University of North Dakota
Department of Physics
*Frozen Fury Rocketry Team*

# ***NASA Student Launch Initiative***
*Preliminary Design Report*

Submitted by:
The University of North Dakota Frozen Fury Rocketry Team

*November 3rd, 2017*

**Abstract:**

*This is the Preliminary Design Report that is submitted to the NASA Student Launch Initiative by the University of North Dakota Frozen Fury Rocketry Team. This document will explain all the design decisions that the team has made, along with safety requirements. It also includes a budget and project timeline. Work verification requirements derived by NASA and the team are included.*

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# *1 - Introduction: Summary of Preliminary Design Report (PDR)*

## 1.1 – Team Summary

**School Name:** University of North Dakota
**Organization:** Frozen Fury Rocketry Team

**Location:**
The University of North Dakota
Witmer Hall, Room 211
101 Cornell Street Stop 7129
Grand Forks, North Dakota 58201

**Project Title:** Frozen Fury Rocketry Team NASA Student Launch Initiative 2017-2018

**Name of Mentor:** Tim Young
**Certification:** Level II NAR certification (NAR# 76791)
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**Name of Mentor:** Kevin Rezac
**Certification:** Level II NAR certification (NAR# 75455)
**Contact Info:** kevin.rezac@und.edu

**Foreign Nationals:**
Tori Fischer – Canada
John Heide – Canada
Nelio Batista Do Nascimento Jr. – Brazil

## 1.2 – Launch Vehicle Summary

| | |
|---|---|
| Length (in.) | 108 |
| Diameter (in.) | 6 |
| Center of Gravity (in.) | 61 |
| Center of Pressure (in.) | 78 |
| Mass w/ motor(lbs.) | 32.32 |
| Mass w/out motor (lbs.) | 24.14 |
| Motor Type | AeroTech L1150-P |
| Recovery System | Single Deployment |

***Table 1:*** *Launch Vehicle Summary*

The length of the launch vehicle was chosen to be 108 inches because this allowed for the simulated apogee to be lower. Along with the added mass, the elongated fin can creates more space inside the launch vehicle which will allow for an additional 10% ballast to be integrated if need be. The diameter of the launch vehicle was chosen to be 6 inches. This is ample space for the integrated payloads, recovery system, and altimeter bay. The total mass of the launch vehicle was determined to be 32.32 lbs. The center of gravity is ahead of the center of pressure which allows the launch vehicle to have a stable flight profile. To ensure that the target apogee is hit an AeroTech L1150-P solid rocket motor was chosen.

## 1.3 – Payload Summary

For this year's NASA Student Launch Initiative three different experimental payloads were presented. They were as follows, Target Detection, Deployable Rover, and Landing Coordinates via Triangulation. The UND Frozen Fury Rocketry team selected the Deployable Rover as the experimental payload for this year's competition. The objective of this payload is that upon landing the rover will be deployed via remote activation. Linear actuators will be utilized to remove the nose cone exposing the rover payload bay. The rover payload bay will be on a locked bearing during flight, which will rotate once the rocket has landed to orient the rover for proper deployment. The rover will then be deployed from the rocket and drive five feet, stop, and initiate deployment of the solar arrays.

There were three different rover designs that the team had come up with. One of the designs was a rover with two tank-style treads. The second design was a rover with two wheels, with body of the rover contained within the diameter of the two wheels. The third design for the rover was based on the Berkley openROACH project, this rover would have legs, and this would allow it to scramble across the terrain. The rover design that was selected was the rover with two tank-style treads. The reasoning for this decision will be further discussed in the Payload Criteria section of this report.

# *2 - Changes Made Since Proposal*

## 2.1 – Vehicle Design Changes

| **Change** | **Reasoning** |
|---|---|
| Length of rocket was increased from 73.847 inches to 108 inches. | This was done to increase stability of the launch vehicle, as well as to allow adequate space for payloads, recovery systems, and the altimeter bay. |
| The power unit was upgraded from an AeroTech K780R to an AeroTech L1150-P. | Since the length of the rocket was increased, the net weight of the rocket increased as well. By upgrading the power unit, the launch vehicle is able to reach above target apogee. |

*Table 2: Launch Vehicle Design Changes*

## 2.2 – Recovery Design Changes

There were no design changes regarding the recovery subsystem. The methods that were proposed will progress to the next phase of project development and preliminary testing.

## 2.3 – Payload Design Changes

There were no major design changes on the deployable rover payload that will be integrated into the rocket. The methods that were proposed will progress to the next phase of project development and preliminary testing.

# *3 - Safety*

Drew Ross is the safety officer for the 2017-2018 Frozen Fury Rocketry Team. The safety officer will be responsible for the safety of the students, team and public throughout the duration of the competition. He is to make sure the team follows all laws and regulations. Many power tools and large machine are used throughout the duration of this project. Our main workspace is large workshop located in the basement of the physics building. The new shop foreman, Jim, is extremely thorough and has spent the past 6-months cleaning the entire workshop. Every machine now has a packet attached that contains operation and safety instructions. Material Safety Data Sheets (MSDS) have been placed out in the open next to each chemical we will be using. At the beginning of this project all team members participated in a safety briefing in the workshop where every machine was discussed, and all safety expectations were reviewed. A culture of safety has been established to ensure that all decisions we make are scrutinized with safety having the most significance.

## 3.1- Risk Level Assessment

Managing risk is extremely useful so we can identify what areas of our project need additional work to improve safety. To rank the probability and the severity of the hazards associated with building high-powered rockets we will use the following Risk Matrix.

Frozen Fury Risk Matrix

| **Probability** | **Consequence** | | |
|---|---|---|---|
| | Severe (1) | Moderate (2) | Minimal (3) |
| High (A) | A1 | A2 | A3 |
| Medium (B) | B1 | B2 | B3 |
| Low (C) | C1 | C2 | C3 |

Risk Acceptance and Management Approval Level

| Risk Level | Acceptance Level |
|---|---|
| High Risk | **Unacceptable**. Documented approval from the MSFC EMC or an equivalent level independent management committee. |
| Medium Risk | **Undesirable**. Documented approval from the facility/operation owner's Department/Laboratory/Office Manager or designee(s) or an equivalent level management committee. |
| Low Risk | **Acceptable**. Documented approval required from the supervisor directly |

| | |
|---|---|
| 🟩 | responsible for operating the facility or performing the operation. |

## 3.1.1 General Project Analysis

| General Risk | Impact | Mitigation Tactic | Likelihood of Risk |
|---|---|---|---|
| Time Scheduling for Construction | Due to climate of Northern Midwest, time is of great concern because of limited opportunities for test launches | Accelerated construction, testing and launch scheduling of the rocket | B2 |
| Resources – tools, materials, transportation, PPE,etc. | Can potentially cause a great limit on the project's development for construction of the launch vehicle | Assemble inventory list of procured materials, and check weekly that stock is enough. Prepare a list of suppliers for immediately-needed materials and safety equipment | C3 |
| Budget– costs of materials and tools | Will cause issues with advancement of the project, essentially bring the project to a standstill until funds are available to purchase needed instruments and hardware | Update and periodically monitor Team budget spreadsheet, account for all expenditures and areas of income. Allocate funds needed to meet the requirements of the project goals, and nothing more. | B2 |
| Scope/Functionality-Purpose of Project | Without necessary engineers for the work for needed projects and project phases, efficiency will be low, and the quality of work will be substandard | Have assigned duties for teammates for specific groups on the project, allow a maximum number of people to assist for each team. This will ensure that work on the project progresses smoothly. | B3 |

## 3.1.2 Personal Hazard Analysis

| General Hazard | Cause of Hazard | Impact | Risk Level | Risk Mitigation | Verification |
|---|---|---|---|---|---|
| Power Tools | Improper placement of personnel body or objects near power tools. | Injury to hands, limbs and eyes. | A1 | Wear recommended personal protective equipment (PPE). Train team members for all power tools. | Verify that team member using power tools have completed the relevant training from the Frozen Fury Safety Program(FFSP) |
| Flammable Materials | If flammable material is kept near or used near an open flame or area with sparks | Fire. Burns to skin. | B1 | Store flammable materials in flammable metal cabinet. Make sure to return flammable materials to the cabinet once used. | Verify that team member working with flammable materials have completed the relevant training from the FFSP |
| Hazardous Substance Handling | Inadequate ventilation or lack of PPE | Irritation of skin, eyes, lungs and face | A3 | Train team members in proper chemical handling techniques. Wear PPE and handle in properly ventilated area. | Verify that team member working with Hazardous substances have completed the relevant training from the FFSP |
| Chemical fumes | Inadequate ventilation or lack of PPE | Irritation of skin, eyes, lungs | A3 | Wear dust mask when applying. Handle in properly ventilated area. | Verify all team member completed the relevant training from the FFSP |
| Tripping hazards | Lack of situational awareness or improperly | Personal injury | B2 | Provide proper stations for storage of tools and equipment. | Verify all team member completed the relevant training from the FFSP |

| | | | | | |
|---|---|---|---|---|---|
| | placed objects | | | Always keep work area clean. | |
| Electricity | Electrocution due to bad wiring or situational awareness | Electrocution and burns | B1 | Always turn off equipment and tools before working on them for repairs as well as after using them. | Verify that team member using power tools have completed the relevant training from the Frozen Fury Safety Program(FFSP) |
| Falling Rockets | Parachute failed to deploy | Personal injury | C1 | Verify recovery systems before launch, and if parachutes are folded properly | Follow launch operations procedure for recovery |
| Cold Conditions | Inadequate preparation with clothing or lack of PPE. | Frostbite, Hypothermia. | B2 | Wear proper cold gear for cold launch conditions. | Verify all team member completed the relevant training from the FFSP |
| Falling payloads | Poorly secured payloads or bad rocket structural integrity | Personal injury | C1 | Verify payloads are secured before launch. Visually check rocket for any cracks that could compromise structural integrity. | Follow launch operations procedure when preparing rocket. Go through preflight checks with at least two people (one being safety officer) and sign off on the prelaunch check sheet |

### 3.1.3 Environmental Concerns

| Environmental Hazard | Cause of Hazard | Impact | Risk Level | Risk Mitigation | Verification |
|---|---|---|---|---|---|
| Rocket crashes into water body. | Parachute failed to deploy | Environmental damage | B2 | Plan proper launch area without risk of water contamination | Follow all MSDS and safety procedures. Do post flight inspections from the launch operations procedure. |
| Fume inhalation of hazardous fumes due to proximity to rocket. | Personnel not safe distance from rocket. | Irritation of lung, eyes and nose. | B3 | Keep proper distance from rocket before launch. Keep only required crew members around rocket. | NASA USLI Student Handbook, page 40, Minimum Distance Table, for L motor minimum safe distance is 300 feet. |
| Upon recovery, ground destruction may be discovered, loose propellant may be present | Poorly secured propellant or bad rocket structural integrity | Reversible environmental damage | C2 | Verify all rocket component s are secured before launch. | Go through pre launch checks with at least two people (one being safety officer) and sign off on the pre launch check sheet. Do post flight inspections from the launch operations procedure. |
| Rocket ash can have hazardous effects on the ground below the launch pad. | Poor launch pad setup with blast shield | Environmental damage | B2 | Verify blast shield is properly secured before launch. During clean up, properly dispose of the waste materials. | Go through pre launch checks with at least two people (one being safety officer) and sign off on the pre launch check sheet. Do post flight inspections from the launch operations procedure. |
| Dissolution of rocket fuel into open water | Poor situational | Severe environment- | B1 | Plan proper launch and | Follow all MSDS and safety procedures. |

| | | | | | |
|---|---|---|---|---|---|
| causes contamination of water source | awareness or unsecure propellant | al damage | | recovery area. Be mindful of wind conditions as to predict rocket movement. | |
| Ignition produces sparks capable of setting fire to dry grass and other flammable material. | Poor launch pad setup with blast shield or bad situational awareness | Burns, damage to environment | B1 | Keep flammable materials away from rocket. Always have a fire extinguisher handy during launches. | Verify at least three team members present have completed the Emergency Action Plan & Fire Protection training from the FFSP. |
| Potential hazard to wildlife if small rocket pieces are ingested. | Poor cleanup of rocket parts after launch | Damage to wildlife. | C1 | Team will function as cleanup crew at impact and launch site to ensure all rocket parts are recovered. | Go through pre launch checks with at least two people (one being safety officer) and sign off on the pre launch check sheet. Do post flight inspections from the launch operations procedure. |
| High Winds | Weather conditions | Launch Delayed | B3 | Double check the weather while preparing the rocket so it can fly safely under the current conditions, if not delay launch for a different day. | Go through preflight checks with at least two people (one being safety officer) and sign off on the pre launch check sheet. |
| Rocket drifts outside set limits | High wind conditions | Rocket could be unreachable or lost | B1 | Make sure that the rocket can perform as intended in different wind speeds during simulations | Go through preflight checks with at least two people (one being safety officer) and sign off on the pre-launch check sheet. |
| Wet black powder | Rain | Recovery systems might not fire, Launch delayed | B2 | Always properly store black powder in a flameproof metal box. If black | The charges will be sealed promptly and only if the black powder has been verified as dry. |

| | | | | | |
|---|---|---|---|---|---|
| | | | | powder gets wet, replace powder do another preflight and pre launch check. | |
| Fog or low visibility | Weather conditions | Would lose the rocket during recovery operations, Launch delayed | B2 | Double check the weather while preparing the rocket so it can perform its job safely under the current conditions, if not delay launch for a different day. | Go through preflight checks with at least two people (one being safety officer) and sign off on the pre launch check sheet. |
| Rocket body damage from birds | Wildlife and poor situational awareness | Rocket and wildlife could get damaged and land hard | B2 | Observe migratory flight patterns over launch range and cancel launch when birds are overhead. | Go through preflight checks with at least two people (one being safety officer) and sign off on the pre launch check sheet. |

