UNIVERSITY OF SOUTH FLORIDA

NASA Student Launch 2017

Critical Design Review

January 12, 2018

SOCIETY OF AERONAUTICS AND ROCKETRY

4202 East Fowler Avenue MSC Box 197

Tampa, Florida 33620

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1 Team Summary

1.1 Team Name & Mailing Address

Society of Aeronautics and Rocketry (SOAR) at University of South Florida (USF)
4202 East Fowler Avenue MSC Box 197
Tampa, Florida 33620

1.2 Team Personnel

1.2.1 Team Mentor, NAR/TRA Number and Certification Level

Team mentor: Jim West, Tripoli 0706 (Tripoli advisory panel member), Certification Level 3, 863-712-9379, jkwest@tampabay.rr.com

1.2.2 Team Academic Advisor

Team academic advisor: Dr. Manoug Manougian, Professor & Director of STEM Education Center, 813-974-2349, manoug@usf.edu

1.2.3 Safety Officer

Team Safety Officer: Kevin Kirkolis, Sophomore Undergraduate, Mechanical Engineering, 708-217-3737, kirkolis@mail.usf.edu

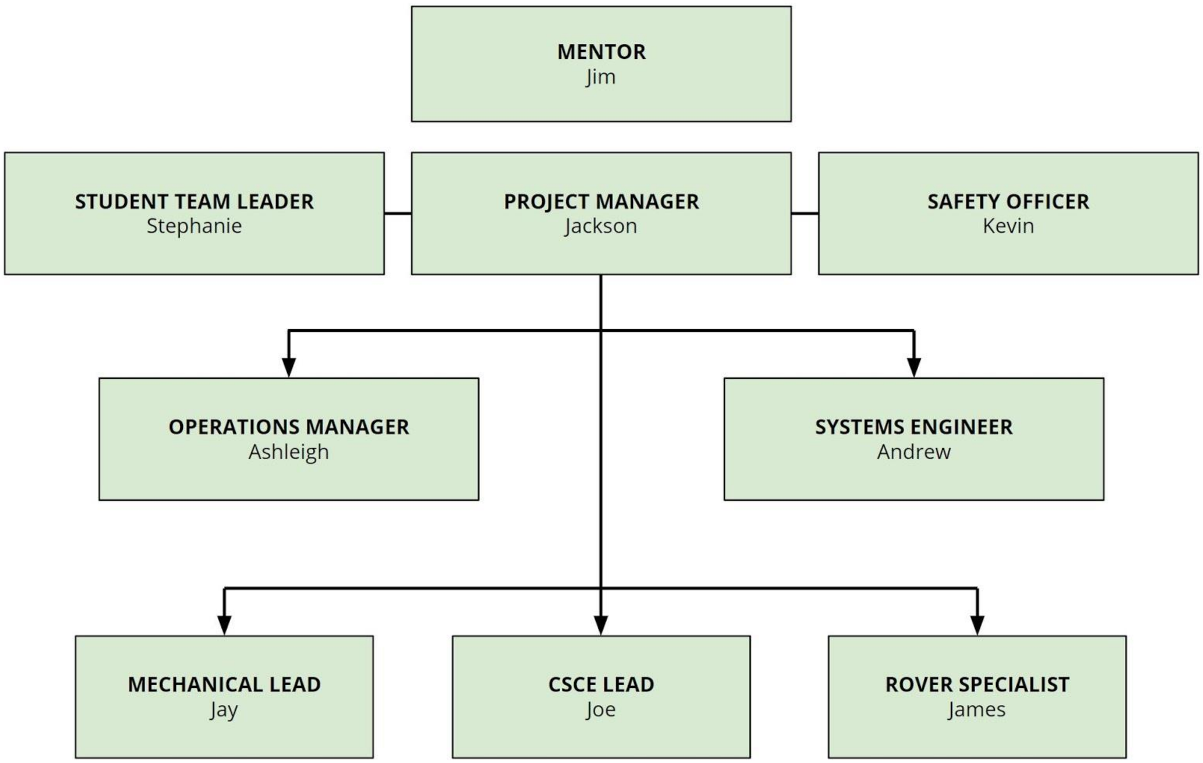
1.2.4 Student Team Leader

Student Team Leader: Stephanie Bauman, Junior Undergraduate, Physics, 334-549-9144, sbauman1@mail.usf.edu

1.2.5 Team Structure and Members

1.2.5.1 Team Leadership and Organization Chart

Figure 1: Team organization chart.



1.2.5.2 Team Members

SOAR's 2018 NASA Student Launch Initiative Team consists of approximately 25 members, including the leaders listed above in the organizational chart. Additionally, team members are also organized under the functional teams detailed below.

Table 1: Functional teams and descriptions.

Functional Team	Team Lead	Description
Rocketry Team	Kevin Kirkolis	Rocketry Team is responsible to design, build, test, and modify launch vehicle and all recovery systems.
Rover Team	Javian Hernandez	Rover Team is responsible to develop, design, test, and prepare the rover payload system, as well as the rover deployment system. The team will implement all mechanical, electrical, and

		computer engineering designs and systems necessary for a rover that meets all design criteria.
CSCE Team	Joseph Caton	CSCE Team is responsible to design all computer hardware and software needs for the design of the rover and rocket. They will work closely with the electrical engineer lead to ensure system will have continuity. The team lead will remain in close contact with the systems engineer to make sure that all systems function properly.

1.2.5.3 Additional Duties

Additional duties are positions that are functionally designated to better assist the team in accomplishing its goals and requirements.

1.2.5.3.1 Rover Design Specialists: James Waits and Chris Purdie. Primary design stakeholders for rover design.

1.2.5.3.2 Outreach Coordinators: Ashleigh Stevenson and Josh Lowenberg. Develops and organizes outreach events.

1.2.5.3.3 Computer Science Lead: Linggih Saputro. Primary code developer and computer design expert.

1.3 NAR/TRA Affiliates

The Society of Aeronautics and Rocketry at the University of South Florida will seek guidance and collaboration with the Tampa prefecture (#17) of the Tripoli Rocket Association for the designing and construction of this year's NSL rocket. The local TRA chapter also provides a site for our sub-scale and full-scale launches under experienced supervision.

2 Launch Vehicle Summary

SOAR's full scale launch vehicle purchased 5" G10 fiberglass tubing, a nose cone and a 75mm motor mount tube from Wildman Rocketry, a reliable vendor. The bulkheads, fins and centering rings are custom cut from SOAR members using ⅛" structural FRP fiberglass from McMaster-Carr. For the recovery equipment, SkyAngle Classic II 60" and 20", and Fruity Chutes Iris Ultra 36" parachutes will be used with sections of ½" and ¼" tubular Kevlar shock cord. The epoxy variants used on the full scale build will range from standard 30-minute epoxy, epoxy mixed with fine-cut carbon fiber fabric and aeropoxy.

2.1 Size and Mass

Table 2: Launch vehicle size and mass.

Diameter	5.148 in
Length	111 in
Projected Unloaded Weight	26.7 lbs
Projected Loaded Weight	36.8 lbs
Projected Fully Ballasted Weight	40.2 lbs
Projected Motor	Aero Tech L1420R-P
Airframe Material	Fiberglass

Note: Unloaded and Loaded Weight do not include 0.375 lbs of default removable ballast.

Figure 2: Overview drawing of launch vehicle assembly.

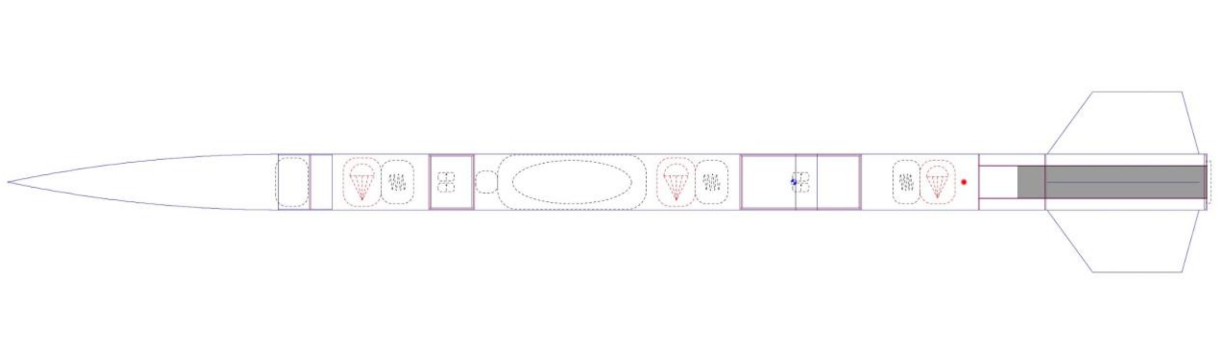
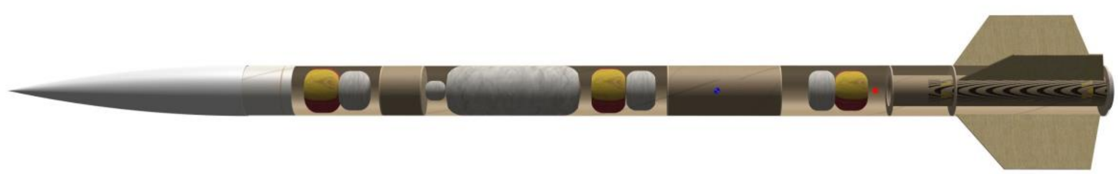


Figure 3: 3D overview of launch vehicle assembly.



2.2 Motor Choice

The final motor decision for use in the full scale launch vehicle are the Aerotech L1420 75mm motor. This motor was chosen because the thrust available guaranteed the launch vehicle to easily exceed the goal apogee of 5,280 feet. To reach the target apogee of 5,280 feet, fine adjustment of projected apogee through alteration of fin design, and the design of a removable ballast system is feasible and possible. Also, these motors, under most configurations exceed the target apogee altitude and, in addition to the adjustable balance system, in our previous experience, the constructed rocket is most often somewhat heavier than the simulated weight due to epoxy and parts not accounted for in the simulation software.

Table 3: Aerotech L1420R-P motor data.

Average Thrust	1420 N
Maximum Thrust	1814 N
Total Impulse	4603 Ns
Burn Time	3.2 s
Case Info	CTI Pro75-4G

2.3 Recovery System

A dual deployment system, activated at apogee, 950 feet, and 800 feet AGL upon descent, will be used to follow NSL guidelines and to accommodate the rocket design. The first parachute deployment will be a drogue at apogee via separation initiated by a black powder charge. There are two main parachute deployments; one at 950 feet to separate the main altimeter bay and booster section and the other at 800 feet to separate the nosecone from the rover compartment airframe. There will be two separate altimeter bays; the main altimeter bay responsible for deploying the drogue and one main, and the payload altimeter bay for the other main parachute. The rocket will use a total of four altimeters, and all will be the Atlus Metrum EasyMini due to their size and ease of use.

2.4 Milestone Review Flysheet

Please see Appendix 14.2.

3 Payload Summary

3.1 Payload Title

The Deployable rover payload has been chosen and will be referred to as the Sidewinder, or Rover payload throughout this document.

3.2 Rover Design Summary

The concept of the Sidewinder came from the need to maximize the space within the payload section of the launch vehicle making more efficient use of it. We referred to an entry into *Journal of Terramechanics* "Experimental study and analysis on driving wheels' performance for planetary exploration rovers moving in deformable soil" and concluded that both a larger diameter and a larger surface area contacted with the ground for our rover wheel is needed . The largest possible diameter the wheels can be is the diameter of the rocket body therefore justifying our "sideways" approach to our design thought process. The sidewinder is compartmentalized to allow for easy access to all components and includes a "newtonian" leg giving better traction to the two wheels.

There are two identified systems and five subsystems within the Rover payload itself. All of which will be discuss in more detail later in this document but for now they are as follows:

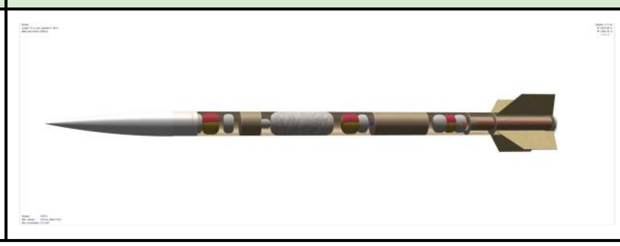
1. Deployment system with subsystems (Brains, Skeleton)
2. Rover Body system with subsystems (Brains, Skeleton, Solar Deployment)

4 Changes Made Since PDR

4.1 Changes Made to Vehicle Criteria

There were major changes to the rocket design submitted in the Preliminary Design Review. During the first build sessions, our mentor made note of the limited and tight space available for recovery equipment. This required a change through increased airframe length. Due to the increased external surface area of the rocket, a major redesign and analysis of the fin design was required to address the new CG and overall weight added, and to address the issue of fin flutter. The Internal Coupling Stage was removed, to simplify the launch vehicle assembly and deployment methods.

Figure 4: Changes to rover compartment design.

PDR Design	CDR Design
	

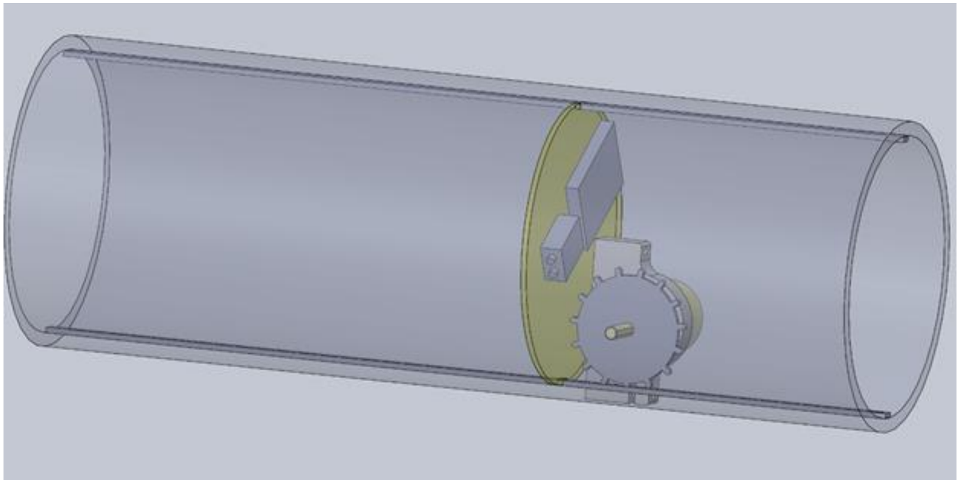
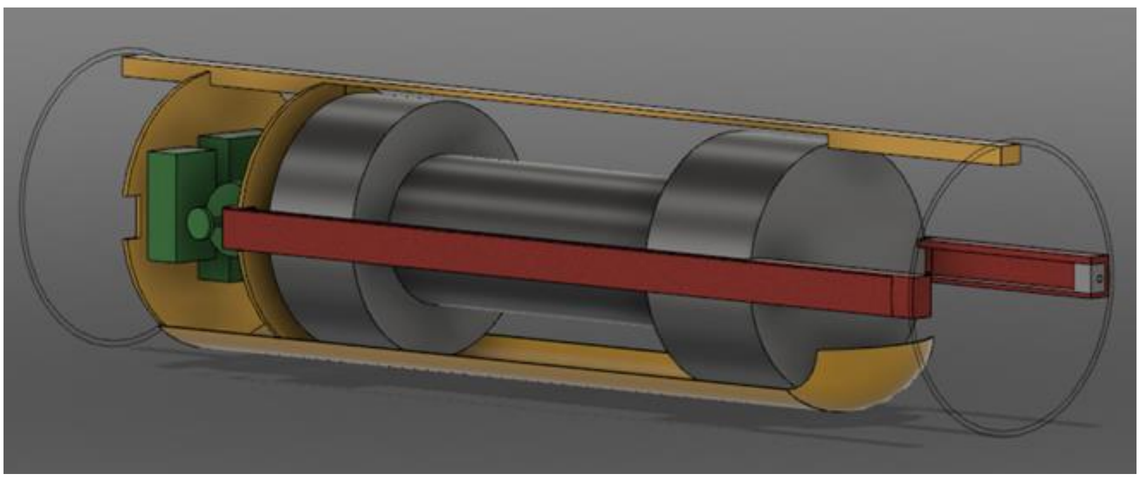
Notice that the CDR design is 17 inches longer than the PDR design and has shortened fins.

4.2 Changes Made to Payload Criteria

There are some changes to the rover payload design submitted in the Preliminary Design Review. Our mission success criteria have been updated to include more specific goals we as a team wish to accomplish.

The previous design for the deployment system involved a gear system which would move along a track that would move the faceplate and rover to the exit of the compartment. This design was deemed functional, but posed some problems that needed to be addressed. Along with the difficulty finding a motor and gear combination that is powerful enough and can fit within the design constraint we referred to a simpler winch and sled type system. It is pictured below and will be discussed more in detail in the deployment system section.

Figure 5: Payload deployment design comparison.

PDR Deployment system design

CURRENT Deployment Design


4.3 Changes Made to Project Plan

Currently, full scale construction is ahead of schedule and is set to launch at the latest date of February 17th. If our choice of motor is available and received in early January, and the rocket is completed then the earliest launch date will be January 20th. With this date in mind, members of the NSL Team are working to finalize construction of the full scale launch vehicle by January 15th.

However, the rover construction is slightly behind schedule, and the test deployment system was not available for the subscale launch. A 3D printed version of the deployment sled has been created, and the design has been fully realized. Additionally, test code has been written for a test rover that is a a functional but not a dimensional facsimile of the final rover. Therefore, the development timeline has been pushed back to begin construction on January 13.

Two of our three planned outreach events were successful but one event had to be rescheduled for sometime in the upcoming weeks. SOAR has finalized a date for our Boy Scout event and have added a new event not included in the PDR but it will occur before submission of the CDR.

Please see Project Plan section for details on updated Project Plan.

5 Vehicle Criteria

5.1 Selection, Design, and Rationale

5.1.1 Mission Statement

The University of South Florida Society of Aeronautics and Rocketry will design and build a rocket and payload, guided by the criteria set forth in the 2018 NASA Student Launch Handbook, that will win one or more categories of award for the 2018 NASA Student Launch Competition, while meeting or exceeding all documentation deadlines and requirements. The chosen payload is a rover, which will be designed to deploy from a section of the rocket, autonomously move at least five feet, and deploy solar panels. Further, the SOAR NSL Team intends to win the following categories: Experiment Design Award, Altitude Award, and Best Looking Rocket. The project will culminate in a successful rocket launch and payload delivery at the official Launch Day in Huntsville, AL. SOAR's participation and success in this competition will further its goal of becoming the preeminent engineering organization at the University of South Florida, recruiting dedicated and talented members to increase our capabilities, and encouraging the University of South Florida College of Engineering to add an Aerospace Engineering Major to its catalog.

5.1.2 Mission Success Criteria

The following table will show the requirements that need to be met in this mission, how we will meet the requirements, and the verification of meeting them.

Table 4: Detailed mission requirements and confirmation methods.

Requirement	Method	Verification	Verification Status
NASA Student Launch Initiative Required Success Criteria			
The vehicle will deliver the payload to an apogee altitude of 5,280 feet above ground level (AGL).	Testing/ Demonstration	The rocket will utilize the Aerotech L1420 motor as the propulsive factor and we can alter the flight path with the adjustable ballast. Current simulations and calculations place apogee between 5271 and 5288 feet, depending on conditions and ballast.	To be tested at full scale launch.

The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the altitude award winner.	Inspection	Rocket will feature four altimeters, capable of deploying charges and recording the flight apogee. NSL Inspection as well as inspected and approved by the safety officer. Full-scale testing, pre-launch checklist.	Operation of selected altimeters verified at subscale vehicle launch. Further testing during full scale launch.
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.	Inspection/ Demonstration	Each altimeter will have an arming switch via an electronic rotary switch. There will be two protruding switches in the switchband of the main altimeter bay, and two inset switches in the payload altimeter bay. All four switches will be visible and physically accessible.	Operation of selected switches verified at subscale launch. Further testing during full scale launch.
Each altimeter will have a dedicated power supply.	Inspection	One standard 9V Alkaline batteries will be configured to each altimeter and be sufficient in supplying power to enable function. During subscale launch testing, each altimeter was connected to a separate 9-volt battery, which were tested prior to flight, and both altimeters initiated the charges reliably at the correct altitudes.	Operation of selected batteries verified at subscale launch. Further testing during full scale launch.
Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).	Testing/ Inspection	There are two settings to the electronic rotary switch. The switch itself has small mechanical components that allow it to remain in its set position. During subscale launch testing, rotary switches that lock in the "ON" position were used, and were in the "ON" position during recovery.	Operation of selected switches verified at subscale launch. Further testing during full scale launch.
The launch vehicle will be designed to be recoverable and	Testing/ Demonstration/ Inspection	The launch vehicle will contain parachutes on every separate or tethered part of the rocket	Full scale testing to be conducted.

reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.		that will be released at apogee, 950 feet, and 800 feet that will allow it time to open up properly and safely. During subscale testing, the parachutes intended for use in the final design were not available for use, so no relevant data was available regarding the descent time and rate. This will be gathered during full scale testing.	
The launch vehicle shall have a maximum of four (4) independent sections.	Inspection	The rocket will be broken up into four sections: the nose cone, rover compartment, main altimeter bay, and the booster section. The nose cone and rover compartment will be tethered together, as will the altimeter bay and booster. Subscale launch vehicle constructed to these specifications. Full scale designed to same specifications.	Subscale construction complete. Full scale construction nearly complete.
The launch vehicle shall be limited to a single stage.	Inspection	Launch vehicle will contain only one motor to light and start the flight. Subscale launch vehicle constructed to these specifications. Full scale designed to same specifications.	Subscale construction complete. Full scale construction nearly complete.
The launch vehicle shall be capable of being prepared for flight at the launch site within 3 hours, from the time the Federal Aviation Administration flight waiver opens.	Testing	There will be Final Assembly and Launch Procedure Checklist before the test flights of the subscale rocket and the full-scale rocket that will be timed to ensure we complete the list safely and within the time of 3 hours. During subscale launch, launch vehicle preparation was completed in less than two hours.	Subscale launch testing complete. Full scale launch to be conducted.

The launch vehicle shall 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 component.	Testing	The launch vehicle and the electronic components within will be properly connected and sealed to prevent anything from causing it to disconnect or be damaged. The batteries will have a life long enough to be at the launch pad for an hour without losing any power. Subscale rocket remained on pad for 30 minutes and performed properly.	Subscale launch testing complete. Full scale launch to be conducted.
The launch vehicle shall be capable of being launched by a standard 12-volt direct current firing system.	Demonstration	The ignitor used in the rocket will be able to withstand a 12-volt DC firing system. Firing system used during subscale launch was 12-volt DC. Full scale launch vehicle designed to same specifications.	Subscale launch testing complete. Full scale launch to be conducted.
The launch vehicle shall require no external circuitry or special ground support equipment to initiate launch.	Inspection/ Demonstration	The only required external circuitry will be the 12-volt direct current firing system that is compatible with the ignitor in the launch vehicle. During subscale launch, no external circuitry or special ground support equipment was used. Full scale launch vehicle designed to same specifications.	Subscale launch testing complete. Full scale launch to be conducted.
The launch vehicle shall 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	Inspection	The motor being used in the launch vehicle will be a Aerotech L1420, which is certified by the National Association of Rocketry and it made of ammonium perchlorate.	Aerotech L1420 motors have been ordered.

Canadian Association of Rocketry (CAR).			
Pressure vessels on the vehicle shall be approved by the RSO and shall meet the following criteria.	Inspection	Our design does not contain a pressure vessel.	Verified with submission of Project Proposal.
The total impulse provided by a University launch vehicle shall not exceed 5,120 N·s.	Inspection	The motor chosen is not bigger than an L class motor and has a total impulse of 4603 N-s.	Inspection of manufacturer's specifications complete.
The launch vehicle shall have a minimum static stability margin of 2.0 at the point of rail exit.	Analysis/ Demonstration	The center of pressure and the center of gravity in comparison to the diameter of the body tube will have a minimum stability margin of 2.0. Current simulations for configurations under consideration place stability margin between 3.14 and 3.65 calibers. When launch vehicle is complete, it will be physically balanced to verify data.	Analysis complete. Full scale balance to be completed.
The launch vehicle shall accelerate to a minimum velocity of 52 fps at rail exit.	Analysis/ Demonstration	The motor that was chosen for the rocket will allow the rocket to achieve a minimum of 52 fps at rail exit. Current simulations for configurations under consideration place velocity at rail exit at 65 fps.	Analysis complete. Full scale testing altimeter data will verify.
All teams shall successfully launch and recover a subscale model of their rocket prior to CDR.	Demonstration	SOAR will have a subscale model ready and launched prior to CDR.	Verified on 12/16/17 the date of the subscale launch.
All teams shall successfully launch and recover their full-scale rocket prior to FRR in its final flight	Demonstration	The full-scale rocket will be built and launched as well as recovered prior to the FRR and it will be the same rocket flown on launch day.	Full scale testing to be completed.

configuration. The rocket flown at FRR must be the same rocket to be flown on launch day.			
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.	Inspection	There are no external or protruding components from the payload.	Verified through submission of CDR.
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.	Demonstration	We have ordered both the Aerotech L1420 and Cesaroni L1350 which are both similar in thrust characteristics. Our prefered motor is the Aerotech L1420 but if it does not arrive in time we will use the Cesaroni L1350.	Aerotech L1420R-P motors have been ordered. Cesaroni L1350 motors will be ordered if necessary.
The vehicle must be flown in its fully ballasted configuration during the full-scale test flight.	Inspection	The completed payload or equivalent simulated weight will be used in the full-scale test flight.	
USF SOAR Success Criteria			

Vehicle will have modular capability to adjust to wind conditions to reach 5,280 feet under all conditions.	Design/ Analysis/ Demonstration	Launch vehicle will incorporate removable ballast system and calculation sheet will be developed to enable the team to adjust the amount of ballast on the day of the launch. This system is still under development and not included as a design in this report. Apogee and stability for all conditions will be calculated for all potential ballasted weights using OpenRocket software. Properly ballasted configuration will be tested during full scale and subscale launches.	Design complete. Analysis complete. Full scale launch to be completed.
The launch vehicle will separate into two tethered, deployable parts to satisfy the intended design concept.	Demonstration	Numerous ground tests with specific shear pin configurations will be used to determine the appropriate mass needed for charges and the type and amount of shear pins. During the full scale flight, the rocket will separate, with visual confirmation, into two distinct parts with a safe distance between them; the nose cone and rover compartment, and the main altimeter and booster section. During subscale testing, there were some complications as detailed in the subscale flight section. Adjustments will be made to separation charges and shear pins.	Subscale testing complete. Full scale launch testing to be completed.

5.2 Mass Statement

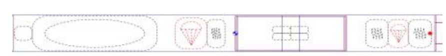
Please see Appendix 14.3 for detailed mass statement

5.3 Selected Design Elements and Justification

5.3.1 Altimeter Bay

The Internal Coupling Stage was removed from the rocket design. Through a discussion with the mentor, and thoughtful design consideration, it seemed reasonable to eliminate the need for a separate coupler (fixed to the main altimeter bay) and 3D printed piston system. To account for these component removals, the rover compartment airframe and the main altimeter bay were extended in length to add structural support.

Figure 6: A design comparison of the deployment systems above the main altimeter bay.

PDR Design	CDR Design
	

The PDR design is the Internal Coupling Stage on the left. Within this stage are the 3D printed system, shock cord and one of the main parachutes. The CDR design on the right shows a longer main altimeter bay (12 inches) with an extended switchband (2 inches).

5.3.2 Fin Design

Concern with fin flutter was present in the PDR fin design due to the high wing area with the current thickness of the fins. Although the fins are ⅛" structural fiberglass, fin flutter calculations such as NACA's Flutter Boundary and revised Trapezoidal equations were used to analyze alternatives.

Table 5: Detailed mission requirements and confirmation methods.

NACA Flutter Boundary	Trapezoidal
$V_f = a\sqrt{\dfrac{G}{\dfrac{1.337AR^3P(\lambda+1)}{2(AR+2)(\frac{t}{c})^3}}}$	$V_f = 1.223\underbrace{\left[C_s\sqrt{\frac{P_0}{P}}\right]}_{a}\underbrace{\left[\sqrt{\frac{G}{P_0}}\sqrt{\left(\frac{T}{B}\right)^3\left(\frac{2+B}{1+\lambda}\right)}\right]}_{f}$

Figure 5: The NACA Flutter Boundary equation was used in an academic article detailing a high-altitude rocket and weather balloon project.

The results of these equations show the maximum velocity that the fins can endure before compromising structural integrity. The projected fin flutter velocity for the fin design with the dimensions of 14” root chord, 6” tip, 8” height and 5.82” sweep length was 440 feet per second. The rocket design with theses fin dimensions experienced a max velocity of 733 feet per second. The rocket’s velocity exceeds 440 feet per second, rendering the current design unacceptable and unsafe for flight. Two alternatives were evaluated and considered for this problem.

Doing a Carbon Fiber fabric overlay on the fins will buff the thickness to approximately 3/16 (0.1875) inches. Increasing the fin thickness under the same fin dimensions estimates the fin velocity to be limited at 806 feet per second, which would withstand the projected max velocity of 793 feet per second.

Table 6: Pros and cons of 3/16 inch fins.

Pros	Cons
Integrating a Composite Material	Adds Considerable Time to Construct
Superior Strength	Requires Precise Techniques and Detail
Valuable Build Experience	Needs Additional Build Materials

Fin height plays into fin flutter analysis and its equations. The height will affect the geometry of the fins, alter the wing area, and affect the tip-to-chord and aspect ratio. By shortening the fin height by 2 inches, from 8” to 6”, the tip chord changes from 6” to 8” and the sweep length decreases from 5.82” to 4.37”. If the fins are kept at ⅛” thickness and the height is decreased by 2”, the the fin velocity is projected at about 755 feet per second. OpenRocket simulations with this fin design estimated the max velocity to be at about 788 feet per second. This specific fin design has minimal clearance but can be proven safe for flight.

Table 7: Pros and cons of 1/8 inch fins.

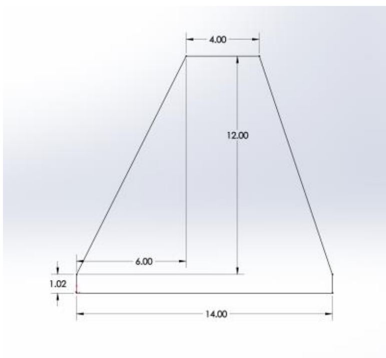
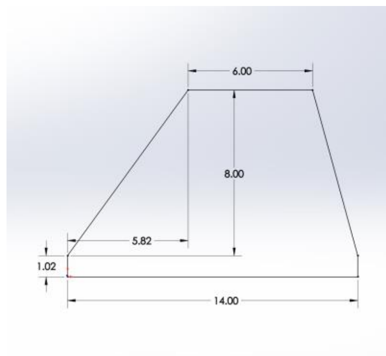
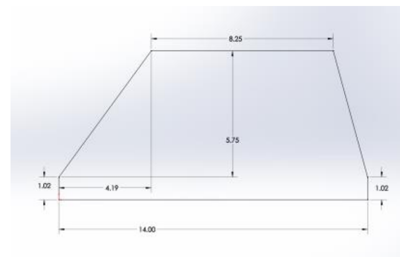
Pros	Cons
Easy to Manufacture and Build	Material Not As Strong as 3/16” FG or Carbon Fiber Overlay
Accelerates the Production Timeline	

After evaluating the alternatives to the fin design, it was decided to forgo increasing the thickness and instead, shortening the height of the fins while maintaining the thickness at ⅛”. This was primarily done with the goal of completing full scale construction for a test launch in January, and to repeat the reliable build processes used for the subscale.

As mentioned above, the specific dimensions of the modified sections of the rocket are as follows;

1. Rover Compartment Airframe - extended 15.75 inches, 32” to 47.75”
2. Main Altimeter Bay - extended 2 inches, from 10” to 12”
3. Switchband on the Main Altimeter Bay - extended 1 inch, from 1” to 2”
4. Payload Altimeter Bay - extended 1 inch, 3” to 4”

Figure 7: Transitions of fin designs.

<table>
<tr><th>PDR Design</th><th>Initial CDR Design (Pre Fin Flutter Analysis</th><th>Final CDR Design (Post Fin Flutter Analysis)</th></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
</table>

The above are schematics of fin design based upon parameters of root and tip chord, height and sweep length. The recessed area that is 1.02” long was kept constant throughout all fin designs. The forward facing side of the fin is on the left for each design

The final dimensions of the fin design are as follows, an extra ¼” was cut off the 6” height under the notion that ideal conditions are rare therefore adding safety despite our calculations checking out;

1. Height (From Exterior Airframe Surface) - 5.75”, 6” before cut
2. Root Chord - 14”
3. Tip Chord - 8.25”, 8” before cut
4. Sweep Length - 4.19”, 4.37” before cut

With these specific dimensions after the additional ¼” cut, the projected fin flutter velocity ranges from 806 to 809 feet per second. The max velocity of the rocket under this fin design given the dimensions above is 748 feet per second. The disparity between max fin flutter and vehicle velocity is desirable and preferable to accommodate safety standards.

5.3.3 Removable Ballast System

In order to maximize the potential for reaching exactly 5280 feet for the competition launch under any conditions, an adjustable ballast system has been designed that it can be loaded in the nose cone shoulder. If maximum ballast is needed, it is designed in such as way that it can be added in a balanced manner such that the stability margin remains between three and six calipers, preferably in the lower portion of that range.

The ballast system is designed as several layered circular modular elements that stack on top of each other. The system is made of 3D printed layers and removable 1-ounce weights. The system is also broken up into three different sections. The first section accounts for the presence of the bulkhead's U-bolt. It is comprised of 2 layers each 0.35" tall, and 4.3" in diameter. The second section is composed of 11 layers each 0.4" tall and 4.3" in diameter. The third section is the final capping layer. It is a slightly smaller diameter as the nose cone shoulder at 4.7" and is designed to secure the first two sections and the entire nose cone ballast system to the respective bulkhead with ¼" threaded rods with lock nuts at one end and wing nuts on the other.

The design of the ballast system layers are pictured below. The first section can hold a total weight of 8-ounces (0.25 pounds), 4-ounces in each layer and the second section can hold in total weight 66-ounces, with 6-ounces (0.375 lbs) in each layer. The third section is designed to not hold any weight. The entire ballast system stands 5.35" tall.

Under the worst environmental conditions permitted (20 mph winds), the ballast system will be loaded with 0.375 lbs of ballast, given that the payload rover weighs exactly 10 lbs. Default loaded weight will be adjusted based on the final verified weight of the rover and further full scale testing. Further adjustable ballast will be added in accordance with the reference table in Table 18.

Figure 8: Section one of ballast system (2 layers).

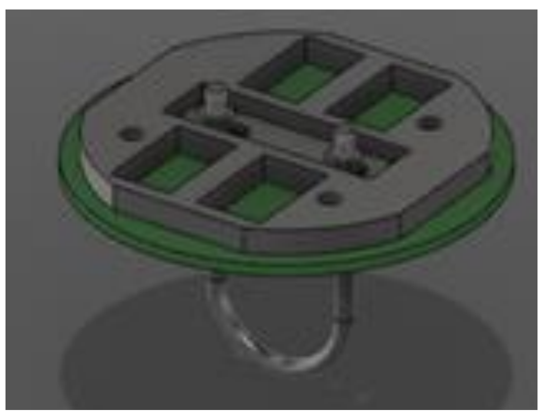


Figure 9: Section two of ballast system (11 layers).

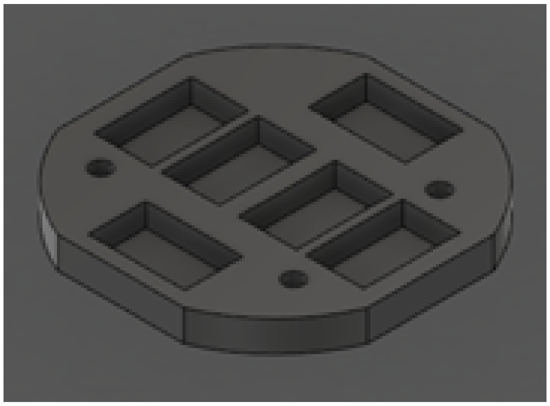


Figure 10: Section three of the ballast system (1 layer).

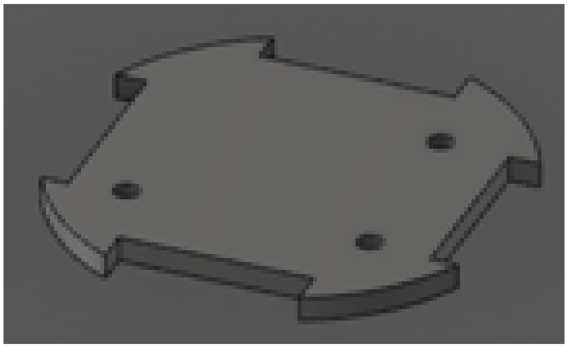
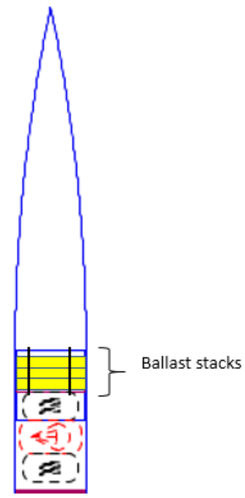


Figure 11: Assembled ballast system.

Figure 12: Installed ballast system.



5.3.4 Booster Section

The booster section is composed of the 5" x 5.148" airframe, fins and the 75mm inner motor mount. The motor mount will be secured to the inside of the airframe using three ⅛" fiberglass center rings (approximately ID: 2.95" x OD: 5") with carbon fiber epoxy fillets and joints. The fins will be ⅛" fiberglass sheets as well, and will be cut with respect to the outer airframe diameter (5.148", or 2.574" from center) in measurements to tip and root chord, sweep length and height. The fins will have a recessed area equivalent to the root chord, and approximately 26 mm (about 1") deep that will be secured to the motor mount with carbon fiber epoxy fillets and the centering rings described above. The final specifications of the fins after fin flutter analysis will leave the root chord at 14", but the new height (from external airframe) to be 5.75", the tip chord at 8.25". The booster section is 36" long, with the motor mount at 21" long. This subsystem is tethered to the main altimeter bay with a 30' length of ½" tubular kevlar shock cord, and deploys a 20" drogue parachute at apogee via a black powder charge from the lower half of the main altimeter bay.

5.3.5 Main Altimeter Bay

The main altimeter bay houses 2 of 4 on-board altimeters to control deployment and separation, and acts as a critical coupling component to the entire launch vehicle. The main altimeter bay is a 4.753" x 4.987" fiberglass tube, and is 12" long. The bay will be capped with bulkheads composed of two layers (one with 4.987" diameter, the other with 4.753" diameter) of ⅛" fiberglass. There will be three vertical slots cut (separated by 3.9175" on the circumference of the outer coupler wall) to extend the channels of the deployment system to the end of the airframe The main altimeter bay will use the Atlus Metrum EasyMini altimeters, and will detonate black powder charges at apogee and at 950 feet upon descent. The first charge at apogee will disconnect the 2-56 size shear pins securing the booster section to the lower half of the altimeter bay, deploying the drogue parachute. At 950 feet upon descent, the second wave of charges will detonate and separate from the Rover Compartment airframe and deploy the Fruity Chutes Iris 36” main parachute and 20 feet of ¼” tubular kevlar shock cord used for the booster section and main altimeter bay.

5.3.6 Payload - Deployable Rover

The rover is based on the Sidewinder design and is detailed in a separate section. The main justification for the design sideways-loading design is to maximize the wheel diameter to be the same as the internal diameter of the cargo area. The wheel base is only limited by the length of the cargo area.

5.3.7 Rover Compartment

The rover compartment is the section of airframe that houses the rover, payload altimeter bay and electronics, payload deployment system, and the recovery hardware used for both this subsystem and the nosecone. This airframe is 45.75” long and will be secured to the rocket with shear pins to the upper half of the Main Altimeter Bay. The payload altimeter within the rover compartment is secured in an area between 14” to 18” from the top of this airframe. Below this is the payload deployment system, a winch and sled system will use a small high torque stepper motor to wind a set of small cords attached to the exit end of the payload compartment, which will propel the motor, faceplate, and rover out of the tube. This deployment system, will be held motionless inside the payload compartment during launch by a set of push/pull solenoids that will act as pins holding the deployment system and rover inside the body compartment until the ejection sequence is triggered. The nose cone, Rover Compartment airframe, Payload Altimeter Bay, the payload, and the recovery equipment stored in between the nose cone and Payload Altimeter Bay, are designed to separate from the Main Altimeter Bay and Booster Section.

5.3.8 Payload Altimeter Bay

The Payload Altimeter Bay is a unique and important subsystem for the Deployable Rover payload. This altimeter bay is the same type of coupler as the Main Altimeter Bay (ID: 4.753” x OD: 4.987”) and will house the other two Altus Metrum EasyMini altimeters. These altimeters will control black powder charges programmed to detonate at an altitude lower than the main parachute deployment in the Main Altimeter Bay, to avoid issues with shock cord entanglement and to separate the tethered sections. The bay will be capped with bulkheads composed of two layers (one with 4.987” diameter, the other with 4.753” diameter) of ⅛” fiberglass. The altimeter bay will be secured in place using a combination of ¼-20 t-nuts and screws. This arrangement will allow the Payload Altimeter Bay to be easily accessible and fixed during flight. The top bulkhead will have the ejection canisters responsible for deploying the SkyAngle Classic II 60” parachute and the 20 feet of ½” tubular kevlar shock cord at a height of 800 feet.

5.4 Design Summary and Dimensional Drawings

The design of the launch vehicle is 111 inches long and weighs 27.2 pounds with no motor equipped, and the minimal ballast of 0.375 pounds arranged. Below is a detailed depiction of the rocket and its components. See Appendix 14.3 for a detailed mass statement.

Figure 13: Launch vehicle body components and dimensions.

