

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



*NASA Student Launch Initiative  
Critical Design Report*

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

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**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 Critical Design Review Report (CDR)

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### 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](mailto: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.)	107
Diameter (in.)	6
Center of Gravity (in.)	64
Center of Pressure (in.)	77
Mass w/ motor(lbs.)	32.94 lbs.
Mass w/out motor (lbs.)	24.44 lbs.
Motor Type	AeroTech L1150-P
Recovery System	Single Deployment
Launch Rail Length (ft.)	12

*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 create more space inside the launch vehicle which will allow for an additional 10% ballast to be integrated if needed. 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 Preliminary Design Review

### 2.1 – Vehicle Design Changes

Change	Reasoning
Length of rocket was increased from 108 inches to 107 inches	This was done to increase stability of the launch vehicle. Also lower the kinetic energy of the sub components upon impact.
A ballast of 20 ounces was added	This was done to increase stability of the launch vehicle
Stability off the launch rail was increased to 2.4	This was done in order to comply with the NASA Requirements outlined in the Student Launch Handbook
The overall weight of the launch vehicle was reduced	This was done in order to lower the kinetic energy of the sub components upon impact on landing

Table 2: Launch Vehicle Design Changes

### 2.2 – Recovery Design Changes

The main parachute will deploy at 1500 feet, instead of 1000 feet as previously proposed. This was done to help lower the kinetic energy of the sub components upon landing.

### 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 a large workshop located in the basement of Witmer Hall, UND’s Physics and Mathematics 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	<b>Unacceptable.</b> Documented approval from the MSFC EMC or an equivalent level independent management committee.
Medium Risk	<b>Undesirable.</b> Documented approval from the facility/operation owner’s Department/Laboratory/Office Manager or designee(s) or an equivalent level management committee.
Low Risk	<b>Acceptable.</b> 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 placed objects	Personal injury	B2	Provide proper stations for storage of tools and equipment. Always keep work area clean.	Verify all team member completed the relevant training from the FFSP



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 components 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 causes contamination of water source	Poor situational awareness or unsecured propellant	Severe environmental damage	B1	Plan proper launch and recovery area. Be mindful of wind conditions as to predict rocket movement.	Follow all MSDS and safety procedures.



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 powder gets wet, replace powder do another preflight and pre launch check.	The charges will be sealed promptly and only if the black powder has been verified as dry.



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)

**General Failure Modes:**

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. 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. Verify black powder holders are properly secured.	Follow launch operations procedure for recovery systems and altimeter bay 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.
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.
Black powder charges damage rocket	Blast damages rocket body because of a weak point on body	The parachutes may not be able to allow soft landing. Rover deployment may be inhibited	C2	Measure correct amount of black powder. Make sure bulkheads and rocket body are in good condition and no weak points.	Make sure the shear pins and other parts offer consistent resistance so that consistent amounts of black powder are used. Thus, blast does not find a "new" weak point.

**Rover Subsystem:**

Failure Modes	Cause	Effect	Risk Level	Risk Mitigation	Verification
Rover cannot handle terrain	Insufficient ground clearance; Terrain rougher than expected	Rover fails to travel 5 feet	B3	Allow the chassis to ride higher, allowing more clearance. Attach spikes or rubber pads to track for better traction.	The rover would be tested on rough terrain to assure its mobility.
Loss of rover power	Damaged wiring; dead battery	Rover fails completely	C3	Soldering procedure is done with proper technique and	Check soldering joints to make sure they are sufficient. Make sure there are no shorts in the circuit.





				equipment. Wiring will be done Properly to ensure no shortages with quality materials.	
Rover upside down	Improper deployment; Rough terrain	Rover fails completely	B3	Self-righting design?	Test strength of solar panels and torque of servos to know if it can self right
Remote fails to activate rover	Poor signal due to loss of line of sight. Rover located in a ditch, over a hill, behind an obstacle, etc... Damaged receiver	Rover fails to deploy	B3	Apply the correct frequency and transmission strength.	Testing will be done previous to launch with obstacles present at varying distances.
Premature Activation	Interference from other teams signal; Human error	Rover attempts to drive while contained in payload bay; Rover attempts to deploy solar panels in payload bay	C2	Place remote away from students until needed. Switch cover? 2-key activation?	Verifying unique wavelength for activation.
Tracks Jam	Debris lodged between sprockets and the tread.	The rover will become immobile	B3	Apply tracks guards to prevent debris from jamming treads.	The rover would be tested on similar terrain before launch. Make sure tracks are not loose.
No Deployment of Solar Panels	Mech. failure; Power loss; Obstruction; Poor electrical connection	Solar panels don't deploy,	C3	Wiring will be done Properly to ensure no shortages with quality materials. Rover will be right side up	Multiple Tests of solar panel deployment.



Mechanical failure	Tread detaches; Axle breaks; Chassis cracks; etc.	Possible rover failure, likely immobile	B3	Ensure high quality 3D prints, ensure tread is secured on	Do structural analysis on 3D parts, and test 3D parts thoroughly
Rover stepped on after deployment	Wandering livestock	Partial or complete rover failure		Rover makes noise? Have better luck?	Visually confirm all livestock have evacuated the area
Battery explosion	Overheating	Complete rover failure, potential injury to humans	C1	Battery is charged and wired up correctly, safe from any potential physical damage	Ensure batteries are charged, connected, and placed properly
Rover catches fire	Short circuit; Damaged battery	Rover failure, potential injury to humans	C1	Check wiring thoroughly and have a new battery for launch	Visually verify no wires are shorting or exposed, check that battery has no visual faults

**Deployment Subsystem**

Failure Modes	Cause	Effect	Risk Level	Risk Mitigation	Verification
Nose Cone separates during flight	-Shear pins not installed properly. -Linear Actuators engage early	-Rocket will become unstable -Rover could fall out	C1	Ensure pins are installed correctly and adequately. Don't push remote trigger before landing	Double check pins and have a safety cover for the remote deployment trigger



Remote does not activate the deployment system	-Parachute deploys too early -RF interference	Rocket drifts out of sight and range of the remote	B3	-Check deployment altitude on altimeter -Use unique RF signal for activation	-Perform RF activation check before launch
The rover deploys incorrectly	-Gyro readings are incorrect -stepper motor failure -Electrical Failure	Deployment system fails to orientate rover correctly	B3	Test gyro before flight.	Check all electrical connections Ensure gyro data is correct
Rovers path is blocked by another part of the rocket.	-Poor landing -parachute covers the rovers exit	-rover will fail to travel required distance. -rover will get caught up in the parachute or other pieces.	C3	Plan carefully to prevent unwanted movements or placement of other components	Test deployment in the test bed to ensure no failures and proper deployment
Rover comes loose during flight	Attachment point fails; Premature release	Damage to rover and deployment mechanism; Improper deployment	B2	Perform a shake test to confirm proper attachment	Make sure all points that hold and maintain the rover's position are secure and intact.
Fire	Battery overheat; short circuit	Damage to rocket/payload; Damage to people; Black powder charges activate prematurely	C1	Check all connections throughout the system before launch	Perform multiple tests before launch. Check to make sure there are no exposed wires.
Nose cone fails to be separated from the rocket	-Batteries aren't charged - not a good connection to the airframe -Actuators not strong enough	Rover will not deploy	B3	Test several terrains and rocket orientations for proper deployment	Verify that batteries are fully charged and properly connected. Ensure that the actuators used are strong enough to remove the nose cone.



	-Actuators fail to remove nose cone				
Deployment structure breaks on impact with ground	-Deployment mechanisms and structure not built sturdy enough -Parachute fails to deploy correctly	-Rover fails to deploy correctly	B2	-Ensure deployment systems can withstand impact with the ground - Ensure parachute deploys correctly	Make a final verification of structural integrity before launch. Check parachute and parachute cords before launch
Parachute fails to deploy	-Charges fail to split rocket at proper joints -Parachute rips at deployment -Altimeter fails	Deployment systems and rover system are damaged on impact, fail to deploy	B1	-Ensure altimeter will not fail -Ensure Charges are strong enough to separate rocket -Ensure parachute will not rip at deployment	See that the parachute does indeed deploy every time during test launches and make sure it's under similar conditions for the final.



### 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)**

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

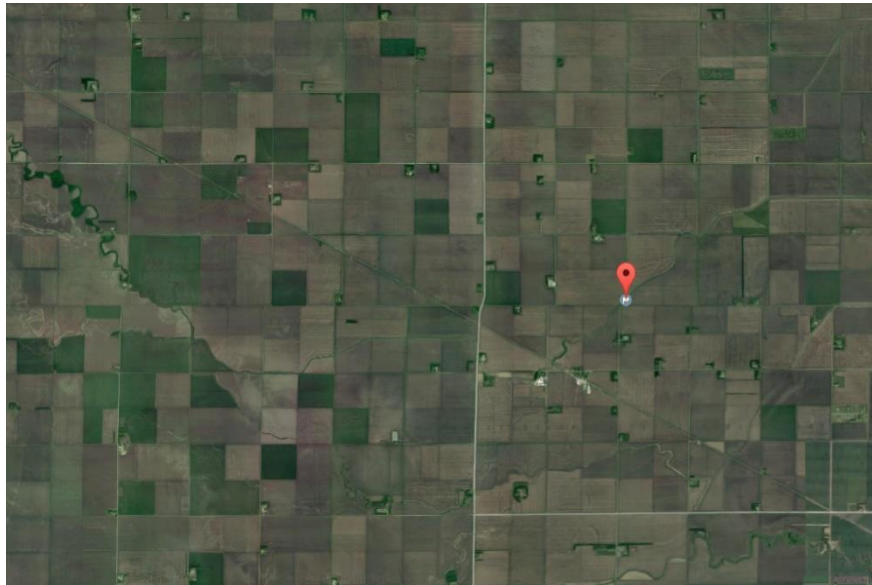


**Launch Site:**

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.





## 3.4 – Launch Operations Procedures

### **Recovery parachute preparations:**

- Inspect shock cords and parachutes for any preexisting damage.
- Secure the parachutes onto the U-bolts attached to the bulkheads inside the rocket.
- Fold the parachutes and insert them into the fire proof bag before placing them inside the rocket.
- Insert the shock cords carefully so they don't get tangled when the parachutes are deployed.
- Assemble all rocket sections together so they are secure.

### **Motor Preparations:**

- Before handling the motor, make sure there are no open flames in the vicinity.
- Inspect the motor and the metal motor casing for any visible damage.
- Evenly coat the outside of the motor with lubricant and insert the motor inside the motor casing. Be careful not to get any lubricant inside of the motor.
- Once the motor is ready, place it in a secure portable magazine until you are ready to go to the launchpad.
- Once ready, insert the motor into the motor mount and secure it with the locking rings. Make sure the motor can't move around once inside the rocket.
- Once the rocket is on the launching rail, test each altimeter to see if they respond properly with 3 beeps each.
- Ensure that the rocket is secure and can only move along one axis as the launching rail is in the upright position.

### **Igniter Preparations:**

- Turn off all electrical input for the ignition system before connecting anything.
- Check ignitor for any preexisting damage and slowly insert it into the motor until it is all the way at the top of the motor.
- After securing the ignitor, attach the wires from the ignition system and ensure that no short will occur.
- Secure the wires and then get to a safe distance before signaling the RSO that the rocket is ready to launch.

### **Launching the rocket:**

- The RSO will signal that the rocket is ready to launch and will do a 5 second countdown and ignite the motor.
- If, in any case the rocket fails to launch, shut of the electrical ignition system and wait 1 full minute before going to inspect the rocket.
- First check for any faulty wiring in the ignition system, check for shorts, faulty connections and continuity.
- If no immediate problem was discovered replace the ignitor with another one and go through the ignitor preparation process again.
- If the rocket still doesn't launch, remove it from the rail and go through a more thorough inspect of the ignitor system and the motor.



