University of South Florida

NASA Student Launch
Centennial Challenge MAV Project

Preliminary Design Review

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Society of Aeronautics and Rocketry

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TABLE OF CONTENTS

1. SUMMARY OF PDR REPORT…… 3
   - 1.1 TEAM SUMMARY…… 3
   - 1.2 LAUNCH VEHICLE SUMMARY…… 3
   - 1.3 AGSE SUMMARY…… 3

2. CHANGES MADE SINCE PROPOSAL…… 4
   - 2.1 VEHICLE CRITERIA…… 4
   - 2.2 AGSE CRITERIA…… 4
   - 2.3 PROJECT PLAN…… 4

3. VEHICLE CRITERIA…… 5
   - 3.1 MISSION OVERVIEW…… 5
     - 3.1.1 MISSION STATEMENT…… 5
     - 3.1.2 MISSION REQUIREMENTS…… 5
     - 3.1.3 MISSION SUCCESS REQUIREMENTS…… 6
   - 3.2 VEHICLE DESIGN SUMMARY…… 6
   - 3.3 SUBSYTEM OVERVIEW…… 7
     - 3.3.1 PAYLOAD BAY…… 7
     - 3.3.2 ALTIMETER BAY…… 8
     - 3.3.3 AIRFRAME AND STRUCTURE…… 9
     - 3.3.4 MOTOR SYSTEM…… 9
   - 3.4 PROJECT RISK ASSESSMENT…… 11
   - 3.5 EVALUATION AND VERIFICATION PLAN…… 13
   - 3.6 MANUFACTURING PLAN…… 18
     - 3.6.1 COMPONENTS NEEDED…… 19
     - 3.6.2 FACILITIES…… 20
   - 3.7 TESTING PLAN…… 21
   - 3.8 MATURITY OF DESIGN…… 21
   - 3.9 VEHICLE DIMENSIONS AND SCHEMATICS…… 22
   - 3.10 MASS STATEMENT…… 24
   - 3.11 RECOVERY SYSTEMS…… 25
     - 3.11.1 DEPLOYMENT PROCESS…… 25
     - 3.11.2 ATTACHMENT SCHEME…… 26
   - 3.12 MISSION PERFORMANCE PREDICTIONS…… 26
   - 3.13 SAFETY…… 31
     - 3.13.1 SAFETY OFFICER RESPONSIBILITIES AND DUTIES…… 31
     - 3.13.2 NAR/TRA PERSONNEL…… 32
     - 3.13.3 HAZARD RECOGNITION…… 33
     - 3.13.4 ACCIDENT AVOIDANCE…… 33
     - 3.13.5 LAUNCH PROCEDURES…… 33
     - 3.13.6 CAUTION STATEMENTS…… 33
     - 3.13.7 HAZARD ANALYSIS…… 34

4. AGSE CRITERIA…… 36
   - 4.1 MISSION OVERVIEW…… 36

4.1.1 MISSION STATEMENT…………………………………………………… 36
4.1.2 MISSION REQUIREMENTS…………………………………………… 36
4.1.3 MISSION SUCCESS REQUIREMENTS……………………………… 37
4.2 AGSE DESIGN SUMMARY……………………………………………………….. 38
4.2.1 MECHANICAL ARM……………………………………………………… 38
4.2.2 PROCESSING UNIT AND ACCOMPANYING SOFTWARE………… 38
4.2.3 RAIL SYSTEM……………………………………………………………..38
4.3 AGSE SUBSYSTEM OVERVIEW………………………………………………… 40
4.3.1 PAYLOAD CAPTURE…………………………………………………… 40
4.3.2 PAYLOAD CONTAINMENT…………………………………………….. 40
4.3.3 RAIL SYSTEM AND IGNITER INSTALLATION……………………… 40
4.4 EVALUATION AND VERIFICATION PLAN……………………………………… 40
4.5 PRELIMINARY INTEGRATION PLAN…………………………………………… 41
4.6 TESTING PLAN……………………………………………………………………… 42
4.7 MATURITY OF DESIGN…………………………………………………………… 42
4.8 AGSE DRAWINGS AND DIMENSIONS………………………………………….. 43
4.9 AGSE CONCEPT FEATURES AND DEFINITION……………………………… 46
4.9.1 CREATIVITY AND ORGINALITY……………………………………… 46
4.9.2 UNIQUENESS AND SIGNIFIGANCE………………………………….. 46
4.9.3 SUITABLE LEVEL OF CHALLENGE………………………………….. 47
4.10 AGSE SCIENCE VALUE………………………………………………………….. 48
4.10.1 AGSE OBJECTIVES…………………………………………………… 48
4.10.2 SUCCESS CRITERIA………………………………………………….. 48
4.10.3 EXPERIMENTAL LOGIC, APPROACH, AND METHOD OF INVESTIGATION ………………………………………………………… 48
5. PROJECT PLAN………………………………………………………………………… 49
5.1 BUDGET PLAN……………………………………………………………………… 49
5.2 FUNDING PLAN…………………………………………………………………….. 52
5.3 TIMELINE……………………………………………………………………………... 53
5.4 EDUCATIONAL ENGAGEMENT PLAN AND STATUS………………………… 54
5.4.1 ENGAGEMENT AT LOCAL SCHOOLS……………………………….. 54
5.4.2 ENGAGEMENT AT THE UNIVERSITY OF SOUTH FLORIDA……...55
5.4.3 ONLINE ENGAGEMENT………………………………………………… 55
6. CONCLUSION…………………………………………………………………………… 55

1. Summary of PDR Report

1.1. Team Summary

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1.2. Launch Vehicle Summary

The final rocket will have a length of 102 inches, a diameter of 4 inches, and a projected weight of 514 ounces with a dry weight of 386 ounces. We will be using an L1112BT motor from Gorilla Rocket Motors. The rocket will contain two parachutes: a drogue parachute and a main parachute. The rocket will house a payload bay and its electronics near the nosecone of the vehicle, an altimeter bay in the middle, and 4 fins at the aft end of the rocket.

1.3. AGSE Summary

The Autonomous Ground Support Equipment (AGSE) will autonomously capture and place the payload, raise the rocket, and install the igniter. Each element of the AGSE will be integrated together on the launch platform controlled by a central computing system. The AGSE will consist of the following components: Robotic Arm, Vision System, Rover, and Rail System.

2. Changes Made Since Proposal

2.1 Vehicle Criteria

Minor changes to the launch vehicle have been made in the ongoing process of modeling and simulation. These changes have served to refine and optimize the projected flight path. However, the overall design of the launch vehicle has remained relatively unchanged. The current changes are found in the motor selection, the shift from the GR L1065, with 4209.7 Ns impulse, to the current selection a L1112BT, with 3709 Ns impulse, both rockets are sold by Gorilla Rocket Motors. The spatial dimensions of the rocket have also been reduced for maximal efficiency.

2.2 AGSE Criteria

While the core components necessary to achieve the requirements set forth remain largely unchanged, the SOAR team has made major modifications to the AGSE in the time since the proposal's submission. Namely, as it relates the AGSE loading and payload retrieval. Currently the intention, in this aspect, is to create a rover that searches, identifies, and grips the payload using a robotic arm attached to the rover to interact with its environment. The full focus of SOAR will be focused on the completion of this lofty ambition, but to ensure success, regardless of obstacles and constraints, we have formulated a modular development cycle. In this we will ensure that the critical mission objectives are prioritized.

As the lifecycle of the competition has progressed designs have matured appropriately. The design of the launch rail has evolved to include a worm gear set for accurate and reliable lifting of the launch vehicle into position. Discussion has been renewed on the end effector of the arm and the current plan is to test and verify two competing designs. The first is the original closed-circuit pneumatic gripper, utilizing the concept of jamming phase transition, which was set forth in the proposal, however the reliability and simplicity of a claw gripper are undeniable merits.

2.3 Project Plan

With the introduction of new ideas and methods of design came a plethora of modifications not only to the overall rocket design but also to budget plans, build plans and the launch itinerary. Do to the influx of new ideas brought by the diverse group of individuals that comprise the team the budget for the entire project increased. In order to accommodate for this change several budgeting tactics became more stringent. Budgeting tactics used include: finding individuals that would be willing to sponsor the team's endeavors, selling t-shirts with the team's logo on the front and requesting an influx of funding from the USF student government. Along with the budget and launch itinerary, the educational outreach dates have been updated as well.

3. Vehicle Criteria

3.1 Mission Overview

3.1.1 Mission Statement

For the NASA Student Launch Initiative the USF Society of Aeronautics and Rocketry will be adhering to both mission statement set by the competition and the mission statement for our organization itself.

NASA Student Launch Mission Statement

“USF SOAR will develop a high powered rocket using an L class motor to achieve an exact altitude of 5,280 feet. All components will be safely recovered. During the process, USF SOAR will focus on developing outreach for STEM programs and become familiar with project life cycle as used in NASA operations.”

USF SOAR Mission Statement

“The Society of Aeronautics and Rocketry (SOAR) at USF promotes engineering education and academic performance in a social environment through participation in projects and competitions dedicated to rocketry, aerospace, and other space exploration technologies. SOAR provides an opportunity of students from all majors and fields of interest to enhance their knowledge in research, engineering, project management, and other tangential skills pertinent to the aerospace industry.

As an organization we seek to contribute to the development of new and innovative systems that further human space exploration efforts. We strive to be a professional research organization, producing data relevant to the field. In the mindset of a professional organization we adhere to strict timelines, budget restrictions, management structures, teamwork, and fostering collaborations between the academic, commercial and government space industries in mission technology design.”

3.1.2 Mission Requirements

In order to achieve our goal of building an L class rocket with a 5,280 foot apogee we have developed a set of requirements for our associated subsystems in order to ensure success. Each requirement is followed by a verification plan that is currently a work in progress. Refer to Table 4 of Section 3.5 or the launch vehicle requirements as explained in the Student Launch Initiative handbook. Furthermore refer to Table 5 of Section 3.5 for the launch vehicle requirements as set for USF SOAR.

3.1.3 Mission Success Requirements

a) The vehicle achieves apogee between 5,000 and 5,400 feet.
b) At apogee, the drogue parachute is successfully ejected.
c) Between 500 and 600 feet AGL, the nosecone and payload bay are separated from the rest of the vehicle, and the main parachute and payload parachutes are successfully ejected.
d) No portion of the vehicle or payload sustains any major damage during flight or landing.

3.2 Vehicle Design Summary

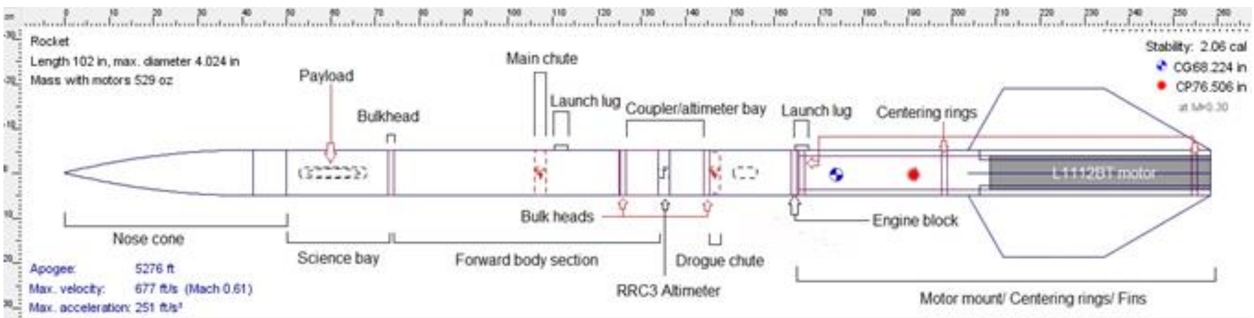

Figure 1. Rocket layout (generated using OpenRocket)

The rocket will be 102 inches in length and will have a projected total weight of 529 ounces and a dry weight of 451 ounces. The rocket will consist of four sections: the nosecone/payload bay, forward body section, altimeter bay, and the aft body section. The major connections will be via coupler tube, one connecting the payload bay to the forward body tube and one connecting the altimeter bay to the aft body tube.

The nose cone will be constructed out of plastic with an ogive nose cone shape that follows an ogive graph with a shape parameter of 1. The nose cone will span a total of 17 inches in length and will have a hollow inside resulting in a wall thickness of 0.08 inches. It will be filled with foam and additional mass in the form of metal pellets in order to push up the center gravity and decrease altitude.

The payload bay, located directly under the nose cone will also be constructed out of fiberglass and have a length of 12 inches. The payload bay is where the MAV payload will be held. The inside of the payload bay will consist of centering rings and a closed circuit pressurization mechanism that will ensure that the payload vibration does not perturb the flight path of the rocket. A bulkhead will separate the payload bay from the following forward body section.

The forward body section will have a length of 24 inches long and will be crafted out of fiberglass. This section will house our main parachute that will be fixed in place through the utilization of a 4 inch diameter birch bulkhead and a strap nylon parachute cord rated for 6,000 pounds of force. A kraft 4 inch long phenolic coupler tube will house the altimeter bay and will connect the upper rocket sections to their bottom counterpart. The altimeter bay will be screwed into the forward bay and fit into the aft bay via coupler.

The aft body section, the longest component of the rocket body will have a length of 48 inches and will be fabricated out of fiberglass. This section will house our drogue chute, the L1112BT-P rocket motor, the motor mount and an engine block.

The fins will be made of G10 fiberglass and stand approximately 5.4 inches from the aft body tube. The fin design will consist of four trapezoidal shaped fins that will have a sweep angle of 29.6°. Each fin will have a root chord of 21.5 inches and will extend 5.4 inches outward. Fiberglass will be used in the fabrication of the four fins explained above.