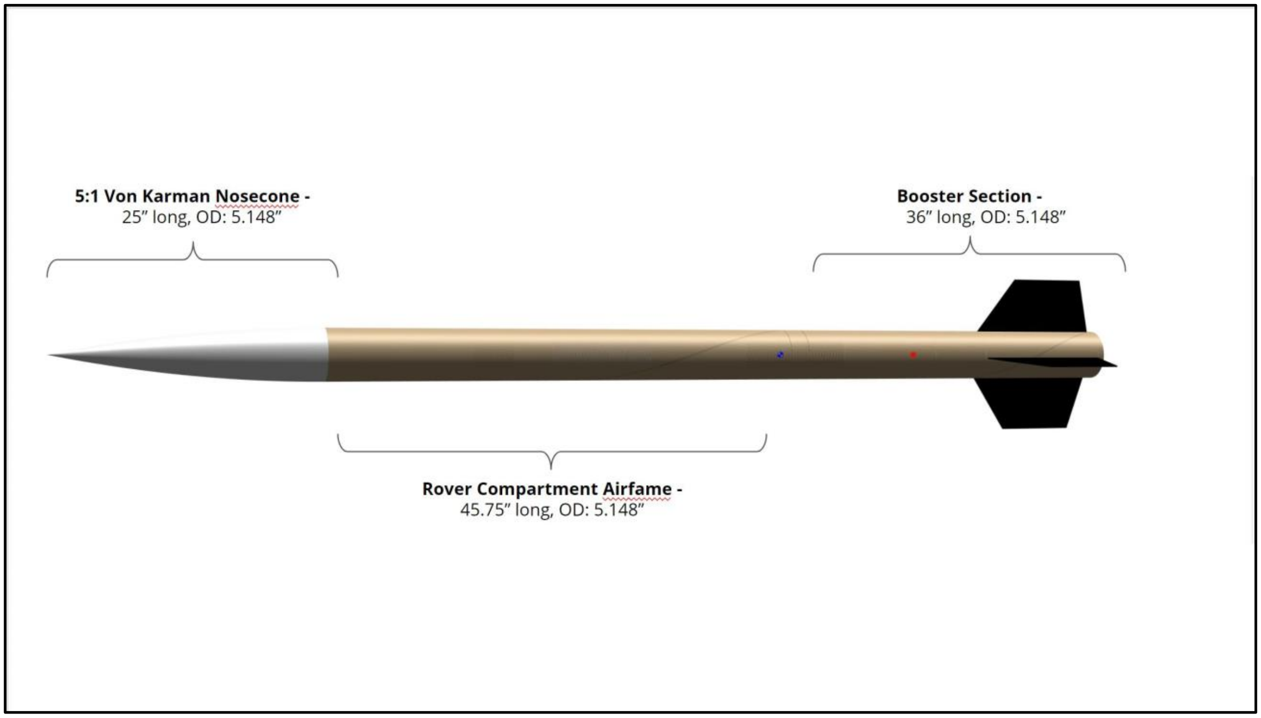
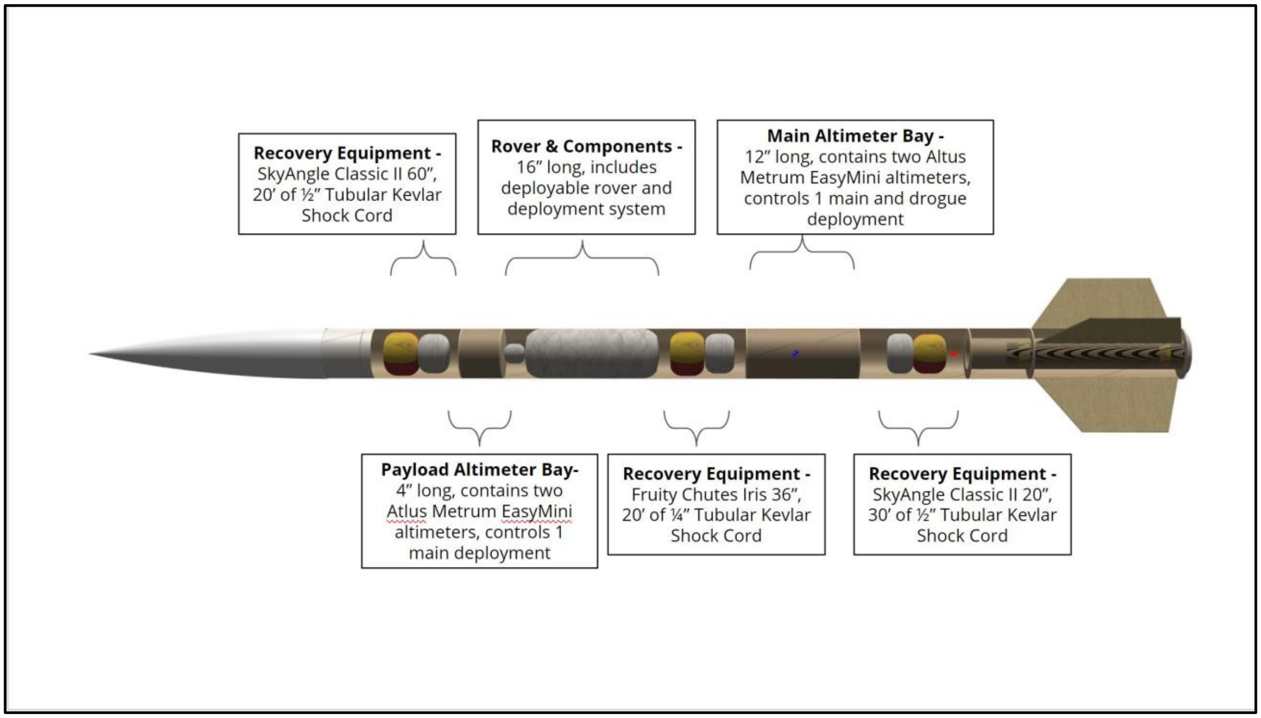


Figure 14: Launch vehicle functional components.



5.5 Production Readiness

5.5.1 Manufacturability

All of the manufacturing of the launch vehicle requires standard equipment, processes, training, and tools. No specialized, non-standard, or currently unavailable tools or equipment are necessary to complete the design as presented in this report. See Appendix VIII for full list of equipment, tools, and supplies that have been received, that have been ordered and approved, or are available for use to SOAR. Additionally, see below the current construction of the launch vehicle in our on-campus workshop.

Figure 15: Mentor Jim West and Systems Engineer Andrew Sapashe talk about assembly of the payload altimeter bay.

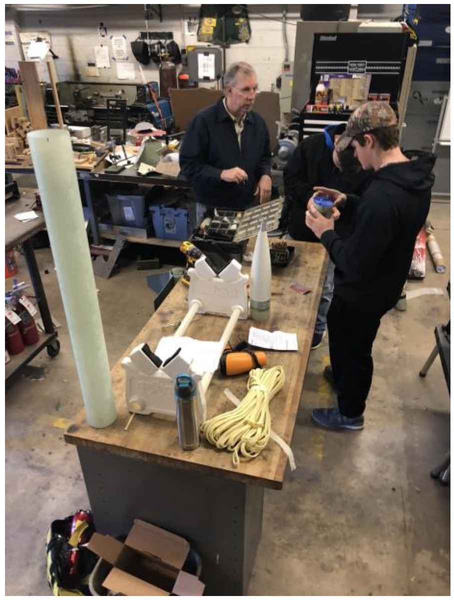


Figure 16: Oskar Boer and Jackson Stephenson work on the motor mount fillets

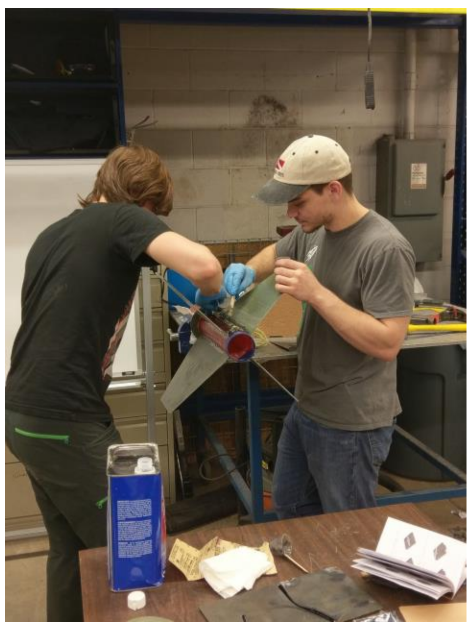


Figure 17: Sam works at sanding the fiberglass bulkheads to be flush with the G12 coupler.

5.5.2 Documentation Package

As evidenced throughout this package, sufficient documentation, including Solidworks drawings, OpenRocket drawings, safety checklists, bills of material, and photo documentation have been gathered that will allow the team to successfully build the final version of the launch vehicle.

5.5.3 Quality and Test Plan

Quality: All components of the launch vehicle are inspected by the Project Manager or Team Leader prior to being installed on the launch vehicle. All work conducted by team members is also inspected by the Project Manager or Team Leader after completed. Functional analyses such as fin flutter analysis and parachute descent rates are conducted to ensure materials are appropriate for the application.

Testing: As detailed in this report, both subscale and full scale ground and launch testing of the launch vehicle has and will be conducted to ensure that each component is appropriate for the application and that the launch vehicle operates as predicted.

5.6 Integrity of Design

5.6.1 Suitability of shape and fin style for mission

The current fins are ⅛" Structural FRP fiberglass manufactured by McMaster-Carr. A fin flutter analysis was requested due to the thickness of the material. After calculations using three different equations for reference, it was decided that a fin height (from the external surface of the rocket) needed to be 5.75" in order to be sufficient in withstanding high fin flutter velocity. The fin flutter velocity of the final design is 217 m/s (712.3 fps). The final rocket motor selection is the Aerotech L1420. In order for the rocket to keep its max velocity below 217 m/s, the ballast needs to be at least 14 pounds. The simulations depict the rocket able to reach an apogee of over a mile even with 20 pounds. This new shortened fin style allows more payload weight and other forms of ballast to be in the rocket, and ensures the vehicle will be capable a target height of 5,280 feet. The full scale launch in January or February will give more data and insight as to how much removable ballast needs to be used to get to a mile apogee as close as possible.

5.6.2 Proper use of materials in fins, bulkheads, and structural elements

The material used for the fins, bulkheads and centering rings is Structural FRP Fiberglass (⅛" thickness). This material is comparatively lightweight for its strength, making it a good option to use in critical structural components while minimizing excess weight. The tensile strength and compressive strength are at 24,000 psi, and the flexural strength rests at 35,000 psi. This fiberglass type offered by McMaster-Carr, is non-conductive and can withstand temperatures up to 140 degrees Fahrenheit.

5.6.3 Sufficient motor mounting and retention

A 75mm G12 fiberglass tube and three ⅛" centering rings (ID: 2.95" & OD: 5") are to be attached together using an application of carbon fiber epoxy. The centering rings are positioned (from the aft forward) 0.125", 14.75" and 21" from the base of the motor mount. A 75mm flanged motor retainer will be fixed to the base centering ring using an array of 4-40 stainless steel screws. The motor mount will be fixed to the airframe using 14.75" fin slots. There will be a recessed space 0.125" inside from the base of the airframe, to limit the protrusion of the motor retainer. Aeropoxy is applied first to the motor retaining centering, binding the points of contact. Carbon fiber epoxy fillets are applied to the root chord of the fins and added as a extra fillet for the motor retaining centering rings. Aeropoxy fillets are also applied to where the fins meet the external surface of the airframe.

5.7 Final Mass Estimate

Table 8: Final mass estimate.

System Name	Projected Weight (pounds)
Loaded Rocket (motor & max ballast)	37.202
Nosecone (bulkhead & minimum ballast configuration)	2.99
Rover Compartment (airframe, payload altimeter bay & rover)	13.964
Booster Section (airframe, motor mount & recovery equipment)	6.522

Main Altimeter Bay (G12 coupler, bulkheads, altimeters & recovery equipment)	1.824
Parachutes	1.802
Aerotech 75mm L1420 Motor (Total / Propellant)	10.1

5.8 Other Components Justification

Due to the limited room available in the Payload Altimeter Bay (294.5 in^3, compared to the Main Altimeter Bay at 922.8 in^3), different types and sizes of altimeter sleds were considered to allow space for flight computers, batteries, wires and other electrical components used within these bays. Normally, the sleds are fixed to the threaded rods, that secure the bulkheads against the coupler, vertically. However, a design that would position the altimeters and electronics horizontally would maximize space while allowing functionally of these critical systems. The new sleds were designed on SolidWorks and printed using a high infill of ABS plastic, making them strong and printed to design accurately. The design is essentially a ⅛" thick disc with special cutouts on the perimeter to make room for any wires or fasteners if needed.

6 Subscale Flight Results

6.1 Subscale Flight Data

Table 9: Subscale flight 1 - Cesaroni 54mm 3G K740.

Device - EasyMini, Version 1.6.8, Serial 3365			
Flight	1		
Flight Time	86.3 sec		
Maximum Height	958.8 m	3146 ft	
Maximum Speed	122.1 m/s	401 fps	Mach 0.4
Maximum Boost Acceleration	26.9 m/s^2	88 ft/s^2	2.74 G
Average Boost Acceleration	11.7 m/s^2	38 ft/s^2	1.19 G
Ascent Time	3.7 sec (Boost)	10 sec (Coast)	

Drogue Descent Rate	14.6 m/s	48 fps	
Main Descent Rate	10 m/s	33 fps	
Descent Time	48.8 sec (Drogue)	23.7 sec (Main)	

Figure 18: Subscale flight 1 altimeter data.

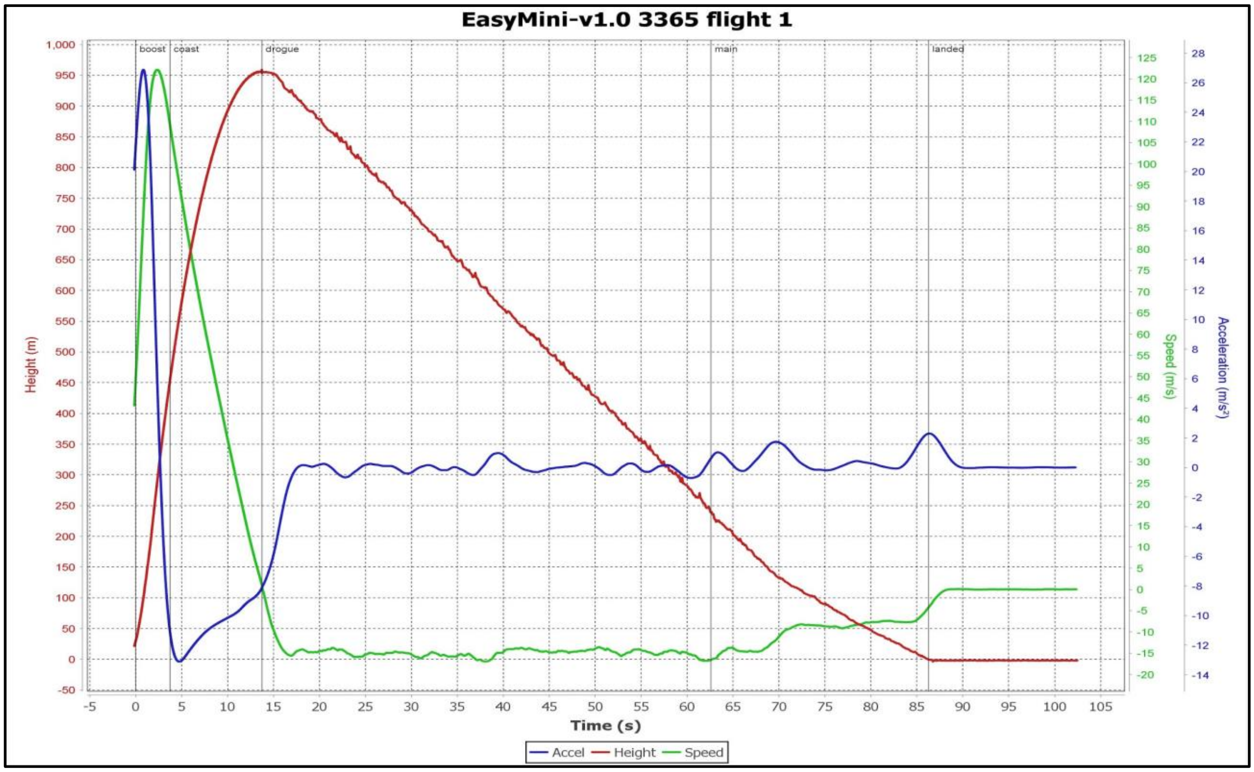
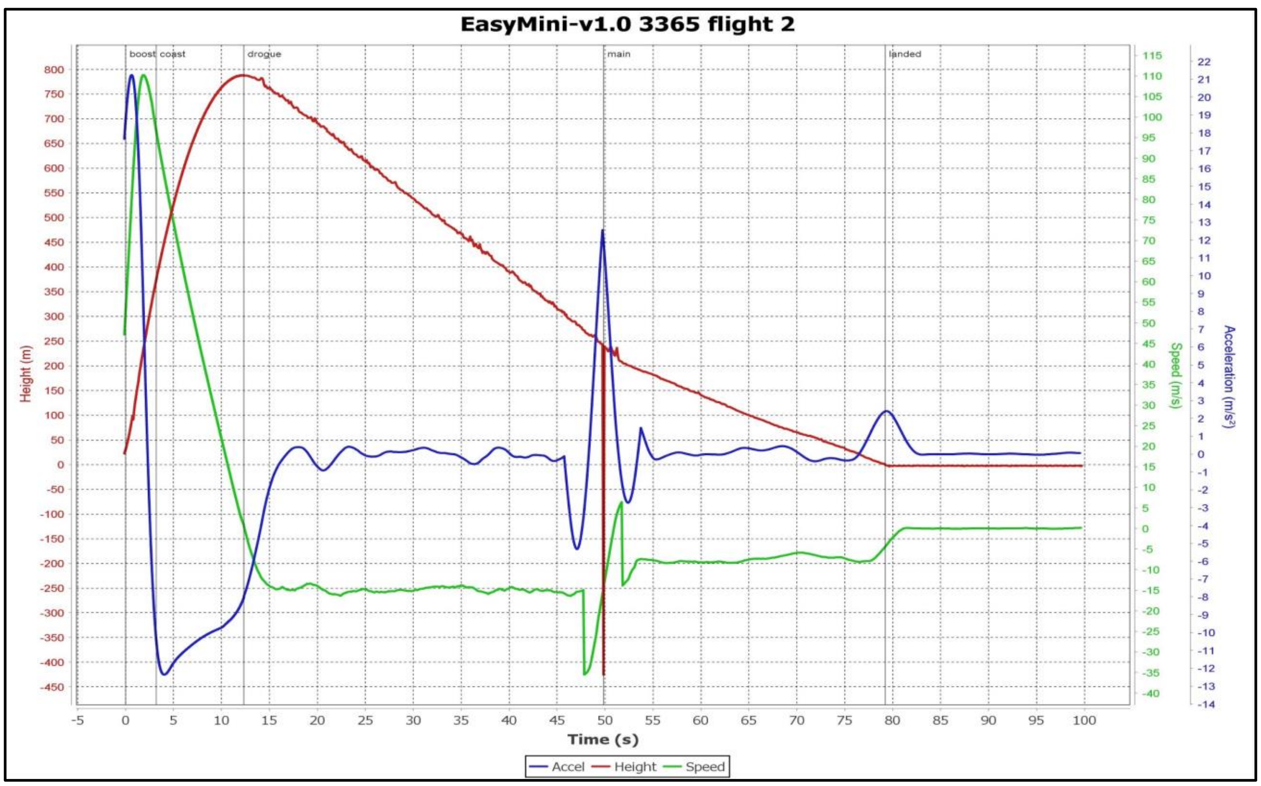


Table 10: Subscale flight 2 - Cesaroni 54mm 3G K940.

Device - EasyMini, Version 1.6.8, Serial 3365			
Flight	2		
Maximum Height	788.4 m	2587 ft	
Maximum Speed	110.2 m/s	362 fps	Mach 0.3
Maximum Boost	21.2 m/s^2	70 ft/s^2	2.17 G

Acceleration			
Average Boost Acceleration	11.7 m/s^2	38 ft/s^2	0.95 G
Ascent Time	3.2 sec (Boost)	9.1 sec (Coast)	
Drogue Descent Rate	15.2 m/s	50 fps	
Main Descent Rate	7.3 m/s	24 fps	
Descent Time	37.5 sec (Drogue)	29.4 sec (Main)	
Flight Time	79.2 sec		

Figure 19: Subscale flight 1 altimeter data.



6.2 Comparative Subscale Variables

The 4" tubing supplied the nose cone, fiberglass tubing, centering rings (ID: 2.95" x OD: 4"), and couplers. The G12 5" airframe used for the full scale in relation to the 4" launch vehicle creates a scaling ratio of 4:5. The motor selected for the subscale was chosen to be a Cesaroni 4G 54mm K740, as it was the strongest 4G 54mm motor available through our supplier. It was most important to maintain a size relationship among the launch vehicle components, and allow the weight to vary as necessary to obtain a close relationship between thrust to weight ratio between the subscale and full scale. Additionally, the nosecone shape was maintained between the subscale and full scale. This would mimic the form, profile, and interference drag when compared to the full scale launch vehicle. The following components and internal subsystems on the subscale were resized to replicate the 4:5 diameter ratio as best as possible:

1. Launch Vehicle Diameter - 4” wide, 80% of the width of the full scale
2. Main Altimeter Bay - 8” long, 80% the length of the full scale
3. Booster Section airframe - 30” long, 83% the length of the full scale
4. Rover Compartment airframe - 39” long, 85% the length of the full scale
5. Nose cone length - 20” long, 80% the length of the full scale

Power and motor scaling variable are also important. Primarily the thrust to weight ratio of the rocket to the motor was retained within practicable limitations. Additionally, the C-Star type motor is a motor type manufactured by Cesaroni that provides a higher specific impulse than other types of rockets, making it more efficient. Keeping all of these factors consistent would provide the most accurate velocity, acceleration, and apogee data possible. Below is a table of relevant motor characteristics for the subscale and full scale launch motors. Please note that these are compared to the motor the team intended to use as of the Preliminary Design Review, not the final motor selection.

Table 11: Subscale and full scale motor comparison.

Motor	Cesaroni K740	Cesaroni L1350
Manufacturer	Cesaroni Technology	Cesaroni Technology
Common Name	K740	L1350
Diameter	54.0mm	75.0mm
Length	40.4cm	48.6cm
Total Weight	1469g	3571g
Prop. Weight	846g	1905g

Average Thrust	740.1N	1349.6N
Maximum Thrust	883.9N	1672.5N
Total impulse	1873.9Ns	4263.1Ns
Burn Time	2.5s	3.2s
Specific Impulse	226s	228s
Propellant Info	C-Star	C-Star (SLOW)

1. Weight of Launch Vehicle - 22.8 lbs, 63% of the weight of the full scale
2. Thrust to Weight Ratio - 7.83:1, as close as practicable to the thrust to weight ratio of the full scale, which was, at the time of subscale launch, 8.6:1

6.3 Subscale Launch Simulation Under Launch Day Conditions

The subscale launch on Saturday, December 16th, took place at Varn Ranch in Plant City, Florida. It was a clear day with minimal cloud cover and the temperature ranged from 53 to 77 degrees Fahrenheit. Wind speed averaged at 4 mph. A simulation was done through OpenRocket using similar launch parameters such as coordinates, launch rail length and wind speed. The International Standard Atmosphere condition was used for the simulation, placing the temperature at 69.8 degrees Fahrenheit and the pressure at 3 mbar (0.04 psi). The simulation approximated the following subscale flight results;

Table 12: Subscale launch simulation.

Apogee	1053 m	3456 ft
Max Velocity	154 m/s	505 fps
Max Acceleration	75 m/s^2	246 fps
Time to Apogee	14.9 sec	
Flight Time	161 sec	
Ground Hit Velocity	3.18 m/s	10.4 fps

6.4 Subscale Flight Analysis

6.4.1 Simulated & Real Flight Comparisons

On both the simulation and first actual flight, the subscale rocket exceeded 3,000 feet. The time to apogee for the first and second flights were 13.7 and 12.3 seconds respectively, compared to 14.9 seconds for the simulation. The max velocity and acceleration on the actual flights were considerably lower than the simulated values, 401 fps (velocity) on Flight 1 and 362 fps (velocity) on Flight 2 compared to 505 fps on the simulation. One hypothesis for a lower max velocity on the actual flight is the consideration of unaccounted weight and drag due to the rudimentary paint job.

6.4.2 Error/Disparity Analysis

A few notable errors between the simulated and actual flights are found in the values for flight time and ground hit velocity. This is understandable given the parachute deployment failure on both subscale flights. Complete separation was not achieved, and thus only one of the two main parachutes were deployed. The total flight time for the first and second flights were 86.3 and 79.2 seconds respectively, and the simulated flight time was 161 sec. A shortened flight time due to a parachute deployment failure would also result in a higher ground impact velocity. The simulated launch approximated the ground hit velocity to be at 3.18 m/s, which translates to a foot pound force of less than 75, meeting the recovery requirement. The actual ground hit velocity was represented with the descent rate value programmed into the EasyMini altimeters. On the first flight the final descent rate was measured at 10 m/s, and on the second at 7.3 m/s. Both of these values are too high a velocity for safe impact, as they amount to a foot pound force greater than 75.

6.5 Subscale Results & Influence on Full Scale Design

The deployment failures on both subscale flights were a surprise as to the ineffective separation procedures and design. As you recall from earlier, the case where the four 4-40 shear pins did not break and detach on the first flight, and the shock cord entanglement on the second flight provoked necessary and important discussion for improving the parachute deployment system. Extensive ground testing for the full scale launch vehicle will determine the number and strength of shear pins necessary for a safe and proper deployment. There are several areas to improve the deployment system and avoid the issues experienced during the subscale flight via testing;

1. Lesser shear pin strength
2. Alternate shear pin layout
3. Increased black powder charges
4. Program altimeters for deployments at different heights, thus preventing premature shock cord exposure

7 Recovery Subsystem

7.1 Mission Success Criteria

The following table will show the requirements that need to be met in this mission, how we met the requirements, and the verification of meeting them.

Table 13: Detailed recovery system mission requirements and confirmation methods.

Requirement	Method	Verification	Verification Status
NASA Student Launch Initiative Required Success Criteria			
The launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude.	Demonstration	The launch vehicle is designed to deploy the drogue parachute at apogee, with the main Booster section parachute at an altitude of 950ft and the Main Payload section parachute at an altitude of 800ft. During subscale launch testing, the altimeters successfully initiated the separation charges for all of the points of separation at the programmed altitudes.	Subscale testing complete. Full scale testing to be completed.
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.	Testing	A ground ejection test for the drogue and main parachute will be completed prior to initial subscale and full-scale launches. Ground tests from the subscale launch were successful, although in order to protect the parachutes from damage, they were not used during ground testing.	Subscale testing complete. Full scale testing to be completed.
At landing, each independent sections of the launch vehicle	Analysis/ Demonstration	The correct and appropriate parachute size will be chosen in order to slow the launch vehicle down enough to ensure a kinetic	Analysis complete. Subscale testing complete. Full scale testing to be

shall have a maximum kinetic energy of 75 ft·lbf		energy of less than 75 ft·lbf. Multiple tests will be simulated. Calculations in this report detail the descent rate and kinetic energy at impact. During subscale launch testing, even though one of the parachutes failed to deploy, there was no damage to the launch vehicle, indicating that the parachutes used were provided sufficient drag force to prevent launch vehicle damage and verifying prior calculations. Of course, the full scale launch vehicle will use different parachutes, since the new parachutes were not received in time to use them.	completed.
The recovery system electrical circuits shall be completely independent of any payload electrical circuits.	Design/ Inspection	NSL Inspection as well as inspected and approved by safety officer. Recovery system electrical system is connected only to the recovery system altimeters. Payload design incorporates a power supply made up of 3V batteries which is integrated into the rover wheels. During operation the 3V batteries will power the rover two motors and all electronics.	Verified with design submission. Safety officer and NSL inspections to be completed.
All recovery electronics will be powered by commercially available batteries.	Design/ Inspection	NSL Inspection as well as inspected and approved by safety officer. Current design incorporates commercially available 9V batteries. During the subscale launch, all four 9V batteries powering the four altimeters successfully powered the altimeters to initiate all separation charges.	Verified with design submission. Safety officer and NSL inspections to be completed.
The recovery system shall contain redundant, commercially available altimeters.	Design/ Inspection	NSL Inspection as well as inspected and approved by safety officer. During subscale launch, two Missile Works RRC3 Sport dual deployment altimeters were used for drogue and #1 main parachute deployment. Two Altus Metrum EasyMini dual deployment	Verified with design submission. Safety officer and NSL inspections to be completed.

		altimeters were used for #2 main parachute deployment. All four altimeters successfully initiated the separation charges. For the full scale launch vehicle, four Altus Metrum EasyMini dual deployment altimeters will be used.	
Motor ejection is not a permissible form of primary or secondary deployment.	Design/ Inspection	NSL Inspection as well as inspected and approved by safety officer. Launch vehicle design does not include motor motor ejection as means of deployment.	Verified with design submission. Safety officer and NSL inspections to be completed.
Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.	Design/ Inspection	NSL Inspection as well as inspected and approved by safety officer. Launch vehicle has been designed with shear pins at each separation point: between altimeter bay and booster, between altimeter bay and payload section, and between nose cone and payload section.	Verified with design submission. Safety officer and NSL inspections to be completed.
Recovery area will be limited to a 2500 ft. radius from the launch pads.	Analysis/ Demonstration	Data from simulations. Drift calculated manually. Subscale and full-scale launch data. During subscale launch testing, the winds were less than 5 mph. The launch vehicle with appropriate simulated payload weight drifted approximately 50 yards using the same parachute as the full scale launch vehicle. Under similar conditions, the full scale would have drifted approximately 275 feet. At this rate, the full scale would drift over 2500 feet in 20 mph winds. Due to this, the drift calculations were completed again and smaller parachutes were selected.	Analysis complete. Subscale testing complete. Full scale testing to be completed.
An electronic tracking device will be installed in the launch	Design/ Inspection	A loud audible beacon transmitter has been included in both altimeters bays separate from the recovery electronics. The beacon	Verified with design submission. Safety officer and NSL inspections to be

vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver.		will produce a high enough decibel that will allow us to locate the separate sections.	completed.
Any rocket section, or payload component, which lands untethered to the launch vehicle, will also carry an active electronic tracking device.	Design/ Inspection	A loud audible beacon transmitter has been included in both altimeters bays separate from the recovery electronics. The beacon will produce a high enough decibel that will allow us to locate the separate sections.	Verified with design submission. Safety officer and NSL inspections to be completed.
The electronic tracking device will be fully functional during the official flight on launch day.	Design/ Inspection	The sounding beacons are planned to be installed within the altimeter bays and will be functional on launch day.	Verified with design submission. Safety officer and NSL inspections to be completed.
SOAR Success Criteria			
The launch vehicle will separate as follows: 1. At apogee, the booster section will separate from the main altimeter bay and the drogue parachute will deploy. 2. At 1000 feet, the payload section will separate from	Demonstration	Black powder charges will be used for all launch vehicle section separation. Ground testing and launch testing will be conducted on subscale and full scale rockets to determine the amount of black powder required to successfully and safely separate the designated sections of the launch vehicle. Altimeters will be programmed and programming verified prior to launch. Altimeter batteries will be tested prior to each launch and replaced if voltage is below 9.0V. During subscale launch testing, all	Subscale testing complete. Full scale testing to be completed.

the main altimeter bay and the first main parachute will deploy. 3. At 800 feet, the nosecone will separate from the payload section and the second main parachute will deploy.		altimeters set off black powder charges at the correct altitudes. During subscale ground and launch testing, 1.5 grams of black powder was used for each of the separation charges and small centrifuge canisters were used to contain the black powder. While this was sufficient for the drogue and nosecone main parachute deployments, it was insufficient to fully deploy the rover compartment main parachute. Therefore, extensive full scale ground testing will be completed prior to the test launch. Additionally, the centrifuge canisters will not be used, as they may have limited the force of the charge.	
Parachutes will deploy safely without shock cord or shroud line entanglement.	Demonstration	Parachutes and shock cords will be packed in such a way as to prevent entanglement of the shock cords. Shock cords will be folded in a Z-type fold, and parachutes will be folded in accordance with the checklist. During subscale launch testing, the drogue parachute deployed without any complications. However, the nose cone parachute shock cord became entangled with the drogue parachute shock cord. Because of this, the deployment schedule has been altered. Specifically, instead of deploying both main parachutes at 800 feet, the booster section parachute will deploy at 950 feet, and the nosecone section parachute will deploy at 800 feet. When deployed this way, the sections that are intended to descend separately will not have a chance to become entangled with one another.	Subscale testing complete. Full scale testing to be completed.
Drogue parachute will	Demonstration	Shear pins will be selected and gauged to prevent early separation	Subscale testing complete. Full scale

deploy without the load from the shock cord resulting in unintentional separation of either main parachute separation point.		of either main parachute separation point. Combinations of 2/56 and 4/40 shear pins will be used appropriately to ensure main parachute separation points remain intact prior to intended separation altitude. During subscale launch testing, shear pin selection prevented early separation of main parachute separation points. However, on the first subscale launch, one of the separation points failed to separate and on the second subscale launch, at the same separation point, separation occurred, but the parachute failed to deploy from the launch vehicle. Further ground and flight testing on the full scale will be conducted to ensure proper separation.	testing to be completed.

7.2 Selected Design Elements and Justification

7.2.1 Parachutes

All parachute data is based on L1420R-P motor flight simulation and under conditions detailed previously.

One SkyAngle Classic II 60 and one Fruity Chutes Iris Ultra 36" HP Compact Chute will be used from main parachute descent, along with a 20 inch SkyAngle Classic II drogue that deploys at Apogee. The SkyAngle and Fruity Chute series of parachutes are extremely reliable, easy to fold and pack, and have been extensively tested and reviewed. Further, specific instructions on folding the parachutes are readily available, making it even easier to utilize for the project. No such tests are available for many other commercially available parachutes.

During the preliminary design review, it was noted that the descent time calculated would result in drift beyond the launch competition limitations. Therefore, some more specific calculations were conducted to determine the size parachute that would meet both the kinetic energy at landing and drift limitations.

In order to accomplish this, first it was necessary to determine the maximum descent speed for each section that would result in a maximum kinetic energy at landing of 75 ft. lb. force. For this, the formula for the relationship between energy and velocity was used.

$$V = \sqrt{\frac{2E}{m}}$$

Where 75 ft-lb force = 101.69 N·m

In order to calculate the parachute coefficient of drag and canopy area needed to achieve the desired descent velocities, the following formula for parachute size and drag was used.

$$A * C_d = \frac{2gm}{\rho v^2}$$

Where A = parachute surface area, C_d = coefficient of drag, ρ = density of air

Calculations specified that the product of the parachute surface area and coefficient of drag is required to be a minimum of the following for the two sections.

Table 14: Minimum parachute AC_d.*

Nosecone and Payload Section	56.19 ft^2
Booster and Altimeter	14.42 ft^2

This result was compared to the manufacturer specified data for various parachutes and the selected parachutes have the following characteristics.

Table 15: SkyAngle Classic II 60 parachute characteristics.

Area*Coefficient of Drag	39.3*1.89 = 74.277
Material	Zero-porosity 1.9 oz. silicone-coated balloon cloth
Surface Area	39.3 sq. ft.
Drag Coefficient	1.89
Number of Lines	3
Line Length	60 in.
Line Material	3/8” tubular nylon (950 lbs)
Attachment Type	Heavy-duty 1,500 lb. size 12/0 nickel-plated swivel

Table 16: Fruity Chutes Iris Ultra 36" HP Compact Chute parachute characteristics.

Area*Coefficient of Drag	12.1923*2.2 = 26.82
Material	Lightweight 1.1oz Mil-spec calendared ripstop nylon
Surface Area	12.19 sq. ft.
Diameter	36 in. (47.28 in. equivalent flattened)
Drag Coefficient	2.2
Number of Lines	8
Line Material	1/4" Kevlar and 400# Spectra Nanoline

7.2.2 Shock Cord Harnesses

For shock cord, the team prefers to side with proven performance of components unless it is clear that other options need to be considered. Since the team's previous NSL rocket design was nearly twice the weight of this year's design and the design weight is not critical, the ½" tubular Kevlar has once again been chosen as the preferred shock cord for this design for the nosecone and payload main parachute and also for the booster and altimeter drogue parachute. Kevlar tubing is tested for 7200 lb shock, which is more than sufficient for the purposes to which it will be applied. In order to reduce weight and increase available space, however, ¼" tubular Kevlar will be used for the booster and altimeter bay main parachute. The relatively small yet strong shock cord allows for easy storability within the airframe, without adding any unnecessary risks. All shock cord sections will be attached to the the bulkheads via 5/16" D-rings and will be folded using a layered Z-fold as seen below.

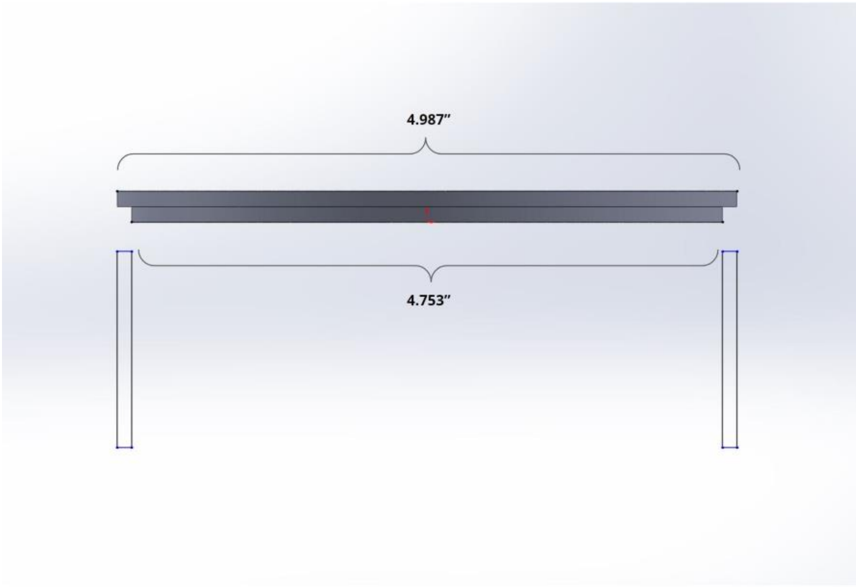
Figure 20: Layered Z-fold of shock cord inside airframe section.

7.2.3 Bulkheads

Like the custom fins, ⅛" structural FRP fiberglass sheets, supplied by McMaster-Carr, were chosen to construct the bulkheads for the altimeters bays. Two sheets were used to create a single bulkhead to cap and secure altimeters, electronics and any other components stored within the altimeter bay. The inside fiberglass sheet has a diameter of 4.753", matching the inner diameter of the G12 fiberglass coupler used as the altimeter bay. The outer sheet has a diameter of 4.987" which caps the G12 coupler and fits inside the 5" diameter of the main airframe.

Figure 21: Subscale bulkhead section..

Figure 22: Full scale bulkhead dimensions



7.2.4 Hardware

As quick links, D-rings, and U-bolts are readily available, very inexpensive, and contribute very little to the overall weight of the launch vehicle, it is preferred to select components that are dependable and have proven capabilities. For this reason, 5/16" zinc-plated U-bolts and locking D-rings have been chosen as the recovery device interface apparatus for this design. The team has previously used these components with success over several launches, and, as stated above, have been used under more aggressive circumstances than the present project encompasses.

7.2.5 Altimeters

Although there are numerous available types and brands of altimeter available to be purchased, the team generally prefers to utilize technology that has been proven in other applications, especially when there is no compelling reason to choose another option. Additionally, we rely on the advice of our team mentor and his evaluation of components based on his almost 30 years of experience with high powered rockets. However, with the addition of the adjustable ballast system in the main altimeter bay, it has become necessary to minimize the space taken up by the electronics in the main altimeter bay. Also, it is now most practical to mount the altimeters horizontally (perpendicular to the body tube) rather than vertically. The Missile Works RRC3 “Sport” altimeters were used for the main altimeter bay on the subscale. On the full scale, there is a possibility of adding removable ballast to the main altimeter bay and thus orientating the RRC3 altimeters horizontally. To ensure space in the main altimeter bay, and maintain recovery functionality, the Altus Metrum EasyMini altimeter will be used within the main altimeter bay for both the primary and redundant means to indicate the deployment of both the drouge, booster, and nosecone parachutes at apogee, 1000 feet, and 800 feet respectively.

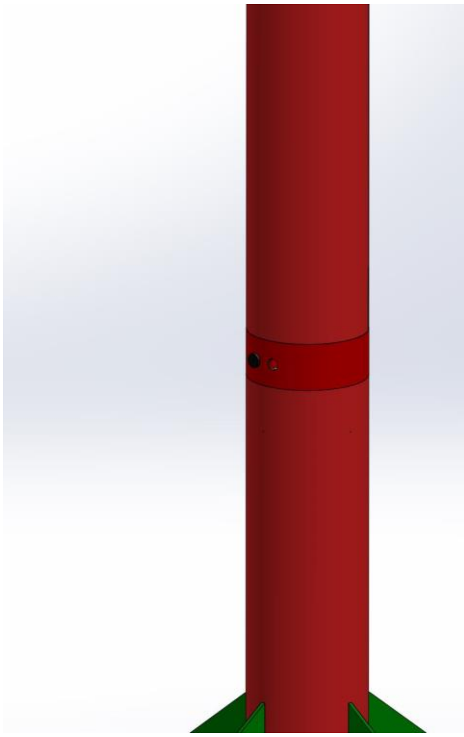
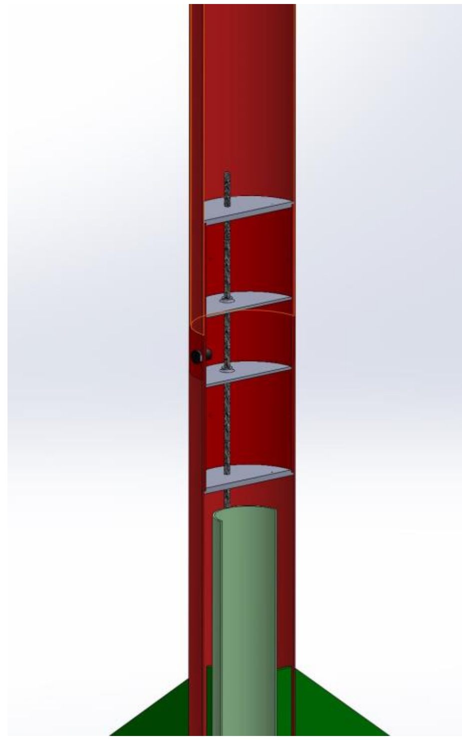
7.3 System Redundancy

Each subsystem within the overall recovery system will operate with redundant and parallel altimeters, operating independent of each other and all other onboard electronics. The EasyMini altimeter will identify the moment of apogee, and a signal will be sent to a charge which will shear the pins and separate the booster section from the main altimeter bay, releasing the drogue parachute. In the event of a failure of the main charge, another signal will be sent to a seperate powder charge and a redundant EasyMini altimeter to ensure that the pins shear and the section separates. The same EasyMini altimeter will then identify the moment when the launch vehicle is 950 feet above ground, and a signal will be sent to the second charge to separate the rover compartment from the main altimeter bay, fully separating the booster section and main altimeter bay from the rest of the rocket. This separation releases the main parachute for these two sections. There is a simultaneous redundant charge to ensure the separation and main parachute deployment. Further, two EasyMini altimeters will be installed in the payload altimeter bay for the purpose of separation of the nose cone from the rover compartment. These charges will be set to 800 feet above the ground, and will be signaled separately and simultaneously. Each altimeter located within both altimeter bays will be powered by a separate 9-volt battery, and operate independent of all other altimeters.

7.4 Recovery Systems Designs

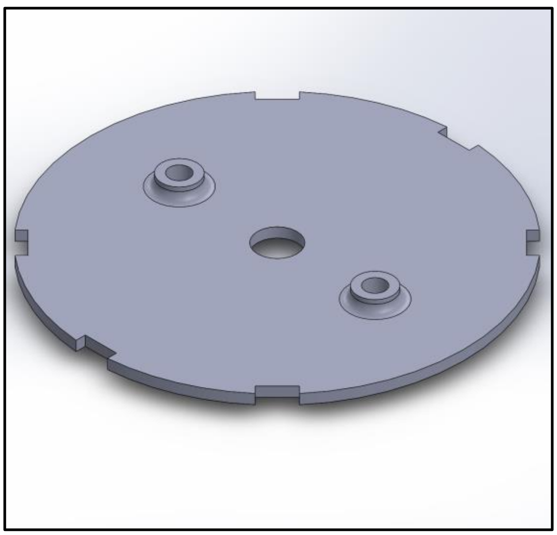
7.4.1 Main altimeter bay design

Figure 23: Main altimeter bay cross-section.

