Rose Rocketry Club

Project Silverstein Proposal

Rose-Hulman Institute of Technology
September 20, 2021

5500 Wabash Ave, Terre Haute, IN 47803

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

1 Proposal Summary

1.1 Team Summary

Rose Rocketry houses a collegiate competition team, a research organization, and an enthusiast's hub. Our goal is to bring co-curricular activities in the aerospace field to campus. We recognize that aerospace is an exciting and expanding industry, however, not one of the other 90+ clubs and teams on Rose-Hulman's campus offer students aerospace experience. Rose Rocketry aims to provide students with R&D opportunities and a competitive environment to put them to use. We go head to head with many of the nation's top engineering schools in the NASA University Student Launch Initiative (USLI).

Table 1.1: Project Summary and Mentor Contact Information

Team Name	Rose Rocketry
Project Name	Project Silverstein
Mailing Address	5500 Wabash Ave, Terre Haute, IN 47803
Mentor Name	Gary Kawabata
Mentor Contact	rocketguy9914@gmail.com
Mentor Certifications	NAR 89092; TRA 3019
NAR/TRA Sections	Indiana Rocketry Group Tripoli #132 NAR Section #711
Student Leader	Garrett Hart
Student Leader Contact	Garrett.Hart@rose-hulman.edu (812) 870-9933
Academic Advisor Contact	Scott.Kirkpatrick@rose-hulman.edu (812) 877-8383

The team has decided to dedicate our project to an alumnus of Rose-Hulman, Abe Silverstein. Abe was integral to the planning of the Apollo missions in the 1960's and 70's as well as in holding management positions at NASA and its predecessor, NACA. The name *Project Silverstein* was given to last year's project, wherein we had to withdraw due to external circumstances. However, we would like to dedicate a complete project in his memory and, thusly, have chosen this year's project to be *Project Silverstein*.

1.2 Student Leaders

The Rose Rocketry Student Launch (RR-SL) team operates within the Rose Rocketry Club on campus. The Rose Rocketry Club is an approved organization from 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 Leaders and Contact Information

Position	Student	Contact
President	Garrett Hart	Garrett.Hart@rose-hulman.edu
Vice President	Ryan St. Clair	Ryan.St.Clair@rose-hulman.edu
Secretary	Jessica Russell	Jessica.Russell@rose-hulman.edu
Treasurer	Donald Hau	Donald.Hau@rose-hulman.edu
Public Affairs Chair	Athena Henderson	Athena.Henderson@rose-hulman.edu
Safety Chair	Donald Hau	Donald.Hau@rose-hulman.edu

1.3 Team Members

The RR-SL team consists of 30 students for the 2021-2022 season who are eager to bring new aerospace opportunities to the Rose-Hulman campus. The backgrounds of these members vary widely between academic major, class year, rocketry experience, and personal interest in NASA SL activities.

2 Team Facilities

The RR-SL team has a dedicated workspace in the Branam Innovation Center (BIC). 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.

Within the BIC and KIC, the RR-SL team is supported by a project space containing the items shown in **Figure 2.1**.

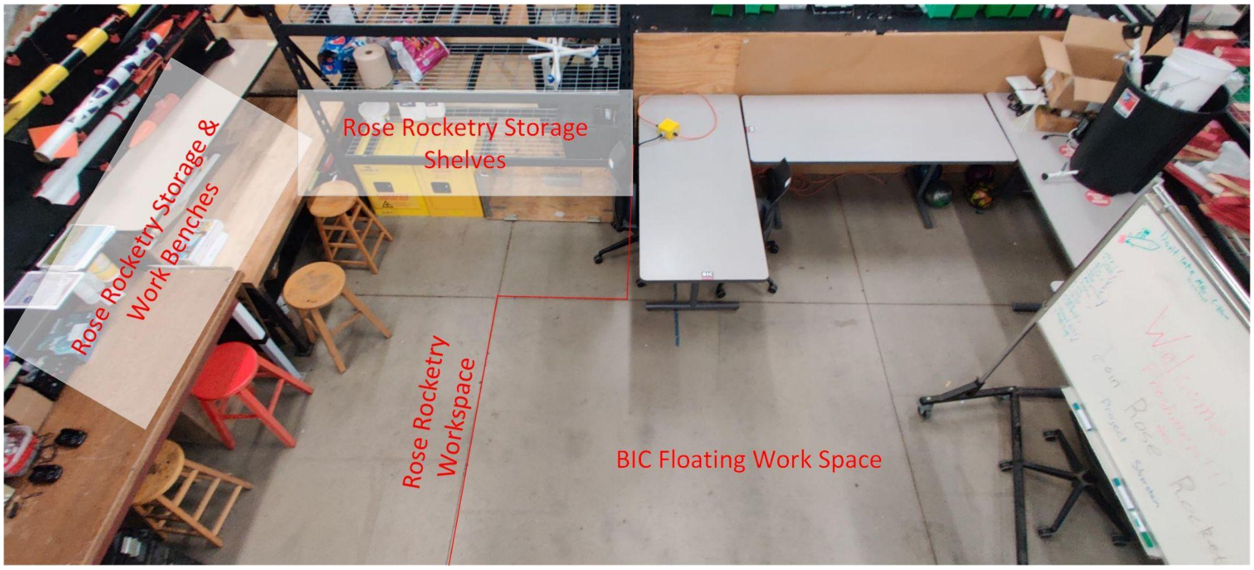

Figure 2.1: Rose Rocketry Workspace

The floating workspace is an area available to all BIC teams, but storage in the area is prohibited. We will use this space for constructing the launch vehicle and remove all tools and materials from the space after each meeting. We will make significant use of this space because our official space is very limited.

