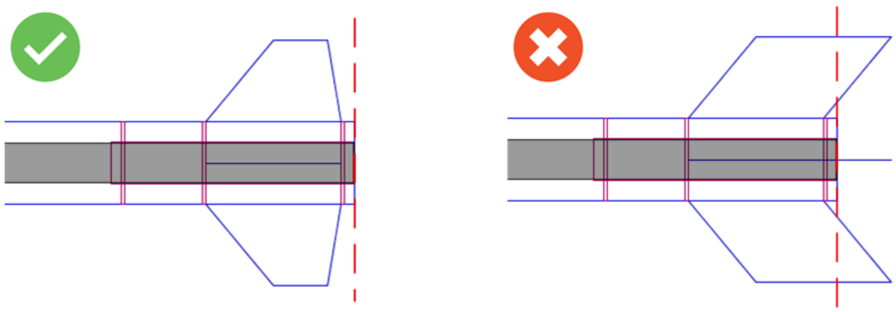

Figure 4.2: Trapezoidal fin design consideration

4.1.1. Material Selection

The proposed rocket will use fiberglass in major aero-structural components such as the airframe, nose cone, and fins. This material has been selected primarily due to its high strength and rigidity for low cost. Additionally, our team has constructed past large-scale rockets with fiberglass, and this prior experience will result in higher-quality construction than other materials. Cardboard was considered for the proposed design. However, it was discarded for strength and rigidity reasons to ensure the rocket could be staged for the time required by the competition. Additionally, water damage would be a significant failure risk during a two-hour staging. Carbon fiber would also meet our material requirements, however, its cost quickly eliminated it from our proposed design.

4.1.2. Construction Methods

To construct the proposed fiberglass rocket, our team intends to employ a variety of construction methods. Since the rocket parts we will receive will be bare airframe, couplers, fiberglass sheets, and a nose cone, many of these parts would need to be prepared for construction. To attach the fins, the airframe will need to be slotted. Our team has constructed a fin-slotting fixture that allows us to mount airframe tubes securely and to pass a fixed-base router across the top to precisely slot airframes for 1/8 in fiberglass fins. These fins will be cut out of the fiberglass sheets using the BIC's waterjet. Joining of the airframe and fins will be accomplished by permanently epoxying them together, being careful to form strong fillets, while employing a variety of positioning jigs. Finally, the airframe will finally need to be drilled and tapped at the coupler interfaces to accept screws for assembly and disassembly of the final rocket.

4.2. Vehicle Altitude Simulation

Primary altitude simulation has been conducted using OpenRocket simulation software since this software has proven to be accurate for past vehicles in a wide range of launch conditions. Preliminary simulation results of the proposed rocket design at 5 degrees launch angle and 5 mph wind are shown in Figure 4.3 below. Final design simulations will be conducted at minimum, median, and maximum rail angles and in a range of wind conditions.

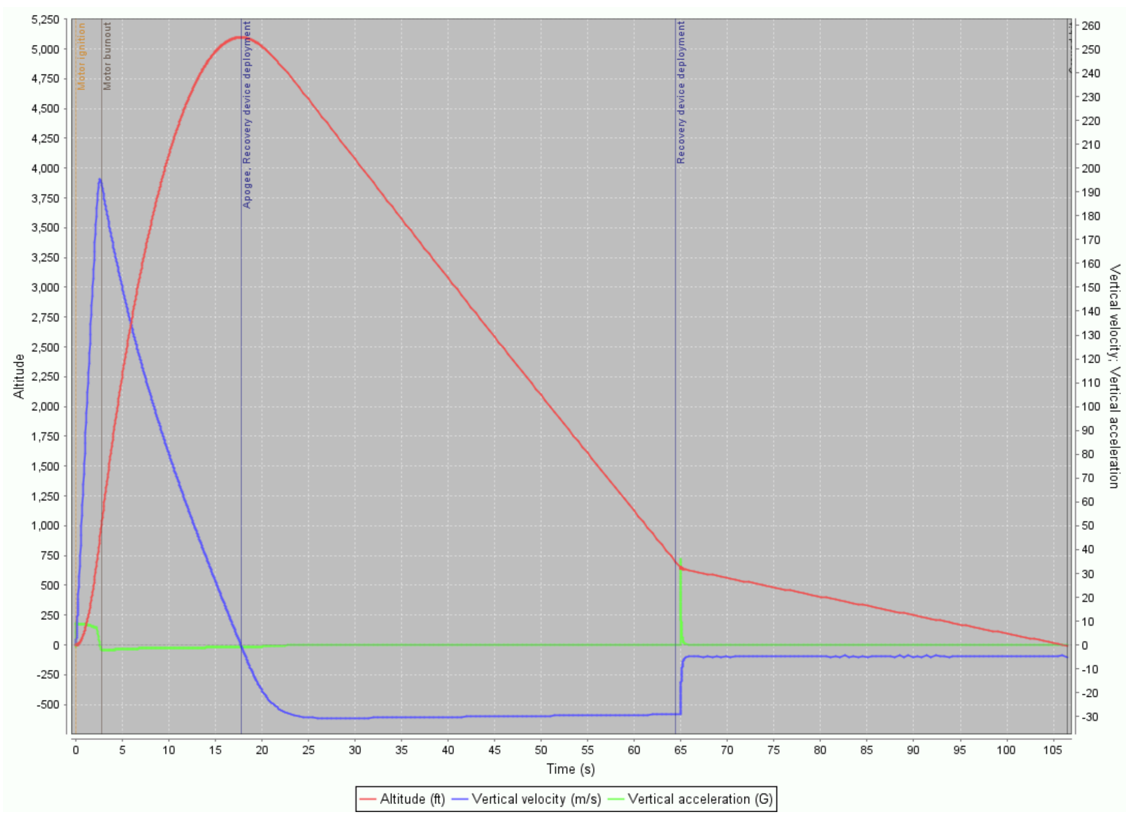

Figure 4.3: Simulated Flight Profile

4.3. Proposed Recovery System Design

The recovery system will follow standard High Power Rocketry (HPR) layouts with significant heritage in NAR activities and competitions. The avionics bay will be centrally located in order to minimize the need for long wire runs, and will be a solid full-coupler design rather than a toroidal design to maximize usable space. The drogue parachute will be located aft of the avionics bay, while the main parachute will be located directly forward; this configuration allows a motor ejection charge to be used as an additional backup charge in addition to both altimeters to ensure drogue deployment in the extreme case of multiple altimeter failures. Only off-the-shelf parachutes will be used to ensure reliability; additionally, purpose-built stitched Kevlar harnesses will be used to connect all recovery components.

4.4. Design Technical Challenges and Solutions

The goal of this rocket design is to minimize technical challenges. The rocket proposed in the previous competition year, Project Silverstein, involved too much new development. Because the rocket was large and complex, we struggled to document, construct, and test it successfully while still meeting competition deadlines. Learning from last year, we are implementing a dramatically smaller vehicle with a simpler vehicle design and a more aggressive development timeline. In addition, we have eliminated air brakes from our technical design. In support of this goal, we recently redesigned and successfully flew the subscale test from the prior competition in a configuration very similar to this initial proposal. This means that we have already solved many technical and logistical challenges from last year, including how to properly construct and assemble a dual-deploy rocket. This airframe will be flown more times this year, prior to the competition, in order to build more knowledge and launch experience.