Outside View	Systems View
	

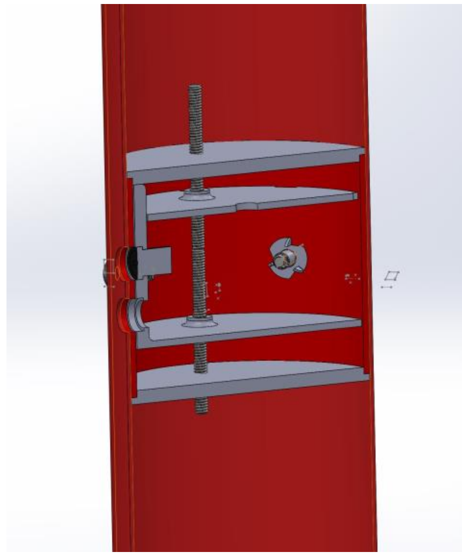
7.4.2 Main altimeter sled design

Figure 24: Main altimeter sled.



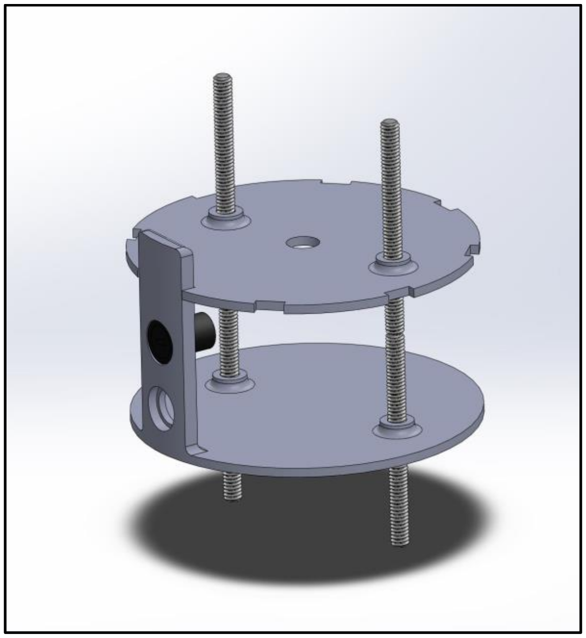
7.4.3 Payload altimeter bay design

Figure 25: Payload altimeter bay cross-section.

Outside View	Systems View
	

7.4.4 Payload altimeter sled design

Figure 26: Payload altimeter sled.



7.4.5 Recovery Schematics & Sequencing

Seen in the figures below are the three altimeter and parachute deployment sequences, which map the process, functionality, and redundancy of the the recovery systems within the rocket.

As mentioned in the altimeter section above, this altimeter layout offers a redundant system for the drogue, booster, and payload parachutes.

Figure 27: Drogue parachute deployment sequence.

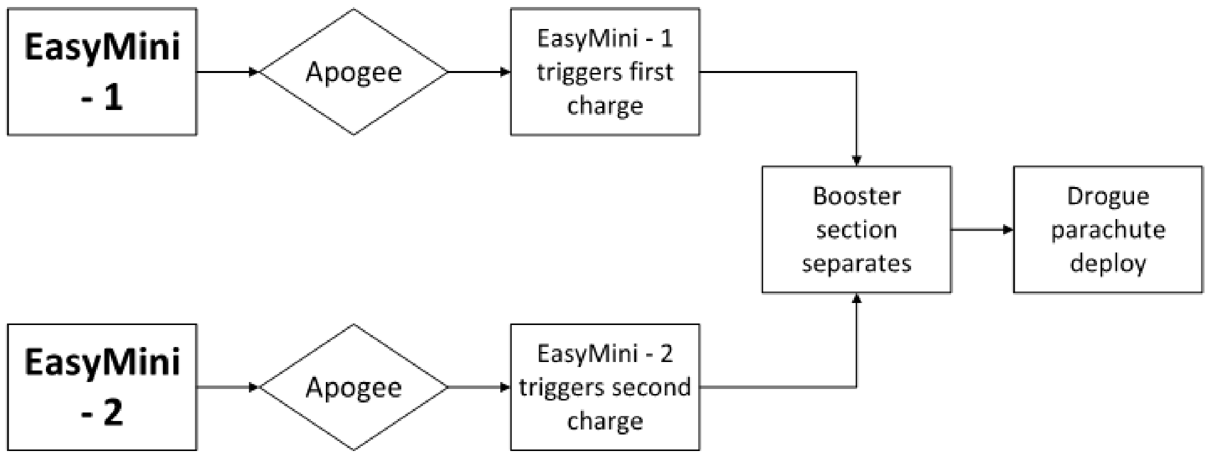


Figure 28: Booster section main parachute deployment sequence.

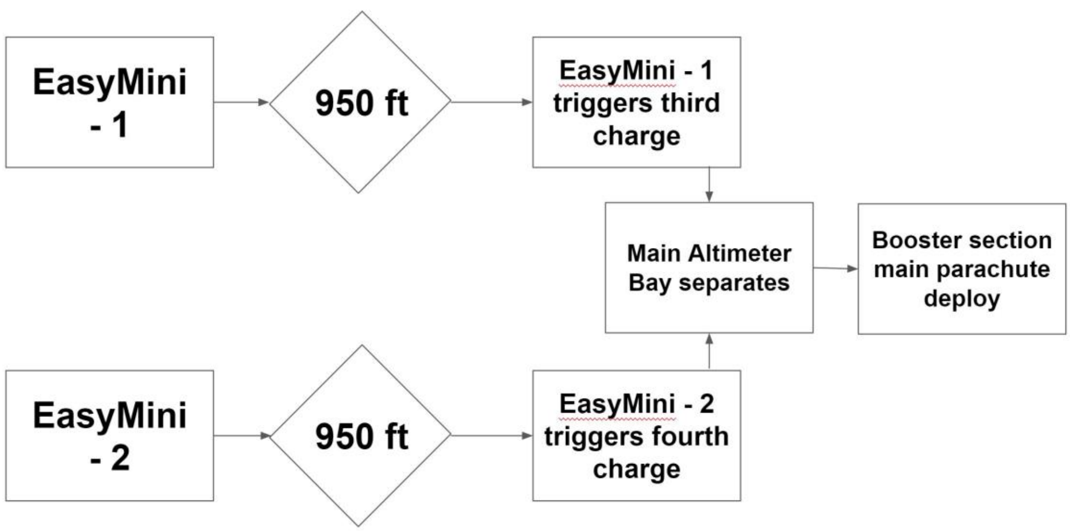


Figure 29: Payload section main parachute deployment sequence.

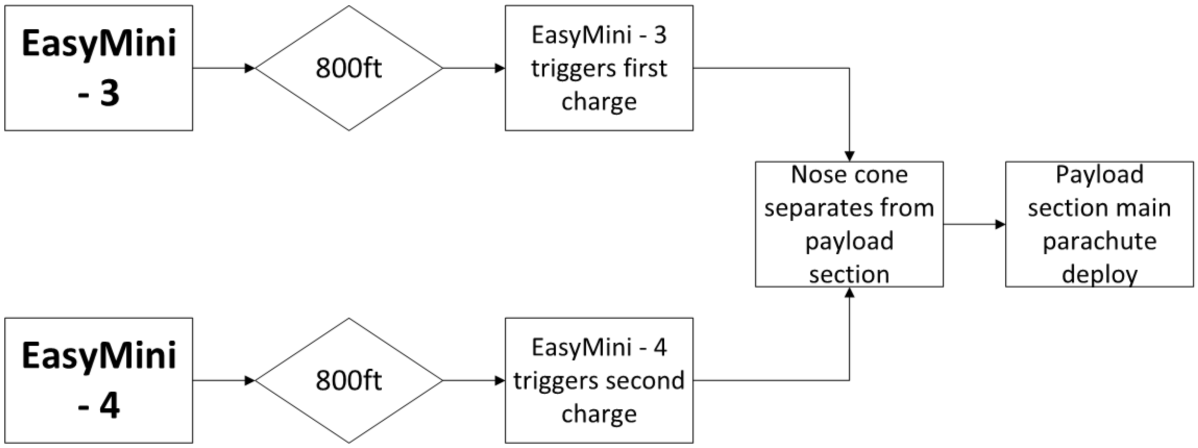
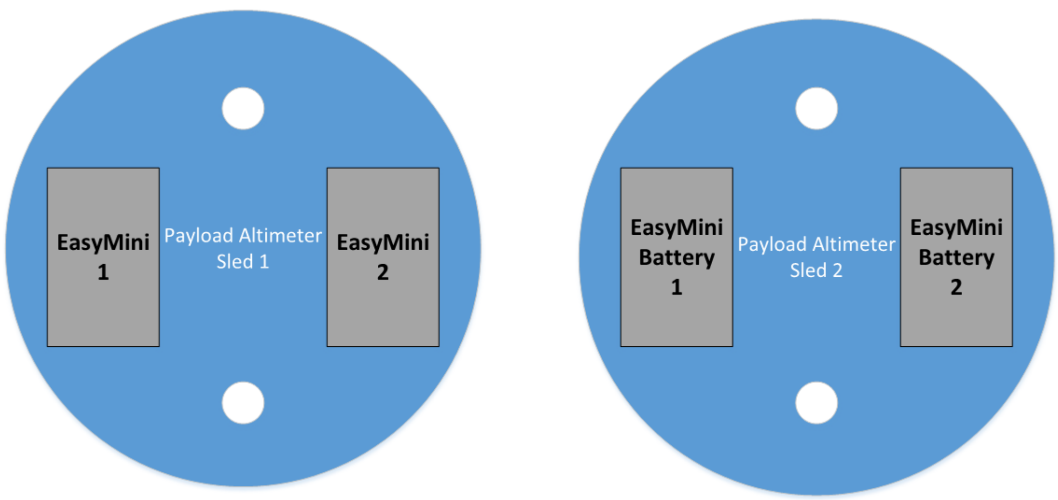


Figure 30: Payload altimeter bay sled layout.



8 Mission Performance Predictions

8.1 Flight

8.1.1 Flight Profile Simulations

The projected altitude was calculated using OpenRocket using the below parameters.

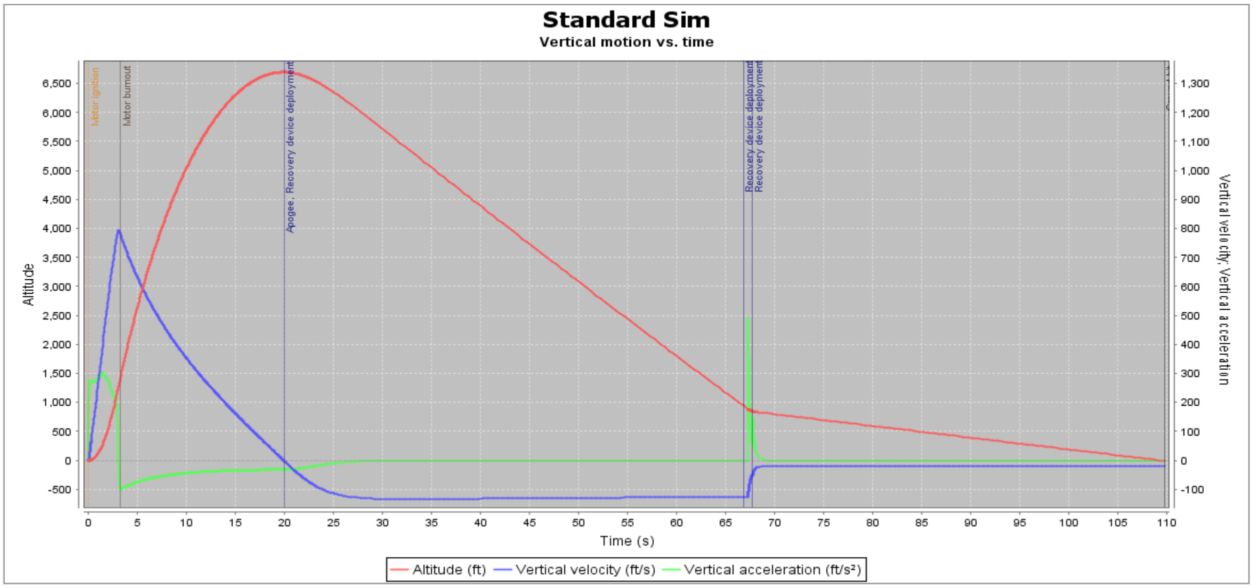
Table 17: L1420R-P motor default simulation with zero wind.

Simulation Parameters

Average Windspeed	0 mph
Standard Deviation	0.0 m/s
Turbulence Intensity	10% (Medium)
Wind Direction	90 degrees
Launch Rod Length	96 inches
Launch Rail Angle	0 degrees
Atmospheric Conditions	International Standard Atmosphere
Calculation Method	Extended Barrowman
Simulation Method	6-DOF Runge-Kutta 4
Simulation Data	
Apogee	6695 feet (see Notes below)

Apogee Notes: Although the simulated apogee is well above that of the 5280 feet goal, based on subscale flight and previous similar full scale flights, the team estimates that the actual apogee will be 83-88% of the simulation apogee. For this simulation, that places the apogee at 5557-5892 feet. Additionally, this simulation is conducted with the minimum ballast of 0.375 lbs, and the launch vehicle is designed to reach the goal altitude with properly adjusted ballast. Under zero wind conditions and fully ballasted, the simulation apogee is 6391 feet, which places the estimated apogee at 5304-5624 feet. In either case, at fully permitted ballast of 3.72 lbs, the simulation apogee is 6199 feet, which results in an estimated apogee of 5145-5455 feet. In addition to this discrepancy, it is often the case that the constructed rocket is slightly heavier than the simulation rocket due to unaccounted-for hardware and epoxy, which will result in an even lower apogee. Further calculations will be conducted after full scale test flight to ensure that the estimated apogee under ballast is accurate.

Figure 31: Graph of flight profile under Aerotech L1420R-P motor.



8.1.2 Altitude Predictions (including complications not included above)

Table 18: Altitude predictions for ballast configurations.

Wind Speed (mph)	Total Ballast Weight (pounds)	Projected Apogee (feet)
0	2.4375	5285.9
1	2.3750	5286.8
2	2.3125	5286.5
3	2.2500	5285.3
4	2.1875	5283.8
5	2.0625	5288.0
6	2.0000	5283.9
7	1.8750	5286.0
8	1.8125	5281.5
9	1.6250	5288.8
10	1.5625	5278.8

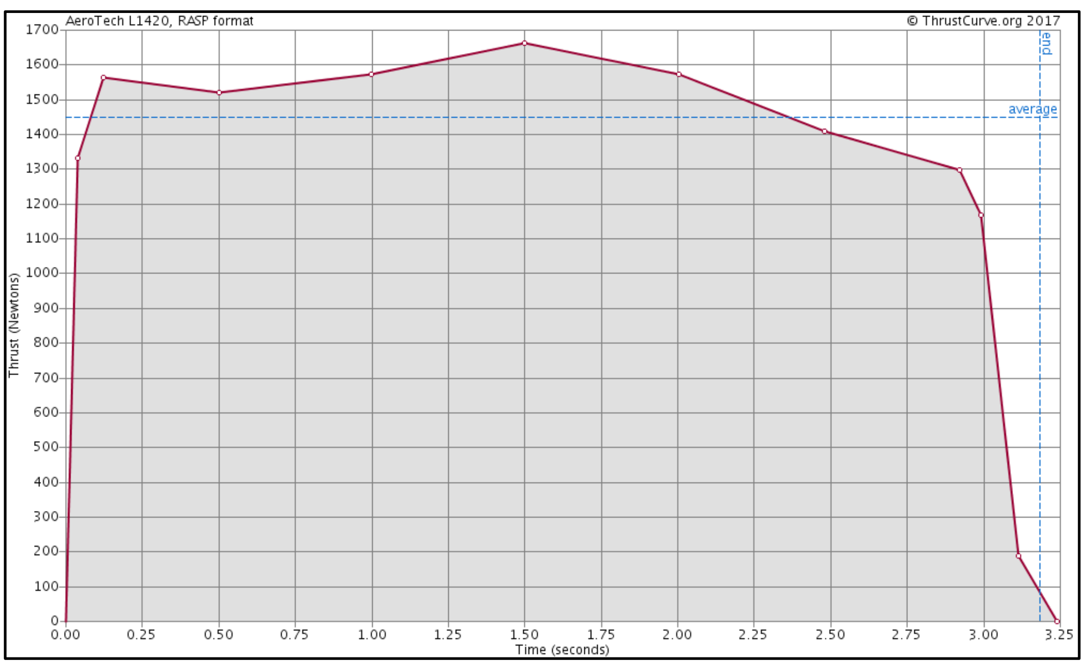
11	1.4375	5286.7
12	1.3125	5284.8
13	1.1875	5284.6
14	1.0625	5288.2
15	0.9375	5289.0
16	0.8750	5286.4
17	0.7500	5280.0
18	0.6250	5282.6
19	0.5000	5284.4
20	0.3125	5288.9

8.1.3 Component Weights

Please see Appendix 14.3 for detailed mass statement

8.1.4 Simulated Motor Thrust Curve

Figure 32: Aerotech 75mm 4G L1420



8.2 Stability

8.2.1 Stability Margin

Table 19: Stability margin with L1420 motor and maximum ballast.

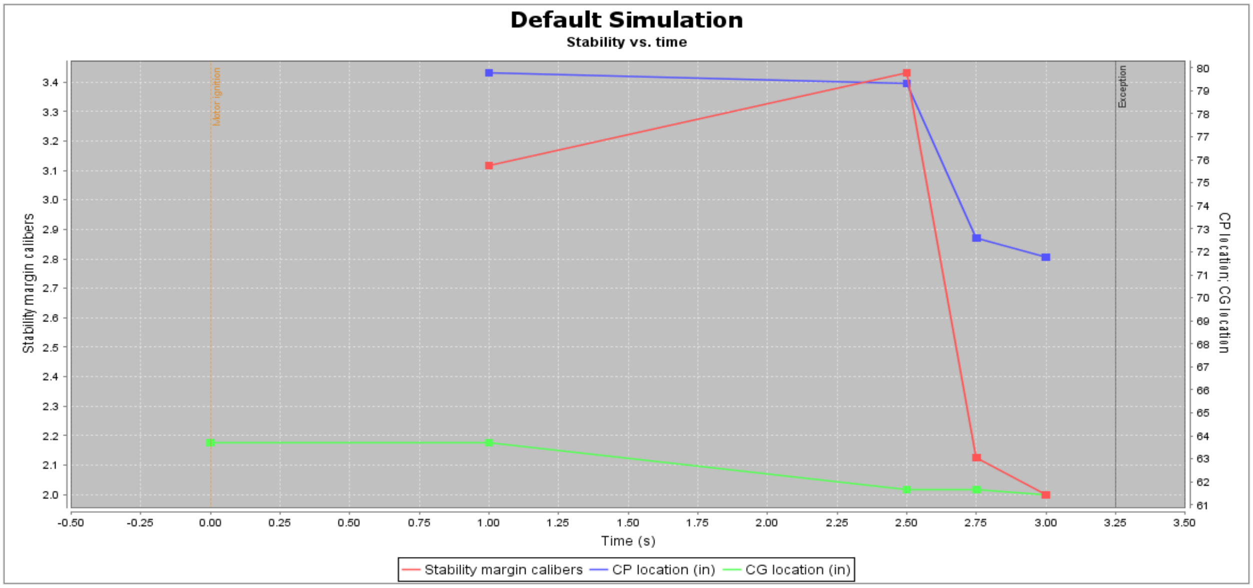
Configuration with L1420 Motor Max Ballast	
Max Ballast	2.71 pounds
Center of Pressure	88.308 inches
Center of Gravity	69.488 inches
Calibers	3.66

Table 20: Stability margin with L1420 motor and minimum ballast.

Configuration with L1420 Motor Min Ballast	
Min Ballast	0.375 pounds
Center of Pressure	88.308 inches
Center of Gravity	72.143 inches
Calibers	3.14

8.2.2 Stability margin, CP, and CG

Figure 33: Stabilty vs time graph.



8.3 Kinetic Energy at Landing

Calculations based on the formula for the relationship between parachute drag and velocity, the same as calculated in the Recovery Subsystem section give the following results.

Table 21: Descent velocity of rocket components.

Rocket Component	Velocity
Nosecone and Payload	4.36 m/s or 14.30 ft/s
Booster and Altimeter Bay	5.10 m/s or 16.73 ft/s

From this information, the kinetic energy at landing can be derived using the below formula.

$$KE = \frac{1}{2}mv^2$$

Table 22: Kinetic energy at landing.

Rocket Component	Kinetic Energy
Nosecone and Payload	39.59 ft-lbs force
Booster and Altimeter Bay	57.16 ft-lbs force

8.4 Drift

The drift of the launch vehicle is calculated by multiplying the descent time, as calculated by the online descent rate calculator located at https://descentratecalculator.onlinetesting.net/, by the wind speed. The drift is calculated for each separate section of the rocket.

The descent time is calculated by adding the descent time under the drogue to the descent time under the main separately in order to provide the most accurate descent time.

The booster section and altimeter will descend under a Fruity Chutes Iris Ultra 36" HP Compact Chute and has a total descent time of 83 seconds when opening at 950 feet. The nosecone and rover compartment will descend under a SkyAngle Classic 60 parachute and has a total descent time of 84 seconds when opening at 800 feet. The drogue parachute is a SkyAngle 20 Classic parachute. The justification for the parachute selection is discussed under the Recovery Subsystem section.

Table 23: Drift analysis of booster section and altimeter at various wind speeds.

Wind Speed (mph)	Wind Speed (ft./s)	Drift (ft.)
0	0	0
5	7.33	608.39
10	14.66	1216.78
15	23.46	1947.18
20	29.33	2434.39

Table 24: Drift analysis of nosecone and rover compartment at various wind speeds.

Wind Speed (mph)	Wind Speed (ft./s)	Drift (ft.)
0	0	0
5	7.33	615.72
10	14.66	1231.44
15	23.46	1970.64
20	29.33	2463.72

8.5 Alternate Calculation Methods

Alternate calculations were conducted using the descent time from Rocket Reviews descent rate calculator located at https://www.rocketreviews.com/descent-rate-calculator.html. Under the same parachute, the descent time of the booster section and altimeter was 66 seconds. Also using the same parachute, the descent time for the nosecone and payload was 59 seconds.

Table 25: Alternate drift analysis of booster section and altimeter at various wind speeds.

Wind Speed (mph)	Wind Speed (ft./s)	Drift (ft.)
0	0	0
5	7.33	483.78
10	14.66	967.56
15	23.46	1548.36
20	29.33	1935.78

Table 26: Alternate drift analysis of nosecone and rover compartment at various wind speeds.

Wind Speed (mph)	Wind Speed (ft./s)	Drift (ft.)
0	0	0
5	7.33	432.47
10	14.66	864.94
15	23.46	1384.14
20	29.33	1730.47

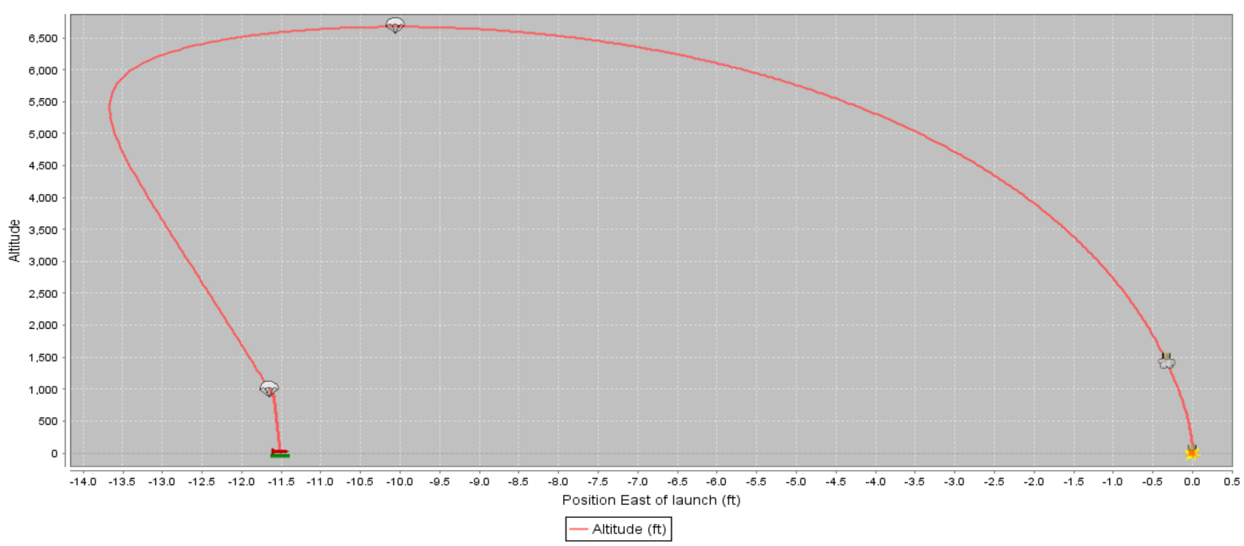
8.6 Discrepancies

Discrepancies between the drift calculations can largely be explained by the fact that the first mentioned descent rate calculator was specially designed for the SkyAngle parachutes and the second calculator is not. In order to obtain a descent calculation in the second one, it is necessary to estimate the equivalent diameter of the SkyAngle parachutes. In the case of the Fruity Chutes parachute, the equivalent diameter given by the manufacturer was used to calculate the drift in both cases. Here, the discrepancy is not so easily explained, especially since the calculation methods are not available for examination. However, as both calculations place the drift area well within the designated parameters, this should not be a significant issue.

8.7 Simulations

See Appendix 19 for drift analysis exported data.

Figure 34: Graph of flight profile under Aerotech L1420R-P motor.



9 Safety

Safety is a critical and necessary component in any STEM activity, especially the handling and construction of rockets and its hazardous counterparts. The Society of Aeronautics and Rocketry is dedicated to promoting the concept of space exploration through amateur rocketry, while ensuring our members are informed and safe during every process and step.

9.1 Safety Officer Duties & Responsibilities

The safety officer will be in charge of ensuring the team and launch vehicle is complying with all NAR safety regulations. The following is the list of the Safety Officer's responsibilities:

1. Ensure all team members have read and understand the NAR and TRA safety regulations.
2. Provide a list of all hazards that may be included in the process of building the rocket and how they are mitigated, including MSDS, personal protective equipment requirements, and any other documents applicable.
3. Compile a binder that will have all safety related documents and other manuals about the launch vehicle.
4. Ensure compliance with all local, state, and federal laws.
5. Oversee the testing of all related subsystems.
6. Ensure proper purchase, transportation, and handling of launch vehicle components.

7. Identify and mitigate any possible safety violations.
8. Identify safety violations and take appropriate action to mitigate the hazard.
9. Establish and brief the team on a safety plan for various environments, materials used, and testing.
10. Establish a risk matrix that determines the risk level of each hazard based off of the probability of the occurrence and the severity of the event. Ensure that this type of analysis is done for each possible hazard.
11. Enforce proper use of Personal Protective Equipment (PPE) during construction, ground tests, and test flights of the rocket.

9.2 NAR/TRA Safety

9.2.1 Procedures

The following launch procedure will be followed during each test launch. This procedure is designed to outline the responsibilities of the NAR/TRA Personnel and the members of the team.

1. A level 2 certified member and an NAR/TRA Personnel will oversee any test launch of the vehicle and flight tests of the vehicle.
2. The launch site Range Safety Officer will be responsible for ensuring proper safety measures are taken and for arming the launch system.
3. If the vehicle does not launch when the ignition button is pressed, then the RSO will remove the key and wait 90 seconds before approaching the rocket to investigate the issue. Only the Project Manager and Safety Officer will be allowed to accompany the RSO in investigating the issue.
4. The RSO will ensure that no one is within 100 ft. of the rocket and the team will be behind the RSO during launch. The RSO will use a 10 second countdown before launch.
5. A certified member will be responsible for ensuring that the rocket is directed no more than 20 degrees from vertical and ensuring that the wind speed is no more than 5 mph. This individual will also ensure proper stand and ground conditions for launch including but not limited to launch rail length, and cleared ground space. This member will ensure that the rocket is not launched at targets, into clouds, near other aircraft, nor take paths above civilians. Additionally, this individual will ensure that all FAA regulations are abided by.
6. Another certified member will ensure that flight tests are conducted at a certified NAR/TRA launch site.
7. The safety officer will ensure that the rocket is recovered properly according to Tripoli and NAR guidelines.

9.2.2 Safety Codes

SOAR conducts launches under both NAR and TRA codes and will abide by the appropriate High-Power Rocketry Safety Code Requirements during all operations.

9.2.2.1 NAR Safety Code (Appendix 14.6)

9.2.2.2 TRA Safety Code (Appendix 14.6)

9.3 Hazardous Materials

9.3.1 Listing of Hazardous Materials

SOAR will maintain a list of all hazardous chemicals used on-site. The Safety Officer will ensure that material safety data sheets are requested and obtained from the supplier of any new product ordered by the SOAR. The Safety Officer will maintain a master listing of all hazardous materials and MSDS for all materials.

9.3.2 Labels

Material received by SOAR must have intact, legible labels. These labels must include the following:

1. The name of the hazardous substance(s) in the container
2. A hazard warning
3. The name and address of the manufacturer or other responsible party

9.3.3 Training

A Safety Officer will be appointed by SOAR's Executive Board will insure that all members at sites where hazardous materials are kept or used receive training on hazardous material handling. The training program will include the following:

1. The location and availability of the MSDS and files
2. Methods and procedures that the employee may use to detect the presence or accidental release or spill of hazardous materials in the work area, including proper clean up
3. Precautions and measures employees can take to protect themselves from the hazardous materials

Annual training will be conducted for all members who deal with hazardous materials. Each new member will be trained in the handling of hazardous materials at the possible opportunity. Training must be conducted for all members when any new chemical or hazardous material enters the work site. This training must occur before the chemical or hazardous material is used by any member. After each training session, the trainer will certify a roster of all participants. Included with the roster will be a list of all hazardous materials included in the training.

9.3.4 Health, Safety, and Emergency Procedures

The following information will be available at the work site, if requested or required:

1. A list of all hazardous materials used on site
2. Unusual health and environmental hazards (both air and water) that may result from the release of specific quantities of hazardous substances

9.4 Safety Briefing

9.4.1 Hazard Recognition

The team Safety Officer will orchestrate all potentially hazardous activities, as well as brief the members who may participate in such activities on proper safety procedures, and ensuring that they are familiar with any personal protective equipment which must be worn during those activities. If a member fails to abide by the safety procedures, he/she will not be permitted to participate in the potentially hazardous activities. In addition to briefing the members on safety procedures, the team Safety Officer must remain in the immediate vicinity of the hazardous activity as it is occurring, so as to mitigate any potentially dangerous incidents and answer any safety questions which may arise.

9.4.2 Accident Avoidance

It will be the duty of the team Safety Officer to verify, in advance, that procedures planned for testing or construction of materials by team members satisfy safety requirements. In the event that the Safety Officer judges a planned procedure to be unsafe, said procedure will thus be revised or eliminated.

9.4.3 Launch Procedures

At the team meeting most closely preceding the launch, the Safety Officer will be given time to help the members review launch safety and precautionary measures. Topics discussed at this time include but are not limited to: laws and regulations mandated by the Federal Aviation Administration (FAA), the National Fire Protection Association (NFPA), and Florida State Statutes; prohibited launchpad activities and behaviors; maintaining safe distances; and safety procedures pertaining to any potentially hazardous chemicals which will be present during the launch. All team leaders must be in attendance at this briefing, and they are obliged to address the other members with any further safety concerns they are aware of that were not mentioned by the Safety Officer. At this time, launch procedures will be scrutinized, paying special attention to the parts involving caution.

9.5 Caution Statements

9.5.1 Definitions

Warnings, cautions, and notes are used to emphasize important and critical instructions and are used for the following conditions.

9.5.1.1 Warning

An operating procedure, practice, etc., which, if not correctly followed, could result in personal injury or loss of life.

9.5.1.2 Caution

An operating procedure, practice, etc., which, if not strictly observed, could result in damage to or destruction of equipment.

9.5.1.3 Note

An operating procedure, condition, etc., which is essential to highlight.

9.6 Checklists

9.6.1 Warnings

Warnings will be typed in red and will appear just prior to the step in the checklist to which they apply, the warning will include possible consequences of failure to heed warning and list any appropriate personal protective equipment required.

9.6.2 Cautions and Notes

Each checklist will include a column labeled Caution/Note. This column will display the caution or note associated with the relevant step in the checklist. Cautions will be typed in orange.

9.6.3 Field Packing List

- ☐ Tools
  - ☐ Power drill and drill bits
  - ☐ Dremel tool with attachments
  - ☐ Sheet sander
  - ☐ Screwdrivers
  - ☐ Wire cutters/strippers
  - ☐ Scissors
  - ☐ Small funnel
  - ☐ Pliers
  - ☐ Wrenches
  - ☐ PVC Cutters
- ☐ Parts
  - ☐ Rocket components
  - ☐ Quick links
  - ☐ Motor casing
  - ☐ Motors (in water resistant container)
- ☐ Parts (cont)
  - ☐ E-matches
  - ☐ Igniter (in water resistant container)
  - ☐ Parachutes
    - ☐ Large × 2
    - ☐ XL × 1
    - ☐ Drogue × 1
  - ☐ Nomex protectors
  - ☐ Spare parts toolkit (nuts, bolts, washers, etc.)
  - ☐ Shear pins
  - ☐ Motor retainer adapter
- ☐ Consumables
  - ☐ Charge insulation (in water resistant container)
  - ☐ Black powder (in water resistant container)
  - ☐ Duct tape
- ☐ Consumables (cont)
  - ☐ Electrical tape
  - ☐ Sandpaper
  - ☐ Electrical wire
  - ☐ Silicone
  - ☐ Graphite powder

- ☐ Consumables (cont)
  - ☐ White lithium grease
  - ☐ 9V batteries
  - ☐ Rail lubricator
  - ☐ Extra CPVC
  - ☐ Extra launch lugs

9.6.4 General Pre-Flight Inspection Checklist

Table 27: General pre-flight inspection checklist.

Task	SO Verification
Inspect fins for damage and security	
Inspect rocket body for dents, cracks, or missing parts	
Inspect parachutes for holes and parachutes cords for abrasions or tears	
Inspect shock cords for abrasion or tearing	
Inspect bulkheads and U-bolts for security	
Clean all components of debris and carbon residue	

9.6.5 Final Assembly and Launch Procedure Checklist

Table 28: Final assembly and launch checklist.

Task	Warning/Caution	SO Verification
1. Prior to Departure		
Ensure all tools and materials needed for launch are available.		
Ensure all required personnel are present.		
Prepare new batteries for the	Parachutes may fail to	

recovery systems.	deploy. Mission failure.	
2. Recovery Preparation – Main Altimeter Bay		
Install new 9V batteries into altimeter bay	Parachutes may fail to deploy. Mission failure.	
Ensure altimeter bay is programmed to deploy at the correct height	Parachutes may fail to deploy. Mission failure.	
Perform continuity check of e-matches	Parachutes may fail to deploy. Mission failure.	
Connect e-matches to altimeters	Ensure e-matches are dry. Parachutes may fail to deploy. Mission failure.	
Warning: Keep away from flames. **PPE Required**: Eye protection, gloves.		
Measure two portions of black powder and deposit in each of the CPVC tube inserts on side of altimeter bay to be inserted into booster section.	Ensure black powder is dry. Insufficient charge will result in failure of separation or ejection. Parachutes may fail to deploy. Mission failure.	
Pack insulation tightly on top of black powder and secure with pressure sensitive tape.		
Measure two portions of black powder and deposit in each of the CPVC tube inserts on side of altimeter bay to be inserted into upper airframe.	Ensure black powder is dry. Insufficient charge will result in failure of separation or ejection. Parachutes may fail to deploy. Mission failure.	
Pack insulation tightly on top of black powder and secure with pressure sensitive tape.	Ensure insulation is dry. Packing too loosely may result in insufficient force to separate or eject. Parachutes	

	may fail to deploy. Mission failure.	
2.1. Recovery Preparation – Payload Altimeter Bay		
Install new 9V batteries into altimeter bay	Parachutes may fail to deploy. Mission failure.	
Ensure altimeter bay is programmed to deploy at the correct height	Parachutes may fail to deploy. Mission failure.	
Perform continuity check of e-matches	Parachutes may fail to deploy. Mission failure.	
Connect e-matches to altimeters	Ensure e-matches are dry. Parachutes may fail to deploy. Mission failure.	
Warning: Keep away from flames. **PPE Required**: Eye protection, gloves.		
Measure two portions of black powder and deposit in each of the CPVC tube inserts.	Ensure black powder is dry. Insufficient charge will result in failure of separation or ejection. Parachutes may fail to deploy. Mission failure.	
Pack insulation tightly on top of black powder and secure with pressure sensitive tape.	Ensure insulation is dry. Packing too loosely may result in insufficient force to separate or eject. Parachutes may fail to deploy. Mission failure.	
3. Launch Vehicle Assembly		
Caution: During assembly, ensure that all launch vehicle body sections fit snugly but not tightly. If fit is too tight, sand with fine grit sandpaper until fit is properly adjusted and apply a small amount of graphite powder if necessary.		

Inspect all parachutes for abrasions, rips, tears, or frayed shroud lines.	Parachute may not create enough drag. Launch vehicle section lands with excessive kinetic energy. Damage to launch vehicle.	
Fold all parachutes in accordance with parachute packing instructions.	Shroud lines may become entangled. Launch vehicle section lands with excessive kinetic energy. Damage to launch vehicle.	
3.1. Booster section		
Inspect booster section lower shock cord for damage or fraying.		
Inspect booster section lower shock cord quick link attachment knot and tape for security and condition.		
Inspect quick link for corrosion and clean or replace if necessary.		
Attach quick link to booster section lower shock cord.		
Fold booster section lower shock cord in Z-type fashion.		
Insert booster section lower shock cord part way into the booster section and attach quick link to drogue parachute swivel.	Ensure parachute remains properly folded during this process.	
Attach quick link to U-bolt on booster section side of		

altimeter bay.		
Close quick link locking gate securely.		
Completely insert booster section lower shock cord into booster section.		
Insert the drogue parachute into the booster section.	Ensure that Nomex protector completely covers parachute.	
Slide altimeter bay into booster section.	Ensure that shear pin holes are aligned.	
Insert shear pins in shear pin holes.	Number and type of shear pins to be determined during ground testing. Please reference ground test report.	
Inspect booster section upper shock cord for damage or fraying.		
Inspect booster section upper shock cord quick link attachment knots and tape for security and condition.		
Inspect quick links for corrosion and clean or replace if necessary.		
Attach quick link to one end of booster section upper shock cord.		
Secure quick link to U-bolt on booster section upper side of altimeter.		

Close quick link locking gate securely.		
Secure quick link to swivel of main parachute #1.		
Close quick link locking gate securely.		
Set aside lower airframe assembly.		
3.2. Payload		
Inspect payload to payload altimeter bay quick link for corrosion and clean or replace if necessary.		
Use quick link to attach payload and payload altimeter bay U-bolts together.		
Inspect payload section shock cord for damage or fraying.		
Inspect both payload section shock cord quick link attachment knots and tape for security and condition.		
Inspect quick links for corrosion and clean or replace if necessary.		
Attach quick links to both ends of payload section shock cord.		

Attach shock cord quick link to U-bolt on upper side of payload altimeter bay.		
Close quick link locking gate securely.		
Slide the payload and payload altimeter bay into the payload section of the airframe.	Ensure screw, air pressure, and access holes are lined up.	
Ensure arming wires are visible and accessible through access hole.		
Insert machine screws into four designated holes to secure payload altimeter bay to payload section of airframe.		
3.3. Nose Cone		
Inspect quick link on upper end of payload section shock cord for corrosion and clean or replace if necessary.		
Attach quick link to U-bolt on nose cone.		
Attach nose cone quick link to swivel of #2 main parachute.		
Close quick link locking gate securely.		
Slide #2 main parachute into the payload section of	Ensure parachute remains properly folded and shroud	

airframe.	lines are unencumbered. Ensure Nomex protector completely covers parachute to prevent entanglement with landing module parachute.	
Fold payload section shock cord in Z-type fashion.		
Insert payload section shock cord part way into the booster section.	Ensure parachute remains properly folded during this process.	
Slide nose cone into payload section of altimeter bay.	Ensure shear pin holes are aligned.	
Insert shear pins in shear pin holes.	Number and type of shear pins to be determined during ground testing. Please reference ground test report.	
3.4. Final Vehicle Assembly		
Retrieve lower airframe assembly.		
Fold payload section shock cord in Z-type fashion.		
Insert booster section upper shock cord part way into the booster section.	Ensure parachute remains properly folded during this process.	
Slide #1 main parachute into the lower side of payload section of airframe.	Ensure parachute remains properly folded and shroud lines are unencumbered. Ensure Nomex protector completely covers parachute to prevent entanglement with landing module	

	parachute.	
Slide upper side of main altimeter bay into payload section of airframe.	Ensure shear pin holes are aligned.	
Insert shear pins in shear pin holes.	Number and type of shear pins to be determined during ground testing. Please reference ground test report.	
4. Motor Preparation		
Warning: Keep away from flames. Inspect motor for cracks and voids. Refer to MSDS for white lithium grease. **PPE Required**: Eye protection, gloves.		
Assemble the motor in accordance with manufacturer's instructions.	https://www.youtube.com/watch?v=d0xjmJ-Yur8	
Insert completed motor assembly into the booster section.		
Securely screw on motor retainer ring.		
5. Launch Procedure		
Have the launch vehicle inspected by the RSO		
Be sure power is turned off from launch control.	Motor may ignite prematurely causing critical injury to personnel and equipment damage.	
Inspect launch pad and rail for debris, corrosion, and stability.	Adjust as necessary. Lubricate as necessary.	

Place the launch vehicle on the rail.	Test launch vehicle on launch rail for resistance or friction. Adjust as necessary. Lubricate as necessary.	
Turn on altimeters and get continuity confirmation.	Parachutes may fail to deploy. Mission failure.	
6. Igniter Installation		
Insert ignitor into the launch vehicle	Ensure that the igniter is inserted up the motor until it reaches a dead-end and then pull back about 1-2 in. Failed or delayed ignition possible.	
Use the manufacturer cap to secure the e-match cord to the motor retainer.	Conduct final check to ensure security of e-match.	
Ensure igniter wires attached to power source.		
Arrange wires carefully to ensure continued attachment to igniter throughout launch sequence.		
7. Launch Sequence		
Ensure ignitor power switch is on at launch control.		
Ensure all personnel are at safe standoff distance.		
Ensure ignitor power switch is on at launch control.		
8. Post Launch Procedure		

Monitor drift and locate launch vehicle after flight.	Ensure launch vehicle is recovered in a timely manner.	
Measure drift from launch pad.		
Recover launch vehicle, determine altitude, and deactivate altimeters		
Deactivate all electronics.		

9.6.6 Post-Flight Inspection Checklist

Table 29: Post-flight inspection checklist.

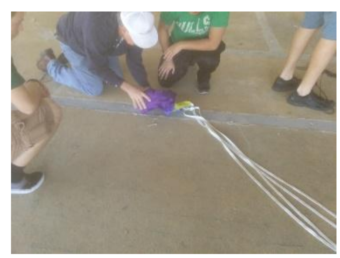
Post Flight Inspection	
Task	**SO Verification**
Listen to record altimeter for apogee altitude.	
Inspect fins for damage and security.	
Inspect rocket body for dents, cracks, or missing parts.	
Inspect parachutes for holes and parachutes cords for abrasions or tears.	
Inspect shock cords for abrasion or tearing.	
Check batteries with voltmeter.	
Clean all components of debris and carbon residue.	
Remove motor from motor casing after it has cooled long enough to be handled but before completely cooled.	

