Piedmont Student Launch Team

2018 NASA Student Launch Proposal

Piedmont Virginia Community College
501 College Drive, Charlottesville, Virginia 22902

September 20, 2017

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Fredrick Kepner, Katie Wallace, Zachary Koch, Ryan Connelly
George C. Marshall Space Flight Center
Academic Affairs Office
Huntsville, Alabama 35812

Dear Mr. Kepner, et al.,

The Piedmont Student Launch Team, representing Piedmont Virginia Community College (PVCC), is pleased to offer the following proposal for participation in the 2018 NASA Student Launch. We formed this team last year with the goal of establishing and sustaining a new opportunity for PVCC students to explore the educational and career-building experience that the Student Launch challenge offers. Reaction within the college and surrounding community has been overwhelmingly positive and supportive, and we eagerly look forward to making our college proud again in the challenge ahead. We are once again honored to have PVCC Professor of Physics Dr. Yana Goddard working with us as our faculty advisor.

For this year's challenge, we have chosen to undertake the Deployable Rover experiment, and over the next several months we look forward to working with the team at NASA and with our colleagues in the nearby Tripoli Central Virginia TRA prefecture and Valley AeroSpace Team NAR section that will be assisting us. We are also looking forward to engaging with our local community in educational outreach. As a community college, PVCC is especially well positioned to assist us in furthering this endeavor, and in fact has already helped us to line up multiple outreach opportunities.

As you evaluate this proposal, please do not hesitate to contact me with any questions or concerns you may have. I can be reached by email at leader@piedmontlaunch.org. Thank you for this opportunity and for your time and consideration in reviewing this proposal. All of us on the Piedmont Student Launch Team look forward to working with your agency in the coming months.

Very respectfully,

Andrew Oxford
Team & Project Leader

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Glossary of Acronyms

ABS	-	Acrylonitrile Butadiene Styrene
AGL	-	Above Ground Level
APCP	-	Ammonium Perchlorate Composite Propellant
ATF	-	Bureau of Alcohol, Tobacco, Firearms, and Explosives
CA	-	Cyanoacrylate (Super Glue)
CAD	-	Computer Aided Design
CDR	-	Critical Design Review
CG	-	Center of Gravity
CHEC	-	Community Homeschool Enrichment Center
CNC	-	Computer Numerical Control
CTI	-	Cesaroni Technology Incorporated
FAA	-	Federal Aviation Administration
FRR	-	Flight Readiness Review
FSEE	-	Family Space Exploration Event
GNU	-	GNU's Not Unix
GPS	-	Global Positioning System
IDE	-	Integrated Development Environment
LCO	-	Launch Control Officer
MIG	-	Metal Inert Gas
MSDS	-	Material Safety Data Sheet
NAR	-	National Association of Rocketry
NFPA	-	National Fire Protection Association
NOVAAR	-	Northern Virginia Association of Rocketry
NRAO	-	National Radio Astronomy Observatory
OD	-	Outer Diameter
PDR	-	Preliminary Design Review
PLA	-	Polylactic Acid
PLAR	-	Post Launch Assessment Review
PPE	-	Personal Protective Equipment
PSLT	-	Piedmont Student Launch Team
PVCC	-	Piedmont Virginia Community College
RSO	-	Range Safety Officer
STEM	-	Science, Technology, Engineering, and Math
TIG	-	Tungsten Inert Gas
TRA	-	Tripoli Rocketry Association
VAST	-	Valley AeroSpace Team

1 General Information

1.1 Introduction

The Piedmont Student Launch Team (PSLT), representing Piedmont Virginia Community College (PVCC) in Charlottesville, Virginia, is comprised of students with backgrounds ranging from amateur rocketry, finances, electronics, programming, mathematics, data analysis, engineering, project management, and communications as well as International Science Fair and Robotics Challenge competitors. In addition, PVCC, as a true *community* college, is committed to the success of this team as part of the community, and strongly supports the team's outreach efforts to further the promotion of Science, Technology, Engineering, and Math (STEM) education in the community at large. Between the skills and experience of the team members, mentor, and faculty advisor, the enthusiasm of a returning and excited team, the commitment of the college administration, and the generous support of major sponsors, PSLT is well positioned to succeed in the 2018 NASA Student Launch.

Name	Title	Email	Telephone
Dr. Yanina Goddard	Professor of Physics	ygoddard@pvcc.edu	434-961-5341
Andrew Oxford	Team Leader	leader@piedmontlaunch.org	434-996-4658
Troy Dodd	Safety Officer	safety@piedmontlaunch.org	434-953-6901

Table 1.1 - Team Contacts

All deliverables due to NASA throughout the period of performance will be provided on the team website at http://piedmontlaunch.org.

1.2 Team Organization and Members

PSLT currently consists of 21 students, one team mentor, and one faculty advisor. Recruiting is continuing, so it is possible that a small number of additional student team members may be added prior to the PDR.

The team is organized into five project areas with area leaders:

- Administrative
- Engagement & Outreach
- Launch Vehicle
- Payload
- Safety

In addition to major project areas, there are functional areas to categorize the work team members do, based on their interests and skills. Functional areas do not have leaders:

- Analysis
- Communications
- Education
- Electronics
- Graphic Arts
- Outreach
- Programming
- Structural

There are several key roles on the team for people who are in charge of a project area, who direct a major function within a project area, or are required under the statement of work.

Name	Role	Project Areas	Functional Areas
Alex	Deputy Safety Officer Webmaster	Safety Payload Launch Vehicle	Electronics Programming Structural Analysis
Andrew	Team Leader & Project Manger	Administrative	None
Anna	Director of Testing & Analysis	Launch Vehicle Payload	Analysis
D'Ann	Director of Social Media	Engagement & Outreach	Communications
Jesse	Director of Engagement & Outreach	Engagement & Outreach	Outreach Education
Lu	Treasurer	Administrative Engagement & Outreach	Structural Education Outreach Communications
Rodney	Director of Launch Vehicle	Launch Vehicle	Structural Analysis
Sander	Director of Payload	Payload	Electronics
Troy	Safety Officer Director of Art	Safety Launch Vehicle	Structural Graphic Arts

Table 1.2 - Key Positions

In addition to the key roles, other team members work in one or more project areas, and in many cases, perform multiple functions within those areas.

Name	Project Areas	Functional Areas
Branson	Launch Vehicle Payload	Structural
Carl	Launch Vehicle Payload	Electronics Structural
Chris	All	Graphic Arts
Daniel	Launch Vehicle Payload	Electronics Structural
James	Launch Vehicle Administrative	Electronics Structural
Jack	Launch Vehicle Payload	Electronics Programming Structural
Michael	Launch Vehicle	Structural Analysis

Name	Project Areas	Functional Areas
Nathanael	Launch Vehicle Engagement & Outreach	Electronics Structural Communications
Nelly	Launch Vehicle	Communications
Shane	Launch Vehicle Payload	Electronics Programming Structural
Sophia	Launch Vehicle Payload Engagement & Outreach	Structural Analysis Education Outreach Communications
Victoria	Launch Vehicle Engagement & Outreach Administrative	Structural Analysis Education

Table 1.3 - Other Team Members

1.3 NAR / TRA Section Assistance

For purposes of mentoring, design & documentation review, and launch assistance, PSLT will be working primarily with Tripoli Central Virginia TRA #25 (also known as Battle Park). The Battle Park launch field near Culpeper, VA (approximately 40 minutes from PVCC) has a nominal flight ceiling of 16,000 ft AGL based on their FAA waiver, with frequent flights to 6,000 ft AGL or more being safely recovered. With this capability, PSLT will be able to perform full-scale test flights using the full-scale motor.

As a backup launch site, PSLT will be working with the Valley AeroSpace Team (VAST) (NAR Section #687 / Tripoli Western Virginia #36). The VAST launch field near Monterey, VA (approximately an hour and a half from PVCC) has a nominal flight ceiling of 10,000 feet AGL and can support launches to at least 6,000 ft AGL.

Additionally, PSLT will be working with the Northern Virginia Association of Rocketry (NOVAAR) (NAR Section #205). The NOVAAR launch field near Warrenton, VA (approximately an hour and a half from PVCC) has a nominal ceiling of only 4,500 ft AGL so it will not be used for full-scale test flights unless other options are not available; however, it may still be used for subscale test flights.

2 Facilities and Equipment

2.1 Available Facilities and Equipment

PSLT has access to a variety of workspaces, tools, and equipment, both on and off campus. These workspaces should provide ample capacity to develop the necessary products for the project, including the experiment payload, test equipment, and the subscale and full-scale launch vehicles.

2.1.1 Oakhaven Farm Workshop

The team mentor has opened his workshop for the team to use. This workshop is a recently-renovated 1,000 sq. ft stand-alone workspace set up primarily for rocketry work by multiple concurrent people. It has been used by PSLT in the past, as well as for mentored build days for local people new to rocketry, and easily accommodates 15 or more people at a time. It is available from 8:00 AM to 10:00 PM seven days a week, and longer by arrangement. It provides the necessary space and equipment to fabricate and assemble the structural and electrical components of the rocket. The workshop offers a full complement of stationary and portable power tools, hand tools, and support equipment for fabricating with phenolic tubing, wood, and fiberglass, and tools for simple metalworking. It also contains a dedicated electronics work area with associated tools and equipment. The shop maintains a comprehensive set of safety equipment, including readily-accessible Personal Protective Equipment (PPE) such as eye and face protection, dust masks, and latex gloves, along with shop safety equipment such as spill cleanup kits, multiple fire extinguishers, eye wash station, and readily-accessible Material Safety Data Sheets (MSDSs).

Available tools include:

- Standard hand tools (saws, screwdrivers, hammers, etc.)
- Standard power tools (drills, Dremel, sanders, routers, etc.)
- Drill press
- Stationary saws (table saw, compound miter saw, band saw, scroll saw)
- Electrical equipment (multimeter, voltage testers, etc.)
- Soldering and electronics station

2.1.2 PVCC Engineering Workshop

PVCC maintains an engineering workshop open to student clubs and activities. It offers many of the same tools found at Oakhaven Farm, as well as advanced machines such as laser cutters and CNC equipment. Because it is a shared facility, storage space is limited. The workshop has a large space that allows for the entire team to work together. The shop requires school personnel to open it and requires scheduling a time slot, typically available from 8:00 AM to 8:00 PM Monday through Thursday, and 8:00 AM to 5:00 PM on Friday, with possible options to get access during the weekend.

Available tools include:

- CNC mill
- TIG and MIG welding equipment
- Pipe benders
- Tensile and torsion material testing equipment
- Metal lathe
- Laser cutter
- Standard hand and power tools

2.1.3 PVCC Electronics Workshop

PVCC also maintains a workshop dedicated to electronics and electrical work. It is a ventilated room with advanced tools to aid in the development of electronics. It contains an open space with lab tables available and a bank of spare parts. Basic electronics and soldering equipment is available, and a lab tech is typically available for assistance. This workshop is used by classes and is open for general use on a variable schedule that is posted on the door.

2.1.4 3D Printers

PSLT has access to two different 3D printers, one at Oakhaven Farm and one at PVCC. Both are available for use at any time.

Oakhaven Farm:

- Large build volume
- Wide range of options for print material
- Dual material printing capability
- Ideal for printing prototypes, tools, and final parts where very high precision is not necessary

PVCC:

- Moderate build volume
- Only prints in ABS
- Very high precision
- Ideal for printing final parts where very high precision is necessary

2.2 Required Supplies

Construction supplies required to build the rockets and payloads may include some or all of the following. These supplies will be acquired as needed from the team's budget:

- Phenolic and fiberglass tubing
- ¼ in. plywood
- Fiberglass sheet stock
- Fiberglass cloth
- Hardware (U-bolts, screws, bolts, nuts, etc.)
- Aluminum sheet and bar stock
- Recovery system supplies (Kevlar recovery harness, parachutes, etc.)
- Avionics and payload electronics (altimeters, microcontrollers, switches, GPS units, etc.)