## 3.1.4 Failure Modes and Effects Analysis (FMEA)

| Failure Modes | Cause | Effect | Risk Level | Risk Mitigation | Verification |
|---|---|---|---|---|---|
| Parachute deploy at wrong altitude | Late or early deployment of parachute due to faulty altimeter setup | Rocket body could rip apart if parachute deployed when rocket is moving too fast. | B1 | Check batteries for altimeter before launch and verify parachutes are properly folded so they deploy without getting tangled. Double check the altimeters on launch day to make sure all wires are hooked up correctly | Follow launch operations procedure for recovery systems and parachutes when preparing rocket. Go through preflight checks with at least two people (one being safety officer) and sign off on the prelaunch check sheet. |
| Motor failure due to faulty ignitor | Damaged or poorly secured ignitor, or faulty wiring setup | Motor fails to ignite when expected | B3 | Check ignitor for any visible faults before attempting to place it. Verify if ignitor is placed and secured properly before launch. | Follow launch operations procedure for motor assembly when preparing rocket. Go through preflight checks with at least two people (one being safety officer) and sign off on the prelaunch check sheet. |
| Shock cord failure | Damaged or frayed shock cord | Parachute wouldn't work properly and rocket might come down hard | B1 | Visually inspect shock cord for any damage before use. | Follow launch operations procedure for recovery systems and parachutes when preparing rocket. Go through preflight checks with at least two people (one being safety officer) and sign off on the prelaunch check |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | sheet. |
| Parachutes getting entangled | Improperly packed parachute | Parachute might not open properly and rocket might come down at terminal velocity | A1 | Verify that the recovery system on launch day and how the parachute is folded to make sure it will not tangle | Follow launch operations procedure for recovery systems and parachutes when preparing rocket. Go through preflight checks with at least two people (one being safety officer) and sign off on the prelaunch check sheet. |
| Fin damage | Rocket land too fast or in landed in a bad position | Can’t fly rocket until new fins are installed | C1 | Inspect fins for structural integrity before launch. | Go through preflight checks with at least two people (one being safety officer) and sign off on the prelaunch check sheet. |
| Unstable launch pad | Poor launch pad setup | Rocket could launch in an unintended direction. Could lead to injury | B1 | Verify launch pad is level and secure with and without the rocket before launch. | Go through preflight checks with at least two people (one being safety officer) and sign off on the prelaunch check sheet.<br>NASA USLI Student Handbook, page 40, Minimum Distance Table, for L motor minimum safe distance is 300 feet. |
| Torn parachute | Poor inspection of materials | Rocket will fall down faster than intended. Might get damaged | B2 | Visually inspect parachutes for any tears or holes before properly folding them. | Follow launch operations procedure for recovery systems and parachutes when preparing rocket. Go through preflight checks with at least two people (one being safety officer) and sign off on |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | the pre launch check sheet. |
| Ejection charge doesn’t ignite | Bad black powder or altimeter setup | Parachutes won’t deploy and rocket will land at terminal velocity | A1 | Double check the altimeters on launch day to make sure all wires are hooked up correctly.<br>Verify black powder holders are properly secured. | Follow launch operations procedure for recovery systems and altimeter bay when preparing rocket.<br>Go through preflight checks with at least two people (one being safety officer) and sign off on the pre-launch check sheet. |
| Dead batteries | Poor awareness of equipment | Payload failure | B2 | Conduct routine battery checks. Fully charge batteries prior to each launch. | Go through preflight checks with at least two people (one being safety officer) and sign off on the pre-launch check sheet. |

## 3.2 – Material Safety Data Sheets (MSDS)

The MSDS documentation for all chemicals and printed out and have been placed clearly next to each chemical. The safety precautions for most of the materials were found on the West Systems Inc online company page and Science Lab.com Each team member has read and will comply to all safety codes dictated on the MSDS sheets. The MSDS will not be attached to the PDR for paper conservation.

The following are materials addressed in our safety information contained within this document:

- NAR High Powered Safety Code
- OSHA Power Tools
- Ammonium-Perchlorate
- Epoxy 105 West systems
- Fast hardener 205 West Systems
- Filler 404 West Systems
- Fiber-Glass 727 West Systems

## 3.3 – NAR High Powered Rocket Safety Code - Mitigation

The National Association of Rocketry (NAR) High-Powered Safety Code has been printed out and is available in our workshop. All team members have been briefed on the document and will refer to it as the governing document for general rocket safety.

**Minimum Distance Table (L-Motor Highlighted)**

| Total Impulse (Newton-Seconds) | Motor | Minimum Diameter of Cleared Area (ft.) | Minimum Personnel Distance (ft.) | Minimum Personnel Distance (Complex Rocket) (ft.) |
|---|---|---|---|---|
| **0 -- 320.00** | H or smaller | 50 | 100 | 200 |
| **320.01 – 640.00** | I | 50 | 100 | 200 |
| **640.01 – 1,280.00** | J | 50 | 100 | 200 |
| **1,280.01 – 2,560.00** | K | 75 | 200 | 300 |
| **2,560.01— 5,120.00** | **L** | **100** | **300** | **500** |
| **5,120.01- 10,240.00** | M | 125 | 500 | 1000 |

*High Power Rocket Safety Code – Minimum Distance Table (nar.org).*

The Following is a detailed summary of how we intend to comply with the NAR High Power Rocket Safety Code.

**Certification:**
Team mentor Dr. Tim Young holds a level 2 NAR certification (#76791). He will be present during every one of our flights. Dr. Young will obtain the motors for us and directly supervise their construction.

**Materials:**
We will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket. Our rocket will be constructed of carbon-fiber tubing and nose cone, with resin fins. The only metal present will be in the form of small rods, bolts and other small hardware.

**Motors:**
The Aerotech L1150 motor we will use in our rocket was also used last year. Proper safety will be observed by our team regarding the motor, supervised by returning team members who handled the motor last year. A mentor will be present during all motor handling phases.

**Ignition System:**
Our rocket ignition systems will not be active until it has arrived at the launch site and is adequately prepared for flight. The electric igniter provided with the motor will be the only igniter type used.

**Misfires:**
The NAR members present will ensure that the misfire guidelines are followed, as well as the team leaders to ensure that all team members and spectators in the area understand the dangers and will not approach the rocket for any means.

**Launch Safety:**
The team will ensure all individuals present at a launch know the dangers present and will treat each flight attempt as a "heads up flight." Meaning that, during the countdown and flight, someone will direct everyone to keep an eye on the rocket, and be alert for its descent back to the frozen fields of North Dakota. A ten second count down will always be used to ensure the safety of every person at the launch site.

**Launcher:**
Our rocket will be launched vertically, and we will take necessary precautions if wind speed will affect our launch. We have a steel blast shield to protect the ground from rocket exhaust. Dry grass around our launch pad will be sufficiently cleared away. The rail is long enough, and has been simulated, to ensure the rocket reaches stable flight before exiting.

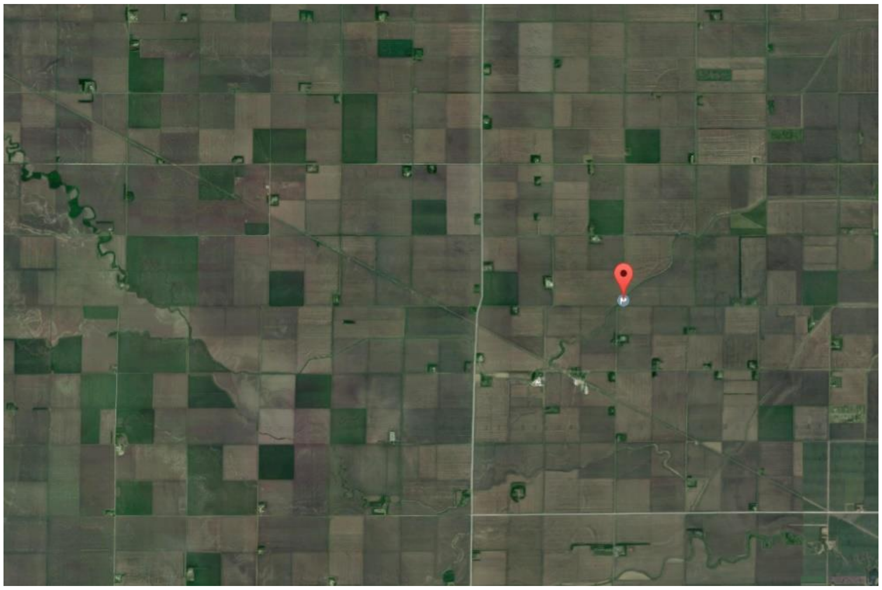
**Size:**
The motor we will use has 3489 Ns of Total Impulse. Our rocket will weigh 32.32 pounds, well below one third of the 302.6 maximum-pound thrust the motor will provide.

**Flight Safety:**
Tim Y. has details on our FAA altitude clearance. We will refrain from launching in high winds or cloudy conditions. There are many flight paths around Grand Forks due to the UND being a large aviation school. A Waiver and/or Notice To All Airmen (NOTAM) will be submitted prior

to every flight to ensure all aviation personal can plan accordingly and take necessary precautions to maintain a safe distance from our launch site.

**Launch Site:**
Our launch site is of an adequate size, with plenty of room for recovery for our planned altitude.

**Launch Location:**
Our launch site is 60 miles south of Grand Forks, ND. This location provides an adequate amount of space to satisfy minimum distance requirements. The areas surrounding Grand Forks provides miles of flat farmland with excellent visibility. There are not any buildings or highways within 1500ft, and pursuant to the table above, all personal on-site will maintain a 300ft perimeter from the launch site



*Launch Location near Fargo, North Dakota*

**Recovery System:**
We will use a 24-inch parachute for drogue, and a 96-inch with a 12-inch spill hole main parachute to ensure rocket recovery. The main parachute and drogue parachute will both be placed in flame-retardant Nomex bags.

**Recovery Safety:**
Power lines are scarce near our launch site, but we will refrain from recovering if it happens to land in a dangerous location such as up a tree or tangled in power lines. If such an event happens, the local power company will be notified.

## *4 - Vehicle Criteria*

The launch vehicle will be constructed with carbon fiber, fiberglass, and plywood. To hit the target of 5,280 feet for apogee, the launch vehicle will be optimized. Optimization will not only come from mass being increased or decreased, but will also come from payload weight distribution and the selection of the optimal motor to power the flight of the vehicle. The launch vehicle will contain a nose cone, payload bay, recovery payload bay, altimeter bay, recovery payload bay, and engine bay.

## 4.1– Selection, Design and Verification of Launch Vehicle

**Mission**

The mission objective of the 2017-2018 University of North Dakota Frozen Fury Rocketry Team is to design, build, launch, and fly a rocket with a deployable rover payload and hit a target apogee of 5,280 feet while working within the given formula for this year's rocket development process that is given the 2017-2018 NASA Student Launch Initiative Handbook.

**Mission Success Criteria**

The following criterium must be met for mission success:

- Rocket Launch: A successful full-scale rocket launch will be completed. The launch will be successful if the rocket reaches an altitude of 5280 (±100) feet above ground level (AGL). The launch will be overseen by professionals from the NAR in accordance to NASA directives.
- Rocket Recovery: A successful recovery of the launch vehicle will consist of the successful deployment of parachutes within the airframe. This means the black powder charges will be ignited at the desired altitude and the parachutes will deploy from the internals of the airframe. The connected rocket and parachutes will land on the ground. Once recovered the launch vehicle will be completely reusable.
- Payload Deployment: The launch vehicle will successfully carry and deploy the rover that will be housed in a payload section within the airframe. The rover shall complete assigned objectives.

### 4.1.1 – Selection and Design Overview

Selection of launch vehicle components has immediate impacts on the design of the launch vehicle. That is why they are combined in this section. This section will give an in-depth summary of why certain design elements were selected.

**Airframe:**

There were two leading options for the air frame, carbon fiber and fiberglass. Both options present great upsides, however they also have their drawbacks. After in-depth analyzation of each alternative, these are the positives and negatives of the carbon fiber and fiberglass. On a scale of 1-5, where one is poor and five is excellent, the comparison of the two composite materials can be analyzed in the table below.

| Specifications | Carbon Fiber | Fiberglass |
|---|---|---|
| Density | 5 (Excellent) | 1(Poor) |
| Tensile Strength | 5 (Excellent) | 2 (Fair) |
| Compressive Strength | 5 (Excellent) | 4 (Good) |
| Stiffness | 5 (Excellent) | 2 (Fair) |
| Abrasion Resistance | 2 (Fair) | 2 (Fair) |
| Processing/Machining | 4 (Very good) | 5 (Excellent) |
| Fatigue Resistance | 4 (Very good) | 3 (Good) |
| Conductivity | 5 (Excellent) | 1 (Poor) |
| Heat Resistance | 5 (Excellent) | 5 (Excellent) |
| Moisture Resistance | 3 (Good) | 3 (Good) |
| Resin Compatibility | 3 (Good) | 5 (Excellent) |
| Cost | 2 (Fair) | 4 (Very good) |

*Table 3: Carbon Fiber vs Fiberglass*

Looking at carbon fiber the positive impacts are noted immediately. Carbon fiber is not only lighter than fiberglass but is more durable as well. Carbon fiber is stiffer than fiberglass, making it a better material for rocket building where flexibility is unwanted. It out performs fiberglass in tensile strength and compressive strength. However, the draw back with carbon fiber is that it is more expensive than fiberglass. It is also harder to work with than fiberglass. In addition to being harder to work with, the mode of failure carbon fiber presents is catastrophic compared to that of fiberglass. Carbon will shatter at the point of failure, whereas fiberglass will start to develop fractures or deform before it breaks. Fiberglass has a few benefits over carbon fiber; it is cheaper, easier to handle, and is more compatible with resin than carbon fiber. However, it is lacking in the performance categories. It is not nearly as light and durable as carbon fiber. Despite being more expensive and harder to work with, a carbon fiber air frame was selected because it will ultimately perform better than fiberglass.

### Fin Design:

The purpose of putting fins on a rocket is to provide stability during flight, that is, to allow the rocket to maintain its orientation and intended flight path. If the rocket was launched without fins, it would begin to travel on an unstable flight path soon after launch. This is most likely caused by forces such as wind or the aerodynamics of the rocket in relation to the forces exerted by gravity and the rocket motor. The fins will allow us to put the center of pressure aft of the center of gravity.