Post Flight Inspection	
Task	**SO Verification**
Disassemble motor casing after it has cooled long enough to be handled but before completely cooled.	
Remove all O-rings	
Place components except for motor casing tube into soapy water to remove carbon residue.	
After soaking, clean components with neutral cleaner, dry and reassemble.	

9.6.7 Parachute Folding Instructions

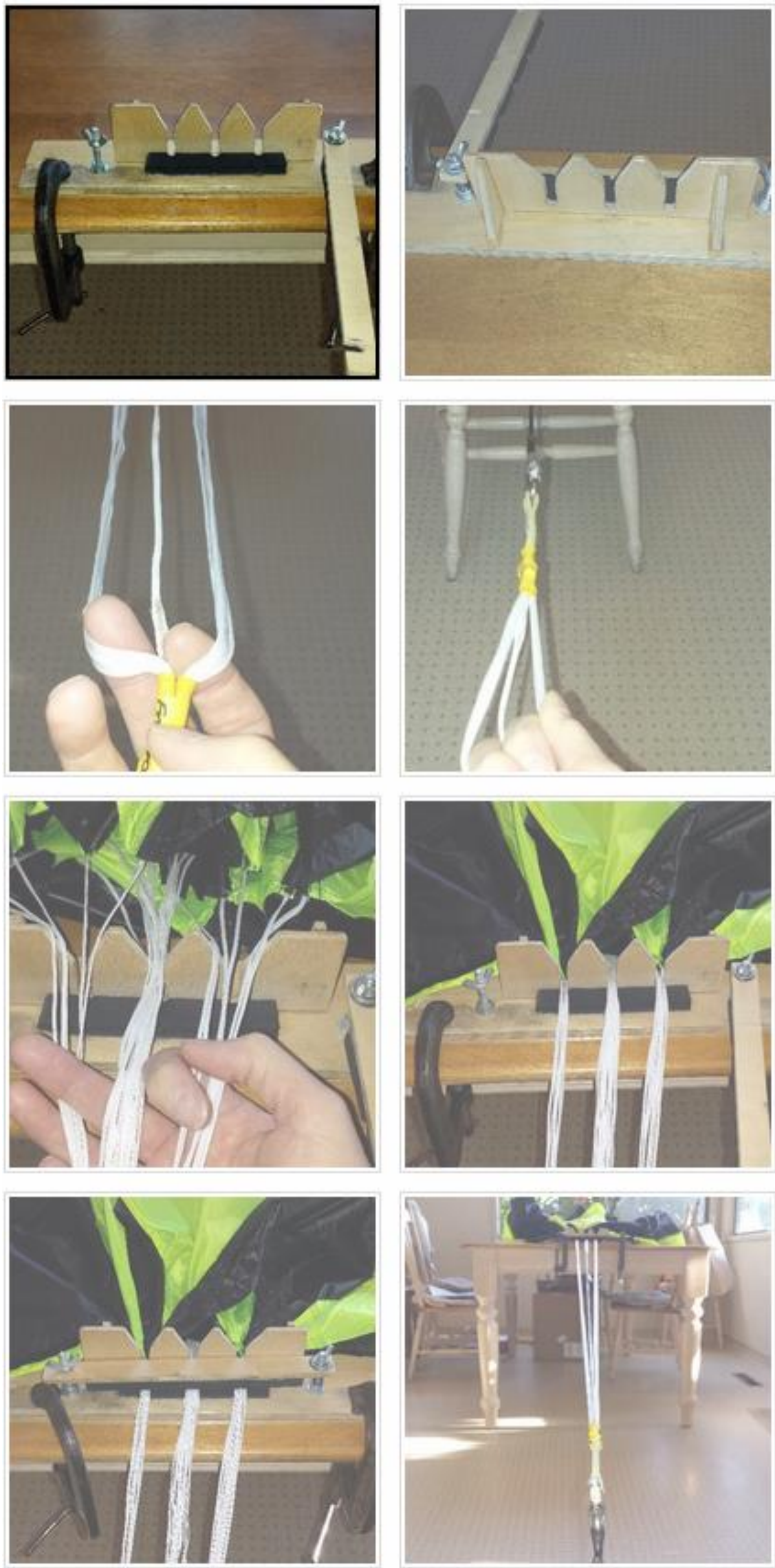
Table 30: SkyAngle Parachute folding instructions and figures.

Instructions	Figure
1. Lay parachute out neatly on the long axis and pull taut.	
2. Inspect parachute for rips, tears, or abrasions.	
3. Arrange the canopy so it lays flat on the floor. Then line up suspension line seams of parachute and stack neatly lengthwise.	

4. Compress parachute to ensure air pockets are removed.	
5. Fold along the long axis using Z-type fold of approximately 6 in. width, beginning with the side opposite the suspension line seams.	
6. Compress parachute to ensure air pockets are removed.	
7. Fold along the length of the parachute using Z-type fold of approximately the below lengths, depending on the parachute size, beginning with the top of the parachute. XL – 8 in. to 10 in. Large – 6 in. to 8 in. Drogue – 6 in. or less	
8. Continue folding in this fashion up to the point where the shroud lines connect to the parachute.	
9. Ensure shroud lines are untangled. Pull the shroud lines taut while maintaining the parachute fully folded.	
10. Fold the shroud lines, using Z-type fold on top of the folded parachute until only about 4 to 6 in. remain extended beyond the folded parachute.	

11. Attach appropriately sized Nomex protector to end of shroud line near swivel. Wrap electrical tape around shroud line above Nomex protector to ensure Nomex protector does not slip during flight or ejection.	
12. When inserting the parachute into the respective launch vehicle section, roll the folded parachute slightly upward around the shroud lines to ensure security.	

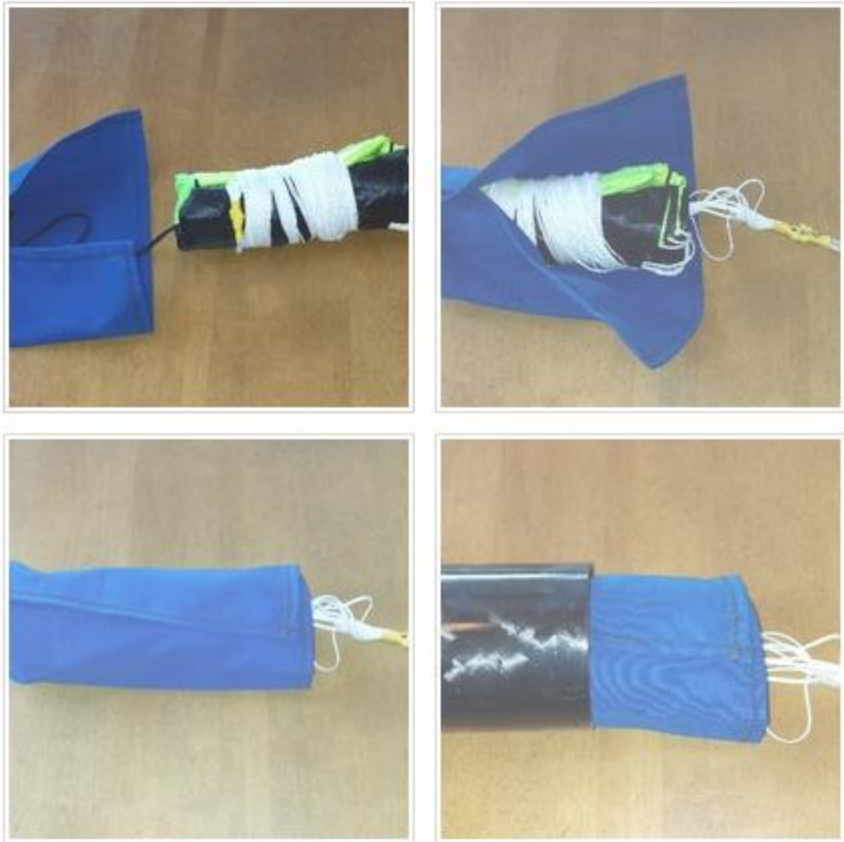
Table 44: Fruity Chutes Parachute folding instructions and figures.









9.6.8 Motor Assembly Instructions

https://www.youtube.com/watch?v=d0xjmJ-Yur8

9.7 Safety Manual

9.7.1 Warnings

Warnings will be typed in red and will appear just prior to the step, procedure or equipment to which they apply, the warning will include possible consequences of failure to heed warning and list any appropriate personal protective equipment required.

9.7.2 Cautions

Cautions will be typed in orange and will appear just prior to the step, procedure or equipment to which they apply, the caution will include possible consequences of failure to heed caution.

9.7.3 Notes

Notes will be typed in bold black and will appear just prior to the step, procedure or equipment to which they apply.

9.8 Legal Compliance

The Safety Officer and Project Manager have read all relevant laws and regulations that apply to this project in order to ensure compliance with these laws. As well, the team members will also be briefed on these laws as they apply to the project. The material reviewed includes:

9.8.1 Federal Aviation Regulations (FARs)

- 14 CFR: Aeronautics and Space, Chapter 1, Subchapter F, Part 101, Subpart C: Amateur Rockets
- 27 CFR: Part 55: Commerce in Explosives
- NFPA 1127 "Code for High Power Rocket Motors"

9.8.2 State of Florida Laws and Regulations

- Florida Statute: Title XXV: Aviation, Chapter 331: Aviation and Aerospace Facilities and Commerce
- Florida Statute: Title XXXIII: Regulation of Trade, Commerce, Investments, and Solicitations, Chapter 552: Manufacture, Distribution, and Use of Explosives

9.9 Purchase, Transportation & Storage of Motor

The motor will be purchased and stored by one of our organization's mentors. This person is certified for the purchase of high powered rocket propellant and Society of Aeronautics and Rocketry 21 well versed in storage. The propellant will be stored in an off-campus garage, where several other rocket components have been stored carefully. There will be a clear indication that there is propellant in the room, by large lettering on the magazine and yellow/black cautionary tape. There will also be a clear indication to keep away, in addition to warning about fire in the area. Our mentor shall maintain primary access to the propellant upon storage and shall prep it for transportation. It will be secured carefully within a vehicle, bound down to avoid unnecessary motion and without the risk of any other object resting or falling on top of it.

9.10 Statement of Compliance

All team members understand and will abide by the following safety regulations:

- 1.6.1. Range safety inspections of each rocket before it is flown. Each team shall comply with the determination of the safety inspection or may be removed from the program.
- 1.6.2. The Range Safety Officer has the final say on all rocket safety issues. Therefore, the Range Safety Officer has the right to deny the launch of any rocket for safety reasons.
- 1.6.3. Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

9.11 Hazard Analysis

9.11.1 Hazard Categories

9.11.1.1 Controls Risk Assessment

The hazards outlined in this section will discuss the risks associated with the launch vehicle mechanical and electrical controls. This is critical as failures in any system will result in a failed mission.

9.11.1.2 Hazards to Environment Risk Assessment

The hazards outlined in are risks that construction, testing or launching of the rocket can pose to the environment.

9.11.1.3 Logistics Risk Assessment

The hazards outlined are risks to the schedule associated with parts ordering, milestone accomplishment, and project completion. These hazards may also be associated with the physical movement of the launch vehicle from its current location to the launch site.

9.11.1.4 Launch Pad Functionality Risk Assessment

The hazards outlined are risks linked to the launch pad functionalities.

9.11.1.5 Payload Capture Device Risk Assessment

The hazards outlined in this section will discuss the risks associated with the payload capture device. The payload capture device interfaces with multiple systems, making it prone to hazards.

9.11.1.6 Recovery Risk Assessment

The hazards outlined are risks associated with the recovery. Since there are three recovery systems onboard, many of the failure modes and results will apply to all of the systems but will be stated only once for conciseness.

9.11.1.7 Shop Risk Assessment

Construction and manufacturing of parts for the rocket will be performed in both on-campus and off-campus shops. The hazards assessed are risks present from working with machinery, tools, and chemicals in the lab.

9.11.1.8 Stability and Propulsion Risk Assessment

The hazards outlined are risks associated with stability and propulsion. The team has multiple members of the team with certifications supporting that they can safely handle motors and design stable rockets of the size that the team will be working with. This area is considered a low risk for the team, but it is still important to address any potential problems that the team may face throughout the project.

9.11.2 Risk Level Definitions

9.11.2.1 Severity

The severity of each potential risk is determined by comparing the possible outcome to criteria based on human injury, vehicle and payload equipment damage, and damage to environment. Severity is based on a 1 to 3 scale, 1 being the most severe. The severity criteria are provided below.

Table 31: Safety severity definitions.

Severity Definitions – A condition that can cause:					
Description	Personnel Safety and Health	Facility/Equipment	Range Safety	Project Plan	Environmental
1 – Catastrophic	Loss of life or a permanent disabling injury.	Loss of facility, systems or associated hardware that result in being unable to complete all mission objectives.	Operations not permitted by the RSO and NFPA 1127 prior to launch. Mission unable to proceed.	Delay of mission critical components or budget overruns that result in project termination.	Irreversible severe environmental damage that violates law and regulation.
2 – Critical	Severe injury or occupational related illness.	Major damage to facilities, systems, or equipment that result in partial mission failure.	Operations not permitted by the RSO and NFPA 1127 occur during launch. Mission suspended or laws and regulations are violated.	Delay of mission critical components or budget overruns that compromise mission scope.	Reversible environmental damage causing a violation of law or regulation.
3 – Marginal	Minor injury or occupational related illness.	Minor damage to facilities, systems or equipment that will not compromise mission objectives.	Operations are permitted by the RSO and NFPA 1127, but hazards unrelated to flight hardware design occur during launch.	Minor delays of non-critical components or budget increase.	Mitigatable environmental damage without violation of law or regulations where restoration activities can be accomplished.

9.11.2.2 Probability

The probability of each potential risk has been assigned a level between A and E, A being the most certain. The scale of probabilities is determined by analyzing the risks and estimating the possibility of the accident to occur. Table depicts the levels of probability for each risk.

Table 32: Risk probabilities.

Description	**Qualitative Definition**	**Quantitative Definition**	**Lette r**
A – Frequent	High likelihood to occur immediately or expected to be continuously experienced.	Probability is > 90%	A
B – Probable	Likely to occur or expected to occur frequently within time.	90% ≥ probability > 50%	B
C – Occasional	Expected to occur several times or occasionally within time.	50% ≥ probability > 25%	C
D – Remote	Unlikely to occur, but can be reasonably expected to occur at some point within time.	25% ≥ probability > 1%	D

E – Improbable	Very unlikely to occur and an occurrence is not expected to be experienced within time.	1% ≥ probability	E

9.11.3 Risk Assessment Levels

Each risk is finally assigned a risk level based upon a combination of the risk's severity and probability. These levels range from high (red) to minimal (white) and are defined.

Table 33: Risk assessment levels.

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

Table 34: Levels of risk definitions.

Level of Risk	Definition
High Risk	Highly Undesirable. Documented approval from the RSO, NASA SL officials, team faculty adviser, team mentor, team leads, and team safety officer.
Moderate Risk	Undesirable. Documented approval from team faculty adviser, team mentor, team leads, team safety officer, and appropriate sub-team lead.
Low Risk	Acceptable. Documented approval by the team leads and sub-team lead responsible for operating the facility or performing the operation.
Minimal Risk	Acceptable. Documented approval not required, but an informal review by the sub-team lead directly responsible for operating the facility or performing the operation is highly recommended.

9.11.4 Current and Probable Risk

Through past years of rocket design and competition, as well as what orders are already underway below is a table of risk that shall continue to grow and be edited by the safety officer throughout the project.

9.11.5 Personnel Hazard Analysis

Area	Hazard	Cause	Effect	Pre RAC	Mitigation	Post RAC	Verification
Shop	Using power tools and hand tools such as blades, saws, drills, etc.	Improper use of PPE. Improper training on the use of equipment.	Mild to severe cuts or burns to personnel. Damage to rocket or components of the rocket. Damage to equipment	3C	Individuals will be trained on the tool being used. Those not trained will not attempt to learn on their own and will find a trained individual to instruct them. Proper PPE must be worn at all times. Shavings and debris will be swept or vacuumed up to avoid cuts from debris.	4D	Training will be documented for designated individuals.
Shop	Sanding or grinding materials.	Improper use of PPE. Improper training on the use of equipment.	Mild to severe rash. Irritated eyes, nose or throat with the potential to aggravate asthma. Mild to severe cuts or burns from a Dremel tool and sanding wheel.	2C	Long sleeves will be worn at all times when sanding or grinding materials. Proper PPE will be utilized such as safety glasses and dust masks with the appropriate filtration required. Individuals will be trained on the tool being used. Those not trained will not attempt to learn on their own and will find a trained individual to instruct them.	4E	Training will be documented for designated individuals.

Shop	Working with chemical components resulting in mild to severe chemical burns on skin or eyes, lung damage due to inhalation of toxic fumes, or chemical spills.	Chemical splash. Chemical fumes.	Mild to severe burns on skin or eyes. Lung damage or asthma aggravation due ot inhalation.	2C	MSDS documents will be readily available at all times and will be thoroughly reviewed prior to working with any chemical. All chemical containers will be marked to identify appropriate precautions that need to be taken. Chemicals will be maintained in a designated area. Proper PPE will be worn at all times when handling chemicals. Personnel involved in motor making will complete the university's Lab and Research Safety Course. All other individuals will be properly trained on handling common chemicals used in constructing the launch vehicles.	3E	Training will be documented for designated individuals. Certificates will be kept on file for trained individuals until the individuals graduate and leave the organization.
Shop	Damage to equipment while soldering.	Soldering iron is too hot. Prolonged contact with heated iron.	The equipment could become unusable. If parts of the payload circuit become damaged, they could become inoperative.	3C	The temperature on the soldering iron will be controlled and set to a level that will not damage components. For temperature sensitive components sockets will be used to solder ICs to. Only personnel trained to use the soldering iron will operate it.	4D	Training will be documented for designated individuals.
Shop	Dangerous fumes while soldering.	Use of leaded solder can produce toxic fumes.	Team members become sick due to inhalation of toxic fumes. Irritation could also occur.	3D	The team will use well ventilated areas while soldering. Fans will be used during soldering. Team members will be informed of appropriate soldering techniques.	4E	Training will be documented for designated individuals.

Shop	Overcurrent from power source while testing.	Failure to correctly regulate power to circuits during testing.	Team members could suffer electrical shocks which could cause burns or heart arrhythmia.	1D	The circuits will be analyzed before they are powered to ensure they don't pull too much power. Power supplies will also be set to the correct levels. Team members will use documentation and checklists when working with electrical equipment.	2E	When available, an electrical engineering student will supervise electrical operations.
Shop	Use of white lithium grease.	Use in installing motor and on ball screws.	Irritation to skin and eyes. Respiratory irritation.	3D	Nitrile gloves and safety glasses are to be worn when applying grease. When applying grease, it should be done in a well ventilated area to avoid inhaling fumes. All individuals will be properly trained on handling common chemicals used in constructing the launch vehicles.	4E	Training will be documented for designated individuals.
Shop	Metal shards.	Using equipment to machine metal parts.	Metal splinters in skin or eyes.	1D	Team members will wear long sleeves and safety glasses whenever working with metal parts. Individuals will be trained on the tool being used. Those not trained will not attempt to learn on their own and will find a trained individual to instruct them.	4D	Training on this equipment is provided by the university through the Design for X Labs orientation and safety training program.

9.11.6 Failure Modes and Effects Analysis (FMEA) Analysis

Area	Hazard	Cause	Effect	Pre RAC	Mitigation	Post RAC	Verification
Logistic	Not enough time for adequate testing.	Failure to create a precise timeline.	Imprecision in the launch vehicle design and less verification of design.	3C	Create a rigorous timeline and ensure everyone stays on schedule. Make due dates at least three days in advance for deliverables. Use shared calendar to keep all personnel apprised of deadlines. A more detailed schedule was created to make sure the team remains on track. Each task has a description and expected deliverables. Full scale completion date moved earlier in the schedule to allow more testing. Alternate launch site (Bunnell) may be used if needed.	3E	Project schedule has been set with sufficient buffer time to absorb delays. Subscale testing was conducted according to the project plan. Current timeline allows for at least two full scale launch days, with a potential for 3-4 total launches.
Logistic	Parts ordered late or delayed in shipping.	Long shipping times and delays, failure to order parts in timely fashion.	Project schedule delayed. Selected functions unavailable.	2C	Shared calendar will be used to keep all personnel apprised of deadlines. Reminder notifications will be sent to technical leads well in advance of deadlines. When possible, suitable substitute parts will be maintained on hand. Finance managers will be recruited and trained to track budget and parts ordering.	2E	Project schedule has been shared to all team members. Backwards plans were created to visualize team progress and track construction milestones. Multiples of common construction items have been ordered.
Logistic	Parts fail or break.	Normal wear and tear. Improper installation.	Project delay. Damage to launch vehicle.	2C	When practicable, maintain suitable replacement parts on hand.	2E	Use checklist when assembling launch vehicle. Ensure technical lead supervision in handling of parts.

		Improper handling.					
Pad	Unstable launch platform.	Uneven terrain or loose components.	If the launch pad is unstable while the rocket is leaving the pad, the rocket's path will be unpredictable.	2E	Confirm that all personnel are at a distance allowed by the Minimum Distance Table as established by NAR. Ensure that the launch pad is stable and secure prior to launch.	3E	Use the Launch Procedure checklist when placing launch vehicle on launch rail.
Pad	Unleveled launch platform.	Uneven terrain or improperly leveled launch tower.	The launch tower could tip over during launch, making the rocket's trajectory unpredictable.	1E	Inspect launch pad prior to launch to confirm level. Confirm that all personnel are at a distance allowed by the Minimum Distance Table as established by NAR.	1E	Use the Launch Procedure checklist when placing launch vehicle on launch rail.
Pad	Rocket gets caught in launch tower or experiences high friction forces.	Misalignment of launch tower joints. Deflection of launch platform rails. Friction between guide rails and rocket.	Rocket may not exit the launch tower with a sufficient exit velocity or may be damaged on exit.	2E	During setup, the launch tower will be inspected for a good fit to the rocket. The launch vehicle will be tested on the launch rail. If any resistance is noted, adjustments will be made to the launch tower, allowing the rocket to freely move through the tower.	2E	Use the Launch Procedure checklist when placing launch vehicle on launch rail.
Pad	Sharp edges on the launch pad.	Manufacturing processes.	Minor cuts or scrapes to personnel working with, around, and transporting the launch tower.	3D	Sharp edges of the launch pad will be filed down and de-burred if possible. If not possible, personnel working with launch tower will be notified of hazards.	4E	Use the Launch Procedure checklist when placing launch vehicle on launch rail.

Pad	Pivot point bearings seize.	Load is larger than specifications. Debris enters bearings.	Launch platform will experience higher resistance to motion causing a potential hindrance the vehicle raising.	2D	Bearings will be sized based on expected loads with a minimum factor of safety. The launch platform will be cleaned following each launch and will be cleaned prior to each launch. Proper lubrication will be applied to any point expected to receive friction.	2E	Use the Launch Procedure checklist when placing launch vehicle on launch rail.
Payload	The rover deployment system fails to operate.	Rover sled is stuck. Fishing line is cut.	Rover cannot exit the vehicle, mission failure.	2D	The deployment system will be tested extensively with different variables. A guide will be put into place for the fishing wire and the sled will be sanded to remove any bumps.	2E	Deployment system testing. Full scale test launch.
Payload	Failure of on board electronics	)verheating from compacted space, solar panels, direct sunlight.	Rover cannot operate properly, mission failure.	2D	Various ventilation holes will be put around rover body but will have filters to keep dirt and other debris out.	4E	Inspection by Safety Officer. Ground and full scale launch testing.
Payload	Deployment system accidental operation during flight.	G-forces form flight and weight from the payload stress the system enough to break it, causing it to “deploy” early and come out of the rocket.	Mission failure. Possible damage to launch vehicle.	1D	Extensive testing will be performed prior to lunch. Strong solenoids will be used.	3E	Use Prior to Departure checklist when departing for launch field.

Recovery	Parachute deployment failure.	Altimeter failure. Electronics failure. Parachutes snag on shock cord.	Parachute deployment failure. Sections fail to separate. Damage to the launch vehicle.	2D	Shroud lines and shock cord will be measured for appropriate lengths. Altimeter and electronics check will be conducted with checklist several hours prior to launch. Nomex shields will be secured low on shroud lines to prevent entanglement. Main parachutes will deploy at different altitudes.	2E	Subscale test launch resulted in shroud lines and/or shock cords becoming entangled. Full scale testing will be conducted under new configuration.
Recovery	Sections fail to separate at apogee or at 1000 feet.	Black powder charges fail or are inadequate. Shear pins stick. Launcher mechanics obstruct separation.	Parachute deployment failure. Sections fail to separate. Damage to the launch vehicle.	2D	Correct amount of black powder needed for each blast charge will be calculated. Black powder will be measured using scale. Altimeter and electronics check will be conducted with checklist several hours prior to launch. Inside of rocket body will be coated with graphite powder in areas of launcher mechanics. Couplings between components will be sanded to prevent components from sticking together. Fittings will be tested prior to launch to ensure that no components are sticking together. In the event that the rocket does become ballistic, all individuals at the launch field will be notified immediately.	2E	Subscale ground and launch tests verified that the amount of black powder is adequate. However, In subscale test launch, all black powder charges successfully ignited, but full separation of booster main parachute was not achieved. Full scale ground testing will include parachutes in order to better simulate actual launch conditions. Use Launch Vehicle Assembly checklist when assembling launch vehicle.

Recovery	Sections separate prematurely.	Construction error. Premature firing of black powder due to altimeter failure or incorrect programming.	Structural failure, loss of payload, target altitude not reached.	1D	Use multiple shear pins to prevent drag separation. Verify altimeter altitudes.	1E	In subscale test launch, all sections successfully separated at designated altitudes. Altimeters performed correctly.
Recovery	Altimeter or e-match failure.	Parachutes will not deploy.	Rocket follows ballistic path, becoming unsafe.	2E	Dual altimeters and e-matches are included in systems for redundancy to eliminate this failure mode. E-matches will be tested for continuity prior to installation. Should all altimeters or e-matches fail, the recovery system will not deploy and the rocket will become ballistic, becoming unsafe. All personnel at the launch field will be notified immediately.	2E	In subscale ground testing, e-matches successfully ignited separation charges. In subscale test launch, primary and backup altimeters and black powder charges performed successfully.
Recovery	Rocket descends too quickly.	Parachute is improperly sized.	The rocket falls with a greater kinetic energy than designed for, causing components of the rocket to be damaged.	2E	The parachutes have each been carefully selected and designed to safely recover its particular section of the rocket. Extensive ground testing was performed to verify the coefficient of drag is approximately that which was used during analysis.	2E	The website http://descentratecalculator.onlinetesting.net/ was used to calculate theoretical descent values. Subscale testing resulted in no damage to rocket components.

Recovery	Rocket descends too slowly.	Parachute is improperly sized.	The rocket will drift farther than intended, potentially facing damaging environmental obstacles.	3E	The parachutes have each been carefully selected and designed to safely recover its particular section of the rocket. Extensive ground testing was performed to verify the coefficient of drag is approximately that which was used during analysis.	3E	The website http://descentratecalculator.onlinetesting.net/ was used to calculate theoretical descent values. Subscale testing resulted in no damage to rocket components.
Recovery	Parachute has a tear or ripped seam.	Parachute is less effective or completely ineffective depending on the severity of the damage.	The rocket falls with a greater kinetic energy than designed for, causing components of the rocket to be damaged.	2E	Through careful inspection prior to packing each parachute, this failure mode will be eliminated. One spare large parachute will be on hand. Rip stop nylon was selected for the parachute material. This material prevents tears from propagating easily. In the incident that a small tear occurs during flight, the parachute will not completely fail.	2E	During subscale launch, parachutes were damaged. For full scale testing and launch, new parachutes and large Nomex protectors are being purchased.
Recovery	Recovery system separates from the rocket.	Bulkhead becomes dislodged. Parachute disconnects from the U-bolt.	Parachute completely separates from the component, causing the rocket to become ballistic.	1E	The cables and bulkhead connecting the recovery system to each segment of the rocket are designed to withstand expected loads with an acceptable factor of safety. Should the rocket become ballistic, all personnel at the launch field will be notified immediately.	1E	During subscale test launch, all parachutes remained attached to components and all U-bolts and bulkheads performed sufficiently so that all sections landed safely.

Recovery	Lines in parachutes become tangled during deployment.	Parachute becomes unstable or does not open. Parachute cord becomes caught in landing device.	The rocket has a potential to become ballistic, resulting in damage to the rocket upon impact.	1E	Nomex protection cloths will be used between parachutes to avoid entaglement. Ground testing will be performed to ensure that the packing method will prevent tangling during deployment prior to test flights. Parachutes will be deployed at different altitudes.	1E	During subscale launch tests parachute lines became entangled. Full scale testing will be conducted under new configuration and settings. Use Launch Vehicle Assembly and Parachute Folding checklists when assembling launch vehicle.
Recovery	Parachute does not inflate.	Parachute lines become entangled.	Parachute does not generate enough drag.	2E	Parachute lines will be carefully folded in accordance with checklist. Nomex covers will be secured at lower end of shroud lines.	2E	Subscale test launch showed that the parachute that did deploy successfully opened, verifying that the folding and packing technique with reference to this are appropriate. Use Launch Vehicle Assembly and Parachute Folding checklists when assembling launch vehicle.
Stability	Motor CATO (catastrophic failure) (on launch pad or while in flight).	Improper motor manufacturing . Injury to personnel.	Launch vehicle is destroyed and motor has failed. Moderate explosion.	1D	Ensure nozzle is unimpeded during assembly. Inspect motor for cracks and voids prior to launch. Ensure all team members are a safe distance away from the launch pad upon ignition of the rocket.Wait a specified amount of time before approaching the pad after a catastrophe. All fires will be	2E	Motor preparation checklist will be utilized to inspect motor prior to launch. Manufacturer's instructions will be followed in assembling the motor.

					extinguished before it is safe to approach the pad.		
Stability	Motor Retention Failure.	The drogue parachute ejection charge applied a sufficient force to push the motor out the back of the launch vehicle.	The motor is separated from the launch vehicle without a parachute or any tracking devices.	1D	Ensure that the centering rings have been thoroughly epoxied to both the motor mount and to the inner walls of the airframe. Ensure that motor is properly secured using motor mount adapter and retainer ring.	1E	Motor preparation checklist will be utilized to inspect motor prior to launch. Manufacturer's instructions will be followed in assembling the motor. During full flight test, drogue parachute charge was not sufficient to eject motor. Motor mount adapter and retainer ring prevented motor from ejecting.
Stability	Loss of stability during flight.	Damage to fins or launch vehicle body, poor construction.	Failure to reach target altitude, destruction of vehicle.	1D	The CG of the vehicle will be measured prior to launch. Launch vehicle will be inspected prior to launch. Proper storage and transportation procedures will be followed.	2E	General Pre-Flight Inspection will be conducted prior to launch. Final Assembly and Launch Procedures Checklists will be used during assembly and launch. Launch vehicle will be cleaned and inspected in accordance with Post-Flight Checklist.

Stability	Change in expected mass distribution during flight.	Payload shifts during flight, foreign debris is deposited into the PEM along with the payload.	Decrease in stability of the launch vehicle, failure to reach target altitude, destruction of vehicle.	1D	The payload will be centered inside the launch vehicle and secured. Inspection will be conducted to ensure parachutes and shock cord do not move freely in the airframe.	2E	Final Assembly and Launch Procedure Checklists will be used to assemble launch vehicle and to fold and insert parachutes.
Stability	Motor retention failure.	Design of retention fails. Retention assembly failure.	Motor falls out of booster section while propelling body forward and launch vehicle fails to achieve 5280 ft altitude.	2D	Retention rings will be machined using designs from SolidWorks to ensure proper dimensions. Robust material such as aluminum will be used to ensure the integrity of the design.	2E	During subscale launch test, motor mount adapter and retainer ring prevented motor from ejecting.
Stability	Mass increase during construction.	Unplanned addition of components or building materials.	Launch vehicle does not fly to correct altitude. All sections land with high kinetic energy. Possible minor damage to rocket body and/or fins.	2C	Record will be maintaned of mass changes. Launch vehicle simulations will be repeated for each mass change. Additional launch vehicle simulations will be performed at plus 5% of caclulated mass. Subscale and full scale launches will be performed with accurate mass.	3E	During subscale test launch, launch vehicle did not reach planned altitude. The team has selected a larger motor for full scale launch. New open rocket simulation indicates more than sufficient height at apogee, which will be altered by the adjustable ballast system.
Stability	Motor fails to ignite.	Faulty motor. Delayed ignition. Faulty e-match. Disconnected e-match.	Rocket will not launch. Rocket fires at an unexpected time.	1D	Checklists and appropriate supervision will be used when assembling. NAR safety code will be followed and personnel will wait a minimum of 60 seconds before approaching rocket. If there is no activity after 60 seconds, safety officer will check the ignition system for a	1E	Igniter Installation checklist will be used when installing ingiter. During subscale test launch, igniter performed as expected.

					lost connection or a bad igniter.		
Stability	Rocket doesn't reach high enough velocity before leaving the launch pad.	Rocket is too heavy. Motor impulse is too low. High friction coefficient between rocket and launch tower.	Unstable launch.	1E	Too low of a velocity will result in an unstable launch. Simulations have been and will continue to be run to verify the motor selection provides the necessary exit velocity. Ful scale testing will be conducted to ensure launch stability. Should the failure mode still occur, the issue should be further examined to determine if the cause was due to a faulty motor or in the booster needs to be redesigned.	1E	Subscale testing resulted in sufficient velocity. Motor and booster performed as expected.
Stability	Internal bulkheads fail during flight.	Forces encountered are greater than the bulkheads can support.	Internal components supported by the bulkheads will no longer be secure. Parachutes attached to bulkheads will be ineffective.	2E	The bulkheads have been designed to withstand the force from takeoff with an acceptable factor of safety. Additional epoxy will be applied to ensure security and carbon fiber shreds will be added where appropriate. Electrical components will be mounted using fasteners that will not shear under the forces seen during the course of the flight. Full scale testing will be conducted and	2E	During subscale flight, all bulkheads performed as expected. Full scale testing will be conducted.

					bulkheads inspected after each flight.		
Stability	Motor retainer falls off.	Joint did not have proper preload or thread engagements.	Motor casing and spent motor fall out of rocket during when the main parachute opens.	2E	Checklists and appropriate supervision will be used when assembling.	2E	Motor preparation checklist will be utilized to inspect motor prior to launch. Manufacturer's instructions will be followed in assembling the motor.

9.11.7 Environmental Concerns Analysis

Area	Hazard	Cause	Effect	Pre RAC	Mitigation	Post RAC	Verification
Environmental	Harmful substances permeating into the ground or water.	Improper disposal of batteries or chemicals.	Impure soil and water can have negative effects on the environment that in turn, affect humans and animals, causing illness.	2E	Batteries and other chemicals will be disposed of properly in accordance with the MSDS sheets. Should a spill occur, proper measure are to be followed in accordance with the MSDS sheets and any EHS standards.	2E	MSDS sheets will be kept on hand in the shop and at the launch field.
Environmental	Spray painting.	The rocket will be painted.	Water contamination. Emissions to environment.	3D	All spray painting operations will be performed in a paint booth by trained individuals. This prevents any overspray from entering into the water system or the air. Additionally, when possible, painting will be conducted by	3E	Paint booth will be marked with appropriate signage for hazardous material. Training will be documented for designated individuals.

					trained professionals rather than SOAR members.		
Environmental	Plastic and fiberglass waste material.	Plastic used in the production of electrical components and wiring and fiberglass used in production of launch vehicle components.	Plastic or fiberglass material produced when shaving down or sanding components could harm animals if ingested by an animal. Plastic could find its way down a drain and into the water system.	3D	All plastic material will be disposed of in proper waste receptacles. Personnel will used protective equipment when sanding or cutting plastic and fiberglass.	4E	Waste receptacles will be available and properly marked. Protective equipment is on hand.
Environmental	Wire waste material.	Wire material used in the production of electrical components.	Sharp bits of wire being ingested by an animal if improperly disposed of.	3D	All wire material will be disposed of in proper waste receptacles.	4E	Waste receptacles will be available and properly marked.
Environmental	Low cloud cover.	N/A	Unable to test entire system.	3C	When planning test launches, the forecast should be monitored in order to launch on a day where weather does not prohibit launching or testing the entire system.	3E	Monitor local weather and verify on launch day

Environmental	Rain.	N/A	Unable to launch. Damage electrical components and systems in the rocket.	3C	When planning test launches, the forecast should be monitored in order to launch on a day where weather does not prohibit launching or testing the entire system. Have a plan to place electrical components in water tight bags. Have a location prepared to store the entire rocket to prevent water damage. Electronics on the ground station are all stored in water tight control boxes to seal out any moisture.	3E	Monitor local weather and verify on launch day
Environmental	Thunderstorms.	N/A	Damage due to electrical shock on system.	2D	When planning test launches, the forecast should be monitored in order to launch on a day where the weather does not prohibit launching or testing the entire system. Should a storm roll in, the entire system should be promptly packed and removed from the premise to avoid having a large metal object exposed during a thunderstorm. In the event that the system cannot be removed, personnel are not to approach the launch pad during a thunderstorm.	2E	Monitor local weather and verify on launch day

Environmental	High winds.	N/A	Have to launch at high angle, reducing altitude achieved. Increased drifting. Unable to launch.	2D	When planning test launches, the forecast should be monitored in order to launch on a day where weather does not prohibit launching or testing the entire system. If high winds are present but allowable for launch, the time of launch should be planned for the time of day with the lowest winds.	2E	Monitor local weather and verify on launch day. Adjustable ballast system is designed to be adjustable to different wind conditions, however, testing has not yet been conducted. Full scale flight testing will be conducted and calculations performed based on subscale and full scale testing, as well as previous similar launches.
Environmental	Trees.	N/A	Damage to rocket or parachutes. Irretrievable rocket components.	2D	Launching with high winds should be avoided in order to avoid drifting long distances. Drift calculations have been computed, so we can estimate how far each component of the rocket will drift with a particular wind velocity. The rocket should not be launched if trees are within the estimated drift radius.	2E	Drift calculations conducted using planned parachutes predict that launch vehicle will remain within the allowed drift range, which is free of trees.
Environmental	Swampy ground.	N/A	Irretrievable rocket components.	2D	With the potential of the ground being extremely soft at local launch sites and in Huntsville, the rocket should not be launched if there is swampy ground within the predicted drift radius that would prevent the team from retrieving a component of the rocket.	2E	Drift calculations conducted using planned parachutes predict that launch vehicle will remain within the allowed drift range, which is free of bodies of water.

Environmental	Ponds, creeks, and other bodies of water.	N/A	Loss of rocket components. Damaged electronics.	2D	Launching with high winds should be avoided in order to avoid drifting long distances. The rocket should not be launched if a body of water is within the estimated drift radius. Should the rocket be submerged in water, it should be retrieved immediately and any electrical components salvaged. Electrical components are to be tested for complete functionality prior to reuse.	2E	Drift calculations conducted using planned parachutes predict that launch vehicle will remain within the allowed drift range, which is free of bodies of water.
Environmental	Extremely cold temperatures.	Batteries discharge quicker than normal. Shrinking of fiberglass.	Completely discharged batteries will cause electrical failures and fail to set off black powder charges, inducing critical events. Rocket will not separate as easily.	3D	Batteries will be checked for charge prior to launch to ensure there is enough charge to power the flight. Should the flight be delayed, batteries will should be rechecked and replaced as necessary. If the temperatures are below normal launch temperature, black powder charges should be tested to ensure that the pressurization is enough to separate the rocket. If this test is successful, the rocket should be safe to launch.	3E	Use Final Assembly and Launch Procedure Checklists when assembling launch vehicle. Test all batteries prior to installation and as close in time as practicable to the launch time.

Environmental	Humidity.	N/A	Motors or black powder charges become saturated and don't ignite.	2D	Motors and black powder should be stored in an water resistant container.	2E	Use Field Packing List when preparing tools, parts, and consumables to go to the field. Black powder will be kept in commercially approved packages, which are designed to prevent moisture buildup.
Environmental	UV exposure.	Rocket left exposed to sun for long periods of time.	Possibly weakening materials or adhesives.	3D	Rocket should not be exposed to sun for long periods of time. If the rocket must be worked on for long periods of time, shelter should be sought.	3E	Rocket is constructed and maintained in an air conditioned workshop.

10 Payload Criteria

10.1 Selection, Design, and Rationale of Payload

Deployable rover payload has been chosen. It will be designed according to the following criteria:

10.2 Mission Criteria and Verification

Table 35: Detailed payload mission requirements and confirmation methods.

Requirement	Method	Verification	Verification Status
NASA Student Launch Success Criteria			
Each team will choose one design experiment option from the following list.	Inspection	SOAR has selected Option 2: Deployable Rover as its experimental payload.	Verified with submission of Project Proposal.
Additional experiments (limit of 1) are allowed, and may be flown, but they will not contribute to scoring.	N/A	SOAR has not selected a second experiment.	N/A
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.	N/A	SOAR has not selected a second experiment.	N/A
Teams will design a custom rover that will deploy from the internal structure of the launch vehicle.	Demonstration	A winch and sled system will be designed to both secure and deploy the custom rover. The rover will emerge from within and be cleared out of the launch vehicle.	Rover ground testing to be conducted. Full scale launch testing to be conducted.

At landing, the team will remotely activate a trigger to deploy the rover from the rocket.	Demonstration/Testing	Rover will utilize a receiver and team will operate a transmitter that will remotely trigger the rover to deploy from the launch vehicle.	Rover ground testing to be conducted. Full scale launch testing to be conducted.
After deployment, the rover will autonomously move at least 5 ft. (in any direction) from the launch vehicle.	Demonstration/Testing	During rover ground testing and full scale launch testing will be conducted to see how far the rover can travel from the launch vehicle. After full scale launch day any necessary adjustments will be made and further testing will be conducted to ensure rover travels at least 10 feet from launch vehicle.	Rover ground testing to be conducted. Full scale launch testing to be conducted.
Once the rover has reached its final destination, it will deploy a set of foldable solar cell panels.	Demonstration/Testing	Rover will be designed to deploy solar panels once it has reached its destination. Testing will be conducted prior to competition day to ensure solar cells deploy after rover has reached its final destination.	Rover ground testing to be conducted. Full scale launch testing to be conducted.
SOAR Payload Success Criteria			
Deployable rover will travel at least 10 ft after departing from launch vehicle.	Rover will have enough power from its batteries to run its motors continuously for 45 min	Each battery is rechargeable and will be fully charged no later than 24 hours before the launch. Team leads will check the voltage in each battery with a multimeter	Rover ground testing to be conducted. Full scale launch testing to be conducted.
The rover will be under 10 pounds in total weight	Rover body and wheels will be made out of lightweight materials. Rover is design to	The rover will be weighed before launch. Any excess weight will be shed from removing	Rover ground testing to be conducted. Full scale launch testing to be conducted.

	include only absolutely necessary electronics, sensors, and wires.	some batteries first, then parts of the rover body, then sensors.	
The rover will have the capability to distribute power from its solar cells to its batteries	Rover will have power controllers and distribute power directly to half of its batteries at a time.	The team leads will test the voltage output from its solar panels with a multimeter and monitor the changing levels of the voltage from its batteries.	Rover ground testing to be conducted. Full scale launch testing to be conducted.
The rover will have the capability to avoid objects autonomously	The rover is designed with cameras and other sensors and will be programmed to detect objects and maneuver around them	Team leads will perform practice runs by putting various objects of different sizes in front of the rover and adjust programming if needed	Rover ground testing to be conducted. Full scale launch testing to be conducted.
The rover will have the capability to communicate the status of all its batteries and location from the rocket body	The rover will include power sensors in each battery section and communicate with the team via wireless connection through the rocket body	The team leads will remove each battery one at a time and verify that the missing battery is relayed to the team.	Rover ground testing to be conducted. Full scale launch testing to be conducted.