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. Access hours are limited to 8 A.M - 12 A.M during the week and 10 A.M - 12 A.M on weekends. To gain machine shop access, students are required to complete a 12-hour training program with a BIC shop instructor. Upon completion, students gain access to machine shop equipment, including lathes, drill presses, mills, and other machinery (with the supervision of a peer). This information is summarized in **Table 2.1**.

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, ventilation booth, electronics lab, wind tunnel, 3D printers, common hand tools, common power tools
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-beingof our members. In addition to the safety protocols of the BIC/KIC facilities and the campus wide policies used to ensure student health and safety from COVID-19, the team has developed our own safety practices to protect against the risks associated with high-power rocketry in our workspace and on launch day.

3.1 COVID-19 Policies

In accordance with the Rose Ready document (the COVID-19 response plan from Rose-Hulman), we are conducting in-person meetings only when deemed necessary and following all outlined safety protocols. As of September 20, these protocols include the following: masking regardless of vaccination status, handwashing and surface disinfection, and indoor limitations on eating, among others. The complete guidelines can be found at the Rose-Hulman Rose-Ready website: https://www.rose-hulman.edu/about-us/community-and-public-services/health/Rose-Ready.pdf.

In addition, attendance is taken during each meeting and at BIC and KIC entrances for both record-keeping and contact tracing purposes. As of September 13th, 2021, over 90% of Rose-Hulman students have been verified as fully vaccinated.

3.2 Safety Chair

Donald Hau has been designated as the safety chair for the 2021-22 academic year. Although this position is identified as a chair, it carries the same authority and responsibility within the team as an officer. The difference is, per our school's student government association, a person may hold both an officer and chair position, but not two officer positions. This allows the team to elect the most qualified member for the job, even if they already hold an officer position. The safety chair is responsible for holding all team members accountable for the safety measures listed in this section. In support of this, the safety chair will be responsible for updating and maintaining all safety rules and documentation. The safety chair (or an equally knowledgeable member under guidance of the safety chair) 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.

3.3 Material Safety

The risk posed by the materials used throughout the season will be evaluated using 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 ventilated paint booth, and a ventilated sanding booth. The safety chair will be responsible for briefing all team members on any and all potential material hazards.

3.4 NAR/TRA Protocols and Motor Handling

The rocket motors used for the NASA-SL competition will only be handled via our team mentor, who holds the necessary Level 2 NAR certification. This 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 with a nearby fire extinguisher. The Rose-Hulman BIC director, public safety office, team safety chair, and team's advisor each have a key to the cabinet.

3.5 Risk 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**.

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 removed
Catastrophic	5	Life threatening or debilitating injuries	Failure resulting in total loss of system or equipment	Flight canceled or destroyed

The probability and severity scales above are combined and mapped to provide the team with a risk assessment matrix, shown in **Table 3.3**.

Table 3.3: Mapped Risk Assessment Matrix

Category	Negligible	Marginal	Moderate	Critical	Catastrophic
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

3.6 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
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, no open flames, 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 paint booth and BIC/KIC ventilation system where necessary
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

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
Epoxy Contact	4 (environmental contamination, broken PPE, resin spill)	2 (skin irritation, eye irritation, burns)	8	Discard broken PPE, limit exposure, wear proper PPE
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
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
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
Flying debris	2 (Improper use of machinery, machinery failure)	4 (Blunt force trauma, lacerations)	8	Maintain a safe distance from machines under operations, ensure those working on machinery are properly certified by the BIC
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
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.)

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
Improper use of tools	3 (Use of BIC/KIC machine shop, soldering irons)	3 (Damage to equipment is unlikely, Injury may range from deep lacerations, burns, to lost fingers)	9	Ask BIC/KIC personnel or team Safety Officer before using high-risk tools, attend BIC safety training
Soldering burn	4 (Lack of attention or general clumsiness)	2 (Low temperature solder is most often used meaning only minor burns)	8	Ensure proper attention and personal health (getting enough sleep, proper nutrition, etc.)
Tripping Hazard	2 (Lapse of attention or general clumsiness)	3 (Unlikely to damage equipment or humans but with potential to seriously harm in the wrong environment)	6	Maintain proper situational awareness in all situations