Due to weight and cost restrictions thirty minute epoxy will be used to as a bonding agent to connect several rocket components to one another. Inside the aft tube centering rings will be epoxied to the aft airframe walls and to a motor mount which will be holding the rocket motor in place. It is crucial that the centering rings are epoxied correctly to the motor mount and perfectly parallel to the launch surface when tilted upright for launch. The rocket fins will also be epoxied to the motor mount of the rocket. The rocket fins will be positioned along the aft tube perfectly parallel to the rocket body. The rocket body coupler connecting the upper and lower body tubing will epoxied into the payload bay to ensure rocket recovery mechanisms to deploy.

3.3 Subsystem Overview

3.3.1 Payload Bay

The payload bay is being designed with the goals of the MAV competition in mind. Our major design requirements for the payload are as follows: have enough volume to store the payload and all necessary mechanisms, be capable of securing the payload safely and mitigating vibration, be capable of opening and closing outside the rocket, and have no protruding elements that could affect the flight of the rocket.

With these design requirements in mind we established three potential options for payload design that would be optimal:

1. A simple hatch door mechanism with a foam padded interior, dimensioned to store the MAV payload with minimal vibration.
2. A compliant mechanism made of laser cut and 3-D printed plastic that could securely hold the payload with mechanical interaction after applying a small amount of force to place it into the system.
3. A closed circuit pneumatic “airbag” that can inflate to engulf the payload which would allow our payload bay not only secure to the MAV payload but allow it to hold payloads of varying sizes and shapes.

While determining our most viable option we considered the following factors: reliability, cost, manufacturability, mass, and integration into the overall rocket design. We have decided to engage in preliminary tests with proposed three ideas but we will be engaging in the last idea as our current primary option due to its variability, and its originality.

As can be seen in figure 2 below we have designed a closed pneumatic system composed of three components: a firm plastic airbag with a U shape that allows the insertion of a payload, a vacuum pump with reversible solenoid to be activated by an external turnkey screw, and a pressurized cylinder reservoir to maintain a closed pneumatic circuit. All appropriate pneumatic fittings and centering mechanisms will be included among the final design once initial testing is completed.

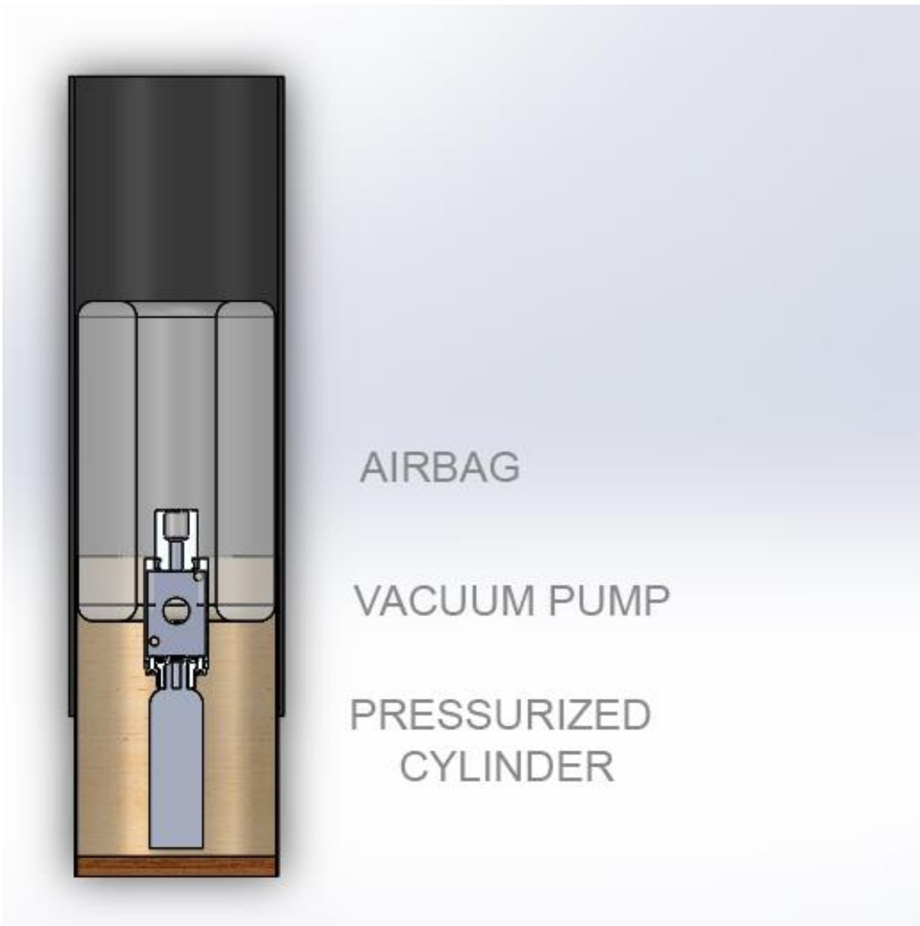

Figure 2: Payload Bay and Pneumatic Payload Enclosure

The door of the payload bay will be a hatch mechanism cut from the original fiberglass tube and fitted to prevent flight instability due to protruding elements. When the hatch is closed a small tab will be engaged when the solenoid valve is switched, sliding into an internal slot on the hatch door and securing the hatch in place for flight.

3.3.2 Altimeter Bay

The altimeter bay for the rocket will be located between the fore body tube and the aft body tube. The bay will secured into the fore tube by several screws whereas it will be attached to the aft tube by couplers. The purpose of the altimeter bay is to provide the altitude after flight and to be the main control hub of our recovery system.

The bay is constructed from a phenolic kraft coupler, a 1” ring of fiberglass, and two wooden bulkheads. Two threaded rods will be run through the length of the bay, and four segments of 1” pvc piping will protrude from either bulkhead to hold black powder for section separation upon recovery, covered by fabricated plastic blastcaps. The fasteners will include wingnuts on the threaded bolts and four total U bolts to fasten the parachutes.

We will be using two RRC3 altimeters powered by 9 volt batteries, both mounted on a G10 fiberglass plate securely stored within the altimeter bay. The altimeters will be wired to two keyed locks that must be armed and removed on the launch pad. The barometric altimeters will keep record of the altitude at apogee in addition to activating the black powder charges at apogee and 500 feet AGL.

3.3.3 Airframe and Structure

The airframe of the rocket will consist of 4 segments, all made of 98 mm fiberglass. The total length of the airframe will be 85 in consisting of a 12 in payload bay, a 24 in fore body tube, 1 inch altimeter bay body tube, and an aft tube of 48 in.

We chose an all fiberglass airframe as opposed to our usual choice of phenolic tubing. Our normal method of fabrication involves using phenolic and layering it with fiberglass and resin to increase strength but in order to reduce fabrication time and cost we opted to use preformed fiberglass tubes for increased rigidity and strength.

We will be using a plastic nose cone and G10 fiberglass fins as. Fastening for all fiberglass and phenolic will be done via 30 minute epoxy or ¼ 20 countersunk screws. Further reinforcement will be added via carbon fiber and resin along fin fillets, and silica mixed with epoxy to strengthen internal fillets along the centering rings and motor mount.

3.3.4 Motor System

The vehicle will use a commercially available solid motor propulsion system for the rocket. Specifically, the L1112BT motor from Gorilla Rocket Motors will be used and is certified by the Tripoli Rocketry Association, Inc. This motor has a total impulse of 3709 Newton-seconds, a maximum thrust of 1297 Newtons, and a burn time of approximately 3.3 seconds . OpenRocket simulations have been run using this motor to achieve a simulated apogee of 5280 feet and maximum velocity of approximately 692 feet per second .

The thrust curve shown in figure 4 (thrustcurve.org) has a fairly steady and consistent thrust ending around 3.3 seconds. Around the 2.7 second mark, the thrust decreases exponentially until burnout.

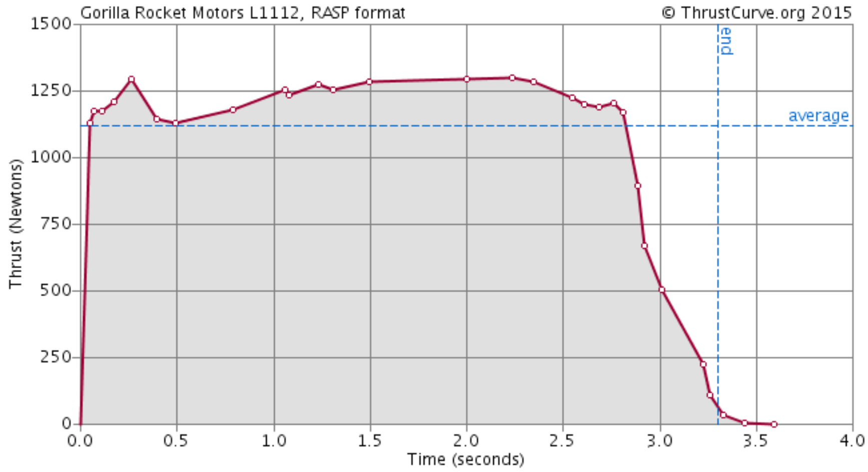

Figure 3. The thrust curve of an L1112BT motor

The motor shall be secured in a 36 inch phenolic kraft motor mount. The motor casing will be prevented from moving upwards towards the nose cone via snapring and it will be further held in retention by a 75 mm aeropack motor retainer to prevent the motor casing from sliding out of the motor mount tube. The motor retainer will be JB welded onto the lowest centering ring and allowed to protrude slightly from the bottom of the rocket. The simple threaded mechanism will allow the motor and casing to be inserted and removed with ease.

Figure 4. Aeropack Motor Retainer

The motor mount will be held into place by three birch centering rings purchased from Public Missiles Ltd. They will be epoxied onto the motor mount using 30 minute epoxy, and will in turn be epoxied onto the airframe. Epoxy fillets will be formed along all connected edges in order to increase rigidity and shear strength by filling any remaining voids.

3.4 Project Risk Assessment

The following is an assessment of potential risks and modes of failure within the project cycle. The categorization of risks has been based on its probability of occurrence and its associated hazard category.

Table 1. Hazard Risk Index Matrix

HAZARD RISK INDEX MATRIX				
Probability of Occurrence	Hazard Category			
	Catastrophic [1]	Critical [2]	Marginal [3]	Negligible [4]
Frequent [A]	1A	2A	3A	4A
Probable [B]	1B	2B	3B	4B
Occasional [C]	1C	2C	3C	4C
Remote [D]	1D	2D	3D	4D
Improbable [E]	1E	2E	3E	4E

Hazard Categories

1. **Catastrophic**: May cause a permanent damage to project and prevent completion.
2. **Critical**: May cause severe damage to the project and cause delays in deliverables.
3. **Marginal**: May cause minor damage to the project and cause restructuring of the schedule.
4. **Negligible:** May cause slight problems with the project and cause slight restructuring of the previous plan or schedule.

Table 2. Criticality of Failure Mode

CRITICALITY		
Class Index	Severity/Probability	Criticality
1	1A, 1B, 1C, 2A, 2B, 3A	High
2	1D, 2D, 2C, 3C, 3B	Moderate
3	1E, 2E, 3E, 3D, 4B, 4A	Low
4	4E, 4D, 4C	Negligible

Table 3. Project Failure Mode Table

Risk	Effect	Hazard	Solution
Key members are no longer available to work on the project.	Work is rushed, incomplete, or incorrectly done.	1C	Ensure all members are kept actively engaged, have a dedicated task, and a point of contact. Divide up work so there is equal load among members and have a contingency plan.
Low Funds	Design decisions are compromised, work is late or incomplete.	2D	Carefully manage budget and work on fundraising.
Necessary Components Delivered Late	Work is delayed or forced to proceed without component	2C	Make all purchases early and be careful to ensure all components are ordered well before testing.
No Manufacturing Equipment	Work is delayed, incomplete or haphazardly completed.	3D	Before dedicating yourself to a particular method, ensure we have the consistent access to capabilities.
Negative Test Results	Total project delayed	2D	Make sure design is done properly and fabrication is done carefully, leave time for simulation and backup tests.
Design too Complex	Project delay or no completion	3E	Ensure the design falls within the scope of our capabilities and leave time for redesigns if necessary.