10.3 Selected Design Elements and Justification

10.3.1 Main Rover Design: Sidewinder

Figure 35: Sidewinder rover.

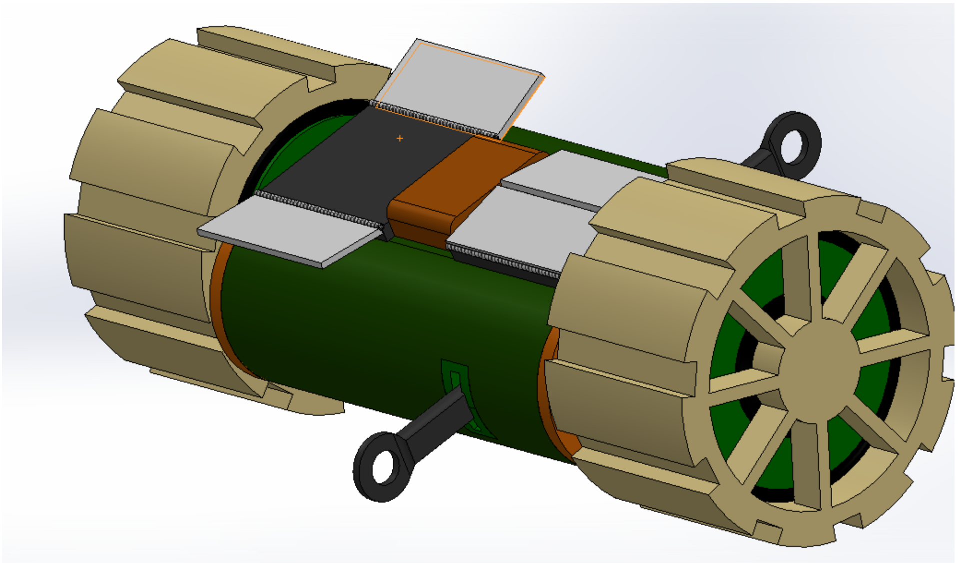


Figure 36: Sidewinder rover views.

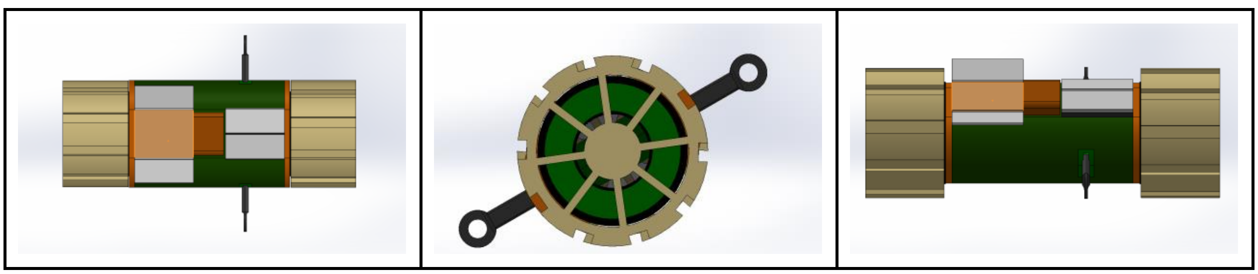
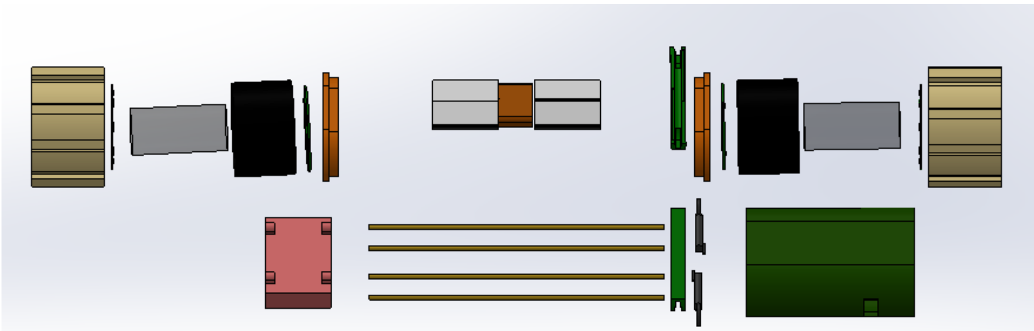


Table 36: Sidewinder rover pros and cons.

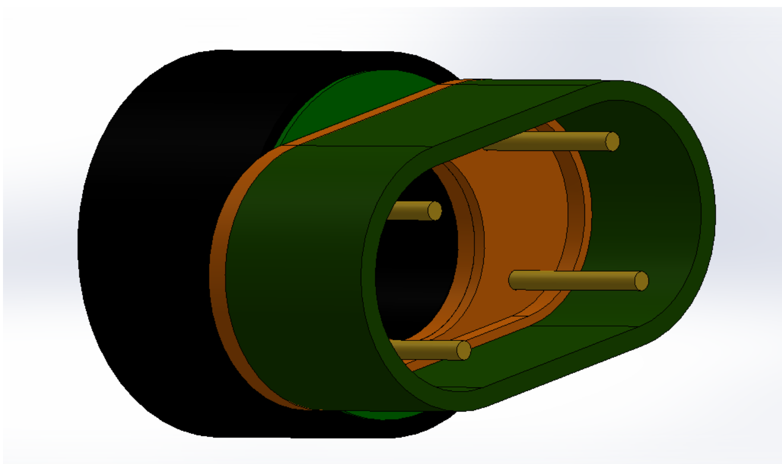
Pros	Cons
Takes up the most volume for the payload section, and allows for the largest diameter wheels.	Maneuverability around objects will be a problem
Design is modular. Parts or assemblies can be change quickly. This allow for fast repairs and efficient research and design.	Heavier than some designs
Large relative body size makes for easy	Will have difficulty going over objects if

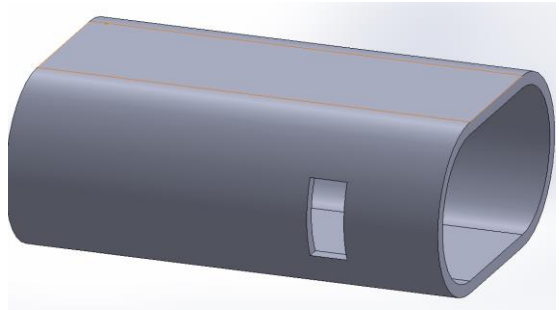
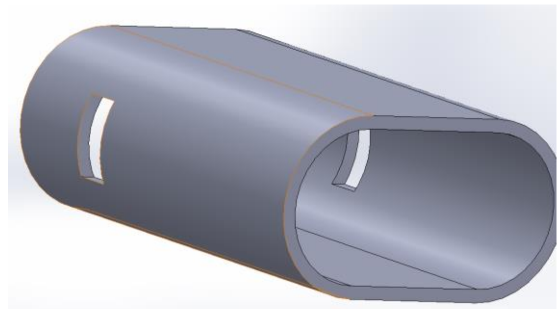
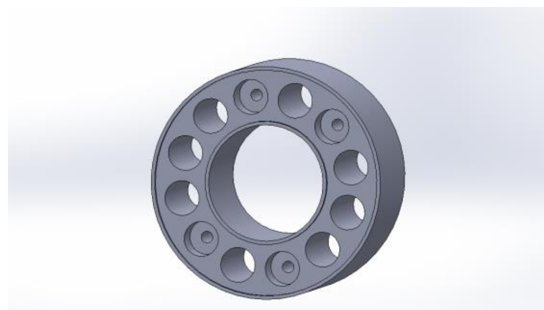
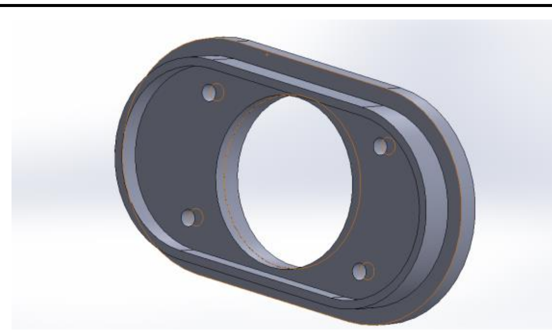
incorporation of a wide variety of sensor and other electronics.	needed
Rover will be able to hold up to 16 AA size batteries plus a 5V battery for the nav system. This allows it to have massive power reserves to accomplish the mission.	

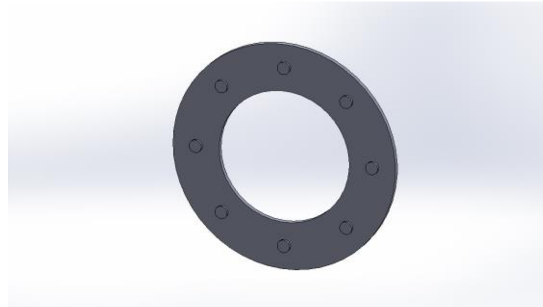
Figure 37: Sidewinder rover components.

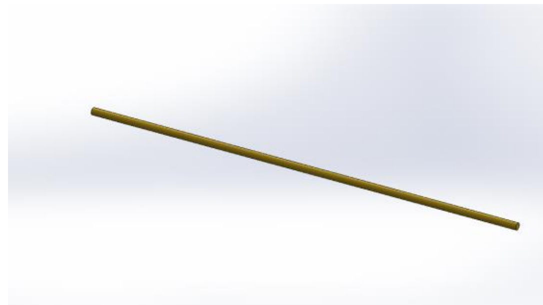
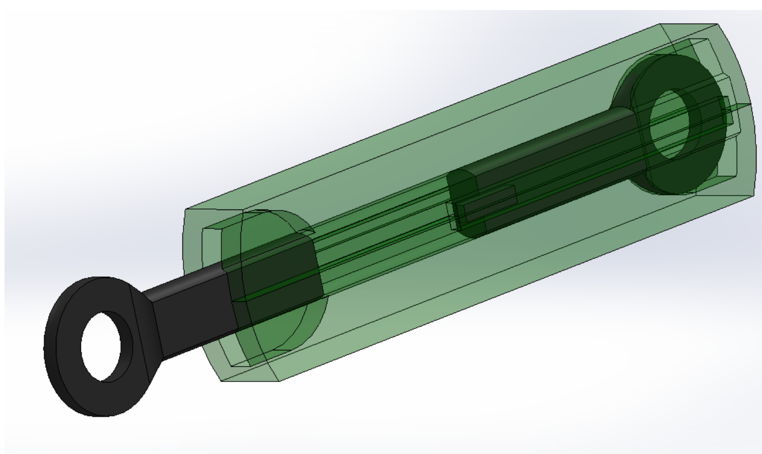
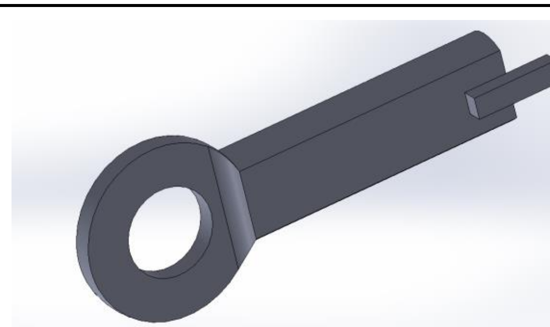


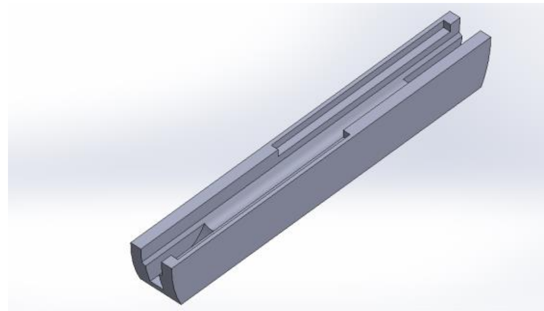
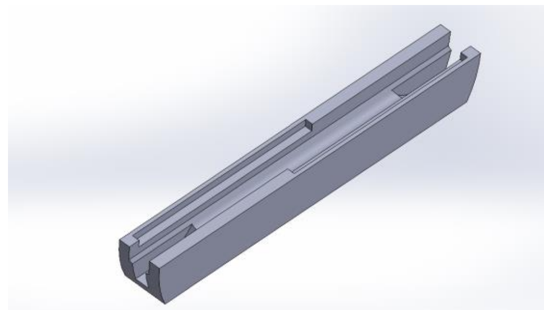
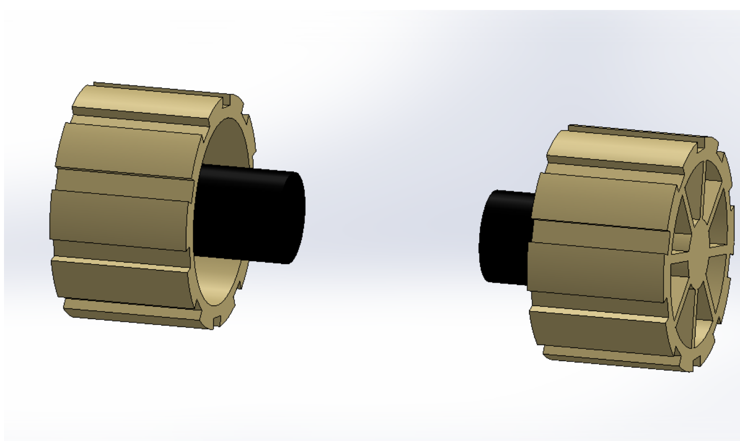
Structural System PN RA100	

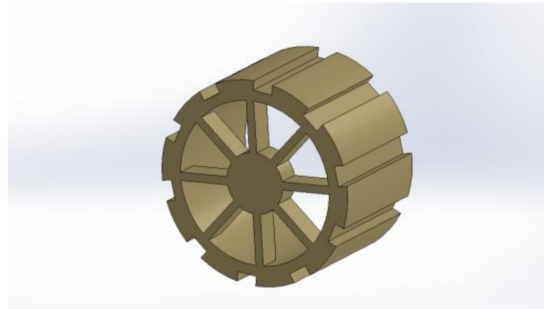


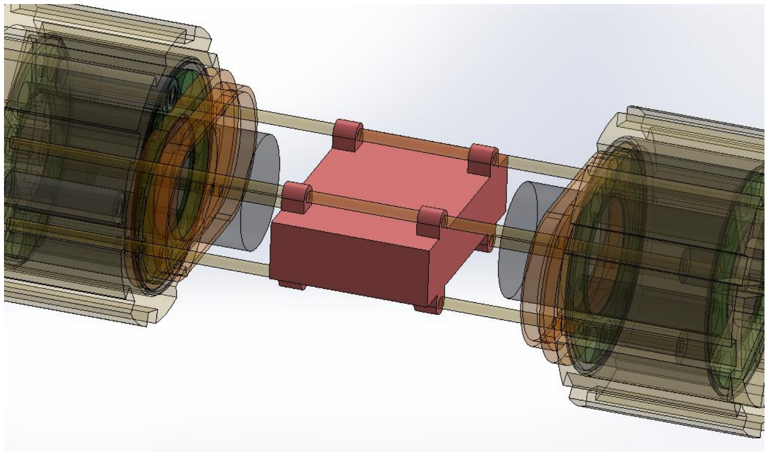
Main Rover Body PN:R101 Quantity: 1 This is the outer cover for the main body segment of the rover. It is made to fit the internal diameter of the rocket body wall lengthwise. And it is designed for ground clearance vertically. Ports are cut in the front and back for the Newtonian leg assembly. The dimensions of this part will change to fit rocket body internal diameter. Length of part may change to change length of rover. If current volume is excessive for requirements body will be reduced to save weight and space. Additional ports in body may be cut for sensors. Portions of top and bottom of body may be removed for solar panel assembly installation.	 
Side Rover Body Segment PN:R102-R103 Quantity: 2 These parts are placed on either side of the main rover body segment. The side body segment houses the batteries and is where the skeletal support rods begin and end. There are eight battery holes in the part, sized to fit the AA battery type. This makes the power system extremely flexible. The system voltage can be changed quickly to a wide spectrum of voltages including 12V, 24V and 48V just by changing to different AA battery voltages and/ or changing the series/parallel connections.	
Body Segments Connector PN:R104-R105 Quantity: 2 This is the part that joins the main body and the side body segments.	

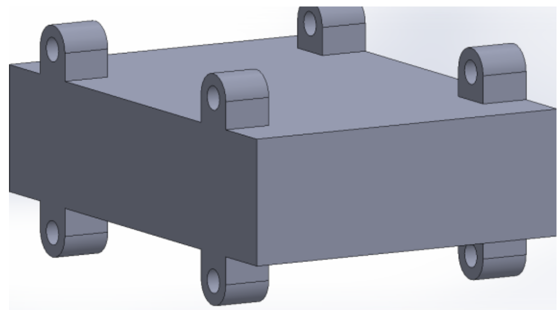
<table>
<tr><td>Battery Compartment Cover.
PN:R106-R109
Quantity: 4
These parts attach to the side body segments. They allow for quick access to battery compartment. They will cover and hold batteries, terminal boards, terminal springs.</td><td></td></tr>
<tr><td>Skeletal Support Rods
PN:R110-R113
Quantity: 4
These parts are within the rover. They are basic steel threaded rods used to squeeze all body pieces together. They are also used to mount and secure internal components.

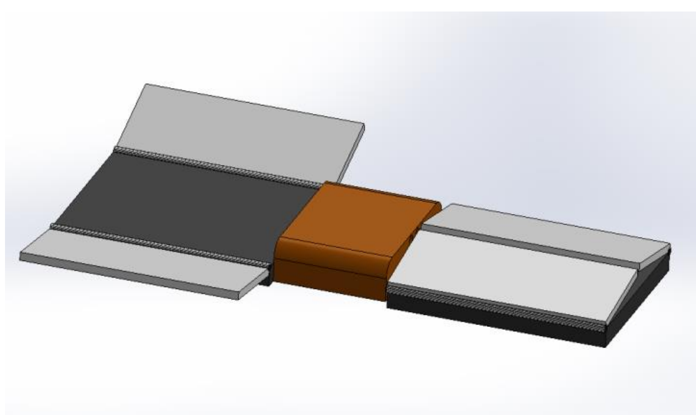
Rods will have to be cut to specific length and will have to be recut if rover length changes.</td><td></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Newtonian Leg Assembly PN RA400</td><td></td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Newtonian Leg
PN:R401-R402
Quantity: 2
This part rests within the Newtonian leg assembly and is spring loaded while in the rocket body. The rocket body walls hold the legs back. When the rover is deployed the legs automatically deploy.</td><td></td></tr>
</table>

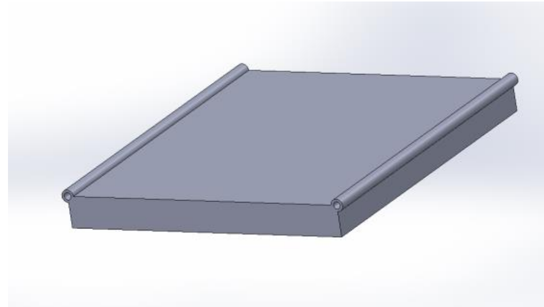
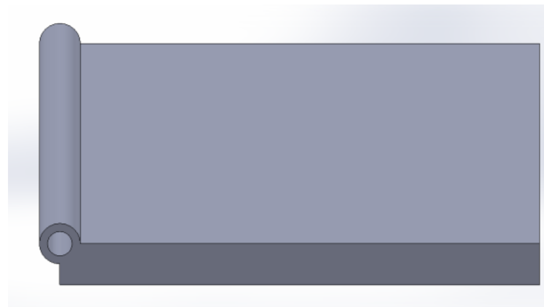
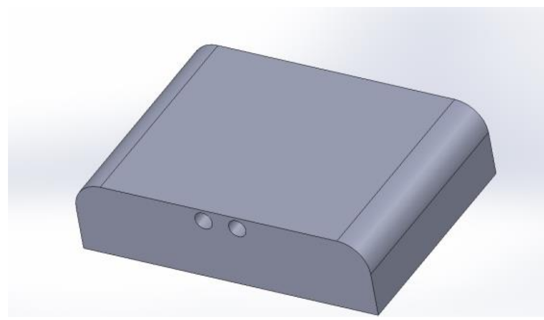
A rotating wheel may be added to replace the circular ring. The end will need to be hollowed out to make room for the deployment spring.	
Leg Ejector Body Half 1 PN:R404 Quantity: 1 This part houses the Newtonian legs and the leg deployment spring. It prevents the Newtonian legs from rotating. It not the same as the other half. The cutouts for the restraining tabs make them different.	
Leg Ejector Body Half 2 PN:R405 Quantity: 1 This part houses the Newtonian legs and the leg deployment spring. It prevents the Newtonian legs from rotating. It not the same as the other half. The cutouts for the restraining tabs make them different.	
Drive Section PN: RA300	
	

Wheels PN:R306-R307 Quantity: 2 These parts are placed at the ends of the rover covering the side body segments. The wide hollow design allows the wheel to completely cover the side body portion of the rover. this allow for that portion of the body to be maximized without threat of the body portion from hitting ground obstacles. Wheels are currently 4.8 inches in diameter. Wheel treads are flexible and will be the subject of future research to determine the best tread pattern for different conditions. Currently the gaps between the treads is 0.5 inches.	
Motor Assembly PN: Quantity: 2 This motor sits at 1.45 inches in diameter and 2.45 inches long. The motor has a stall torque rating of 42kg-cm. This motor will drive the wheels and has a rating of 100RPM. It is a brushed DC motor with a d-shaped shaft that is 5mm in diameter	
Control/Sens/Nav/Com PN: RS600	



Controller Housing PN:RS602 Quantity: 1 This object represents the designated space for the controller housing. It is positioned in the center of the rover and is attached to the skeletal support rods. This part is split into two so that the controller can be sandwiched in between. The ports for connections will be cut as needed.	
Solar Assembly PN: RA500	



Solar System Base PN:R501-R502 Quantity: 2 This part is the base piece for the solar system. It mounts to the body of the rover and acts as a pivot point for the solar cell arms. Solar cells will be mounted on the surface. When the final dimensions of the solar cells are finalized they will be recessed into the plate.	
Solar System Panel PN: R503-R506 Quantity: 4 This part is the rotating piece for the solar system. It mounts to the base of the solar assembly. Solar cells will be mounted on the surface. When solar cells are chosen the design of the panel will be changed so that the cells are recessed into the plate.	
Solar System Deployment Trigger Block PN:R508 Quantity: 1 This part is placed in between the two folding solar cell assemblies. It will house the trigger mechanisms holding the solar panels closed. Four pins holding back the panels can be made to be pulled independently. Thereby making it possible to create redundant deployment systems. This part will be designed with more detail when the trigger mechanisms are developed.	

10.4 Payload Deployment Method

10.4.1 Objective of the Deployment system

1. To initiate when commanded by the ground safety officer
2. Move a 10 lb payload beyond the exterior of the vehicle
3. Secure the payload prior to activation
4. Release the payload when beyond the exterior of the vehicle

10.4.2 Deployment thought process

In addition to meeting the above requirements, the design needs to take into consideration other variables

The simplicity of the design prevents an over complicated design from failing upon launch. The more simplistic the design, the better. This means relying more on as few electronic components as possible.

The weight of the deployment system cannot be too large, or the rocket will not reach the desired Apogee. The maximum weight for the rover and deployment system is set at 10lbs. For this reason, alternative materials such as 3D printed parts are preferable to metal as they are lighter and do not have large forces being applied.

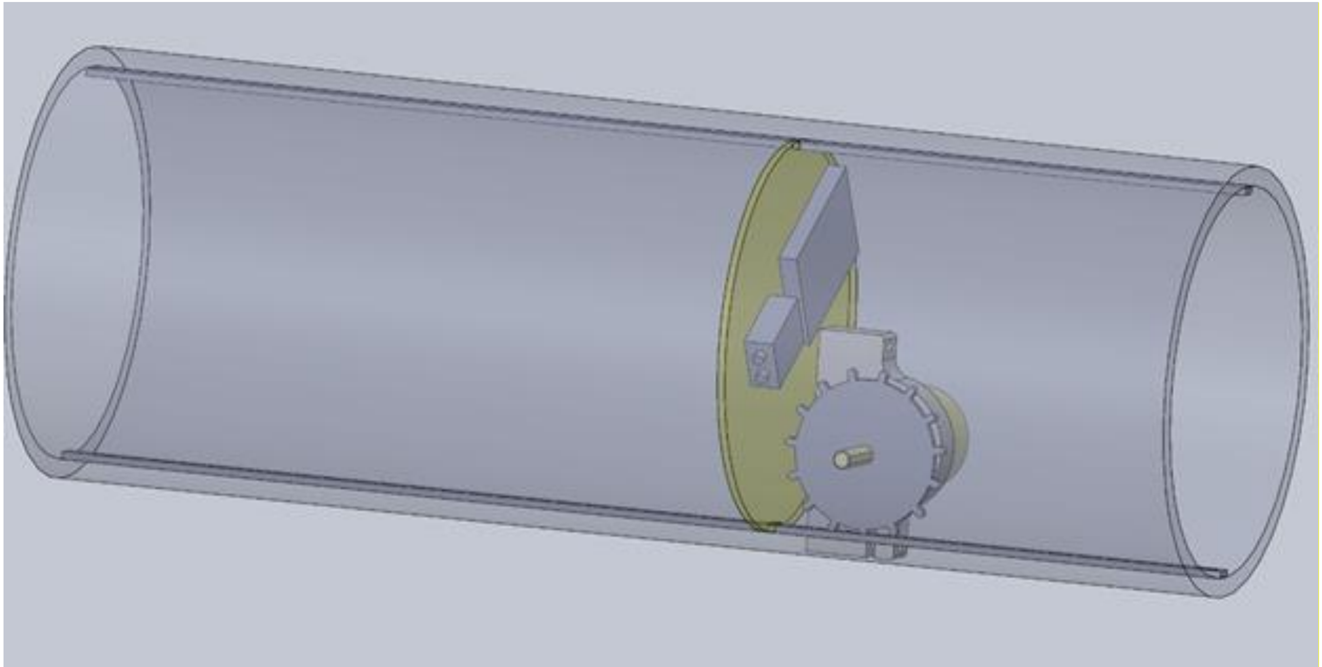
The size is important because it must fit within the frame of the rocket and compress to allow for as large of a rover as possible. This also affects the weight of the system as a larger system tends to be heavier.

Ease of loading and unloading the rover into the vehicle. Not only does the system have to deploy the rover, it must be able to load and secure the rover. It must be capable of loading while the rocket is assembled. Taking safety into consideration is very important for this, a sensitive system may launch the rover prior to being set and secured.

10.4.3 Previous design from PDR: Rack and pinion

Previously upon initiation by the ground team, the payload will be moved by a rack and pinion system inside of the vehicle. A powered bike sprocket and bike chain, fixed to the inside of the vehicle, will be used as the rack and pinion as seen below. The motor, battery, and onboard computer will be secured to the back side of the plate. The payload will be secured with a fixed attachment that goes through the tread of the wheel and expands on the other side to secure the payload in relation to the plate. This allows the payload to move with the rack and pinion while still inside of the vehicle frame. Outside of the vehicle frame, the payload will be able to detach from the plate using its own forward motion.

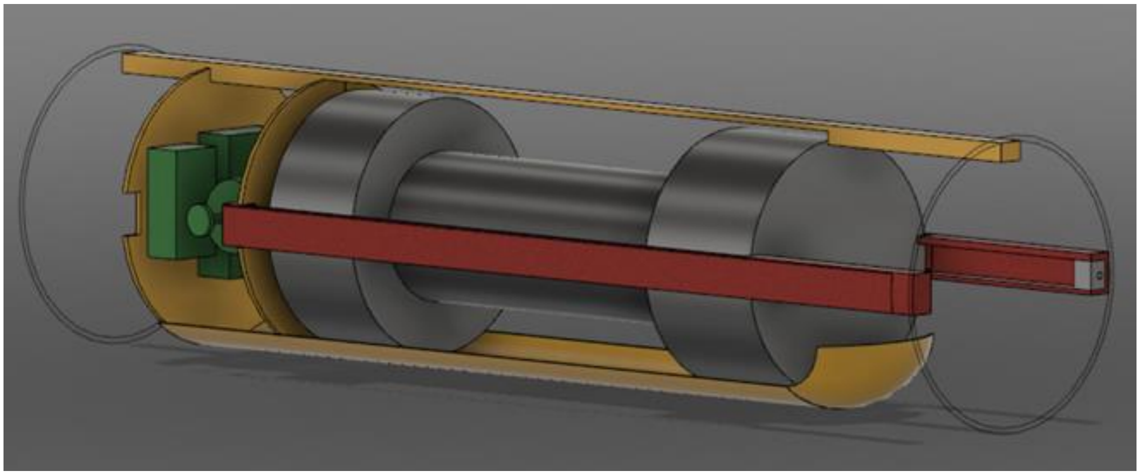
Figure 38: Rack and pinion rover deployment device drawing.



10.4.4 Current Design: Sled and Winch System

The reason for the change from the previous design to the new one is based on the availability of materials and the considerable weight that the system will be. The rover will sit in a sled as pictured below. Behind the sled there are two plates that are attached where the motor and various electronics are secured into. The motor will spin a spool of fishing line wire which will pull the entire sled forward towards the opening of the rocket body. There are three railings attached directly to the rocket body and fit between the treads of the wheels of the rover. The sled and the rover will slide in over them. The railing are placed to prevent the rover from spinning or moving in such as way to prevent the system from operating properly and the sled is designed with a curved end to prevent the sled from digging itself into the ground. The railings are also hollowed to allow the spool to guide itself to the end of the rocket.

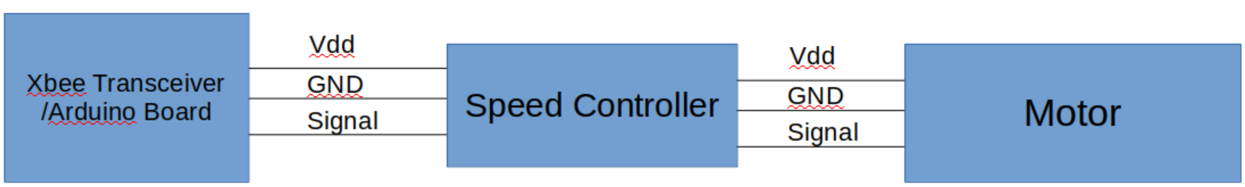
Figure 39: Sled and winch rover deployment system.



10.4.5 Deployment Systems Electronics

The main deployment system will utilize two XBee RF transceivers that communicate between the base station and onboard system. The base station will consist of one XBee transceiver and a computer which will be connected by USB. The onboard deployment system will have the XBee transceiver connected to a shield that is designed to be attached an Arduino. Upon activation from the base station signal, the Arduino will enable the speed controller that will control the speed of the motor. A manual switch will be used as a backup activation method to the deployment system.

Figure 40: Rover system electronics



10.4.6 Rover Body Electronics

Table 37: Rover body electronic components.

Component	Voltage	Current	Size
12V 100RPM 583 oz-in Brushed DC Motor	12V	68 mA	37x37x63.5mm
Velotech Magic Multirotor Speed Controller	5V	BEC Output: 2A Constant: 30A	48x26x10mm

XBee Pro S3B	2.4 - 3.6 VDC	Tx: 215 mA Rx: 26 mA Sleep: 2.5 uA	3.29 x 2.44 x 0.546cm

10.4.7 Distance Determination

Table 38: Pros and cons of distance determination options.

	Pros	Cons
Accelerometer	-Accurate measurement of acceleration up to 16G -Can measure acceleration on 3 axes. -Low power usage up to 23μA	-Acceleration measurement on slopes may affect distance determination -Additional programming and calculation to determine distance
Hall Effect Sensor	-Every rotation of the wheels will be sensed -Saves space and weight due to small size	-Can be knocked loose -Possible short-circuit and will not work
Bluetooth Connection	-Wireless Connection -Gives a general sense how far rover is from rocket body	-Signal is degraded within rocket and rover -May send trigger signal too soon due to signal strength

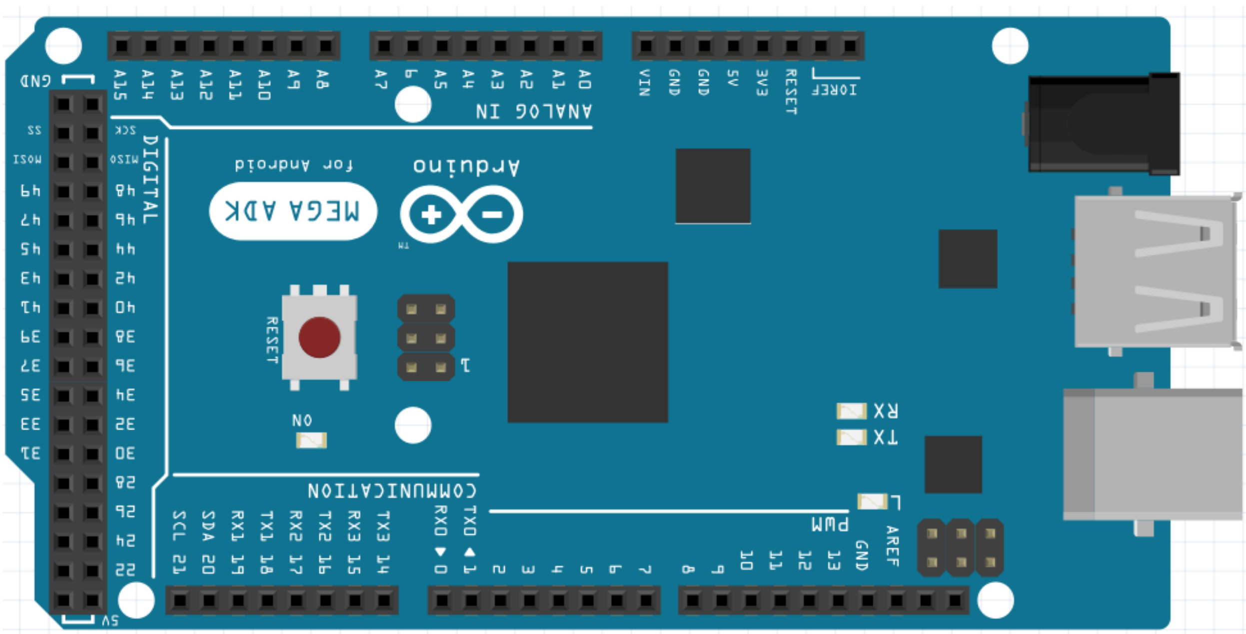
10.4.7.1 Hall Effect Sensor

The AH3362 is an AECQ100 qualified high voltage high sensitivity Hall Effect Unipolar switch IC designed for position and proximity sensing which will detect a magnet that will be located within the wheel assembly of the rover. The sensor will operate at 3.5V which is managed by the Arduino and this operating voltage will also minimize the amount of current leakage from the IC. The sensor will keep track of the amount of rotations over a given period of time. The equations to compute the distance will be the following, $V \omega r$ $\omega = (RPM * 2\Pi)/60$ $d = V * t$. V is linear velocity in meters/second, ω = angular velocity in radians/second, d = distance in meters.

10.4.7.2 ADXL345 Digital Accelerometer

The ADXL345 Accelerometer will be used to verify that the rover is moving. This verification will be used in addition to the hall effect sensor so that way if the rover is moving it will keep the hall effect sensor active and will continue counting. The accelerometer can be used to determine the distance traveled by the equation: $d = 1/2 * a\,t^2$ where d: distance in meters, a: acceleration in m/s^2 and t: time in seconds. The sensor will be set to the lowest sensitivity of 2g in order to account for any variation of acceleration from the rover.

Figure 41: Arduino Mega pin layout.



The connections to the pins from the subsystem components will be outlined in the block diagrams, A# (Analog Pin), D# (Digital Pin), PWM# (Pulse Width Modulation Pin).

Figure 42: Hall Effect sensor.

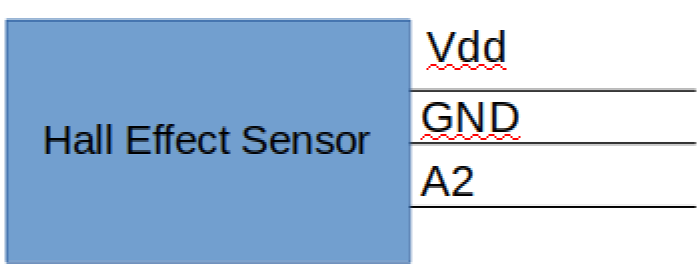


Figure 43: Speed Controller with Motor for left and right wheels.

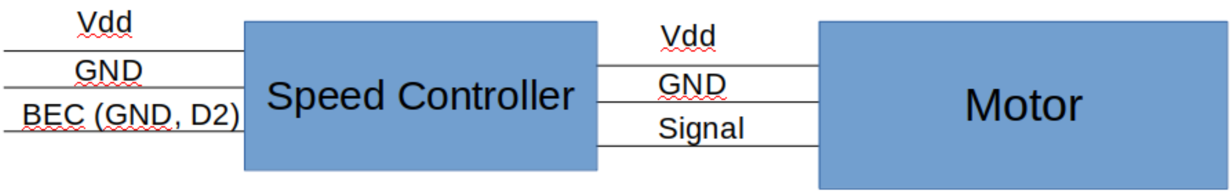
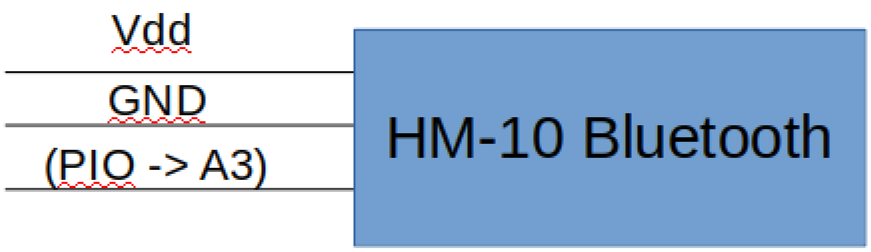


Figure 44: HM-10 Bluetooth Dongle to Arduino.



The design is complete and is on track to be fabricated to meet NASA mission requirements. Further development with the electrical systems is needed to meet SOAR rover requirements.

11 Project Plan

11.1 General Requirements

Table 39: General requirements and verifications.

Requirement	Verification Method	Verification Plan	Verification Status
NASA Student Launch Success Criteria			
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).	Demonstration	USF SOAR is a student-only organization. Team leads will monitor all operations and construction of the rocket and payload to ensure all work is done by the student members. Safety Officer will monitor that all handling of explosive items, electric matches or igniters, and motor assembly are	Verified during Project Proposal submission. Will continue to be verified throughout the course of the project until final launch day.

		conducted by the team mentor.	
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.	Demonstration	Team leader and project manager will work with sub- team leaders to construct a project timeline that includes project milestones. Project manager will designate a finance officer to monitor and create the project budget. Safety officer will build checklists, as well as risk/mitigation charts. Project manager will designate an outreach coordinator to build educational engagement opportunities. SOAR has hired a Marketing Manager to handle all community support efforts for the organization and this project. Project manager will maintain an organizational chart of all assigned personnel.	Verified with submission of Proposal,PDR, and CDR. Will continue to be verified throughout the course of the project as more documents are submitted.
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.	Demonstration	SOAR has submitted information on foreign national students who are a member of the team as of the date of this report. Team leads will continue to monitor membership and ensure that all foreign national students are recognized.	Verified with submission of PDR as stated in requirement.
The team must identify all team members attending launch week activities by the Critical Design Review (CDR).	Demonstration	Project manager and team leads will designate potential launch week participants who have been actively engaged throughout the project. A list of attending	Verified with submission of CDR as stated in the requirement.

		participants has been provided with this document. .	
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.	Demonstration	SOAR has designated an Outreach Coordinator to organize and handle all outreach events. So far over 200 students have been reached and we expect to reach more with our spring events. All educational engagement forms are submitted to proper officials no more than two weeks after an event.	Verified on 12/20/17 when SOAR's outreach event reached 400 participants.
The team will develop and host a website for project documentation.	Demonstration	SOAR has developed a website which is currently up to date with current project documentation.	Verified as current website is up and running with current documentation. .
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.	Demonstration	SOAR will create deadlines to ensure all deliverables are completed and uploaded on time.	Verified with submission of Proposal, PDR, and CDR. Will continue to be verified upon submission of upcoming documents.
All deliverables must be in PDF format.	Inspection	A selected team member will be in charge of reviewing all documentation before submission and will be in charge of ensuring all deliverables will be in PDF format.	Verified with submission of Proposal, PDR, and CDR. Will continue to be verified upon submission of upcoming documents.
In every report, teams will provide a table of contents including major sections and their respective sub-sections.	Inspection	One team member has been designated to format and submit all documentation and is familiar with the	Verified with submission of Proposal, PDR, and CDR. Will continue to be verified upon

		requirement for table of contents, sections, and subsections.	submission of upcoming documents.
In every report, the team will include the page number at the bottom of the page.	Inspection	One team member has been designated to format and submit all documentation and is familiar with the requirement for page numbers.	Verified with submission of Proposal, PDR, and CDR. Will continue to be verified upon submission of upcoming documents.
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.	Demonstration	The SOAR team has access to computers, speaker phones, Wi-Fi connection, and a video camera for teleconference purposes.	Verified during PDR presentation on 11/8/17. Will continue to be verified with upcoming presentations.
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.	Demonstration	Launch vehicle will be designed to utilize standard rails made available on the NSL launch site.	Verified with submission of previous documents which include launch vehicle design.
Teams must implement the Architectural and Transportation Barriers Compliance Board Electronic and Information Technology (EIT) Accessibility Standards (36 CFR Part 1194)	Inspection	SOAR will thoroughly read and adhere to the Architectural and Transportation Barriers Compliance Board Electronic and Information Technology (EIT) Accessibility Standards.	Verified with submission of Project Proposal.

Each team must identify a "mentor."	Demonstration	Jim West, Tripoli 0706 (Tripoli advisory panel member), Certification Level 3 has been designated as the team mentor.	Verified with submission of Project Proposal.

11.2 Vehicle Requirements

Please see requirements Table 4: Detailed mission requirements and confirmation methods.

11.3 Recovery System Requirements

Please see requirements Table 13: Detailed recovery system mission requirements and confirmation methods.

11.4 Experiment Requirements

Please see requirements Table 35: Detailed payload mission requirements and confirmation methods.

11.5 Safety Requirements

Table 40: Safety requirements and verifications.

Requirement	Verification Method	Verification Plan	Verification Status
NASA Student Launch Success Criteria			
Each team will use a launch and safety checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any launch day operations.	Inspection/ Demonstration	Designated Safety Officer will develop launch checklists and ensure that all checklists are used during relevant operations. Final checklists will be included in FRR report and used during LRR and all launch day operations.	Subscale checklist completed and will be verified during full scale launch.
Each team must identify a student safety officer who will be responsible for all items in	Demonstration	Kevin Kirkolis has been identified as the team's Safety Officer.	

section 5.3.			
The role and responsibilities of each safety officer will include the items designated in the 2018 NSL Handbook.	Demonstration	SOAR NSL Safety Officer will be assigned the designated duties. Duties are listed and designated in this report and will be so designated in all future reports.	Verified with submission of Project Proposal.
During test flights, teams will abide by the rules and guidance of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch Initiative does not give explicit or implicit authority for teams to fly those certain vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.	Demonstration	SOAR will abide by all rules and guidance of the Tampa Tripoli Rocket Association RSO. Safety Officer or designated team lead will supervise all operations to ensure rules and guidance are followed.	Verified on 12/16/17 the date of the subscale launch. Safety Officer will continue to monitor operations.
Teams will abide by all rules set forth by the FAA.	Demonstration	FAA rules are made available on the team share drive, and the safety officer will verify that all rules are followed.	Verified with submission of Project Proposal. Safety Officer will continue to monitor operations.