3.7 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
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
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
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
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
Safe Misfire	2 (Improper motor construction, motor casing flaw)	4 (Partial destruction of the vehicle and/or payload, damage to launch pad)	8	Mentor will perform motor reloading cautiously

Catastrophic Misfire	2 (Structural weakness in the motor, tipped during launch)	5 (Complete destruction of the vehicle and payload, complete destruction of the launch pad)	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
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
Incomplete 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
Recovery System Failure	2 (Improper construction of recovery devices, parachute entanglement)	5 (Partial or complete destruction of the vehicle and/or payload)	10	Inspect construction of recovery devices
Radio Telemetry Failure	2 (Interference, electronic failure)	4 (Reduced possible methods of payload locating)	8	Redundant RF transmission equipment
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
Hypothermia	1 (Failure to wear appropriate clothing)	3 (Possible hospitalization)	3	Ensure team members limit exposure to dangerously low temperatures

3.8 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
COVID-19	2 (Over 90% vaccination rate between students and faculty)	3	6	All members must follow the Rose Ready document.
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
Testing Failure	2 (faulty part, improper rocket construction)	5 (major project delay, increased cost, possible disqualification from incomplete flight)	10	Careful design and consideration of every configuration that flies, only fly previously tested or extensively analyze rocket configurations
Failure to receive parts	2 (shipping delays, failure to order parts on time)	5 (major project delays, cannot continue fabrication)	10	Treasurer shall ensure orders are purchased in a timely manner
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 and competition delays) 4 (limited team personnel allowed to travel	4	Prepare logistics and scout drivers ahead of time
Major Equipment Failure	1 (equipment part failure, student misuse)	4 (possible large project delays, person injury)	4	Students are trained on all equipment, follow equipment maintenance

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 Chair, and by any Range Safety Officers.
6. Wear appropriate PPE for all team-related work.
7. 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.
8. Never misuse the materials or equipment I will work with in this project for any reason.
9. Acknowledge that the team will not be permitted to fly a rocket until the team mentor has reviewed the design.
10. Recognize that the team is expected to comply with established amateur rocketry design and safety guidelines as supervised by the team's mentor.
11. Acknowledge that failure to comply with any of the aforementioned safety regulations is cause for expulsion from the team.
12. Acknowledge that any action deemed unsafe by the team's mentor 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 vehicle architecture has four major sections: the Avionics Bay, Recovery System, Mission Payload, and the Rose Petal Controller (see **Section 4.2**). Although the team would prefer to place the Mission Payload aft of the recovery system, the proposed design of the Rose Petal Controller requires most of the aft airframe to be occupied. Because of this, the Mission Payload will be located within the nose cone, mounted on a custom insert sled as shown in **Figure 4.1**. Work will be done on the nose cone to accept the threaded payload insert. This makes for convenient assembly, as commercially available nose cones are sold with a hollow structure and an opening through the bottom wide enough to avoid meaningful constraints on the payload design. The general characteristics of the rocket are provided in **Table 4.1**.

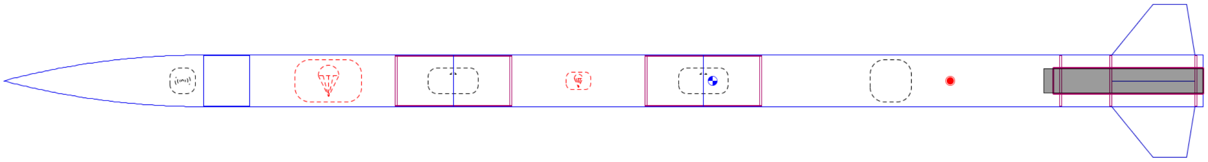

Figure 4.1: OpenRocket vehicle design

The proposed launch vehicle uses a fiberglass aerostructure and nose cone. The vehicle has four trapezoidal fins made from fiberglass-reinforced plywood. The angle of sweepback for these fins is such that the tip chord is not negatively (from the fore of the vehicle) displaced from the extent of the airframe (see **Figure 4.2**). This is done to minimize the likelihood of damage to the fins or the aerostructure upon landing.