When designing the fin, the team had to keep a few different parameters in mind. First, we needed to consider the induced drag caused by the fin geometry. The next factor that was taken into consideration was stability that certain fins provided. It was found that a clipped delta and a trapezoidal style fin seemed work well for stability. Another factor looked at was manufacturability of the fin, or how easy or hard it would be to manufacture the fins. The final factor was durability of the fin. As seen in the CAD picture below the design the chosen fin design was a modified trapezoidal design. With this design, it is understood that it will be able to eliminate potential for damage of fin breaking off on landing if the corner were to catch upon impact. Additionally, trapezoidal fins have low induced drag. After implementing our fin design into open rocket, it confirmed that it is an applicable design for our rocket and, if needed, can be adjusted in size to help reach the targeted height of one mile (5,280 ft.) as accurately and safely as possible. The leading edge will be rounded, and the trailing edge will be streamlined to further reduce drag. It should also be noted that each fin has through-the-wall tabs which insert into the rocket. These tabs help secure the fin to the rocket.

| **Fin Type** | **Stability Rating** | **Aesthetic Rating** | **Manufacturability Rating** | **Durability Rating** | **Total Rating** |
|---|---|---|---|---|---|
| Trapezoidal | 5 | 4 | 3 | 5 | 17 |
| Clipped Delta | 5 | 3 | 5 | 4 | 17 |
| Parallelogram | 4 | 5 | 3 | 2 | 14 |
| Modified Trapezoid | 5 | 5 | 4 | 5 | 19 |
| Custom | 3 | 5 | 2 | 3 | 13 |

*Table 4: Decision Matrix*

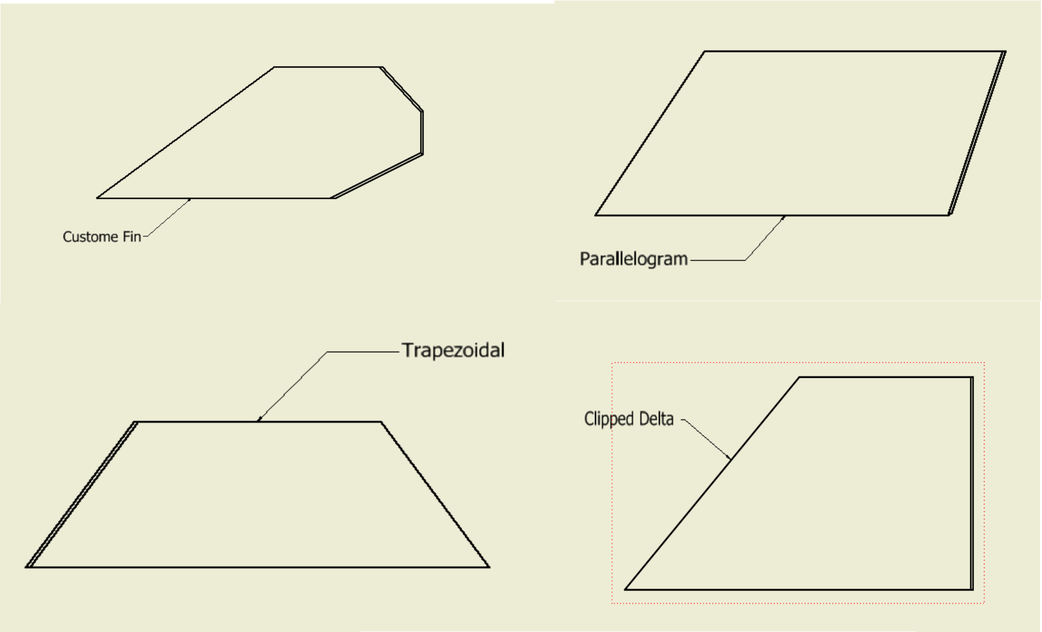


*Figure 1: Proposed Fin Designs*

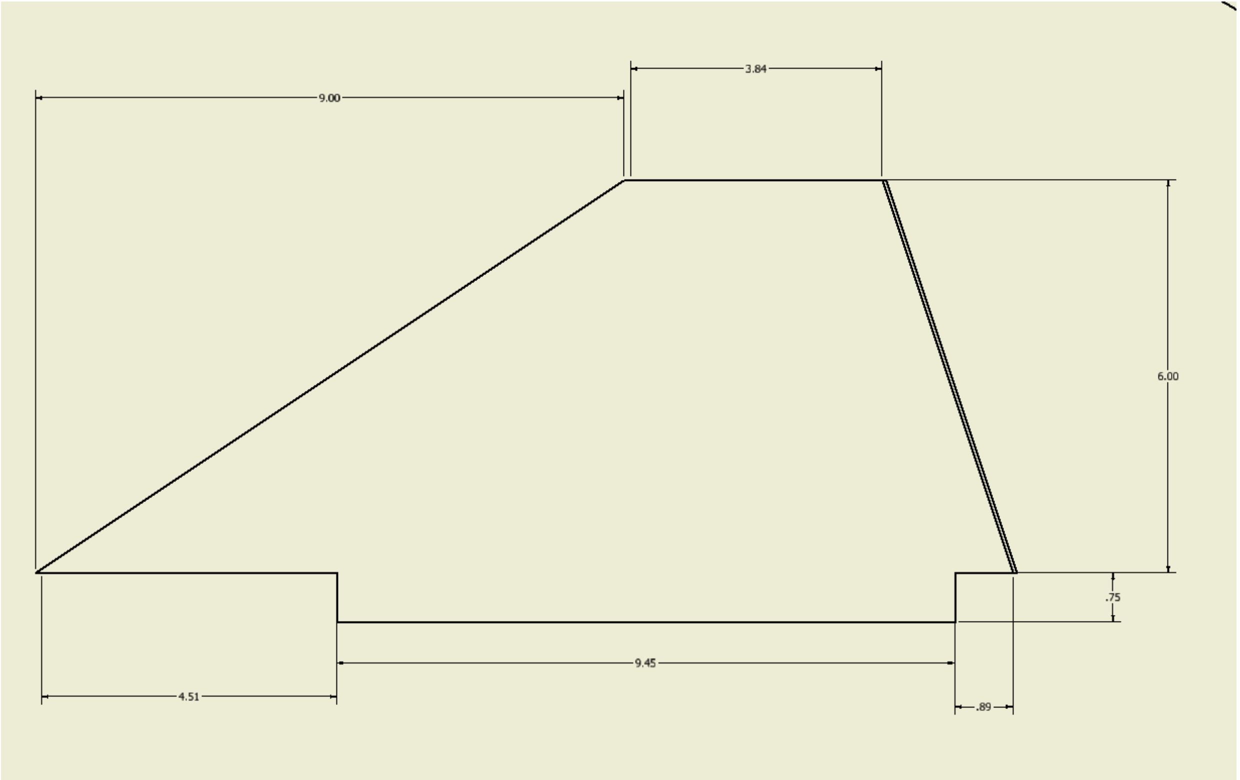


*Figure 2: Selected Fin Design (Note: Dimensions are from scale launch vehicle)*

Table 5 shows a decision matrix of how the team came about on choosing this fin design. The modified trapezoid fin design was selected as it scored highest on the decision matrix. A maximum of 20 points could be scored and the modified trapezoid fin design scored 19.

**Bulkhead Material:**

Internal bulkheads will be constructed out of ¼-in. birch plywood purchased from a Grand Forks, ND local hardware retailer. The rationale behind choosing birch plywood is that it has a very clean face and very few knots. The use of higher grade wood ensures the bulkheads will have uniform grain and will be structurally strong in order withstand the stress of flight. Bulkheads are cut from the plywood using a table saw and then sanded to fit securely in the 6-in. diameter rocket body tube. The bulkheads are affixed inside the airframe with West Systems epoxy on both the superior and inferior edges for added strength. The plywood bulkheads make certain the rocket structure is rigid throughout its entire length.

**Motor Selection:**

When selecting the motor, three key items were looked at; the total impulse of the motor, the mass of motor, and the simulated apogee of motor in the optimized rocket. The total impulse and mass of the motor were taken into consideration to determine the specific impulse, a measure of the total impulse per unit of propellant consumed. Specific impulse is important to the selection of the motor because it indicates the efficiency of a motor. The higher the specific impulse the more efficient the motor is. Simulated apogee was also taken into consideration because the target apogee for the 2017-2018 rocket is 5,280 feet.

There was a wide variety of motors to select from to power this year's rocket. Through process of elimination four ideal motors presented themselves. These four motors with their specifications and how they fit in with the team's derived constraints can be seen in Table 6.

| **Name of motor** | **Motor mass (kg)** | **Total Impulse (Ns)** | **Simulated Apogee (ft)** |
|---|---|---|---|
| AeroTech L1000 | 2.19 | 2702 | 4331 |
| AeroTech L1420 | 4.56 | 4616 | 7656 |
| AeroTech L1150R | 3.68 | 3489 | 5588 |
| AeroTech L952W | 5.017 | 5050 | 3601 |

*Table 5: Motor Comparison*

The motor that was selected for the 2017-2018 rocket is the AeroTech L1150R. This was because it gave the best simulated apogee. Specific impulse was taken into consideration, but after great deliberation it was decided that the L1150R would be the optimal power unit for the launch vehicle at this stage of the designing process.

### 4.1.2 Summary of Vehicle Design

The launch vehicle will have an airframe that is constructed out of carbon fiber. Bulkheads made from plywood will separate payload, altimeter, and engine bay sections. The fins will have a trapezoidal geometry to optimize flight stability and apogee. The motor will be an AeroTech L1150R.

## 4.2 – Recovery Subsystem

The recovery subsystem will employee an altimeter bay along with a single main parachute and a single drogue parachute. The altimeter bay will be linked to two separate black powder charges. These charges will be ignited by the altimeter when the desired altitude is reached. The desired altitude for ignition of the black powder is programmed into the altimeter before each flight that is performed. For safety, a reserve parachute is also integrated within the recovery subsystem. The main purpose of the reserve parachute is to be deployed if the main parachutes do not successfully deploy. This chute will be deployed at 800 feet AGL. For recovery of the launch vehicle an electronic tracker will be installed within the airframe. This will allow the team to locate the launch vehicle after it lands, and will expedite the recovery process. This section will give an in-depth summary of why certain recovery subsystem components were selected.

**Number of Parachutes:**

For this year's launch vehicle, there were two options for number of parachutes. The first having a single main parachute and having the launch vehicle come down as one unit, the second option was having two main parachutes and the launch vehicle coming down as two separate units. Adding a second parachute was deemed unnecessary. There is no need, at this point of development, to add in a secondary main parachute and have the launch vehicle come down in two separate pieces. It would make the recovery subsystem more complex without having an immediate benefit. This year's launch vehicle will have one main parachute, with a drogue as well.

## 4.3 – Mission Performance Prediction

This section will describe the launch vehicles flight profile, altitude predictions, component weights and simulated motor thrust curve. The stability margin and center of pressure(CP)/center of gravity locations will be shown and described as well. Drift for five different cases will be displayed.

The launch vehicle has a length of 108 in. and a diameter of 6 in. This is an adequate size for the launch vehicle as it allows space for the experimental payload, motor, and recovery subsystems while still being stable. The launch vehicle has a simulated apogee of 5,587 ft. The rocket itself weighs approximately 24 pounds without the motor and approximately 32 pounds with the motor. The experimental payload net weight, which includes the rover and its deployment system weighs approximately 9 pounds. This weight is expected to change throughout the course of development and is just an estimate. A ballast of 10% of total weight of the launch has not been implemented into the design because it is deemed unnecessary at this point in time. After the first test launch and actual flight data is received a ballast may be implemented if necessary.

### Flight Profile

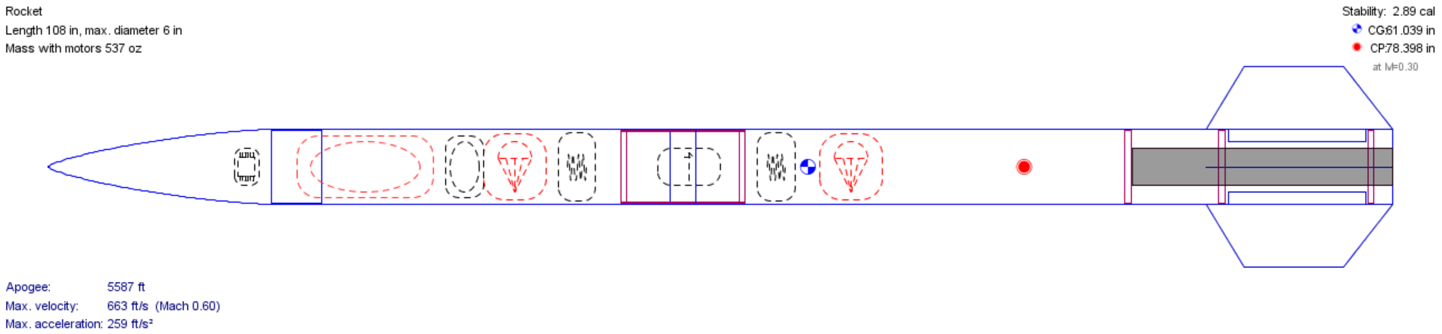


*Figure 3: Side Profile of Rocket (OpenRocket)*

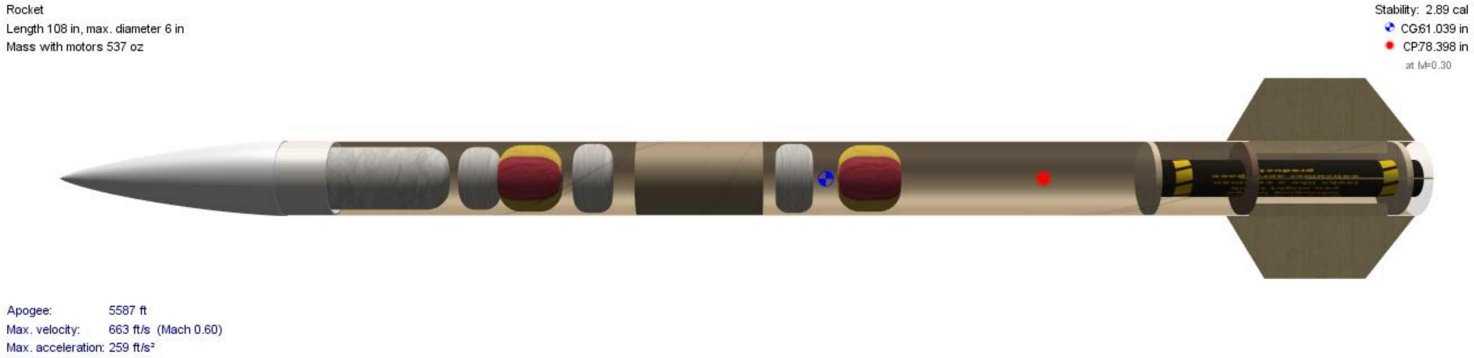


*Figure 4: 3D Render of Rocket (OpenRocket)*

| | |
|---|---|
| Mass of Launch Vehicle (Unloaded) | 24.14 pounds (lbs) |
| Mass of Launch Vehicle (Loaded) | 32.32 lbs |
| Length of Launch Vehicle | 108 inches (in) |
| Diameter of Launch Vehicle | 6 in. |
| Center of Pressure (CP) | 78.30 in. from nose cone |
| Center of Gravity (CG) | 61.04 in. from nose cone |
| Stability Margin | 2.89 |
| Mass of Rover Payload Bay (w/ Rover) | 9 lbs |
| Mass of Rover | 5 lbs |
| Apogee | 5587 feet (ft) |
| Max. Velocity | 639 ft/s |
| Max. Acceleration | 249 ft/$s^2$ |
| Time to Apogee | 18.2 seconds (s) |
| Velocity at Deployment | 106 ft/s |
| Altitude of Deployment of Drogue | 5888 ft. (Apogee) |
| Altitude of Deployment of Main Parachute | 1000 ft. |
| Ground Impact Velocity | 31.5 ft/s |