The following is a list of major consumable supplies that will be required for the construction of the launch vehicles and payloads. It may change as the design develops. These supplies are maintained in quantity in both the Oakhaven Farm and PVCC Engineering workshops and are available for the team's use. Any additional consumables will be acquired as needed from the team's budget.

- Adhesives and resins (epoxy, CA, etc.)
- 3D printer filament (ABS, PLA, etc.)
- Solder
- Cutting fluid
- Two-part expanding foam
- Tape (masking tape, duct tape, etc.)
- Electrical supplies (wire, connectors, etc.)

2.3 Technical Tools

The following software and technical tools will be used by the team to facilitate collaboration, technical design and development, communication, and project management.

2.3.1 ShareFile

ShareFile is an online document sharing system that allows easy access to the files needed by the team. The team uses it to organize and compile documents in a central location as well as share important links and information such as meeting notes and agendas.

2.3.2 GNU Octave

GNU Octave is a program that will allow the team to perform large calculations to aid in the development of the rocket and its flight. These calculations would be difficult to do by hand and are best done with a programmable mathematical tool such as GNU Octave.

2.3.3 MATLAB

In addition to GNU Octave, PSLT has limited access to MATLAB on the computers at PVCC for doing complex calculations.

2.3.4 RockSim

RockSim is a popular rocket design and simulation program that will be used to help design the rocket before it is physically modeled and tested. The program includes calculations for all major rocket characteristics, such as centers of mass and pressure, apogee, maximum velocity, and rail-exit velocity. Apogee Components, maker and distributor of RockSim, has provided multiple licenses of the software to PSLT under a one-year educational license.

2.3.5 OpenRocket

PSLT will also use OpenRocket, a free, open source simulation and design software similar to RockSim, for performing simulations on launch vehicle designs. Using both RockSim and OpenRocket will allow PSLT to compare different models to help ensure that designs perform as expected.

2.3.6 Inventor

Autodesk Inventor is mechanical design and 3D CAD software offering professional-grade 3D mechanical design, documentation, and product simulation tools. PSLT makes use of Inventor to lay out models, prepare schematic diagrams, and design parts for 3D printing.

2.3.7 Slack

Slack is a professional communications and collaboration platform by which members can send instant messages, both in focused channels and as direct messages. It also acts as a discussion board and a quick file-sharing utility. It is ideal for use outside of meetings and for when members are not able to attend a meeting.

2.3.8 GoToMeeting

Through one of PSLT's major sponsors, the team has access to Citrix GoToMeeting. The team uses this popular teleconferencing system to hold meetings with members who are unable to attend in person.

2.3.9 Google Drive

Google Drive is being used to host the team's primary project planning document. It provides a quickly-accessible online location to manage key elements of the project, especially the primary team assignments and due dates.

2.3.10 Teleconference Facilities

Two of PSLT's main sponsors have facilities for doing teleconferencing utilizing high-quality voice and video equipment. These facilities will be available to the team for the required reviews with NASA.

3 Safety

3.1 Culture of Safety

A Culture of Safety is an organizational atmosphere for safety and health that is understood and accepted as the number one priority. In a safe working environment, there are always high safety standards, personnel always feel comfortable reporting any safety concerns, and no conflict exists between safety and getting the job done. PSLT is fully committed to maintaining a Culture of Safety for its team members by ensuring personnel are properly trained prior to any task, safe procedures are strictly followed, and all team members make safety their first concern.

3.2 Safety Officer

PSLT has designated Troy Dodd as the Safety Officer. He will be responsible for developing and implementing a safety plan that encompasses the design, construction, testing, and launching of the team's high powered rockets and payloads, as well as all other aspects of the project. The Safety Officer is or will become familiar with all laws and regulations as specified by the National Fire Protection Association code 1127; the Federal Aviation Administration (14 CFR 101); the Bureau of Alcohol, Tobacco, Firearms, and Explosives (U.S.C. Chapter 40 and 27 CFR Part 555); the National Association of Rocketry; and the Tripoli Rocketry Association. The Safety Officer will brief team members on all risks involved while working, as well as all safety procedures outlined in the safety plan. The Safety Officer shall also be responsible for creating checklists to ensure proper procedures are followed during the fabrication, testing, launch, and recovery of all rockets and payloads.

The team has designated a Deputy Safety Officer. The Deputy's primary job is to help promote a Culture of Safety in the team by assisting the Safety Officer with his duties and ensuring that a safety-focused individual is available at all team activities.

3.3 Safety Plan and Risk Assessments

3.3.1 Risk Severity-Probability Matrix

In order to assess the pre- and post-mitigation levels of risk for identified hazards, the common risk severity-probability designations shown in Figure 3.1 will be used. These or similar designations are used in risk assessment by the Department of Defense, NASA, and other governmental and private organizations to characterize both the probability and the severity of any given hazard. Any hazard which PSLT identifies that is not Low or Minimal Risk will have a mitigation applied as shown in the following sections. The risk level both before and after the applied mitigation is shown in Tables 3.1 – 3.4.

Probability	Severity			
	1 Catastrophic	2 Critical	3 Marginal	4 Negligible
A – Frequent	1A	2A	3A	4A
B – Probable	1B	2B	3B	4B
C – Occasional	1C	2C	3C	4C
D – Remote	1D	2D	3D	4D
E – Improbable	1E	2E	3E	4E

Severity - Probability			
High Risk Unacceptable	Medium Risk Undesirable	Low Risk Acceptable	Minimal Risk Acceptable

Figure 3.1 - Severity-Probability Risk Designations

3.3.2 Material Safety

Some of the materials that will be used in the construction, testing, and operation of the rockets are particularly hazardous and will need to be handled with extreme caution. Team members acknowledge that there are potential risks involved with working with these materials, and will learn about these risks and how to mitigate them prior to handling them. In addition, team members acknowledge that all energetics may only be purchased and handled by the Team Mentor. These materials include Ammonium Perchlorate Composite Propellant (APCP), motor ignitors, and black powder. All materials will be stored in a safe manner per their Material Safety Data Sheets (MSDS), such as storing black powder at a minimum of 25 ft from any heat source, and personnel will be briefed on how to safely store and work with these materials. The following Table 3.1 is sample of materials risk assessments and mitigations.

Hazard			
Effect(s)			
Cause(s)	Mitigation(s)	Pre-Mitigation	Post-Mitigation
Burns			
Minor to serious injury to personnel. Minor to serious damage to property			
Unintentional motor ignition in storage	Motors will be stored away from heat sources. Motors will be stored away from ignition sources. Motors will be stored in sealed containers	2D	2E
Unintentional motor ignition during motor preparation	Motors will be prepared away from all nonessential personnel. The person preparing the motor will ground themselves before handling motor components. Motors will be prepared away from heat sources. Motors will be prepared away from ignition sources. The ignitor will not be inserted into the motor until the rocket is on the launch pad. All other NAR guidelines will be followed regarding motor handling	1C	2E
Unintentional motor ignition during launch pad preparation	All nonessential personnel will vacate the area before the ignitor is inserted into the motor. Ensure power is disabled to the launch control system before connecting to the ignition leads. Discharge control system clips before connecting them to the ignitor leads	2C	3E
Unintentional black powder ignition in storage	Black powder will be stored away from heat sources. Black powder will be stored away from ignition sources. Black powder will be stored in sealed containers	2D	2E
Unintentional black powder ignition during rocket preparation	All nonessential personnel will vacate the area before black powder charges are prepared. The person preparing the black powder charge will ground themselves before handling the black powder. Black powder charges will be prepared away from heat sources. Black powder charges will be prepared away from ignition sources	2C	3E

Hazard			
Effect(s)			
Cause(s)	Mitigation(s)	Pre-Mitigation	Post-Mitigation
Unintentional black powder ignition during launch pad preparation	All black powder charge ignition systems will require a switch to be armed before they will be able to ignite, and those switches will not be armed until the rocket is on the launch pad. All nonessential personnel will clear the area before black powder charges are armed	3C	3E
Aerosolized spray paint ignites	Painting with spray paint will be done outside. Painting with spray paint will be done away from ignition sources	3C	3E
Acetone / acetone fumes ignite	Acetone will be used away from ignition sources. Acetone will be stored in sealed containers. Acetone will not be left open longer than necessary	2D	2E
Denatured alcohol / denatured alcohol fumes ignite	Denatured alcohol will be used away from ignition sources. Denatured alcohol will be stored in sealed containers. Denatured alcohol will not be left open longer than necessary	2D	2E
Battery ignites	Battery leads will not be crossed. Electrical systems will be analyzed for the appropriate voltage before any batteries are connected	2D	3E
Unintentional ignitor ignition	Ignitors will be kept away from sources of electrical buildup. Personnel handling ignitors will ground themselves first	3D	4E
Respiratory illness			
Long-term health issues			
Inhaling fiberglass dust	All personnel in the vicinity will wear dust masks when fiberglass is being worked with. All dust will be cleaned up after working with fiberglass, and at least 10 minutes will be given for any remaining dust to settle before personnel remove their masks	1B	1E
Inhaling acetone fumes	Personnel will take care when working with acetone. Personnel will not place their heads directly over open acetone	3C	3E
Inhaling denatured alcohol fumes	Personnel will take care when working with Denatured alcohol. Personnel will not place their heads directly over open denatured alcohol	3C	3E
Inhaling aerosolized spray paint	Personnel will wear at least dust masks, preferably respirators while using spray paint	3C	3E

Table 3.1 - Initial Material Risk Assessment Sample

3.3.3 Facility & Equipment Safety

The facilities and equipment used to fabricate the rockets, payloads, and testing equipment contain all manner of tools and machinery such as drill presses, table saws, and soldering irons. Team members will be trained in proper use of tools and machinery, and will wear appropriate clothing and Personal Protective Equipment (PPE) while working. This will include wearing closed-toe shoes, not wearing loose clothing, not wearing jewelry, and having long hair restrained prior to entering a work facility. All team members will be briefed about potential risks and how to mitigate them prior to working, including maintaining a distraction-free environment. The following Table 3.2 is a sample of facility and equipment risk assessments and mitigations.

Hazard Effect(s) Cause(s)	Mitigation(s)	Pre-Mitigation	Post-Mitigation
Burns			
Minor to serious injury to personnel. Minor to serious damage to property			
Touching soldering iron	Personnel will be trained not to touch the element on the soldering iron without being sure that it is cool	3C	4D
Splashing solder	Personnel will wear heavy, long-sleeved clothing when working with the soldering iron. Personnel will wear safety glasses when working with the soldering iron	2C	4C
Touching recently cut metal	Personnel will be trained not to touch metal unprotected for at least 5 minutes after it has been cut. Personnel will wear heavy gloves when cutting metal	3B	4C
Touching output of hot-air gun	Personnel will be trained not to touch the output of the hot-air gun unprotected for at least 5 minutes after use	3C	4D
Cuts / Punctures			
Minor to serious injury to personnel			
Drill comes into contact with personnel	Personnel will be trained to not touch moving equipment. Personnel will maintain a distraction free environment when working	3C	3D
Saw blade comes into contact with personnel	Personnel will be trained to not touch moving equipment. Personnel will maintain a distraction free environment when working	1C	1E
Sharp tool slips	Personnel will maintain a distraction free work environment	3C	4D

Hazard			
Effect(s)			
Cause(s)	Mitigation(s)	Pre-Mitigation	Post-Mitigation
Personnel trips on cord	Cords will be secured and out of major walkways	3C	3E
Personnel slips	Personnel will wear high traction shoes when working. The floor of the work space will be kept clean	3C	3E
Impacts			
Minor to serious injury to personnel			
Personnel trips on cord	Cords will be secured and out of major walkways	3C	3E
Personnel slips	Personnel will wear high traction shoes when working. The floor of the work space will be kept clean	3C	3E
Respiratory illness			
Long-term health issues			
Inhaling lead fumes from solder	Non-lead-based solder will be used	2C	4C
Inhaling fumes from the laser cutter	The filter and suction system will be in use when the laser cutter is being used	3C	4E

Table 3.2 - Initial Facility & Equipment Risk Assessment Sample

3.3.4 Launch Site Safety

At launch events where rockets will be in flight, team members will need to be alert and follow all safety procedures. At a launch site, team members understand that all instructions given by the Range Safety Officer (RSO) must be followed at all times. All NFPA, FAA, ATF, NAR, and TRA rules and regulations, such as minimum safe distance to stand back and handling and inspection of energetics, and observing airspace regulations will be strictly adhered to at all times at a launch site. The following Table 3.3 is a sample of possible launch site risks and mitigations.