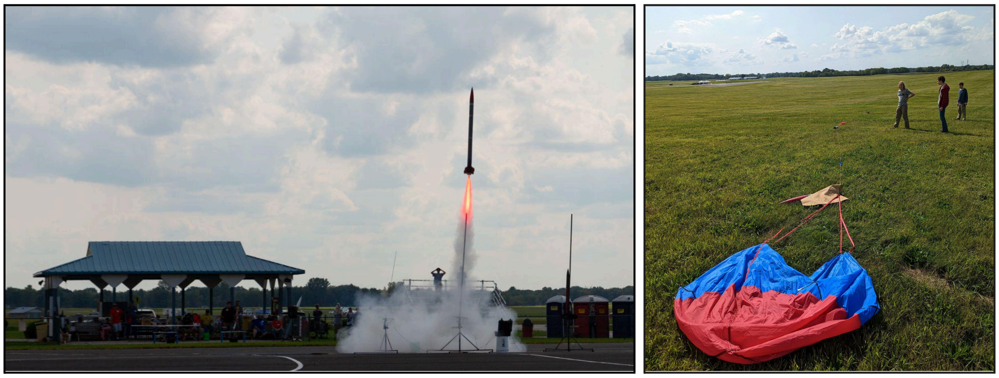

Figure 4.4: Recent Subscale Flight Test and Recovery

Because of the decision to simplify the launch vehicle, the main technical challenge for this project will primarily be the payload subsystem. The challenges and solutions associated with development of this system are detailed in Section 4.5 below.

4.4.1.1. Payload Preliminary Design

The objective of our vehicle payload is to autonomously receive Radio Frequency (RF) commands upon landing and perform a series of tasks with an on-board camera system based on the RF commands received. The camera system will be capable of swiveling 360 degrees to take images of the entire surrounding area of the launch vehicle. A miniaturized computer onboard the Payload will process the Automatic Packet Reporting System (APRS) commands sent by the official management team on launch day. After processing the APRS commands, the computer will control the camera and collect and process video data in order to complete the series of tasks defined by the competition handbook. In order to accomplish these goals, payload design is divided into two subsystems: RF system and mechanical system.

4.4.2. Payload Radio/APRS (RF) System

The payload computer will be a single board computer (SBC) with the capability of running a linux operating system. We will design and build a custom electronics that will handle voltage regulation, altitude sensing, and radio communications. We will use open source libraries OpenCV and Direwolf to help assist our software in applying filters and time stamps to images and with APRS decoding. An on-board altimeter, separate from the altimeter used in the recovery system, will be used to determine when to activate the communications. This will help keep power consumption low while on the launch pad. Once the altimeter reads a successful flight profile and that the payload has landed, it will enable the radio. Due to anticipated supply chain issues, we will build a custom antenna for receiving our RAFCO commands. The team will be evaluating several antenna designs in the following weeks to ensure ground station commands are received reliably. Our design will utilize a software defined radio (SDR) to process the received RF signal from the above mentioned antenna. A benefit of using an SDR is that we can adjust how the signal is processed on the fly, unlike our alternative ideas. Additionally, the team has two SDR's available for immediate prototyping from the previous season and experience using SDR hardware and software. In the event of supply chain issues which prevent procurement of additional SDRs, needed as backups and to allow parallel development cycles, the team will develop a custom solution with a voice chip in order to process the commands. Due to the extreme fluctuations and scarcity of the electronics supply chain, both methods of RF processing will be pursued initially. To power the payload, we use lithium-polymer (LiPo) batteries. These have high energy density, and, although they present an added safety risk, the team has prior experience in handling them safely. We will include a system for detecting battery level for estimated pad time left.

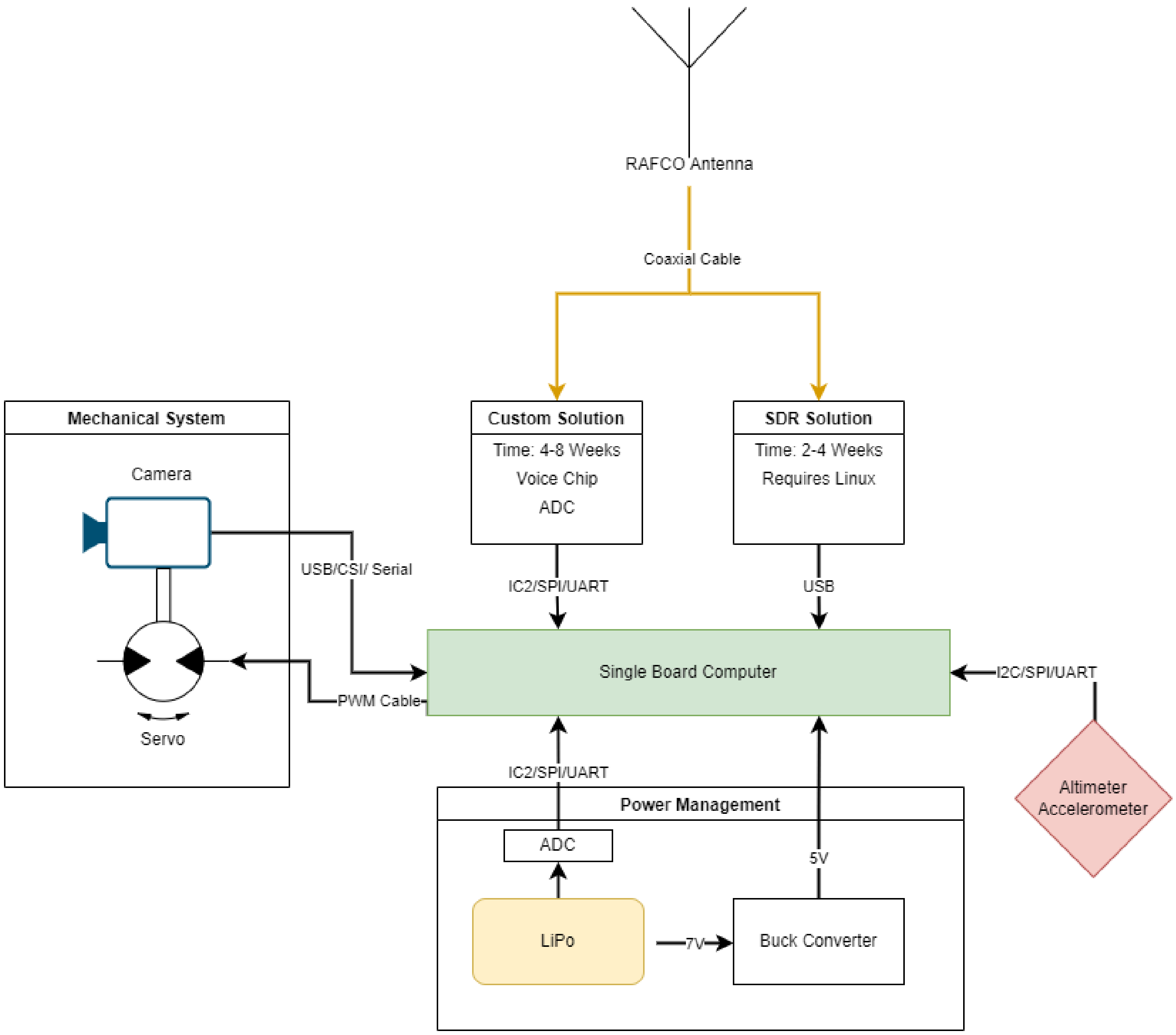

Figure 4.5 Payload System Diagram

4.4.3. Payload Mechanical System

The mechanical system has two main functions: first it will ensure the payload section to the correct orientation so that the camera may leave the section and have a better view of the surrounding area. Second, after the camera is deployed the mechanical system will rotate the camera based on the RF commands received from the payload computer.