*Table 6: Size/Vehicle Dimensions*

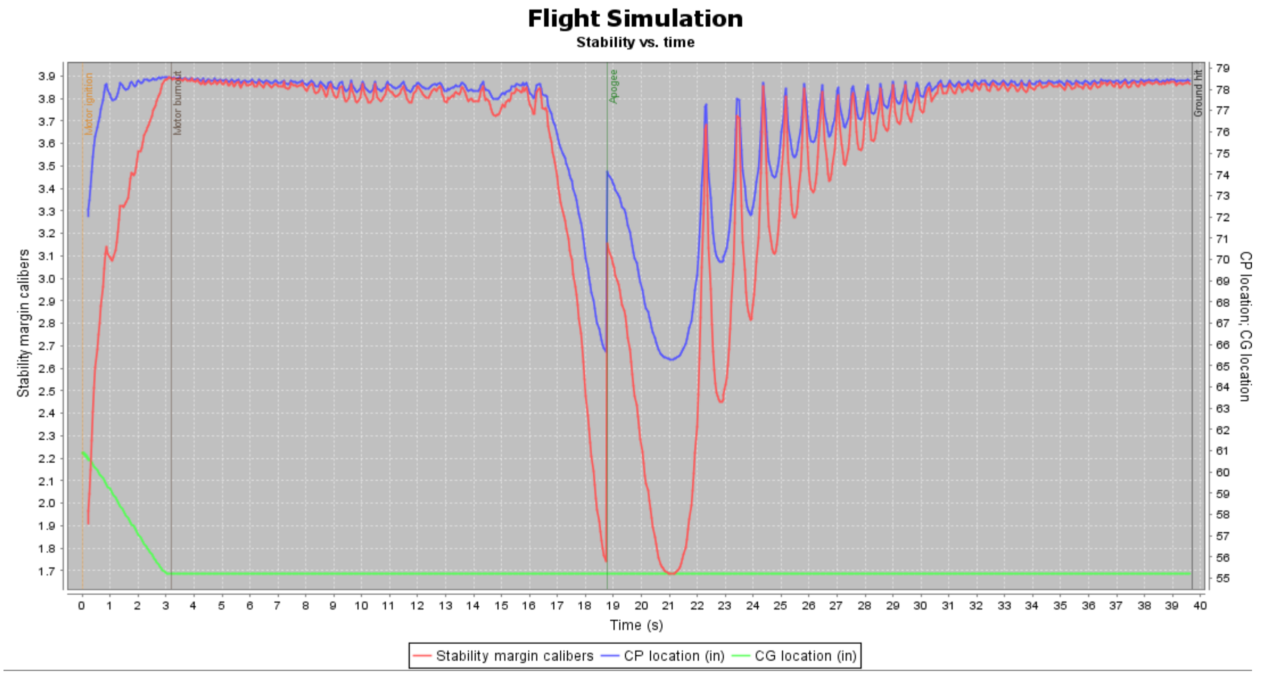


*Figure 5: Stability vs Time Simulation*

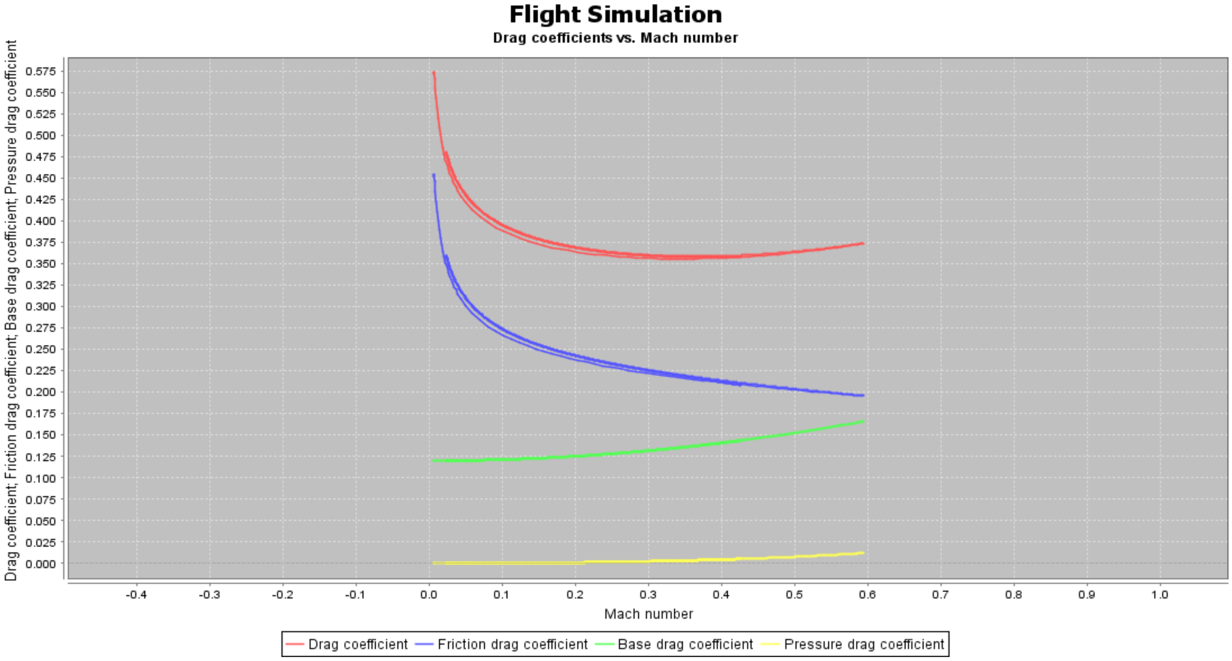


*Figure 6: Drag coefficients vs. Mach Number*

## Fin Specifications

| | |
|---|---|
| Root chord | 15 in. |
| Height | 5 in. |
| Tip chord | 8 in. |
| Sweep Length | 3.033in |
| Sweep Angle | 31.2° |

*Table 7: Fin Specifications*

## Motor Specification

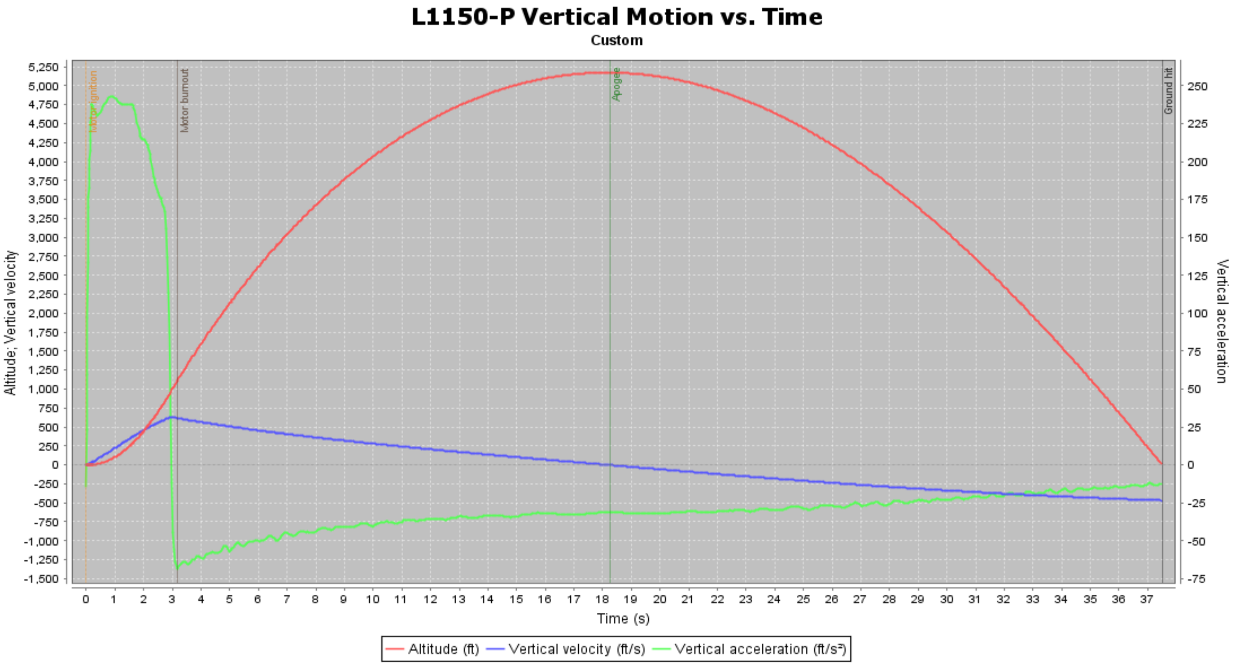


*Figure 6: Vertical Motion vs. Time*

| | |
|---|---|
| Manufacturer | AeroTech |
| Entered | May 25, 2006 |
| Last Update | Jul 22, 2015 |
| Mfr. Designation | L1150R |
| Common Name | L1150 |
| Motor Type | Reloadable |
| Delays | P |
| Diameter | 2.95 in. |
| Length | 20.9 in |
| Total Mass | 130 ounces (oz.) |
| Empty Mass | 56.7 oz. |
| Average Thrust | 1148 N |
| Total Impulse | 3489 Ns |
| Max. Thrust | 1310 N |
| Burn Time | 3.1 s |

*Table 8: L1150 Motor Specifications*

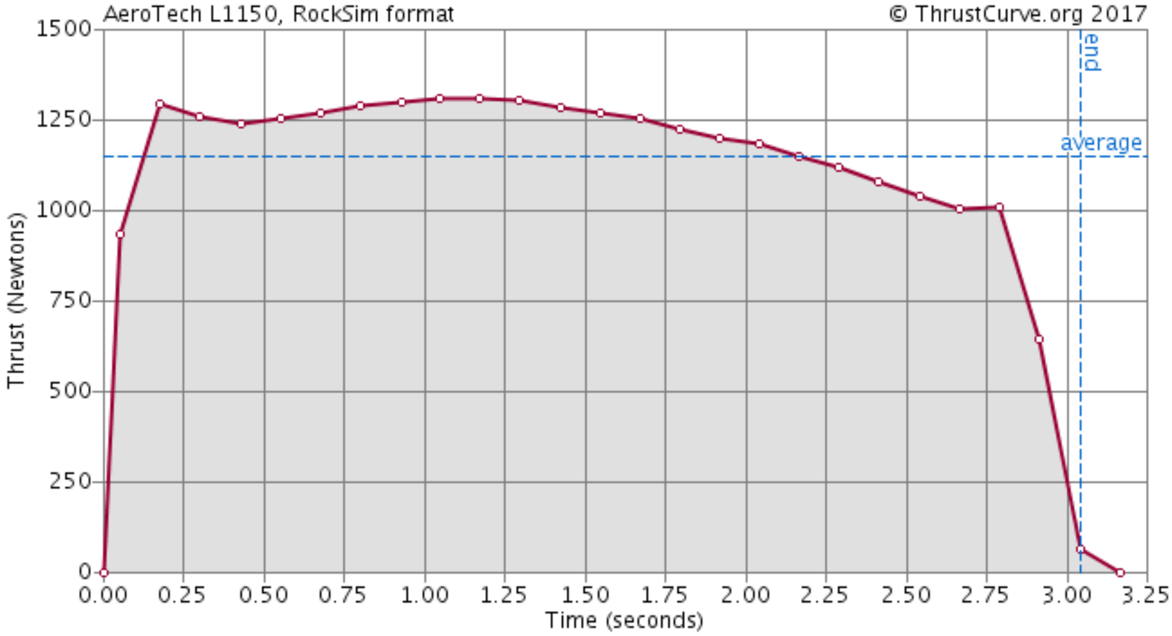


*Figure 7: Thrust curve of L1150*

The L1150R thrust curve data was simulated by using thrustcurve.org. The data in Table 9 was taken from the OpenRocket software used to simulate flights. All simulations, except the thrust curve simulation were completed using OpenRocket.

## Drift Simulations

The following five figures will represent the drift the launch vehicle will have from the launch site. The five scenarios that have been simulated are for no-wind, 5-mile per hour (mph) wind, 10-mph wind, 15-mph wind, and 20-mph wind. All the drift simulations were completed using OpenRocket.