### **Equipment for Main Parachute**

- Main parachute – 96 inches with 12-inch spill hole
- Large deployment bag
- 3 large quick links
- Main shock cord

### **Equipment for Drogue Parachute**

- Drogue parachute – 42 inches
- Small deployment bag
- 2 large quick links
- 1 small quick link
- Drogue shock cord

### **Folding parachute – Main parachute**

- When the parachute is already folded as a half circle, and as flat as possible, at least 3 people begin to lay out the chute.
- One person holds the lines to prevent them from becoming tangled.
- The other two individuals hold the parachute along the folded edges.
- The chute is folded in half three times.
- Starting from the top, it is folded into thirds by folding the tip of the chute to the middle, then folding down again.
- The chute is placed into the bag.
- The chute's rip cords are connected to the large quick link in the middle loop of the main shock cord.
- On the top of the chute, but still in the bag, the parachute rip cords and some of the shock cord are carefully placed, to ensure they do not become tangled.

### **Folding parachute – Drogue parachute**

- The drogue is spread between the three people in the same manner as the main parachute.
- While one team member keeps the cords untangled, two members fold the chute in half three times, and then fold it into thirds length wise.
- The parachute is placed in the small bag.
- The rip cord of the parachute is connected to the middle loop in the drogue shock cord using the small quick link.
- The rip cords and part of the shock cord are folded in a manner that doesn't tangle the cords, and are placed on top of the parachute inside the bag.



## Altimeter bay

- Equipment for Altimeter Bay
  - Altimeter
  - 2 9V batteries
  - 8 washers
  - 4 wing nuts
  - Battery holder
- The altimeter is calibrated, making sure that all parachute deployment numbers are correct
- Two new 9-V batteries are placed on the altimeter board and secure them
- Charges are placed in the charge cups, threading the electric matches through the holes. The charge for the main is 2.5 g and should be placed on the bottom altimeter bay cup. The charge for the drogue is 1.66 g and should be placed in the top altimeter bay cup.
- The wires are connected to the altimeter making sure the positive and negative wires are in the appropriate places.
- The batteries are attached.
- The altimeter board is slid into place and secure with wing nuts.
- The area is cleared of unnecessary personnel and continuity is checked for using the switch on the exterior of the rocket. If there is good continuity, two beeps will be heard after the initial set of beeps. If the continuity is not good there will be double beeps after the initial set of beeps.
- The appropriate side of the main shock is attached to the bottom of the altimeter bay using a large quick link.
- The appropriate side of the drogue shock cord is attached to the top of the altimeter bay using a large quick link.

## Assembly

- The appropriate side of main shock cord is attached to the altimeter bay.
- The appropriate side of drogue shock cord is attached to the altimeter bay.
- The main bag is attached to the bottom of the fin can.
- The drogue bag is attached to the bottom of the payload bay.
- The rocket is pushed together.



## Motor Preparation

- Equipment for Motor
  - Motor casing
  - Motor grain
  - Motor retainer
  - 3 screws
  - Electric match
- Our engine will come pre-assembled, and will be left in the cardboard tube that it came in until the rocket is ready to be placed on the launch rail
- The motor is placed into the metal casing, making sure the motor is placed fully in its casing, and the motor closure is tightened.
- The casing is inserted into the motor mount tube, being careful since a vacuum is created.
- The rocket is secured with the motor retainer and the three screws
- The red safety cap is left on until the rocket is placed on the launch pad

## Launch procedure

- Check to see if the altimeter is turned on, has the right number of beeps, and is functioning properly.
- We will place the rocket onto the launch rail.

## Main steps of flight

- Rocket motor ignition
- Motor burnout
- Roll induction system activates
- Arduino, partnered with the gyroscope module takes flight data on induced roll
- After 720 degrees gyroscope module informs Arduino to stabilize
- Arduino communicates stabilization commands to motors

## Post Flight Inspection

- We will check to ensure no fires were started by the rocket near the launch site, nor at the landing site.
- The area will be examined for harmful debris.
- We will ensure that the ejection charges are spent before handling the rocket in any capacity.
- We will then check to make sure the motor casing is still in the rocket.



## 4 - Vehicle Criteria

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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–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 criterion 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 ( $\pm 100$ ) 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 analysis 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.

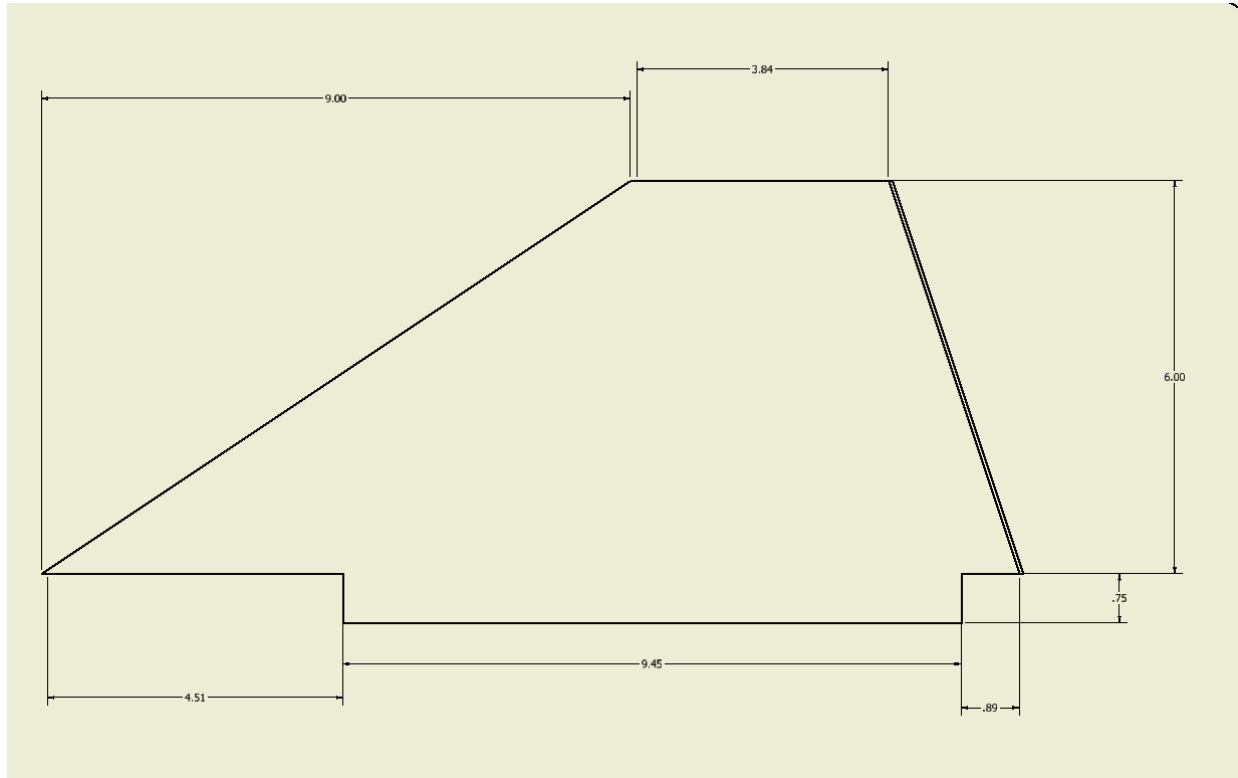


Figure 1: Selected Fin Design (Note: Dimensions are from scale launch vehicle)

### Bulkhead Material:

Internal bulkheads will be constructed out of  $\frac{1}{4}$ -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. 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 – Subscale Flight Results

The subscale flight took place early November. Launch was on a clear day, the temperature was approximately 10-15F(Fahrenheit), with winds averaging 5-10mph. The launch vehicle has a half-scale model of the full-scale launch vehicle. The size, and design of the fins were to scale. However, the length was not entirely to scale, it was a little bit longer. This was to accommodate the altimeter bay. The scale-rocket reached an apogee of approximately 1,250 feet AGL (above ground level). The first figure shows the altimeter data, the second figure shows the roll of the rocket, along with acceleration the rocket performed throughout the duration of the flight.