Hazard			
Effect(s)			
Cause(s)	Mitigation(s)	Pre-Mitigation	Post-Mitigation
Ballistic / high speed return of the team's rocket			
Minor to serious injury to personnel. Possible death. Minor to serious damage to property. Destruction of the launch vehicle. Destruction of the payload. Failure of the mission			
Ejection charges not powerful enough to separate the rocket at apogee	Ejection charges will be tested multiple times before each flight to ensure energetic separation. There will be a total of 4 ejection charges that can separate the rocket	1C	2E
Ejection charge ignitor is bad	All ignitors will be inspected prior to use. There will be a total of 4 ejection charges that can separate the rocket, each of which will have a different ignitor	1D	4E
Ejection charge ignitor is not properly connected to bridge	All electrical connections in the recovery system will be inspected before each flight. There will be a total of 4 ejection charges that can separate the rocket, each of which will be connected to a different bridge. The altimeters will beep out their continuity status	1D	4E
Bridge is not properly connected to altimeter	All electrical connections will be inspected before each flight. There will be a total of 4 ejection charges that can separate the rocket, each of which will be connected to a different bridge. The altimeters will beep out their continuity status	1D	4E
Altimeter does not have sufficient charge to fire ignitor	Each altimeter will be connected to a different battery. The batteries will be replaced before each flight with new ones	1C	2E

Hazard			
Effect(s)			
Cause(s)	Mitigation(s)	Pre-Mitigation	Post-Mitigation
Chute release is jammed and does not open	There will be 2 chute releases used, connected in series, so that if one fails, the other can still release the parachute. Both chute releases will be tested before each flight to ensure proper operation	2D	3D
Chute release does not have sufficient power and does not open	There will be 2 chute releases used, connected in series, so that if one fails, the other can still release the parachute. Both chute releases will be charged before each flight	2C	3E
Parachute is melted together by the ejection charge and does not open	A parachute protector will be placed on the recovery harness between the parachute and the ejection charges	2B	2E
Parachute is not ejected from the rocket when ejection charge fires	The recovery system will be designed as a "cannon," such that the gas from the ejection charges firing pushes the parachute out of the rocket. There will be 4 ejection charges, so if one fails to push the parachute out of the rocket, there will be backups	1C	2E
Black powder does not ignite because it is wet	Black powder will be stored in sealed containers. Liquids will be kept away from black powder when it is being worked with	1D	1E
Ballistic / high speed return of other rockets			
Minor to serious injury to personnel. Possible death. Minor to serious damage to property			
Some failure of the rocket	Personnel will be alert at all times at a launch. When a rocket is being launched, personnel will stop what they are doing and watch the rocket until it is safe	1C	3C
Motor comes free			
Minor to serious injury to personnel. Damage to the rocket. Minor to serious damage to property			
The motor mount is not properly secured to the airframe	Stress tests will be performed on the motor mount to ensure it is able to withstand flight forces. The motor mount will be inspected before each launch	2C	2E
The motor retainer is not properly secured to the motor tube	Stress tests will be performed on the motor retainer to ensure it is able to withstand flight forces. The motor retainer will be inspected before each launch	2C	2E
The motor casing fails	The motor casing will be inspected before each launch	3C	3D

Table 3.3 - Initial Launch Site Risk Assessment Sample

3.3.5 Project Risks

Safety of the project itself will be taken into consideration with a plan to keep the project moving forward as desired. The following Table 3.4 shows some of the risks involved with the project and their mitigations.

Hazard			
Effect(s)			
Cause(s)	Mitigation(s)	Pre-Mitigation	Post-Mitigation
Falling behind schedule			
Deliverables are not completed on time. Work is not done. Work is done poorly			
Team member(s) withdrawing from the team	All work will be kept in public discussion, so that if a team member withdraws from the team, others can pick up their work. When team members join, they will be made aware of the commitment necessary to be a part of the team	2B	3C
Missing a subscale or full-scale test flight	Deadlines for construction and testing of the subscale and full-scale rockets are far enough in advance of flights that even if there are delays, they can be made up for. There are multiple launch site options for test flights, each with differently timed launches, so if one is missed, it can be made up at another	1C	3D
Education & outreach event is below expected participation	Many more events than are necessary to meet the minimum requirement are being planned. PSLT has built enough of a reputation in the local area to draw a significant number of participants	2C	3D
Team member(s) are overloaded with work	Workloads will be fairly evenly distributed among team members. Team members will communicate if they are overloaded and need someone else to take over some of their work	3B	4C
Team member(s) forget a deadline	All deadlines are kept in a single document which all team members have access to. Frequent reminders will be sent out about deadlines by the project manager	1B	2D
Funding shortage			
Necessary components, tools, or materials cannot be purchased. The team is unable to travel to launch week			
Insufficient fundraising is done	A significant amount of money has already been raised. There are fundraising plans to cover the rest of the project	1C	3D
Designs are overly complicated	Designs will be thought through to ensure they are able to accomplish the mission, without being more complicated than necessary	3C	3D

Table 3.4 - Initial Project Risk Assessment Sample

3.4 Federal Rules and Regulations

PSLT will follow all laws and regulations for amateur rocketry as put forth by the Federal Aviation Administration (14 CFR chapter 1, Subpart F, Part 101, Sections A and C), including, but not limited to: ensuring that any launch does not create a hazard to persons, property, or other aircraft (§101.23 pt. 4); launch of any high powered rocket will not occur within 5 nautical miles of an airport boundary, or within controlled airspace without prior authorization from the FAA (§101.25 pt. e and f); and any rocket launches will stay outside the greater of the two separation distances (one-quarter the maximum expected altitude or 1500 ft) from any unassociated person or property (§101.25 pt. g).

PSLT will also strictly adhere to all federal, state, and local laws pertaining to the storage, transportation, and use of energetics and flammable or combustible materials as directed by the ATF, NAR, TRA, Commonwealth of Virginia, and local area laws. All energetics will be stored and transported in appropriate magazines or containers. There will be no smoking, open flames, or spark-producing devices in any magazine, within 50 ft of any outdoor magazine, or within any room containing an indoor magazine. Energetics will be stored a minimum of 75 ft from an inhabited building (27 CFR §555.219).

PSLT will also follow all codes as put forth by the National Fire Protection Association (NFPA 1127, Code for High Powered Rocketry). These codes are designed to set guidelines for safe operation of high power rockets for users and the public, while discouraging unsafe use. PSLT will fully comply with all NFPA codes including but not limited to: following all instructions, and respecting all decisions made by the Range Safety Officer; allowing only an appropriately certified person to purchase, store, or handle rocket motors and ignitors (§§5.4.1-5.4.2.2); using only certified rocket motors as intended by the manufacturer (§4.5.1); properly storing the rocket motors and ignitors (§4.19); and remaining behind the minimum required clear distance until the RSO declares the range clear (§4.15.1).

3.5 Procedures for NAR / TRA Personnel

The Safety Officer will work in conjunction with NAR / TRA personnel and the Level 2 certified rocketry mentor to ensure that the team complies with the NAR and TRA high power rocketry safety codes. The Safety Officer, mentor, and NAR / TRA personnel shall ensure that before launch, all conditions are met for a safe launch. The RSO will thoroughly check every rocket to assess its ability to safely fly prior to the rocket launching, and the RSO's decision is final. The RSO and the Launch Control Officer (LCO) will make sure that all spectators will remain beyond the minimum safe distance before proceeding with the launch, (e.g., 100 ft minimum for a rocket with a J motor or smaller, and 200 ft for a rocket with a K motor). The RSO / LCO shall arm the launch system, ensure that the sky and the range are clear, and then count down from 5 before launching; if the vehicle does not launch, the RSO / LCO shall disarm the system and wait 60 s before investigating. Only the RSO may give the all clear signal for anyone to leave the spectator area. NAR / TRA personnel along with the Safety Officer shall ensure no one attempts to catch the rocket on return, or remove it from a dangerous location such as a power line.

3.6 Briefing of Team Members

The Safety Officer will brief the team on all possible risks throughout the design and fabrication process, and before each launch. As part of the team briefing, the Safety Officer will describe the tasks involved, potential risks associated with each task, and steps to mitigate those risks. In addition, the team briefings will contain information about pertinent Federal, State, and Local laws. The Safety Officer will regularly brief the team to remind them of the risks in order to maintain a Culture of Safety. Before every launch, the Safety Officer will brief members on proper procedure and ensure all guidelines are followed as specified by the NAR / TRA.

3.7 Inclusion of Caution Statements

The Safety Officer will provide caution statements, including any required PPE, for any hazards involved in the undertaking of this project, which may occur during fabrication, testing, launching, and recovery of the rockets. The statements shall be placed on any necessary document (e.g., checklists, procedures, and written briefings). All documents shall be reviewed by the Safety Officer to ensure that necessary caution statements are included.

3.8 Safety Contract

Prior to joining Piedmont Student Launch Team, prospective members must acknowledge and sign the PLST Safety Contract. The contract states that prospective members understand that safety is the top priority, that they have thoroughly read the entire Safety Section of the PLST 2017-2018 Handbook, understand all safety rules, including the importance of a Culture of Safety, shop safety, testing safety, and launch event safety. PLST members will also acknowledge that during launches there will be range safety inspections of their rockets by the RSO to determine flight safety. The RSO has the final say in a rocket's ability to fly, and all team members will abide by that decision, or will not be able to fly. PLST members acknowledge that blatant disregard for the safety rules will result in dismissal from the team. A copy of this contract is included below.

Team Member Safety Contract

By joining the Piedmont Student Launch Team, I acknowledge that I have read and understand all of the safety rules in the Piedmont Student Launch Team 2017-2018 Handbook. I understand that while on the team there is the potential that I or others may get injured, and to mitigate that risk I agree to follow all safety rules including:

- Following all instructions given by the Team Mentor, Faculty Advisor, Safety Officer, Deputy Safety Officer, or Team Leader
- I will always get help when I am unsure, and I will avoid doing anything perceived as unsafe. If I ever see something unsafe happening, I will speak up. I will never work under the influence of any drugs or alcohol, and I will not work when tired, hurried, or hungry. I will never work in the shop alone, and never engage in horseplay
- I will always be aware of my surroundings, what I am doing, and what others around me are doing. I will always think about how I plan on completing a task prior to doing it, and will stay focused. I will familiarize myself with all tools and machinery. I will make sure they are in proper working order before use
- I will always wear appropriate Personal Protective Equipment before starting a task requiring PPE. While in the shop I will not wear any jewelry, loose clothes, sandals or other open toed shoes. I will keep long hair tied back
- At a launch event, I will always follow instructions from the Range Safety Officer in charge of the launch. I will immediately stop working when a rocket is about to launch, and I will always keep my eye on the rocket until it lands safely on the ground

I acknowledge that the activities of the Piedmont Student Launch Team are potentially dangerous, and I accept the risks involved. I acknowledge and understand that the Piedmont Student Launch Team practices a culture of safety at all times and above all other considerations, and I agree to be a part of that culture of safety.

I acknowledge that blatant disregard for the safety rules, or knowingly engaging in unsafe behavior will result in dismissal from Piedmont Student Launch Team. By signing below, I agree to all terms above in this contract.

Printed Name: ____ Date: _________________

Signature: ____

4 Technical Design

The following sections describe the currently projected designs for the launch vehicle and payload. They are still preliminary designs, and as such are subject to change.