3.5 Evaluation and Verification Plan

Table 4. Requirements from NSL Handbook and Verification Plan

Requirement Number	Description	Design	Verification
1.1	The vehicle shall deliver the payload to an apogee altitude of 5,280 feet above ground level (AGL).	The structural design and motor selection will be determined around the projected altitude.	The design shall be verified via simulation, calculations, and finally testing
1.2	The vehicle shall carry one commercially available, barometric altimeter	The launch vehicle will have two barometric RRC3 altimeters.	The design shall be inspected and tested.
1.3	The launch vehicle shall be designed to be recoverable and reusable.	The launch vehicle will engage a dual stage parachute recovery system that will limit the kinetic energy of all components upon impact.	The recovery system will be analyzed, inspected, simulated, and tested.
1.4	The launch vehicle shall have a maximum of four (4) independent sections.	The launch vehicle will have three independent sections upon recovery after aft bay separation and nosecone/payload separation.	The requirement will be reflected in design.
1.5	The launch vehicle shall be limited to a single stage.	The launch vehicle will have one stage.	The requirement will be reflected in design.
1.6	The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours.	The team will have launch day procedures that will be practiced to ensure launch on schedule.	The requirement will be reflected in design and practice.
1.7	The launch vehicle shall be capable of remaining	All sensitive equipment will be adequately	The requirement shall be met in

	in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board component.	protected.	design and tested.
1.8	The launch vehicle shall be capable of being launched by a standard 12 volt direct current firing system.	The launch vehicle will be developed to work with standard 12 volt ematches.	The requirement shall be met in design and verified in testing.
1.9	The launch vehicle shall use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP)	The team will purchase a commercially available APCP motor.	The requirement will be met in design.
1.10	The total impulse provided by a launch vehicle shall not exceed 5,120 Newton-seconds (L-class)	The team will purchase a commercially available L-class motor.	The requirement will be met in design.
1.11	Pressure vessels on the vehicle shall be approved by the RSO	The payload pneumatic system will be operated with a 4:1 safety factor, include an emergency dump valve, and include a full pedigree as requested.	The requirement will be met upon final design, verified via manufacturer specifications, and testing verification.
1.12	All teams shall successfully launch and recover a subscale model of their full-scale rocket prior to CDR.	A subscale launch is scheduled for 11/21/2015.	The requirement shall be met in testing.
1.13	All teams shall successfully launch and recover their full-scale	A full-scale launch in its final configuration is scheduled for	The requirement shall be met in testing.

	rocket prior to FRR in its final flight configuration.	2/20/2015.	
1.14	Each team will have a maximum budget of $7,500 they may spend on the rocket and its payload(s).	A detailed budget will be followed to ensure that the project remains under the maximum budget.	The requirement will be verified in inspection.
1.15	Vehicle Prohibitions.	No prohibited items will be used in the launch vehicle	The requirement will be verified in design.
2.1	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.	The recovery system will deploy a drogue at apogee and a main chute at 500 feet AGL.	The requirement will be verified in design and verified in testing.
2.2	Teams must perform a successful ground ejection test for both the drogue and main parachutes.	Ejection systems will be tested prior to launch.	The requirement will be met in testing.
2.3	At landing, each independent section of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf.	Simulations and hand calculations will be done to ensure a low maximum kinetic energy on impact.	The requirement will be met in calculation, simulation, and testing.
2.4	The recovery system electrical circuits shall be completely independent of any payload electrical circuits.	The recovery system will be managed by the RRC3 altimeters.	The requirement will be met in design.
2.5	The recovery system shall contain redundant, commercially available	The recovery system will use two RRC3 altimeters.	The requirement will be met in design.

	altimeters.		
2.6	Motor ejection is not a permissible form of primary or secondary deployment.	Motor ejection will not be utilized.	The requirement will be met in design.
2.7	A dedicated arming switch shall arm each altimeter, which is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	Each altimeter will have a dedicated key switch available on the outside of the rocket.	The requirement will be met in design.
2.8	Each altimeter shall have a dedicated power supply.	Each altimeter will have one dedicated 9 volt battery.	The requirement will be met in design.
2.9	Each arming switch shall be capable of being locked in the ON position for launch.	The key switches used will be able to be locked in an on position.	The requirement will be met in design and verified in testing.
2.10	Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.	Shear pins will be used at separation points at the fore and aft bay.	The requirement will be met in design and verified in testing.
2.11	An electronic tracking device shall be installed in the launch vehicle and shall transmit the position of the tethered vehicle or any independent section to a ground receiver.	A GPS will be implemented with the altimeter in the altimeter bay.	The requirement will be met in design and verified in testing.
2.12	The recovery system electronics shall not be	All electronic systems will be properly	The requirement will be met in

	adversely affected by any other on-board electronic devices during flight	integrated, shielded, and have appropriate cable management.	design and verified in testing.

Table 5. Requirements from USF SOAR and Verification Plan

Requirement Number	Description	Design	Verification
S1	The payload will be able to seal completely with no protrusions.	The design of the payload will focus on locking the hatch mechanism and ensuring a uniform body tube on closure.	The requirement shall be met in inspection, analysis, and testing.
S2	The closed pneumatic circuit in the payload will meet all safety requirements	The reservoir chosen will be pressurized at 1/4 of its total capacity and will be accompanied by manufacturer specifications and include an emergency dump valve in the design.	The requirement shall be met in inspection, design, analysis, and testing.
S3	The payload pneumatics will seal the payload in place and be able to be activated by a switch outside the payload bay.	The pneumatic connections will be chosen carefully and the payload airbag will be specially designed. The solenoid vacuum will be worked to a switch outside the payload bay to be armed by the AGSE or human	The requirement shall be met in inspection, design, analysis, and testing.

		operator.	
S4	The parachutes will not be damaged by the ejection charge.	The chutes will both have Kevlar chute protectors separating them from the black powder charges.	The requirement shall be met in inspection, analysis, and testing.
S5	The parachutes shall not break off from the rocket after separation.	Appropriate weighted shock cord will be used in addition to checking all fastening systems and associated yield stresses.	The requirement shall be met in inspection, analysis, and testing.
S6	All epoxied sections, including centering rings and bulkheads will be able to withstand max thrust of the motor.	Calculations shall be done to determine the max shear strength of all epoxied sections.	The requirement shall be met in inspection, analysis, and testing.
S7	All components of the rocket will be held together until the time of separation.	Appropriate shear pins will be utilized.	The requirement shall be met in inspection, design, and testing.
S8	The motor retention system shall prevent motor movement.	The snap ring and retaining ring shall be calculated for their shear strength.	The requirement shall be met in inspection, design, and testing.

3.6 Manufacturing Plan

In order for the team to successfully fabricate a subscale rocket, a full scale rocket as well as the ground support systems that meet all the competition criteria, efficient manufacturing plans must be initialized. Several factors must be considered when constructing a manufacturing plan that will allow for the team to efficiently and also effectively manufacture viable rocket and ground support components. When constructing a manufacturing plan the team considered two major factors: components needed and facilities.

3.6.1 Components needed

The structural components includes all the elements in the rocket and ground support systems that are associated with structural soundness. Elements externally and internally found in the rocket and ground support systems all required design modifications and were optimized in order to fit the specific requirements.

When designing components that would be mounted inside the launch vehicle, factors such as weight and weight distribution were examined and manipulated and theoretically tested. The rocket must have an ideal weight as well as weight distribution such that the whole system does not overshoot or undershoot the required apogee of 5280 feet.
Bulkheads fabricated out of kraft phenolic will be used simply do to the weight and durability of the material. Kraft phenolic has a low weight to volume ratio of 59.30 pounds per cubic foot (0.95 g/cm^3) making it a perfect material for internal rocketry composition. Bulkheads are going to be used to divide the rocket up into several sections, allowing for mounting and the separation of different bays as well as the protecting internal components from the thermodynamic heat transfer of the motor.

The centering rings as well as the engine block designed for the full scale and subscale rocket will be crafted out of birch wood. Birch has a mass to volume ratio of 42 pounds per cubic foot (0.67 g.cm^3) which is low enough to make use of the substance for aeronautics. The centering rings are a paramount component in the fundamental structure of the launch vehicle. The centering rings position the motor mount in a way that directs the thrust of the motor directly downward away from the velocity vector of the rocket. If any centering ring is not perfectly orthogonal to the motor mount the motor will direct thrust at an angle that is not 90 degrees to the ground, skewing the launch trajectory. Both centering rings as well as the bulkheads will give the body sections of the rocket increased stability.

A tube coupler connecting the forward section and the aft section of the launch vehicle was optimized to induce a lower weight but not compromise structural soundness of the system. Kraft phenolic was again used for the coupler tubing system.

Two parachutes were added into the design in order to support the recovery system of the vehicle. It is crucial to install two parachutes of two different sizes into a launch vehicle in order to ensure minimal launch displacement from the launch site to the final landing site. The altimeter bay, located in the middle of the rocket will deploy our two parachutes through the implementation of contained charges. The main chute will will have a diameter of 2.5 feet with a drag coefficient of approximately 2.59. The main chute will be made of 1.9 oz ripstop nylon and will be packed into the forward section of the launch vehicle in between the altimeter bay and science bay. The drogue chute will also be made of the 1.9 oz ripstop nylon but will have a diameter of 1.8 feet, reducing its drag coefficient to 1.16. This chute will be installed in the aft section of the rocket body. The drogue chute is designed to deploy at apogee and slow the rocket velocity down in anticipation for the main chute deployment.

Electronics such as barometers and other programmable CPUs will be installed inside the aft bay to record and measure flight data.

The materials selection for external components relied on durability and weight constraints. The nose cone will be constructed out of plastic with an ogive nose cone shape that follows an ogive graph with a shape parameter of 1. The nose cone will span a total of 17 inches in length and will have a hollow inside resulting in a wall thickness of 0.08 inches. Aerodynamics as well as structural reliability played factors in the construction of the nose cone. The wall thickness of the nose cone was minimized so that weight was minimized but structural reliability was not compromised.

The forward, aft body tubing and also the fin set of the launch vehicle will be composed up of fiberglass tubing. Fiberglass tubing was selected as the external material for the launch vehicle due to the durability of the material and the relatively low mass to volume ratio the material has (approximately 115.5 lbs/ft^3).

The rail system used in the vertical positioning of the launch vehicle will consist of an aluminum rail attached to a worm gear assembly that will raise the rocket prior to launch. There will be a ratcheting safety system in place. Aluminum was used in the rail system because of the lightweight, durability and low cost of the metal.

The AGSE will be made from a combination of Tetrix kits and 3D Printed Parts. There will be six degrees of freedom our AGSE arm will incorporate. Five of the six degrees of freedom will be within the arm itself and the last will be a rotating base that the arm will sit on top of. The material chosen for the ends of our AGSE arm gripper will be a rubber coating to easily pick up the PVC payload and a plethora of other objects.

3.6.2 Facilities

In order to successfully design and manufacture successful rocket and launch equipment the team will need a workspace which is readily available to all group members and also a workspace that has proper manufacturing equipment for the team.

The manufacturing location where the majority of the rocket components and ground support equipment will be fabricated will be in the DFX lab on the USF, Tampa campus. The DFX lab has workspaces that are well ventilated and have room for component epoxying as well as component assembly. The DFX lab also have 3D printers as well as laser cutter printers in which the team can use for component fabrication. Component and vehicle parts will be stored in this room in order to maximize team organization and efficiency.

3.7 Testing Plan

Table 6. Launch Vehicle Testing Plan

Test Name	**Test Description**
Ejection Charge Test	Simulate the ejection charges on the ground in order to determine if the charge will be sufficient to initiate separation in flight.
Subscale Launch	Launch a subscale version of the rocket to determine design stability and recovery success.
Full-Scale Test Launch	Launch the full-scale rocket as it will be launched to ensure all systems are functioning properly.
Parachute Packing	Pack parachute and take measurements of packed length and diameter, and ensure easy removal.
Payload Bay Tests	Build and test capabilities in terms of mission success and reliability of three potential payload designs in order to determine best choice for final integration.
Static Testing	Static testing of the motor to verify the thrust curve and ensure that the total impulse is what is needed for our launch vehicle.
Altimeter Test	After the altimeter is programmed, test to ensure that it is able to activate the black powder charges in ground tests.

3.8 Maturity of Design

While still in an ongoing design, the current state of the rocket design has a significant level of maturity. All team members have been working to contribute new ideas to the further development of our launch vehicle. The sheer volume of ideas and suggestions has given us considerable work in parsing ideas and determining their merit. Part of the maturity of our design is due to experience designing and fabricating other rockets. Building off of this knowledge and the innovative thinking by members we are producing a launch vehicle we can be confident in.

The difficulties present within the competition have given us new ground to cover including, reaching a specific altitude, and developing a unique payload bay. All throughout this design stage however members have been increasing their knowledge working with simulation and modeling programs such as OpenRocket and Solidworks. As we move forward with design decisions we would like to increase the types of simulations we perform to include fluid dynamics and stress simulations on vital components.

Ultimately, we believe that we have established a firm foundation from which to move to a more detailed design. We will continue to select design options and engage in component testing however until the finalization of our full-scale rocket. We believe that our design is at the appropriate maturity for the current stage of the project life cycle.