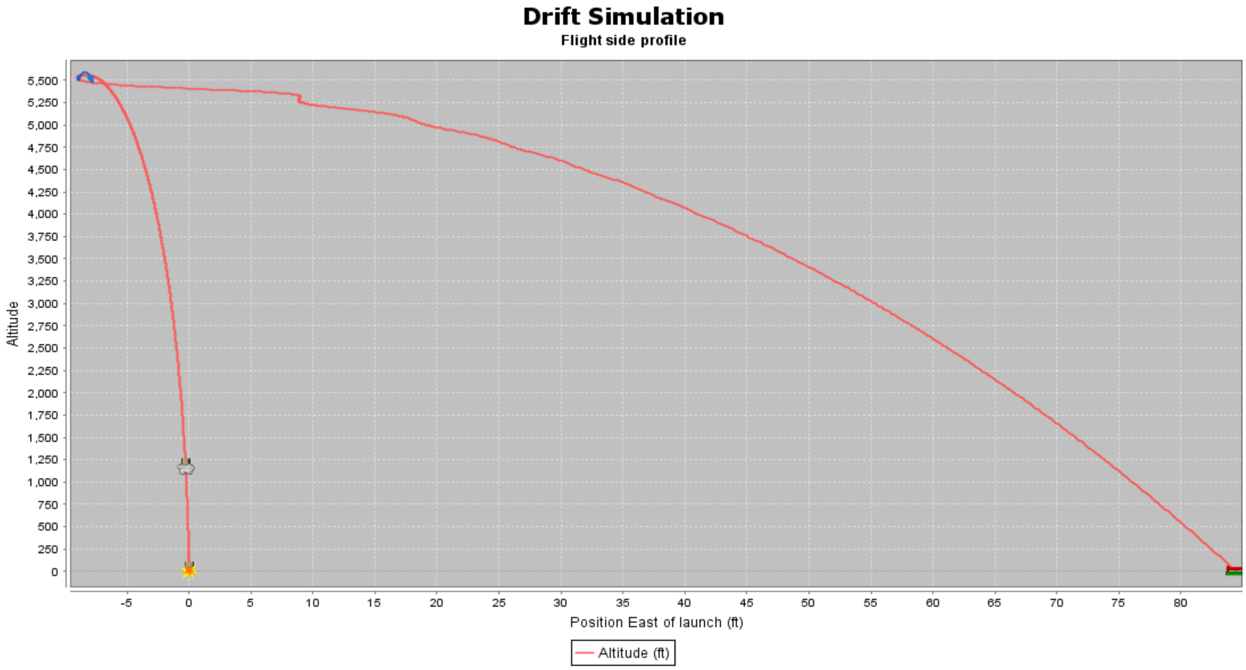


*Figure 7: Drift with no-wind*

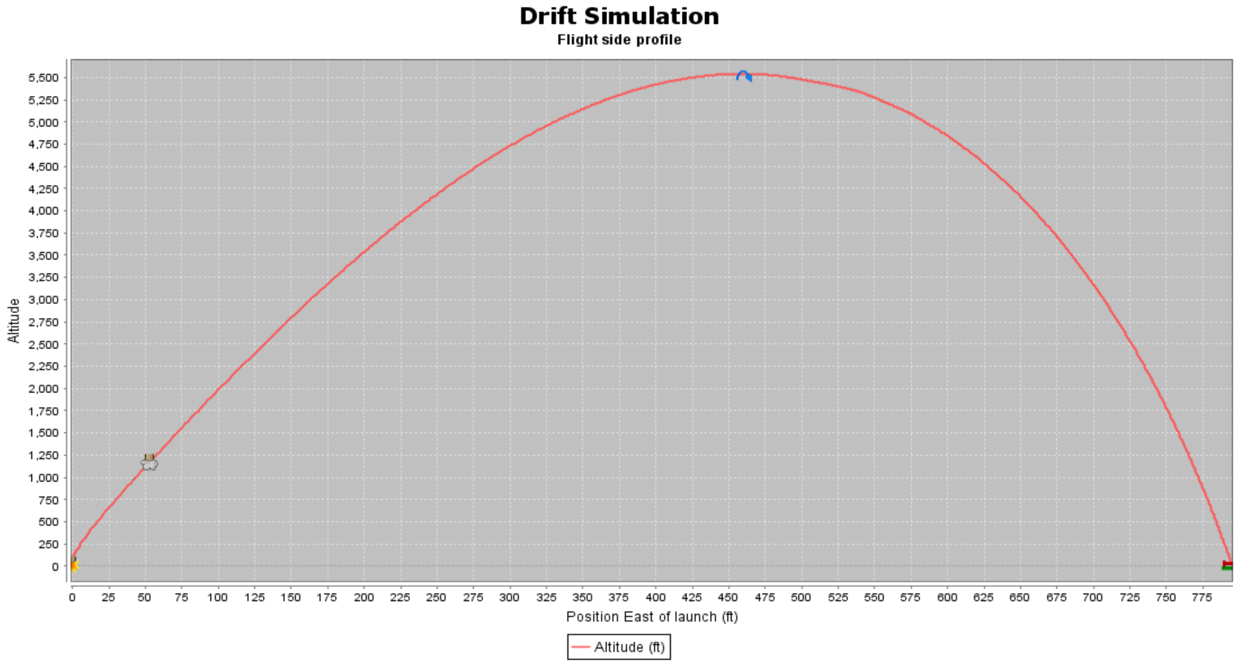


*Figure 8: Drift with 5-mph wind*

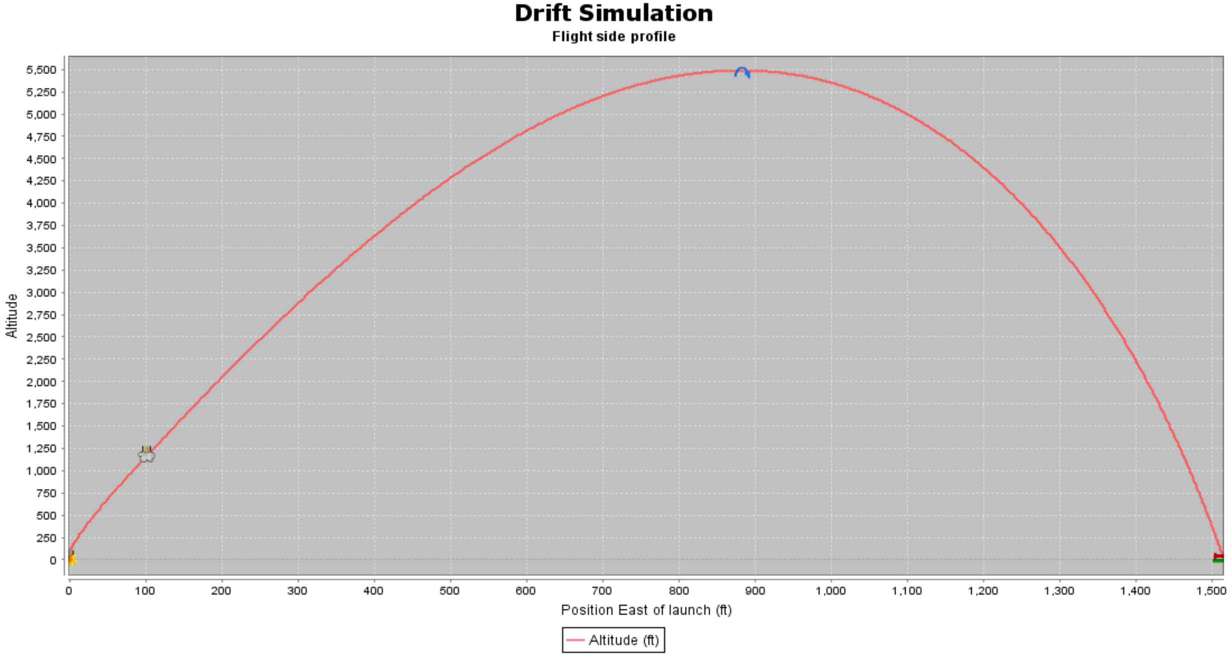


*Figure 9: Drift with 10-mph wind*

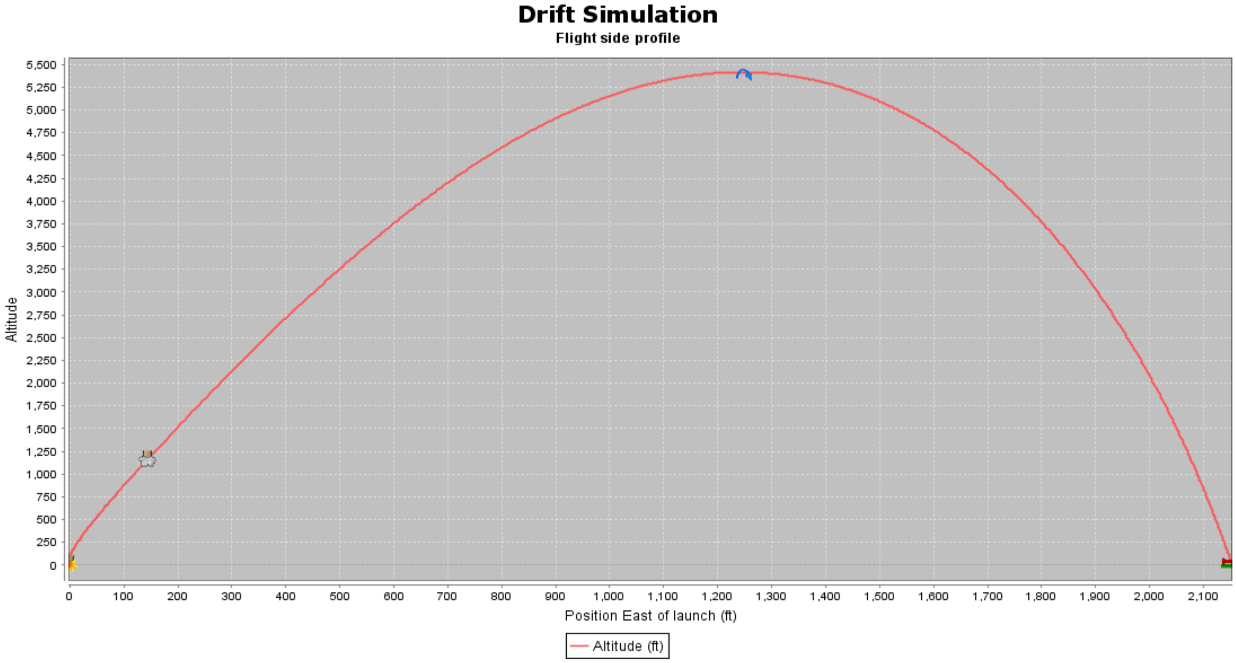


*Figure 80: Drift with 15-mph wind*

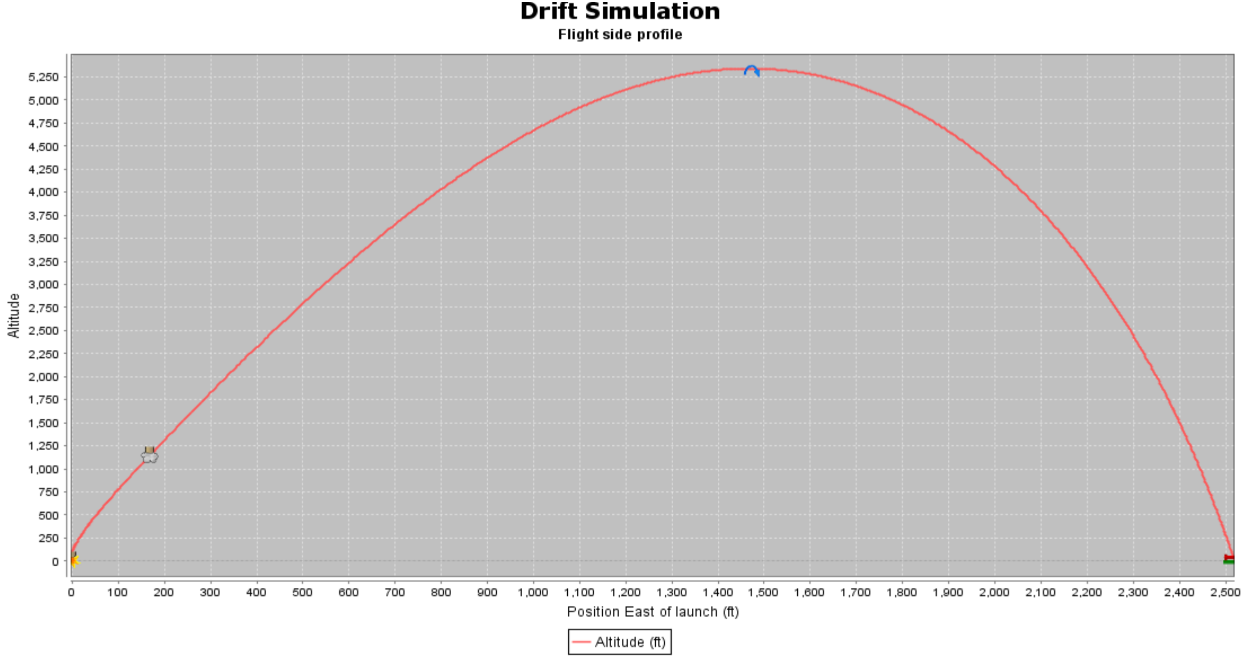


*Figure 11: Drift with 20-mph wind*

# 5 - Payload Criteria

## 5.1 – Selection of Payload: Deployable Rover

For this year’s NASA Student Launch Initiative three different experimental payloads were presented. They were as follows, Target Detection, Deployable Rover, and Landing Coordinates via Triangulation. The UND Frozen Fury Rocketry team selected the Deployable Rover as the experimental payload for this year’s competition.

**Mission**

The objective of the deployable rover is that upon landing the deployment process of the rover will be remotely activated. Linear actuators will be utilized to remove the nose cone exposing the rover payload bay. The rover payload bay will be on a locked bearing during flight. Once the deployment process is initiated after landing, the payload by will be orientated so that the rover is right side up. The whole payload bay will rotate inside the rocket body. Once the orientation of the rover is corrected, the rover will begin the process of exiting the launch vehicle. The rover will then drive five feet, stop, and initiate deployment of the solar arrays. These objectives are given in the 2017-2018 NASA SLI Handbook.

**Mission Success Criteria**

For success, the following criterium must be met:

- Rover Deployment: The rover must successfully deploy itself from the internal air frame of the launch vehicle. The rover can only begin the deployment process once the launch vehicle has landed and the NAR official gives permission for deployment to be initiated.
- Rover Navigation: The rover must successfully navigate itself, autonomously, five feet from the launch vehicle.
- Solar Array Deployment: The rover, once the rover is five feet from the launch vehicle, must successfully deploy an array of solar panels.

## 5.2 – Rationale of Payload Selection and Design

There are two main subsystems within the deployable rover payload. One the subsystems is the system that will deploy the rover from the internal airframe of the launch vehicle, and the second subsystem is the rover itself. This section is broken into two sub-sections, one for each subsystem. The following sections will give an in-depth summary of why certain design elements were selected.

### 5.2.1 Rover Deployment Subsystem Design

There were two main ideas that came forward when brainstorming on how to get the rover out of the internal airframe of the launch vehicle. One idea is to use black powder and e-matches to blow out the deployable rover payload section of the rocket upon landing. The second idea is to use linear actuators to remove the deployable rover section once the launch vehicle lands. As of completion of this report the idea the team has selected is using linear actuators to deploy the rover from the internal structure of the launch vehicle.

The reasoning behind choosing the linear actuators as the mode of operation to deploy the rover was that the ejection charges have a higher risk factor. Using the ejection charges there is a high risk of malfunction which ultimately risks the integrity of the rover before deployment. Using linear actuators would be more complex, as there is more electronic components and software development but would allow for a more precise opening. The linear actuator would also be easier to test throughout the design process as the payload bay would not be subjugated to explosions. The option of using ejection charges would be simpler in execution, but more challenging to contain the blasts and the risk of damaging the rover or the rover payload bay is higher. Using the linear actuators provides a safe, yet not so complex, solution to the deployment problem of the deployable rover experiment. Using linear actuators and a hinged system the rover could be deployed from two orientation scenarios; upside down or right side up. The rover payload bay design will allow for deployment in any orientation if designed and tested properly.

### 5.2.2 Rover Design

During the initial brainstorming phase three potential rover configurations arose.