With these functions in mind, we split the solution into four steps: tether separation, self-righting, camera deployment, and camera rotation. We considered the payload section both leaving the airframe and staying in the entire mission. We chose to stay in the Airframe, as leading mechanical designs worked better this way. The pros and cons for staying inside the airframe are listed in **Table 4.2.**

Table 4.2 Staying in the Airframe

Pros	Cons
• Deployment complexity reduced • More space inside vehicle • Not counted as an independent section	• Would need mechanism to self-right entire rocket body • Constrained to rocket body • More necessary structural changes to airframe

4.4.3.1. Tether Separation

Once the payload determines the rocket has landed, the payload section will separate the tether attaching it to the rocket. The separation is to prevent the parachute dragging or knocking over the payload. The leading method to do so is a form of electronically actuated quick release. This system will be closed when unpowered as a fail-safe.

4.4.3.2. Self Righting

The self-righting challenge refers to how to orient the payload section such that the camera will deploy per handbook requirements. We are pursuing multiple methods so that in testing, we can choose the fastest and most effective and possibly implement more than one to increase robustness. The three designs are outlined in the following sections.

4.4.3.2.1. Inflation

After landing and tether separation, the payload section will inflate small tubes. These tubes are shaped such that even if the payload is upside down, it will be pushed into a mostly upright position. The two methods for inflation are a gas-generating reaction and stored compressed air. Chemical inflation is preferred because it is very simple and lightweight. However, the team has prior experience with pneumatic actuation, and inflating the tubes using a solenoid valve and compressed air source will be a backup approach. Once the self-righting inflatable system is deployed, final stabilization will be done with a set of deployable legs. A preliminary design of this actuation process is shown in Figure 4.5

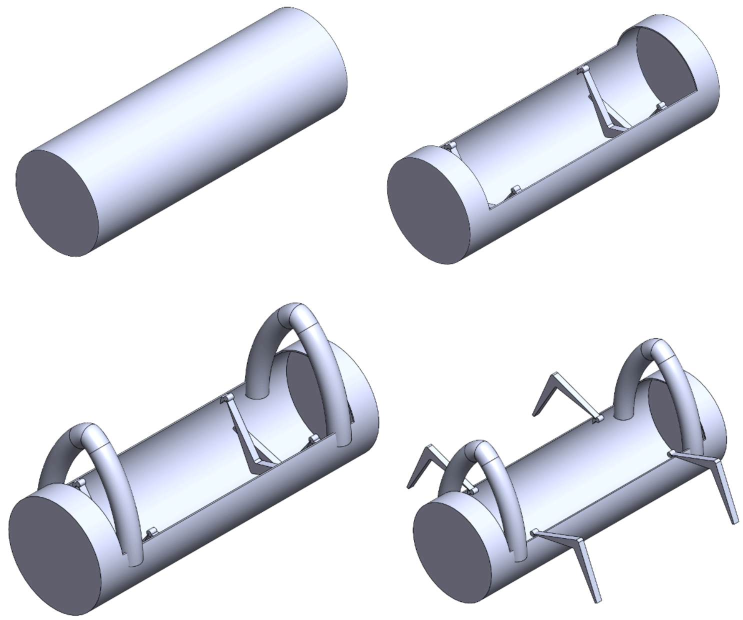

Figure 4.6 Inflation self-correction design

4.4.3.2.2. Rotating Airframe

After landing and tether separation, the payload section will rotate about the center. There will be a door mechanism which will open when deploying our camera. The rotating motion will be created through the use of a motor and turntable mechanism. The motor and electronics will be stored in the airframe on either end of the rotating section for compatibility, shown in gray in Figure 4.6.

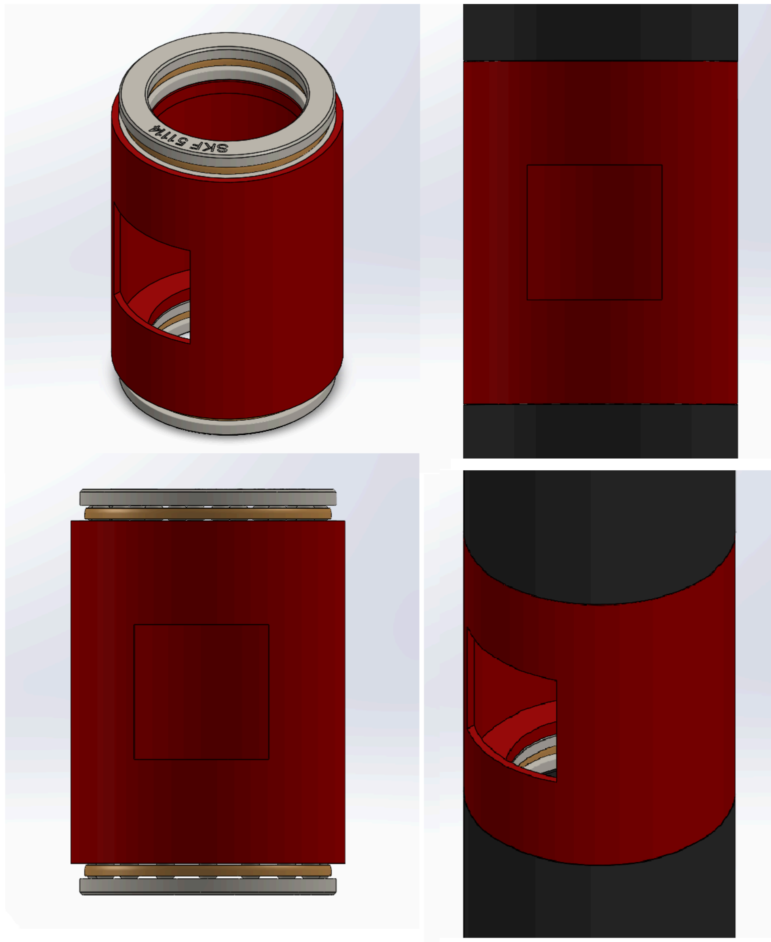

Figure 4.7 Rotating airframe design

4.4.3.2.3. Weight and Orientation Sensor

The final option we considered is using the geometry and mass distribution of the payload to increase the chance that it lands in a predictable orientation. Using an orientation sensor of any variety, the camera will rotate (using a servo motor) to the opening and deploy as described in Section 4.2.2.3.