3.9 Vehicle Dimensions and Schematics

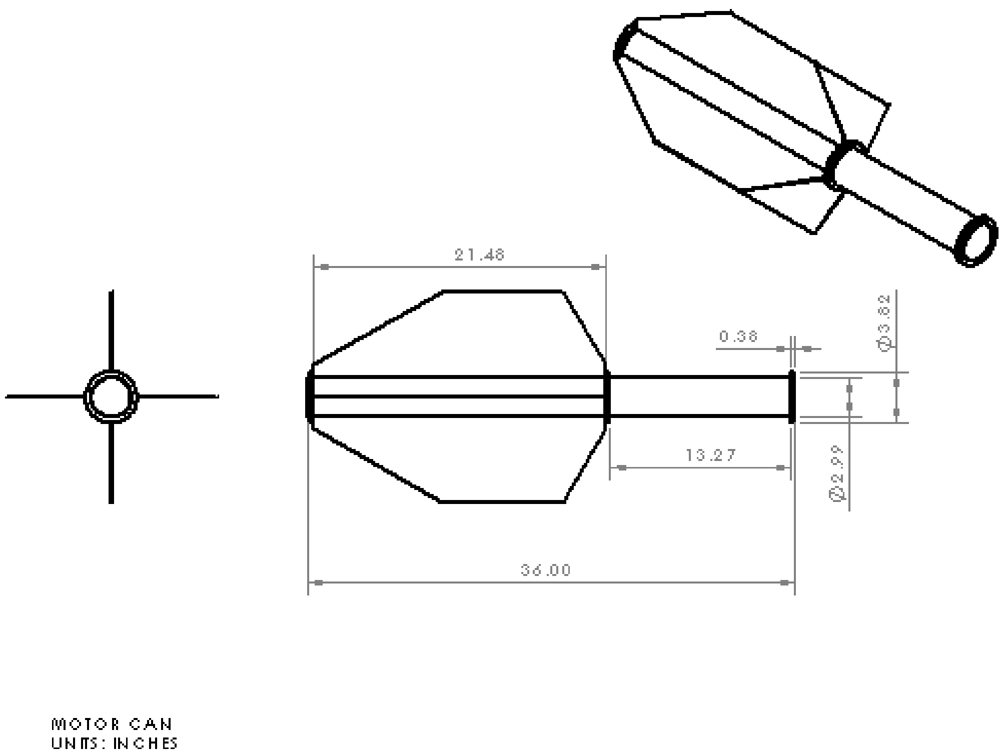

Figure 5: Motor Can Dimensions

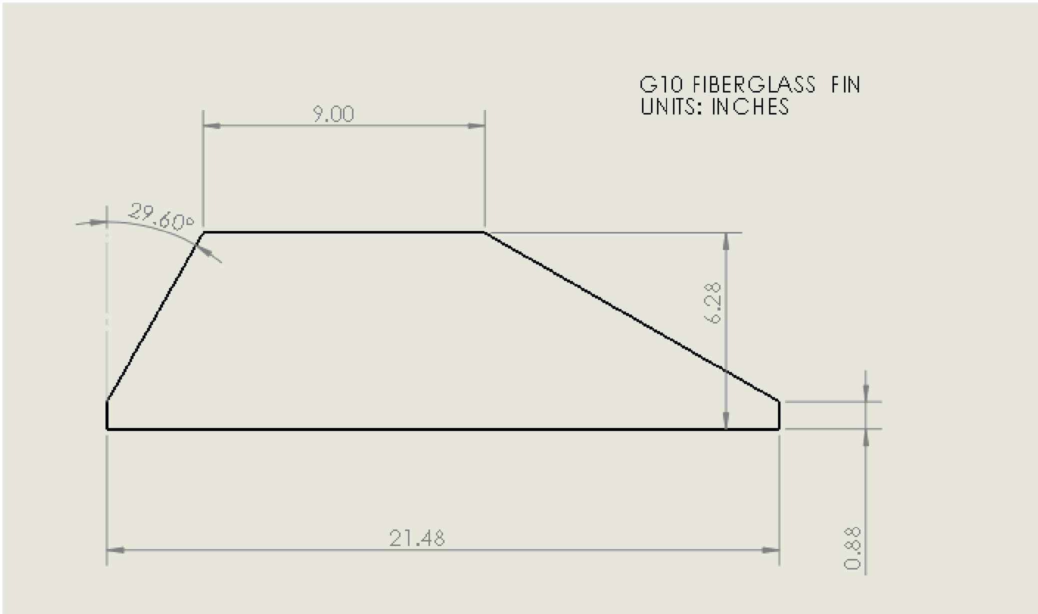

Figure 6: Fin Dimensions

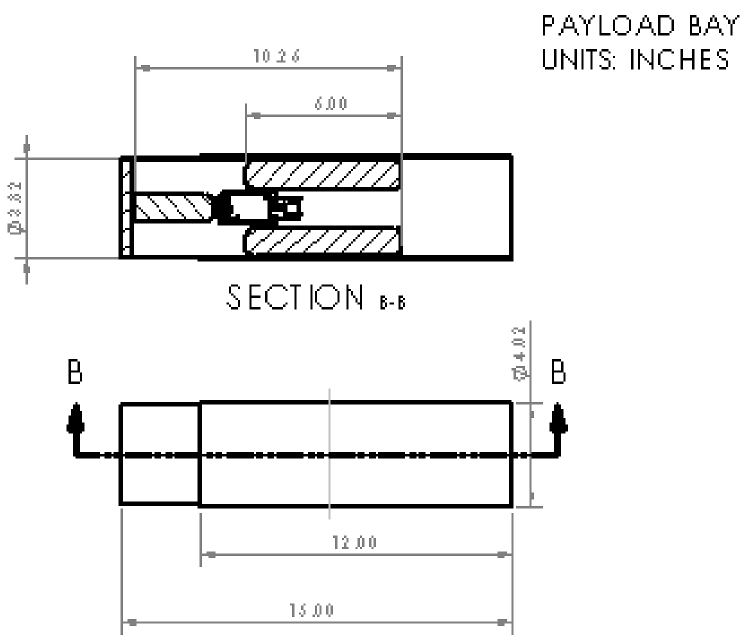

Figure 6: Payload Bay Dimensions

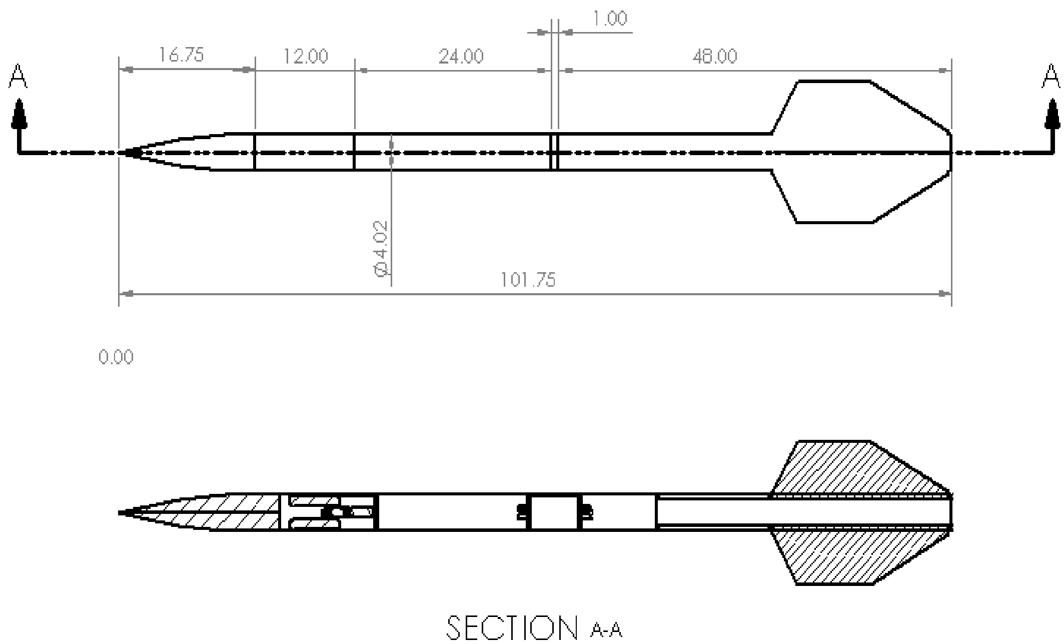

Figure 7: Total Launch Vehicle Dimensions

3.10 Mass Statement

Table 7. Mass Statement

Name	Unit Mass (oz)	QTY	Mass (oz)
Nosecone	32.75	1	32.75
Payload Mechanism	35	1	35
Airframe	52.7	1	52.7
Main Chute	45	1	45
Couplers	4.91	2	9.82
Bulkhead	2.31	3	6.93
Altimeters	0.282	2	0.564
Drogue Chute	24	1	24
Shock Cord	0.17	72	12.24

Centering Ring	0.916	3	2.748
Fin	38.5	4	139
Motor Retainer	4.62	1	4.62
Motor Mount	22	1	22
Motor System	142	1	142
Loaded Weight			529.372
Empty Weight			451.372

The mass statement was developed based on manufacturer reported mass of the above components. The accuracy of the mass statement at this point in time is dependent on the reporting of the manufacturer. Throughout the fabrication process we will carefully measure each component of our rocket upon completion in order to develop a much more complete view of the final rocket mass. Based on our selected motors maximum thrust of 1297 N, 291.577 lbs to prevent it from leaving the launchpad, so at our current loaded estimate of 33.08 lbs we fall well below this maximum weight.

We do anticipate over time due to design changes, epoxy, and fastening elements our design will increase in weight. Should we need to further increase the weight we will add foam into our hollow nose cone along with the several weighted balls in order to add additional mass.

3.11 Recovery Systems

3.11.1 Deployment Process

The recovery system will use dual-deployment in compliance with the Recovery Subsystem Requirements outlined in the NASA Student Launch handbook. The drogue parachute will be deployed at apogee. After the drogue parachute has been deployed and the rocket has descended to an altitude of 500ft the RRC3 altimeters will deploy the main parachute via an additional ejection charge. The ejection charges will be stored on the end of the altimeter bay, compacted by flame retardant material and covered with a blast cap.

The rocket airframes will be held together by shear pins as is customary to ensure there will be no separation prior to our selected event locations.

Blast caps will be placed on both ends of the altimeter bay airframe. They will have pyrodex charges, flame-retardant wadding, and e-matches which will be connected to the altimeter bay. For the purpose of redundancy we will use two RRC3 altimeters to ensure parachute deployment.

3.11.2 Attachment Scheme

All rocket airframes will be connected by U-bolts, and shock cord. The shock cords will be 21 ft in length. This will be to prevent any of the partitions from colliding after deployment of the parachute. The shock cord will be tied to the U-bolts in a common parachute self-tightening knot. The U-bolts connections for the drogue chute will be between the altimeter bay and the uppermost centering ring, while the U-bolt connections for the main chute will be between the altimeter bay and the bulkhead of the nosecone/payload assembly.

3.12 Mission Performance Predictions

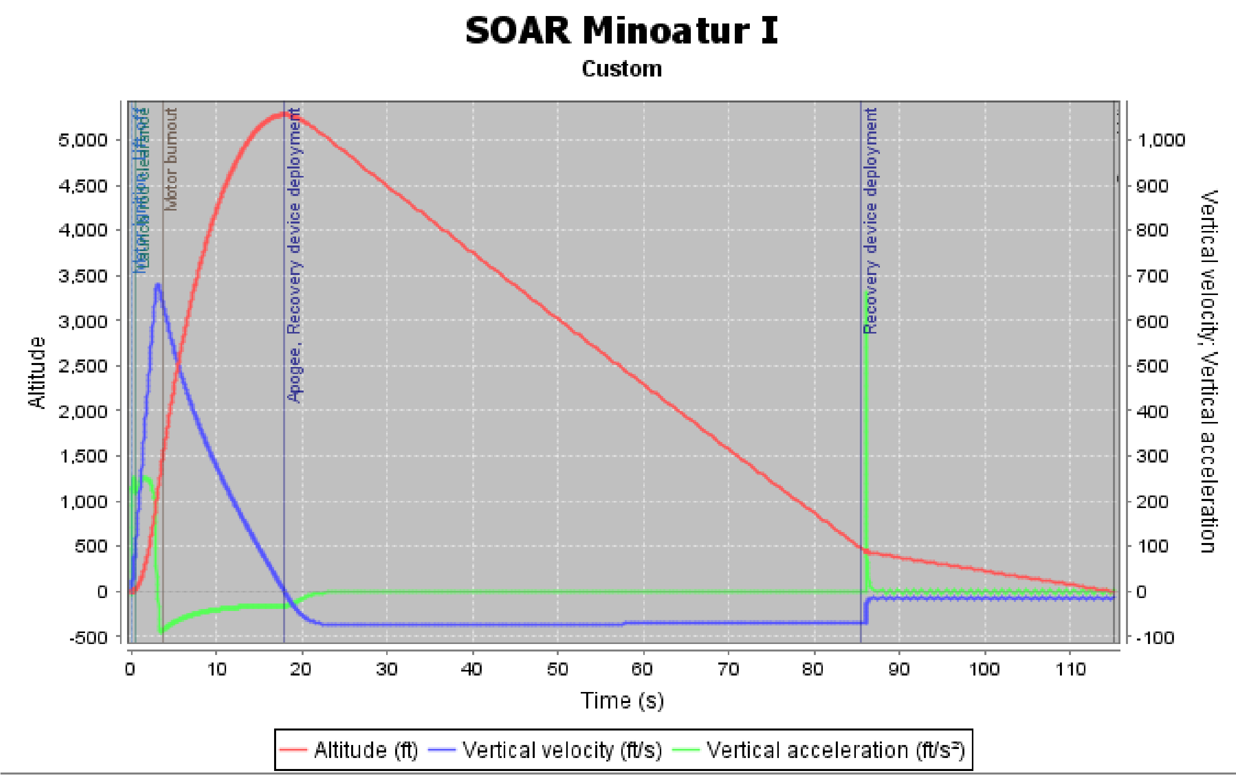

Figure 8: Mission Performance Simulation

Several simulations were run in OpenRocket in order to determine the mission performance of our designed launch vehicle. The simulations were run in a 6 - DOF system with conditions similar to Huntsville, Alabama. The plot layers information for the projected altitude over time, the velocity over time, and finally the acceleration over time.

The rocket reaches apogee at 5280 feet in good conditions. The maximum velocity is 678 ft/s, the max acceleration is 252 ft/s^2, the total flight time is 115 s with apogee reached at 17.9 s. The velocity t impact is 15.9 ft/s. The launch vehicle deploys its drogue chute at apogee and deploys its main chute at 500 feet as evidenced by Figure 8.

Figure 9: Launch Vehicle Model with CP as red dot (76.506 in) and CG as blue dot (68.224 in) as measured from the nosecone.

For our launch vehicle we ensured that we had a separation between the center of gravity, and center of pressure by at least 1.5 calibers, resting at comfortable 2.06 at launch. Figure 10 below shows the stability margin calipers over time until the drogue deployment at apogee. With the motor loaded the center of gravity is at 68.224 inches from the nosecone, and the center of pressure is 76.506 inches away from the nose cone providing a stability of 2.06 cal.