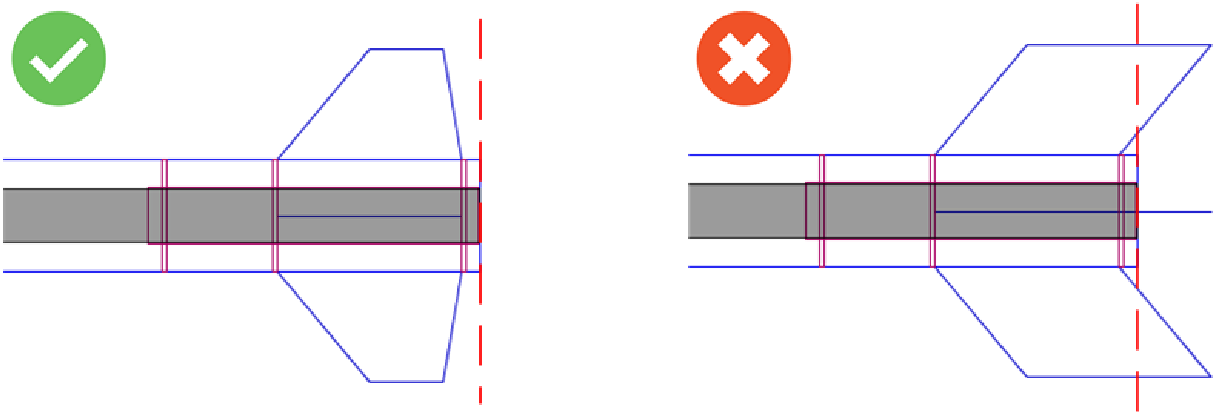

Figure 4.2: Trapezoidal fin design consideration

Table 4.1: Rocket characteristics

Rocket Length	3.66 m
Airframe Diameter	0.156 m
Dry Mass (no motor)	14.63 kg
Liftoff Mass	18.20 kg
Static Stability Margin	4.63 calibers
CG *	2.16 m
CP *	2.89 m

*Reported from the nose cone end of the rocket

Design iteration was performed using the open-source rocket simulation program, OpenRocket. The software is capable of modeling rockets and simulating flights. This software is free to use and is publicly available to download on their website: http://openrocket.info/. The simulation was done using the extended Barrowman equations with six degrees of freedom (three translational axes and three rotational axes). A fourth order Runge-Kutta integration method was selected, along with a spherical approximation of the earth, which is sufficiently accurate for the purposes of this design. The results of the simulation are shown in **Figure 4.3** and **Table 4.2**.

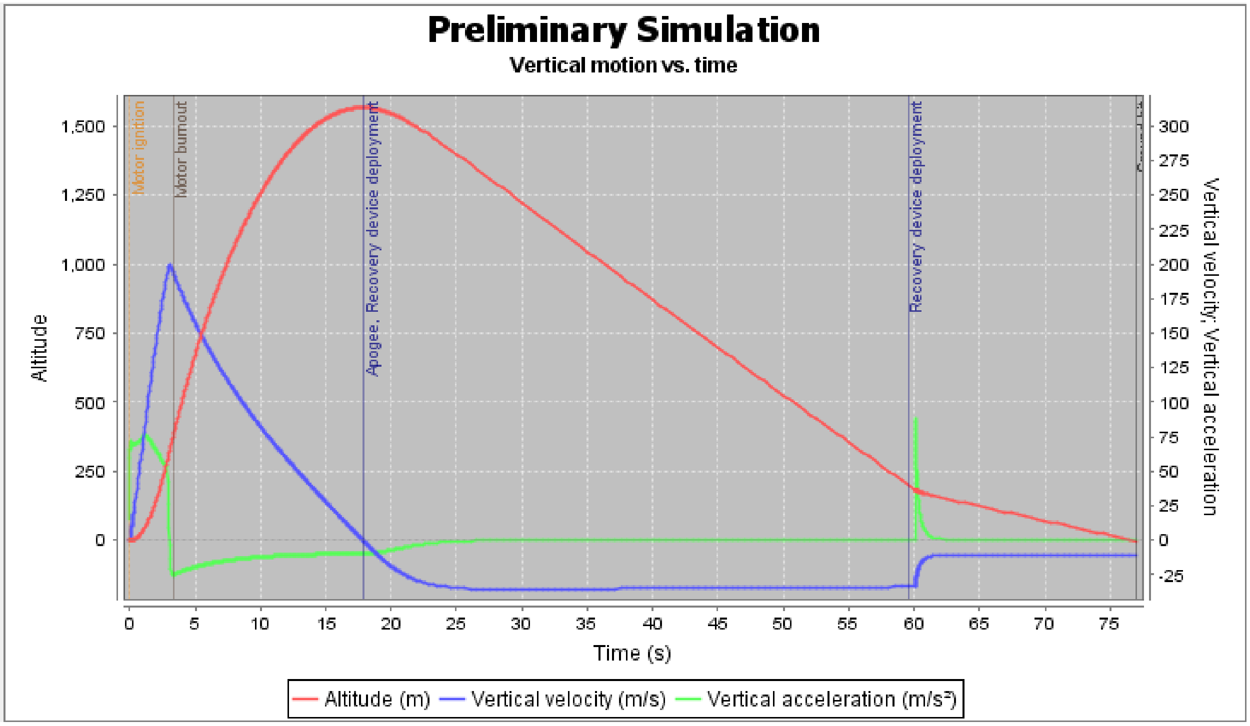

Figure 4.3: Simulation of the vehicle showing the altitude, velocity, and acceleration

Table 4.2: Rocket launch simulation characteristics

Apogee	1614 m
Maximum Velocity	207.9 m/s
Maximum Acceleration	78.9 m/s^2
Maximum G Load	+8.04 G

4.2 Apogee Assurance and “Rose Petal” System

In order to ensure that the vehicle meets its altitude target, the vehicle will use pneumatically actuated drag flaps (dubbed “Rose Petals”) to actively control deceleration. During flight, the vehicle will monitor its flight path via a combination of accelerometer and barometer data and compare its predicted apogee to the target apogee for the mission. If its projected altitude at any point in the flight differs from the target, it will adjust its aerodynamic drag to correct the discrepancy by deploying or retracting a set of flaps. The preliminary designs will use either hinged panels or sliding lateral plates positioned just above the motor mount.