- A rover with two tank-style treads, with the body contained within the height and length of the treads.
- A rover with two wheels. The body of the rover contained entirely within the diameter of the wheels
- A rover with multiple legs to scramble across the terrain. Based on the Berkeley openROACH project

| **Design** | **Navigation of Terrain (1-10)** | **Maneuverability (1-5)** | **Size (1-5)** | **Stability (1-5)** | **Sturdiness (1-5)** | **Level of Complexity (1-5)** | **Thought-provoking (1-5)** | **Total** |
|---|---|---|---|---|---|---|---|---|
| Tread | 7 | 4 | 3 | 5 | 5 | 8 | 2 | 34 |
| Wheels | 4 | 5 | 4 | 2 | 4 | 10 | 3 | 32 |
| openROACH | 9 | 3 | 5 | 3 | 1 | 1 | 5 | 27 |

*Table 9: Decision Matrix for Rover Type*

Table 7 provides a decision matrix that was used when selecting the rover style for the experimental payload. The three designs were graded on a weighted scale of importance of certain specifications that were derived by the team. Based on the grading it is shown that the rover utilizing treads instead of wheels was the best option to pursue.

### 5.2.3 Deployable Solar Array Design

For the deployable solar array panels that will deploy from the rover three potential designs were considered.

- Three stacked solar panels opening in a trifold formation.
- Two stacked panels where the panels would open, the same way a book opens up when set on a coffee table.
- Two stacked panels where the upper panel would slide off to reveal the lower panel.

| Design Type | High Output (1-5) | Complexity (1-5) | Cost Effectiveness (1-5) | Total |
|---|---|---|---|---|
| 3-panel flip | 5 | 3 | 2 | 10 |
| 2-panel flip | 3 | 5 | 5 | 13 |
| 2-panel slide | 5 | 2 | 1 | 8 |

*Table 10: Decision Matrix for Deployable Solar Arrays*

Table 7 provides the decision matrix that was used when selecting the design option for the deployable solar panels. Based on the decision matrix, and team discussion it was decided a 2-panel flip option would be the most feasible and practical design option for the task given.

## 5.3 – Summary of Payload Design

This section will summarize all the parts of the deployable rover design. There are three noticeable subsystems within the deployable rover payload. The deployment subsystem, the rover subsystem, and the solar deployment subsystem. This section will include renders of the design that will be implemented for the experimental payloads.

### 5.3.1 - Rover Design Summary

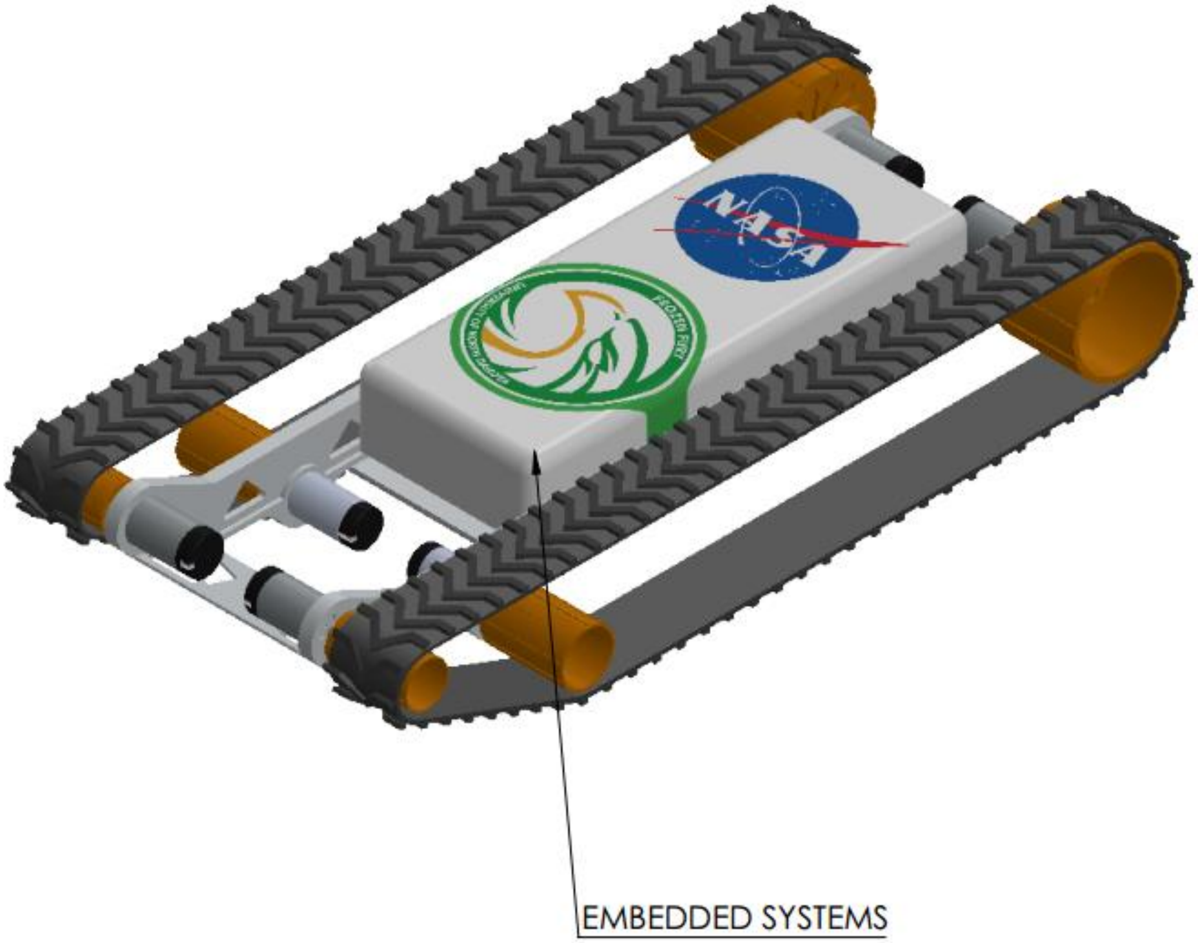


*Figure 9: 3D Render of Rover*

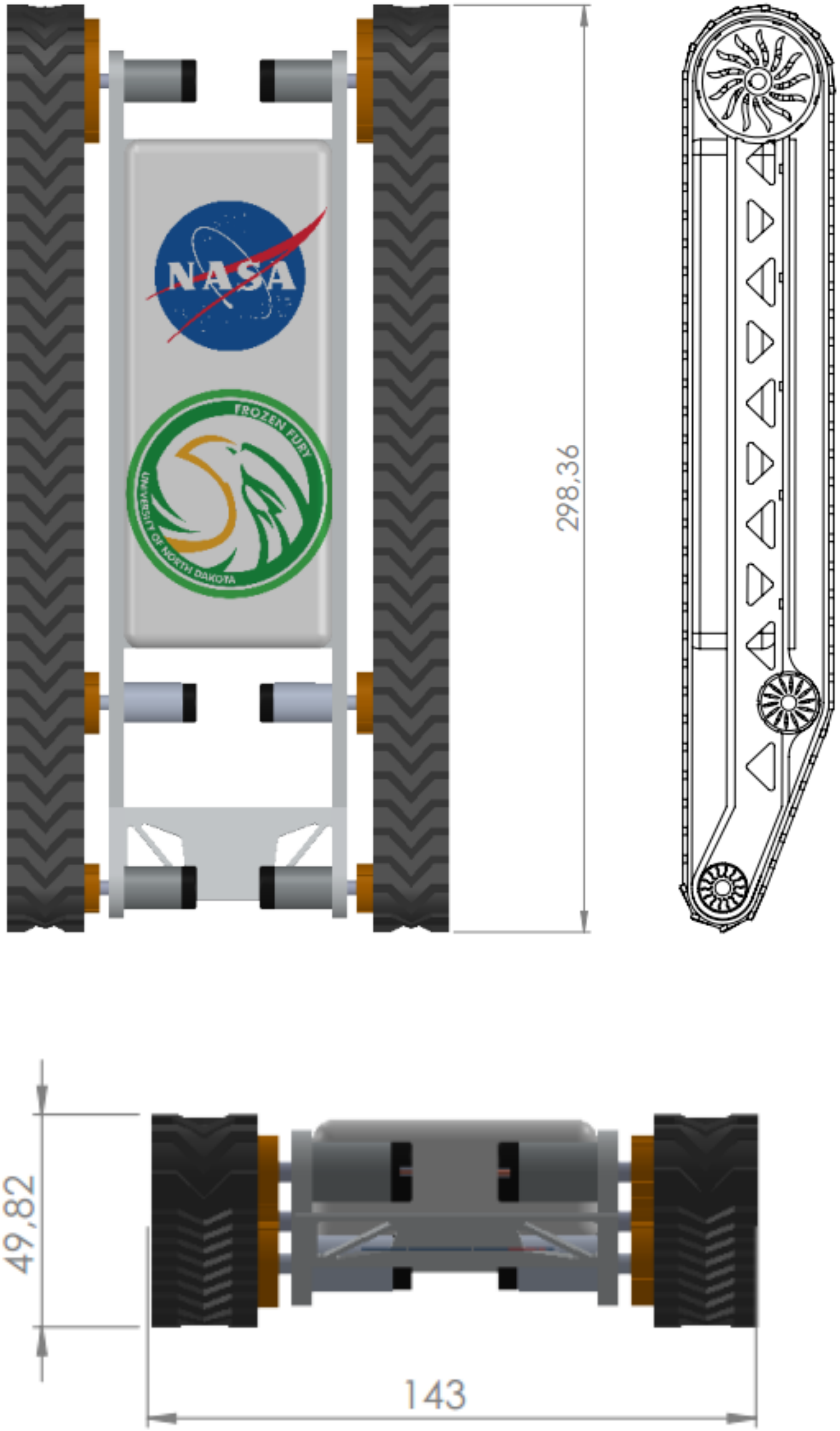


*Figure 10: Top and Front Profile of Rover (Dimensions in mm)*

The table below provides the dimensions of the rover in Imperial Units.

| | |
|---|---|
| Height (in) | 1.91 |
| Length (in) | 11.73 |
| Width (in) | 5.75 |

*Table 11: Rover Dimensions in Imperial Units*

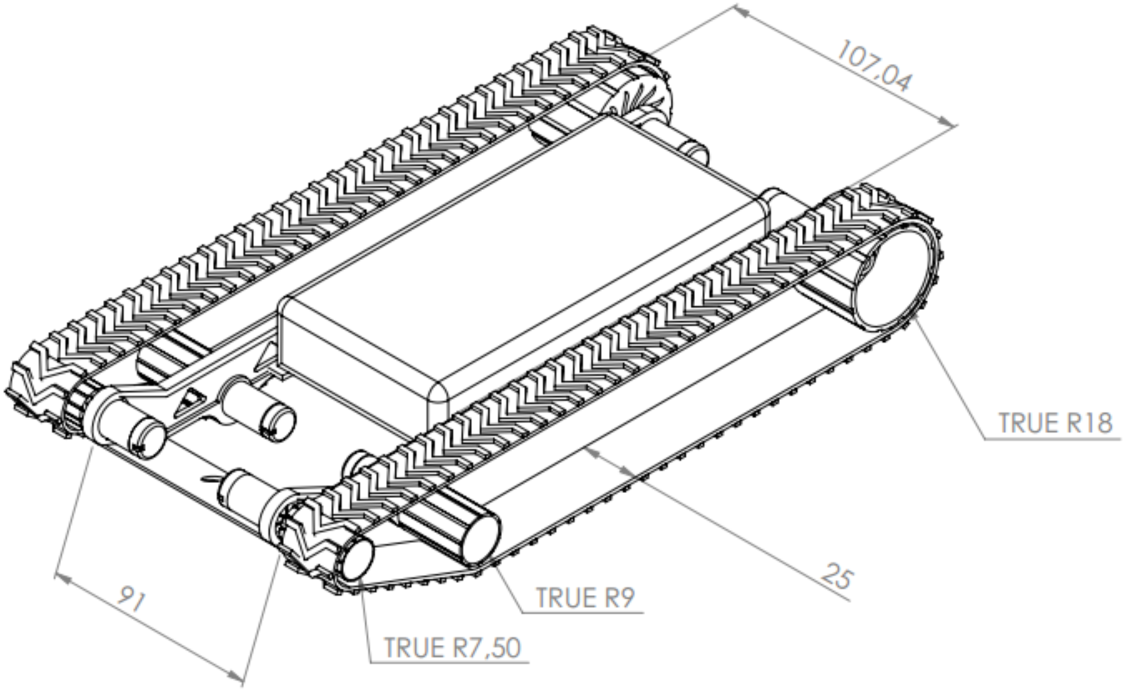
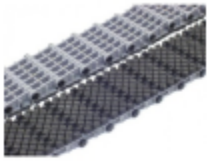


*Figure 11: Figure describing rover body width and tread width*

In Figure 11 the rover body is about 4.2-in wide, that is from inside tread to outside tread. The width of the treads is going to be approximately .98-in. This design will allow for ample room within the rover body to house the rovers electronics bay and solar panel deployment system. This design is also compact and will allow the rover to fit within the airframe of the rocket.


OPTION 1


OPTION 2


OPTION 3

*Figure 14a: Tread option 1* *Figure 13b: Tread option 2* *Figure 12a: Tread option 3*

The figures 12a – 12c are proposed tread designs for the rover. The decision has yet to be made on what tread will be implemented on the final rover design. This will be done through testing at the rover testing facility that was constructed for this rover. A fourth option would be to build and test treads in house utilizing current 3D printing technology. This option has not been explored yet, it is not known how difficult it will be to create treads in house with the technology that is available to the team.

## 5.3.2 – Rover Payload Bay Design Summary

The following figures will show how the rover will be housed inside the airframe of the rocket. The rover will be housed within a set of three rings. The back ring, will have a circular plate, attached to this circular plate there will be rod which is connected to a servo motor. This servo motor will be controlled by a microcontroller. The idea is to have a gyroscope attached to the rover payload bay that will feed back orientation data to the microcontroller upon landing. Once the deployment process is activated, the microcontroller will turn the servo until the rover is orientated properly. Once the rover is orientated correctly the microcontroller will then activate the linear actuators which will push to nose cone away from the body of the launch vehicle and allow the rover to escape from the internal structure of the rocket.