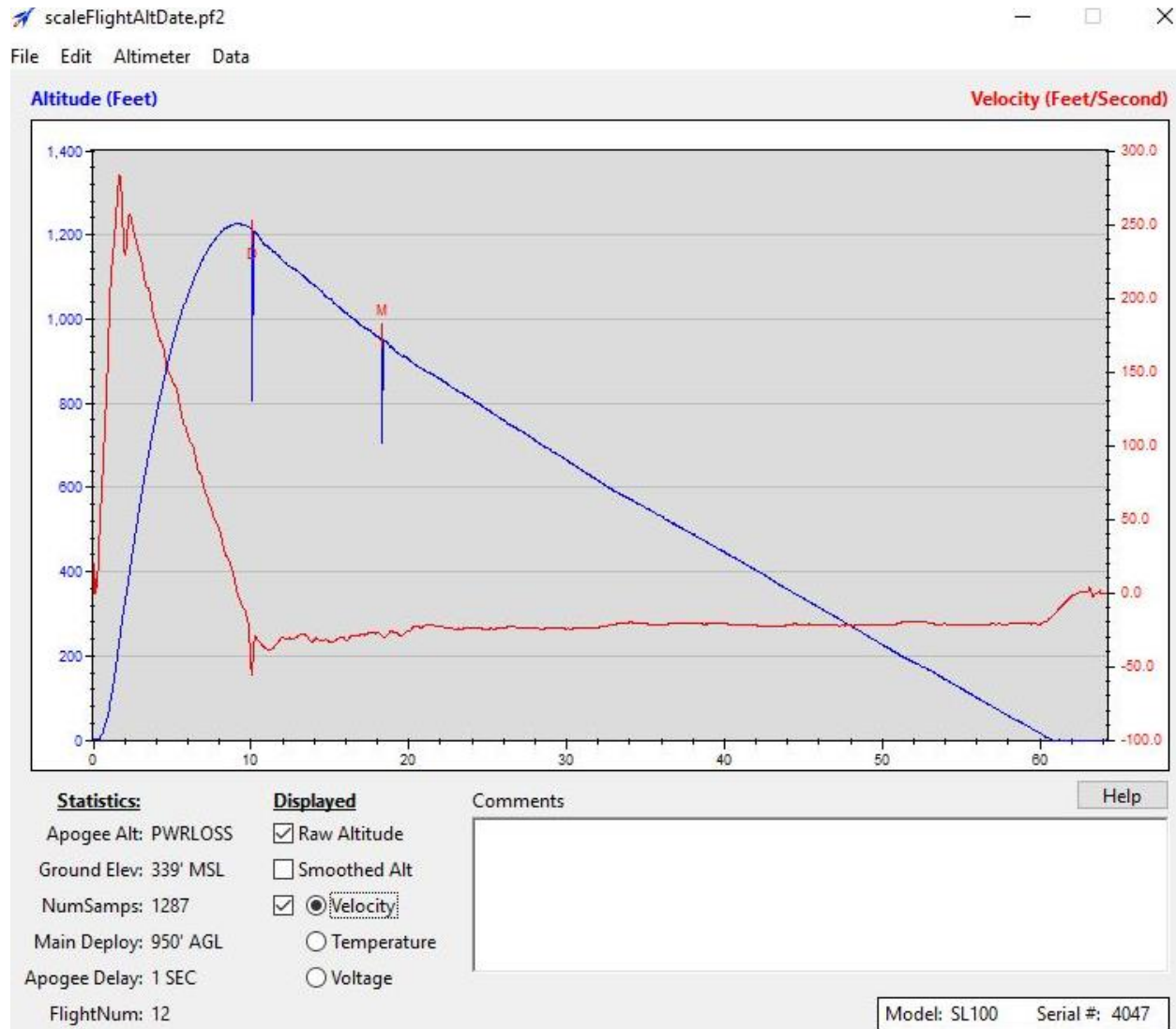


Figure 2: Altimeter flight data from sub-scale launch

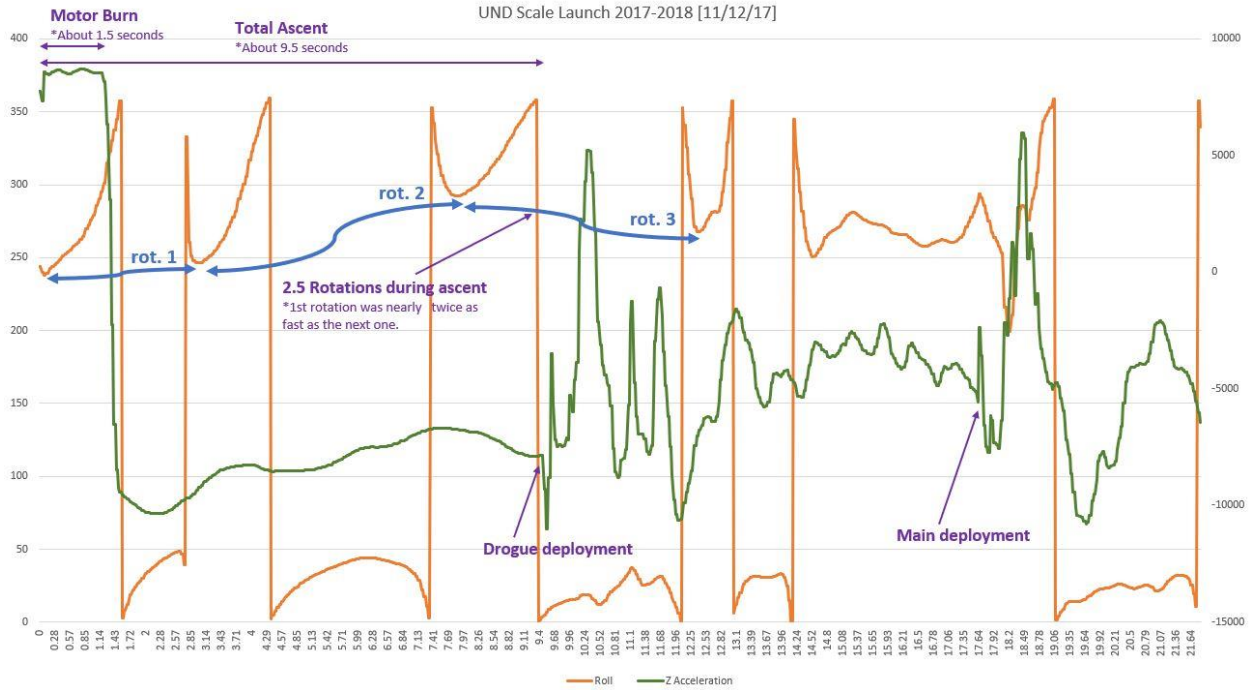
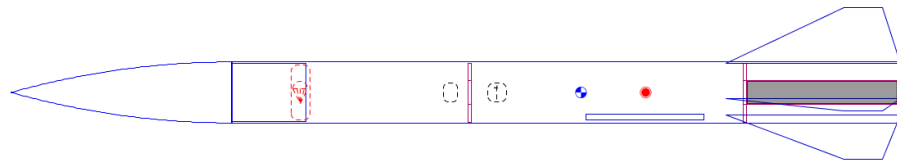


Figure 3: Flight data of the scale launch from the onboard data logger



Apogee: 1945 ft  
 Max. velocity: 497 ft/s (Mach 0.45)  
 Max. acceleration: 619 ft/s<sup>2</sup>

Figure 4: Side profile of the LOC Forte used for subscale flight

The flight data received from the launch has given us confidence that we are able to fabricate a rocket in house and launch it successfully. We also learned how to fold, and pack the parachutes so that they deploy correctly during launch. We believe the fin selection we chose for the sub-scale launch vehicle will integrate well into the full-scale launch vehicle. The simulated apogee was higher than what was recorded. The simulated apogee is 1,945 feet. Actual flight data read that the launch vehicle went approximately 1,250 feet



## 4.2 – Recovery Subsystem

The recovery subsystem will employ 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.

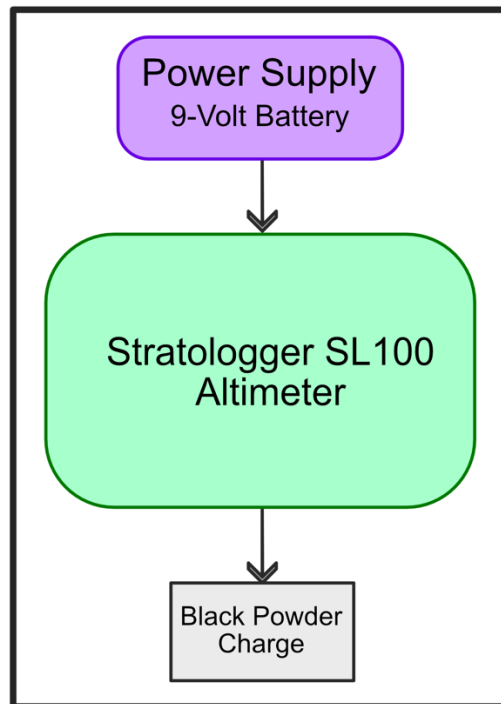


Figure 5: Altimeter bay electronics block diagram

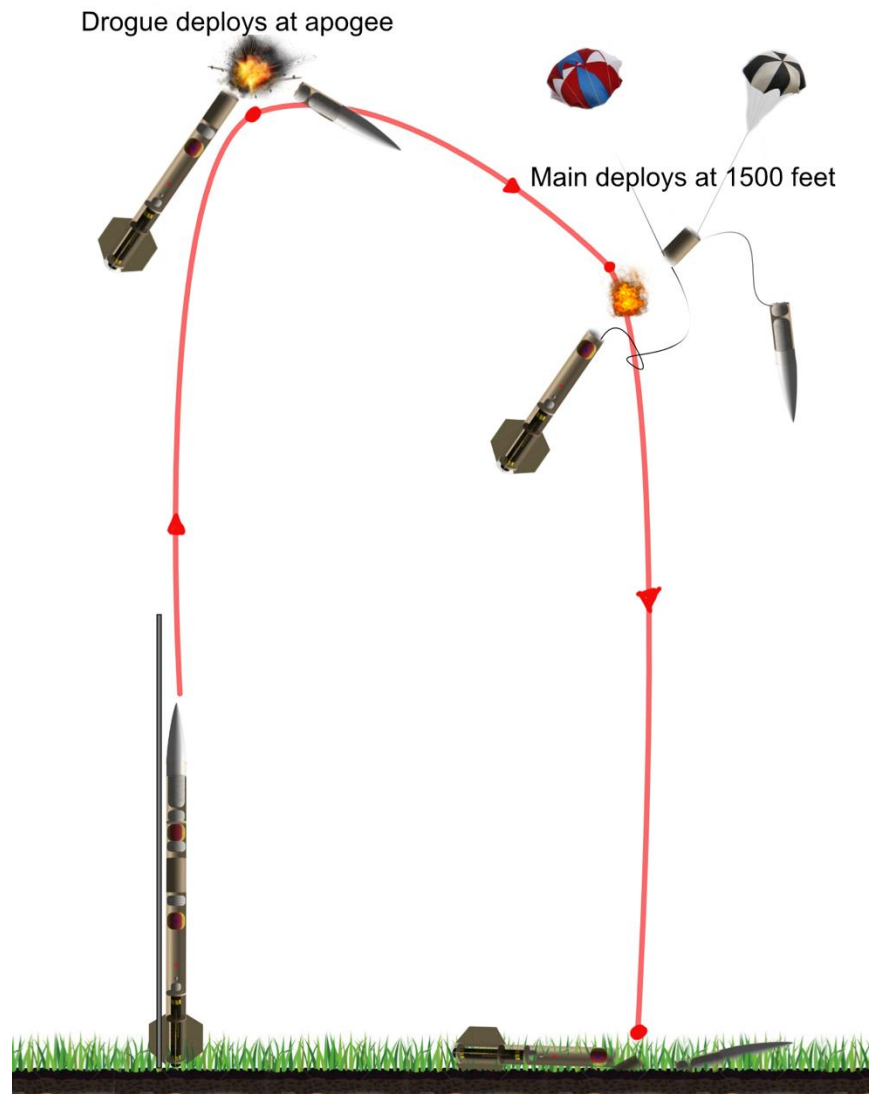


Figure 6: Recovery subsystem sequence



## 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 107 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 5,566 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 7 pounds. This weight is expected to change throughout the course of development and is just an estimate. A ballast of under 10% of total weight of the launch has been implemented, it is 1.25 pounds. The ballast was implemented to add stability to the launch vehicle.

### Flight Profile

Mass of Launch Vehicle (Unloaded)	24.44 lbs.
Mass of Launch Vehicle (Loaded)	32.94 lbs
Length of Launch Vehicle	107 in.
Diameter of Launch Vehicle	6 in.
Center of Pressure (CP)	77.61 in. from nose cone
Center of Gravity (CG)	64.70 in. from nose cone
Stability Margin	2.15 cal
Mass of Rover Payload Bay (w/ Rover)	7 lbs
Mass of Rover	4 lbs
Apogee	5566 ft
Max. Velocity	673 ft
Max. Acceleration	264 $ft/s^2$
Time to Apogee	18.4 seconds (s)
Velocity at Deployment	64.6 ft/s
Altitude of Deployment of Drogue	5566 ft. (Apogee)
Altitude of Deployment of Main Parachute	1000 ft.
Ground Impact Velocity	20.2 ft/s

Table 4: Size/Vehicle Dimensions

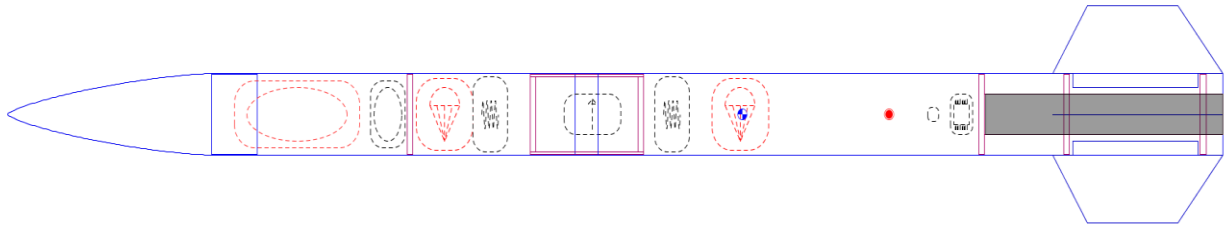


Figure 7: Side Profile of Rocket (OpenRocket)

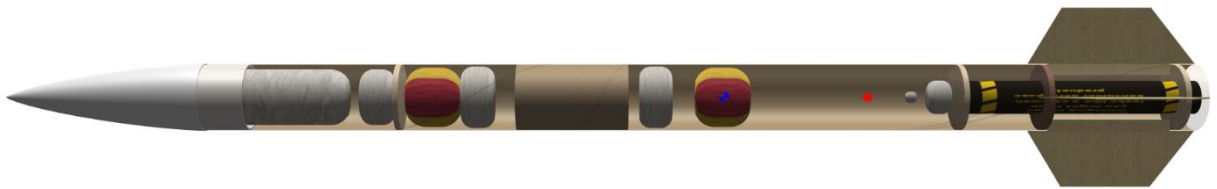


Figure 8: 3D Render of Rocket (OpenRocket)