4.4.3.3. Camera Deployment

In order for the antenna and camera to be in line-of-sight with the ground station and horizon, respectively, we will raise the camera and antenna above the payload section. This will be accomplished with a rotating arm controlled with a motor.

4.4.3.4. Camera Rotation

Camera rotation, per handbook requirement 4.2.1.1, will be accomplished with a servo on the camera deployment arm.

4.5. Requirements Verification

In order to ensure the proposed launch vehicle design fulfills all the requirements set forth by the competition, the team has individually reviewed each requirement and ensured it is addressed within the design given here. For each requirement, a responsible team member has been selected from existing officer positions and projected subsystem leads. This is summarized in Table 4.4 through Table 4.8 below.

Table 4.4 Individual Verification of General Requirements

No.	Requirement Description	Summary of Proposed Approach	Responsible Member
1.1	Students on the team will do 100% of the project. Teams will submit new work.	Students' hands will be the only ones on the rocket, and the team will review all documents before submission to check for plagiarism	President and team advisor
1.2	Maintain a project plan including milestones, budget, checklists, STEM engagements, and risks	The project plan work is divided among the officers depending on their expertise is updated for every milestone	All officers
1.3	Identify participating members in launch week by CDR	A survey will be sent out in December to gage interest for launch week with confirmation shortly thereafter	President and Vice President
1.4	STEM engagement will engage 250 participates to be considered for relevant awards	The lead of engagement will create the event and log all necessary information to be considered for awards	Public Affairs Officer
1.5	Maintain social media presence	The teams instagram will be updated every week with progress updates	Public Affairs Officer

1.6-10	All deliverables will be submitted by email by the deadline in pdf format with the necessary sections	The team will review deliverables before submission to ensure required sections are present, and will submit on time and adhere to all NASA action items	President
1.11	The team will provide computer equipment necessary to host the video teleconference	The team will test and obtain all equipment including a camera, microphone, and quiet room, prior to the conference	President
1.12	The team will use launch pads provided by NASA SL	The rocket will designed to 1515 or 1010 specification	Vehicle Subsystem Lead
1.13	The team will identify a mentor for liability reasons	The team has and will continue to communicate with our mentor about rocket design and will continue to include his contact information in deliverables	President
1.14	The team will track hours worked	The team has created a "hours worked" form that every member fills out after working on a given deliverable	President

Table 4.5: Individual Verification of Vehicle Requirements

Req. No.	Requirement Description	Summary of Proposed Approach	Responsible Team Member
2.1	The vehicle will deliver the payload to an apogee altitude between 4,000 and 6,000 feet above ground level (AGL).	The vehicle has a target altitude of 5000 ft. Simulations, scale models, and test flights will be used to verify the performance of the vehicle.	Vehicle Subsystem Lead
2.2	Teams shall declare their target altitude goal at the PDR milestone.	Extensive simulation will be performed before PDR completion; flexibility for adjustments in payload mass or geometry will be maintained in vehicle design.	Vehicle Subsystem Lead
2.3	The launch vehicle will be designed to be recoverable and reusable.	The team has designed the launch vehicle with a drogue and main parachute to stabilize the rocket's descent and ensure recoverability and reusability in future launches.	Vehicle Subsystem Lead

2.4	The launch vehicle will have a maximum of four (4) independent sections.	The team has designed a launch vehicle with three independent sections.	Vehicle Subsystem Lead
2.4.1	Coupler/airframe shoulders which are located at in-flight separation points will be at least 2 airframe diameters in length.	The team has selected off-the-shelf couplers which fulfill these requirements.	Vehicle Subsystem Lead
2.4.2	Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length.	The team has selected an off-the-shelf nosecone which fulfills these requirements.	Vehicle Subsystem Lead and Safety Officer
2.5	The launch vehicle can be prepared for flight at the launch site within 2 hours of the launch window.	The team will track the preparation time throughout the season for different systems and schedule accordingly on the launch day.	All Subsystem Leads
2.6	The vehicle and payload can maintain launch-ready configuration on the pad for a minimum of 2 hours.	Materials, components, and power sources have been selected with the appropriate durability. The rocket will be tested for this in launch-ready configuration.	Payload Electronics and Recovery Leads
2.7-2.9	The launch vehicle must be launched using only a NASA-designated 12v launch system, with commercial igniters.	The team will only use a NASA-designated 12v launch system with commercial igniters.	Vehicle Subsystem Lead and Safety Officer
2.10	The launch vehicle will use COTS solid motors approved by NAR	The team will only buy motors approved by the NAR and are solid motors. All selection will be made by the CDR and included in the deliverable without modification except in extreme circumstances	Treasurer and President
2.11	The launch vehicle will be a single motor propulsion system	Our launch vehicle will only be a single-stage and designed around this requirement	Vice President and Vehicle Subsystem lead
2.12	The total impulse will not exceed L-class	Our launch vehicle will be designed around a motor that is L-class or less	Vice President and Vehicle Subsystem
2.13	Pressure Vessels will be approved by the RSO and will meet criteria including relief valves and a minimum factor of safety	The team does not plan to use pressure vessels, but if that plan changes, the safety officer will review and enforce these guidelines with subteam implementing them	Safety Officer

2.14	The launch vehicle will have a minimum static stability of 2.0 at rail exit	The launch vehicle will be designed around this requirement and verified by the safety officer after design	Vehicle Subsystem Lead and Safety Officer
2.15	The launch vehicle will have a minimum thrust to weight ratio of 5.0 : 1.0.	The launch vehicle will be designed around this requirement and verified by the safety officer after design	Vehicle Subsystem Lead and Safety Officer
2.16	Any structural protuberance on the rocket will be located aft of the burnout center of gravity. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.	The launch vehicle will be designed around this requirement and verified by the safety officer after design	Vehicle Subsystem Lead and Safety Officer
2.17	The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.	The launch vehicle will be designed around this requirement and verified by the safety officer after design	Vehicle Subsystem Lead and Safety Officer
2.18	All teams will successfully launch and recover a subscale model of their rocket prior to CDR.	The subscale model will be designed and recovered successfully prior to the CDR	Vehicle Subsystem Lead and President
2.18.1	The subscale model should resemble and perform as similarly as possible to the full-scale model; however, the full-scale model will not be used as the subscale model.	The subscale model will be designed with an emphasis on similarity to the full-scale model while still staying on this requirement	President and Vehicle Subsystem Lead
2.18.2	The subscale model will carry an altimeter capable of recording the model's apogee altitude.	The subscale model will include an altimeter to record the total altitude as per this requirement	Vehicle Subsystem Lead
2.18.3	The subscale rocket shall be a newly constructed rocket, designed and built specifically for this year's project.	The rocket will be built specifically for the CDR	Vehicle Subsystem Lead
2.18.4	Proof of a successful flight shall be supplied in the CDR report.	The team will supply data from the subscale in the CDR report	President
2.18.4.1	Altimeter flight profile graph(s) OR a quality video showing successful launch, recovery events, and landing as deemed by the NASA	The team will record or provide flight profile graphs and include them into the CDR	President