4.1 Launch Vehicle

The following design is for the final full-scale launch vehicle. Prior to construction of this rocket, a subscale vehicle will be built and flown to validate the design. Based on commonly-available airframe sizes, the subscale will be approximately two-thirds the size of the full-scale, using a 4 in. diameter airframe. All other features of the subscale will be sized appropriately to model as closely as possible the design of the full-scale. The exact subscale design is not included as it may change based on design changes to the full-scale vehicle.

4.1.1 Projected Airframe Design

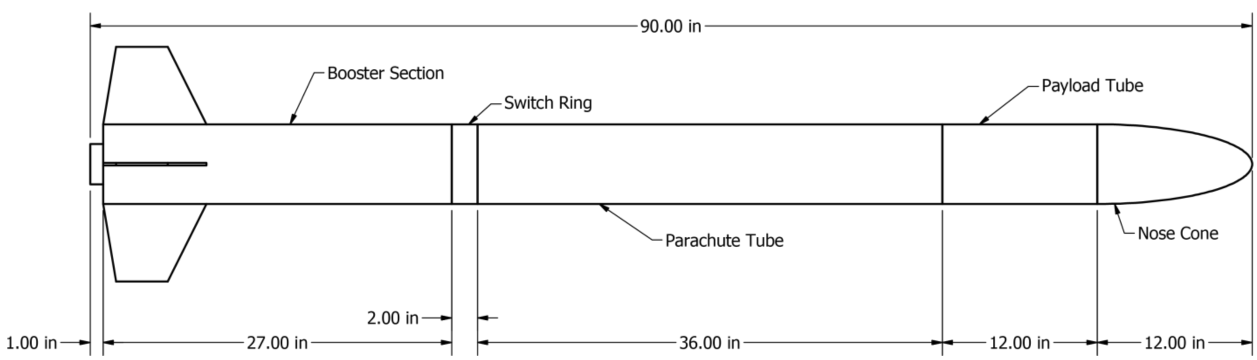


Figure 4.1 - Overall Airframe Design

The rocket will be made of standard, 6 in. diameter parts (actual OD 6.17 in.). It will be 90 in. in length with a weight of approximately 385 oz (24.1 lbs) without the motor. The primary construction material will be G12 fiberglass.

The upper section of the launch vehicle will be used to house the payload. The lower section will house the avionics bay, parachute, and motor. The launch vehicle will split into two sections at apogee, releasing a parachute secured by a redundant pair of Jolly Logic Chute Releases.

4.1.1.1 Nosecone / Payload Sled

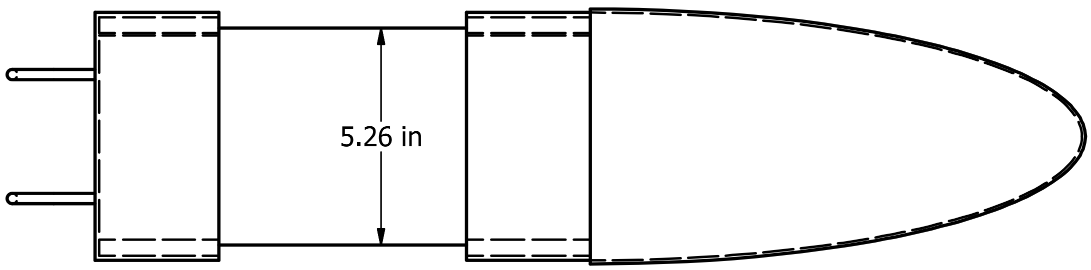


Figure 4.2 - Nosecone Design – Top View

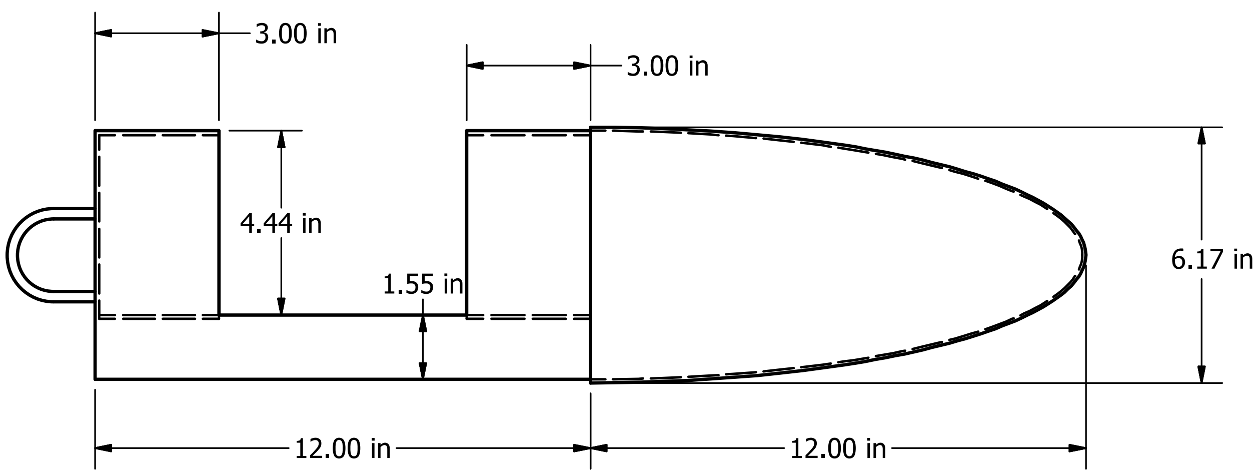


Figure 4.3 - Nosecone Design – Side View

The nosecone will be an ellipsoid shape to ensure that, if the upper section lands point-first, it will tip over, rather than embedding vertically into the ground. This part of the system acts as a sled to allow the rover to deploy regardless of how the launch vehicle lands (see section 4.2.5 for more details).

Material: ABS

Construction Method: The nosecone will be 3D printed. It will be secured to the payload tube by shear pins (see section 4.2.5 for more detail)

Dimensions: 6.17 in. OD; 12 in. length; 5.998 in. shoulder OD; 12 in. shoulder length

4.1.1.2 Payload Tube

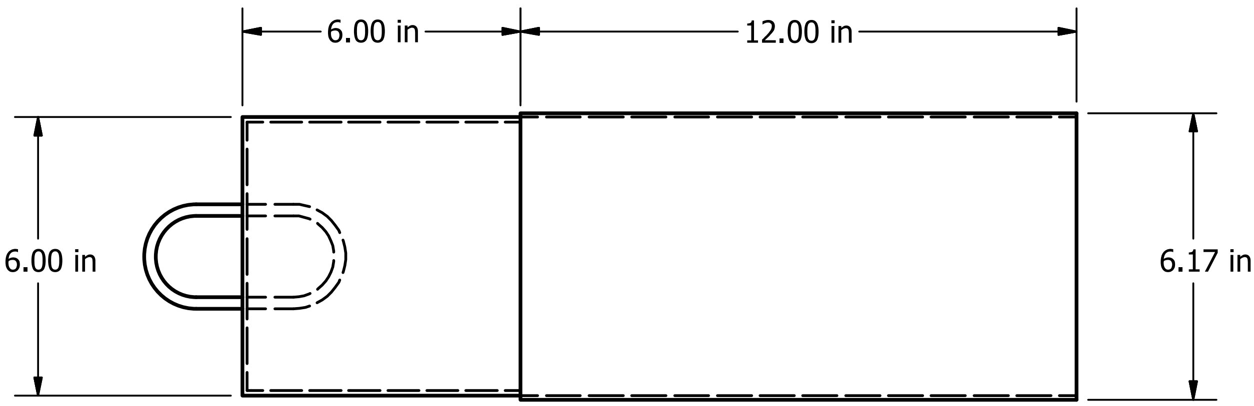


Figure 4.4 - Payload Tube Design

The payload tube, along with the nosecone, is where the payload will be contained until deployment (see section 4.2.5 for more details). The aft end of the shoulder will be capped by a bulkhead. This bulkhead will have the attachment points for the recovery harness. The nosecone will be secured to the fore end of the payload tube by shear pins. The aft end of the payload tube will be inserted into the fore end of the parachute tube and secured with shear pins.

The payload tube will have a pair of externally mounted switches to arm the energetics used to separate the payload sled / nosecone from the payload tube and the energetics used to secure the rover payload to the sled.

Material: G12 fiberglass

Construction Method: The airframe and coupler sections will be cut to length from commercially available components and epoxied together. It will be secured to the parachute tube and nosecone by shear pins

Dimensions: 6.17 in. OD; 12 in. length; 5.998 in. shoulder OD; 6 in. shoulder length

4.1.1.3 Parachute Tube

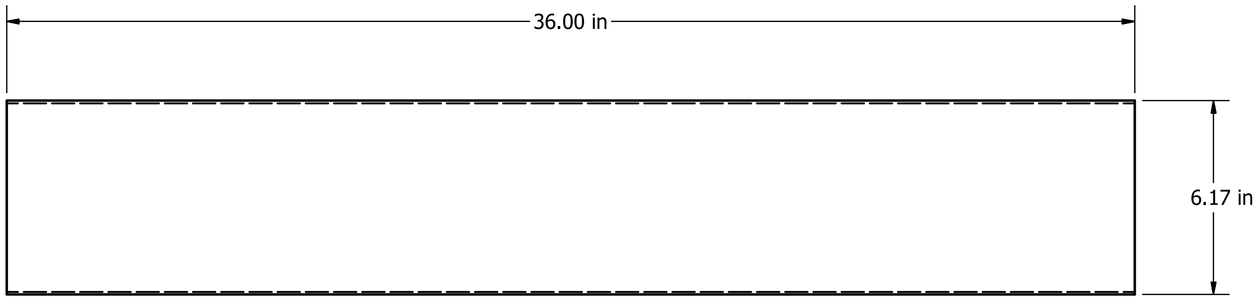


Figure 4.5 - Parachute Tube Design

This section of body tube will hold the parachute. It will attach to the payload tube as described in section 4.1.1.2. The fore end of the avionics bay will be inserted into the aft end of the parachute tube and secured with either screws or rivets during flight.

Material: G12 fiberglass
Construction Method: The parachute tube will be cut to length from a commercially available body tube. It will be secured to the payload tube by shear pins and the avionics bay by screws or rivets
Dimensions: 6.17 in. OD; 36 in. length

4.1.1.4 Avionics Bay

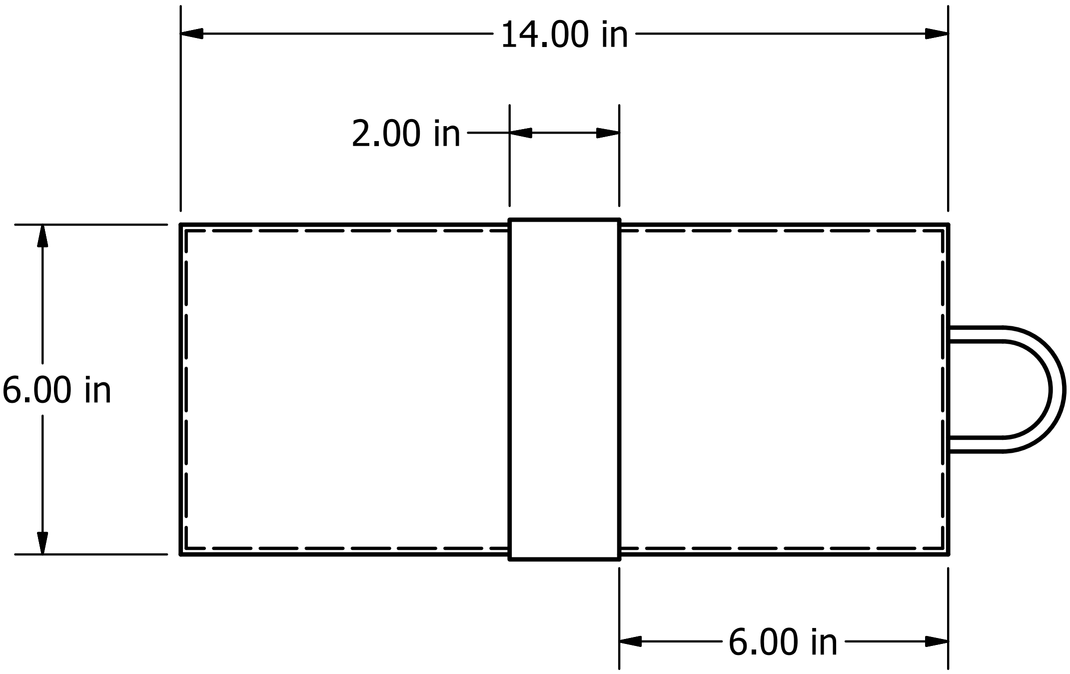


Figure 4.6 - Avionics Bay Design

The avionics bay will contain the two altimeters and the batteries for each altimeter. There will be a switch ring externally accessible on the avionics bay. The switch ring will have two switches mounted in it, one for each altimeter. The avionics bay will be capped on both ends by bulkheads. The fore bulkhead will have attachment points for the recovery harness, four ejection cups, and four bridges (see section 4.1.2 for more details). The avionics bay will be attached to the parachute tube as described in section 4.1.1.3. The aft end of the avionics bay will be inserted into the fore end of the booster section and secured with screws or rivets during flight.