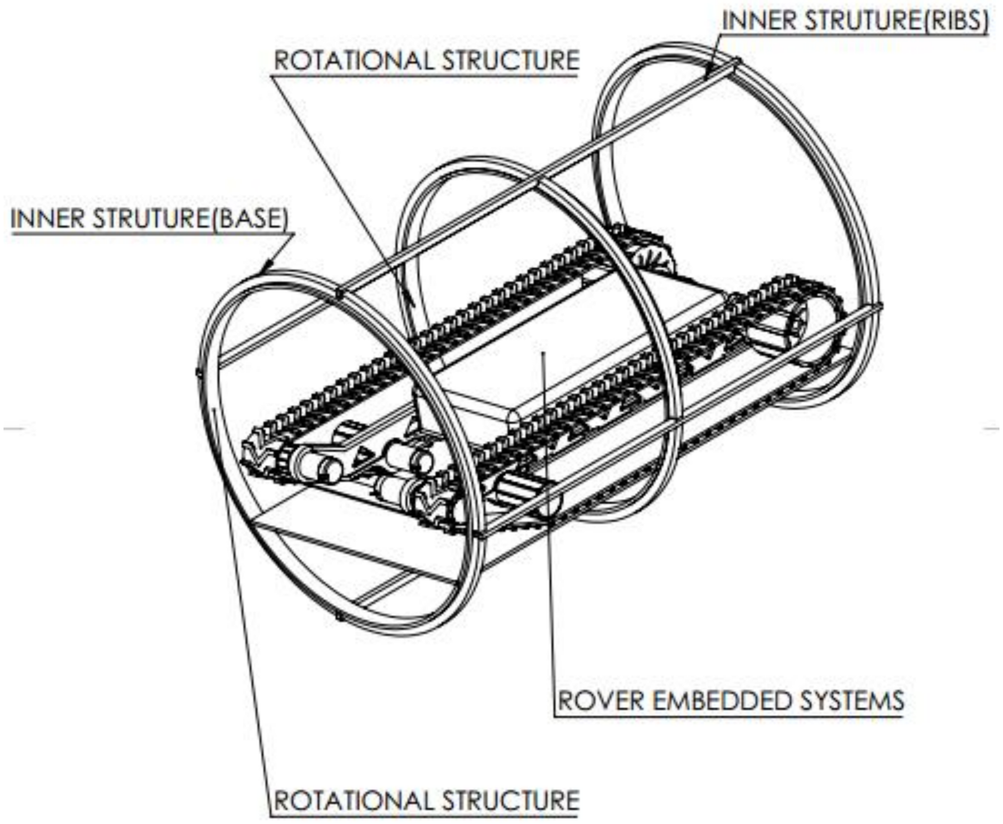


*Figure 15: Rover Payload Bay Design*

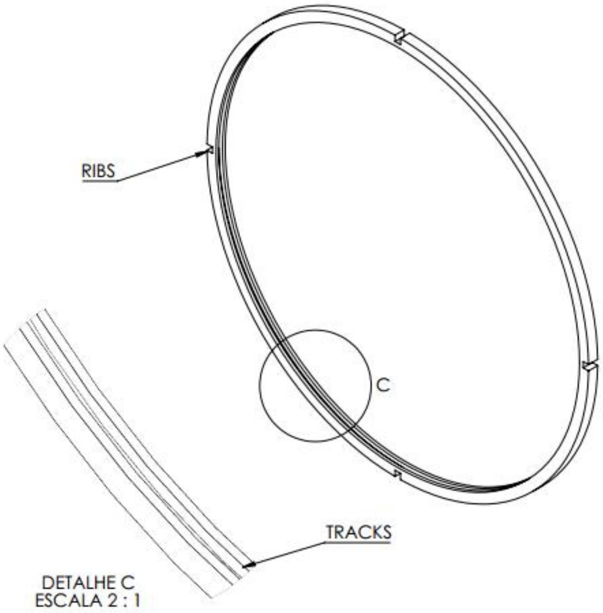


*Figure 16: Rotational Ring Design*

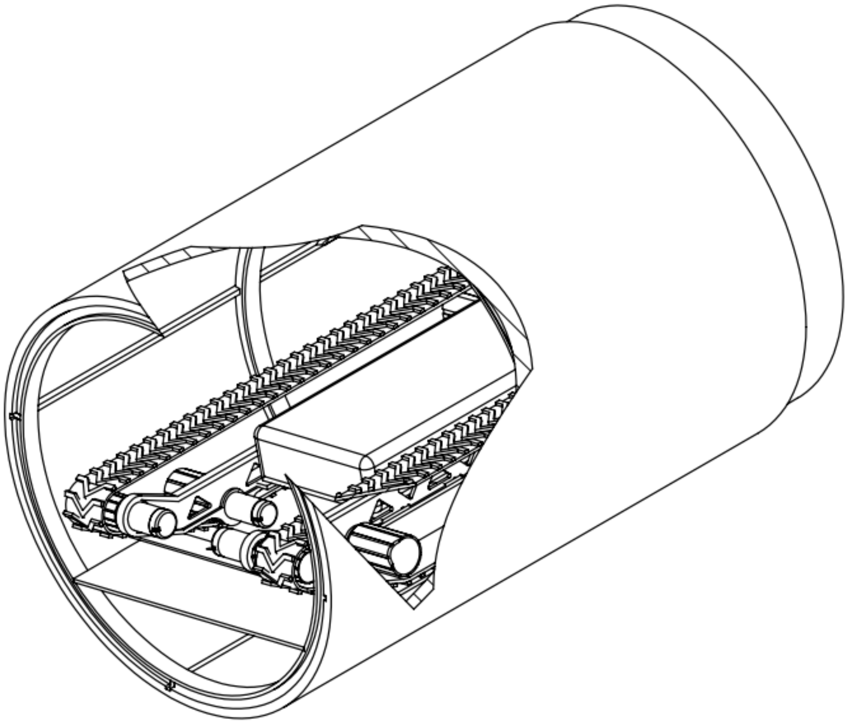


*Figure 17: Rover Payload inside airframe*

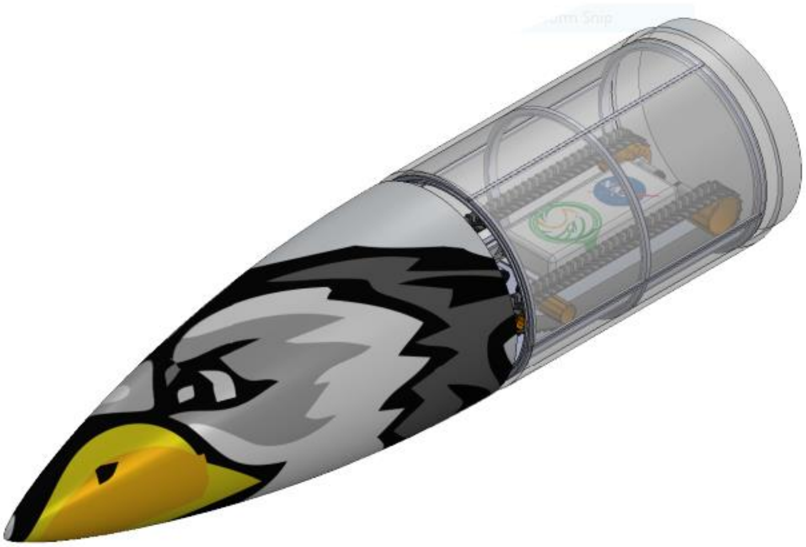


*Figure 18: Rover payload is situated near the nose cone*

# 6 - Project Plan

## 6.1 – Timeline

The following is a projected schedule for the year. We normally have team meetings every Tuesday and Thursday with construction expected on weekends. As we get further into the project, we will add more detailed timeline for the completion of rocket and payload construction, and educational outreach.

| Date | Event |
|---|---|
| Oct. 06, 2017 | Awarded proposals announced |
| Oct. 12, 2017 | Kickoff and Preliminary Design Report (PDR) Q&A |
| Oct. 16, 2017 | Preliminary team website meeting |
| Oct. 23, 2017 | PDR draft meeting |
| Oct. 30, 2017 | Team website Final Review |
| Oct. 30, 2017 | PDR Final Review |
| Nov. 03, 2017 | Team web presence established |
| Nov. 03, 2017 | PDR report, presentation slides, and flysheet posted on the team website by 8:00 a.m. CST |
| Nov. 06 - Nov. 29, 2017 | PDR video teleconferences |
| Dec. 06, 2017 | Critical Design Review (CDR) Q&A |
| Dec. 11 2017 | CDR |
| Dec. 15, 2017 | CDR |
| Dec. 16, 2017 - Jan. 09, 2018 | Winter Break |

| | |
|---|---|
| Jan. 12, 2018 | CDR report, presentation slides, and flysheet posted on the team website by 8:00 a.m. CST |
| Jan 16 – Jan 31, 2018 | CDR video teleconferences |
| Feb. 07, 2018 | Flight Readiness Review (FRR) Q&A |
| Feb. 12, 2018 | FRR draft meeting |
| Mar. 05, 2018 | FRR reports, presentation slides, and flysheet posted to team Website by 8:00 a.m. CDT |
| Mar. 06 - Mar. 22, 2018 | FRR video teleconferences |
| Apr. 04, 2018 | Teams travel to Huntsville, AL and Launch Readiness Review (LRR) |
| Apr. 05 2018 | LRR's and safety briefing |
| Apr. 06, 2018 | Rocket Fair and Tours of MSFC |
| Apr. 07, 2018 | Launch Day |
| Apr. 08, 2018 | Backup launch day |
| Apr. 27, 2018 | PLAR posted on the team Website by 8:00 a.m. CDT. |

*Table 12: Project Timeline*

## 6.2 – Budget

The following is a preliminary budget for the year. Several items such as the parachute can likely be re-used from previous rockets, so the total cost may be less than projected. Some parts may be printed in the 3D printers available on campus to save money.

| **2016-17 UND Rocket Team "Frozen Fury" Budget** | | | |
|---|---|---|---|
| | | | |
| Scale Launch | | | |
| Materials | Quantity | Unit Cost ($) | Total Cost |
| Rocket Kit | 1 | 80 | 80 |
| Scale Rocket Motors | 2 | 35 | 70 |
| Total for Scale Launch | | | $ 150.00 |
| | | | |
| Full Scale Launch | | | |
| Materials | Quantity | Unit Cost ($) | Total Cost |
| Retrieval | | | |
| Parachute (96") | 1 | 90 | 90 |
| Drogue Parachute (36") | 1 | 21 | 21 |
| Shock Cord | 6 | 1.1 | 6.6 |
| Sub Total | | | $ 117.60 |
| Engine | | | |
| K780R | 4 | 136 | 544 |
| Casing | 1 | 450 | 450 |
| Motor Mount Tube | 1 | 15 | 15 |
| Sub Total | | | $ 1,009.00 |
| Body | | | |
| 6" G12 Fiberglass Filament Wound Tube 48" long | 2 | 207 | 414 |
| 6" Diameter Phenolic Coupler Tube | 4 | 15 | 60 |
| Sub Total | | | $ 474.00 |
| Nose Cone | | | |
| 6" Fiberglass Conical 5:1 Nose Cone | 1 | 116 | 116 |
| Sub Total | | | $ 116.00 |
| Electronics | | | |
| Arduino MEGA 2560 REV3 Circuit Board | 2 | 50 | 100 |
| Gyro and Accelerometer Module | 3 | 5 | 15 |
| 25' 20 Gauge Red/Black Wire | 1 | 6.5 | 6.5 |
| Logitech Webcam | 1 | 40 | 40 |
| D/C Motor | 1 | 28 | 28 |

| | | | |
|---|---|---|---|
| Li-Po Battery 5000mAh | 2 | 54.67 | 109.34 |
| Battery Charger | 1 | 37 | 37 |
| StratoLogger CF Altimeter | 3 | 55 | 165 |
| Sub Total | | | $ 500.84 |
| Fabrication | | | |
| Nuts & Washers | 20 | .50 | 10 |
| 1/4" by 6' Plywood | 1 | 15 | 15 |
| 1/8" by 6' Plywood | 1 | 15 | 15 |
| Xacto Knife | 1 | 2 | 2 |
| Paint and Gloss | 1 | 30 | 30 |
| Sub Total | | | $ 72.00 |
| Total for Full Scale Launch | | | $ 2,289.44 |
| | | | |
| Travel | | | |
| Items | Quantity | Unit Cost ($) | Total Cost |
| ND State Van | 1 | 700 | 700 |
| 4/5/18 Hotel Room | 11 | 85 | 935 |
| 4/6/18 Hotel Room | 11 | 85 | 935 |
| 4/7/18 Hotel Room | 11 | 85 | 935 |
| 4/8/18 Hotel Room | 11 | 85 | 935 |
| 4/9/18 Hotel Room | 11 | 85 | 935 |
| Total for Travel | | | $ 5,375.00 |
| | | | |
| **Grand Total** | | | **$ 7,814.44** |

*Table 13: Budget*

## 6.3 – Requirements Verification

The requirements verifications are derived from the NASA SLI requirements that are given within the NASA SLI 2017-2018 Handbook. There are four major sections that have requirements that need to be met in order to be competitive in this year's competition

### 6.3.1 – General Requirements

| Requirement Number | Requirement | Method of Verification |
|---|---|---|
| 1.1 | Students on the team will do 100% of the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder or any variant of ejection charges, or preparing and installing electric matches (to be done by the team's mentor). | Senior members of the team will be given different leadership tasks to guide newer members and promote a learning environment for all aspects of the project. |
| 1.2 | The team will provide and maintain a project plan to include, but not limited to the following items: project milestones, budget and community support, checklists, personnel assigned, educational engagement events, and risks and mitigations. | Calendar, checklists, and outreach goals will be accessible to team members via the team website and cloud-based archives such as Google drive, Dropbox, and GroupMe. |
| 1.3 | Foreign National (FN) team members must be identified by the Preliminary Design Review (PDR) and may or may not have access to certain activities during launch week due to security restrictions. In addition, FN's may be separated from their team during these activities. | Upon initial meetings login sheets were supplied to new team members inquiring about FN status. All FN team members must be identified by the team lead and were included in Section I. |
| 1.4 | The team must identify all team members attending launch week activities by the Critical Design Review (CDR). Team members will include: 1.4.1, 1.4.2, and 1.4.3. | Written verification will be handed out and completed after completion of sub-scale launch to account for those members attending the trip to Huntsville. |
| 1.4.1 | Students actively engaged in the project throughout the entire year | Weekly and special meetings are posted on the team calendar and members are subscribed to team chat applications. |
| 1.4.2 | One mentor (see requirement 1.14). | see Section I |
| 1.4.3 | No more than two adult educators. | see Section I |