Table 41: Team Derived Requirements and Verification Plans (Vehicle, Recovery, and Experiment Team Derived Requirements found in relevant sections.)

Requirement	Verification Method	Verification Plan	Verification Status
The team will engage 1000 students through education engagement events by the submission of the FRR on 3/5/18.	Demonstration	SOAR has designated an Outreach Coordinator to organize and handle all outreach events. So far 881 students have been	Partially completed.

		reached and we expect to reach more with three more events planned.	

12 Project Budget and Timeline

12.1 Testing

12.1.1 Launch Vehicle

Due to the deployment failures encountered on the subscale flights, extensive ground testing will take place to ensure this failure does not occur for the full scale test launch. Different shear pin sizes and arrangements will be experimented with varying amounts of black powder as the primary ejection charge. This series of ground tests will occur for all points of separation. The table below is a glimpse to the type and specificity of these tests;

Table 42: Ground testing shear pin recording table.

Point of Separation	Shear Pin Size	# of Shear Pin & Arrangement	Grams of Black Powder
Nosecone & Rover Compartment			
Main Alt Bay & Booster			
Rover Compartment & Main Alt Bay			
Main Alt Bay & Booster			

12.1.2 Payload

The payload must complete a series of three tests to both prove the integrity of the design and prove its capabilities to meet NASA and USF SOAR mission success criteria.

They rover payload must complete:

1. Drive test
2. Drop test
3. Object avoidance test.

12.1.2.1 Drive Test

Objective. To provide data to justify the rover payloads ability to travel 5 feet away from the rocket body in a "rough" terrain environment.

This test will justify two parts of the rover. The motors strength and tire tread ability to maneuver in loose dirt/sand and the programming of the rover payload. This test is necessary to because it is it one of the mission criteria for NASA. This test will most likely not result in design changes but with rover programming changes.

This test will be placed in a testing area which will be a box 6ft long 1.75ft wide and 4inches tall. And will be filled with sand and other soil mixtures (testing variable). The rover will be prompted to start at one end and the we will measure the distance the rover has gone.

12.1.2.2 Drop Test

Objective, to justify the rover's structural integrity.

This test will include a sample fiberglass tube with the deployment system and rover inside. The user will drop the tube at various heights (the testing variable) to stimulate a filed parachute deployment. The user will then prompt the rover mission to start and inspect for damaged pieces.

This is test is necessary to justify the material choices for the rover body. The results of this test will most likely not result in major design changes but will change material choice.

12.1.2.3 Object Avoidance Test

Objective To test the rover's ability to avoid obstacles

This test will include objects of different sizes (testing variable) and the user will place them randomly in the testing area. The rover will be prompted to initiate its mission and the user will measure how well the rover preforms.

This test is necessary to provide confidence in the USF SOAR mission success criteria which includes object avoidance.

The results of the test will only refine the programming portion of the rover payload.

12.2 Budget

12.2.1 Projected Budget

Table 43: Projected budget.

Rocket Materials	$1,000
Launch Motors	$400
Test Launch Motors	$800
Subscale Materials	$600
Subscale Motor	$350
Payload	$800
Miscellaneous Hardware	$400
Travel	$1,500
TOTAL	$5,850

12.2.2 Current Budget

Table 44: Current budget.

	Price	Shipping	Total
Full Scale			
NSL Full-scale Rocket	$3,097.76	$213.59	$3,311.35
NSL Full Scale Recovery	$1,554.22	$54.92	$1,609.14
NSL Full Scale Electronics	$105.95	$8.25	$114.20
Subscale			
NSL Subscale Rocket	$882.33	$54.99	$937.32
NSL Subscale Recovery	$345.05	$19.94	$364.99

NSL Subscale Electronics	$0.00	$0.00	$0.00
Rover			
NSL Rover	$540.40	$40.62	$581.02
Supplies			
NSL General Supplies	$92.65	$19.51	$112.16

Table 45: Funding plan.

Funding	
USF Student Government	$7,500
TOTAL	$7,500

12.3 Timeline

Table 46: Project planning timeline.

Date	Item Due	Team Responsible	Status
November 4th, 2017	Start Subscale Construction	Rocketry Team	Complete
November 5th, 2017	Prototype Rover Parts Purchase Orders Filed	Rover Team, CSCE Team	Complete
November 17, 2017	Begin Rover Construction & Testing	Rover Team	Delayed
November 17, 2017	Begin Interactive Subscale Payload Design & Construction	Rover Team, CSCE Team	Delayed
November 24th, 2017	Post-Tests Detailed Rover Parts List Filed	Rover Team, CSCE Team	Delayed
December	Interactive Subscale Payload Complete	Rover Team,	Delayed

15th, 2017		CSCE Team	
December 15th, 2017	Subscale Construction & Inspection Complete	Rocketry Team	Complete
December 16th, 2017	Conduct CDR/ Subscale Launch	Entire NSL Team	Complete
January 6th, 2018	Deployment design finalized	Rover Team	Complete
January 7th, 2018	Action plan due, meeting dates established	Rover Team	Complete
January 7th, 2018	Start full scale construction	Rocketry Team	Complete
January 12th, 2018	CDR Due	Entire NSL Team	
January 13th, 2018	Prototype rover build starts	Rover Team	
January 13th, 2018	Test box build completed.	Rover Team	
January 19th, 2018	Deployment system complete, Test predictions due, prototype rover complete.	Rover Team	
January 20th, 2018	Dummy deployment system test.	Rover Team	
January 20th, 2018	Possible full scale launch day.		
January 21th, 2018	Finalized rover building begins.	Rover Team	
January 21th, 2018	Launch analysis completed pending full scale launch day occurs.		
January 24th, 2018	Full scale rover parts order due.	Rover Team	
January 27,	Updates to deployment system and	Rover Team	

2018	communication systems due.		
February 2nd, 2018	"LAUNCH" programming complete.	CSCE Team	
February 3rd, 2018	Fully assembled rover testing.	Rover Team	
February 4th, 2018	Action improvement plan completed, design review due. (Action improvement plan is a plan associated with the "next step" in mind based on project progression.)	Rover Team	
February 7th, 2018	FRR Q&A	Entire NSL Team	
February 16th, 2018	Programming edits due, rover finalized, test predictions due.	Rover Team, CSCE Team	
February 16th, 2018	Full Scale Construction Complete	Rocketry Team	
February 17th, 2018	Conduct FRR/ Full Scale Launch	Entire NSL Team	
February 18th, 2018	Action improvement plan update, launch analysis due, rover launch review due.	Rover Team	
February 23rd, 2018	Programming edits, update parts list.	Rover Team	
February 24th, 2018	Fully assembled rover test and analysis.	Rover Team	
February 25th, 2018	FRR rough draft due.		
March 2nd, 2018	Programming edits due.	CSCE Team	
March 3rd, 2018	Fully assembled rover test and analysis.	Rover Team	
March 4th, 2018	Action improvement plan update, design review competed, FRR final edits due.	Rover Team	

March 5th, 2018	FRR due	Entire NSL Team	
March 9th, 2018	Final day to order, programming edits due.	Rover Team	
March 10th, 2018	Fully assembled rover test and analysis.	Rover Team	
March 11th, 2018	Action improvement plan update and final design review.	Rover Team	
March 23rd, 2018	Programming edits due.	CSCE Team	
March 24th, 2018	Fully assembled rover test and analysis.	Rover Team	
March 25th, 2018	(Small) Action improvement plan completed and rover completed.	Rover Team	
March 31st, 2018	Final programming edits due, final rover test and analysis due.	Rover Team, CSCE Team	
April 7th, 2018	Competition day	Entire NSL Team	
April 27th, 2018	PLA due	Entire NSL Team	

13 Educational Engagement Plan

The Society of Aeronautics and Rocketry plans on organizing events with the community and local schools to inform students on our projects and teach them the importance of STEM Education. We will also be engaging in university events that bring in local students to learn about STEM Education, specifically in the engineering field. In addition to these events we will be organizing other events to showcase our current and previous projects to teach fellow students about what we do. We have also developed a questionnaire to give to students after the presentation so that we can gain some insight on whether or not the kids learned anything from our presentation. The questionnaire will be used in future events. Some of our past activities and upcoming events are described below.

13.1 Past Events

13.1.1 Engineering Block Party

On August 24th 2017, members of our organization set up a booth in the main building of the College of Engineering at the University of South Florida. We informed students and educators of the various projects we work on and how these projects provide valuable hands on experience that will allow students to use what they learn in the classroom in the STEM field. We brought some of our rockets and equipment and allowed participants to get up close to examine the different parts and components. We taught participants about the functionality and importance of each piece in order to showcase the ability of our rockets.

13.1.2 Rocket Exhibition

On August 8th 2017, our organization set up an event in the Marshall Student Center Ballroom at the University of South Florida to showcase our rockets and other various equipment. We set up multiple stations including:

1. A showcase of our organization's past rockets with information describing what they were created for and some details about the design.
2. A virtual reality launch experience that allowed participants to use a virtual reality headset to view one of our rocket launches as if they were actually there.
3. A rocket building/launch station that provided participants with a chance to build their own rocket on the computer and use a simulator to launch it. This station gave participants an idea of how we visualize our designs for the projects we are working on.
4. A presentation about our organization's projects to show how much work and research that goes into planning and engineering a rocket.

13.1.3 E-Council Open House

On August 28th 2017, members from our group set up a booth inside the College of Engineering at The University of South Florida in order to inform students on the projects we are currently working on. We provided participants with a chance to interact with some of our rockets that way they could get a closer look at the various parts and components. We also gave a short presentation to talk about our organization, the various projects that we work on, and our goals for the current school year.

13.1.4 USF Student Organization Showcase

On August 30th 2017, members of our team set up a booth at the USF Student Organization Showcase in order to provide students with information about our organization and the projects that we are involved in. We showcased our rocket from last year's NASA Student Launch Competition and showed students the opportunities that our organization can help them get connected to. Students were able to see the different components of the rockets and learn about each component's functionality.

13.1.5 Roboticon

On October 8th 2017, members from our team set up a booth at Roboticon which was held in the Sun Dome at the University of South Florida. We presented to grade school students from the surrounding counties who were attending the event. We informed the students and their parents about the projects we are working on and how we work in teams to achieve multiple goals. We talked about the different teams we have, the importance of setting and meeting goals, and the process of engineering certain rockets. We showed students multiple rockets our organization has built and taught them about each component along with its purpose.

13.1.6 USF Foundations of Engineering Class Presentation

On October 20th 2017, members from our team gave presentation to two Foundations of Engineering Classes about our organization and the projects we are working on. We showed the students one of our rockets and explained the importance of each section as well as its functionality. We also told the kids about the different projects we are working on and what it means to be a part of that project team. We wanted to show the students how to connect what they learn in the classroom to the STEM field and how gaining engineering experience now can be beneficial for future endeavors.

13.1.7 Engineering Day at USF

On November 3rd 2017 two members of our team set up a booth to talk to local high school students about our organization and the various projects we work on. We brought two of our larger rockets that were built for specific competitions and one of our Tripoli Level 1 certification rockets. We showed students the parts of the rockets including their parachutes, fins, and nosecones. We discussed the specific design of each rocket and what its function was. We wanted to share with students what possibilities our university and organization can provided for them especially when it comes to valuable hands-on STEM experience. We explained to students how different disciplines and majors are incorporated into our projects in order to fill the engineering, business, and administrative aspects of our teams.

13.1.8 Great American Teach in at Palm Harbor Middle School

On November 15th 2017 members from our team presented a PowerPoint presentation about our organization and what we do to middle school students. We talked about the engineering cycle and how it applies to our rocket building. We discussed how an idea is developed from the design stages to the building stages. We stressed the process of what it takes to build something along with the safety measures that must be met. We also stressed that because the engineering cycle is in fact a cycle that it takes repetitive testing until you get the final product. We also talked about STEM education and how all of the disciplines come together to complete a project. Overall, the students were interested in the things we do and how we are able to do them.

13.1.9 USF Engineering SuperFAM

On December 5th 2017 the Engineering College at USF hosted international recruiters and students in order to increase awareness of the college's programs and benefits available to students. The event was also used for recruiters to gain insight on the type of students to recruit for our university. For this event, we set up a table and several of our rockets in order to demonstrate our capabilities. We also conducted several short explanatory speeches to the groups concerning our past accomplishments and future projects. Our goal was to show that even though the university does not over an aerospace degree there are opportunities in the aerospace field that can be quite beneficial.

13.2 Projected Events

13.2.1 Patio Tuesday Involvement Invasion at USF

Projected event for January 9th where members of our team will participate in patio tuesday, a university hosted event. This patio tuesday will involve variou student organizations and allow us to recruit new students to be apart of our organization. We will be presenting a board explaining our projects.

13.2.2 Northeast High School Presentation

Projected event for spring semester where a group of our members will speak to students from the Academy of Information Technology at Northeast High School in Saint Petersburg. We plan on using online resources like Scratch (https://scratch.mit.edu), a free online coding community, to teach kids about block code. We are developing a lesson plan that walks the kids through developing a short coding project.

13.2.3 Boy Scout Presentation

Projected event for January 29th 2018 where a group of our members will speak to a local boy scout group and demonstrate how to build and launch a stomp rocket.

13.2.4 Engineering Expo at USF

Projected event taking place over two days, February 16th and 17th in 2018 where student grades K-12 will come to the university to understand the importance of STEM education. This event will allow us to connect to students and teach them about our organization and how we are able to gain valuable engineering experience. We will also provide students with a form of active engagement.

Table 47: Upcoming Educational Engagement events.

Event	Date
Patio Tuesday at USF	1/9/2018
Boy Scout Presentation	1/29/2018
Engineering Expo at USF	02/16/2018
Northeast High School Academy of IT Presentation	TBD

14 Appendix

14.1 Contributors

- **Project Management/Logistics**
  - Jackson Stephenson
  - Ashleigh Stevenson
  - Andrew Sapashe
  - Stephanie Bauman
- **Launch Vehicle**
  - Jackson Stephenson
  - Kevin Kirkolis
  - Stephanie Bauman
  - Andrew Sapache
- **Editing and Formatting**
  - Stephanie Bauman
  - Ashleigh Stevenson
- **Presentation**
  - Ashleigh Stevenson
- **Electronics/Coding**
  - Joe Caton
  - Linggih Saputro
- **Rover**
  - Javian Hernandez
  - Andrew Sapashe
  - James Waits
  - Chris Purdie
  - Jackson Stephenson
  - Joe Caton
- **Educational Engagement**
  - Jackson Stephenson
  - Ashleigh Stevenson
- **Safety**
  - Stephanie Bauman
  - Kevin Kirkolis

14.2 Milestone Review Flysheet (CDR)

Milestone Review Flysheet 2017-2018

Institution	University of South Florida	Milestone	CDR

Vehicle Properties	
Total Length (in)	111
Diameter (in)	5.148
Gross Lift Off Weigh (lb.)	37.2
Airframe Material(s)	G12 Fiberglass
Fin Material and Thickness (in)	FRP Fiberglass at 1/8"
Coupler Length/Shoulder Length(s) (in)	12 / 5

Motor Properties	
Motor Brand/Designation	Aerotech
Max/Average Thrust (lb.)	407.8 / 319.2
Total Impulse (lbf-s)	1034.8
Mass Before/After Burn (lb.)	10.1 / 4.4
Liftoff Thrust (lb.)	340
Motor Retention Method	AeroPack 75mm Flanged Motor Retaining Center

Stability Analysis	
Center of Pressure (in from nose)	88.3
Center of Gravity (in from nose)	72.1
Static Stability Margin (on pad)	3.14
Static Stability Margin (at rail exit)	3.2
Thrust-to-Weight Ratio	9:1
Rail Size/Type and Length (in)	1515 and 96 in
Rail Exit Velocity (ft/s)	67.75

Ascent Analysis	
Maximum Velocity (ft/s)	793
Maximum Mach Number	0.71
Maximum Acceleration (ft/s^2)	302
Predicted Apogee (From Sim.) (ft)	6690

Recovery System Properties — Drogue Parachute				
Manufacturer/Model	SkyAngle / Classic II			
Size/Diameter (in or ft)	20			
Altitude at Deployment (ft)	Apogee			
Velocity at Deployment (ft/s)	-3.32			
Terminal Velocity (ft/s)	-133.51			
Recovery Harness Material	Tubular Kevlar			
Recovery Harness Size/Thickness (in)	1/2 in			
Recovery Harness Length (ft)	30 ft			
Harness/Airframe Interfaces	The 1/2" tubular kevlar shock cord is epoxied and secured to the motor mount. The drogue parachute's shroud lines will be attached to a d-link in a butterfly or another standard loop in the shock cord closer to the booster section			
Kinetic Energy of Each Section (Ft-lbs)	Section 1	Section 2	Section 3	Section 4
	827.59	4154.54	1918.12	603.39

Recovery System Properties — Main Parachute #1 (p. 4 for #2)				
Manufacturer/Model	Fruity Chutes / Iris Ultra			
Size/Diameter (in or ft)	36 in			
Altitude at Deployment (ft)	950			
Velocity at Deployment (ft/s)	-125.19			
Terminal Velocity (ft/s)	-49.73*			
Recovery Harness Material	Tubular Kevlar			
Recovery Harness Size/Thickness (in)	1/4 in			
Recovery Harness Length (ft)	20 ft			
Harness/Airframe Interfaces	*Slowest speed reached before second main parachute deploys. Shroud lines attached to a 500 pound ball bearing swivel. This swivel will be secured to shock cord with d-link, and upper bulkhead of main altimeter bay.			
Kinetic Energy of Each Section (Ft-lbs)	Section 1	Section 2	Section 3	Section 4
	727.65	3652.87	1686.5	530.53

Recovery Electronics	
Altimeter(s)/Timer(s) (Make/Model)	Atlus Metrum / EasyMini
Redundancy Plan and Backup Deployment Settings	Each altimeter will be paired with a spare altimeter set to deploy 50 feet after its parent charge with the same charge mass
Pad Stay Time (Launch Configuration)	8 hours

Recovery Electronics		
Rocket Locators (Make/Model)	Transolve / BeepX	
Transmitting Frequencies (all - vehicle and payload)	None	
Ejection System Energetics (ex. Black Powder)	Black Powder	
Energetics Mass - Drogue Chute (grams)	Primary	2 g
	Backup	2 g
Energetics Mass - Main Chute (grams)	Primary	3 g
	Backup	3 g
Energetics Masses - Other (grams) - If Applicable	Primary	1 g (Nosecone)
	Backup	1 g (Nosecone)

Milestone Review Flysheet 2017-2018

Institution	University of South Florida	Milestone	CDR

Payload	
	Overview
Payload 1 (official payload)	The Society of Aeronautics and Rocketry at the University of South Florida are designing, developing and testing a depolyable rover to be their competitive payload of choice. The rover is essentially a cylinder in shape, with wheels at the ends and all necessary electrical components in the rover body situated between the two wheels. The rover is expected to be 5 inches wide and 14 inches long, but will continue to be redesigned to have reduced size but perform the same tasks.
	Overview
Payload 2 (non-scored payload)	

Test Plans, Status, and Results	
Ejection Charge Tests	The full scale rocket will have three points of separation; the drogue section (booster section and main altimeter bay), the first main (main altimeter bay and rover compartment) and the second main (rover compartment and nosecone). Due to the deployment and separation failures experienced from the subscale flights, all three of these separation points will start with 2-56 shear pin sizes. Extensive ground testing at a safe location will be conducted to find out the necessary charge amounts to deploy the rocket sections and the equivalent weight / ballast that may reside within them. If necessary, the shear pin holes can be increased from 2-56 to 4-40 if necessary. Initial estimates have two 2-56 shear pins for the drogue section, four for the first main and three for the second main. If necessary, black powder charges can be increased in place of increasing shear pin size.
Sub-scale Test Flights	The subscale test flights were done on December 16th, 2017. The temperature was in the 60s with minimal winds. Pre-launch procedures before first flight included loading and setting the black powder charges, activating altimeters with standard 9V batteries, securing the payload altimeter bay and folding and storing the recover equipment. Saftey officer verified all parts and procedures. First flight used a Cesaroni 54mm 4G K740. Apogee was 3,146 feet and max acceleration of 88 fps^2 and max velocity of 401 fps. Drogue deployed at apogee as expected. The second deployment charge at 1,000 feet, with the first main separating from the rover compartment but the charges did not detach from the main altimeter bay and first main did not deploy. The third deployment charge at 800 feet detached the nosecone and deployed parchute. For the second flight, a Cesaroni 54mm 4G K940 was used was used. This flight reached an apogee of 2,587 feet and max acceleration of 70 fps^2 and max velocity of 362 fps. Deployment and separation at apogee was successful. At 1,000 feet the charges detached the two 4-40 used on this flight for the main alitmeter bay. The shock cord stored in the payload section / rover compartment did not fully extend and detach from the rocket because the parachute was tightly packed. The drogue and first main shock cord became entangled. The rocket safely reached ground without any damage.
Full-scale Test Flights	The full scale test flight is scheduled for Saturday, February 17th, at Varn Ranch. This flight will include at the very least, a mock deployment system capable of holding and securing a ballast comparable to the rover's projected weight. Key features of the rover design such as the wheels and body plan to be included in this ballast-only configuration. Full scale construction is ahead of schedule, and the launch vehicle itself may become ready for a test flight on January 20th. The only conditions that will promote a launch in January are the acquirment of the Aerotech L1420 motor shipment, and if an adequate ballast has been prepared and prepared for launch. This full scale launch will provide valuable data and insight on the accuracy and dependancy on simulations, and the neccesary ballast configuration needed to deliver the launch vehicle to one mile high.

Milestone Review Flysheet 2017-2018			
Institution	University of South Florida	Milestone	CDR

Additional Comments
Note that all calculations were done using the minimum ballast weight of 0.375 lbs.

Recovery System Properties				
Main Parachute #2				
Manufacturer/Model	SkyAngle / Classic II			
Size/Diameter (in or ft)	60 in			
Altitude at Deployment (ft)	800			
Velocity at Deployment (ft/s)	-48.09			
Terminal Velocity (ft/s)	-20.46			
Recovery Harness Material	Tubular Kevlar			
Recovery Harness Size/Thickness (in)	1/2 in			
Recovery Harness Length (ft)	20 ft			
Harness/Airframe Interfaces	The SkyAngle parachute comes equipped with a swivel on the end of its shroud lines, which will be attached via d-link to the 20 feet of 1/2" tubular kevlar shock cord. This shock cord will be stored and attached to the U-bolt			
Kinetic Energy of Each Section (Ft-lbs)	Section 1	Section 2	Section 3	Section 4
	19.44	57.16	45.05	14.17

14.3 Detailed Mass Statement

Parts Detail

Payload

Nose cone	Fiberglass ($1.85\ g/cm^3$)	Ogive	Len: 25 in	Mass: 1.31 lb
Bulkhead	Fiberglass ($1.85\ g/cm^3$)	Dia_{out} 4.998 in	Len: 0.125 in	Mass: 0.164 lb
SkyAngle Classic II 60"	Ripstop nylon ($67\ g/m^2$)	Dia_{out} 60 in	Len: 3.5 in	Mass: 1.14 lb
Shroud Lines	Braided nylon (3 mm, 1/8 in) ($3.5\ g/m$)	Lines: 3	Len: 60 in	
Ballast		Dia_{out} 4.5 in		Mass: 0.375 lb
Payload Tube	Fiberglass ($1.85\ g/cm^3$)	Dia_{in} 5 in Dia_{out} 5.148 in	Len: 47.75 in	Mass: 3.76 lb
Rover		Dia_{out} 5 in		Mass: 10 lb
Payload Altimeter	Fiberglass ($1.85\ g/cm^3$)	Dia_{in} 4.753 in Dia_{out} 4.987 in	Len: 4 in	Mass: 0.479 lb
Bulkhead	Fiberglass ($1.85\ g/cm^3$)	Dia_{out} 4.753 in	Len: 0.125 in	Mass: 0.148 lb
Bulkhead	Fiberglass ($1.85\ g/cm^3$)	Dia_{out} 4.987 in	Len: 0.125 in	Mass: 0.163 lb
Bulkhead	Fiberglass ($1.85\ g/cm^3$)	Dia_{out} 4.987 in	Len: 0.125 in	Mass: 0.163 lb
Bulkhead	Fiberglass ($1.85\ g/cm^3$)	Dia_{out} 4.753 in	Len: 0.125 in	Mass: 0.148 lb
EasyMini Altimeter		Dia_{out} 0.8 in		Mass: 0.014 lb
EasyMini Altimeter		Dia_{out} 0.8 in		Mass: 0.014 lb
Shock cord	Kevlar (9/16 inch & 2000 lb strength) ($7.65\ g/m$)		Len: 240 in	Mass: 0.103 lb
Deployment System		Dia_{out} 2 in		Mass: 0 lb

Booster stage

Main Altimeter Switchband	Fiberglass ($1.85\ g/cm^3$)	Dia_{in} 5 in Dia_{out} 5.148 in	Len: 2 in	Mass: 0.158 lb
Booster Section	Fiberglass ($1.85\ g/cm^3$)	Dia_{in} 5 in Dia_{out} 5.148 in	Len: 36 in	Mass: 2.84 lb
Main Altimeter	Fiberglass ($1.85\ g/cm^3$)	Dia_{in} 4.753 in Dia_{out} 4.987 in	Len: 11 in	Mass: 1.32 lb
Shock cord	Kevlar (9/16 inch & 2000 lb strength) ($7.65\ g/m$)		Len: 240 in	Mass: 0.103 lb
Fruity Chutes Iris 36"	Ripstop nylon ($67\ g/m^2$)	Dia_{out} 47 in	Len: 3.5 in	Mass: 0.312 lb

Shroud Lines	Braided nylon (3 mm, 1/8 in) (3.5 g/m)	Lines: 10	Len: 36 in	
Bulkhead	Fiberglass (1.85 g/cm³)	Dia_{out} 4.753 in	Len: 0.125 in	Mass: 0.148 lb
Bulkhead	Fiberglass (1.85 g/cm³)	Dia_{out} 4.987 in	Len: 0.125 in	Mass: 0.163 lb
Bulkhead	Plywood (birch) (0.63 g/cm³)	Dia_{out} 4.753 in	Len: 0.125 in	Mass: 0.051 lb
Bulkhead	Plywood (birch) (0.63 g/cm³)	Dia_{out} 4.987 in	Len: 0.125 in	Mass: 0.056 lb
EasyMini Altimeter		Dia_{out} 0.8 in		Mass: 0.014 lb
EasyMini Altimeter		Dia_{out} 0.8 in		Mass: 0.014 lb
Motor Mount	Fiberglass (1.85 g/cm³)	Dia_{in} 2.953 in Dia_{out} 3.071 in	Len: 21 in	Mass: 0.784 lb
75mm Flanged Motor Retainer		Dia_{out} 3.9 in		Mass: 0.125 lb
Shock cord	Kevlar (9/16 inch & 2000 lb strength) (7.65 g/m)		Len: 360 in	Mass: 0.154 lb
SkyAngle 20" Drogue	Ripstop nylon (67 g/m²)	Dia_{out} 20 in	Len: 3.25 in	Mass: 0.35 lb
Shroud Lines	Braided nylon (3 mm, 1/8 in) (3.5 g/m)	Lines: 3	Len: 20 in	
Trapezoidal fin set (4)	1/8" McMaster Structural FG (1.66 g/cm³)	Thick: 0.125 in		Mass: 2.21 lb
Centering ring	Fiberglass (1.85 g/cm³)	Dia_{in} 3.071 in Dia_{out} 5 in	Len: 0.125 in	Mass: 0.102 lb
Centering ring	Fiberglass (1.85 g/cm³)	Dia_{in} 3.071 in Dia_{out} 5 in	Len: 0.125 in	Mass: 0.102 lb
Centering ring	Fiberglass (1.85 g/cm³)	Dia_{in} 3.071 in Dia_{out} 5 in	Len: 0.125 in	Mass: 0.102 lb

14.4 Parts, Equipment, and Resources

Received

Item Name	Supplier	Product Number	Quantity
5" G12 filament wound fiberglass tube	Wildman Rocketry	4 foot section	2
5" G12 filament wound fiberglass tube	Wildman Rocketry	1 foot section	1
5 INCH FILAMENT WOUND 5 TO 1 VON KARMAN NOSECONE WITH METAL TIP	Wildman Rocketry	5 to 1 Von Karman	1
5.0 INCH G12 COUPLER 12 INCHES LONG	Wildman Rocketry	G12 COUPLER	2
Tender Descender Lvl 2	Apogee Components	29151	1
Structural Fiberglass Sheet 24" Wide x 24" Long, 1/8" Thick	McMaster-Carr	8537K43	5
Birch Plywood (Common: 1/2 in. x 2 ft. x 4 ft.; Actual: 0.476 in. x 23.75 in. x 47.75 in.)	Home Depot	Model # 1503004 Internet #202088758 Store SKU #112345	2
RRC3 "Sport" Altimeter	Apogee Components	9095	2
KEVLAR SHOCK CORDS Tubular Kevlar 7200 lb test for 5" and larger rockets	Top Flight Recovery	TUK-1/2"	15
5/16 in. Zinc-Plated Quick Link	Home Depot	Model # 42724 Internet #205887588 Store SKU #732613	8
EasyMini Altimeter	Apogee Components	9201	2
EasyMini Altimeter	Apogee Components	9201	2
75mm Flanged Motor Retainer	Apogee Components	24069	1
75 mm G12 FG tubing (motor mnt)	Wildman Rocketry	2 foot section	1
Structural Fiberglass Sheet 12" Wide x 12" Long, 1/8" Thick	McMaster-Carr	8537K23	1
L293D Dual H-Bridge Motor Control	Adafruit Technologies	807	4
4 in. Fiberglass Tomach	Madcow Rocketry	K-197	1
3.91" x 4.03" FG Coupler 2 ft. length	Hawk Mountain	FTEX2-3.91, 3.91 X 24"	1
ADXL345 Digital Accelerometer	Adafruit Technologies	1231	2
Hall Effect Board Sensor	Diodes Inc. (through Mouser.com	621-AH3362Q-P-B	4

Received

Item Name	Supplier	Product Number	Quantity
Arduino Mega 2560 Microcontroller Rev3	robotshop.com	RB-Ard-33	1
4" Phenolic Tube	Rocketarium.com	36" long (1 unit)	1
RRC3 "Sport" Altimeter	Apogee Components	9095	2
1oz, Grey, Adhesive Stick on Wheel Weights, GM, Ford, Automobiles, Trucks,SUVs, 72 oz/box, US Quality, (72pcs).	Amazon	N/A	1
4" X 8" G12 FW FIBERGLASS COUPLER	Apogee Components	13607	1
Structural Fiberglass Sheet 24" Wide x 24" Long, 1/8" Thick	McMaster-Carr	8537K43	3
Smart Video Car Kit for Raspberry Pi with Android App, Compatible with RPi 3, 2 and RPi 1 Model B+ (Pi Not Included)	Amazon	N/A	1
Rechargeable Batteries 3 Volts, 600 Mah, .66" Diameter x 1.36" High	McMaster-Carr	1109K3	16
Compression Spring Music-Wire, Closed & Flat Ends, 2" Long, 7/8" OD, 0.635" ID	McMaster-Carr	9657K252	1
12V 100RPM 583 oz-in Brushed DC Motor	robotshop.com	RB-Dfr-670	2
AMX3d 5V 30mA Micro Mini Power Solar Cells For Solar Panels, (53X30mm)	amazon	B01BFX65YK	4
Cesaroni 75-3G Case	Tom's Rocket Gear	N/A	1
4-40 x 1/2" Nylon Shear Pins (Pack of 20)	Tom's Rocket Gear		3
2-56 x 1/2" Nylon Shear Pins (Pack of 20)	Tom's Rocket Gear		3
Raspberry Pi 3 Model B Motherboard	Amazon	N/A	1
SAMPLE PACK - DRY FABRICS - SELECT FROM 12 DIFFERENT SWATCHES	RockWest	SAMPLES-FABRICS	1
RRC3 - 98mm Dual Modular Sled System	MAC Performance Rocketry	N/A	1

Received

Item Name	Supplier	Product Number	Quantity
RRC3 - 98mm Dual Modular Sled System	MAC Performance Rocketry	N/A	1
2 PACK OF LARGE RAIL GUIDES	Wildman Rocketry		2
2/56 shear pins	Tom's Rocket Gear		1
4/40 shear pins	Tom's Rocket Gear		1
3M Half Facepiece Reusable Respirator 6200/07025(AAD), Respiratory Protection, Medium(Pack of 1)	Amazon	6100-PAR	2
3M Half Facepiece Reusable Respirator 6100/07024(AAD), Respiratory Protection, Small (Pack of 1)	Amazon	6100-PAR	1
3M Half Facepiece Reusable Respirator 6300/07026(AAD), Respiratory Protection, Large (Pack of 1)	Amazon	6100-PAR	1
3M 2097 P100 Particulate Filter with Organic Vapor Relief, 5 Pair	Amazon	2097 x5SNW	1
G & F 13016NEW EyePRO Safety Goggles with 99% Protection Against UV-A, B and C Rays, Impact, and Ballistic Resistant and Clear Lenses (12 Pack)	Amazon	13016-NEW	1
Gateway Safety 6980 Cover2 Safety Glasses, Clear Lens, Black Temple	Amazon	6980	3
Fiskars The Original Orange Handled Scissors	Amazon	12-94518697WJ	1
IIT 90450 5 Piece Stainless Scissors Set	Amazon	90450	1
Sharpie Permanent Marker, Fine Point, Black, 2 Count (Pack of 6) 12 Markers Total	Amazon	30162-6	1
Sharpie Permanent Markers, Ultra Fine Point, Black, 12 Count	Amazon	37001	1

Received

Item Name	Supplier	Product Number	Quantity
Red Steer 13155-2L Suede Cowhide Leather Palm Glove, Large (Set of 2 Pairs)	Amazon	13155	1
MidWest Gloves and Gear Midwest Gloves and Gear 7733P03-M-AZ-6 Heavyweight Suede Cowhide Work Glove, Medium, 3-Pack	Amazon	7733P03-M-AZ-6	1
Swanson Tool S0101CB Speed Square Layout Tool with Blue Book and Combination Square Value Pack	Amazon	S0101CB	1
Johnson Level, & Tool CS10 Carpenter Square	Amazon	CS10	1
DigiPas DWL80E Mini Pocket Size Digital Level, Electronic Angle Gauge, Protractor, 4 inch 0.1° accuracy	Amazon	DWL-80E	1
iGaging IP54 Electronic Digital Caliper 0-6" Display Inch/Metric/Fractions Stainless Steel Body	Amazon	100-333-8B	1
AmazonBasics 16/3 Vinyl Outdoor Extension Cord - 50 Feet (Orange)	Amazon	MW-A1/B3-1650	1
WeighMax W-4830 Industrial Postal Scale 330lb	Amazon	W-4820	1
Master Lock Padlock, Covered Aluminum Lock, 1 9/16 in. Wide, Black, 141D	Amazon	141D	1
Forney 53185 Cowhide Leather Palm Premium Women's Work Gloves, Small	Amazon	53185	2
1½" x 6ft PowerTye Made in USA Utility Lashing Strap, Black, 2-Pack	Amazon	CECOMINOD050440	1

Received

Item Name	Supplier	Product Number	Quantity
AMIR Digital Kitchen Scale, 500g/ 0.01g Pro Cooking scale with Back-Lit LCD Display, Accuracy Pocket Food Scale, 6 Units, Auto Off, Tare, PCS Function, Stainless Steel, Batteries Included (Silver)	Amazon	FOOD SCALE	1
Logitech HD Pro Webcam C920, Widescreen Video Calling and Recording, 1080p Camera, Desktop or Laptop Webcam	Amazon	960-000764	1
AmazonBasics Lightweight Mini Tripod	Amazon	WT0352G	1
Homak 1-Compartment Stackable Bin Small Parts Organizer	Home Depot	HA01080643	1
DEWALT 20-Volt Max Lithium-Ion Cordless Jig Saw (Tool-Only)	Home Depot	DCS331B	1
DEWALT MAXFIT Steel Screwdriving Set (63-Piece)	Home Depot	DWA2SLS63ND	2
Allen Long Arm SAE/Metric Ball-Plus Hex Key Set (22-Piece)	Home Depot	56618G	1
Dremel Rotary Tool Sanding/Grinding Accessory Set (31-Piece)	Home Depot	686	2
DEWALT 4 in. 8 TPI Aluminum/Fiberglass Cutting Jig Saw Blade HCS T-Shank (5-Pack)	Home Depot	DW3755H	3
Simple Green All-Purpose Wipes (40-Count)	Home Depot	3800000113312	5
Yost 4 in. Rapid Action Bench Vise	Home Depot	4-RAV	1
Professional Woodworker Drill Bit Set (29-Piece)	Home Depot	52007	2

On Order

Item Name	Supplier	Product Number	Quantity
ELECTRONICS ROTARY SWITCH	Apogee Components	9128	4
ELECTRONICS ROTARY SWITCH	Apogee Components	9128	4
Pololu Universal Aluminum 6mm Mounting Hubs (4-40)	Robotshop	RB-Pol-136	1
KEVLAR SHOCK CORDS Tubular Kevlar 7200 lb test for 5" and larger rockets	Top Flight Recovery	TUK-1/2"	30
Cesaroni K 740 C-Star 54mm 4 grain	Tom's Rocket Gear		1
Cesaroni 75mm 3grain case only	Tom's Rocket Gear		1
Bluetooth Module HM-10 for Arduino	Robotshop.com	HM-10	2
DFRobot Serial Bluetooth Module	Robotshop.com	RB-Dfr-10	2
G12 5" filament wound fiberglass tube	Wildman Rocketry	4 foot section	1
Structural Fiberglass Sheet, 24" Wide x 24" Long, 3/16" Thick	McMaster-Carr	8537K44	4
SkyAngle Cert 3 Large parachue	Wildman Rocketry	C3/L	2
SkyAngle Cert 3 24" Drogue	Wildman Rocketry	C3/D	1
Smart Electronics 3pin KEYES KY-017 Mercury Switch Module for Arduino diy Starter Kit KY017	Newegg	9SIADTU5T50155	3
Nomex Fabric, 24" x 24"	Wildman Rocketry	FCP24X24	3
9V Battery Box	Maplin	CK65V	8
EasyMini Altimeter	Apogee Components	9201	2
SparkFun XBee Wireless Kit	Spark Fun	KIT-13197 RoHS	1
AMX3d 5V 30mA Micro Mini Power Solar Cells For Solar Panels	Amazon	B01BFX65YK	8
Energizer A23 Battery, 12V (Pack of 4)	amazon	B005HX2YT0	2

On Order

Item Name	Supplier	Product Number	Quantity
Uxcell Open Frame Push Pull Solenoid, Electromagnet, DC 12V, 0.3A, 3.6W, 3 mm, 35 g	amazon	B00S4U5THM	2
MagicShield 500M 100LB Super Dyneema Strong Braided Fishing Line	amazon	B009661Y72	1
Smbbit Stainless Steel Shelf Support Corner Brace Angle Bracket Angle Code Right Angle 6 hole, 38mm x30mm x1.3mm(thick) (8Pack)	amazon	100165	1
Cesaroni L1350 C-Star Rocket Motor	Chris's Rocket Supplies	L1350	3
5.0 INCH G12 COUPLER 12 INCHES LONG	Wildman Rocketry	G12CT-5.0	1
SkyAngle Classic II 60" Parachute	MadCow Rocketry	SA-CL-60	1
SkyAngle Classic II 20" Parachute	Tom's Rocket Gear	1537	1
Iris Ultra 36" HP Compact Chute	Fruity Chutes	IFC-36-SR	1
AeroTech 75mm L1420	Tom's Rocket Gear		1
AeroTech 75mm L1420	Wildman Rocketry	L1420R-P	3
500# Ball Bearing Swivels	Apogee Components	14512	3
1/4" Tubular Kevlar Shock Cord	Top Flight Recovery	TUK-1/4"	25
Transolve BeepX Rocket Locator	Apogee Components	9121	2
Premium Wire Stripper	Robotshop	RB-Ibo-133	1
ST-10 Electronic Hand Tool Kit	Robotshop	RB-Ibo-34	1
LCM-1950 High-Speed Autoranging Digital Multimeter	Robotshop	RB-Ibo-74	1
Fowler 54-554-730 6"/150mm Inside Digital Spring Caliper	Global Industrial	T9FB228499	1
5/16 in. Zinc-Plated Flat Washer (25-Piece per Bag)	Home Depot	802314	3
Machine screws, Phillips flat head, Stainless steel 18-8, #2-56 x 1/4"	Bolt Depot	7662	50

On Order

Item Name	Supplier	Product Number	Quantity
Machine screws, Phillips flat head, Stainless steel 18-8, #2-56 x 5/16"	Bolt Depot	7663	50
Machine screws, Phillips flat head, Stainless steel 18-8, #2-56 x 3/8"	Bolt Depot	7664	50
Hex machine screw nuts, Zinc plated steel, #2-56	Bolt Depot	9194	150
Hex machine screw nuts, Zinc plated steel, #4-40	Bolt Depot	2642	150
Machine screws, Phillips flat head, Zinc plated steel, #4-40 x 1/4"	Bolt Depot	7596	50
Machine screws, Phillips flat head, Zinc plated steel, #4-40 x 5/16"	Bolt Depot	9332	50
Machine screws, Phillips flat head, Zinc plated steel, #4-40 x 3/8"	Bolt Depot	7597	50
SAE flat washers, Zinc plated steel, #4	Bolt Depot	4282	150
SAE flat washers, Zinc plated steel, #2	Bolt Depot	13536	150
#10-32 x 5/16 in. Zinc-Plated Tee Nut (4 per Pack)	Home Depot	802291	6
#10-32 x 1/2 in. Fine Zinc-Plated Phillips-Slotted Steel Round-Head Combination Machine Screw (8-Pack)	Home Depot	803321	3
#10-32 x 5/8 in. Zinc-Plated Round-Head Combo Drive Machine Screw (8-Pieces)	Home Depot	813421	3
#10-32 x 3/4 in. Stainless Steel Phillips-Slotted Round-Head Combo Drive Machine Screw (4-Piece)	Home Depot	814411	6
1/4 in.-20 tpi x 1/2 in. Coarse Zinc-Plated Steel Round-Head Combination Machine Screw (5-Piece per Pack)	Home Depot	803461	5