	management panel are acceptable methods of proof. Altimeter flight profile graph(s) that are not complete (liftoff through landing) shall not be accepted.		
2.18.4.2	Quality pictures of the as landed configuration of all sections of the launch vehicle shall be included in the CDR report. This includes but not limited to nosecone, recovery system, airframe, and booster.	The team will take pictures of the subscale that will be included in the CDR report	President and Vehicle Subsystem Lead
2.18.5	The subscale rocket shall not exceed 75% of the dimensions (length and diameter) of your designed full-scale rocket. For example, if your full-scale rocket is a 4" diameter 100" length rocket your subscale shall not exceed 3" diameter and 75" in length.	The subscale will be designed to be 75% or less than the total full-scale rocket.	Vehicle Subsystem Lead
2.19	All teams will complete demonstration flights as outlined below.	Demonstration flights will be conducted	Vice President
2.19.1	Vehicle Demonstration Flight—All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration.	The team will fly the full-scale rocket twice before competition	Vice President
2.19.1.1	The vehicle and recovery system will have functioned as designed.	The team will extensively test and verify the recovery system in components and as a full system multiple times.	Vehicle and Recovery Subsystem Leads and Safety Officer
2.19.1.2	The full-scale rocket shall be a newly constructed rocket, designed and built specifically for this year's project.	The team will design and build a new rocket.	President
2.19.1.3	If the payload is not flown during the vehicle demonstration flight, mass simulators must be used.	The team will fly the payload during the vehicle demonstration flight.	Payload Subsystem Lead
2.19.1.4	If the payload changes the external surfaces of the rocket (such as	The payload will not change the external surface of the rocket during	Payload Subsystem

	camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale Vehicle Demonstration Flight.	flight. Payload deployment mechanisms will be operational during the Vehicle Demonstration Flight.	Lead
2.19.1.5	Teams shall fly the competition launch motor for the Vehicle Demonstration Flight.	The team will decide a reliable motor ahead of time and acquire multiple motors of the type before full-scale testing begins. Correct motor and installation will be verified by multiple people before each test fight.	Vehicle Subsystem Lead and Safety Officer
2.19.1.6	The vehicle shall be flown in its fully ballasted configuration during the full-scale test flight.	The team will have multiple people verify the rocket is fully ballasted and in configuration before every test flight.	Vehicle Subsystem Lead and Safety Officer
2.19.1.7	After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified without the concurrence of the NASA Range Safety Officer (RSO).	The team will post visual reminders and announcements in communications channels to not modify the rocket without NASA concurrence	Vehicle Subsystem Lead and Safety Officer
2.19.1.8	Proof of a successful flight shall be supplied in the FRR report.	Photos of all phases of flight and altimeter logs will be taken during testing and provided in the FRR.	Vehicle Subsystem Lead and Safety Officer
2.19.1.8.1	Altimeter flight profile data output with accompanying altitude and velocity versus time plots is required to meet this requirement.	The team will recover altimeter, time, and velocity data with the launch vehicle and provide it to NASA.	Vehicle Subsystem Lead and Safety Officer
2.19.1.8.2	Quality pictures of the as landed configuration of all sections of the launch vehicle shall be included in the FRR report.	The team will take quality pictures of the landed configurations of all sections of the launch vehicle and include them in the FRR.	Vehicle Subsystem Lead and Safety Officer
2.19.1.9	Vehicle Demonstration flights shall be completed by the FRR submission deadline.	The team will complete all Vehicle Demonstration flights by the FRR submission deadline.	Vehicle Subsystem Lead and Safety Officer
2.19.2	Payload Demonstration Flight—All teams will successfully launch and recover their full-scale rocket containing the completed payload prior to the Payload	The team will perform at least one demonstration flight with payload incorporated.	Vehicle Subsystem Lead and Safety Officer

	Demonstration Flight deadline.		
2.19.2.1	The payload shall be fully retained until the intended point of deployment (if applicable), all retention mechanisms shall function as designed, and the retention mechanism shall not sustain damage requiring repair.	The team will ensure that the payload is fully retained and that any forces in a nominal flight do not damage the payload or retention mechanism.	Vehicle Subsystem Lead and Safety Officer
2.19.2.2	The payload flown shall be the final, active version.	The team will ensure the payload flown on demonstration flights is the same payload.	Vehicle Subsystem Lead and Safety Officer
2.19.2.3	If the above criteria are met during the original Vehicle Demonstration Flight, occurring prior to the FRR deadline and the information is included in the FRR package, the additional flight and FRR Addendum are not required.	If the Payload is not flown during the Vehicle Demonstration Flight the team will write and submit a FRR Addendum by the deadline.	President and Vice President
2.19.2.4	Payload Demonstration Flights shall be completed by the FRR Addendum deadline. NO EXTENSIONS WILL BE GRANTED.	The team will have all demonstration fights completed by the FRR Addendum	Payload Subsystem Lead, Vehicle Subsystem Lead
2.20	An FRR Addendum will be required for any team completing a Payload Demonstration Flight or NASA required Vehicle Demonstration Re-flight after the submission of the FRR Report.	The team will complete an FRR Addendum if our Vehicle Demonstration flight is not accepted by the NASA team	President and Vice President
2.20.1	Teams required to complete a Vehicle Demonstration Re-Flight and failing to submit the FRR Addendum by the deadline will not be permitted to fly a final competition launch.	The team will listen to the NASA team whether we are allowed to launch at the final competition launch	Vehicle Subsystem Lead and Safety Officer
2.20.2	Teams who successfully complete a Vehicle Demonstration Flight but fail to qualify the payload by satisfactorily completing the Payload Demonstration Flight requirement will not be permitted to fly a final competition launch.	The team will listen and adhere to guidelines from the NASA team on whether their Payload Demonstration Flight is satisfactory	Vehicle Subsystem Lead and Safety Officer

2.20.3	Teams who complete a Payload Demonstration Flight which is not fully successful may petition the NASA RSO for permission to fly the payload at launch week.	The team will petition the NASA RSO for permission to fly if their Payload Demonstration Flight does not qualify to fly at launch week	Vehicle Subsystem Lead and Safety Officer
2.21	The team's name and Launch Day contact information shall be readily accessible from the rocket systems.	The team will mark all separable systems with the team name and Launch Day contact information.	Vehicle Subsystem Lead and Safety Officer
2.22	All Lithium Polymer batteries will 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.	The team will clearly mark all Lithium Polymer batteries. The vehicle design will ensure that batteries will be protected from impact.	Vehicle Subsystem Lead and Safety Officer
2.23.1	The launch vehicle will not utilize forward firing motors.	The team will not utilize forward firing motors.	Vehicle Subsystem Lead and Safety Officer
2.23.2	The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)	The team will not utilize motors that expel titanium sponges.	Vehicle Subsystem Lead and Safety Officer
2.23.3	The launch vehicle will not utilize hybrid motors.	The team will not utilize hybrid motors.	Vehicle Subsystem Lead and Safety Officer
2.23.4	The launch vehicle will not utilize a cluster of motors.	The team will not utilize a cluster of motors.	Vehicle Subsystem Lead and Safety Officer
2.23.5	The launch vehicle will not utilize friction fitting for motors.	The team will not utilize friction fitting for motors.	Vehicle Subsystem Lead and Safety Officer
2.23.6	The launch vehicle will not exceed Mach 1 at any point during flight.	The team will use simulation and experimentation to ensure that the rocket does not exceed Mach 1 at any point during flight.	Vehicle Subsystem Lead and Safety Officer
2.23.7	Vehicle ballast will not exceed 10% of the total unballasted weight of	The team will weigh all components to ensure that the vehicle ballast will	Vehicle Subsystem