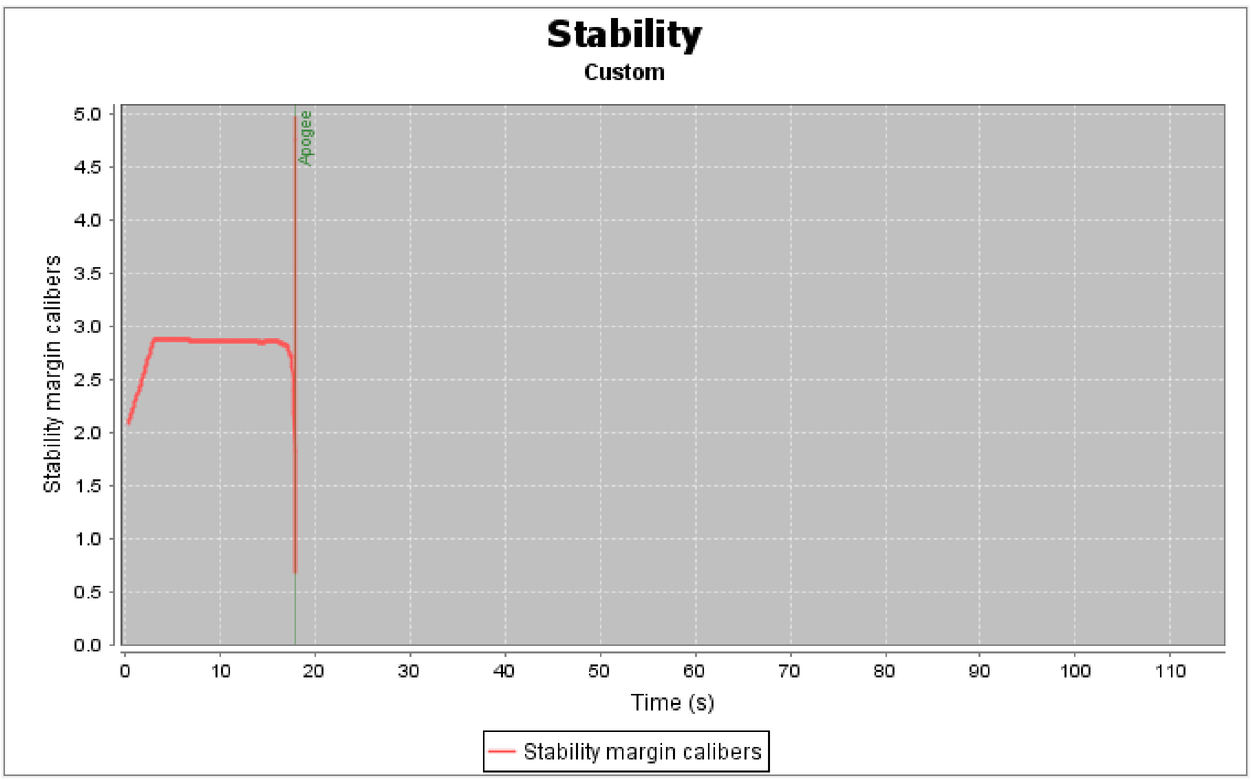

Figure 10: Stability Margin Calibers vs Time

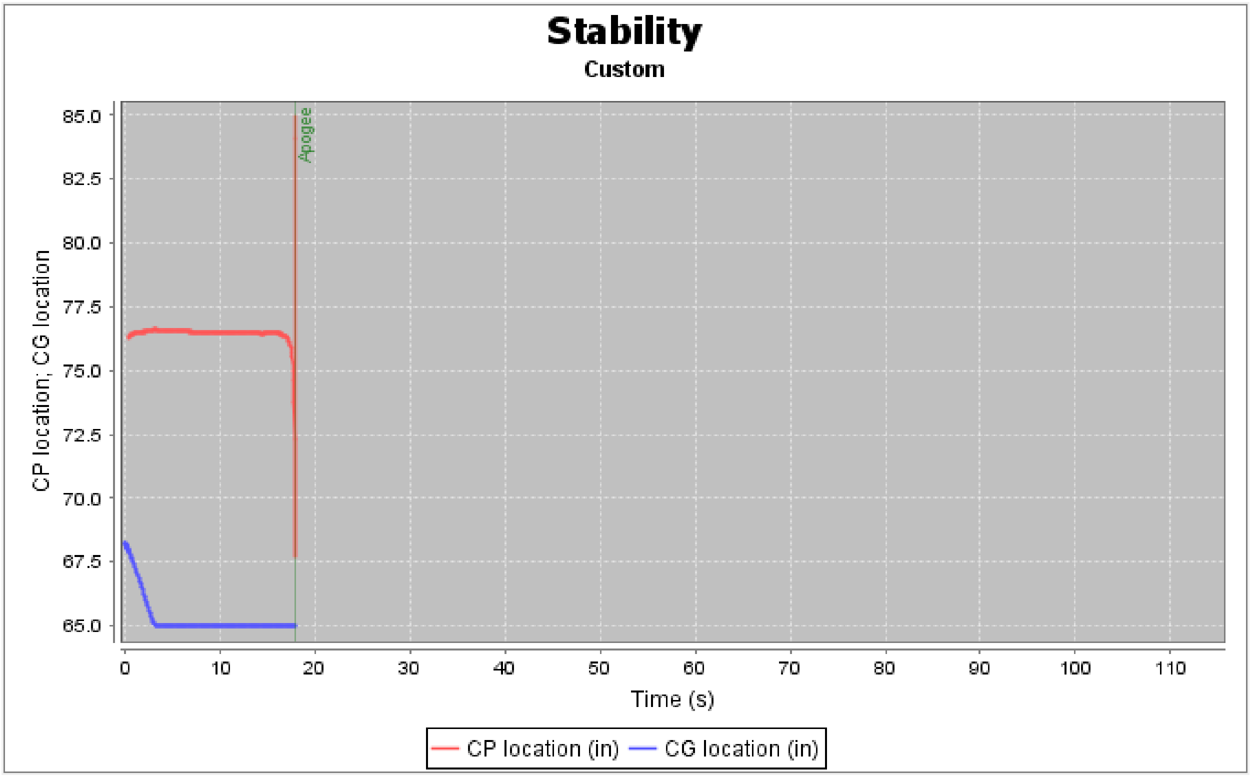

Figure 11: Center of Pressure and Center of Gravity Location over Time

Table 8: Kinetic Energy of each Disparate Section at Impact

Subsection	Kinetic Energy
Nosecone/Payload	14.46836733
Fore Airframe	18.69298993
Aft Airframe	64.39932374

Table 8 shows the kinetic energy of each tethered section of the rocket upon landing. These values were calculated assuming a 25% mass gain during the course of the development cycle. As can be seen above the heaviest section of the rocket, the Aft Airframe still falls under the necessary 75 lbf-ft energy limit on impact. Should we need to further reduce the impact due to additional mass we have selected another main parachute with a large area in order to further reduce velocity on descent.