Sliding lateral plates are considered because the force extending the plates is perpendicular to airflow. The advantage to this is that extension of the Rose Petal is not directly opposed by aerodynamic forces; however, there is concern that the force normal to the airframe due to airflow will cause a significant frictional force causing the plates to jam. The hinged panels would rotate out from the vehicle and slow the vehicle down. The main advantage of hinged panels is that if the system fails, it is likely to close to avoid bringing the vehicle apogee too low.

In order to characterize the variability of the apogee, we developed a custom Monte Carlo simulation using the SciPy library. With all of the unknown variables on launch day, we wanted to predict variability in the vehicle apogee so that we may choose a system configuration with the highest probability of success.. The simulation was based on a Newmark-Beta finite difference approximation of the kinematic equations, assuming an approximate drag coefficient, ignoring rotation during flight, using the given cant angle of the launch rail, and using the manufacturer-supplied thrust curve for a one of our proposed engines (the L1350). Random adjustments were made to the thrust, drag coefficient, and launch angle, and the simulation was repeated 5000 times to produce a probability curve for the apogee of the rocket. **Figure 4.4** shows the trajectories of the random trials, while **Figure 4.5** shows the frequency of each apogee range.

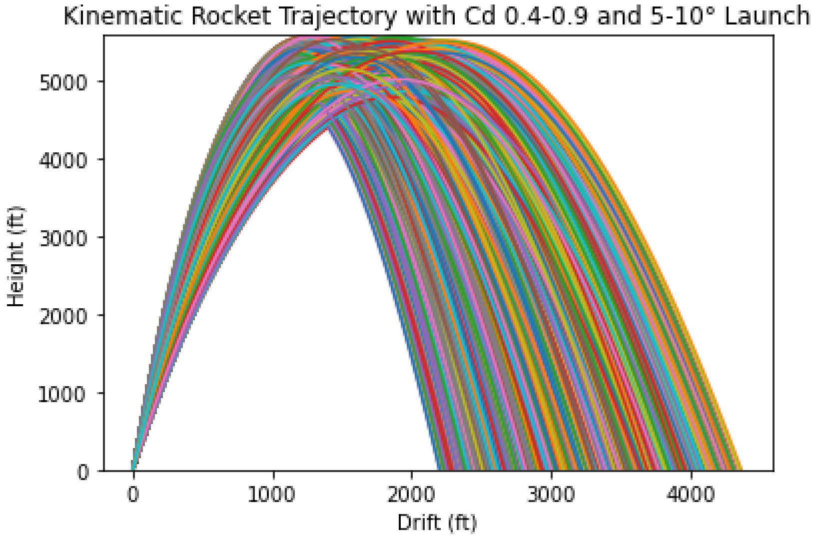

Figure 4.4: Simulated Rocket Trajectories with varying Launch Angle and drag coefficient

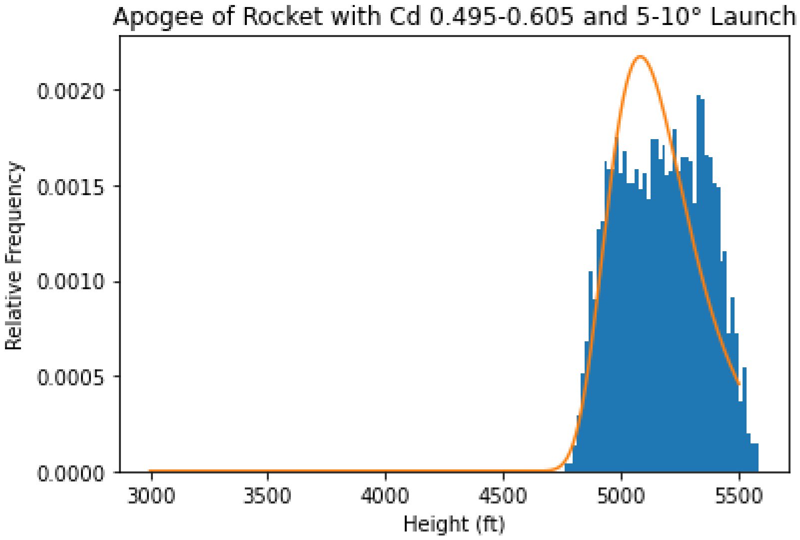

Figure 4.5: Distribution of Apogees with varying Launch Angle and drag coefficient

The launch angle was given by NASA in the 2022 Handbook, and the thrust variation of 5% is projected by the motor manufacturer. Our Open Rocket model calculates a Cd of 0.55, and we varied that by a standard 10%. **Figure 4.5** shows the estimated probability curve for our generated apogees. The current ranges for this simulation are generous, but as our research and development continues, our simulations will handle more variations and improve the apogee predictions. In particular, as the design and testing process continues, the expected range of the drag coefficient will decrease significantly. However, even with generous ranges for all variables under consideration, the apogee is not expected to exceed the range required for the competition as the 95% confidence interval is between 1481.6 m and 1738.3 m. Active control of the Rose Petals will then bring the vehicle apogee to a precise altitude within our confidence interval.