On Order

Item Name	Supplier	Product Number	Quantity
1/4 in.-20 tpi x 1 in. Coarse Zinc-Plated Steel Round-Head Combination Machine Screw (4-Piece per Pack)	Home Depot	803481	6
1/4 in.-20 tpi x 3/4 in. Zinc-Plated Round-Head Combo Drive Machine Screw (5-Piece)	Home Depot	803471	5
1/4-20 x 5/16 in. x 3/4 in. Stainless-Steel Pronged Tee Nut (25-Pack)	Home Depot	4149	3
#4 ROUND NYLON SPACERS (0.115” ID 0.187” OD)	Servo City	561-KSP2	24
#4 ROUND NYLON SPACERS (0.115” ID 0.187” OD)	Servo City	561-KSP4	24
Seminole Duplex Wire 24 gauge -500 feet	MJG Technologies	FW24D	1
MJG Firewire Initiator	MJG Technologies		4
5/16 in. Zinc-Plated Quick Link	Home Depot	42724	15
MAX Alkaline 9-Volt Battery (6-Pack)	Home Depot	522SBP6H	3
C2G 4in Cable Ties - White - 100pk	Office Depot	394684	1
StarTech.com 6in Nylon Cable Ties - Pkg of 100	Office Depot	845479	1
C2G 7.5in Cable Ties - White - 100pk	Office Depot	949685	1
1-1/4 in. PVC Ratcheting Cutter	Home Depot	70165	1
#8-32 Zinc-Plated Steel Coarse Tee Nuts (4 per Pack)	Home Depot	18861	19
#8-32 x 1/2 in. Phillips-Slotted Round-Head Machine Screws (100-Pack)	Home Depot	27622	1

Equipment

Equipment Type
LPKF ProtoMat S63 PCB Milling Machine
Benchman MX CNC Milling Machine
FSLaser – Pro LF 36 Laser Cutter
MakerBot – Replicator 3D Printer
MakerBot – Replicator Z18 3D Printer
MakerBot – Replicator 2X 3D Printer
Stratasys – uPrint SE PLUS 3D Printer
Misc Power Tools
Compressed Air
Power Drops
Wifi/wired Internet
Function Generators
Network Analyzers
Solder Station
Hot Air Rework Tool
Mixed Domain Oscilloscope
Multimeter
LCR Meter
Frequency Counter
Fume Extractor
Electronics Vice
Dremel Tool
Arbitrary Waveform Generators
Vacuums
Work Benches
Vinyl Cutter
MakerBot 3D Scanner
General Purpose Computers
Drafting/design workstations
Paper Cutter
Haptic Devices
Small Hand Tools
Powered Hand Tools
3D Printers
Laser Cutters
Lathe
Small Hand Tools
Powered Hand Tools
Drill Presses
Manual Milling Lathes
Buffer
Cold Saw
Shear
Arbor Press
Bandsaw
CNC Milling Machines

Equipment

Equipment Type
CNC Lathe
Manual Milling Machines
Manual Milling Lathes
Surface Grinder
Radial Arm Drill Press
Vertical Bandsaw
Horizontal Bandsaw
Cold Saw
Abrasive Cut-Off Saw
Oxy-Acetylene Torch
Plasma Cutter
TIG Wedler
MIG Welder
Stick Welder
Hand-held Spot Welder
Shear
Bending Brake
Beverly Shear
Tubing Bender
Notcher
Drill Press
Arbor Press
17.5 Ton Hydraulic Press
Buffer
Drill Grinder

14.5 Detailed Drift Analysis Report

# 0mph no angle (Up to date)		
# 416 data points written for 3 variables.		
# Time (s)	Altitude (ft)	Lateral distance (ft)
# Event LAUNCH occurred at t=0 seconds		
# Event IGNITION occurred at t=0 seconds		
0	0	0
# Event LIFTOFF occurred at t=0.04 seconds		
0.04	0.08187	0
0.08	0.43723	0
0.12	1.1933	0
0.15315	2.1439	0
0.17724	3.0233	0
0.19733	3.8785	0
0.21498	4.7212	0
0.23094	5.556	0
0.24562	6.3854	0
0.25929	7.2109	0
# Event LAUNCHROD occurred at t=0.27214 seconds		
0.27214	8.0335	0
0.29141	9.3518	1.61E-06
0.32033	11.519	1.05E-05
0.3637	15.197	3.97E-05
0.42876	21.673	1.25E-04
0.52635	33.535	3.61E-04
0.67273	56.18	0.0010176
0.87273	96.662	0.0027091
1.0727	148.36	0.0058474
1.2727	211.54	0.011342
1.4727	286.46	0.020089
1.6727	373.28	0.032574
1.8727	471.83	0.049266
2.0727	581.71	0.071132
2.2727	702.36	0.098393
2.4727	833.08	0.13151
2.6727	973.1	0.17068
2.8727	1121.8	0.21581
3.0727	1277.6	0.26013
3.1542	1342.1	0.29523
# Event BURNOUT occurred at t=3.2765 seconds		
3.2765	1438	0.32925
3.4599	1579.1	0.39369
3.5708	1662.8	0.41915
3.7302	1781.1	0.4769
3.9302	1926.2	0.56621
3.9692	1954.1	0.56516
4.0277	1995.6	0.56294
4.0785	2031.5	0.57472
4.1177	2059	0.59514
4.171	2096.1	0.63149
4.2508	2151.4	0.67562
4.2999	2185.1	0.68802
4.3648	2229.3	0.69412
4.4621	2295	0.72034
4.5311	2341.1	0.75737
4.6346	2409.6	0.80974
4.7265	2469.7	0.83632
4.8644	2558.6	0.88328
5.0644	2685	0.96133
5.2402	2793.7	1.0428
5.4402	2914.6	1.1258
5.6402	3032.8	1.2059
5.8402	3148.2	1.2937
6.0402	3261	1.3866
6.2402	3371.2	1.4769
6.4402	3478.9	1.5692
6.6402	3584.2	1.6643
6.8402	3687.1	1.7606
7.0402	3787.6	1.8587
7.2402	3885.9	1.9582
7.4402	3981.9	2.0593
7.6402	4075.8	2.162
7.8402	4167.5	2.266
8.0402	4257.1	2.3714
8.2402	4344.7	2.4781
8.4402	4430.2	2.5861
8.6402	4513.7	2.6953
8.8402	4595.3	2.8057
9.0402	4675	2.9172
9.2402	4752.8	3.03
9.4402	4828.8	3.1439
9.6402	4902.9	3.2589
9.8402	4975.2	3.3749
10.04	5045.8	3.492
10.24	5114.6	3.61
10.44	5181.7	3.729
10.64	5247.1	3.8489
10.84	5310.8	3.9696
11.04	5372.8	4.0913
11.24	5433.3	4.2139
11.44	5492.1	4.3373
11.64	5549.3	4.4614
11.84	5604.9	4.5864
12.04	5659	4.7121
12.24	5711.5	4.8385
12.44	5762.5	4.9656
12.64	5811.9	5.0934
12.84	5859.9	5.2218
13.04	5906.4	5.3509
13.24	5951.4	5.4807
13.44	5994.9	5.611
13.64	6037	5.7419
13.84	6077.6	5.8733
14.04	6116.8	6.0052
14.24	6154.6	6.1376
14.44	6191	6.2705
14.64	6226	6.4038
14.84	6259.6	6.5376
15.04	6291.8	6.6717
15.24	6322.7	6.8062
15.44	6352.1	6.9411
15.64	6380.3	7.0763
15.84	6407	7.2117
16.04	6432.4	7.3475
16.24	6456.5	7.4834
16.44	6479.3	7.6196
16.64	6500.7	7.7559
16.84	6520.8	7.8923
17.04	6539.6	8.0289
17.24	6557	8.1654
17.44	6573.2	8.302
17.64	6588.1	8.4385
17.84	6601.6	8.5749
18.04	6613.8	8.7111
18.24	6624.8	8.8471
18.44	6634.5	8.9828
18.64	6642.8	9.1182
18.84	6649.9	9.2531
19.04	6655.7	9.3875
19.24	6660.2	9.5214
19.44	6663.4	9.6549
19.64	6665.4	9.7879
19.84	6666	9.9205
# Event APOGEE occurred at t=20.04 seconds		
20.04	6665.4	10.053
# Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=20.041 seconds		
20.101	6664.9	10.093
20.153	6664.4	10.127
20.204	6663.9	10.161
20.256	6663.2	10.195
20.307	6662.5	10.229
20.359	6661.7	10.263
20.411	6660.8	10.297
20.463	6659.8	10.331
20.515	6658.7	10.365
20.567	6657.6	10.399
20.62	6656.3	10.434
20.673	6655	10.468
20.726	6653.5	10.502
20.779	6652	10.537
20.833	6650.3	10.571
20.887	6648.6	10.606
20.941	6646.8	10.641
20.996	6644.8	10.675
21.051	6642.8	10.71
21.106	6640.7	10.745
21.162	6638.4	10.78
21.218	6636	10.816
21.275	6633.6	10.851
21.332	6631	10.887
21.39	6628.3	10.922
21.448	6625.4	10.958
21.507	6622.5	10.994
21.567	6619.4	11.03
21.627	6616.2	11.066
21.688	6612.8	11.103
21.749	6609.3	11.14
21.811	6605.7	11.177
21.875	6601.9	11.214
21.939	6598	11.251
22.003	6593.9	11.288
22.069	6589.6	11.326
22.136	6585.2	11.364
22.204	6580.5	11.402
22.273	6575.7	11.441
22.343	6570.7	11.48
22.414	6565.5	11.519
22.487	6560	11.558
22.561	6554.4	11.598
22.637	6548.5	11.638
22.714	6542.3	11.679
22.793	6535.9	11.72
22.874	6529.2	11.761
22.956	6522.2	11.802
23.041	6514.9	11.845
23.128	6507.2	11.887
23.217	6499.2	11.93
23.309	6490.8	11.974
23.404	6482	12.018

23.502	6472.8	12.063
23.603	6463.1	12.108
23.708	6452.8	12.154
23.817	6442	12.201
23.93	6430.6	12.248
24.047	6418.5	12.297
24.17	6405.7	12.346
24.299	6392	12.396
24.435	6377.5	12.447
24.578	6361.8	12.5
24.729	6345.1	12.553
24.89	6327	12.608
25.062	6307.3	12.664
25.247	6285.9	12.722
25.448	6262.3	12.782
25.667	6236.2	12.843
25.91	6206.9	12.908
26.181	6173.7	12.974
26.49	6135.4	13.044
26.85	6090.2	13.117
27.282	6035.2	13.195
27.782	5970.7	13.272
28.282	5905.7	13.336
28.782	5840.1	13.388
29.282	5774.1	13.43
29.782	5708	13.463
30.282	5641.6	13.488
30.782	5575.1	13.505
31.282	5508.5	13.516
31.782	5441.8	13.522
32.282	5375.2	13.522
32.782	5308.6	13.519
33.282	5241.9	13.511
33.782	5175.3	13.5
34.282	5108.8	13.486
34.782	5042.3	13.47
35.282	4975.8	13.451
35.782	4909.4	13.431
36.282	4843	13.408
36.782	4776.7	13.384
37.282	4710.5	13.359
37.782	4644.3	13.333
38.282	4578.2	13.305
38.782	4512.2	13.277
39.282	4446.2	13.248
39.782	4380.3	13.218
40.282	4314.5	13.188
40.782	4248.7	13.157
41.282	4183	13.126
41.782	4117.3	13.094
42.282	4051.7	13.063
42.782	3986.2	13.03
43.282	3920.8	12.998
43.782	3855.4	12.966
44.282	3790	12.933
44.782	3724.8	12.9
45.282	3659.6	12.867
45.782	3594.5	12.834
46.282	3529.4	12.801
46.782	3464.4	12.768
47.282	3399.4	12.735
47.782	3334.6	12.701
48.282	3269.8	12.668
48.782	3205	12.635
49.282	3140.3	12.602
49.782	3075.7	12.569
50.282	3011.1	12.535
50.782	2946.6	12.502
51.282	2882.2	12.469
51.782	2817.8	12.436
52.282	2753.5	12.403
52.782	2689.2	12.37
53.282	2625	12.337
53.782	2560.9	12.304
54.282	2496.8	12.271
54.782	2432.8	12.238
55.282	2368.9	12.206
55.782	2305	12.173
56.282	2241.2	12.14
56.782	2177.4	12.108
57.282	2113.7	12.075
57.782	2050.1	12.043
58.282	1986.5	12.01
58.782	1923	11.978
59.282	1859.6	11.945
59.782	1796.2	11.913
60.282	1732.8	11.881
60.782	1669.5	11.849
61.282	1606.3	11.817
61.782	1543.1	11.785
62.282	1480	11.753
62.782	1417	11.721
63.282	1354	11.689
63.782	1291.1	11.657
64.282	1228.2	11.625
64.782	1165.4	11.594
65.282	1102.7	11.562
65.782	1040	11.531
66.282	977.33	11.499
# Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=66.283 seconds		
# Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=66.283 seconds		
66.782	914.76	11.468
66.784	914.54	11.468
66.786	914.31	11.467
66.788	914.08	11.467
66.79	913.85	11.467
66.792	913.61	11.467
66.794	913.37	11.467
66.796	913.13	11.467
66.798	912.88	11.467
66.8	912.63	11.467
66.803	912.38	11.466
66.805	912.12	11.466
66.808	911.85	11.466
66.81	911.58	11.466
66.813	911.31	11.466
66.815	911.03	11.466
66.818	910.75	11.466
66.821	910.46	11.466
66.824	910.17	11.465
66.827	909.87	11.465
66.831	909.57	11.465
66.834	909.26	11.465
66.838	908.94	11.465
66.841	908.62	11.465
66.845	908.28	11.464
66.849	907.95	11.464
66.853	907.6	11.464
66.858	907.25	11.464
66.862	906.89	11.464
66.867	906.52	11.464
66.872	906.14	11.463
66.877	905.75	11.463
66.882	905.35	11.463
66.888	904.94	11.463
66.894	904.51	11.463
66.901	904.08	11.462
66.907	903.63	11.462
66.914	903.17	11.462
66.922	902.69	11.462
66.93	902.2	11.461
66.938	901.69	11.461
66.947	901.16	11.461
66.957	900.61	11.461
66.967	900.04	11.46
66.978	899.44	11.46
66.99	898.82	11.46
67.003	898.16	11.459
67.017	897.48	11.459
67.033	896.76	11.459
67.049	895.99	11.458
67.068	895.18	11.458
67.088	894.32	11.458
67.111	893.39	11.457
67.137	892.38	11.457
67.166	891.29	11.456
67.2	890.08	11.456
67.24	888.73	11.455
67.287	887.2	11.454
67.345	885.41	11.454
67.419	883.25	11.453
67.52	880.49	11.452
67.67	876.6	11.451
67.955	869.72	11.449
68.455	858.15	11.447
68.955	846.65	11.446
69.455	835.13	11.445
69.955	823.62	11.443
70.455	812.11	11.442
70.955	800.6	11.441
71.455	789.09	11.44
71.955	777.59	11.439
72.455	766.09	11.438
72.955	754.58	11.437
73.455	743.09	11.436
73.955	731.59	11.435
74.455	720.09	11.434
74.955	708.6	11.433
75.455	697.11	11.432
75.955	685.62	11.431
76.455	674.13	11.43
76.955	662.65	11.429
77.455	651.16	11.428
77.955	639.68	11.427
78.455	628.2	11.425
78.955	616.72	11.424
79.455	605.25	11.423
79.955	593.77	11.422

80.455	582.3	11.421
80.955	570.83	11.42
81.455	559.36	11.419
81.955	547.9	11.418
82.455	536.43	11.417
82.955	524.97	11.416
83.455	513.51	11.415
83.955	502.05	11.414
84.455	490.59	11.413
84.955	479.14	11.412
85.455	467.69	11.411
85.955	456.24	11.41
86.455	444.79	11.409
86.955	433.34	11.408
87.455	421.89	11.407
87.955	410.45	11.406
88.455	399.01	11.405
88.955	387.57	11.404
89.455	376.13	11.402
89.955	364.69	11.401
90.455	353.26	11.4
90.955	341.83	11.399
91.455	330.4	11.398
91.955	318.97	11.397
92.455	307.54	11.396
92.955	296.12	11.395
93.455	284.69	11.394
93.955	273.27	11.393
94.455	261.85	11.392
94.955	250.44	11.391
95.455	239.02	11.39
95.955	227.61	11.389
96.455	216.2	11.388
96.955	204.79	11.387
97.455	193.38	11.386
97.955	181.97	11.385
98.455	170.57	11.384
98.955	159.17	11.383
99.455	147.77	11.382
99.955	136.37	11.381
100.45	124.97	11.38
100.95	113.57	11.379
101.45	102.18	11.378
101.95	90.791	11.377
102.45	79.401	11.375
102.95	68.013	11.374
103.45	56.628	11.373
103.95	45.244	11.372
104.45	33.862	11.371
104.95	22.481	11.37
105.45	11.103	11.369
# Event GROUND_HIT occurred at t=105.95 seconds		
# Event SIMULATION_END occurred at t=105.95 seconds		
105.95	-0.27358	11.368

# 5mph no angle (Up to date)		
# 423 data points written for 3 variables.		
# Time (s)	Altitude (ft)	Lateral distance (ft)
# Event LAUNCH occurred at t=0 seconds		
# Event IGNITION occurred at t=0 seconds		
0	0	0
# Event LIFTOFF occurred at t=0.04 seconds		
0.04	0.08187	0
0.08	0.43723	0
0.12	1.1933	0
0.15315	2.1438	0
0.17724	3.0233	0
0.19733	3.8785	0
0.21499	4.7211	0
0.23094	5.5559	0
0.24562	6.3854	0
0.25929	7.2109	0
# Event LAUNCHROD occurred at t=0.27215 seconds		
0.27215	8.0334	0
0.29142	9.3517	2.46E-04
0.32034	11.519	0.0015442
0.36372	15.197	0.0056555
0.42878	21.673	0.016432
0.52638	33.535	0.04032
0.67277	56.18	0.063302
0.87277	96.658	0.11082
1.0728	148.34	0.89174
1.1698	177.52	1.5892
1.2897	217.34	2.7486
1.4696	285.01	4.962
1.5655	325.07	6.3034
1.6654	369.64	7.8085
1.8151	441.97	10.378
1.9073	489.72	12.191
2.0192	550.84	14.614
2.1422	622.05	17.466
2.278	705.26	20.841
2.4522	818.69	25.602
2.6505	956.45	31.509
2.6961	989.43	32.937
2.7636	1039	35.079
2.8649	1115.1	38.422
2.9507	1181.2	41.377
3.0795	1282.4	45.912
# Event BURNOUT occurred at t=3.2727 seconds		
3.2727	1434.1	52.759
3.3227	1472.9	54.509
3.3609	1502.3	55.853
3.4182	1546.3	57.868
3.5041	1611.6	60.85
3.5611	1654.4	62.792
3.6465	1718.1	65.687
3.7058	1761.9	67.698
3.7948	1827.1	70.693
3.8906	1896.4	73.868
4.0344	1998.9	78.588
4.2344	2138.5	85.037
4.3876	2243.1	89.908
4.5876	2376.8	96.163
4.7138	2459.5	100.03
4.8555	2550.9	104.34
5.0555	2677.3	110.31
5.2555	2800.7	116.17
5.327	2844.2	118.26
5.4342	2908.6	121.37
5.5347	2968.3	124.24
5.6856	3056.6	128.5
5.8767	3166.2	133.84
6.0767	3278.4	139.32
6.2767	3388	144.73
6.4767	3495.2	150.06
6.6767	3599.9	155.31
6.8767	3702.2	160.48
7.0767	3802.2	165.58
7.2767	3899.9	170.61
7.4767	3995.4	175.58
7.6767	4088.7	180.48
7.8767	4179.9	185.31
8.0767	4269	190.09
8.2767	4356	194.8
8.4767	4441	199.47
8.6767	4524.1	204.07
8.8767	4605.2	208.63
9.0767	4684.4	213.14
9.2767	4761.7	217.6
9.4767	4837.2	222
9.6767	4910.9	226.36
9.8767	4982.7	230.68
10.077	5052.8	234.98
10.277	5121.2	239.22
10.477	5187.8	243.41
10.677	5252.8	247.56
10.877	5316	251.69
11.077	5377.6	255.78

11.277	5437.6	259.83
11.477	5496	263.86
11.677	5552.8	267.86
11.877	5608	271.82
12.077	5661.6	275.76
12.277	5713.7	279.67
12.477	5764.3	283.54
12.677	5813.3	287.4
12.877	5860.9	291.23
13.077	5907	295.02
13.277	5951.5	298.79
13.477	5994.7	302.55
13.677	6036.4	306.29
13.877	6076.6	310.02
14.077	6115.4	313.71
14.277	6152.8	317.37
14.477	6188.8	321.01
14.677	6223.4	324.64
14.877	6256.6	328.25
15.077	6288.4	331.86
15.277	6318.9	335.45
15.477	6348	339.03
15.677	6375.7	342.57
15.877	6402.1	346.1
16.077	6427.1	349.61
16.277	6450.8	353.1
16.477	6473.2	356.58
16.677	6494.2	360.05
16.877	6513.9	363.5
17.077	6532.3	366.95
17.277	6549.4	370.38
17.477	6565.2	373.8
17.677	6579.7	377.2
17.877	6592.8	380.59
18.077	6604.7	383.95
18.277	6615.3	387.3
18.477	6624.6	390.63
18.677	6632.6	393.93
18.877	6639.4	397.2
19.077	6644.8	400.44
19.277	6649	403.64
19.477	6652	406.8
19.677	6653.6	409.92
19.877	6654.1	412.99

Event APOGEE occurred at t=20.077 seconds

20.077	6653.2	416.04

Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=20.078 seconds

20.138	6652.7	416.98
20.19	6652.2	417.76
20.242	6651.6	418.54
20.294	6650.9	419.32
20.346	6650.1	420.1
20.398	6649.2	420.87
20.451	6648.2	421.65
20.503	6647.2	422.43
20.556	6646	423.21
20.609	6644.8	423.99
20.663	6643.5	424.76
20.716	6642.1	425.54
20.77	6640.5	426.32
20.824	6638.9	427.1
20.879	6637.2	427.87
20.933	6635.4	428.65
20.989	6633.5	429.43
21.044	6631.5	430.21
21.1	6629.3	430.99
21.156	6627.1	431.77
21.213	6624.8	432.55
21.27	6622.3	433.33
21.328	6619.8	434.11
21.386	6617.1	434.89
21.444	6614.3	435.68
21.504	6611.3	436.46
21.563	6608.3	437.25
21.624	6605.1	438.03
21.685	6601.8	438.82
21.747	6598.3	439.61
21.809	6594.7	440.41
21.873	6590.9	441.2
21.937	6587	441.99
22.002	6583	442.79
22.068	6578.7	443.59
22.135	6574.3	444.38
22.203	6569.7	445.18
22.272	6565	445.98
22.342	6560	446.79
22.413	6554.9	447.59
22.486	6549.5	448.4
22.56	6543.9	449.21
22.635	6538.1	450.02
22.712	6532	450.83
22.79	6525.7	451.64
22.871	6519.1	452.45
22.953	6512.2	453.26

23.037	6505.1	454.08
23.123	6497.6	454.89
23.211	6489.7	455.71
23.302	6481.5	456.53
23.395	6473	457.34
23.492	6464	458.16
23.591	6454.5	458.98
23.693	6444.6	459.8
23.799	6434.2	460.62
23.909	6423.2	461.44
24.024	6411.6	462.27
24.143	6399.3	463.09
24.267	6386.3	463.91
24.397	6372.4	464.73
24.533	6357.7	465.54
24.677	6342	466.35
24.828	6325.1	467.15
24.989	6307	467.94
25.16	6287.4	468.7
25.344	6266.1	469.44
25.542	6242.8	470.16
25.756	6217.2	470.84
25.99	6189	471.46
26.249	6157.3	472.01
26.542	6121.1	472.46
26.874	6079.5	472.79
27.254	6031.3	472.91
27.714	5972.3	472.72
28.214	5907.5	472.11
28.714	5842.1	471.04
29.214	5776.3	469.57
29.714	5710.3	467.79
30.214	5644	465.75
30.714	5577.6	463.52
31.214	5511	461.12
31.714	5444.5	458.56
32.214	5377.9	455.87
32.714	5311.2	453.09
33.214	5244.6	450.25
33.714	5178.1	447.38
34.214	5111.5	444.48
34.714	5045	441.52
35.214	4978.6	438.49
35.714	4912.1	435.41
36.214	4845.8	432.24
36.714	4779.5	429
37.214	4713.3	425.76

37.714	4647.1	422.47
38.214	4581	419.06
38.714	4515	415.55
39.214	4449	412.02
39.714	4383.1	408.48
40.214	4317.2	404.93
40.714	4251.4	401.32
41.214	4185.7	397.68
41.714	4120.1	394.02
42.214	4054.5	390.31
42.714	3989	386.55
43.214	3923.5	382.76
43.714	3858.1	378.98
44.214	3792.8	375.21
44.714	3727.6	371.47
45.214	3662.4	367.77
45.714	3597.2	364.09
46.214	3532.2	360.38
46.714	3467.1	356.65
47.214	3402.2	352.9
47.714	3337.3	349.12
48.214	3272.5	345.34
48.714	3207.7	341.61
49.214	3143.1	337.95
49.714	3078.4	334.32
50.214	3013.9	330.69
50.714	2949.3	327.05
51.214	2884.9	323.4
51.714	2820.5	319.74
52.214	2756.2	316.1
52.714	2692	312.49
53.214	2627.8	308.88
53.714	2563.6	305.27
54.214	2499.6	301.7
54.714	2435.6	298.18
55.214	2371.6	294.7
55.714	2307.7	291.22
56.214	2243.9	287.66
56.714	2180.2	284.06
57.214	2116.5	280.41
57.714	2052.8	276.73
58.214	1989.3	273.06
58.714	1925.7	269.4
59.214	1862.3	265.71
59.714	1798.9	262.01
60.214	1735.5	258.35
60.714	1672.3	254.77

61.214	1609	251.25
61.714	1545.9	247.74
62.214	1482.8	244.23
62.714	1419.7	240.71
63.214	1356.7	237.17
63.714	1293.8	233.62
64.214	1230.9	230.04
64.714	1168.1	226.45
65.214	1105.4	222.81
65.714	1042.7	219.07
66.214	980.04	215.32
# Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=66.215 seconds		
# Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=66.215 seconds		
66.714	917.47	211.6
66.715	917.25	211.58
66.717	917.02	211.57
66.719	916.79	211.56
66.721	916.56	211.54
66.723	916.32	211.53
66.725	916.08	211.51
66.727	915.84	211.5
66.729	915.59	211.48
66.732	915.34	211.46
66.734	915.09	211.45
66.736	914.83	211.43
66.739	914.56	211.41
66.741	914.29	211.39
66.744	914.02	211.37
66.747	913.74	211.35
66.75	913.46	211.33
66.753	913.17	211.31
66.756	912.88	211.28
66.759	912.58	211.26
66.762	912.28	211.24
66.765	911.97	211.21
66.769	911.65	211.18
66.773	911.32	211.16
66.777	910.99	211.13
66.78	910.66	211.1
66.785	910.31	211.07
66.789	909.96	211.03
66.794	909.6	211
66.798	909.22	210.96
66.803	908.84	210.93
66.808	908.46	210.89
66.814	908.06	210.85
66.82	907.64	210.8
66.826	907.22	210.76
66.832	906.79	210.71
66.839	906.34	210.66
66.846	905.88	210.6
66.853	905.4	210.55
66.861	904.91	210.49
66.87	904.4	210.42
66.879	903.87	210.35
66.888	903.32	210.28
66.899	902.75	210.2
66.91	902.15	210.12
66.922	901.53	210.03
66.935	900.87	209.93
66.949	900.19	209.82
66.964	899.47	209.71
66.981	898.7	209.58
66.999	897.89	209.44
67.02	897.03	209.29
67.043	896.1	209.12
67.068	895.1	208.93
67.098	894	208.71
67.131	892.8	208.47
67.171	891.45	208.18
67.218	889.92	207.84
67.276	888.13	207.43
67.35	885.97	206.9
67.451	883.22	206.18
67.601	879.34	205.1
67.884	872.48	203.08
68.384	860.91	199.54
68.884	849.42	196.14
69.384	837.9	192.64
69.884	826.39	189.11
70.384	814.88	185.63
70.884	803.38	181.97
71.384	791.88	177.98
71.884	780.38	173.86
72.384	768.88	170.07
72.884	757.38	166.43
73.384	745.89	162.57
73.884	734.39	158.46
74.384	722.9	154.32
74.884	711.41	150.21
75.384	699.92	146.07
75.884	688.43	142.01
76.384	676.94	138.1
76.884	665.46	134.56
77.384	653.98	131.12
77.884	642.51	127.37
78.384	631.03	123.36
78.884	619.55	119.46
79.384	608.09	115.98
79.884	596.62	112.59
80.384	585.15	109.07
80.884	573.68	105.58
81.384	562.21	102.23
81.884	550.75	98.817
82.384	539.28	95.284
82.884	527.82	91.921
83.384	516.36	88.743
83.884	504.91	85.492
84.384	493.45	82.028
84.884	482	78.29
85.384	470.55	74.321
85.884	459.1	70.382
86.384	447.66	66.766
86.884	436.21	63.337
87.384	424.77	59.814
87.884	413.33	56.376
88.384	401.89	53.16
88.884	390.45	50.066
89.384	379.01	46.859
89.884	367.58	43.431
90.384	356.14	39.749
90.884	344.72	36.119
91.384	333.29	32.638
91.884	321.86	29.128
92.384	310.44	25.603
92.884	299.01	22.01
93.384	287.59	18.427
93.884	276.17	14.925
94.384	264.75	11.475
94.884	253.33	8.0135
95.384	241.92	4.4244
95.884	230.5	0.79826
96.384	219.09	2.8728
96.884	207.69	6.5856
97.384	196.3	10.822
97.884	184.89	15.192
98.384	173.5	19.118
98.884	162.11	22.595
99.384	150.71	26.071
99.884	139.31	29.652
100.38	127.92	33.364
100.88	116.52	37.092
101.38	105.13	40.554
101.88	93.747	44.029
102.38	82.359	47.62
102.88	70.971	51.155
103.38	59.592	54.928
103.88	48.212	58.999
104.38	36.835	62.894
104.88	25.459	66.518
105.38	14.083	69.924
105.88	2.7091	73.213
# Event GROUND_HIT occurred at t=106.38 seconds		
# Event SIMULATION_END occurred at t=106.38 seconds		
106.38	-8.6569	76.848

10mph no angle (Up to date)
449 data points written for 3 variables.

# Time (s)	Altitude (ft)	Lateral distance (ft)
# Event LAUNCH occurred at t=0 seconds		
# Event IGNITION occurred at t=0 seconds		
0	0	0
# Event LIFTOFF occurred at t=0.04 seconds		
0.04	0.08187	0
0.08	0.43723	0
0.12	1.1933	0
0.15315	2.1439	0
0.17724	3.0233	0
0.19733	3.8785	0
0.21499	4.7211	0
0.23094	5.5559	0
0.24562	6.3853	0
0.2593	7.2109	0
# Event LAUNCHROD occurred at t=0.27215 seconds		
0.27215	8.0334	0
0.29143	9.3517	5.58E-04
0.32035	11.519	0.0035609
0.36372	15.197	0.012938
0.42879	21.672	0.037562
0.52639	33.533	0.091792
0.64305	51.1	0.15611
0.74973	70.43	0.15316
0.90976	105.34	0.19878
1.0889	152.93	1.5987
1.1428	169.03	2.3069
1.1892	183.53	3.0342
1.2357	198.68	3.8739
1.2957	219.18	5.1117
1.3857	251.89	7.2523
1.5207	305.48	10.94
1.5717	327.15	12.449
1.6288	352.29	14.206
1.7083	388.96	16.796
1.8277	447.39	21.049
1.9022	485.91	23.974
1.9696	522.15	26.813
2.0679	577.18	31.238
2.1356	616.59	34.441
2.1927	650.81	37.234
2.2784	703.71	41.6
2.3486	748.43	45.37
2.3985	780.9	48.157
2.4733	830.7	52.482
2.5559	887.24	57.418
2.6228	934.16	61.533
2.7232	1006.4	67.947
2.8008	1063.6	73.106
2.9171	1151.7	81.116
3.0916	1287.8	93.667
3.1102	1302.4	95.016
3.1334	1320.7	96.695
3.1683	1348.1	99.206
3.2205	1389.1	102.97
# Event BURNOUT occurred at t=3.2415 seconds		
3.2415	1405.4	104.49
3.2628	1422	106.03
3.2902	1443.2	108.01
3.3313	1474.9	110.98
3.3853	1516.2	114.85
3.4133	1537.6	116.84
3.4465	1562.8	119.18
3.4962	1600.4	122.66
3.5466	1638.2	126.19
3.5844	1666.5	128.84
3.6356	1704.5	132.41
3.7124	1761	137.74
3.7584	1794.6	140.88
3.8272	1844.5	145.57
3.9306	1918.6	152.56
4.0398	1996	159.9
4.2037	2110.1	170.75
4.4037	2246.2	183.73
4.4663	2288.2	187.78
4.5602	2350.4	193.79
4.6168	2387.7	197.36
4.7017	2443	202.69
4.7608	2481.2	206.39
4.8494	2537.9	211.91
4.9823	2622	220.11
5.1531	2728	230.5
5.3531	2849.5	242.46
5.4329	2897.2	247.21
5.5526	2967.9	254.24
5.7055	3056.8	263.12
5.9055	3170.7	274.57
6.0489	3250.7	282.7
6.2293	3349.5	292.81
6.393	3437.4	301.84
6.593	3542.6	312.75
6.793	3645.4	323.52
6.9754	3737.1	333.2
7.1754	3835.4	343.68
7.3754	3931.5	354.04
7.5754	4025.5	364.26
7.7754	4117.2	374.34
7.9754	4206.9	384.32
8.1754	4294.4	394.19
8.3754	4380	403.94
8.5754	4463.5	413.59
8.7754	4545.1	423.13
8.9655	4620.9	432.09
9.1655	4698.8	441.46
9.3655	4774.8	450.73
9.5108	4828.8	457.38
9.7108	4901.7	466.47
9.9108	4972.8	475.51
10.111	5042.1	484.46
10.311	5109.7	493.31
10.511	5175.5	502.05
10.711	5239.7	510.76
10.911	5302.2	519.44
11.111	5363	528.03
11.309	5421.7	536.43
11.509	5479.4	544.83
11.709	5535.4	553.19
11.909	5589.9	561.51
12.109	5642.8	569.79
12.309	5694.1	578.01
12.509	5744	586.13
12.709	5792.3	594.15
12.909	5839.1	602.15
13.109	5884.5	610.15
13.309	5928.4	618.08
13.509	5970.8	625.95
13.709	6011.7	633.78
13.909	6051.2	641.58
14.109	6089.3	649.33
14.309	6126	657.05
14.509	6161.3	664.73
14.709	6195.2	672.38
14.909	6227.7	679.94
15.109	6258.8	687.44
15.309	6288.5	694.92
15.509	6316.9	702.41
15.709	6343.9	709.91
15.909	6369.6	717.37
16.109	6393.9	724.77
16.309	6416.9	732.1
16.509	6438.5	739.37
16.709	6458.9	746.61
16.909	6477.9	753.83
17.109	6495.6	761.05
17.309	6512	768.25
17.509	6527.1	775.44
17.709	6540.9	782.62
17.909	6553.3	789.77
18.109	6564.5	796.87
18.309	6574.4	803.92
18.509	6583.1	810.91
18.694	6590	817.35
18.86	6595.3	823.09
19.012	6599.3	828.3
19.154	6602.5	833.14
19.288	6604.9	837.69
19.414	6606.7	841.97
19.535	6607.9	846.04
19.65	6608.6	849.92
19.761	6609	853.65
19.869	6609	857.23
# Event APOGEE occurred at t=19.973 seconds		
19.973	6608.6	860.7
# Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=19.974 seconds		
20.034	6608.3	862.73
20.086	6607.9	864.43
20.138	6607.4	866.12
20.19	6606.9	867.81
20.242	6606.2	869.49
20.295	6605.5	871.17
20.347	6604.7	872.85
20.4	6603.7	874.53
20.454	6602.7	876.2
20.507	6601.6	877.86
20.561	6600.4	879.53
20.615	6599.1	881.19
20.67	6597.8	882.84
20.724	6596.3	884.49
20.779	6594.7	886.14
20.835	6593	887.79
20.89	6591.2	889.43
20.947	6589.4	891.06
21.003	6587.4	892.7
21.06	6585.3	894.33
21.117	6583.1	895.96
21.175	6580.8	897.58

21.233	6578.4	899.2
21.291	6575.8	900.82
21.35	6573.2	902.44
21.41	6570.4	904.06
21.47	6567.5	905.67
21.531	6564.5	907.28
21.592	6561.4	908.9
21.654	6558.1	910.5
21.716	6554.7	912.11
21.779	6551.1	913.72
21.843	6547.4	915.33
21.908	6543.6	916.94
21.973	6539.6	918.55
22.04	6535.4	920.15
22.107	6531.1	921.76
22.175	6526.6	923.37
22.244	6522	924.97
22.315	6517.1	926.57
22.386	6512.1	928.18
22.458	6506.8	929.77
22.532	6501.4	931.37
22.607	6495.8	932.96
22.683	6489.9	934.55
22.761	6483.8	936.13
22.84	6477.4	937.71
22.92	6470.9	939.29
23.003	6464	940.86
23.087	6456.8	942.43
23.173	6449.4	944
23.261	6441.7	945.56
23.351	6433.6	947.11
23.443	6425.2	948.65
23.538	6416.4	950.2
23.636	6407.2	951.73
23.736	6397.5	953.27
23.84	6387.4	954.8
23.947	6376.8	956.32
24.058	6365.7	957.84
24.172	6354	959.35
24.291	6341.7	960.85
24.415	6328.6	962.35
24.543	6314.9	963.82
24.677	6300.5	965.27
24.818	6285	966.7
24.966	6268.6	968.11
25.12	6251.2	969.47
25.281	6232.8	970.78

25.452	6213.1	972.03
25.633	6191.9	973.2
25.827	6168.9	974.3
26.039	6143.5	975.32
26.27	6115.4	976.25
26.517	6085.1	977.03
26.793	6050.9	977.64
27.094	6013.2	978.03
27.453	5967.6	978.15
27.832	5919.1	977.88
28.256	5864.3	977.08
28.738	5801.7	975.55
29.238	5736.2	973.37
29.738	5670.3	970.73
30.238	5604.2	967.68
30.738	5538	964.19
31.238	5471.6	960.28
31.738	5405.1	956.1
32.238	5338.6	951.69
32.738	5272.1	946.96
33.238	5205.6	941.87
33.738	5139.1	936.42
34.238	5072.6	930.69
34.738	5006.2	924.73
35.238	4939.8	918.69
35.738	4873.4	912.65
36.238	4807.1	906.51
36.738	4740.9	900.29
37.238	4674.7	894.07
37.738	4608.6	887.87
38.238	4542.5	881.67
38.738	4476.5	875.37
39.238	4410.6	868.94
39.738	4344.7	862.42
40.238	4278.9	855.84
40.738	4213.2	849.15
41.238	4147.5	842.38
41.738	4081.9	835.58
42.238	4016.4	828.74
42.738	3950.9	821.91
43.238	3885.5	815.08
43.738	3820.1	808.24
44.238	3754.9	801.41
44.738	3689.6	794.51
45.238	3624.5	787.53
45.738	3559.4	780.47
46.238	3494.4	773.37

46.738	3429.4	766.18
47.238	3364.5	758.84
47.738	3299.6	751.42
48.238	3234.9	743.91
48.738	3170.1	736.27
49.238	3105.5	728.59
49.738	3040.9	720.96
50.238	2976.4	713.4
50.738	2911.9	705.86
51.238	2847.5	698.3
51.738	2783.2	690.79
52.238	2718.9	683.39
52.738	2654.7	676.08
53.238	2590.5	668.9
53.738	2526.4	661.76
54.238	2462.4	654.63
54.738	2398.4	647.55
55.238	2334.5	640.46
55.738	2270.7	633.31
56.238	2206.9	626.04
56.738	2143.2	618.68
57.238	2079.5	611.28
57.738	2015.9	603.77
58.238	1952.4	596.17
58.738	1888.9	588.6
59.238	1825.5	581.06
59.738	1762.1	573.59
60.238	1698.8	566.28
60.738	1635.6	559.05
61.238	1572.4	551.83
61.738	1509.3	544.67
62.238	1446.2	537.56
62.738	1383.2	530.54
63.238	1320.2	523.56
63.738	1257.3	516.52
64.238	1194.5	509.4
64.738	1131.7	502.19
65.238	1069	494.88
65.738	1006.4	487.53
66.238	943.76	480.24

Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=66.239 seconds
Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=66.239 seconds

66.738	881.23	472.99
66.74	881	472.97
66.742	880.78	472.94
66.743	880.55	472.91
66.745	880.31	472.89

66.747	880.08	472.86
66.749	879.84	472.83
66.752	879.59	472.8
66.754	879.35	472.76
66.756	879.1	472.73
66.758	878.84	472.7
66.761	878.58	472.66
66.763	878.32	472.63
66.766	878.05	472.59
66.768	877.78	472.55
66.771	877.5	472.51
66.774	877.22	472.47
66.777	876.93	472.43
66.78	876.64	472.38
66.783	876.34	472.34
66.786	876.03	472.29
66.79	875.72	472.24
66.793	875.4	472.19
66.797	875.08	472.14
66.801	874.75	472.08
66.805	874.41	472.02
66.809	874.07	471.96
66.813	873.71	471.9
66.818	873.35	471.83
66.823	872.98	471.77
66.828	872.6	471.69
66.833	872.21	471.62
66.838	871.81	471.54
66.844	871.4	471.45
66.85	870.98	471.37
66.856	870.54	471.27
66.863	870.1	471.18
66.87	869.63	471.07
66.878	869.16	470.96
66.886	868.66	470.85
66.894	868.15	470.72
66.903	867.62	470.59
66.913	867.07	470.45
66.923	866.5	470.3
66.934	865.91	470.13
66.946	865.28	469.95
66.959	864.63	469.76
66.973	863.94	469.55
66.989	863.22	469.33
67.005	862.46	469.08
67.024	861.64	468.8
67.045	860.78	468.5

67.067	859.85	468.16
67.093	858.84	467.77
67.123	857.75	467.34
67.157	856.54	466.85
67.196	855.2	466.27
67.244	853.66	465.59
67.302	851.87	464.75
67.377	849.7	463.68
67.478	846.92	462.23
67.625	843.13	460.14
67.898	836.5	456.38
68.398	824.93	449.59
68.898	813.45	442.97
69.398	801.94	436.3
69.891	790.62	429.06
70.371	779.62	421.23
70.871	768.13	412.71
71.371	756.63	404.48
71.871	745.14	396.51
72.348	734.19	389.33
72.848	722.71	382.05
73.348	711.23	374.96
73.848	699.76	367.94
74.348	688.29	361.04
74.848	676.83	354.18
75.348	665.35	346.82
75.848	653.87	339.17
76.348	642.39	331.42
76.848	630.92	323.94
77.348	619.45	316.55
77.848	607.98	308.78
78.348	596.51	300.84
78.848	585.05	293.32
79.348	573.59	286.17
79.81	563.01	279.19
80.31	551.56	271.3
80.81	540.09	263.55
81.31	528.63	256.02
81.81	517.19	248.29
82.31	505.75	239.97
82.81	494.31	231.79
83.31	482.86	223.93
83.81	471.4	216.18
84.14	463.86	211.41
84.64	452.44	204.86
85.14	440.99	198.36
85.64	429.56	191.31