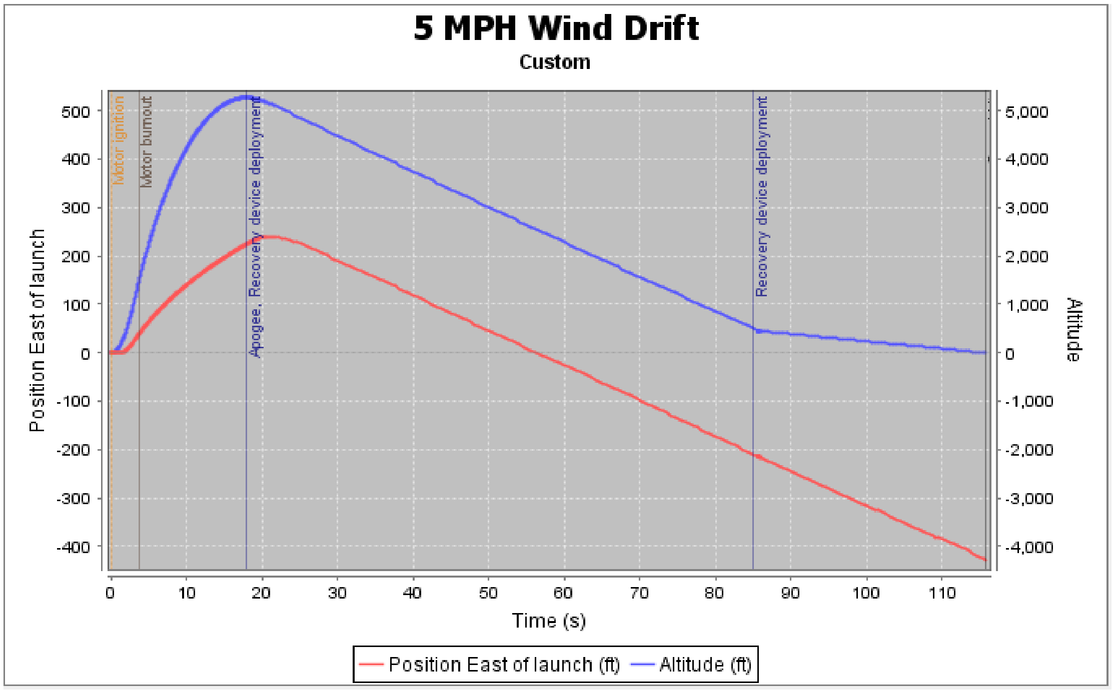

Figure 12: Drift in Position due to 5 mph wind in an east-west direction

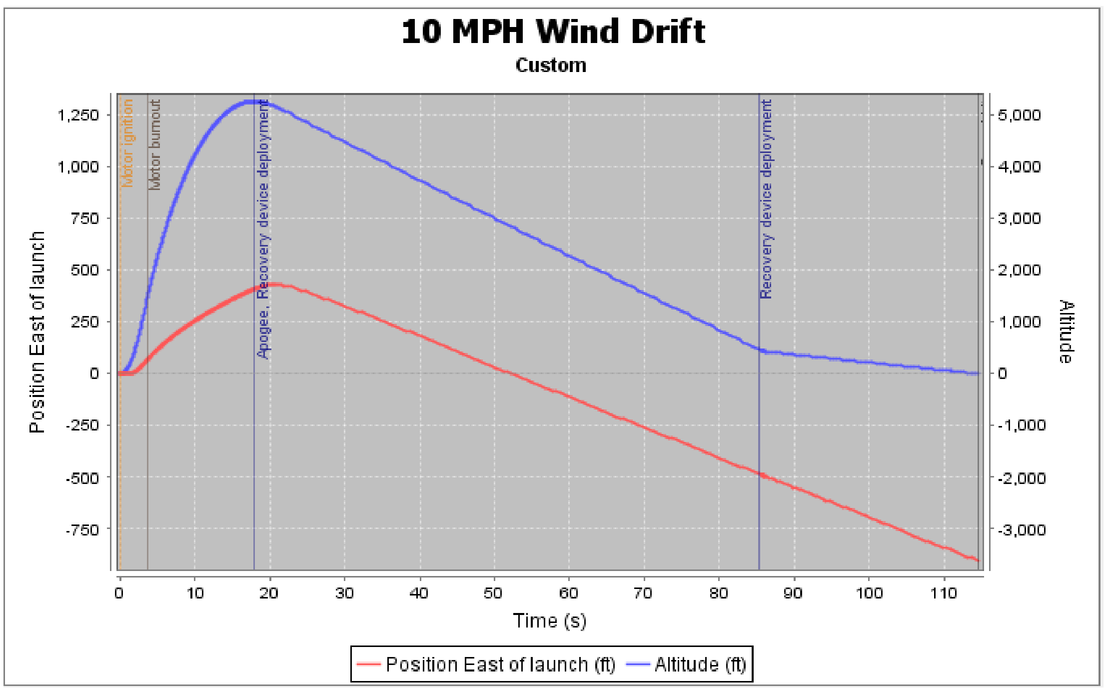

Figure 13: Drift in Position due to 10 mph wind in an east-west direction

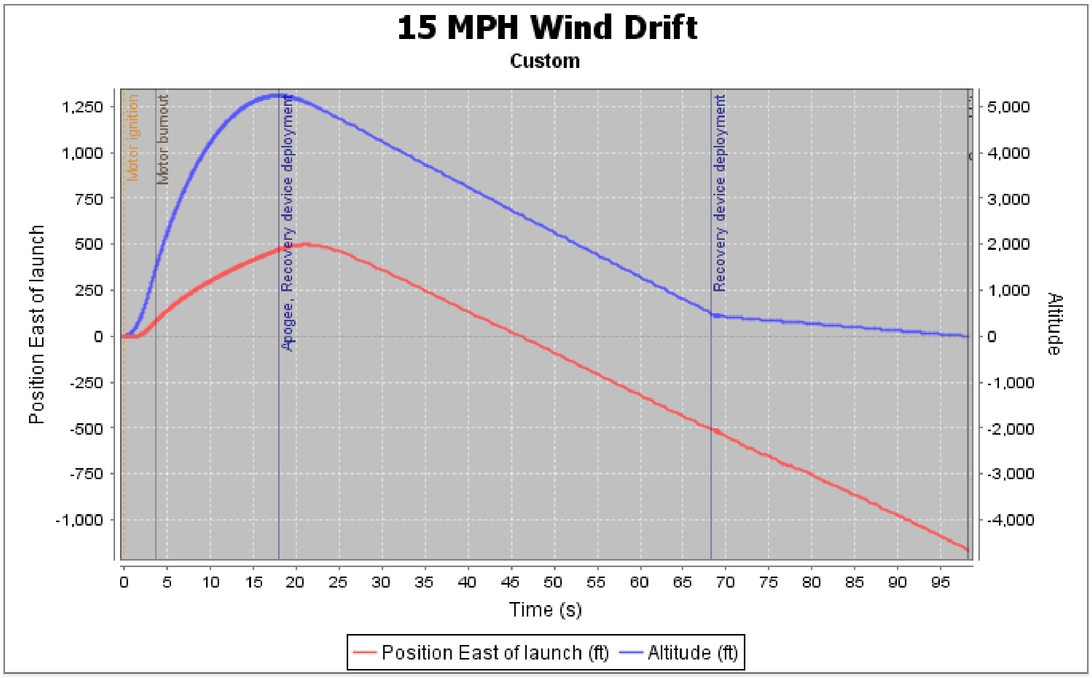

Figure 14: Drift in Position due to 15 mph wind in an east-west direction

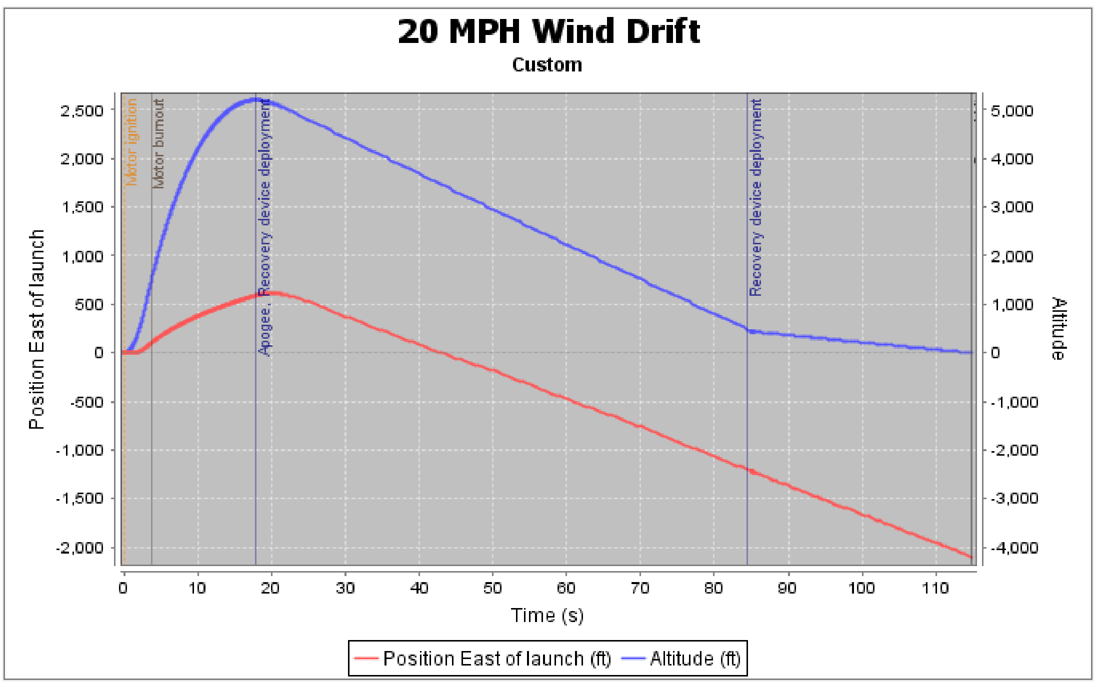

Figure 15: Drift in Position due to 20 mph wind in an east-west direction

Figures 12-15 show the drift in the rocket's position due to wind at varying speeds in an east-west direction. The above predictions assume the rocket is launched in the direction of the wind. Wind drift is important to account for due to safety concerns and the size of the projected launch field, in addition to help determining the final rocket location should GPS systems fail.

3.13 Safety

Safety is critical at the Society of Aeronautics and Rocketry and the University of South Florida in its entirety. While our Safety Officer actively ensures the well-being of members and property, our entire team is expected to maintain constant awareness of all potential dangers. SOAR members are briefed of the potential hazards in our project and encourage them to voice any concerns.

3.13.1 Safety Officer Responsibilities and Duties

As mentioned, all members are expected to maintain awareness of the potential dangers. However, we have nominated Chris Willis to be our official Safety Officer. Chris has earned this role through constant dedication to our organization as well as consistent procedural vigilance. When the safety officer is not available we will turn to our Project Leader to oversee the maintenance of safety.

The roles and responsibilities of the safety officer include, but are not limited to:

A. Monitor all team activities with an emphasis on safety, including:

1) Design of launch vehicle and Autonomous Ground Support Equipment (AGSE)
2) Creation of launch vehicle and AGSE
3) Set-up of launch vehicle and AGSE
4) Exhaustive ground testing of launch vehicle and AGSE
5) Sub-scale launch test(s)
6) Full-scale launch test(s)
7) Competition activities and launch
8) Recovery Activities
9) Educational Engagement Activities

B. Coordinate and implement the safety procedures outlined by the organization for the design, creation, set-up, launch, and recovery of the launch vehicle as well as the design, creation, set-up, and use of the AGSE.

C. Finding the relevant Material Safety Data Sheets (MSDS), sharing them with organization, and maintaining the appropriate folder in the organization's Google Drive, Material Safety Data Sheets. The Safety Officer will also ensure proper and safe conditions of materials during storage, transport, and implementation.

D. Analyze and record the team's hazard analysis tests, failure mode analysis, simulations, experimental data, and other relevant information sources for failures and potentially hazardous trends. As well as coordinating the compliance with safety procedures and improvements to reduce risk.

E. Assist in the management and development of the team's hazard analysis, failure mode analysis, safety simulations, safety procedures, and guidelines.

F. Maintaining responsible and appropriate organizational behavior at all stages of design, development, test, travel, and launch.

G. Finally, the safety officer is expected to familiarize herself with all local, state, and federal laws, rules, customs, and regulations which apply to the use and transportation of motors, propellants, and other sources of risk. Based on this familiarity the safety officer is expected to ensure compliance with the aforementioned regulations.

3.13.2 NAR/TRA Personnel

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 lead 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 launch at targets, into clouds, near other aircraft, nor take paths above civilians. As well 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

3.13.3 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 will not be permitted to participate in the potentially hazardous activity. 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.

3.13.4 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.

3.13.5 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.

3.13.6 Caution Statements

Any potential safety hazards or concerns that may arise throughout the course of this project will be documented where relevant. To minimize risks the design verification process will include a comprehensive investigation to ensure safety in manufacturing, testing, and launching of our rocket. The Safety Officer and Project Lead will present at all design verification meetings.

3.13.7 Hazard Analysis

The following is an assessment of potential risks and modes of failure with the launch vehicle and its associated systems. All possible modes of failure in tasks and equipment have been listed and categorized. The categorization has been based on its probability of occurrence and its associated hazard category.

HAZARD RISK INDEX MATRIX				
Probability of Occurrence	Hazard Category			
	Catastrophic [1]	Critical [2]	Marginal [3]	Negligible [4]
Frequent [A]	1A	2A	3A	4A
Probable [B]	1B	2B	3B	4B
Occasional [C]	1C	2C	3C	4C
Remote [D]	1D	2D	3D	4D
Improbable [E]	1E	2E	3E	4E

<u>Hazard Categories</u>

1. **Catastrophic**: May cause a permanent disabling or fatal injury to personnel or irreparable damage to the surroundings.
2. **Critical**: May cause severe injury or occupational illness and/or damage to facilities, major systems.
3. **Marginal**: May cause minor injury or occupational illness and/or damage to facilities, systems or equipment.
4. **Negligible:** May cause first aid injuries or occupational illness and/or minimal damage to facilities, systems or equipment.

<u>Probability of Occurrence Categories</u>

A. **Frequent**: Likely to occur immediately and will be experienced continuously throughout the life of a part or system.
B. **Probable**: Likely to occur in time and will occur several times in the lifespan of a part or system.
C. **Occasional**: May occur in time and will probably occur during the lifespan of a part of system.
D. **Remote**: Unlikely to occur and the probability of an occurrence in the lifespan of a part or system is low.
E. **Improbable**: An occurrence would be extremely unlikely and it would not be expected to occur during the lifespan of a part or system.

ANALYSIS SOLUTION		
Class Index	Severity/Probability	Suggested Criteria
1	1A, 1B, 1C, 2A, 2B, 3A	Unacceptable
2	1D, 2D, 2C, 3C, 3B	Undesirable (Management Decision Required)
3	1E, 2E, 3E, 3D, 4B, 4A	Acceptable with Review by Management
4	4E, 4D, 4C	Acceptable without Review

Subsystem Analysis

Motor Analysis						
Item #	Component	Function	Hazard Description	Hazard Effects	Hazard Category and Probability	Recommended Control
1	Snap Ring	Fastening Mechanism	Structural Failure	Injury Due to Broken Ring	3D	Control Tools and Safety Equipment
2	Fuel Grain	Fuel Source	Accidental Ignition	Burning Handler	2D	Design to Prevent

Electrical System Analysis						
Item #	Component	Function	Hazard Description	Hazard Effects	Hazard Category and Probability	Recommended Control
1	Power Cable	Transfers Electrical Power	Controller Power Cable Fails	Power Failure/Lack of Control	2C	Provide Warning Devices
2	Battery	Supply Power to Controllers	Leakage of Battery	Loss of Recover/Falling Projectile	2E	Use New Batteries, Ensure Proper Installation
3	E-matches	Ignition	Accidental Ignition	Premature Ignition	3D	Do Not Cross Wire Polarity
4	Wire	Current Flow	Burn Out or Short Circuit	Failure of Instruments/Damage to Handler	4D	Ensure Oversight
5	Gunpowder	Ignition	Accidental Ignition	Explosion	2D	Keep Away From Heat and Sparks

Environmental Analysis						
Item #	Component	Function	Hazard Description	Hazard Effects	Hazard Category and Probability	Recommended Control
1	Strong Winds	N/A	Rocket Stability	Loss of Rocket Control	4A	Provide Warning Devices
2	High Temperature	N/A	Overheating Oxidizer/Electrical Components	High Pressure or Explosion/Electrical Failure	2E	Design to Prevent
3	Rain	N/A	Short Circuit	Loss of Power and Control to Systems	3D	Accept Hazard
4	Corrosion	N/A	Structural Failure	Leaks/Increased Stresses	3E	Provide Warning Devices

4. AGSE Criteria

4.1 Mission Overview

The AGSE is responsible for the retrieval of a “payload” located on the ground and the transportation of said payload from the ground to the rocket. With the payload secured inside the rocket, the AGSE system is then responsible for orienting the rocket properly for launch and initiating the launch process

4.1.1 Mission Statement

The University of South Florida’s Society of Aeronautics and Rocketry, SOAR, will design a vehicle that will launch a payload 5,280ft Above Ground Level, AGL, after the payload is placed inside the rocket. However, there are several steps that must be accomplished prior to a successful launch. Within the 10 minute time limit, SOAR’s GSE will:

a. Locate payload
b. Acquire the payload
c. Place the payload into the science bay
d. Secure payload inside of rocket
e. Raise the rocket perpendicular to the surface
f. Insert igniter
g. Launch rocket

4.1.2 Mission Requirements

Software requirements:
The AGSE software will require the ability of autonomously recognizing the payload. This will be accomplished via image processing and will be discussed in more detail in the following

sections. After the simple recognition of the payload, the AGSE must be able to decide the exact location of the payload so that the mechanical arm has the necessary information to retrieve the payload. The AGSE must also be able to obtain knowledge of the payload destination within the rocket so that the arm is able to successfully place the payload in the rocket. Finally, the AGSE must have reliable knowledge that the payload was delivered successfully so that the launch sequence is initiated if and only if the payload was delivered successfully. In terms of communication between the mechanical arm and the main processing platform of the AGSE, the mechanical arm and processing platform require a compatible means of communication so that any information regarding the location and destination of the payload discovered by the processing platform can be readily and accurately used by the mechanical arm.

Mechanical Requirements:
There are two mechanical requirements to the AGSE system. The first mechanical requirement is the mechanical arm we will use to pick up the payload. To pick up the payload, our arm will need to be fitted with a gripper system to do so promptly. The arm must have the ability not only to pick up the 4oz. payload but to also carry and house the kinect system which will be used for image processing. In total the arm will have to carry/hold approximately 19oz here on earth. Considering the gravity on mars is only 0.375 times that of earth, if our arm can carry the payload and other equipment here on earth then it can carry three times that on mars. Now, assuming our arm has the required capabilities to pick up the payload and house the kinect, it will then need to transfer the payload into the rocket. This can be done with a certain amount of DOF or Degrees of Freedom. Our arm will house servos to perform the mechanical work to move gears which will in turn give us the needed degrees of freedom to place the payload into the rocket. The second mechanical requirement will be our rail system. The rail system must lift the rocket from a horizontal position to a position 5 degrees from vertical. Additional design requirements pertain to lifting time, weight, reliability, durability, cost effectiveness, and transportability. The lifting time and weight is important because of the 10 minute time limit for the AGSE to prepare the rocket and payload for launch and the AGSE must not weigh more than 150 lb total. The cost of failure makes reliability crucial, and the potential for overloads makes durability important. The system must be built with a very limited budget, therefore cost effectiveness is important. Finally, because the AGSE must be transported to the competition it must not be too difficult to transport.

4.1.3 Mission Success Requirements

Overall, mission success is defined by the satisfaction of the mission requirements. The criteria for mission success progresses as follows beginning with the systems ability to first recognize the payload. If the payload is successfully identified, can the system accurately describe the location of the payload and can the mechanical arm use this location information to successfully capture the payload. Finally, can the system accurately communicate the destination of the payload to the mechanical arm, and given the correct information can the arm successfully place the payload in its proper destination. The operation of the arm and processing system will be considered successful if the system is able to detect accurate location information of the payload and destination, and if the mechanical arm is able to accurately retrieve and transport the payload given proper information from the main processor.

4.2 AGSE Design Summary

The design of the AGSE will consist of the following subsystems: mechanical arm, processing unit and accompanying software, and rail system.

4.2.1 Mechanical Arm

The Mechanical arm will be made from a combination of Tetrix kits and 3D Printed Parts. The arm will, as stated above, need to hold approximately 19oz. worth of weight. In total, there will be six degrees of freedom our arm will incorporate. Five of the six degrees of freedom will be within the arm itself and the last will be a rotating base that the arm will sit on top of. One of the most important aspect of our mechanical arm will be the capture device. Our team has decided on a simple and to the point gripper design that will incorporate two prongs controlled by a servo attached to one of the grippers. The back end of our grippers will be in the shape of gears, so that when one gripper is rotated the other rotates as well. The material chosen for the ends of our gripper will be a rubber coating to easily pick up the PVC payload and a plethora of other objects.