4.3 Recovery System Design

The projected vehicle design separates at the fore coupler to deploy recovery devices. In the fore coupler are two separate electronic deployment systems (flight computers, power systems, black powder deployment charges) to provide a redundant recovery architecture. At apogee, a 61 cm (24 in) Drogue Chute (indicated as the smaller recovery device on the OpenRocket schematic) deploys to slow the vehicle to main deployment speeds. At 244 m (800 ft) AGL, the main chute (indicated as the larger recovery device) will deploy to slow the vehicle to an acceptable touchdown speed. The OpenRocket simulations predict a touchdown speed of approximately 3.5 m/s.

4.4 Projected Motor Brand and Designation

To ensure that motor availability does not compromise the flight, two suitable and roughly equivalent motors were selected. Models were specifically selected from two different manufacturers to limit the impact of supply-chain disruptions. These motors are the Cesaroni Technology, Inc. L1350CS-P and Aerotech L1420R-P. Additionally, to account for unforeseen increases in weight during the development process, a second pair of motors offering more total impulse was selected. These motors are the Cesaroni Technology, Inc. L2375WT-P and Aerotech L2200G-P. Simulations using these motors project that an increased mass of 4kg (9lb) can be supported.

4.5 Description of Project Payload

The objective of our vehicle payload is to autonomously locate the launch vehicle upon landing on a gridded aerial image of the launch site without the use of the global positioning system (GPS). Each grid box shall be square and not exceed a width of 76.2 m (250 ft). The team plans to rely on two simultaneous measurement methods for the sake of redundant locating: time integration of inertial measurement unit (IMU) data and Radio Frequency (RF) locating.

At its core, time integration is the simpler and more robust method, requiring only an IMU capable of outputting acceleration in the X, Y, and Z axis, and a microprocessor capable of performing numerical integration. This approach involves performing double integration (with respect to time) on the in-flight acceleration data to determine the change in vehicle position since launch. While simple, because this approach produces a derived measurement via summation, noise or error can accumulate over time. This effect may be amplified if the accelerometer is saturated during high acceleration events, such as parachute deployment.

To reduce the effect this error has on our final measurement, we can transmit the raw IMU data to our ground station , which will be outfitted with more advanced signal analysis hardware and software than available on the payload. In addition, shock absorbing mounts for the IMU can be used to further reduce the effect of external noise on our measurements.

The second approach, RF locating, is more reliable, but also more complex. The location of the launch vehicle can be determined by sweeping a directional RF antenna to find the angle toward the launch vehicle relative to the ground station. Once this has been determined, the distance to the rocket from the team prep area can be found by measuring the strength of a signal sent from the payload to the team prep area. The payload can then stream signal strength data back to the ground station as the ground station signal is attenuated.

To accomplish the aforementioned approaches, the payload will consist of an embedded computer, an IMU and RF transceiver, and an independent power supply. An example of a suitable IMU is the Bosch Sensortek BNO055 because of its wide sample range (±16g) and availability through Adafruit so that it is more likely to be available in the event of a shortage.

4.6 General, Vehicle, Recovery, Payload, and Safety Requirements

Table 4.3: The general requirements mandated by NASA and our plans to fulfill them

1. General Requirements	Strategy to Fulfill
1.1 Students will do 100% of the work	Physical work will be done in the BIC/KIC. All work will be appropriately documented. Copies of design documents will be maintained by the Vice President of the team to ensure that designs are being done by students.
1.2 Team will maintain a project plan	President of the team will maintain and enforce a plan for Project Silverstein.
1.3 Foreign National team members must be identified on the Preliminary Design Review (PDR)	Secretary will keep track of all Foreign National students on the team and report on the PDR.
1.4 Team must identify members who plan to attend Launch Week	Secretary will track all students attending Launch Week.
1.5 Team must engage 250 participants in STEM outreach	Public Affairs Chair will be in charge of engaging the community in STEM outreach events as well as documenting a head count of community members engaged.
1.6 Team will establish a social media presence	Public Affairs Chair will maintain a social media presence for the team.
1.7 Teams will email deliverables to NASA project management	President of the team will keep track of the requirements of all deliverables. Secretary will ensure proper document layout is maintained throughout.
1.8 All deliverables will be in PDF format	
1.9 Report a table of contents in every report	