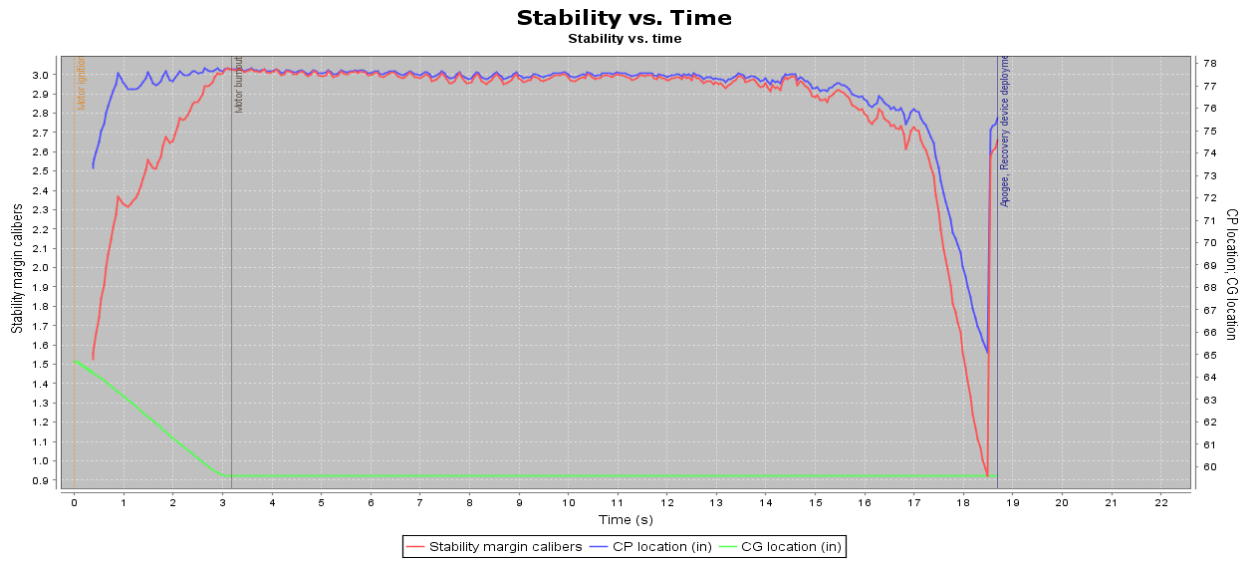


Figure 9: Stability vs Time Simulation

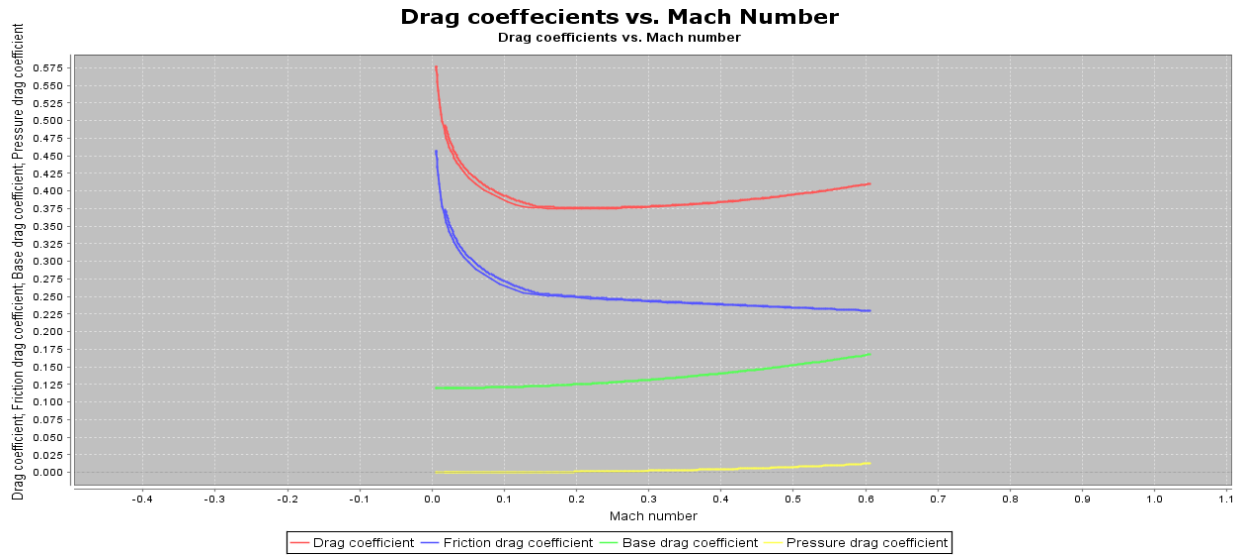


Figure 10: Drag coefficients vs. Mach Number

### Fin Specifications

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

Table 5: Fin Specifications

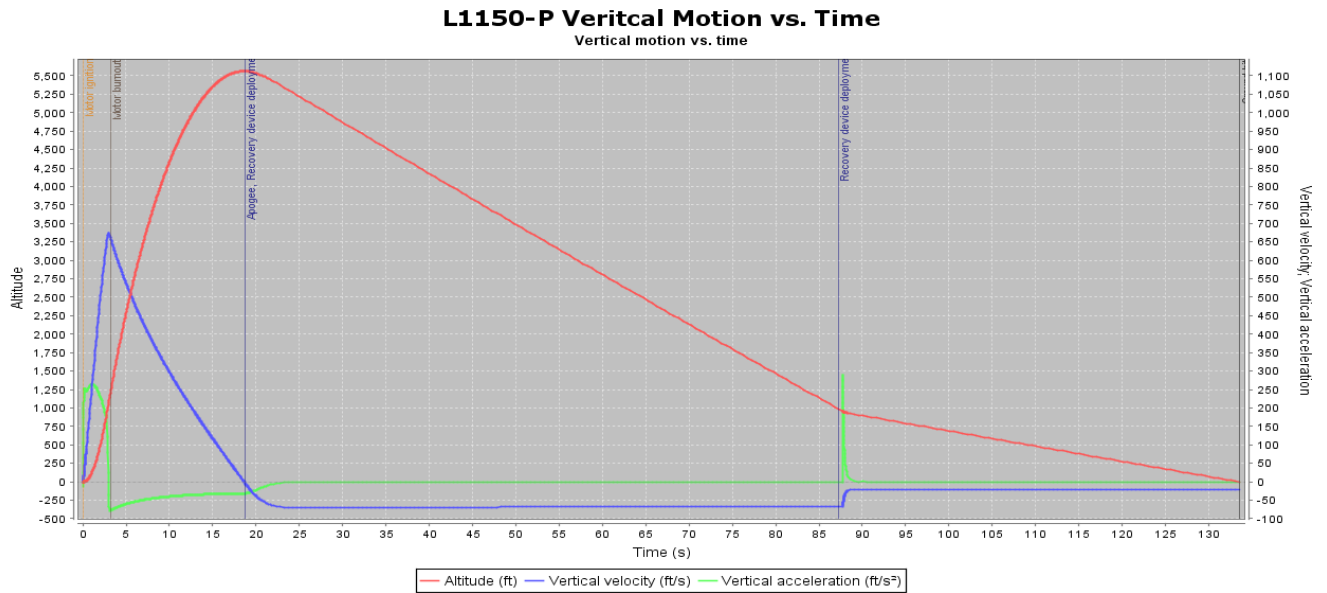


Figure 11: Vertical Motion vs. Time

## Motor Specification

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 6: L1150 Motor Specifications



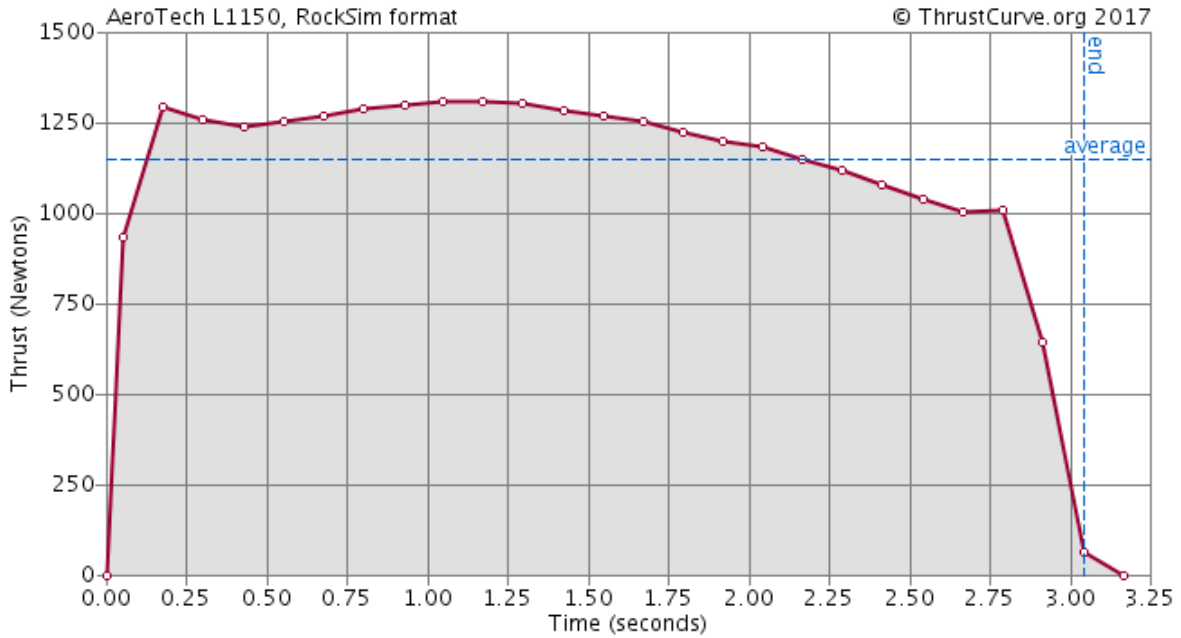


Figure 12: Thrust curve of L1150

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.