4.2.2 Processing Unit and Accompanying Software

The preliminary processing unit selected for the AGSE system is the Raspberry Pi which will interface with a Microsoft Kinect camera via OpenCV software. The Raspberry Pi was chosen as the the main processing platform for the AGSE because it is proven to handle the processing load associated with image processing. Additionally, the Raspberry Pi provides the ability to easily interface with external hardware supporting multiple protocols such as I2C and GPIO. The Microsoft Kinect was chosen for the fact that it is not only is specifically designed for image processing and object detection applications, but also because of its proven compatibility interfacing with OpenCV. Finally OpenCV was chosen as the main software package for image processing due to the compatibility and functionality of the package, as well as the availability of literature to assist in working with the OpenCV software package. Through the use of OpenCV a program will be designed that, given the input video from the Kinect, will be able to identify the payload and determine its location relative to the arm. This program will also be able to communicate the destination of the payload to the mechanical arm and acknowledge the secure placement of the payload.

4.2.3 Rail System

The Rail system will consist of an extruded aluminum rail attached to a worm gear assembly that will raise the rocket prior to launch. There will be a ratcheting safety system in place. In the event that the integrity of the raising mechanism of the rails system fails, the rocket would not fall back to its horizontal position, potentially damaging the rocket and the GSE. The rail length should be long enough to allow the rocket to reach an aerodynamically stable speed upon leaving the launch rail. The necessary length can be estimated by:

$$Length = 0.5 * M * V^2/T + Li$$

where M = rocket original mass

V = velocity to achieve aerodynamic stabilization

T = Initial thrust after pressurization of motor

Li = distance between the top launch lug on the rocket and the bottom of the launch rail

Using mass, thrust, and length data for our rocket and assuming an adequate velocity upon leaving the launch rail is 15 m/s, our launch rail needs to be at least 3 meters. On mars however active stabilization would be required because of the thin atmosphere. A worm set gear ratio of 100 was chosen for the preliminary design requiring a motor torque of 70 lb-in. The blast shield will be connected to the launch rail and will be constructed of stainless steel.Our basic launch rail assembly is shown below without a blast shield or motor.

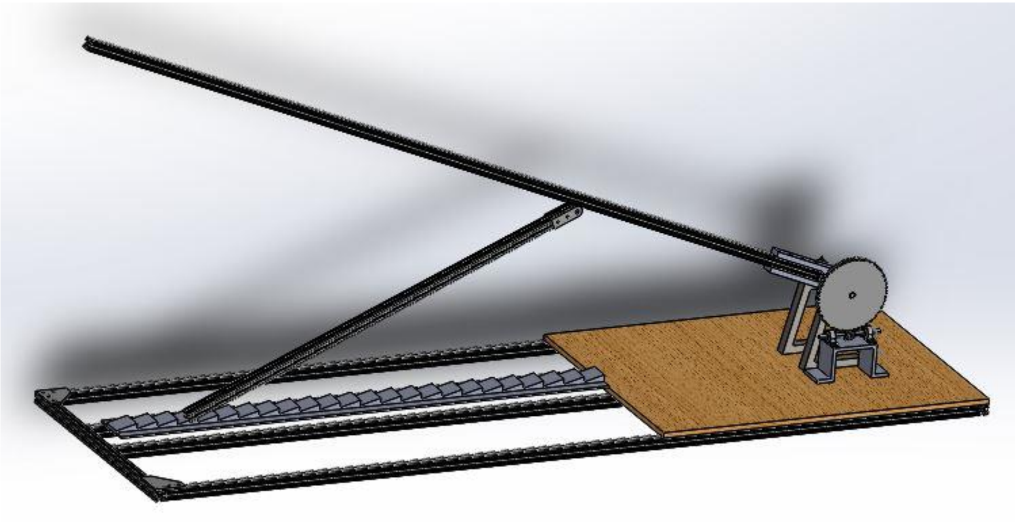

Figure 10: Launch rail 3D generated model

Our worm gear assembly is shown below. A motor will be coupled to the worm shaft. Bearings were placed on either side of the worm because of the large separation force between the gear and the worm.

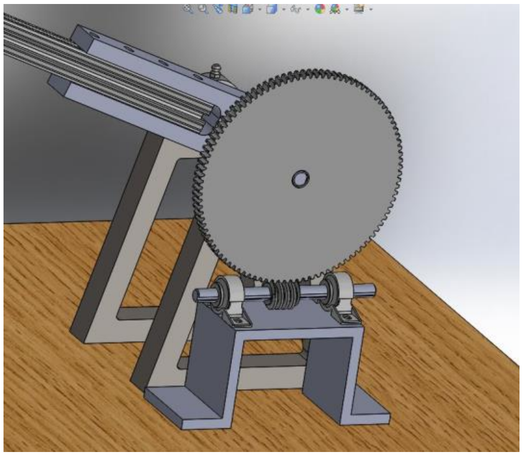

Figure 11:Worm gear 3D model for rail system

4.3 AGSE Subsystem Overview

4.3.1 Payload Capture

Once the payload is placed, the camera in the Microsoft Kinect will use the OpenCV software to detect the location of the payload. Using image processing, the Kinect will recognize the payload and communicate its location for the arm to retrieve. A steady communication between the Open CV and the arm will guide the arm to capture the payload.

4.3.2 Payload Containment

There will be a section in the rocket that will be designed specifically for to protect the payload during the launch and recovery phase. The payload will be placed into a smaller mechanism inside the science bay. This smaller mechanism will enclose the payload and then secure itself inside the science bay. It will be suspended along the axis of the rocket and the hatch will closed and locked by the robotic arm.

4.3.3 Rail System and Igniter Installation

Once the rocket has been raised to 5 degrees from vertical, the insertion of the igniter will be the next step. The igniter will be joined with the blast shield. The igniter will protrude from the center of the blast shield. Using a screw type linear actuator, both the fuse and the blast shield will be pushed toward the nozzle of the motor until the fuse is properly seated. Once the fuse is seated properly, the GSE will run through a systems check and then ignite the motor.

4.4 Evaluation and Verification Plan

In order to verify the correct operation of the AGSE as a whole, preliminary tests on individual components and subsystems will be performed as follows. First a test will be conducted with the Kinect camera and Raspberry Pi system operating in isolation i.e. the mechanical arm and accompanying software for controlling the arm will not be connected. For this test the software of the Raspberry Pi will be configured for recognition of the payload given video input from the Kinect, as well as the determination of the payload location given the Kinect Video. The purpose of this test is to verify that the image processing software is working correctly with the Kinect camera and that the payload can be correctly recognized and located. Additionally, this test will determine the limitations of the payload recognition and location such as the maximum distance where the payload can be accurately recognized and located. Next the arm will be tested in isolation. The mechanical arm will be connected to the Raspberry Pi and a program will be run that controls the operation of the arm. During this test the mechanical arm's ability to respond to location information and directions from the Raspberry Pi software will be evaluated. Additionally, during this test the mechanical arms physical ability to successfully retrieve and secure the payload will be evaluated. For example, is the mechanical arm physically able to grab the payload? what is the maximum range for which the arm can still accurately retrieve and secure the payload? After testing the the abilities of the image processing software and the mechanical arm individually, the abilities of the image processing software working in collaboration with the mechanical arm will be evaluated. For this test the main concern is with the high level operation i.e. can the image processing software and the mechanical arm work together successfully to retrieve and secure the payload.

Once the performance of the operations involving the retrieval of the payload is understood, the transportation of the payload to the rocket, and the payloads security within the rocket will be evaluated. The first test in this section will evaluate the capability of the software to locate and realise the destination within the rocket. Next an evaluation of the physical interaction between the mechanical arm and the compartment within the rocket for securing the payload. For example, are the mechanical arm and payload compartment within the rocket physically compatible in that the mechanical arm can successfully reach and interact with the payload compartment to the extent that the payload can be properly released and secured? Finally, the systems ability to recognize and communicate the payload being successfully transported and secured within the rocket will be evaluated along with the systems ability to successfully prepare the rocket for launch given that the payload has been properly secured.

4.5 Preliminary Integration Plan

The AGSE will be integrated by attaching the robotic arm and the igniter installation system to the rocket rail system. The AGSE arm was designed in a way that allows for the system to function without the reliance of many other systems. Due to the freedom that the AGSE arm has, the arm can be integrated in a variety of ways to different systems. The AGSE arm can be physically attached to the rail system and can also be integrated to our rover concept that autonomously drives over a surface to search for a specified payload.

4.6 Testing Plan

Table 9: Testing plan

Test Name	**Test Description**	**Test Purpose**
Payload Recognition	Given a stream of video from the Kinect camera, the image processing software's ability to detect the payload will be evaluated	To verify the ability of the image processing software to recognize the payload
Determination of Payload Location	Upon recognition of the payload, the software's ability to determine the location of the payload will be evaluated. The output information of the program regarding the location of the payload will be verified in terms of the physical location of the payload relative to the system and mechanical arm.	To verify the system's ability to accurately determine the location of the payload
Mechanical Arm Operation	The overall operation of the arm will be evaluated in terms of several performance metrics including overall speed and accuracy of motion, and range of motion limitations.	To evaluate the mechanical arms ability to retrieve and transport the payload in a manner that is compliant with overall time constraints.
Launch preparation	The system's ability to detect and communicate the successful transportation of the payload will be evaluated along with the systems ability to successfully prepare the rocket for launch.	To ensure that the rocket will be properly prepared for launch by the AGSE system and that launch preparation does not take place unless the payload has been properly secured within the rocket.

4.7 Maturity of Design

Much of the AGSE design is still in the preliminary stages of development while the launch vehicle itself and launch rail component of the AGSE have taken positions of priority for the SOAR team. The design of the remodeled AGSE system has been recently confirmed as we have decided to use an entirely creative and ambitious solution to the problem of payload loading. Subteams appropriate to each system of the AGSE have been designated as progress continues. Research into each component of the systems is ongoing as the parts lists are being finalized for submission. Prototyping with available components have begun through the coordination of University of South Florida assets, namely collaboration with other engineering organizations that have previous experience with and materials for vision systems, image processing, inverse kinematics, and robotic arms. The overall AGSE design is still in the adolescent stages of maturity, but a solid foundation for growth has been laid.

4.8 AGSE Drawings and Dimensions

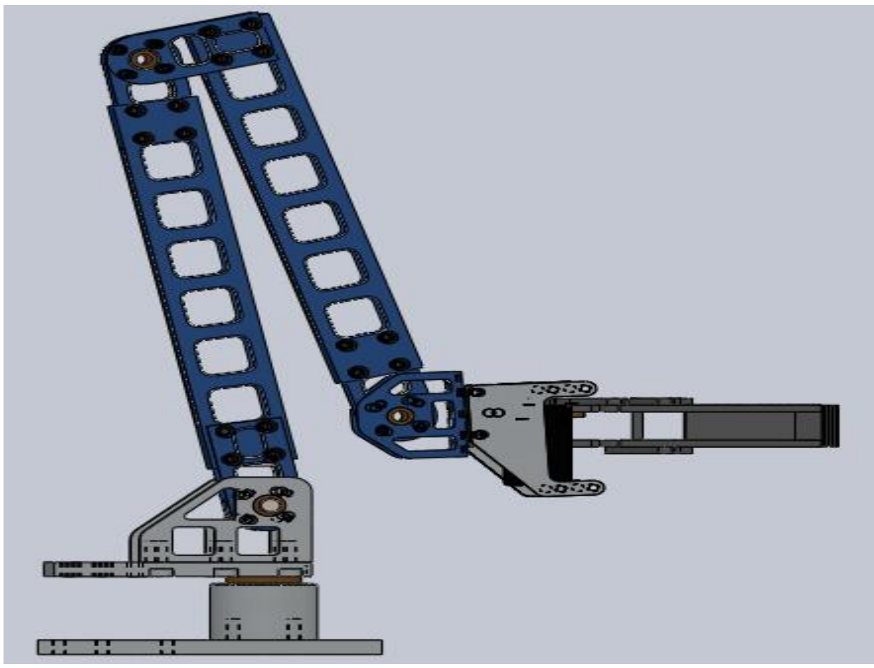

Figure 12: Side view of 3D AGSE model

Figure 13: Angled view of 3D model of AGSE arm

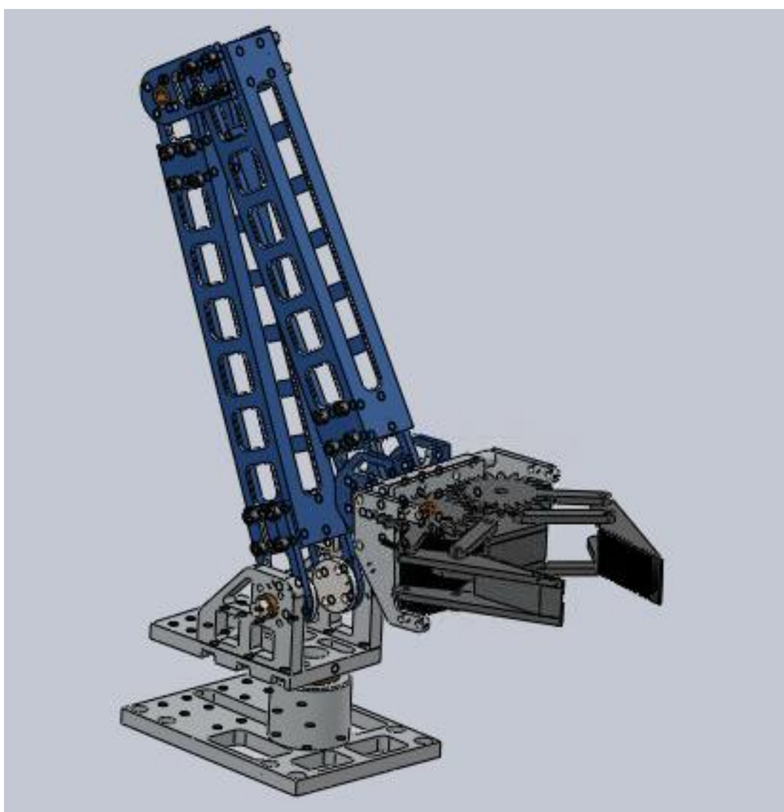

Figure 14: Side view of AGSE arm

The AGSE components are designed modularly, such that in the stages of development if critical failure of a supplementary component is unavoidable the critical assets for mission success can still be deployed for mission success. In this endeavor the robotic arm component of the AGSE is designed as a standalone system, with the capability of being mounted on the rover chassis or mounted on an independent base. The current projected dimensions are subject to change in the course of development as challenges are met and systems optimized. The rubber gripping component of the arm will be 1.25 inches in length, the arm itself will have a fully extended reach of 18 inches and a retracted height of 10.5 inches. In the successful implementation of the rover-arm system, the dimensions of the arm will be scaled appropriately for the greater maneuverability, as it does not need to reach the full length to the payload on its own. The length of the arm will be no more than 6 inches at its greatest length with a retracted width of 9 inches. The base of the arm is designed to be securely bolted to its mounting and has proportions of 4 by 6 inches.