Material: G12 fiberglass.

Construction Method: The switch ring and coupler section will be cut to length from commercially available components. The switch ring will be epoxied to the coupler section. It will be secured to the parachute tube and the booster section by screws or rivets.

Dimensions: 6.17 in. OD at switch ring; 14 in. coupler length (6 in. on each side of switch ring); 5.998 in. coupler OD; 2 in. switch ring length.

4.1.1.5 Booster Section

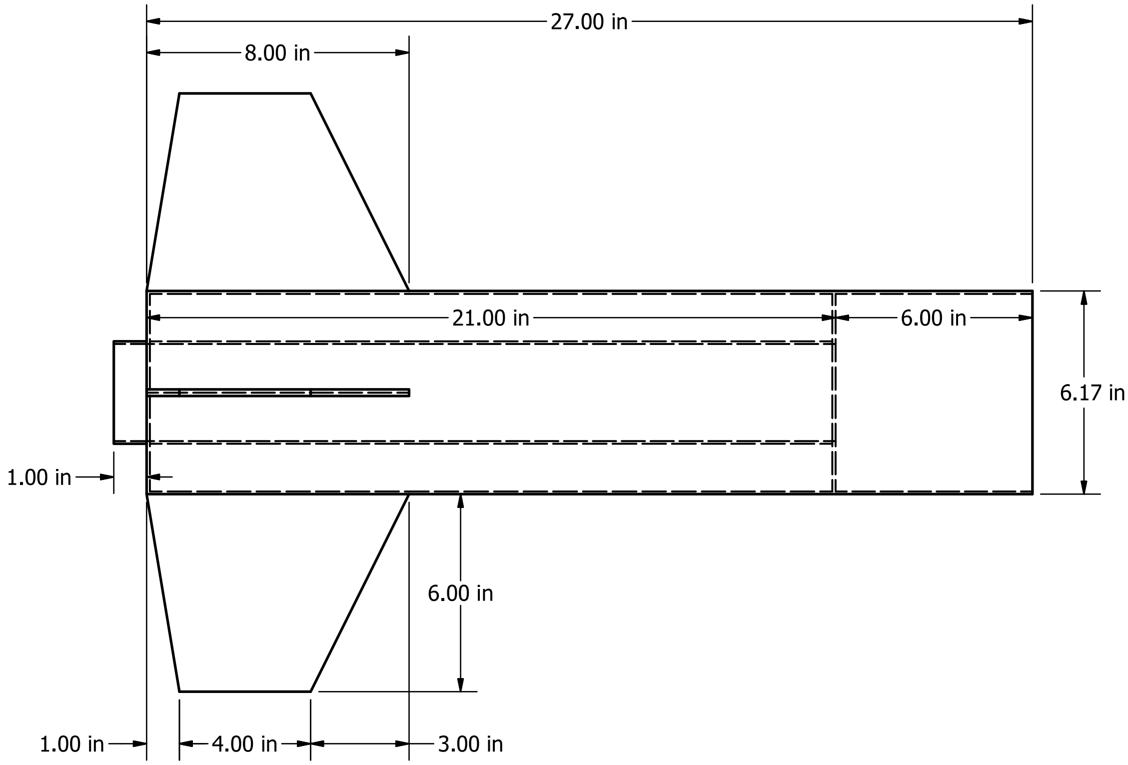


Figure 4.7 - Booster Section Design

The booster section will contain the motor mount tube and four trapezoidal fins. The fins will be mounted through-the-wall. The difference in diameters between the outer tube and the motor mount tube will allow approximately 1.5 in. fin tabs. This space will be filled with two-part expanding foam for added strength and adhesion. The booster section will be secured to the avionics bay as described in section 4.1.1.4. Motor retention will be achieved using a 75 mm Aero Pack retainer.

Material: G12 and G10 fiberglass

Construction Method: The tube sections will be cut to length from commercially available body tubes. The fin slots will be cut with a router. Commercially available centering rings will be used. Commercially available fins will be used. The fins, centering rings, and motor mount tube will be secured with epoxy. The fins will be further secured with epoxy clay fillets. The motor retainer will be secured with J-B Weld / heat-resistant epoxy. It will be secured to the avionics bay by screws or rivets

Dimensions: 6.17 in. OD; 27 in. length; 75 mm motor mount tube; 22 in. motor mount tube length; 8 in. fin root chord; 4 in. fin tip chord; 6 in. fin height; 3 in. fin sweep

4.1.1.6 Material Justification

Fiberglass (G12 for body tubes and couplers, G10 for fins) was chosen because of the added strength it gives relative to phenolic paper tubes. It is also less expensive than alternative options such as carbon fiber. While there are hazards involved with using fiberglass, PSLT has experience in mitigating these hazards.

ABS was chosen for the nosecone because 6 in. ellipsoid fiberglass nosecones are not commercially available. Additionally, by 3D printing the nosecone, the whole payload sled can be made as a single piece, improving both the structural integrity, and allowing for a more flexible design.

4.1.2 Projected Recovery System Design

4.1.2.1 Altitude Control / Recovery Electronics

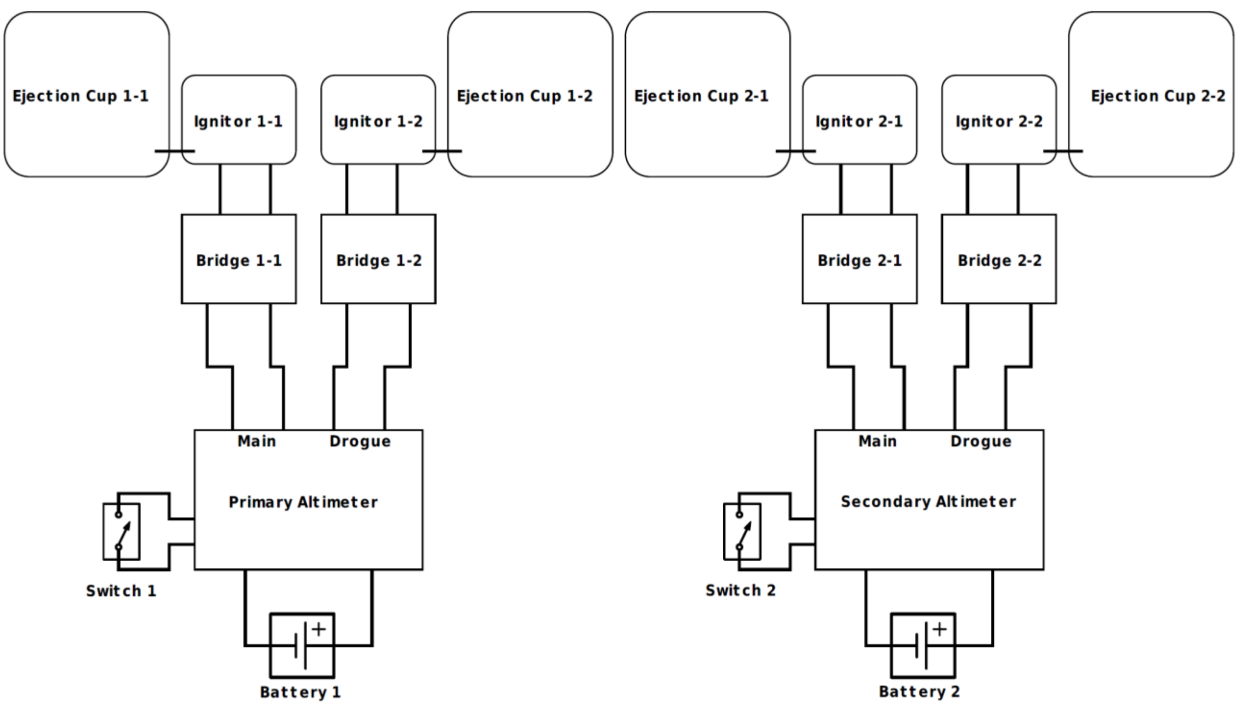


Figure 4.8 - Recovery System Electronics

The recovery system will utilize two completely independent altimeters. One will include a GPS locator and transmitter which will be used to track the rocket during flight. Each altimeter will be separately powered by commercially available batteries.

A range of possible altitudes will be determined based on simulations, subscale test flights, and full-scale test flights. The mass of the rocket will be adjusted based on this data so that the range of likely altitudes lies just above 5,280 ft. If the variation in altitude can be reduced to the point that the velocity at 5,280 ft is at a safe level (to be determined by research and subscale test flights), then the primary altimeter's drogue output will be programmed to deploy the parachute at between 5,200 ft – 5,270 ft (exact altitude to be determined by simulations and subscale test flights). This will slow the launch vehicle, preventing it from overshooting 5,280 ft. The primary altimeter main output will be programmed to fire at apogee as the first redundant charge. The secondary altimeter's drogue output will be programmed to deploy two seconds after apogee, providing a secondary backup. The secondary altimeter's main output will be programmed to fire at 1,000 ft as a final, backup should all the other charges fail.

4.1.2.2 Parachute and Recovery Harness

The fore bulkhead of the avionics bay and the aft bulkhead of the payload tube will each have two U-bolts to be used as the attachment points for the recovery harness.

The recovery harness will be 20 ft long, made of 1/2 in. tubular Kevlar. It will have swivels at each end, each connected to the two U-bolts at that end by two quick links.

The currently projected parachute will have a 144 in. diameter. It will be located approximately 6 ft from the aft of the payload tube on the recovery harness. The design of the parachute compartment is such that the ejection charges will be under the parachutes, which will be under the aft bulkhead of the payload tube. This design will help to ensure that the parachute exits the parachute tube when the ejection charges fire, because the force from them will push directly on the parachute.

4.1.3 Projected Performance and Motor Selection

An Aerotech L1150 has been selected as the preliminary motor. Based on manual calculations and simulations (using an estimated payload mass) done in OpenRocket and RockSim of the projected launch vehicle design, this motor results in an apogee in the approximate range of the target altitude of 5,280 ft. OpenRocket and RockSim, using substantially the same model and parameters, estimated markedly different coefficients of drag (see Table 4.1), yielding a range of apogee values. The manual calculations assumed a drag coefficient between the two software estimates. RockSim has a known bias for underestimating drag coefficients and therefore overestimating expected altitude. Experimentation with the subscale rocket and fine-tuning of the drag coefficients of the vehicles will allow a more focused and accurate estimation of final altitude later in the project. If this analysis recommends a different motor selection prior to the submission of the Critical Design Review, an alternate motor may be used.