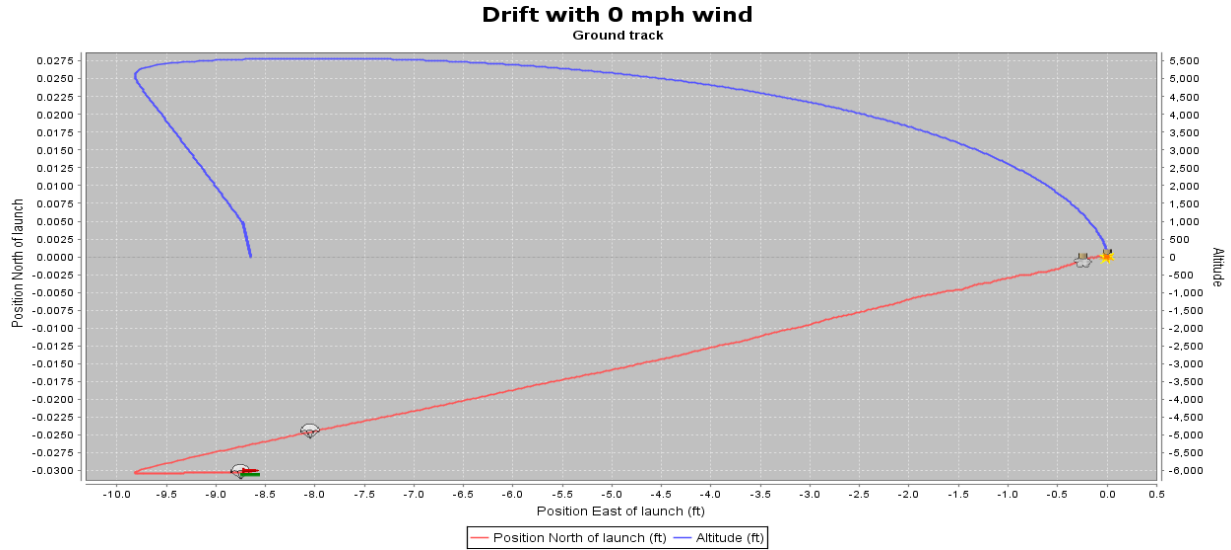


Figure 13: Drift with no-wind

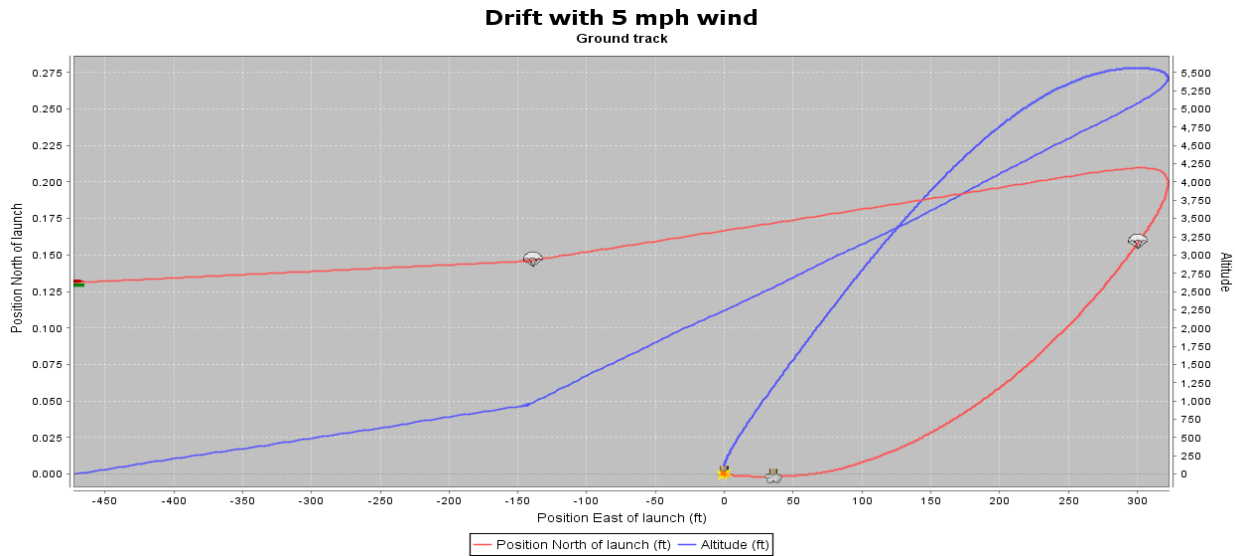


Figure 14: Drift with 5-mph wind

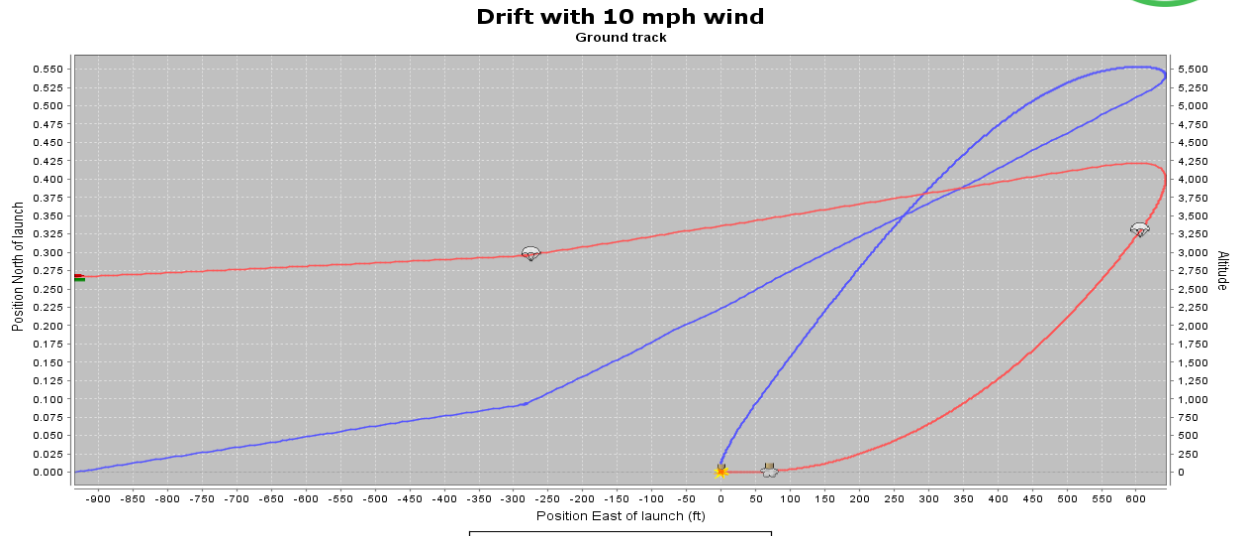


Figure 15: Drift with 10-mph wind

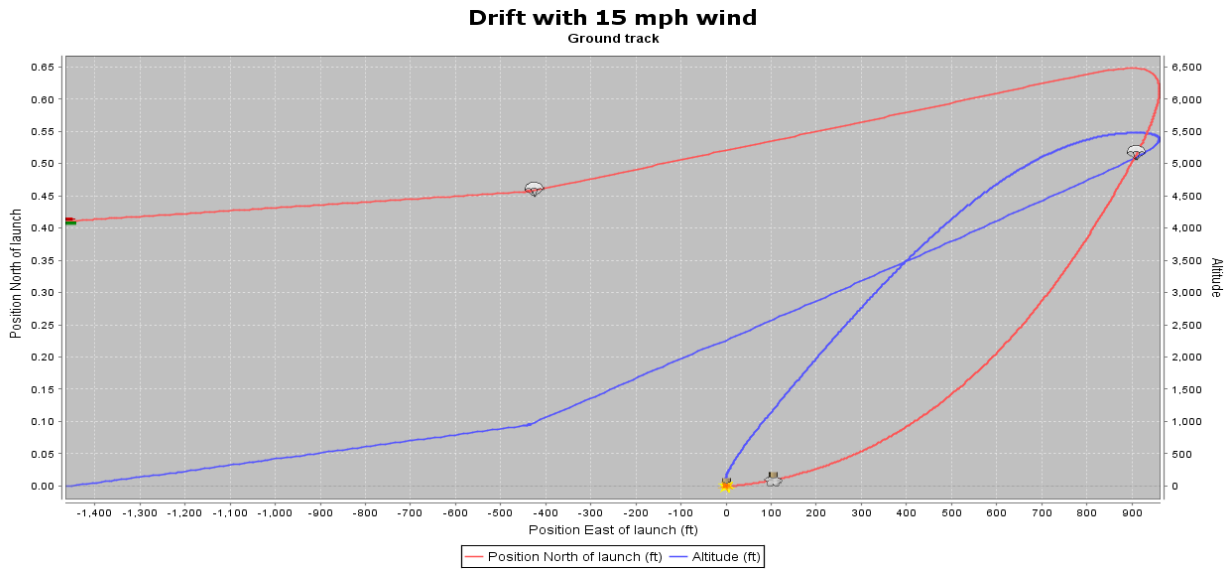


Figure 16: Drift with 15-mph wind

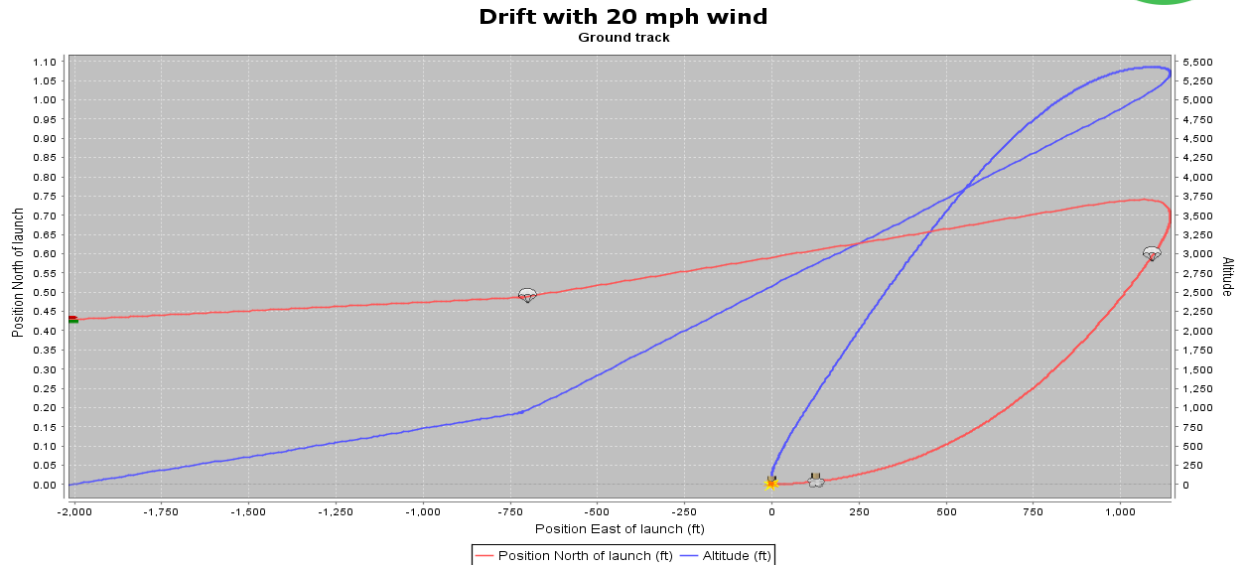


Figure 17: Drift with 20-mph wind



## 5 - Payload Criteria

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### 5.1 – Design of Payload Equipment

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 bay 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 Design

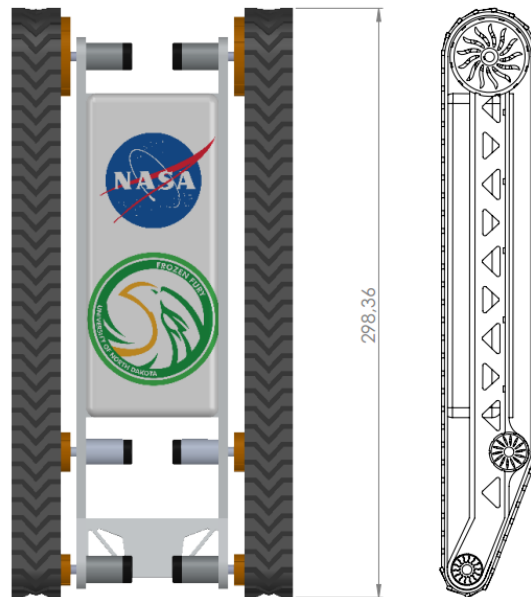
In the Preliminary Design Report three ideas for the rover design were presented. Of the three we selected the track style rover. This design will allow us to navigate difficult terrain, while still being compact and able to fit inside its payload bay in the launch vehicle. The track style rover also allows for easy deployment of the solar panels. The solar panels will open up from the inside of the embedded systems bay.

## 5.3 – Payload Design Review

The experimental payload will have to main components. Deployment of the rover, and then the rover itself. This section will review both systems, which will include drawings and system diagrams.

### 5.3.1 - Rover Design Review

The Rover is the first component that will be reviewed. This section will describe the frame and electronics of the rover. The rover body will be 3D printed using ABS plastic, the treads and wheels will be bought. Along with the electronics and power system for the rover.