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| 1.5 | The team will engage a minimum of 200 participants in educational, hands-on science, technology, engineering, and mathematics (STEM) activities, as defined in the Educational Engagement Activity Report, by FRR. An educational engagement activity report will be completed and submitted within two weeks after completion of an event. A sample of the educational engagement activity report can be found on page 31 of the handbook. To satisfy this requirement, all events must occur between project acceptance and the FRR due date. | Outreach events and checklists will be posted on the website once the initial event is planned. |
| 1.6 | The team will develop and host a Web site for project documentation. | see sites.und.edu/rocketteam |
| 1.7 | Teams will post, and make available for download, the required deliverables to the team Web site by the due dates specified in the project timeline. | Senior members have access to all online extensions of the team and will supply all required materials promptly. |
| 1.8 | All deliverables must be in PDF format. | All documents will be created within applications that support PDF export. |
| 1.9 | In every report, teams will provide a table of contents including major sections and their respective sub-sections. | Table of contents will promptly be updated after the completion of all documents. |
| 1.10 | In every report, the team will include the page number at the bottom of the page. | Application functions will perform automated numbering for all pages. |
| 1.11 | The team will provide any computer equipment necessary to perform a video teleconference with the review panel. This includes, but is not limited to, a computer system, video camera, speaker telephone, and a broadband Internet connection. Cellular phones can be used for speakerphone capability only as a last resort. | The team has access to the department of Physics and Astrophysics' conference room. All required equipment is supplied. |
| 1.12 | All teams will be required to use the launch pads provided by Student Launch's launch service provider. No custom pads will be permitted on the launch field. Launch services will have 8 ft. 1010 rails, and 8 and 12 ft. 1515 rails available for use. | The fullscale design will be fabricated and tested on a 1515 rail before the competition to abide by required regulations. |
| 1.13 | Teams must implement the Architectural and Transportation Barriers Compliance Board Electronic and Information Technology (EIT) Accessibility Standards (36 CFR Part 1194) | Web design will follow guidelines set out in 1194.22 |

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| | Subpart B-Technical Standards (http://www.section508.gov): 1194.21 Software application and operating systems and 1194.22 Web-based intranet and Internet information and applications. | |
| 1.14 | Each team must identify a "mentor." A mentor is defined as an adult who is included as a team member, who will be supporting the team (or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization. The mentor must maintain a current certification, and be in good standing, through the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle and must have flown and successfully recovered (using electronic, staged recovery) a minimum of 2 flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to launch week. One travel stipend will be provided per mentor regardless of the number of teams he or she supports. The stipend will only be provided if the team passes FRR and the team and mentor attends launch week in April. | see Section I |

## 6.2.2 – Vehicle Requirements

| Requirement Number | Requirement | Method of Verification |
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| 2.1 | The vehicle will deliver the payload to an apogee altitude of 5,280 feet above ground level (AGL). | Computer simulations through OpenRocket will model needed parameters of the construction to reach the appropriate altitude. During physical launches the launch vehicle's altimeter will log ascension to verify after recovery. |
| 2.2 | The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the altitude award winner. Teams will receive the | All full sub scale launches will be equipped with a legal barometric altimeter to log altitude data. |

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| | maximum number of altitude points (5,280) if the official scoring altimeter reads a value of exactly 5280 feet AGL. The team will lose one point for every foot above or below the required altitude. | |
| 2.3 | Each altimeter will be armed by a dedicated arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad. | The subscale model has been wired with a toggle switch. The full-scale launch vehicle will be wired with a key switch to arm altimeter. |
| 2.4 | Each altimeter will have a dedicated power supply. | A fully charged 9-volt battery will supply the altimeter with power and a cache of backup batteries will be on hand for all launches. |
| 2.5 | Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces). | A key switch will be used for arming all electronics within the launch vehicle. |
| 2.6 | The launch vehicle will be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications. | All sections of the launch vehicle will be able to be reassembled immediately after recover with exception of shear pins. |
| 2.7 | The launch vehicle will have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute. | Design of launch vehicle will be carried out in OpenRocket. Fabrication will strictly follow these designs, this includes limiting the number of maximum sections to 4. |
| 2.8 | The launch vehicle will be limited to a single stage. | The design of the launch vehicle will be limited to a single motor decided during design and simulations. |
| 2.9 | The launch vehicle will be capable of being prepared for flight at the launch site within 3 hours of the time the Federal Aviation Administration flight waiver opens. | Design of both launch vehicle and payload will take into consideration assembly time restriction. |
| 2.10 | The launch vehicle will be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board components. | All electronics will be powered by independent power supplies and designed to be able to last a time period longer than the given hour. |
| 2.11 | The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system. The firing system will be | All field tests will be carried out by a 12-volt battery system to verify compatibility of NASA provided systems. |

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| | provided by the NASA-designated Range Services Provider. | |
| 2.12 | The launch vehicle will require no external circuitry or special ground support equipment to initiate launch (other than what is provided by Range Services). | All electronics are internally driven and power supplied within the launch vehicle. |
| 2.13 | The launch vehicle will use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR). | The full-scale launch vehicle will use an AeroTech L1150-P motor. See Section II. Motors will be acquired by team mentors. |
| 2.13.1 | Final motor choices must be made by the Critical Design Review (CDR). | Evaluation of the initial chosen motor will be carried out after full scale launch. This launch and evaluation will be finalized before and included in the CDR. |
| 2.13.2 | Any motor changes after CDR must be approved by the NASA Range Safety Officer (RSO), and will only be approved if the change is for the sole purpose of increasing the safety margin. | A priority on full scale fabrication and launch will be emphasized to evaluate motor options before the due date of the CDR given weather conditions. |
| 2.14 | Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria: 2.14.1, 2.14.2, 2.14.13 | As of current design no pressure vessels are to be implemented. If design is to change over the course of fabrication the guidelines given by the following subsections will be evaluated and followed carefully. |
| 2.14.1 | The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews. | N/A |
| 2.14.2 | Each pressure vessel will include a pressure relief valve that sees the full pressure of the valve that is capable of withstanding the maximum pressure and flow rate of the tank. | N/A |
| 2.14.3 | Full pedigree of the tank will be described, including the application for which the tank was designed, and the history of the tank, | N/A |

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| | including the number of pressure cycles put on the tank, by whom, and when. | |
| 2.15 | The total impulse provided by a College and/or University launch vehicle will not exceed 5,120 Newton-seconds (L-class). | The current modeled motor has reached motor class limits. If motor fails to supply appropriate impulse for desired altitude then redesign will be carried out to other parameters of the launch vehicle. L-class will not be exceeded. |
| 2.16 | The launch 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. | Stability margins will be modeled with OpenRocket. Static margin will be achieved before fabrication proceeds. |
| 2.17 | The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit. | Velocity data will be collected from altimeter logs after field tests to verify that the launch vehicle performs between minimum and maximum velocities. |
| 2.18 | All teams will successfully launch and recover a subscale model of their rocket prior to CDR. Subscales are not required to be high power rockets. | A subscale model build has been completed. Launch will commence November 4, 2017. A successful launch should be completed before the PDR teleconference. |
| 2.18.1 | The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale will not be used as the subscale model. | The subscale model is a 1:2 ratio to the launch vehicle. After a successful subscale launch fabrication will begin on a separate full-scale launch vehicle. |
| 2.18.2 | The subscale model will carry an altimeter capable of reporting the model's apogee altitude. | Completed |
| 2.19 | All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown at FRR must be the same rocket to be flown on launch day. The purpose of the full-scale demonstration flight is to demonstrate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for | Fabrication of a full-scale launch vehicle will begin prior to the winter break. Weather permitted, a full-scale launch will be attempted before CDR and several before FRR. |

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| | flight. A successful flight is defined as a launch in which all hardware is functioning properly (i.e. drogue chute at apogee, main chute at a lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full-scale demonstration flight: 2.19.1-2.19.7. | |
| 2.19.1 | The vehicle and recovery system will have functioned as designed. | |
| 2.19.2 | The payload does not have to be flown during the full-scale test flight. The following requirements still apply. | Initial launches will be carried out on only the launch vehicle. Following launches will include actual payload. |
| 2.19.2.1 | If the payload is not flown, mass simulators will be used to simulate the payload mass. | Mass simulations will be constructed or printed for initial launch. |
| 2.19.2.1.1 | The mass simulators will be located in the same approximate location on the rocket as the missing payload mass. | Mass-model will be placed in the bay designed for the actual payload. |
| 2.19.3 | If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale demonstration flight. | Payload internal N/A. Camera system will be completed and installed before initial launch. |
| 2.19.4 | The full-scale motor does not have to be flown during the full-scale test flight. However, it is recommended that the full-scale motor be used to demonstrate full flight readiness and altitude verification. If the full-scale motor is not flown during the full-scale flight, it is desired that the motor simulates, as closely as possible, the predicted maximum velocity and maximum acceleration of the launch day flight. | All motors will be ordered and acquired by team mentors. Team lead will give the team mentor appropriate time to order and supply team with motors that are identical or closely simulate the appropriate L-class motor. |
| 2.19.5 | The vehicle must be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during the launch day flight. Additional ballast may not be added without a re-flight of the full-scale launch vehicle. | No addition to vehicle construction will be carried out after the final field launch. |
| 2.19.6 | After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified | No addition to vehicle construction will be carried out after the final field launch. |

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| | without the concurrence of the NASA Range Safety Officer (RSO). | |
| 2.19.7 | Full scale flights must be completed by the start of FRRs (March 6th, 2018). If the Student Launch office determines that a re-flight is necessary, then an extension to March 28th, 2018 will be granted. This extension is only valid for re-flights; not first-time flights. | Planned launches will be organized on the team calendar and amongst team member during the start of the spring semester. These guidelines will be followed to ensure successful launches before required due dates. |
| 2.20 | Any structural protuberance on the rocket will be located aft of the burnout center of gravity. | Structural and aerodynamic analysis to be carried out by graduate students and incorporated into design and construction. |
| **2.21** | **Vehicle Prohibitions** | |
| 2.21.1 | The launch vehicle will not utilize forward canards. | Payload internal. |
| 2.21.2 | The launch vehicle will not utilize forward firing motors. | Single motor in aft of vehicle. |
| 2.21.3 | The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.) | see Section II |
| 2.21.4 | The launch vehicle will not utilize hybrid motors. | see Section II |
| 2.21.5 | The launch vehicle will not utilize a cluster of motors. | Single motor in aft of vehicle. |
| 2.21.6 | The launch vehicle will not utilize friction fitting for motors. | Motor is secured with motor retainer. |
| 2.21.7 | The launch vehicle will not exceed Mach 1 at any point during flight. | Velocity data will be collected from altimeter logs after field tests to verify that the launch vehicle performs between minimum and maximum velocities. |
| 2.21.8 | Vehicle ballast will not exceed 10% of the total weight of the rocket. | Additional ballasting will be evaluated after field test launches. |

## 6.2.3– Recovery System Requirements

| Requirement Number | Requirement | Method of Verification |
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| 3.1 | The launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main | Simulations will assess the velocity and kinetic energy of the descending vehicle. Initial |

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| | parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue-stage descent is reasonable, as deemed by the RSO. | simulations will model drogue and main sizes. After field data is recovered from the altimeter log evaluation of impact energy can be used to reassess size choice. |
| 3.2 | Each team must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full-scale launches. | All charge tests are carried out after fabrication is completed and again prior to launch. |
| 3.3 | At landing, each independent sections of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf. | Kinetic energy will be calculated from data gathered from the altimeter. |
| 3.4 | The recovery system electrical circuits will be completely independent of any payload electrical circuits. | All power supplies and circuits operate independently of one another. |
| 3.5 | All recovery electronics will be powered by commercially available batteries. | 9-volt batteries are used to supply energy to circuits. Backup batteries will be kept on hand at every launch. |
| 3.6 | The recovery system will contain redundant, commercially available altimeters. The term “altimeters” includes both simple altimeters and more sophisticated flight computers. | Redundancy will be built into the system to ensure parachute deployment occurs even after error in initial deployment at proper altitudes. |
| 3.7 | Motor ejection is not a permissible form of primary or secondary deployment. | Motor casing is held in place by motor retainer. No multistage motors are used. |
| 3.8 | Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment. | Shear pins will be abundantly on hand at all launch sites and used for recovery compartments. |
| 3.9 | Recovery area will be limited to a 2500 ft. radius from the launch pads. | Design will focus on well balanced and ballasted launch vehicle to ensure a lunch normal to the surface. |
| 3.10 | An electronic tracking device will be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver. | Radio tracking beacons will be installed within one of the compartments. |
| 3.10.1 | Any rocket section, or payload component, which lands untethered to the launch vehicle, will also carry an active electronic tracking device. | Current design emphasizes the tethering of all compartments. |

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| 3.10.2 | The electronic tracking device will be fully functional during the official flight on launch day. | Beacons will be tested regularly before all launches, including official launch day. |
| 3.11 | The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing). | All other transmitters and receivers used for the payload will be tested and designed to work at frequencies that does not interfere with beacons. |
| 3.11.1 | The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device. | Altimeter bay is separate and isolated. |
| 3.11.2 | The recovery system electronics will be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system electronics. | The altimeter bay will be shield with adhesive copper tape. |
| 3.11.3 | The recovery system electronics will be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system. | Altimeter bay is separate and isolated. The altimeter bay will be shield with adhesive copper tape. |
| 3.11.4 | The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics. | Altimeter bay is separate and isolated. The altimeter bay will be shield with adhesive copper tape. |

## 6.2.4 – Experiment Requirements

| Requirement Number | Requirement | Method of Verification |
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| 4.1 | Each team will choose one design experiment option from the following list. | The team has chosen the deployable rover project. |
| 4.2 | Additional experiments (limit of 1) are allowed, and may be flown, but they will not contribute to scoring. | Only one experiment will be chosen this year. |
| 4.3 | If the team chooses to fly additional experiments, they will provide the appropriate documentation in all design reports, so experiments may be reviewed for flight safety. | Only one experiment will be flown this year. |
| 4.5.1 | Teams will design a custom rover that will deploy from the internal structure of the launch vehicle. | See Payload Criteria. |

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| 4.5.2 | At landing, the team will remotely activate a trigger to deploy the rover from the rocket. | Receiver circuitry will be housed in the payload bay and powered by an independent power supply. |
| 4.5.3 | After deployment, the rover will autonomously move at least 5 ft. (in any direction) from the launch vehicle. | See Payload Criteria. |
| 4.5.4 | Once the rover has reached its final destination, it will deploy a set of foldable solar cell panels. | See Payload Criteria. |

## 7 - Conclusion & Recommendations:

The 2017-2018 Frozen Fury team's enthusiasm and participation for the NASA Student Launch Competition has started off incredibly well. There are already concept ideas for the rover, and its deployment system. The scale rocket is already complete, and the team will be ready to have their scale launch on November 4th weather permitting. There are members from last year's team who are encouraging the new members. The team members are working very well together, and enthusiasm is high.

Recommendations moving forward are for the team to start selecting rover components such as microcontroller, motors and solar panels. Also, the team needs to consider linear actuators for the deployment system. Along with rocket and payload development the team needs to begin their educational outreach.