	OpenRocket	RockSim	Manual
Expected Apogee (ft)	4981	5764	5180
Rail Exit Velocity (ft/s)	77.8	77.8	72.9
Maximum Velocity (ft/s)	668	691	691
Estimated Coefficient of Drag (C_D)	0.51	0.36	0.40

Table 4.1 - Projected Performance Simulation Results

4.2 Payload

4.2.1 Payload Design Overview

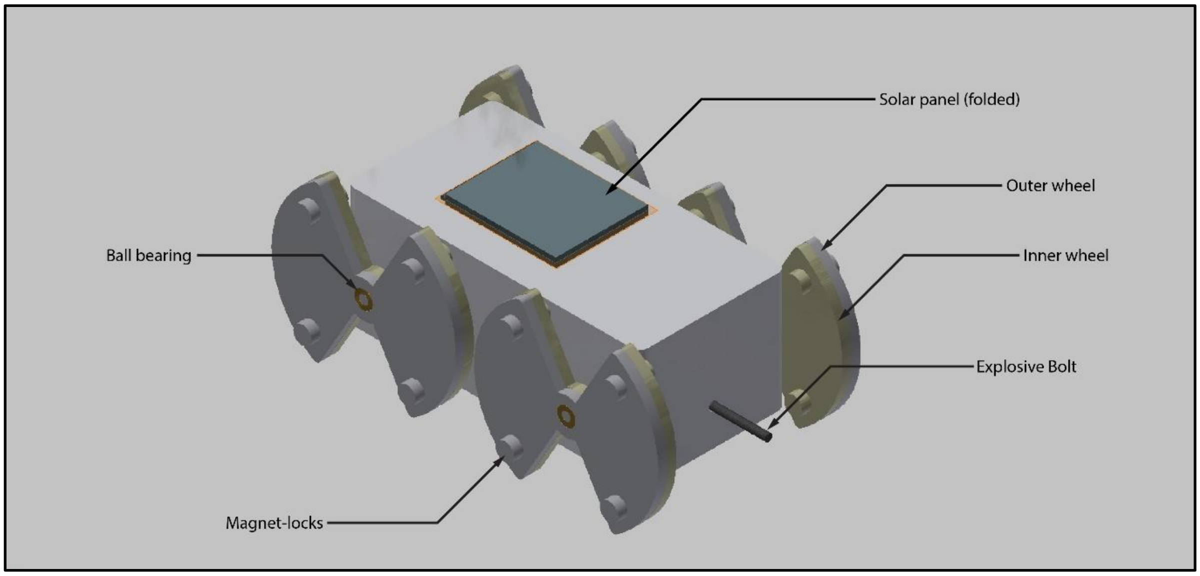


Figure 4.9 - Rover Overview

PSLT has chosen to do the rover deployment challenge. In addition to the minimum requirements presented in the Statement of Work, PSLT has decided to add two additional primary requirements: robustness, and the ability to be used in a variety of environments. The goal for robustness is to be able to withstand a significant amount of suboptimal treatment and still function, even if not all components are functional, as well as the ability to correct for a variety of issues, such as being flipped over. The goal for being able to be used in a variety of environments is to make the rover able to operate in any of the possible environments that might be encountered on an exploration mission to most planetary bodies.

The projected design consists of a rectangular electronics housing with four collapsible wheels. It will be mounted to a sled in the payload tube, fully enclosed in the airframe of the rocket, for the duration of the flight and then will be ejected from the rest of the rocket after clearance has been given.

4.2.2 Rover Structural Design

The rover electronics will be situated inside a 3D-printed plastic housing, approximately 8 in. long by 3 in. wide by 4.5 in. tall. There will be four holes, two on each long side, for the shafts of the wheel motors. A motor for deploying the solar cell panel will sit above the housing, toward the back. This motor will rotate the solar panel on a hinge to deploy it.

3D printed ABS plastic was chosen because it allows for rapid alteration to the design, it is very durable, and it allows complex shapes to be easily manufactured, both for testing and for the final product. Additionally, other materials will be tested for to see if they provide a better solution.

4.2.3 Rover Control System, Sensor, and Communication Design

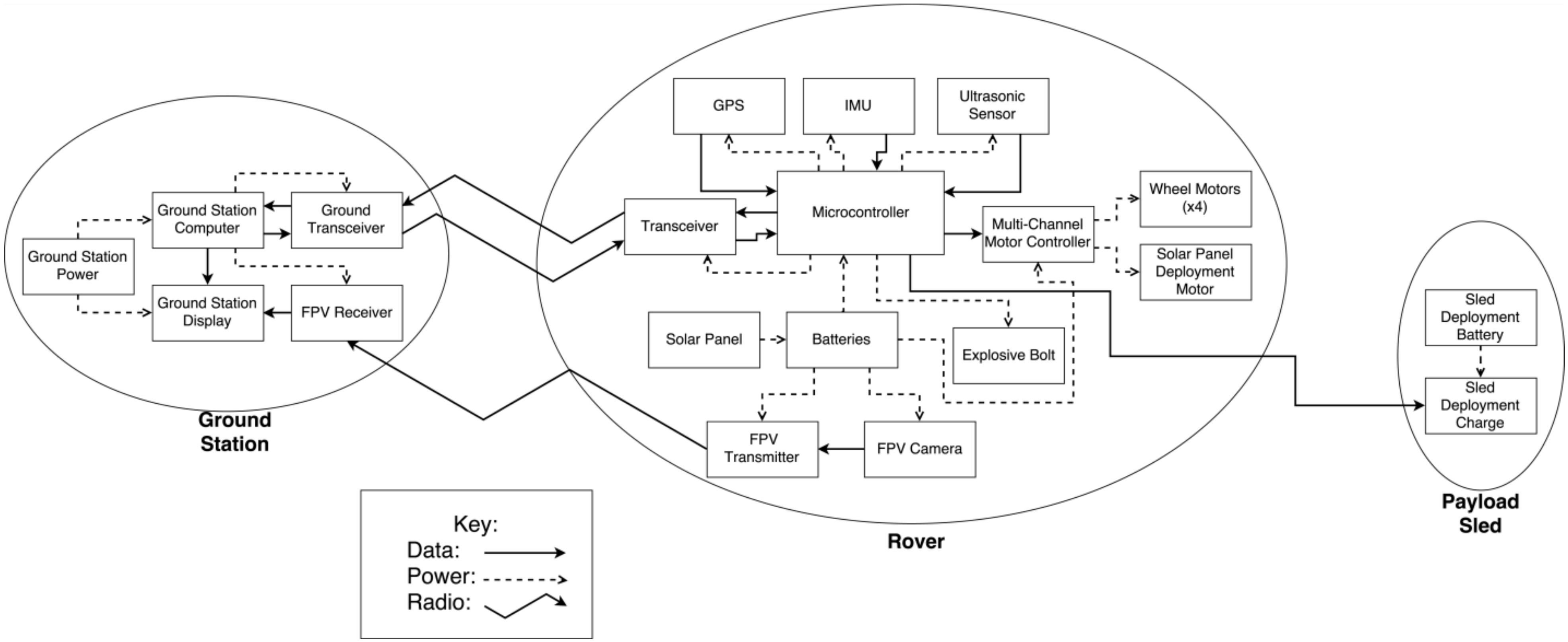


Figure 4.10 – Rover Electronics and Communication Systems

4.2.3.1 Microcontroller

A microcontroller will record, process, and transmit all data from the rover, other than video. Additionally, it will control the movement of the rover, and the deployment of the solar panel. The microcontroller will also stage the deployment of the rover from the launch vehicle after the command to deploy has been given.

Current options for the microcontroller are a Raspberry Pi or an Arduino.

4.2.3.2 GPS Module

A GPS module will be used to track the rover / rocket until landing, and then to track the rover after deployment. This will provide both the location of the rocket during flight and a mechanism to determine both the distance that the rover travels and its displacement.

4.2.3.3 Inertial Measurement Unit

An Inertial Measurement Unit (IMU) will be used to detect the orientation and heading of the rover. It will also be used to determine the acceleration, velocity, and angle of attack of the rocket during flight.

This information will be transmitted to a ground station and will be used to determine whether the flight parameters are within safe limits, particularly when the rocket is at high altitudes and difficult to see. It will also be used to determine the kinetic energy at landing for each section if the rocket, as the payload will be the last section to land, so the velocity of each individual section at landing can be determined.

4.2.3.4 Ultrasonic Sensor

An ultrasonic sensor will be mounted to the front of the rover and will be used to detect obstacles. This will ensure that the rover does not drive into the launch vehicle, rock, another rocket, or any other obstacles while it is moving away from the launch vehicle. However, ultrasonic sensors rely on an atmosphere, so in order to adapt to different planetary circumstances where there may be thin to no atmosphere, laser or radar systems will be considered and may replace the ultrasonic sensor.

4.2.3.5 Motor Controller and Motors

The motor controller will be a multi-channel design capable of sending different power levels to each of the five motors. There will be one motor for each wheel, and one to deploy the solar panel. The necessary speed and torque of these motors will be determined via testing.

4.2.3.6 Transceiver

The transceiver will be used to transmit data from the rover to a ground station. It will also receive commands, specifically the command to deploy the rover.

4.2.3.7 First Person View Camera and Transmitter

The First-Person View (FPV) camera and transmitter will transmit live video from the rover to a ground station. Data from the other sensors can be overlaid on top of the video to monitor the status of the rocket and payload.

4.2.4 Rover Propulsion System Design

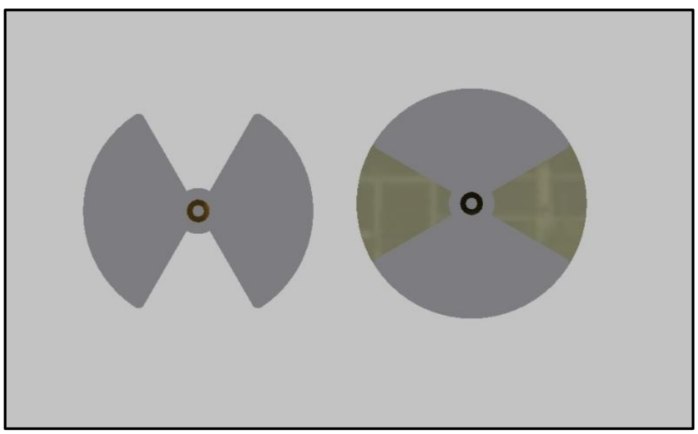


Figure 4.11 - Wheel Deployment Before and After

The rover will have four 4 in. diameter wheels which can be folded down for storage within the rocket during flight. Each wheel will be mounted to a separate motor to drive it.

Each wheel will be made of two pieces, an inner and outer wheel. The inner wheel will be mounted directly to a mounting hub on the motor shaft, and the outer wheel will be mounted to a ball bearing which will be mounted in turn to the motor shaft. Each half of each wheel will have a strong magnet in the corners, so that when the inner wheel is turned, the magnets on each side will align and catch creating a single, circular wheel. The wheels will be 3D printed for easy replacement, modification, and testing.

4.2.5 Rover Deployment System Design

Once the rocket has landed and permission has been given to deploy the rover, a signal will be sent to it, and it will ignite an ejection charge on the rear of the payload sled, which will eject the rover and the sled. The sled with the rover on it will then right itself. After that, the rover will be released from the sled, and move a suitable distance from the rocket to deploy the solar panel.