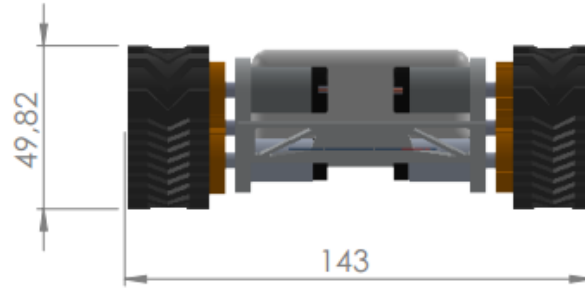


Figure 18: Top and Front Profile of Rover (Dimensions in mm)

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

Height (in)	1.91
Length (in)	8
Width (in)	5.4

Table 7: Rover Dimensions in Imperial Units

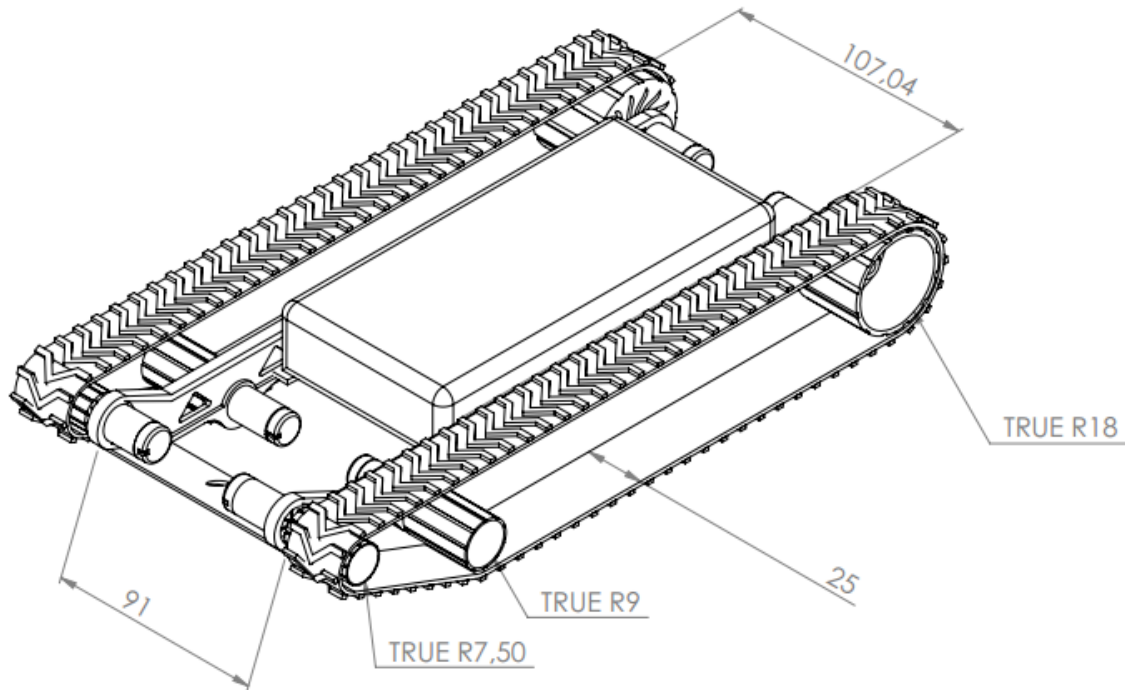


Figure 19: Figure describing rover body width and tread width

In Figure 19 the rover body is about 5.4-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.

Figures 21, 22, and 23 all represent the embedded system bay and its components. Figure 23 is a system diagram of the rover electronics. The Raspberry-Pi ZeroW is the main computer for the rover. It will be tasked with controlling the motors, and making sure the rover will drive five feet. The W at the end of the Zero the Raspberry-Pi means that is wireless and we will be able to view voltage and wattage readings real time since we will be able to connect to it wirelessly. Stacked on the Raspberry-Pi Zero there will be a motor controller. This will allow the allow the Pi to have control of the motors. There are four motors that will be attached to the motor controller. Two electric DC motors for the drivetrain and two servo motors for the deployment of the solar panels.

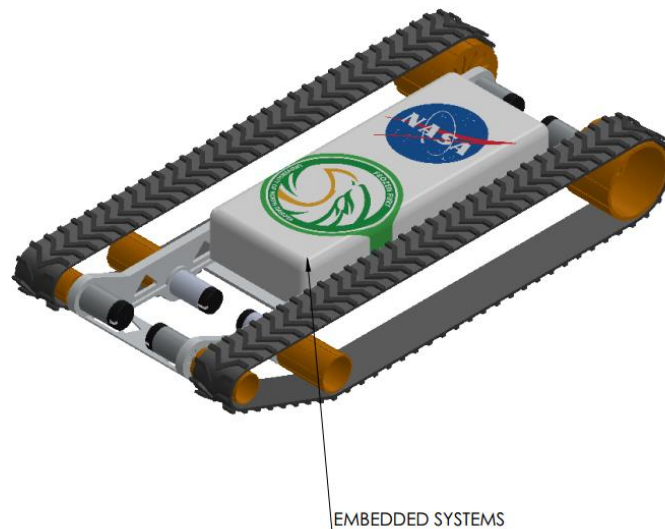
The two electric motors are two 224:1 geared DC (direct current) motors 90-degree shaft motors. The 90-degree output shaft allows for easy integration of the DC motor into the embedded systems bay. The two servos are S3154 Futaba Servos. They have a stall torque of 20.8 oz/in which is within the safety margin for the torque necessary to deploy the solar panels.

The solar panels are mini solar panels that weigh 0.32 oz. (ounces) each. They will attach to the servo control horn. The method of attachment is to epoxy the servo horn to the back side of the solar array panel.

Also onboard the rover will be an accelerometer, this will be used to help with navigation for the rover. It will allow the Pi to count how far the rover has traveled, along with using a set time that will be derived for testing, the Pi can accurately know how far five feet is and stop the rover.

Powering the whole system will be 2200 mAh (milliampere hour) lithium ion battery that supplies 11.1V (volts. There will be a voltage regulator to step down the voltage to 5V so that the rest of the electronics are able to run off the battery.

Figure 20: 3D Render of Rover





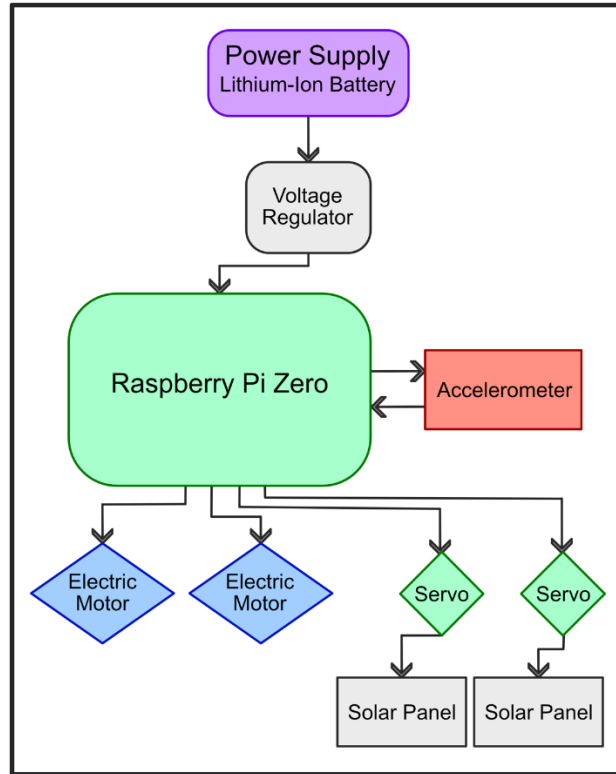


Figure 21: Block diagram of electronic bay of rover

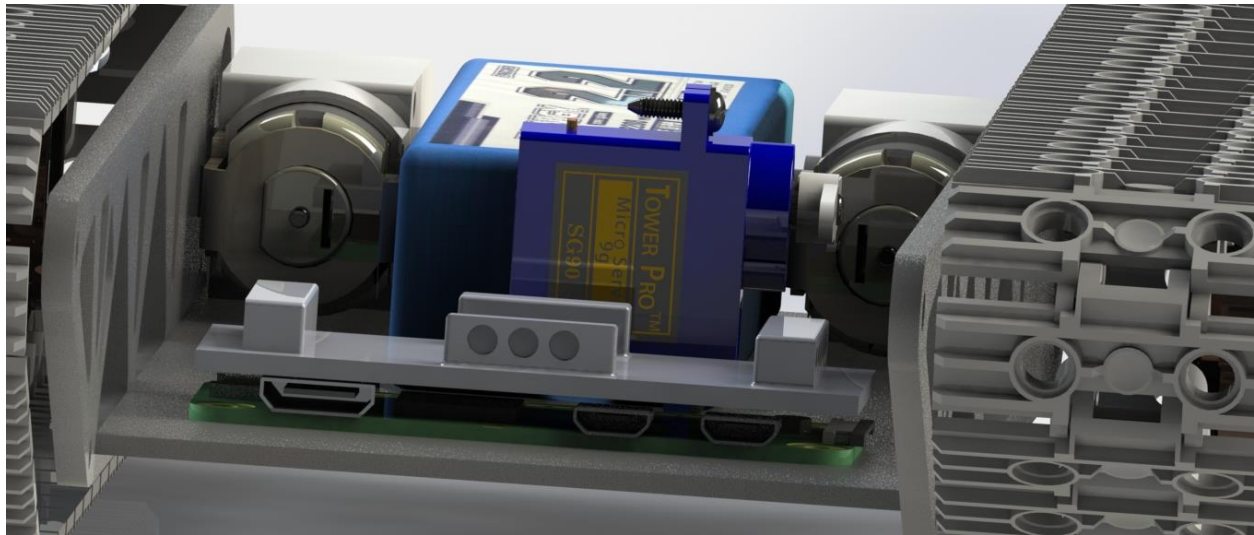


Figure 22: Render the embedded systems bay

Figure 22 shows an uncompleted embedded systems bay. What is shown is the major components. The motor controller for the Raspberry-Pi can be denoted by its grey color, directly below it is the Raspberry-Pi ZeroW its self. The lithium-ion battery can be seen in the middle back half of the bay, and is denoted by a blue rectangle. The servos are directly in-front of the battery pack. The two DC motors are in the rear-right and rear-left of the embedded systems bay.



The tracks and the wheels that run the track will be from Lego. These components need to be durable and we believe that these Lego components provide this. Along with being durable, the tracks are versatile. Sections off track can be added or removed depending on the rover's length, or the type of terrain that is being traversed. Figure 23 presents these components integrated into the rover.

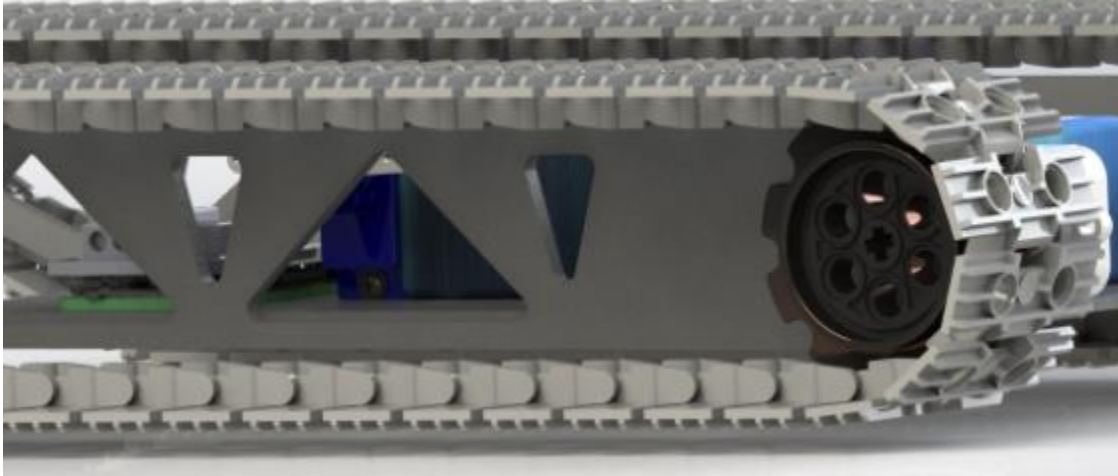


Figure 23: Lego wheel and track system (rear)

### 5.3.2 – Rover Payload Bay Design Review

In the PDR the two ideas were proposed as two possible solutions for extracting the payload. One of the ideas was to use tube, inside our main rocket body, to house the rover. The tube then had two attached plates, one plate in the back of the tube and one plate connected to the back plate and running through the tube (see figure one). The advantage to this design was the ability to reach a maximum extension length for extracting the rover. However, the disadvantage of this deployment method is it requires a smaller rover because the inner tube takes up extra space.