1.10 Report page numbers in every report	
1.11 Team will provide equipment necessary to perform a video teleconference with the review panel	Secretary will keep track of team communication capabilities and equipment.
1.12 The team will be required to use the launch pads provided	Vice-President will ensure tests are performed using a launch pad similar to those provided by NASA at Launch Week.
1.13 Each team must identify a mentor	President will engage a NAR-certified mentor in the activities of the team and report the mentor on deliverables.
1.14 Teams will report the number of hours spent working on each milestone	President of the team will keep track of and maintain the requirements of all deliverables.
2. Vehicle Requirements	
2.1 The vehicle will achieve an apogee between 4000ft. and 6000 ft.	Vehicle team will define an apogee goal and verify that the rocket performs to this goal using various simulation techniques
2.2 Teams will identify a target altitude goal in the PDR	
2.3 The vehicle will carry two commercially available, barometric altimeters	Vehicle team will develop two independent altimeter systems to implement in the vehicle.
2.4 The vehicle will be designed to be recoverable and reusable	Vehicle team, appointed mentor, and club advisor will ensure that vehicle requirements and performance specifications are met.
2.5 The vehicle will have a maximum of four independent sections	
2.6 The vehicle will be capable of being prepared for flight within 2 hours of the time the FAA flight waiver opens	
2.7 The vehicle and payload will be capable of remaining in launch-ready configuration on the pad for a minimum of 2 hours without losing functionality of critical components	
2.8 The vehicle will be capable of being launched by a 12-volt DC firing system	
2.9 The vehicle will not require special ground support equipment or external circuitry for launch	
2.10 The vehicle will use a commercially available solid motor propulsion system using APCP	

2.11 The vehicle will be limited to a single stage	
2.12 The vehicle's total impulse will not exceed 5,120 Newton-seconds (L-class)	
2.13 Pressure vessels on the vehicle will be approved by the RSO with a factor of safety of 4:1, a pressure relief valve, and the full pedigree of the tank will be described	
2.14 The vehicle will have a minimum static stability margin of 2.0 at the point of rail exit. Rail exit is defined at the point where the forward rail button loses contact with the rail	
2.15 The launch vehicle will have a minimum thrust to weight ratio of 5.0 : 1.0	
2.16 Any structural protuberance on the rocket will be located aft of the burnout center of gravity	
2.17 The vehicle will accelerate to a minimum velocity of 52 fps at rail exit	
2.18 A subscale model of the vehicle will be launched and recovered prior to CDR deadline	Vehicle team will conduct various tests on the final full scale vehicle and test vehicles.
2.19 Demonstrations of flights will be completed by successfully launching and recovering a full-scale rocket prior to FRR in its final flight configuration	
2.20 An FRR Addendum will be required for any team completing a Payload Demonstration Flight	Vehicle team will track any changes made to the vehicle after every test flight.
2.21 Rocket parts will be labeled with contact info	Vehicle team will ensure that all vehicle components meet requirements and specifications.
2.22 Lithium Polymer batteries will be protected and labeled	Vehicle team will ensure that vehicle requirements and performance specifications are met. Motor specifications will be met through exhaustive research into each motor.
2.23 The vehicle will not utilize forward firing motors, motors that expel titanium sponges, hybrid motors, a cluster of motors, or friction fit	

motors. The vehicle will not exceed Mach 1 and vehicle ballast will not exceed 10% of the total unballasted weight. Onboard transmitters will not exceed 250mW of power (per transmitter) and will not create excessive interference. The vehicle will not use excessive and/or dense metal in its construction	The vehicle specifications will be predicted through simulation and verified through manufacturing and fabrication. Transmitter power usage will be measured using external hardware.
3. Recovery System Requirements	
3.1 The full-scale 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	Vehicle team will oversee a recovery plan that meets appropriate requirements.
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	Vehicle team will oversee various recovery event tests.
3.3. Each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf at landing	Vehicle team will oversee a recovery plan that meets appropriate requirements.
3.4. The recovery system will contain redundant, COTS altimeters	
3.5. Each altimeter will have a power supply, and all recovery electronics will be powered by COTS batteries	Vehicle team will ensure that all recovery components meet appropriate requirements and that the vehicle meets appropriate recovery specifications.
3.6. Each altimeter will be armed by an arming switch that is accessible from the exterior of the rocket airframe	
3.7. Each arming switch will be capable of being locked in the ON position	
3.8. The recovery system electrical circuits will be completely independent of payload electrical circuits	
3.9. Shear pins will be used for the main parachute compartment and the drogue parachute compartment.	
3.10. The recovery area will be limited to a 2,500 ft. radius from the launch pads	Vehicle team will oversee a recovery plan that meets appropriate requirements.