86.036	420.54	185.77
86.536	409.11	179.04
87.036	397.67	172.02
87.536	386.25	164.54
88.036	374.82	156.67
88.536	363.38	148.73
89.036	351.96	141.05
89.536	340.54	133.43
90.036	329.11	125.61
90.536	317.68	117.79
91.036	306.26	109.73
91.536	294.84	101.34
92.036	283.43	93.232
92.536	272.03	85.577
93.036	260.6	77.958
93.536	249.2	70.532
94.036	237.78	63.361
94.536	226.37	56.355
95.036	214.97	49.37
95.536	203.56	42.302
96.036	192.15	35.126
96.536	180.77	28.184
96.991	170.42	22.59
97.491	159.03	16.722
97.988	147.72	10.357
98.488	136.35	3.8979
98.988	124.97	2.7437
99.488	113.58	9.5692
99.988	102.19	16.795
100.49	90.809	24.403
100.99	79.419	32.11
101.49	68.032	39.737
101.99	56.647	47.3
102.49	45.264	54.891
102.99	33.882	62.536
103.49	22.502	70.139
103.99	11.126	77.578
# Event GROUND_HIT occurred at t=104.49 seconds		
# Event SIMULATION_END occurred at t=104.49 seconds		
104.49	-0.24454	84.706

# 15mph no angle (Up to date)		
# 496 data points written for 3 variables.		
# Time (s)	Altitude (ft)	Lateral distance (ft)
# Event LAUNCH occurred at t=0 seconds		
# Event IGNITION occurred at t=0 seconds		
0	0	0
# Event LIFTOFF occurred at t=0.04 seconds		
0.04	0.08187	0
0.08	0.43723	0
0.12	1.1933	0
0.15315	2.1439	0
0.17724	3.0233	0
0.19733	3.8785	0
0.21499	4.7211	0
0.23094	5.5559	0
0.24562	6.3853	0
0.2593	7.2109	0
# Event LAUNCHROD occurred at t=0.27215 seconds		
0.27215	8.0334	0
0.29143	9.3517	8.90E-04
0.32035	11.519	0.0057235
0.36373	15.197	0.021301
0.4288	21.671	0.062562
0.5264	33.531	0.15493
0.62019	47.361	0.24817
0.71297	63.407	0.29151
0.85215	91.934	0.084179
1.0234	134.44	1.0621
1.0729	148.25	1.6555
1.1147	160.47	2.2663
1.1535	172.22	2.9241
1.1915	184.16	3.6557
1.2325	197.51	4.5382
1.282	214.28	5.7236
1.3563	240.76	7.712
1.4543	278.2	10.619
1.4864	291.09	11.621
1.5153	302.98	12.544
1.5435	314.78	13.456
1.5726	327.23	14.416
1.6085	342.94	15.63
1.6624	367.22	17.529
1.7432	405.23	20.615
1.7747	420.53	21.911
1.8007	433.43	23.032
1.8256	445.88	24.137
1.8516	459.11	25.334

1.8819	474.77	26.779
1.9271	498.64	29.024
1.995	535.51	32.553
2.0365	558.65	34.778
2.0627	573.5	36.204
2.0876	587.78	37.573
2.1155	604	39.124
2.1544	627.01	41.328
2.2129	662.27	44.737
2.2576	689.79	47.443
2.2837	706.07	49.067
2.3123	724.16	50.891
2.3542	750.96	53.623
2.417	791.96	57.835
2.4655	824.29	61.167
2.4968	845.41	63.341
2.535	871.48	66.025
2.5922	911.19	70.137
2.6781	972.1	76.534
2.729	1009	80.466
2.8013	1062.3	86.199
2.8506	1099.2	90.192
2.9163	1149.2	95.617
3.0149	1225.7	103.98
3.0889	1283.9	110.41
3.2	1371	120.07
# Event BURNOUT occurred at t=3.3524 seconds		
3.3524	1488.8	133.19
3.4672	1576	142.9
3.5654	1649.6	151.13
3.7126	1758.2	163.27
3.7575	1790.9	166.94
3.8135	1831.5	171.51
3.8976	1891.8	178.31
3.9326	1916.8	181.12
3.9724	1945	184.28
4.0319	1987	188.99
4.0801	2020.6	192.79
4.1115	2042.5	195.27
4.1475	2067.5	198.11
4.2015	2104.7	202.35
4.2493	2137.5	206.08
4.2761	2155.8	208.15
4.307	2176.8	210.53
4.3534	2208.2	214.08
4.423	2255	219.38
4.4659	2283.6	222.64

4.5123	2314.4	226.17
4.5819	2360.3	231.44
4.6355	2395.3	235.46
4.6866	2428.5	239.25
4.7632	2477.9	244.9
4.8781	2551.2	253.32
4.9536	2598.7	258.81
5.0665	2669.2	267
5.1615	2727.6	273.79
5.3039	2814.1	283.87
5.5039	2933.1	297.84
5.5651	2969	302.06
5.6358	3010.1	306.89
5.7418	3071.1	314.09
5.7881	3097.5	317.23
5.8576	3136.9	321.93
5.9618	3195.4	328.93
6.0299	3233.1	333.44
6.1319	3289.2	340.17
6.2763	3367.5	349.63
6.4763	3473.8	362.56
6.6763	3577.6	375.3
6.8763	3679.1	387.86
7.0763	3778.2	400.25
7.2763	3875.1	412.43
7.4761	3969.7	424.48
7.6761	4062.2	436.41
7.8283	4131.1	445.36
8.0283	4219.9	456.98
8.2283	4306.6	468.45
8.4283	4391.3	479.79
8.5422	4438.6	486.21
8.713	4508.5	495.76
8.829	4555.1	502.17
8.9611	4607.4	509.39
9.1593	4684.3	520.19
9.3593	4760	530.99
9.4996	4812	538.46
9.6996	4884.7	548.99
9.8085	4923.5	554.72
9.9719	4980.7	563.25
10.172	5049.1	573.6
10.354	5109.9	582.89
10.554	5175.1	592.98
10.681	5215.6	599.38
10.779	5246.6	604.34
10.893	5281.9	610.08

11.064	5333.8	618.59
11.123	5351.5	621.5
11.191	5371.7	624.81
11.293	5401.6	629.75
11.446	5445.6	637.14
11.524	5467.8	640.93
11.59	5486.1	644.1
11.68	5511.3	648.52
11.816	5548.4	655.13
11.925	5577.6	660.37
12.013	5600.9	664.55
12.08	5618.3	667.69
12.166	5640.5	671.7
12.295	5673.2	677.67
12.448	5711.4	684.78
12.519	5728.9	688.11
12.593	5746.8	691.58
12.679	5767.3	695.61
12.808	5797.6	701.64
12.958	5832	708.6
13.055	5853.8	713.03
13.153	5875.6	717.49
13.301	5907.5	724.13
13.501	5949.7	733.1
13.701	5990.4	742.07
13.901	6029.6	751.01
14.101	6067.4	759.9
14.301	6103.8	768.76
14.501	6138.7	777.59
14.701	6172.3	786.33
14.9	6204.4	794.94
15.1	6235.2	803.52
15.3	6264.7	812.05
15.5	6292.8	820.56
15.7	6319.6	829.04
15.9	6344.9	837.51
16.1	6368.9	845.95
16.3	6391.6	854.33
16.5	6413	862.66
16.7	6433.1	870.93
16.9	6451.8	879.16
17.1	6469.2	887.36
17.3	6485.3	895.54
17.5	6500.1	903.69
17.7	6513.6	911.81
17.9	6525.8	919.9
18.1	6536.7	927.95

18.3	6546.4	935.97
18.5	6554.7	943.95
18.689	6561.5	951.48
18.867	6566.8	958.53
19.031	6570.8	964.98
19.182	6573.7	970.92
19.323	6575.8	976.42
19.455	6577.3	981.58
19.58	6578.1	986.44
19.699	6578.5	991.05
# Event APOGEE occurred at t=19.813 seconds		
19.813	6578.5	995.47
# Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=19.814 seconds		
19.873	6578.3	997.81
19.924	6578	999.76
19.975	6577.7	1001.7
20.027	6577.3	1003.6
20.079	6576.8	1005.6
20.131	6576.2	1007.5
20.183	6575.5	1009.4
20.236	6574.8	1011.4
20.288	6573.9	1013.3
20.341	6573	1015.2
20.395	6571.9	1017.1
20.448	6570.8	1019
20.502	6569.6	1020.9
20.556	6568.3	1022.7
20.611	6566.9	1024.6
20.666	6565.4	1026.5
20.721	6563.8	1028.4
20.777	6562	1030.2
20.833	6560.2	1032.1
20.889	6558.3	1033.9
20.946	6556.3	1035.8
21.003	6554.2	1037.6
21.061	6552	1039.5
21.119	6549.6	1041.3
21.178	6547.2	1043.1
21.237	6544.6	1044.9
21.296	6541.9	1046.7
21.356	6539.1	1048.5
21.417	6536.2	1050.3
21.478	6533.1	1052.1
21.54	6529.9	1053.9
21.602	6526.6	1055.7
21.665	6523.2	1057.5
21.729	6519.6	1059.2

21.793	6515.9	1061
21.858	6512	1062.8
21.924	6508	1064.5
21.991	6503.8	1066.3
22.059	6499.5	1068
22.127	6495	1069.8
22.197	6490.3	1071.5
22.267	6485.4	1073.2
22.339	6480.4	1074.9
22.411	6475.1	1076.7
22.485	6469.7	1078.4
22.56	6464	1080.1
22.636	6458.2	1081.8
22.714	6452.1	1083.4
22.793	6445.8	1085.1
22.874	6439.2	1086.8
22.956	6432.4	1088.4
23.039	6425.3	1090
23.125	6417.9	1091.6
23.212	6410.3	1093.2
23.302	6402.3	1094.8
23.393	6394	1096.4
23.487	6385.4	1098
23.583	6376.3	1099.5
23.682	6366.9	1101
23.784	6357.1	1102.5
23.888	6346.8	1104
23.995	6336.1	1105.4
24.106	6324.9	1106.8
24.22	6313.1	1108.2
24.339	6300.8	1109.5
24.462	6287.8	1110.8
24.589	6274.2	1112
24.72	6259.9	1113.1
24.857	6244.9	1114.2
25	6229	1115.3
25.146	6212.6	1116.2
25.298	6195.2	1116.9
25.457	6176.9	1117.6
25.629	6156.8	1118.2
25.805	6136	1118.6
25.995	6113.4	1118.8
26.206	6088	1118.8
26.437	6059.9	1118.7
26.687	6029.1	1118.2
26.959	5995.2	1117.5
27.247	5959.1	1116.4

27.55	5920.7	1114.8
27.904	5875.4	1112.6
28.232	5833.2	1110.1
28.613	5783.8	1106.6
29.059	5725.6	1101.9
29.481	5670.3	1096.9
29.981	5604.6	1090.2
30.481	5538.5	1083
30.981	5472.4	1075.2
31.481	5406	1067.1
31.981	5339.7	1058.9
32.481	5273.2	1050.5
32.981	5206.8	1041.9
33.481	5140.3	1033.2
33.981	5073.9	1024.4
34.481	5007.4	1015.3
34.981	4941.1	1006
35.481	4874.7	996.57
35.981	4808.4	986.97
36.481	4742.2	977.24
36.981	4676	967.42
37.481	4609.9	957.49
37.981	4543.9	947.48
38.481	4477.9	937.39
38.981	4411.9	927.24
39.481	4346.1	916.94
39.981	4280.3	906.38
40.481	4214.5	895.6
40.981	4148.9	884.68
41.481	4083.3	873.69
41.981	4017.7	862.58
42.481	3952.3	851.34
42.981	3886.8	840.04
43.481	3821.5	828.81
43.981	3756.2	817.61
44.481	3691	806.27
44.981	3625.8	794.8
45.481	3560.8	783.27
45.981	3495.7	771.66
46.481	3430.8	760.02
46.981	3365.9	748.41
47.481	3301	736.76
47.981	3236.2	725.02
48.481	3171.5	713.3
48.981	3106.9	701.56
49.481	3042.3	689.69
49.981	2977.7	677.72

50.481	2913.3	665.67
50.981	2848.9	653.58
51.481	2784.5	641.66
51.981	2720.3	629.88
52.481	2656	618.13
52.981	2591.9	606.38
53.481	2527.8	594.69
53.981	2463.8	583.13
54.481	2399.8	571.72
54.981	2335.9	560.44
55.481	2272.1	549.22
55.981	2208.3	538.03
56.481	2144.6	526.85
56.981	2080.9	515.63
57.481	2017.3	504.34
57.981	1953.8	492.97
58.481	1890.3	481.53
58.981	1826.9	470.09
59.481	1763.5	458.69
59.981	1700.2	447.29
60.481	1636.9	435.89
60.981	1573.8	424.61
61.481	1510.6	413.52
61.981	1447.6	402.67
62.481	1384.6	391.92
62.981	1321.6	381.15
63.481	1258.7	370.35
63.981	1195.9	359.45
64.481	1133.1	348.62
64.981	1070.4	337.98
65.481	1007.8	327.4
65.981	945.17	316.71
# Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=65.982 seconds		
# Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=65.982 seconds		
66.481	882.64	305.92
66.483	882.41	305.88
66.485	882.19	305.84
66.487	881.96	305.8
66.489	881.72	305.76
66.491	881.49	305.72
66.493	881.25	305.67
66.495	881.01	305.63
66.497	880.76	305.58
66.499	880.51	305.53
66.502	880.25	305.48
66.504	879.99	305.42
66.507	879.73	305.37

66.509	879.46	305.31
66.512	879.19	305.25
66.515	878.91	305.19
66.517	878.63	305.13
66.52	878.34	305.06
66.523	878.05	305
66.527	877.75	304.93
66.53	877.45	304.85
66.533	877.14	304.78
66.537	876.82	304.7
66.54	876.5	304.61
66.544	876.17	304.53
66.548	875.83	304.44
66.552	875.48	304.34
66.557	875.13	304.24
66.561	874.77	304.14
66.566	874.4	304.03
66.571	874.02	303.92
66.576	873.63	303.8
66.581	873.23	303.67
66.587	872.82	303.54
66.593	872.4	303.4
66.6	871.97	303.25
66.606	871.52	303.09
66.613	871.06	302.93
66.621	870.58	302.75
66.629	870.09	302.56
66.637	869.58	302.36
66.646	869.05	302.15
66.656	868.5	301.92
66.666	867.93	301.68
66.677	867.33	301.42
66.689	866.71	301.13
66.702	866.05	300.83
66.716	865.37	300.5
66.732	864.65	300.13
66.748	863.88	299.74
66.767	863.07	299.3
66.787	862.21	298.82
66.81	861.28	298.28
66.836	860.27	297.67
66.865	859.18	296.97
66.899	857.98	296.16
66.939	856.63	295.22
66.986	855.1	294.08
67.044	853.33	292.69
67.115	851.24	290.95

67.204	848.81	288.75
67.334	845.41	285.42
67.548	840.16	279.81
68.048	828.54	266.78
68.548	817.09	254.16
69.048	805.56	241.71
69.259	800.73	236.63
69.759	789.26	225.25
70.259	777.75	214.18
70.759	766.25	203.06
71.259	754.76	192.12
71.759	743.29	181.09
72.259	731.82	170.01
72.759	720.34	159.46
73.259	708.86	148.71
73.759	697.38	137.7
73.933	693.39	133.76
74.265	685.81	125.7
74.765	674.36	112.77
75.265	662.9	99.803
75.567	656	92.437
75.797	650.76	87.192
76.188	641.85	78.928
76.688	630.38	68.649
77.188	618.9	58.367
77.688	607.45	48.581
78.188	596	38.79
78.687	584.59	28.229
79.106	574.99	19.341
79.606	563.53	9.0014
80.106	552.07	1.6283
80.606	540.61	11.602
81.106	529.16	21.891
81.606	517.72	32.804
82.017	508.34	42.297
82.517	496.9	54.15
83.017	485.44	65.831
83.517	474.01	77.121
83.953	464.04	87.028
84.453	452.6	98.709
84.953	441.16	110.52
85.453	429.73	122.25
85.953	418.29	133.65
86.453	406.84	145.03
86.953	395.41	156.67
87.453	383.99	168.26
87.792	376.26	176.18

88.292	364.85	188.52
88.792	353.41	201.22
89.292	341.99	214.21
89.792	330.56	227.18
90.047	324.77	233.46
90.547	313.37	245.22
91.047	301.94	256.55
91.547	290.53	267.5
92.047	279.11	278.42
92.547	267.69	289.46
93.047	256.28	300.77
93.324	249.98	306.97
93.824	238.59	317.6
94.324	227.17	327.96
94.824	215.78	338.53
95.324	204.39	349.02
95.824	193	358.93
96.111	186.47	364.75
96.611	175.11	375.7
96.914	168.22	382.34
97.414	156.85	392.56
97.667	151.11	397.36
98.167	139.75	406.12
98.667	128.36	414.43
99.018	120.36	420.47
99.349	112.86	426.7
99.849	101.49	436.54
100.35	90.099	446.13
100.58	84.973	450.52
101.08	73.616	460.52
101.58	62.222	470.55
102.08	50.844	480.72
102.58	39.477	491.26
102.94	31.131	499.6
103.17	25.982	505.14
103.67	14.636	517.62
104.17	3.2666	529.6
# Event GROUND_HIT occurred at t=104.67 seconds		
# Event SIMULATION_END occurred at t=104.67 seconds		
104.67	-8.0901	541.3

20mph no angle (Up to date)
527 data points written for 3 variables.

# Time (s)	Altitude (ft)	Lateral distance (ft)
# Event LAUNCH occurred at t=0 seconds		
# Event IGNITION occurred at t=0 seconds		
0	0	0
# Event LIFTOFF occurred at t=0.04 seconds		
0.04	0.08187	0
0.08	0.43723	0
0.12	1.1933	0
0.15315	2.1439	0
0.17724	3.0233	0
0.19733	3.8785	0
0.21499	4.7211	0
0.23094	5.5559	0
0.24562	6.3853	0
0.25929	7.2109	0
# Event LAUNCHROD occurred at t=0.27215 seconds		
0.27215	8.0334	0
0.29143	9.3517	0.0015176
0.32035	11.519	0.0097582
0.36372	15.196	0.03608
0.42879	21.67	0.10481
0.51387	31.862	0.23661
0.58877	42.457	0.37164
0.6579	53.592	0.4864
0.73618	67.784	0.55896
0.84384	90.07	0.4444
0.97236	120.88	0.27589
1.0311	136.5	0.90969
1.0692	147.12	1.4457
1.1027	156.81	2.0057
1.1342	166.2	2.6099
1.1679	176.56	3.3387
1.2054	188.48	4.2506
1.2501	203.17	5.4666
1.3039	221.64	7.1124
1.3846	250.92	9.9066
1.4701	284	13.215
1.5053	298.25	14.664
1.5358	310.89	15.957
1.565	323.29	17.231
1.5981	337.62	18.712
1.6477	359.7	21.028
1.7222	394.18	24.754
1.7816	422.84	27.983
1.8191	441.42	30.145
1.8524	458.27	32.151
1.8891	477.17	34.449
1.9328	500.15	37.302
1.9983	535.61	41.793
2.0459	562.1	45.188
2.0779	580.27	47.527
2.1058	596.35	49.599
2.1347	613.2	51.777
2.1724	635.51	54.674
2.229	669.66	59.162
2.2679	693.63	62.366
2.3015	714.65	65.214
2.3393	738.59	68.498
2.3878	769.75	72.83
2.4604	817.52	79.559
2.5694	891.44	90.077
2.6141	922.59	94.539
2.6813	970.13	101.4
2.7341	1008.2	106.96
2.7756	1038.4	111.43
2.8377	1084.4	118.28
2.931	1154.9	128.86
2.9821	1194.2	134.79
3.0355	1235.7	141.06
3.1156	1298.3	150.56
3.1648	1336.6	156.42
3.2386	1393.8	165.17
# Event BURNOUT occurred at t=3.3209 seconds		
3.3209	1456.9	174.84
3.4445	1550.4	189.18
3.4934	1587	194.8
3.5589	1635.7	202.26
3.6572	1707.9	213.38
3.7069	1744.1	218.98
3.7815	1798	227.34
3.8548	1850.4	235.47
3.9192	1896.1	242.55
4.0159	1964	253.09
4.161	2064.4	268.69
4.2391	2117.7	277.02
4.2856	2149.1	281.95
4.3552	2196	289.32
4.4405	2252.7	298.24
4.4865	2283.1	303.01
4.5556	2328.4	310.13
4.6511	2390.5	319.91
4.7135	2430.5	326.27
4.8069	2490.1	335.74
4.8689	2529.2	341.96
4.9287	2566.6	347.91
5.0183	2622.3	356.78
5.0895	2666.1	363.79
5.1464	2700.9	369.37
5.2173	2743.8	376.3
5.2693	2775	381.34
5.3122	2800.7	385.47
5.3766	2839	391.63
5.4732	2895.8	400.84
5.5308	2929.4	406.31
5.6172	2979.3	414.48
5.7258	3041.4	424.64
5.8359	3103.6	434.83
6.001	3195.3	449.99
6.201	3304	468.05
6.2997	3356.8	476.88
6.4477	3434.7	490.03
6.5187	3471.6	496.26
6.5894	3508.1	502.42
6.6955	3562.2	511.59
6.7659	3597.8	517.66
6.8128	3621.3	521.7
6.8576	3643.7	525.56
6.9248	3677	531.33
7.0081	3717.9	538.42
7.0454	3736.1	541.57
7.0887	3757.2	545.21
7.1537	3788.6	550.63
7.2512	3835.2	558.74
7.2904	3853.8	562
7.3312	3873.1	565.4
7.3796	3895.8	569.42
7.452	3929.6	575.43
7.4937	3948.8	578.86
7.5234	3962.6	581.29
7.5545	3976.9	583.83
7.5922	3994.1	586.87
7.6386	4015.3	590.61
7.7083	4046.8	596.2
7.7534	4067.1	599.81
7.7852	4081.3	602.37
7.8159	4095	604.84
7.8518	4110.9	607.73
7.9056	4134.7	612.06
7.9863	4170	618.53

8.0292	4188.7	621.94
8.0618	4202.8	624.52
8.0932	4216.4	626.98
8.13	4232.2	629.86
8.1852	4255.8	634.15
8.268	4290.9	640.56
8.3233	4314.1	644.85
8.3691	4333.2	648.4
8.4137	4351.8	651.86
8.4665	4373.6	655.96
8.5458	4406.1	662.1
8.6464	4446.9	669.82
8.7054	4470.6	674.31
8.7939	4505.8	681
8.9267	4558	690.97
9.0387	4601.3	699.33
9.2066	4665.2	711.82
9.3441	4716.5	721.94
9.5441	4789.6	736.55
9.7441	4860.9	750.97
9.9441	4930.5	765.26
10.077	4975.6	774.7
10.275	5041.7	788.72
10.475	5106.7	802.65
10.675	5169.9	816.46
10.808	5211	825.59
11.007	5271.1	839.19
11.104	5299.8	845.73
11.249	5342.1	855.48
11.385	5380.9	864.59
11.578	5434.9	877.49
11.778	5489.2	890.7
11.978	5541.9	903.8
12.178	5593.1	916.82
12.378	5642.7	929.78
12.578	5690.8	942.62
12.778	5737.4	955.34
12.978	5782.5	968
13.178	5826.1	980.62
13.378	5868.3	993.13
13.497	5892.7	1000.5
13.676	5928.4	1011.5
13.876	5967	1023.7
14.01	5992	1031.9
14.152	6017.8	1040.6
14.344	6051.7	1052.4
14.544	6085.5	1064.5

14.696	6110.2	1073.7
14.829	6131.1	1081.6
14.963	6151.8	1089.6
15.091	6170.9	1097.2
15.284	6198.6	1108.5
15.484	6226	1120.1
15.637	6246.1	1129
15.821	6269.1	1139.8
16.021	6292.7	1151.4
16.221	6315	1163
16.421	6336	1174.5
16.621	6355.7	1185.9
16.821	6374.1	1197.3
17.021	6391.2	1208.6
17.221	6407	1219.9
17.421	6421.4	1231.1
17.621	6434.6	1242.3
17.821	6446.4	1253.4
18.021	6456.9	1264.6
18.221	6466.1	1275.7
18.421	6474	1286.7
18.621	6480.7	1297.8
18.821	6486.1	1308.7
18.994	6489.8	1318.2
19.142	6492.2	1326.3
19.275	6493.9	1333.4
19.398	6494.9	1340.1
19.514	6495.4	1346.4
19.627	6495.5	1352.5
# Event APOGEE occurred at t=19.737 seconds		
19.737	6495.3	1358.4
# Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=19.738 seconds		
19.796	6495	1361.6
19.845	6494.6	1364.2
19.895	6494.2	1366.8
19.945	6493.7	1369.4
19.996	6493.1	1372
20.047	6492.5	1374.6
20.098	6491.7	1377.1
20.149	6490.9	1379.7
20.201	6490	1382.2
20.253	6489	1384.8
20.306	6487.9	1387.3
20.359	6486.7	1389.8
20.412	6485.5	1392.3
20.466	6484.1	1394.8
20.52	6482.6	1397.3

20.575	6481.1	1399.8
20.63	6479.4	1402.2
20.685	6477.7	1404.7
20.741	6475.9	1407.1
20.796	6473.9	1409.5
20.853	6471.9	1411.9
20.91	6469.8	1414.2
20.967	6467.5	1416.6
21.025	6465.2	1418.9
21.083	6462.7	1421.2
21.142	6460.1	1423.6
21.201	6457.5	1425.9
21.261	6454.6	1428.1
21.322	6451.7	1430.4
21.383	6448.7	1432.7
21.445	6445.5	1434.9
21.508	6442.2	1437.2
21.571	6438.8	1439.4
21.634	6435.2	1441.6
21.699	6431.5	1443.8
21.764	6427.6	1446
21.83	6423.6	1448.1
21.897	6419.5	1450.3
21.965	6415.2	1452.4
22.033	6410.7	1454.6
22.102	6406.1	1456.7
22.172	6401.3	1458.8
22.243	6396.4	1460.9
22.315	6391.2	1463
22.388	6386	1465
22.462	6380.5	1467
22.537	6374.8	1469
22.613	6368.9	1471
22.69	6362.8	1472.9
22.769	6356.5	1474.8
22.849	6350	1476.7
22.931	6343.2	1478.6
23.014	6336.2	1480.4
23.099	6328.9	1482.3
23.186	6321.3	1484.1
23.274	6313.4	1485.9
23.365	6305.2	1487.6
23.458	6296.7	1489.4
23.553	6287.8	1491.1
23.649	6278.7	1492.7
23.747	6269.2	1494.3
23.849	6259.3	1495.9

23.953	6249	1497.4
24.06	6238.2	1498.9
24.17	6227	1500.3
24.284	6215.3	1501.7
24.4	6203.1	1503
24.518	6190.6	1504.2
24.642	6177.3	1505.4
24.77	6163.4	1506.4
24.903	6148.8	1507.4
25.039	6133.6	1508.3
25.181	6117.7	1509
25.327	6101.1	1509.6
25.476	6084	1510.1
25.634	6065.6	1510.4
25.804	6045.7	1510.5
25.975	6025.5	1510.4
26.155	6003.9	1510.2
26.342	5981.3	1509.7
26.548	5956.3	1508.8
26.776	5928.3	1507.6
27.025	5897.4	1506.1
27.279	5865.6	1504.1
27.526	5834.5	1501.9
27.814	5798	1498.9
28.153	5754.5	1495
28.562	5701.8	1489.7
28.991	5646.2	1483.5
29.398	5593.1	1477.1
29.799	5540.5	1470.1
30.299	5474.8	1460.7
30.799	5408.8	1450.6
31.299	5342.7	1439.9
31.799	5276.5	1428.7
32.299	5210.3	1417
32.799	5144	1404.5
33.299	5077.7	1391.5
33.799	5011.4	1377.9
34.299	4945.2	1363.9
34.799	4878.9	1349.6
35.299	4812.7	1335
35.799	4746.5	1320.3
36.299	4680.4	1305.7
36.799	4614.3	1291.1
37.299	4548.3	1276.6
37.799	4482.3	1261.8
38.299	4416.4	1246.6
38.799	4350.5	1231.4

39.299	4284.7	1216.3
39.799	4219	1201.2
40.299	4153.4	1186.3
40.799	4087.8	1171.6
41.299	4022.2	1157
41.799	3956.7	1142.4
42.299	3891.3	1127.8
42.799	3826	1113.1
43.299	3760.7	1098.4
43.799	3695.5	1084
44.299	3630.3	1069.6
44.799	3565.3	1055.2
45.299	3500.2	1040.8
45.799	3435.3	1026.5
46.299	3370.4	1012.1
46.799	3305.5	997.69
47.299	3240.7	983.35
47.799	3176	969.04
48.299	3111.4	954.48
48.799	3046.8	939.67
49.299	2982.2	924.92
49.799	2917.8	910.27
50.299	2853.4	895.71
50.799	2789	881.29
51.299	2724.8	866.94
51.799	2660.5	852.75
52.299	2596.4	838.74
52.799	2532.3	824.77
53.299	2468.3	810.9
53.799	2404.3	797.21
54.299	2340.4	783.65
54.799	2276.6	770.13
55.299	2212.8	756.45
55.799	2149.1	742.46
56.299	2085.4	728.34
56.799	2021.8	714.36
57.299	1958.3	700.45
57.799	1894.8	686.43
58.299	1831.4	672.27
58.799	1768	657.98
59.299	1704.7	643.6
59.799	1641.5	629.14
60.299	1578.3	614.55
60.799	1515.2	599.87
61.299	1452.1	585.12
61.799	1389.1	570.27
62.299	1326.1	555.47

62.799	1263.2	540.73
63.299	1200.4	525.95
63.799	1137.6	511.21
64.299	1074.9	496.51
64.799	1012.2	481.81
65.299	949.63	467.21
# Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=65.3 seconds		
# Event RECOVERY_DEVICE_DEPLOYMENT occurred at t=65.3 seconds		
65.799	887.09	452.77
65.801	886.87	452.72
65.803	886.65	452.66
65.805	886.42	452.61
65.807	886.18	452.55
65.809	885.95	452.5
65.811	885.71	452.44
65.813	885.47	452.38
65.815	885.22	452.32
65.818	884.97	452.25
65.82	884.71	452.19
65.822	884.45	452.12
65.825	884.19	452.05
65.827	883.92	451.98
65.83	883.65	451.91
65.833	883.37	451.83
65.836	883.09	451.75
65.838	882.8	451.67
65.842	882.51	451.58
65.845	882.21	451.5
65.848	881.91	451.41
65.851	881.6	451.31
65.855	881.28	451.22
65.859	880.96	451.11
65.862	880.62	451.01
65.866	880.29	450.9
65.871	879.94	450.79
65.875	879.59	450.67
65.879	879.23	450.54
65.884	878.86	450.41
65.889	878.48	450.28
65.894	878.09	450.13
65.9	877.69	449.98
65.905	877.28	449.83
65.911	876.85	449.66
65.918	876.42	449.49
65.924	875.97	449.31
65.932	875.51	449.12
65.939	875.03	448.91

65.947	874.54	448.7
65.955	874.03	448.47
65.965	873.5	448.23
65.974	872.95	447.97
65.984	872.38	447.69
65.996	871.79	447.39
66.008	871.16	447.07
66.02	870.51	446.72
66.035	869.83	446.35
66.05	869.1	445.94
66.067	868.34	445.49
66.085	867.53	444.99
66.106	866.67	444.44
66.128	865.74	443.82
66.154	864.74	443.12
66.183	863.64	442.32
66.217	862.44	441.4
66.257	861.1	440.32
66.304	859.58	439.03
66.361	857.8	437.43
66.432	855.74	435.44
66.521	853.29	432.91
66.641	850.16	429.41
66.827	845.56	423.8
67.261	835.39	410.74
67.761	823.93	396.16
67.902	820.69	392.21
68.209	813.69	384.15
68.709	802.21	371.27
69.209	790.71	358.54
69.709	779.21	346.06
70.209	767.71	333.75
70.488	761.32	326.77
70.988	749.85	313.67
71.252	743.78	306.44
71.382	740.83	302.69
71.761	732.2	291.1
72.261	720.72	275.39
72.728	709.99	261.07
73.228	698.51	245.99
73.648	688.88	233.52
73.957	681.82	224.84
74.457	670.37	211.55
74.68	665.27	205.6
74.799	662.56	202.22
75.006	657.89	196.02
75.201	653.49	189.85

75.577	644.95	177.36
75.825	639.28	169.11
76	635.32	163.59
76.448	625.11	150.16
76.761	617.94	141.28
77.141	609.25	130.49
77.641	597.81	116.23
78.141	586.34	102.26
78.641	574.88	88.018
79.141	563.43	73.139
79.641	551.97	57.921
80.141	540.52	43.063
80.418	534.2	34.778
80.751	526.63	24.292
81.251	515.21	8.5336
81.684	505.31	4.6295
82.184	493.87	18.953
82.684	482.41	33.205
83.184	470.96	47.715
83.653	460.24	61.168
83.873	455.24	67.461
84.373	443.83	82.35
84.625	438.07	90.131
85.125	426.65	106.09
85.453	419.14	116.38
85.772	411.89	125.85
86.135	403.63	136.03
86.635	392.21	149.58
87.135	380.78	163.46
87.635	369.37	178
88.135	357.94	192.74
88.426	351.29	201.54
88.769	343.5	211.88
89.077	336.49	221.18
89.577	325.09	236.88
90.023	314.92	250.71
90.523	303.53	265.41
91.023	292.12	280.04
91.278	286.33	287.45
91.778	274.95	301.21
92.278	263.54	314.47
92.574	256.8	322.49
92.78	252.12	328.42
93.28	240.76	343.48
93.666	231.96	355.01
94.166	220.57	369.35
94.415	214.92	376.57

94.696	208.54	385.22
95.196	197.16	400.78
95.572	188.6	412.64
96.069	177.29	428.33
96.385	170.12	437.77
96.695	163.09	447.04
97.195	151.73	462.78
97.543	143.82	473.72
98.043	132.44	489.03
98.543	121.04	504.62
99.043	109.67	520.12
99.543	98.289	535.13
99.916	89.815	546.53
100.4	78.823	562.14
100.66	72.943	570.5
101.16	61.598	585.85
101.66	50.215	600.95
102.16	38.836	616.27
102.66	27.458	631.57
103.16	16.081	646.7
103.66	4.7041	661.82
# Event GROUND_HIT occurred at t=103.93 seconds		
# Event SIMULATION_END occurred at t=103.93 seconds		
103.93	-1.4596	669.84

14.6 NAR Safety Code

1. Certification. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.
2. Materials. I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.
3. Motors. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.
4. Ignition System. I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.
5. Misfires. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.
6. Launch Safety. I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.
7. Launcher. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.
8. Size. My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high-power rocket motor(s) intended to be ignited at launch.

9. Flight Safety. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.

10. Launch Site. I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).

11. Launcher Location. My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.

12. Recovery System. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

13. Recovery Safety. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.

MINIMUM DISTANCE TABLE

Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 — 320.00	H or smaller	50	100	200
320.01 — 640.00	I	50	100	200
640.01 — 1,280.00	J	50	100	200
1,280.01 — 2,560.00	K	75	200	300
2,560.01 — 5,120.00	L	100	300	500
5,120.01 — 10,240.00	M	125	500	1000
10,240.01 — 20,480.00	N	125	1000	1500
20,480.01 — 40,960.00	O	125	1500	2000

Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors

14.7 TRA Safety Code

Safety Code for High-Power Rocketry
Tripoli Rocketry Association

This High-Power Rocketry Safety Code is the product of many years of effort on behalf of the hobby by those who care about it and whose prime interest is safety This document sets minimum standards, intended to preserve the hobby in a safe environment. Using this Code as the minimum, it will be your responsibility to regulate your own launches safely for the conditions of each launch site. This Safety Code shall be the standard at all Tripoli Sanctioned Launches.

The Tripoli High-Power Safety Code ***supplements*** **NFPA 1127 Code for High Power Rocketry** with sections that are specific to Tripoli. The foundation of the Tripoli High Power Safety Code is NFPA 1127.

1 General Requirements

1-1 Scope

1-1.1 This code shall set practices for safe operation of High Power rocket launches. It will also address some aspects of safe rocket design, and construction, and limitations of motor power, for use by the certified user for the purposes of education, recreation and sporting use.

1-2 Purpose

1-2.1 The purpose of this code shall be to establish guidelines for reasonably safe operation of rockets at Tripoli Sanctioned Launches.

1-3 Definitions:

For the purposes of this code, the following terms shall be defined as stated in this section. Some of these may be redundant from NFPA 1127.

Insured Flier: A flier that has insurance provided by Tripoli or any rocketry organization that TRA has insurance reciprocity with. At this writing this includes NAR only. Note: some types of TRA membership do not include insurance (e.g. Associate, and Honorary members).

Adult Flier: An *Insured Flier* that is 18 years old or older.

High Power Rocketry Flier (HPR Flier): An *Adult Flier* that is certified to fly High Power rockets at their certification level.

Model Rocket Fliers (MR Flier): An Insured Flier who is not certified to fly High Power rockets.

Invited Guests of Fliers (Guests): A person who is not a member of a recognized rocketry organization/not covered by insurance.

Launch Director (LD): A Level 2 or Level 3 flier who has overall administrative responsibility for the launch.

Participants. Persons that are either:

- **HPR Fliers**.
- **Model Rocket Fliers**.
- **Invited Guests of Fliers.**

Range Safety Officer (RSO). A Level 2 or Level 3 flier who has the authority to ensure the safe operation of the range.

Sanctioned Launch. A sanctioned launch is a ***Tripoli Insured Launch***. Any *Sanctioned Launch* shall meet ***ALL*** of the following requirements:

- Responsible person of launch shall be member of Tripoli in good standing.
- Follows the appropriate Tripoli Safety Code.
- All AHJ (e.g. FAA waiver) requirements/regulations met and any required permits secured.
- Landowner permission has been formally obtained.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Spectator. A nonparticipant whose primary purpose is to view a rocket launch.

Spectator Area. An area designated where spectators view a rocket launch.

Tripoli Mentoring Program (TMP). Program to permit Tripoli Junior members to participate in supervised high power rocketry activities.

Tripoli (TRA). Tripoli Rocketry Association, Inc.

Requirements for High Power Rocket Operation

2 **Operating Clearances.** A person shall fly a high-power rocket only in compliance with:

- This code and NFPA 1127;
- *Federal Aviation Administration Regulations*, Part 101 (Section 307,72 Statute 749, Title 49 United States Code, Section 1348, "Airspace Control and Facilities," Federal Aviation Act of 1958);
- Other applicable federal, state, and local laws, rules, regulations, statutes, and ordinances.
- Landowner permission.

3 Legality

3-1 The Tripoli Rocketry Association does not claim Rocketry to be legal in every municipality, state or political jurisdiction.

4 Insurance

4-1 Tripoli rocketry activities are only insured when the provisions of this code are followed.

4-2 No Tripoli member shall misrepresent to any authority or landowner that Tripoli activities are insured .

5 Participation,

Participation Note: The information provided below identifies the minimum requirements for individuals that participate/attend Tripoli Sanctioned Launches.

A Launch Director has the authority to impose more stringent rules.

Participation and Access at Tripoli Launches shall be limited to the following:

5-1 HPR Fliers may access and conduct flights from the High-Power Launch Area and/or Model Rocket Launch Area.

5-2 Non-Tripoli Members age 18 and over who are students of an accredited educational institution may participate in joint projects with Tripoli members.

5-2.1 These individuals are only allowed in the High-Power Launch Area while supervised by an HPR Flier.

5-2.2 They are only allowed in the Model Rocket Launch Area while supervised by an Adult Flier.

5-2.3 The maximum number of nonmember participants shall not exceed five (5) per supervising flier.

5-3 Tripoli Junior Members who have successfully completed the TMP may access and conduct flights from the High-Power Launch Area while under the direct supervision of a Tripoli HPR Flier in accordance with the rules of the TMP.

5-3.1 The maximum number of TMP participants shall not exceed five (5) per supervising flier.

5-4 Children younger than 18 years of age may conduct flights from the Model Rocket Launch Area under the direction of an Adult Flier.

5-5 An invited guest may be permitted in the Model Rocket Launch Area and preparation areas upon approval of the RSO. Invited guests are not permitted in the High-Power Launch Area.

5-6 Spectators are only permitted in the spectator area(s); they are not permitted in the High-Power Launch Area or Model Rocket Launch Area.

6 Tripoli Launch Operations

6-1 Insured Fliers shall provide proof of membership and certification status upon request.

6-2 All flights and static motor tests conducted by a member shall be within the member's certification level, with the exception of permitted certification attempts.

6-3 When three or more rockets are to be launched simultaneously, the minimum spectator and participant distance shall be the value set forth in the Safe Distance Table for a complex rocket with the same total installed impulse, but not more than 610 m (2000 ft), or 1.5 times the highest altitude expected to be reached by any of the rockets, whichever is less.

6-4 No range activity shall be conducted when a thunderstorm has been reported within ten miles, or less, of the launch site or if thunder or lightning is present.

6-5 No rockets shall be launched when the surface winds exceed 20 MPH (32 KPH)

6-6 The minimum safe standoff distance from the spectator area for the Model Rocket Launch Area shall be 50 feet (15 meters).

6-7 All flights planned to exceed 50,000ft AGL shall be submitted to the Class 3 review Committee for approval.

6-8 Launch Director and Range Safety Officer

6-8.1 The LD or RSO may refuse to allow the launch, or static testing, of any rocket or rocket motor that they deem to be unsafe.

6-8.2 The LD or RSO may require greater Safe Standoff Distances than specified in this code.

6-9 Recovery

6-9.1 **A** rocket shall be launched only if it contains a recovery system that is designed to return all parts of the rocket to the ground safely.

6-9.2 Rockets that employ passive recovery (e.g. tumble recovery, aero-braking) need not employ an active recovery system.

Minimum spectator and Participant Safe Distance Standoffs

Total Installed Impulse, N-s		Motor type	Non-Complex		Complex	
			feet	meters	feet	meters
0.01 to	160	High Power G or smaller	100	30	200	61
160.01	320	H	100	30	200	61
320.01	640	I	100	30	200	61
640.01	1280	J	100	30	200	61
1,280.01 to	2,560	K	200	61	300	91
2,560.01 to	5,120	L	300	92	500	152
5,120.01 to	10,240	M	500	153	1,000	305
10,240.01 to	20,480	N	1,000	305	1,500	457
20,480.01 to	40,960	O	1,500	457	2,000	610

7 Referenced Publications

The following documents or portions thereof are referenced within this code. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

7-1 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box *9101, Quincy, MA 02269-9101*

NFPA 1122, Code for Model Rocketry.

NFPA 1125, Code for the Manufacture of Model Rocket Motors.

NFPA 1127, Code for High Power Rocketry

7-2 Government Publications.

Superintendent of Documents, U.S. Government Printing Office, Washington DC 20402.

Federal Aviation Administration Regulations, from the Code of Federal Regulations. Federal

Hazardous Substances Act, from the United States Code (re. Airspace Control)

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7-3 TRA Publications.

Tripoli Rocketry Association, Inc., P. O. Box 87, Bellevue NE 68005.

Articles of Incorporation and Bylaws

Tripoli Motor Testing Committee (TMT), Testing Policies

Appendix A - Additional Tripoli Rulings

A-1 NFPA 1127 was adopted by the Tripoli Board of Directors as the Tripoli Safety Code. (*Tripoli Report*, April 1994, Tripoli Board Minutes, New Orleans, 21 January 1994, Motion 13.)

A-2 All Tripoli members who participate in Association activities shall follow the Tripoli Certification Standards.

A-3 Any Board action(s) with regard to safety, made previous to or after publication of this document, shall be a part of the Tripoli Safety Code.

A-4 Increased descent rates for rocket activities conducted at the Black Rock Desert venue are acceptable if needed to insure a controlled descent to remain inside the FAA approved Dispersion Area.

A-5 A rocket motor shall not be ignited by using:

a. A switch that uses mercury.
b. "Pressure roller" switches