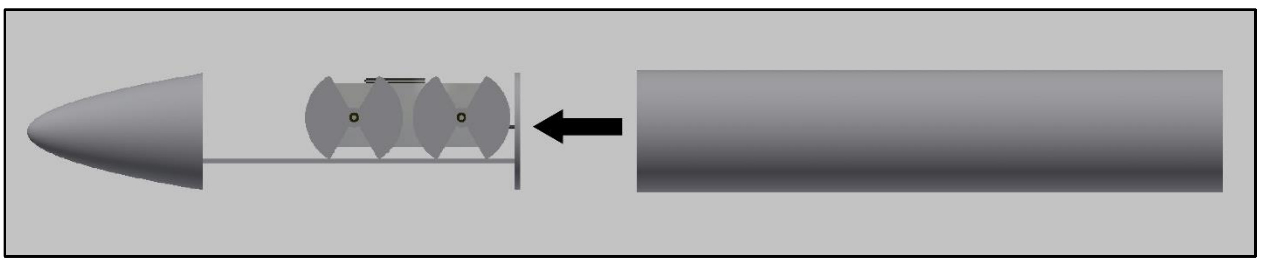


Figure 4.12 - Rover Deployment Part 1

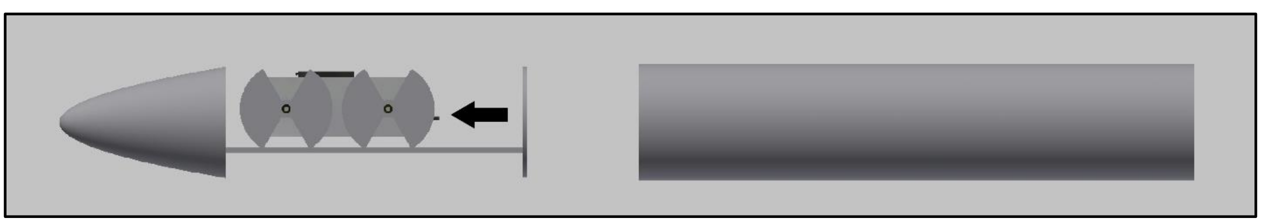


Figure 4.13 - Rover Deployment Part 2

4.2.5.1 Payload Sled

The payload sled will be a single piece consisting of the nosecone, a sled for the rover to rest on, and a bulkhead in the rear. The entire unit will be 3D printed from ABS plastic.

The rounded nosecone on the payload sled ensures that, even if the payload section lands vertically, it will tip over and become horizontal, allowing the payload sled to still deploy properly.

4.2.5.2 Payload Orientation

The CG of the payload sled with the rover on it will be below the center line of the rover, such that when it has been ejected from the rocket, it will roll into an upright position. This way, in most situations, the rover will be upright when it disconnects from the sled.

If the rover, at some point after it has disconnected from the sled, is flipped on its back, that will be detected by the IMU. Once inversion has been detected, the rover will open the solar panel on its back, and use that to lever itself up, flipping it back into the proper orientation.

4.2.5.3 Payload Ejection

The payload sled will be ejected from the rocket using a black powder ejection charge. The charge will be mounted to the back of the bulkhead at the rear of the payload sled. To prevent the sled and rover from going too far from the rocket during deployment, the sled will be tethered to the rocket with a Kevlar recovery harness.

The firing of the ejection charge will be controlled by the rover, which will fire it after a signal has been sent. The charge will have an external switch used to arm it once the rocket is on the launch pad.

4.2.5.4 Payload Separation

The rover will be secured to the payload sled by one or more frangible nylon bolts containing a small black powder charge and ignitor. After the payload sled has been ejected from the rocket, the rover will trigger the charge, fracturing the bolt and releasing the payload from the sled. Once it has been released, it will deploy its wheels and drive off of the sled.

If the rocket lands in a tree, then when the rover separates from the sled, it will simply fall off to the ground. The design of the rover is intended to be robust enough to withstand such a fall and continue functioning.

4.2.6 Alternative Design Options

Several ideas were considered including an S-curved wheel design (shown below in Figure 4.13), a hopping-based propulsion system, and various landers. The chosen options were selected to provide a robust design that is not likely to fail, and that is easily adaptable to most situations.

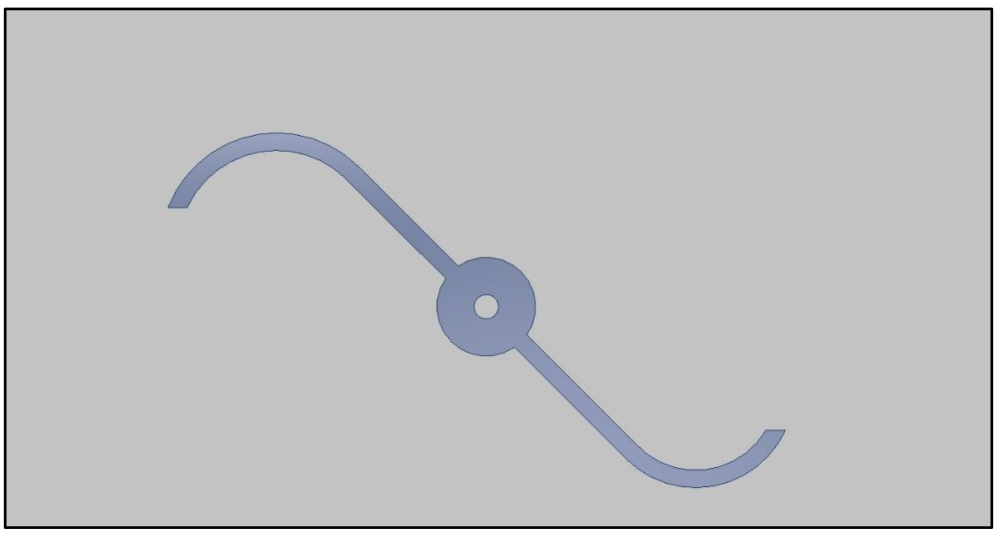


Figure 4.14 - Rover Wheel Alternative

4.3 Major Technical Challenges

Challenge	Solution(s)
Limited space for the rover	Efficient use of space: utilize 3D printing, collapsible wheels
Stress to the rover from in-flight and deployment forces	Utilize strong materials, reinforce key parts of the body of the rover
Controlling apogee	Ballast the rocket, use pre-apogee separation to halt the ascent

Table 4.2 - Major Technical Challenges & Solutions

4.4 Design Requirements

Requirement Number	Verification / Plan
2.1	The chosen motor has a high enough total impulse to lift the projected design to 5,280 ft
2.2	A barometric altimeter will be used as the primary altimeter in the rocket
2.3	The avionics bay will include an externally accessible section for mounting switches
2.4	The avionics bay will contain two separate power supplies, one for each altimeter
2.5	Keyed switches will be used for arming the altimeters to ensure that they stay in the on position during flight
2.6	No parts of the launch vehicle will be designed to wear out frequently or to need to be replaced except for ejection charges and shear pins
2.7	The projected design for the launch vehicle has only two independent sections
2.8	The launch vehicle will be designed with only one stage
2.9	The launch vehicle and payload will be designed such that the majority of the different sections can be prepared for flight in parallel
2.10	All components that might fail if left on the launch pad will be tested to ensure a minimum lifetime of one hour
2.11	The launch vehicle will use a standard ignitor for the motor that can be ignited with no more than 12 V
2.12	The launch vehicle will be designed to not require any additional ground support equipment
2.13	The selected motor will be a commercially available, solid motor propulsion system that uses ammonium perchlorate composite propellant and is approved and certified by the NAR, TRA, or CAR. Preliminary choice is an Aerotech L1150R
2.14	The projected launch vehicle and payload designs to not utilize pressure vessels
2.15	The launch vehicle with payload will be designed to be able to reach the target altitude without requiring more than 5120 N-s of impulse from the motor
2.16	The projected launch vehicle design has a static stability margin of 3.4 at rail exit
2.17	The projected launch vehicle design has a rail exit velocity of approximately 78 ft / s
2.18	The team will build and fly a subscale rocket prior to CDR
2.19	The team will fly the full-scale rocket prior to FRR

Requirement Number	Verification / Plan
2.20	The only structural protuberances that are included in the projected design is an external camera, which will be located aft of the burnout CG
2.21	The projected design does not include: forward canards, forward firing motors, motors that expel titanium sponges, hybrid motors, a cluster of motors, friction fitting for motors, or more than 10% of the weight of the launch vehicle as ballast. It will not exceed Mach 1 at any point during flight
3.1	The projected design uses effectively streamer recovery from apogee until main deployment, with the rocket electronically controlling all deployment
3.2	Ground ejection tests will be included in the pre-flight tests performed for both rockets
3.3	The recovery system will be designed to ensure the kinetic energy of each independent section of the rocket at landing is well under 75 ft-lbf
3.4	The recovery system electronics will be completely independent of the payload electronics. Additionally, they will be in separate sections of the rocket
3.5	The recovery system electronics will be designed to use commercially available batteries
3.6	The recovery system will include at least two completely independent, redundant altimeters
3.7	The projected design does not use motor ejection for primary or secondary deployment
3.8	The projected design uses removable shear pins to secure the parachute compartment
3.9	The rocket will be designed to drift less than 2,500 ft
3.10	One of the altimeters used will include a tracking device which will transmit the position of the rocket. All sections of the rocket will land tethered together
3.11	The recovery system electronics will be located in a separate compartment from all other electronics, and will be shielded from them
4.1	The team has chosen the deployable rover option
4.2	No additional payload options were selected
4.5.1	The projected payload design has the rover entirely enclosed within the airframe until deployment is initiated
4.5.2	The projected design can be communicated with remotely
4.5.3	The projected payload will drive at least 5 ft from the launch vehicle
4.5.4	The projected design includes a solar cell panel which will fold open after the rover has moved away from the launch vehicle

Table 4.3 - Design Requirements

5 Educational Engagement

5.1 Engagement Overview

The Piedmont Student Launch Team has decided to undertake the educational engagement aspect of the project by focusing on minorities in STEM and underprivileged children. PSLT will continue its work with girls, with an emphasis on middle and high schoolers, but will now be expanding on that. PSLT will endeavor to engage as many people as possible to create and sustain interest in pursuing STEM-related education and careers, and will make a specific effort to target those who might otherwise be overlooked.

The Charlottesville and Central Virginia area offers a wide variety of opportunities to engage with the community on educational and career-oriented topics. PVCC, as a community college, carries a mandate to engage the local community in educational initiatives. They have a long history of exceeding this mandate and have committed to providing extensive resources to the team to meet this part of the project. PSLT will seek to leverage all these opportunities to expose as many people as possible to the fun, excitement, and challenge of the STEM fields, through hands-on learning and other methods of presentation.

As part of our promotion of the next generation of science and technology professionals, PSLT is pleased to be working with local Boy Scout Troop #17, who placed 11th in this year's Team America Rocketry Challenge (TARC) and will be competing in the Middle and High School division of Student Launch this year. Team members met with Troop #17 over the summer to offer guidance and support, as well as insight into the Student Launch program. For the upcoming year, PSLT has offered to assist Troop #17 where needed, and the two groups are planning to collaborate on some outreach opportunities to reach a broader audience and promote STEM education and enthusiasm in the community.

5.2 Engagement Plan

The following items represent a partial list of engagement activities PSLT will be looking to undertake.

5.2.1 Community Homeschool Enrichment Center (CHEC)

CHEC is a weekly program that gives homeschoolers a place to take enrichment classes and learn skills such as science and higher math that might otherwise be difficult for their parents to teach. This makes it an ideal place to find students who are interested in learning new skills, including ones related to STEM.

CHEC has three semesters per school year. PSLT will be offering a class during the winter and again in the spring. The class will teach basic principles of rocketry and physics. In the class, students will build and launch model rockets, and they will make experiments to demonstrate what they learned.

5.2.2 Tech Girls – Girls' Geek Day

Tech Girls is a local group that is dedicated to getting girls interested and involved in technology and STEM fields. They hold an event every month of the school year called Girls' Geek Day, which is specifically geared toward girls in elementary school and has an average attendance of 60 girls. PSLT has worked with this group to plan several engagement activities over the course of the project.

5.2.3 Family Space Exploration Event (FSEE)

The Piedmont Student Launch Team will be hosting the Family Space Exploration Event for the second year at PVCC. This event will include robotics demonstrations, building and launching model rockets, and speakers including former NASA astronaut Dr. Kathryn Thornton and a representative from the National Radio Astronomy Observatory (NRAO). PSLT hosted this event last year with nearly 300 in attendance, and this year expected attendance numbers are at least twice that. The FSEE will be held at PVCC on November 11, 2017.

5.2.4 Science Museum of Virginia

The Science Museum of Virginia in Richmond has a special event almost every weekend. PSLT will be partnering with the museum for some of these events. PSLT may also host a rocketry event with the museum.

5.2.5 Big Brothers Big Sisters

The Piedmont Student Launch Team is planning to host a workshop for Big Brothers Big Sisters of the Central Blue Ridge. This event will be a one day class on basic rocketry and physics. PSLT will help the Big Brothers and Big Sisters with assembling model rocket kits and anticipates engaging 50 to 100 people in this activity.