3.11. Descent time of the launch vehicle will be limited to 90 seconds	
3.12. An electronic tracking device will be installed in the launch vehicle and will transmit the position of the vehicle	Vehicle team will ensure that all recovery components meet appropriate requirements and that the vehicle meets appropriate recovery specifications.
3.13. The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight	
4. Payload Experiment Requirements	
4.1 Teams will design a payload capable of autonomously locating the launch vehicle upon landing by identifying the launch vehicle's grid position on an aerial image	Payload team will oversee a design plan for a self-locating payload that meets competition specifications.
4.2 The payload will adhere to the launch vehicle landing zone mission requirements	
4.3 The payload will adhere to the general payload requirements	
5. Safety Requirements	
5.1 Each team will use a launch and safety checklist, which will be included in FRR report, LRR, and any Launch Day operations	Safety Chair will perform necessary safety evaluations of the mission.
5.2 Each team must identify a student safety officer that is responsible for the items in 5.3	Safety Chair is identified in the mission Proposal.
5.3 The safety officer is responsible for monitoring team activities with an emphasis on safety and implementing procedures developed by the team for construction, assembly, launch, and recovery activities. The safety officer manages and maintains revisions of the team's hazard analyses, failure mode analyses, and MSDS/chemical inventory as well as assists in writing these procedures	President will ensure all the appropriate responsibilities are carried out by the Safety Chair.
5.4 During test flights, teams will communicate with the local rocketry club's RSO and follow their rules and guidance	Safety Chair will maintain communication between the RSO and the team such that all the requirements are followed.

5.5 Teams will abide by all FAA rules	Safety Chair will restrict team activities to those that abide by FAA rules.
6. Final Flight Requirements	
6.1 Teams must pass the LRR on Launch Week, launching only once, and give the altimeter to the scoring official upon recovery, with the mentor present for rocket preparation and launching	President of the team will oversee the LRR and scoring deliverables on Launch Week.
6.2 The team must prepare for vehicle inspection and preparation at the Commercial Spaceport Launch Site. The team must adhere to guidelines set for competing at the Commercial Spaceport Launch Site	President of the team will coordinate all vehicle launches, complying with requirements for NAR or TRA sanctioned fields.

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. Although many of the local communities surrounding the team are lifting COVID-19 restrictions, we will give careful consideration to the best medium for hosting each outreach event with the health and safety of RR-SL and community members in mind.

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. The following events are planned for this year:

- The team will promote a live stream of our subscale and full-scale test flights where we will interact with members of our community virtually.
- Virtual Q&A session with a current SpaceX employee and Rose-Hulman alumnus to answer community questions.
- The team will partner with our local children's museum to host an in-person rocket workshop, with the necessary COVID-19 precautions in place.

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.

6 Project Plan

6.1 Project Timeline

We have established a sequence of events for this project, as shown in **Table 6.1**.

Table 6.1: Season Timeline

Milestone	Date
Project Proposal	8:00 a.m. CDT on Monday, September 20th, 2021
Preliminary Design Review	8:00 a.m. CDT on Monday, November 1st, 2021
Subscale Launch	Saturday, December 11, 2021
Critical Design Review	8:00 a.m. CST on Monday, January 3rd, 2022
Full Scale Test Launch	Saturday, Feb. 12, 2022
Flight Readiness Review	8:00 a.m. CST on Monday, March 7th, 2022
Post Launch Assessment	8:00 a.m. CDT on Monday, May 9th, 2022

6.2 Time Log

Since the handbook's release (August 18th), the team has been meeting multiple times a week, with several members per meeting. The time tracked between brainstorming, modeling, and writing is approximately 410 hours.

6.3 Project Funding

The RR-SL team is funded by the BIC/KIC, SGA, and outside donations. These donations include equipment from within other school departments, discounts or donations from outside manufacturers, and monetary funding.

The below budgets have been calculated by consulting with other BIC/KIC teams, analyzing our previous year's competition design, reviewing past USLI competition projects, and using RR-SL team member experience.

6.4 Vehicle Budget

Table 6.2: Vehicle Budget

Item	Cost
Motor Propellant	$300
Motor Hardware	$500
Recovery	$400
Flight Electronics	$200
Rose Petals	$350
Airframe	$500
Nose Cone	$150
Total	$2,400

6.5 Payload Budget

Table 6.3: Vehicle Budget

Item	Cost
Battery Equipment	$80
Microcontroller	$50
Assorted Wire	$30
High Range IMU	$60
Low Range IMU	$60
RF Equipment	$200
Total	$480

6.6 Subscale Budget

We are planning on using a J-class DMS motor. We will be loading the same payload and adjusting our recovery system to impart a similar maximum acceleration on the rocket as the full-scale launch . If time allows, two subscale flights will take place. Our budget is $600.

6.7 Branding Budget

The team expects to spend $300 on branding. These funds will provide stickers and flyers for outreach, website hosting, and help offset the cost of apparel for members.

6.8 Travel Budget

A majority of the team's travel expenses will be reimbursed by the school. This includes rental vehicles, gas, and hotel expenses. A budget of $4000 has been determined by consulting with other Rose-Hulman competition teams who have travelled similar distances in recent years.

6.9 Total Budget

Table 6.4: Total Budget

Item	Budget
Vehicle	$2,400
Payload	$480
Subscale	$600
Branding	$300
Travel	$4000
Total	$7780