The second idea proposed used the same principle as the first, except instead of having a tube inside the main rocket body, it uses the rocket body itself to house the inner plates. The advantage of this is that the rover can be wider and taller. The disadvantages of this are; the plate is not able to extend as far, and the nose cone shoulder must be cut down to gain length on the rover and to fix properly when connecting the nose cone to the rocket body. It should be noted that the shoulder of the nose cone is still large enough to secure shear pins.

#### **Payload deployment operation**

1. Remote activation of the deployment system.
2. On board gyroscope reads orientation of the rocket after it has landed.
3. Stepper motor placed on the rear plate (figure three) orientates the rover in a proper position for extraction. This orientation will ideally be as close to parallel to the ground as possible.
4. Once rover is in position two linear actuators begin to extract the rover plate (figure four). The actuators will also be used to snap the shear pins. Note that the actuators are pushing in opposite directions in order to maximize space for rover dismount.



5. Once rover plate is extended to full length (figure five) the rover activates and drive off the rover plate and continue its task.

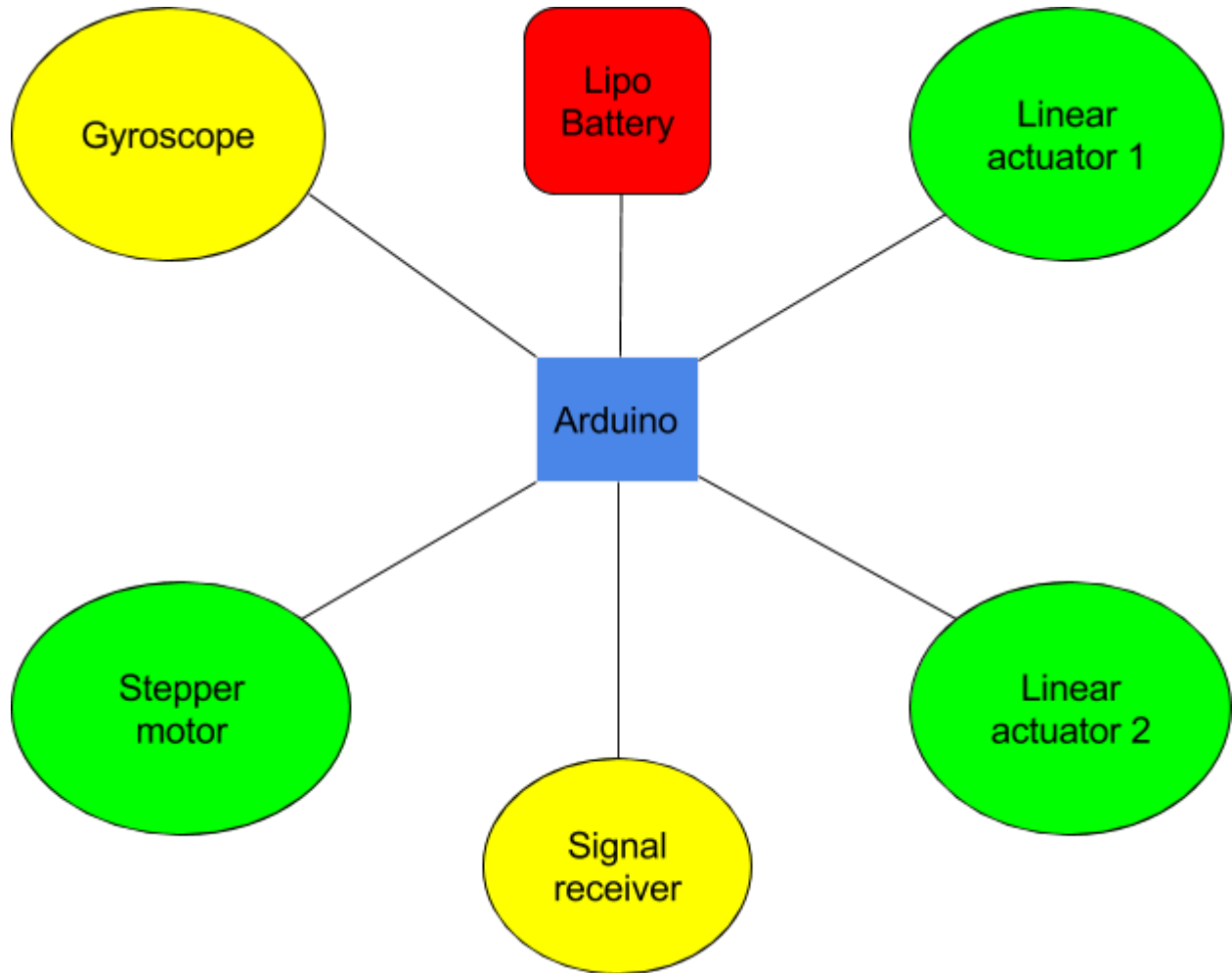


Figure 23: System Diagram of rover deployment system

**This deployment system is complete for the following reasons:**

The design meets the requirements need for its payload, meaning the appropriate space is provided for the rover. Using the gyroscope and stepper motor will optimize the positioning of the rover inside the rocket body. It should also be noted that the stepper motor will act as a break to keep the rover housing mechanism from moving during the rocket's flight.

The rover will be setting on the rover plate inside the rocket. Foam will take up the excess space inside the tube, this will help keep the rover in place during flight and help to absorb any potentially damaging changes in acceleration. Linear actuator will provide enough power to break the shear pins and extract the rover from the rocket tube. Note that the actuator provides 67lbs of thrust per actuator. To help balance the force distribution a plate is added. The actuators



are also placed as close together as possible to reduce chance of the rover plate from twisting upon extraction. Support arms are also added to take stress of the actuator arms, both from buckling and from the weight of the rover and rover plate.

Note that arms are also providing a path for the wires to run to bring power to the actuators.

In figure 25b, two tabs can be seen, these are for the rover plate to slide into. These tabs insure a locked position during flight and allow the plate to be oriented properly

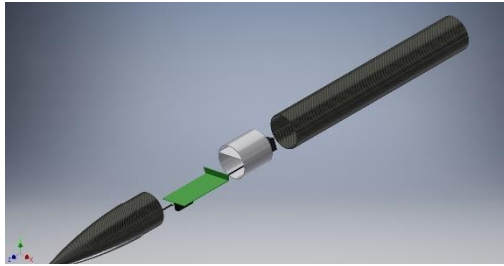


Figure 24a: Deployment system in full

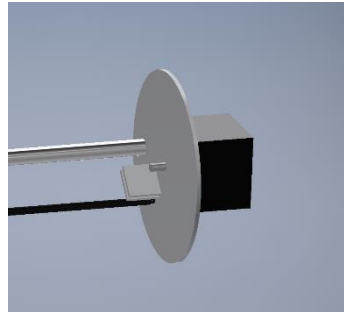


Figure 24b: Stepper motor

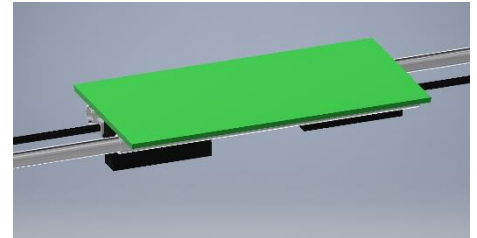


Figure 24c: Rover plate

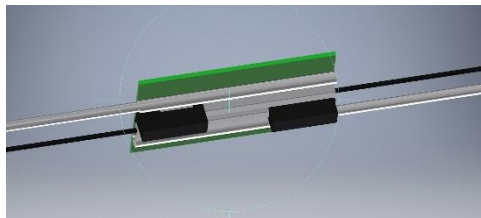


Figure 24d: Linear actuators connected to the rover plate

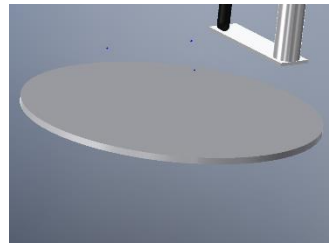


Figure 24e: Nose cone bulkhead

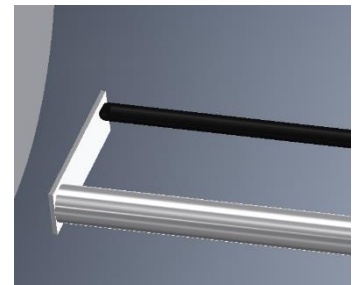


Figure 24f: Actuator force distribution plate

### Possible additions

Add plates on hinges to the front, back, and sides to give rover some extra space when dismounting the rover plate.



## 6 - Project Plan

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### 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 8: Project Timeline

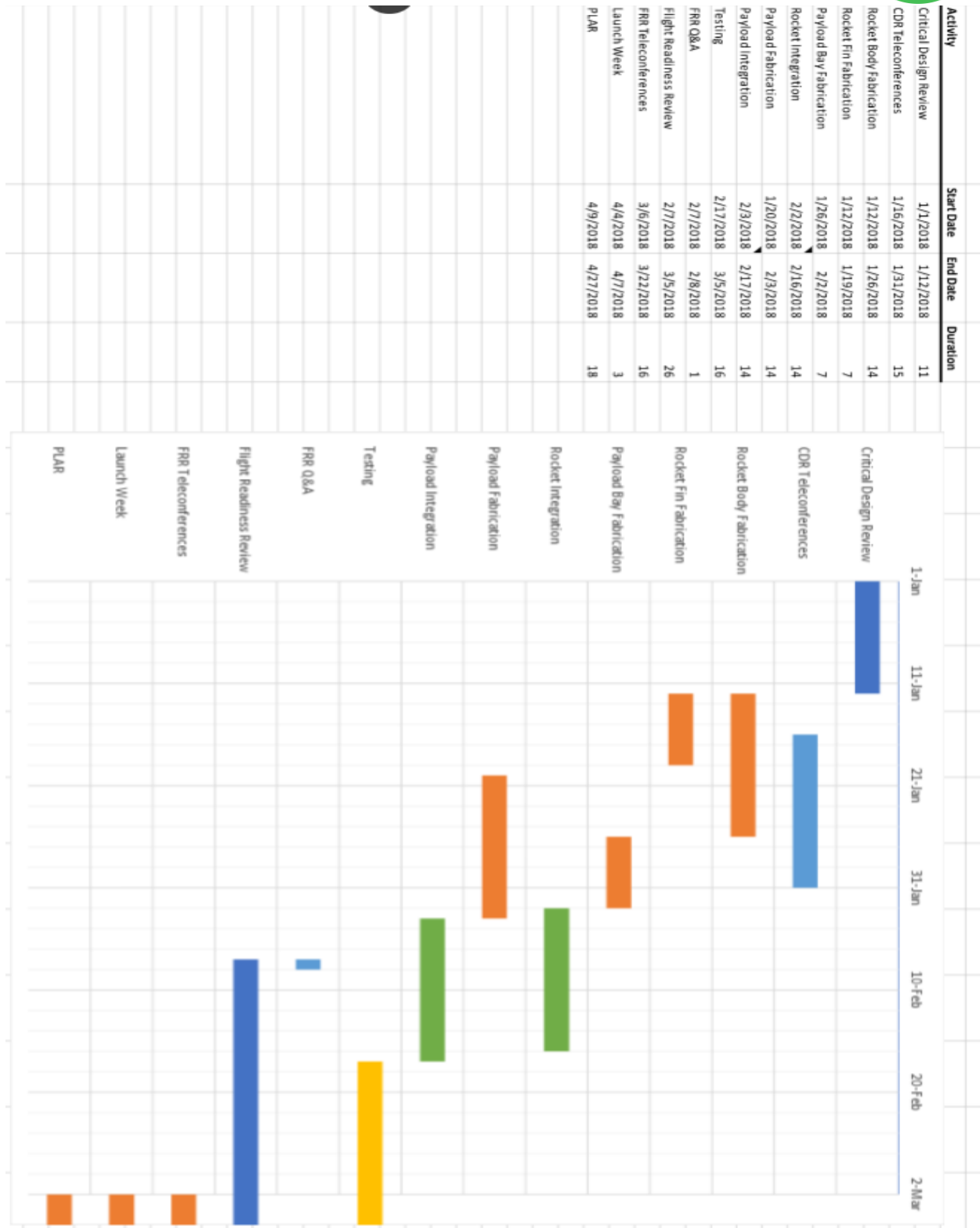


Figure 25: Gantt Chart of development, testing and competition (side)