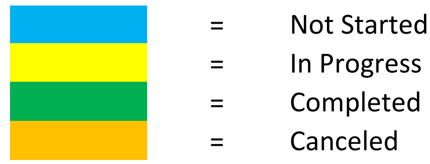
5.2.6 National Air and Space Museum

Similar to the Science Museum of Virginia, PSLT is exploring opportunities to volunteer for events hosted by the nearby National Air and Space Museum. The team will also be looking into the possibility of hosting a one-day event with the museum with a goal of engaging several hundred people.

5.2.7 Jefferson Madison Regional Library

PSLT is partnering with the local Jefferson Madison Regional Libraries to host several after-school enrichment classes on rocketry and other STEM topics. These classes will be offered for children from elementary to high school. Depending on the age group, PSLT will teach the appropriate level of material. Each class will have a limit of 20 students but will be offered once or twice monthly for the entirety of the school year.

6 Project Plan



6.1 Timeline

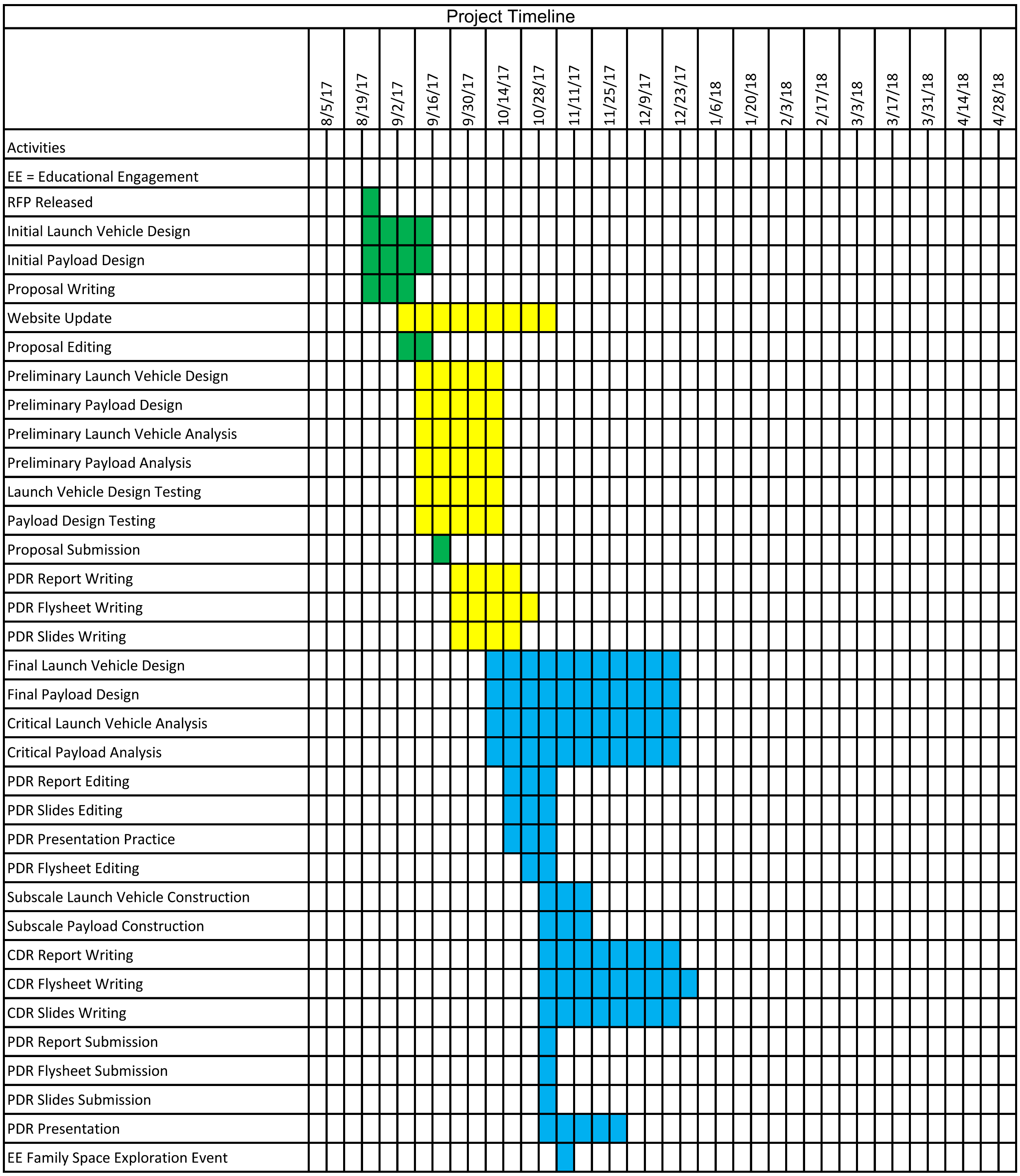


Figure 6.1 - Project Timeline Part 1

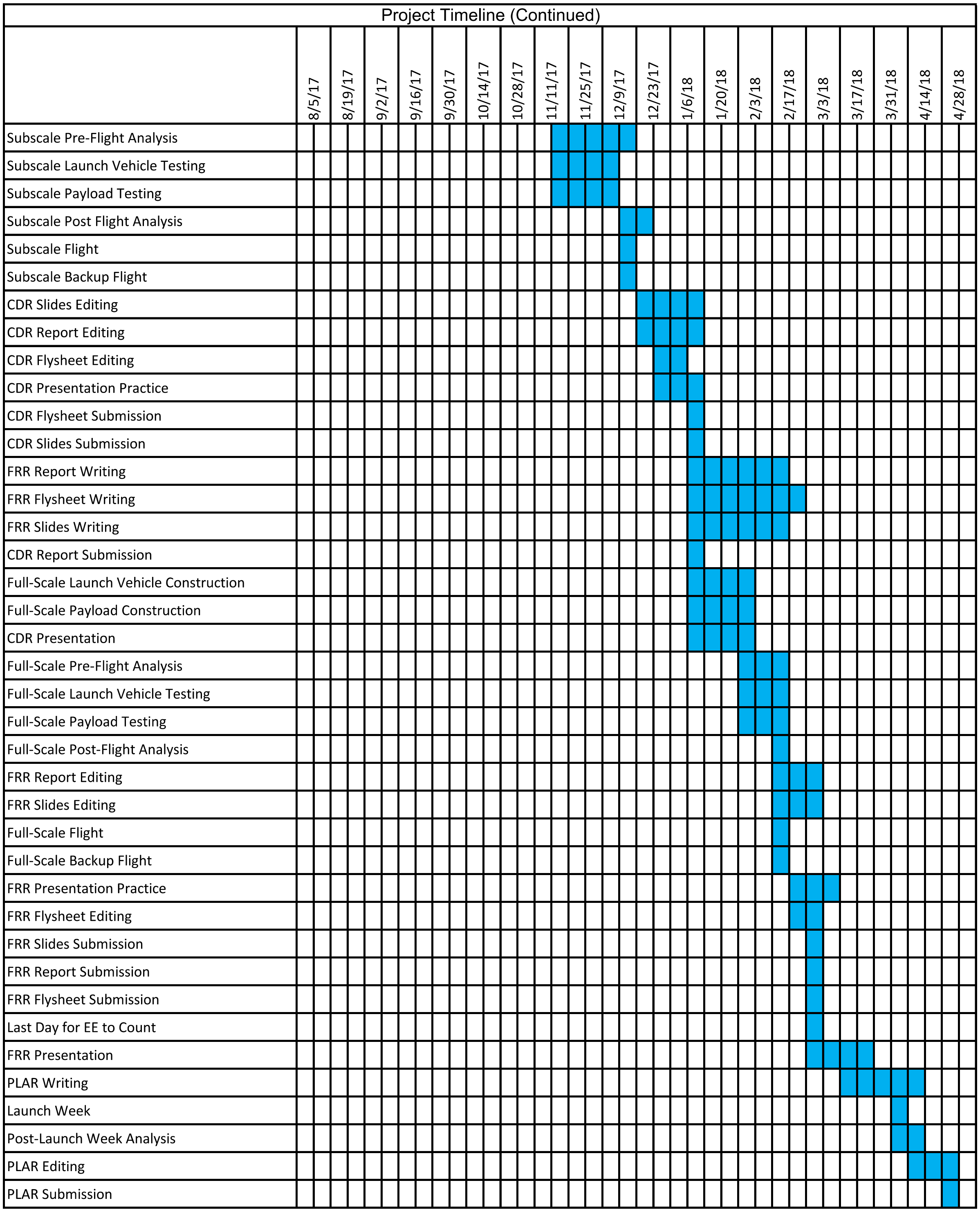


Figure 6.2 - Project Timeline Part 2

The dates provided on the project timeline indicate the date of the left of the two columns that they are above, and that all dates are the Saturday closest to when the beginning or end of an item is.

6.2 Budget

Area	Projected Cost
Educational Engagement	$1,000
Full-Scale Launch Vehicle	$1,000
Full-Scale Payload	$150
Miscellaneous	$200
Motors	$1,000
Safety Equipment	$200
Subscale Launch Vehicle	$500
Subscale Payload	$150
Testing Equipment	$500
Tools & Construction Materials	$300
Launch Week Travel, Food, and Lodging	$9,000
Total	$14,000

Table 6.1 - Projected Budget

Projected travel costs are estimated based on current prices for traveling by two cars and allowing for a four night stay, double-occupancy in Huntsville, AL. All other costs are roughly estimated based on expected materials needed and current pricing of those materials.

6.3 Funding Plan

The three primary sources of funding for the project are PVCC, corporate sponsors, and individual donors. PVCC has already contributed $5,000 to the team's budget and will likely contribute more as the year goes on. PSLT currently has two major local corporate sponsors (Tiger Fuel Company and OFM Computer Systems) who will provide ongoing funding throughout the year as well as directly purchasing many needed supplies for the project. Several local companies have agreed to support the team by providing money as well as services, including facilities for teleconferences, hosting of the team's website, and discounts on food for team meetings. A few key space-enthusiast individual donors who supported the team last year have again pledged several thousand dollars (pending acceptance into the program). Tiger Fuel Company has generously pledged to ensure that the team is able to complete the project and has offered to make up any shortfalls if needed. Based on all of these funding sources, the team is well-positioned financially to be able to undertake this project successfully.

6.4 Team Sustainability

6.4.1 Sustainability of Established Partnerships

A part of the continuation of the team between years will be the selection of new members to fill key roles. These members will be mentored by the team members currently in those roles, so that by the time the current members step down, the new ones will be prepared to take over the role. This mentorship will involve inclusion in any interactions with partners, so that the new member is familiar with any partners of the team that must be interacted with in that role. Additionally, the partners will then already be familiar with the new member.

6.4.2 Engagement of Successive Classes

PSLT has enough members that there will be a significant number that remain on the team at the end of each year. These members will help to bring in new students to be part of the team, as well as being able to pass on lessons learned.

A goal of the team this year is to create a significant amount of documentation that can be used to help future years' teams get started. PSLT has already written a team handbook which details much of the important information that needs to be passed on between years, and it will be expanded upon as the project progresses.

Additionally, by the spring of each year, recruiting for that project year will be stopped, and recruiting will begin for the next project year. This way, new members recruited in the spring will have a chance to be somewhat involved with the project for that year, and so will be prepared to take on roles for the next year.

6.4.3 Sustainability of Funding

The largest single contribution to the team comes from PVCC, which is committed to the continuation of the project. Another large source of funding comes from individual donors, who will change between years, meaning that there will be new ones who can provide funding. Additionally, the team will be able to leverage relationships built with corporate sponsors this year for funding in future years.

6.4.4 Sustainability of Educational Engagement

Many of the educational engagement activities that PSLT will be doing this year are either run by PSLT or are hosted regularly by other organizations. Because of this, the majority of them can be done year after year. Those that are not regular events are not critical to the engagement and outreach activities of the team, and new opportunities can be found to replace them.