	the rocket as it would sit on the pad (i.e. a rocket with an unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast).	not exceed 10% of the total unballasted weight of the rocket.	Lead and Safety Officer
2.23.8	Transmissions from onboard transmitters, which are active at any point prior to landing, will not exceed 250 mW of power (per transmitter).	The team will measure the power supply to ensure that any individual transmitter does not exceed 250 mW of power.	Vehicle Subsystem Lead and Safety Officer
2.23.9	Transmitters will not create excessive interference. Teams will utilize unique frequencies, hand shake/passcode systems, or other means to mitigate interference caused to or received from other teams.	The team will use unique frequencies, hand shake/passcode systems, or other means to mitigate interference.	Vehicle Subsystem Lead and Safety Officer
2.23.10	Excessive and/or dense metal will not be utilized in the construction of the vehicle.	The team will use lightweight metals only if necessary. Structural integrity calculations will be used to verify that if metals are used, they will be limited to ensuring the integrity requirements.	Vehicle Subsystem Lead

Table 4.6: Individual Verification of Recovery System Requirements

Req. No.	Requirement Description	Summary of Proposed Approach	Responsible Team Member
3.1	The full scale launch vehicle will 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 subsystem will utilize a dual-deployment recovery system without using streamer or tumble	Recovery Subsystem Lead
3.1.1	The main parachute shall be deployed no lower than 500 feet.	The team will not deploy the main parachute lower than 500 ft	Recovery Subsystem

			Lead
3.1.2	The apogee event may contain a delay of no more than 2 seconds.	The team's drogue parachute will be deployed in less than 2 seconds after apogee	Recovery Subsystem Lead
3.1.3	Motor ejection is not a permissible form of primary or secondary deployment.	The team will not use motor ejection as a primary or secondary method of deployment	Recovery Subsystem Lead
3.2	Each team will perform a successful ground ejection test for all electronically initiated recovery events prior to the initial flights of the subscale and full scale vehicles.	The team will perform several ejection tests for all electronic recoverys prior to flights	Recovery Subsystem Lead
3.3	Each independent section of the launch vehicle will 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 team will simulate the kinetic energy of all independent sections to ensure they are less than 75 ft-lbfs. During test launches, this number will be confirmed	Recovery Subsystem Lead, President
3.4	The recovery system will 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 team will use COTS altimeters designed for recovery events	Recovery Subsystem Lead, President
3.5	Each altimeter will have a dedicated power supply, and all recovery electronics will be powered by commercially available batteries.	The team will have a dedicated power supply and be powered by COTS batteries	Recovery Subsystem Lead, President
3.6	Each altimeter will 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 team will utilized an external mechanical armin switch to turn on the recovery electronics	Recovery Subsystem Lead
3.7	Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed	The mechanical switch that the team uses will not be able to be switched off during launch	Recovery Subsystem Lead, President

	due to flight forces).		
3.8	The recovery system, GPS and altimeters, electrical circuits will be completely independent of any payload electrical circuits.	The team will separate all recovery electronics from payload electronics	Vehicle Subsystem Lead and Safety Officer
3.9	Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.	The team will design the rocket so that removable shear pins will separate the main and drogue compartments	Vehicle Subsystem Lead and Safety Officer
3.10	The recovery area will be limited to a 2,500 ft. radius from the launch pads.	The team will simulate the rocket to ensure that the recovery radius is less than 2,500 ft.	Recovery Subsystem Lead and Safety Officer
3.11	Descent time of the launch vehicle will 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 team will simulate the rocket to ensure that the decent time is less than 90 secs.	Recovery Subsystem Lead and Safety Officer
3.12	An electronic GPS tracking device will be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver.	The team will use a GPS tracking device to transmit the landing position of the launch vehicle after landing.	Vehicle Subsystem Lead and Safety Officer
3.12.1	Any rocket section or payload component, which lands untethered to the launch vehicle, will contain an active electronic GPS tracking device.	The team will put a GPS tracking device on any sections of the rocket that are untethered to the launch vehicle	Vehicle Subsystem Lead and Safety Officer
3.12.2	The electronic GPS tracking device(s) will be fully functional during the official competition launch.	The team will test the electronic GPS tracking device to ensure functionality during the official competition launch.	Vehicle Subsystem Lead and Safety Officer
3.13	The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).	The team's recovery electronics will be ground-tested with all anticipated radio sources in flight configuration to ensure compliance.	Recovery Subsystem Lead
3.13.1	The recovery system altimeters will be physically located in a	The team's altimeters will be located in a separate compartment than all	Vehicle Subsystem

	separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.	other electronics	Lead and Safety Officer
3.13.2	The recovery system electronics will be shielded from all onboard transmitting devices to avoid inadvertent excitation of the recovery system electronics.	The recovery system electronics will be shielded from all other electronic devices	Recovery Subsystem Lead and Safety Officer
3.13.3	The recovery system electronics will be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.	The recovery system electronics will be shielded from all other electronic devices	Recovery Subsystem Lead and Safety Officer
3.13.4	The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.	The recovery system electronics will be shielded from all other electronic devices	Recovery Subsystem Lead and Safety Officer

Table 4.7: Individual Verification of Payload Experiment Requirements

Req. No.	Requirement Description	Summary of Proposed Approach	Responsible Team Member
4.1	Design a payload that will autonomously upon landing receive RF commands and perform tasks based using an onboard camera system. If there is an extra payload experiment it must be included in all reports for flight safety review.	A payload system with an antenna, camera and supporting mechatronics will be flown. We will not be flying an extra payload.	Payload Electrical / Payload Mechanical Team Leads
4.2.1	Launch Vehicle shall contain an automated camera system capable of swiveling 360° to take images of the entire surrounding area of the launch vehicle	A payload bay door will open up to allow a camera boom and antenna to access the Z axis. A motorized system will allow the camera to rotate.	Payload Mechanical Team Lead