## 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.

<b>2016-17 UND Rocket Team "Frozen Fury" Budget</b>			
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



<b>Grand Total</b>			<b>\$ 7,814.44</b>

Table 9: Budget

### 6.3 Testing

Testing the full-scale launch vehicle will be done in between the months of February and March. The test flight(s) will be used to test the recovery subsystem to see if it behaves properly and works as it is intended to. The test flight will also be used to see if the launch vehicle is durable and can be used again. Either the payload itself or an innate object of the same mass will be in the payload by during flight. This is to see if the experimental payload can withstand a launch and still function as designed.

Before there can be a full scale launch all the components of the launch vehicle need to be tested. These components are the recovery system, the payload system and motor. All these components need to either be validated through simulation and live testing.

To test the recovery system a ground test will be developed. For this ground test the launch vehicle will be assembled in full. The parachutes will be folded and packed within their designated sections. The charges will also be packed, starting at 5g (grams) of black powder. The launch vehicle will be placed 100 feet away and there will be two leads from the charges back to the designated safety area. At the safety area the safety officer will start a countdown and connect the leads to a 9V battery. The charges should go off and the parachutes, including shock cord should fully deploy from the launch vehicle. If this happens, the ground test will be successful, and the recovery subsystem is ready to be used in flight. If the desired results do not occur, there needs to be investigation into why the anomaly happened. Common anomalies are charges not going off, and parachute and shock cord not fully deploying.

The testing for motor will be done through simulation. There will be no ground test of the motor. The motor already has been picked through simulation. There are too many safety hazards, and the Frozen Fury Rocketry team does not have the hardware to test a solid motor safely. The test of the motor and its retention system will be done on the first full-scale test launch.

To test the rover and its deployment system will be tested throughout its development. There is sandbox within the lab that team operates. Here the testing of rover maneuverability, durability and functionality will be tested. The terrain resembles that that of the selected launch/landing terrain used for launch day. Along with testing the rover, the deployment system will be tested in the sand box as well. This is to see of the actuators, and the rest of the system can cope with the terrain. If things do go wrong additional improvements will have to be made, this could add weight to the payload which would add weight to the entire launch vehicle.



## 6.4 – 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

### 6.4.1 – General Requirements

<b>Requirement Number</b>	<b>Requirement</b>	<b>Method of Verification</b>
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



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



	<p>Subpart B-Technical Standards  <a href="http://www.section508.gov">http://www.section508.gov</a>: 1194.21                  Software application and operating systems                  and 1194.22 Web-based intranet and Internet                  information and applications.</p>	
1.14	<p>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.</p> <p>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.</p>	see Section I

### 6.4.2 – Vehicle Requirements

Requirement Number	Requirement	Method of Verification
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.



	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.



	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



	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. Subscalers 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.





	<p>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.</p>	
2.19.1	<p>The vehicle and recovery system will have functioned as designed.</p>	
2.19.2	<p>The payload does not have to be flown during the full-scale test flight. The following requirements still apply.</p>	<p>Initial launches will be carried out on only the launch vehicle. Following launches will include actual payload.</p>
2.19.2.1	<p>If the payload is not flown, mass simulators will be used to simulate the payload mass.</p>	<p>Mass simulations will be constructed or printed for initial launch.</p>
2.19.2.1.1	<p>The mass simulators will be located in the same approximate location on the rocket as the missing payload mass.</p>	<p>Mass-model will be placed in the bay designed for the actual payload.</p>
2.19.3	<p>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.</p>	<p>Payload internal N/A. Camera system will be completed and installed before initial launch.</p>
2.19.4	<p>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.</p>	<p>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.</p>
2.19.5	<p>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.</p>	<p>No addition to vehicle construction will be carried out after the final field launch.</p>
2.19.6	<p>After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified</p>	<p>No addition to vehicle construction will be carried out after the final field launch.</p>



	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.
<b>2.21</b>	<b>Vehicle Prohibitions</b>	
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.



### 6.4.3– Recovery System Requirements

Requirement Number	Requirement	Method of Verification
3.1	The launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue-stage descent is reasonable, as deemed by the RSO.	Simulations will assess the velocity and kinetic energy of the descending vehicle. Initial 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.
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.



## 6.4.4 – Experiment Requirements

<b>Requirement Number</b>	<b>Requirement</b>	<b>Method of Verification</b>
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.
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.

## 6.5.5 Safety Requirements

5.1	Each team will use a launch and safety checklist.	Final Checklists will be included in the FRR and will be used during the LRR and any Launch Day operations.
5.2	Each team must identify a student safety officer who will be responsible for all items in section 5.3.	Drew Ross is our Safety Officer. He is responsible for verifying any safety items listed in this document.
5.3.1	The Safety officer will Monitor team activities with an emphasis on Safety during: (see below)	
5.3.1.1	Design of vehicle and payload	Design completed with redundancies built in



5.3.1.2	Construction of vehicle and payload	Construction of vehicle completed following proper safety procedures and checklists
5.3.1.3	Assembly of vehicle and payload	Assembly completed following proper safety guidelines and checklists
5.3.1.4	Ground testing of vehicle and payload	Ground tests completed following proper safety checklists and proximity guidelines
5.3.1.5	Sub-scale launch test(s)	Successfully completed with proximity guidelines and safety concerns addressed
5.3.1.6	Full-scale launch test(s)	Will follow proper safety checklists and proximity guidelines
5.3.1.7	Launch day	Correct safety guidelines and procedures will be followed according to Safety checklist
5.3.1.8	Recovery activities	Flight only recovered after receiving confirmation and approval for RSO
5.3.1.9	Educational Engagement Activities	Engagement activities are done with safety and inclusion of younger individuals in mind
5.3.2	The Safety Officer will implement procedures developed by the team for construction, assembly, launch, and recovery activities	Safety procedures implemented
5.3.3	The Safety Officer will manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data	Hazard analysis, failure mode analysis, procedures, and chemical inventory all maintained and managed to current revisions
5.3.4	The Safety Officer will assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.	Hazard analysis, failure modes analysis, and safety procedures written



5.4	During test flights, teams will abide by the rules and guidance of the local rocketry club's RSO.	Rocketry club's RSO rules and guidance abided by
5.5	Teams will abide by all rules set forth by the FAA.	Will receive Full scale flight clearance from the FAA and issue a NOTAM.

### 6.4.6 Team Derived Requirements

<b>Requirement Number</b>	<b>Requirement</b>	<b>Verification Plan</b>
6.1.1 - Mission	Reach a target altitude of 5,280 feet AGL	Record data from the altimeter onboard the launch vehicle
6.1.2 - Launch Day	The launch vehicle should be ready to fly the day of launch day	All testing and development will be completed two weeks before competition launch date.
6.1.3 - Altimeter	The altimeter must work during all launches of the rocket	Testing of the batteries that power the altimeter will be conducted, along with tests of the altimeter themselves.
6.1.4 - Launch Vehicle Guidelines	The launch vehicle must fit all the criteria outlined in the NASA SLI Handbook	Through PDR, CDR, and FRR will receive verification from NASA that the launch vehicle meets all the necessary requirements outlined in the handbook
6.1.5 - Subscale Model	Launch a subscale model of the rocket before the CDR.	Subscale launch completed before CDR.
6.1.6 - Full Scale Launch	The full-scale launch will be conducted before March 1 <sup>st</sup> , 2018	Have not yet started construction on the rocket
6.2 - Recovery Devices	The rocket will deploy a drogue and main parachute	Drogue is deployed at apogee, main is deployed at 1500 feet



<p>6.2.1 - Ejection Test</p>	<p>An ejection test will be performed before each full-scale launch to ensure that the recovery system is working properly</p>	<p>Ground ejection test has yet to be completed</p>
<p>6.3.1/6.3.2 - Experiment Requirements: Deployable Rover/ Rover Deployment System</p>		
<p>6.3.1.1- Rover Housing</p>	<p>Rover must be contained within the main body of the rocket for the duration of flight.</p>	<p>A dedicated payload bay will be placed inside the rocket and the rover is designed to fit inside. Visual pre-launch inspection will ensure that the rover is entirely contained.</p>
<p>6.3.1.2 – Rover Autonomy</p>	<p>The rover must be fully autonomous</p>	<p>The rover will have a Raspberry Pi Zero as the computer that will control and monitor all the systems on board the rover</p>
<p>6.3.1.3 – Distance Traveled</p>	<p>Rover must travel at least 5 feet from the landed rocket.</p>	<ul style="list-style-type: none"> <li>• Previous testing on the rover will determine how long it must drive to travel at least 5 feet. The motors will run for at least this length of time.</li> <li>• The rover’s onboard accelerometer will measure its displacement via dead reckoning.</li> </ul>





		<p>The rover will drive until it reckons at least 5 feet.</p> <ul style="list-style-type: none"> <li>Once both the timer and accelerometer checks are passed, the rover will stop driving. Additionally, the rover's final distance from the rocket will be measured via tape</li> </ul>
6.3.1.4 – Solar Panel Deployment	Rover must deploy solar panels	Rover's onboard computer will record voltage across solar panels. If voltage is within 30% of nominal value for the panels, then deployment will be considered successful.
6.3.2.1 – Deployment of Rover	Rover must be extracted from rocket.	In lab testing will ensure that the system works. Visual confirmation on after launch.
6.3.2.2 – Rover Deployment Platform	Rover must turn and leave rover plate.	<p>In lab testing to insure rover is able to turn.</p> <p>Tracks must run in opposite directions for specific amount of time. Visual confirmation of the rover turning.</p> <p>Accelerometer will record rover motion to check if it has left the rover plate.</p>



## 7 - Conclusion & Recommendations

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The 2017-2018 Frozen Fury team's enthusiasm has remained very high. In November, we had our scale launch. It was successful on our first attempt, it had been six years since the last time the scale launch was launched successfully on its first attempt. The team is on schedule. What remains to be done is building and testing of the rover and its deployment system. Fabrication of the full-scale rocket will begin. Recovery subsystem testing will also see more attention in the coming months.

A recommendation would be to start fabricating as soon as possible, to ensure maximum time for testing. During testing issues always arise and things can happen that can cause delays, we want to be sure that we have time to deal with these problems and solve them before launch day in April.