4.2.1.1	The camera shall have the capability of rotating about the z axis. The z axis is perpendicular to the g	We will have an orientation sensor on the payload to allow it to have a system that can account for the rocket's orientation to allow the camera to be relatively perpendicular to the ground.	Payload Electronics and Payload Mechanical Team Leads
4.2.1.2	The camera shall have a FOV of at least 100° and a maximum FOV of 180°	During parts selection we will vet all part options to meet the FOV requirements.	Payload Electronics Team Lead
4.2.1.3	The camera shall time stamp each photo taken. The time stamp shall be visible on all photos submitted to NASA in the PLAR.	The payload electronics system will have software onboard to timestamp each picture immediately after it is taken.	Payload Electronics Team Lead
4.2.1.4	The camera system shall execute the string of transmitted commands quickly, with a maximum of 30 seconds between photos taken.	The mechatronics on board will be performant enough to quickly move the camera.	Payload Mechanical Team Lead
4.2.2	NASA Student Launch Management Team shall transmit a RF sequence that shall contain a radio call sign followed by an alphanumeric sequence of tasks.	Upon receiving the messages, the payload will decode the messages and will ensure that a call sign is followed by the transmission sequence.	Payload Electronics Team Lead
4.2.2.1	An example transmission sequence could look something like, "XX4XXX C3 A1 D4 C3 F6 B2 B2 C3"	The payload will detect a sequence of commands that resemble the example transmission.	Payload Electronics Team Lead
4.2.3	The Nasa Student Launch Management Panel shall transmit the RAFCO using APRS.	We will use a radio solution (either SDR or hardware radio) that is capable of decoding APRS and will communicate the decoded packet to the camera control system	Payload Electronics Team Lead
4.2.3.1	NASA will use dedicated frequencies to transmit the message. NASA will operate on the 2-Meter amateur radio band between the frequencies of 144.90 MHz and 145.10 MHz. No team shall be permitted to transmit on any frequency in this range. The specific frequency used will be shared with teams during Launch Week. NASA reserves the right to	Using an SDR, in the event that NASA decides to update the frequencies used, it will allow us to quickly change to the target frequencies. A hardware solution would require a change in parts to allow for the change in frequency.	Payload Electronics Team Lead

	modify the transmission frequency as deemed necessary.		
4.2.3.2	The NASA Management Team shall transmit the RAFCO every 2 minutes.	The payload software system will loop through and listen for RAFCO every 2 minutes.	Payload Electronics Team Lead
4.2.3.3	The payload system shall not initiate and begin accepting RAFCO until AFTER the launch vehicle has landed on the planetary surface.	The electronics on the payload will measure the altitude and the payload will only begin accepting RAFCO when the electronics have detected a consistent altitude change of zero feet.	Payload Electronics Team Lead
4.2.4	The payload shall not be jettisoned.	The payload will not leave the airframe during the duration of flight.	Payload Electronics Team Lead
4.2.5	The sequence of time-stamped photos taken need not be transmitted back to the ground station and shall be presented in the correct order in our PLAR.	The payload receiving hardware will only have the capability to receive data.	Payload Electronics Team Lead
4.3.1	Black Powder and/or other similar energetics are only permitted for deployment of in-flight recovery systems, not for any surface operations.	The payload system will not use any energetics similar to black powder.	Payload Mechanical Team Lead
4.3.2	Teams shall abide by all FAA and NAR rules and regulations	The payload team leads will ask for and abide by guidance from the Safety Officer.	Safety Officer
4.3.3	Any secondary payload experiment element that is jettisoned during the recovery phase will receive real-time RSO permission prior to initiating the jettison event, unless exempted from the requirement the CDR milestone by NASA	There is no secondary payload experiment and therefore will not require any extra permissions from the RSO.	Safety Officer
4.3.4	Unmanned aircraft system (UAS) payloads, if designed to be deployed during descent, will be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given permission to release the UAS	We do not plan on using unmanned aircraft systems (UAS) for our payload.	Safety Officer
4.3.5	Teams flying UASs will abide by all	We do not plan on using unmanned	Safety Officer

	applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112–95 Section 336; see https://www.faa.gov/uas/faqs). 4.3.6. Any UAS weighing more than .55 lbs. shall be registered with the FAA and the registration number marked on the vehicle.	aircraft systems (UAS) for our payload.	
4.3.6	Any UAS weighing more than 0.55 lbs. Shall be registered with the FAA and the registration number marked on the vehicle.	We do not plan on using unmanned aircraft systems (UAS) for our payload.	Safety Officer

Table 4.8: Individual Verification of Safety Requirements

Req. No.	Requirement Description	Summary of Proposed Approach	Responsible Team Member
5.1	The team will use a launch and safety checklist	The team's Safety Officer maintains these checklists and uses them for every launch and dangerous activity	Safety Officer
5.2	The team will identify a Safety Officer	The team has and will continue to report who the safety officer is in every deliverable and maintain the position as part of the officers of the club according to the university	President
5.3	Responsibility of the Safety Officer	These responsibilities are outlined in the club's constitution and is expected to be at every launch and construction meeting	President and Safety Officer
5.4	The team will abide by the RSO and the NAR or TRA club at any launch they attend	The team will communicate with the club before attending the launch and get confirmation from senior members of the club and RSO before lau	President
5.5	Teams will abide by all rules set forth by the FAA	Guidelines from the FAA	President

5. STEM Engagement

5.1. Planned Activities

The RR-SL team will be conducting multiple educational outreach events throughout the season. The goal of these events is to promote STEM, encourage interest in space exploration, and to have a large community impact.

This year, the RR-SL team has partnered with our local FIRST Robotics Team (FRC), which is also located within our school's BIC, to host outreach events. This provides the team the benefit of shared resources and planning and provides the community the benefit of a more engaging event where they can learn about rocketry, aerospace, robotics, and STEM. Some other events include visiting local junior and high schools to give presentations on previous years' competition rockets and our progress towards this year's competition. To make this an active engagement activity, the team has planned a few activities in which the students can participate in, including FRC activities involving rovers and robotics in space, an egg drop challenge, water rockets, and Scouting Merit Badges. These activities will allow for engaging students with fundamental engineering principles.

5.2. Evaluation of Activity Success

To host a successful outreach event, a meaningful number of community members must be reached, while still delivering engaging and educational contact. The primary metric used to measure our community impact and event success will be a head count of both community participants and team members. To measure the engagement of the students in those activities, the team plans on having the students discuss alternative design methods and plausible future improvements towards their initial design process.

6. Project Plan

6.1. Project Timeline

We have established a sequence of required events and deliverables for this project, as shown in **Figure 6.1**. This project plan has been set based on learnings from the previous competition season, specifically the need for more flexibility. Internal deadlines are based around the project deliverables (shown in orange) and improved from last year. Last competition season, we struggled to do enough physical testing to be confident in our models and mechanical designs. Therefore, this year we are devoting more of the schedule to prototyping and shakedown testing. In addition, we have adjusted the subscale testing to be earlier in the year and will begin constructing the final launch vehicle concurrently with subscale tests to give a less aggressive and failure-critical window for test launches.

Task Name	Duration	Start	Finish
1st Draft Vehicle Desi	17 days	Fri 8/19/22	Sat 9/10/22
Write Proposal	10 days	Thu 9/1/22	Wed 9/14/22
Edit Proposal/Submit	4 days	Thu 9/15/22	Tue 9/20/22
Proposal Due	0 days	Mon 9/19/22	Mon 9/19/22
Form Subteams	5 days	Mon 9/19/22	Fri 9/23/22
Prototyping	19 days	Sat 9/24/22	Wed 10/19/2
Write PDR	10 days	Mon 10/10/2	Fri 10/21/22
Edit/Submit PDR	4 days	Sun 10/23/22	Wed 10/26/2
PDR Due	0 days	Wed 10/26/2	Wed 10/26/2
Manufacture Test Components	16 days	Tue 11/1/22	Tue 11/22/22
Conduct Testing on component parts	10 days	Sun 11/20/22	Thu 12/1/22
Subscale Manufacturi	19 days	Wed 11/16/2	Sun 12/11/22
Write CDR	12 days	Sun 12/11/22	Sun 12/25/22
Edit CDR/Submit	4 days	Wed 1/4/23	Mon 1/9/23
CDR Due	0 days	Mon 1/9/23	Mon 1/9/23
Final Vehicle Manufacturing	22 days	Tue 1/10/23	Wed 2/8/23
Write the FRR	13 days	Mon 2/13/23	Wed 3/1/23
Edit/Submit FRR	3 days	Thu 3/2/23	Mon 3/6/23
FRR Due	0 days	Mon 3/6/23	Mon 3/6/23
Vehicle Refinement	17 days	Fri 3/10/23	Mon 4/3/23
Write Addendum	7 days	Fri 3/24/23	Sat 4/1/23
Edit/Submit Addendu	2 days	Sun 4/2/23	Mon 4/3/23
Addendum Due	0 days	Mon 4/3/23	Mon 4/3/23
Launch Day	0 days	Sat 4/15/23	Sat 4/15/23

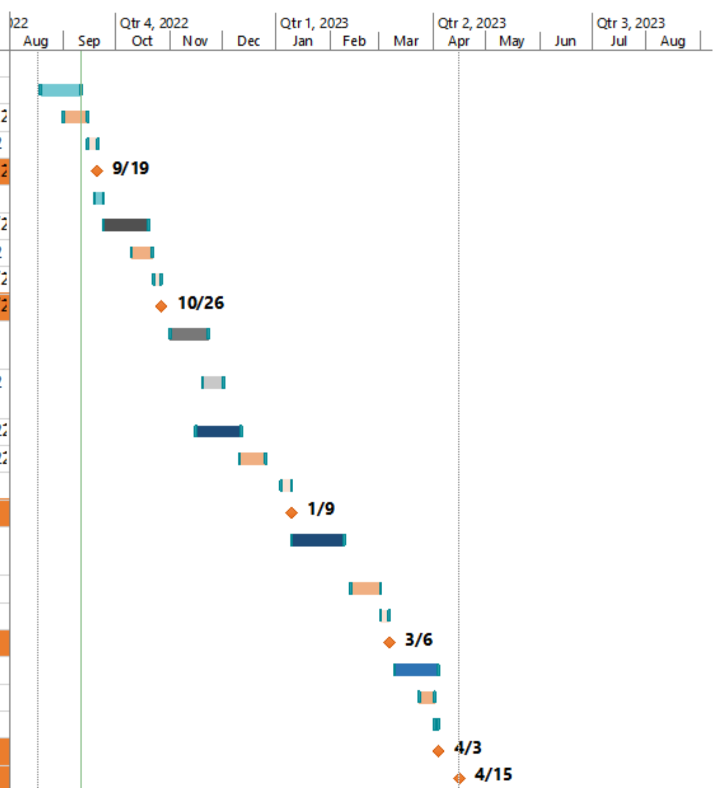

Figure 6.1 Timeline Gantt Chart

6.2. Project Funding and Budget

The RR-SL team is funded by the BIC/KIC, Student Government Association (SGA), and outside donations. Each September the BIC/KIC accepts budget proposals from competition teams. Similarly, SGA pre-allocates budgets at the end of academic year for every registered campus club and allows for additional funding through One-Time Funding Request (OTFR). Additionally, our school's business office has created an official crowdfunding page with a donation link on the school's website. This page will assist the team in organizing crowdfunding campaigns.

Based on last year's BIC/KIC award of $3,000 and the amount we requested this year, we expect to be awarded $4,000 by the BIC/KIC. Awards are finalized in October. Rose Rocketry has been allocated $11,950 by SGA for the 2022-2023 academic year.

A budget for each subsystem is described below. The 2022-2023 project total, including travel, is $19,200. We currently have $11,950 secured, accounting for everything but travel. Based on previous OTFR award amounts the team has received, we expect SGA to cover $5,000 of team travel expenses. The remainder of Table 6.3 will be raised through company sponsorship and crowdfunding.

6.2.1. Vehicle Budget

Table 6.1 Vehicle Budget

Item	Cost
Motor Propellant	$800
Motor Hardware	$200
Recovery	$300
Flight Electronics	$200
Airframe	$500
Hardware	$100
Total	$2,100

6.2.2. Payload Budget

Table 6.2 Payload Budget

Item	Cost
SBC's	$250
Sensors	$100
LiPo's	$100
Cameras	$150
Antenna	$50
Mechatronics	$200
Testing Equipment	$150
Electronic Accessories	$100
Total	$1,100

6.2.3. Subscale Budget

Our subscale will be built as closely to our full scale as possible in regards to dimension, altitude, motor, and payload, scaled appropriately. Although not explicitly required by the competition, we believe the experience gained will be worth the effort and costs, especially considering the age of our team and amount of new members. Our planned budget is $700.

6.2.4. Branding Budget

The team expects to spend $300 on branding. The branding budget will be used to purchase flyers, stickers, and apparel to advocate for the team.

6.2.5. Travel Budget

Although the team did not travel last year, we did price and book travel arrangements. Based on last year's travel costs of $9,500 for 16 members, the increased prices of gas and hotels, and the increase in number of team members, we expect travel to cost $15,000.

Competition travel will be the hardest part of this year's funding to secure. However, this cost can be reduced by restricting the number of students traveling to competitions.

6.2.6. Total Budget

Table 6.3 Total Budget

Item	Budget
Vehicle	$2,100
Payload	$1,100
Subscale	$700
Branding	$300
Travel	$15,000
Total	$19,200

6.3. Sustainability Plan

The team's sustainability plan includes efforts to continue rocket expertise and enthusiasm within our university, within our corporate partners, and within the community.

6.3.1. Student Engagement

The team priotize's sustainability within the university in order to increase active membership and to bring awareness to the club. We recruit during the activities fair, through tours for prospective students, and throughout the year through word of mouth. We teach members about rocketry by helping them build a rocket for their Level 1 NAR certification, at no cost to them, and through getting them involved with NASA SL. In order to increase retention and engagement, we split all members into subteams of their main interest and include all members in design decisions. To continue engaging members throughout the year in rocketry, we also aid in funding Level 2 certifications and independent projects as well as leading smaller teams pursuing liquid-engine and small satellite development.

6.3.2. Funding Sources

Rose-Hulman Institute of Technology provides many internal resources for funding clubs and competition teams. Our club is funded by combined contributions from the local student government and the BIC and KIC workspaces that we use. Further funding can be obtained as-needed from alumni donations and the Office of Institutional Advancement. Additionally, the team actively solicits in-kind donations from corporate and individual sponsors.

6.3.3. Corporate Partners

The team is currently pursuing corporate partnerships through guest speakers, technical mentorship, and company tours. We contact alumni at aerospace companies, including SpaceX and Blue Origin, to ask for advice on technical designs. We also work with companies that have established professional relationships with Rose-Hulman Institute of Technology to organize company tours and guest speakers.

6.3.4. Community

The STEM outreach section reflects our community sustainability plan. It includes presentations and demonstrations at local elementary and middle schools as well as hand-on activities with scouts. For a more detailed description, see Section 5.