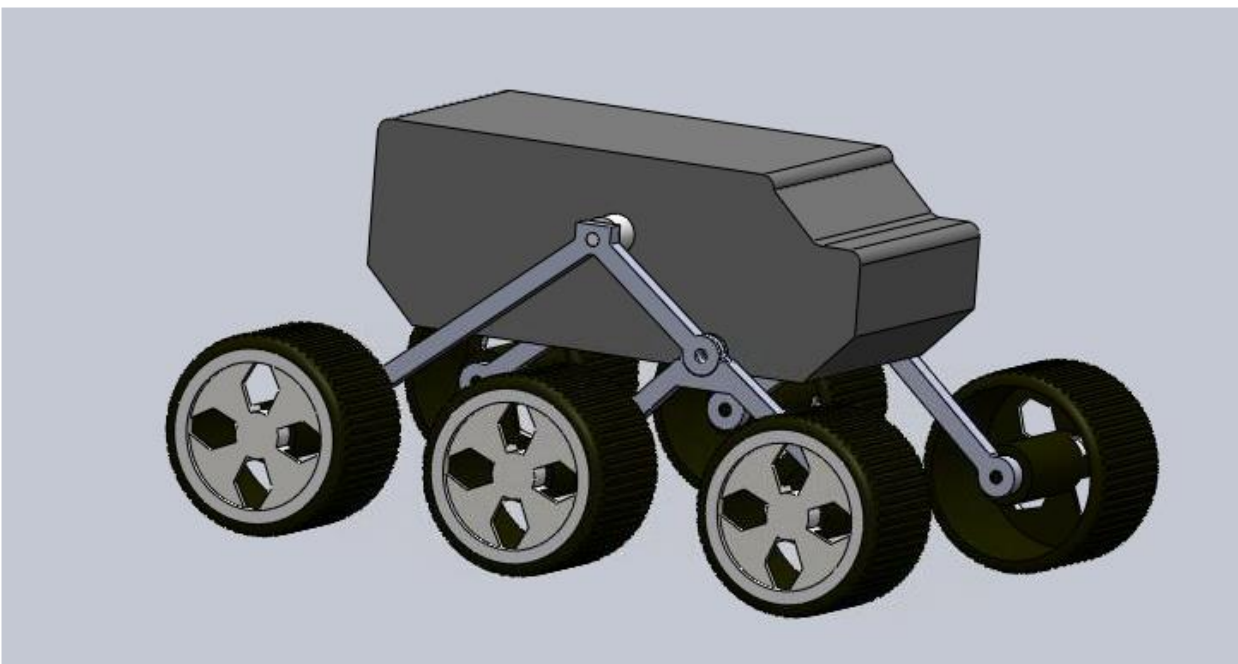

Figure 15: 3D model of rover concept

The plans for the rover itself are continuing to evolve. The current projected dimensions of the rover's body are 8 inches in width, 18 inches in length, 8 inches in height. The wheels are expected to be 6 inches in diameter. The arm will be firmly mounted to the top center of the body of the rover, and mass will be added to the underside of the body to offset the mass of the arm. A Microsoft Kinect will be mounted to the front, acting as the primary set of "eyes" of the rover. These preliminary models have been inspired by files found on GrabCad.

4.9 AGSE Concept Features and Definition

4.9.1 Creativity and Originality

Overall, the preliminary design will be prototyped using more common materials and practices such as robotics kits from Tetrix, and object detection and location algorithms developed used the OpenCV software package. However, as the design progresses original ideas will be used to optimize the design. For example, a Tetrix kit may be used in the prototyping phase as the operation and interaction of the software and arm are being understood, and as the design progresses the arm design will be optimized using original ideas. Some original ideas include designing all of the necessary parts for a mechanical arm on Solidworks and then 3D printing them. One of the most important aspects of our arm is the claw gripper on the end. This piece can easily be improved and innovated using 3D printed models.

4.9.2 Uniqueness and Significance

Mechanical Arm:

Our mechanical arm has the unique ability to easily be attached to a rover like mobile object. Our arm is designed in a way so that it can go mobile with a plate on the bottom that can be secured tightly to a rover for instance. The significance of this simple yet innovate design is that our arm isn't just simply one dimensional. It can sit on its own and do a variety of functions while also having the ability to attach to a rover and go on the road. Along with the mobile capability of our mechanical arm, it also has eyes. Eyes in the case of the Microsoft Kinect that will be attached to our mechanical arm. Not only can a human operate the arm remotely but it can work autonomously. This single aspect of the mechanical arm is a huge advantage to one that can only be controlled by a human operator. For instance, the time delay between earth and mars at its shortest is around 4 minutes and its longest can be upwards of 24 minutes. This is a huge inconvenience, but with an autonomous robot able to see and capture an object, life becomes a little easier.

Rail System:

A custom machined bracket will be used to couple the launch rail to the shaft. The worm set is designed to be non-backdrivable so the launch rail will not fall or move without motor power. A ratchet mechanism is used as a redundancy in case there is slip or failure of the worm set. An encoder will be used to measure the rotation angle of the motor and send that information to the rest of the AGSE system.

Processing Unit and Accompanying Software:

Deliberation into the central computing hub and its accompanying software continues, but has been narrowed to two viable processing systems, the decision of implementation is awaiting the analysis of processing requirements compared to hardware capabilities. The leading avenue of approach is the simplicity and robustness of using the raspberry pi microcontroller, while the contender of this approach is to use two raspberry pis communicating through point-to-point radio telemetry with a personal computer stationed near the launch rail to serve as the major computing hub. The computer would then handle the majority of the image processing and navigation, freeing the raspberry pi's processing to the local rover and arm system. Both concepts would implement the Open Computer Vision image processing libraries.

Designing autonomous, wireless communication for coordinating the rover, the end effector, the launch rail, and the payload bay of the launch vehicle may not be truly unique, but represents a major advancement in the progression of the science, engineering, technology, and mathematical fields. These systems can be readily extrapolated to planetary exploration, such as Mars, but also to a plethora of problems found at home.

Payload Bay:

Though we don't have a definitive design for the payload bay we do have three good ones. The first design is a simple hatch with a foam interior that will be an almost perfect fit for the payload. The significance of the foam is to decrease vibration of the payload upon ascent. This is a very simple and lightweight design that will do the intended job well. The second design we propose is a bistable compliant mechanism. Once the payload is securely placed in the compliant mechanism with force, it won't be going anywhere. This design is unique not only in complexity but on simplicity as well. To secure something with a simple force push is easy and to the point. The third proposed payload bay containment design is a closed circuit pneumatic "airbag". With this design we can account for a plethora of payload sizes. Once the payload is placed inside the payload bay, the airbag will inflate to encompass our payload and secure it tightly.

4.9.3 Suitable Level of Challenge

The AGSE system will likely be an appropriate challenge for the design team in that the development of the AGSE will be difficult yet feasible. Few members of the team have experience in areas immediately related to the development of a system similar to the AGSE i.e. the team would not be able to design and implement the AGSE system without external learning materials. However, the design team is composed of individuals that are capable and willing to learn the information required to successfully design and implement the AGSE system. Additionally, design team members have experience with projects of complexity similar to that of an AGSE subsystem. Overall feasibility will not be an issue. The main challenge of the AGSE development will reside in the integration and optimization of the system. In terms of an individual subsystem the complexity is very easily managed, and in terms of core functionality e.g. detecting an object finding a solution is again much more easily accomplished. As subsystems become integrated the overall complexity increases drastically, and optimizing a design can prove to be much more difficult than accomplishing core functionality e.g. optimizing an image processing algorithm to detect an image one second sooner. Overall delivering a project that satisfies core functionality requirements is feasible, and the optimization of the overall project and the creation of a robust design will provide a suitable challenge.

4.10 AGSE Science Value

4.10.1 AGSE Objectives

The AGSE and the rocket will communicate with each other in order to successfully secure the payload inside of the rocket. The payload will be placed no more than 24” from the GSE’s robotic arm. Using two forms of optics, for redundancies and accuracy, the GSE will locate, grab, and transport the payload safely to the science compartment of the rocket. In addition to securing the payload, the AGSE will raise the rocket, from a horizontal orientation, 90 degrees plus or minus 5 degrees. Once the rocket is raised, a fuse will be inserted using an actuator and then launched.

4.10.2 Success Criteria

To be successful, the payload must be inserted into the rocket and the the rocket launched in a time less than 10 minutes. The payload may not be inserted using gravity assistance or pneumatics. The payload must be secured inside the rocket so that the payload will not loosely move around inside the science bay. In short, the AGSE must autonomously find the payload, load the payload into the rocket, raise the rocket into a launch profile, insert an igniter/fuse, and launch the rocket.

4.10.3 Experimental Logic, Approach, and Method of Investigation

Experimental validation first requires the successful mathematical modeling of all components and their integration. Following this, these models are used in simulation to accurately depict the expected scenarios. Errors or critical flaws found in the modeling and simulation of all systems can be appropriately resolved before hardware failure is experienced. Beyond student calculations, programs for simulation are employed such as MATLAB, Solidworks, LTspice, OpenRocket, Rocksim, etc.

The use of these programs correlates with SOAR’s overall approach to minimize failures before they can begin, emphasizing safety, reliability, and predictability in results. All experiments and results are intended to be shared within the university/academic system as well as shared with any interested parties who feel they can aid from the work done by SOAR. Additionally, with the aid of experienced faculty, the students of SOAR intend to use the rigor of our experiments, modeling, and overall research done here to achieve publishable material.

5. Project Plan

5.1 Budget Plan

Table 10: Budget plan

TOTAL	$6,242.08
Structure	$827.09
Recovery	$427.66
Propulsion	$1,242.00
AGSE	$2,369.75
Subscale	$1,282.18

Table 9 shows a general overview of the projected SOAR NSL budget in totality and broken down into several subprojects. The values shown are as currently calculated but it is important to note that we have left room for a 25-40% margin in the event of redesign, unexpected orders, and overhead costs. The following Tables 11-15 show the more in depth cost breakdown of each subsequent section.

Table 11: Propulsion Budget plan

L1112BT Motor	$310.00	3	PROPULSION
75mm 1400Ns - complete motor	$312.00	1	PROPULSION

Table 12: Recover Budget plan

Strap Nylon Shock Cords 2"	$2.49	7	RECOVERY
Tubular Nylon Shock Cords 1" x 7 yards	$2.49	7	RECOVERY
Cert 3 XX-Large Parachute	$239.00	1	RECOVERY
RRC3 Altimeters	$69.95	2	RECOVERY
Nomex Chute Protector 9x9 for 3" Tube	$6.95	2	RECOVERY
Cert 3 Drogue	$27.50	2	RECOVEY

Table 13: Recover Budget plan

Kevlar Tape	$27.45	1	STRUCTURE
1/2 INCH G10 FIBERGLASS SHEET 2 SQUARE FOOT	$72.00	2	STRUCTURE
Retainer Assembly, 75 mm	$50.00	1	STRUCTURE
Centering Rings	$4.64	4	STRUCTURE
Fiberglass Wrapped Payload Section	$45.29	1	STRUCTURE
Couple/Bulkhead Assembly	$10.34	1	STRUCTURE
Phenolic Airframe Tubing	$22.49	1	STRUCTURE
Bulkplate 3.0"	$1.99	3	STRUCTURE
Phenolic Coupler Tube	$3.69	1	STRUCTURE
3.9" Plastic Nosecone	$21.95	1	STRUCTURE
3.9" Coupler/Bulkhead	$6.89	4	STRUCTURE
98mm G12 Fiberglass Tube 5 ft.	$153.83	1	STRUCTURE
98mm G12 Fiberglass Tube 3 ft.	$92.30	1	STRUCTURE
98mm G12 Fiberglass Tube 4 ft.	$93.38	1	STRUCTURE
30 Minute Epoxy	$17.98	4	STRUCTURE
Hardware	$38.40	1	STRUCTURE

Table 14: Subscale Budget plan

75mm G12 Fiberglass Tube 5 ft.	$102.55	1	SUBSCALE
75mm G12 Fiberglass Tube 3 ft.	$61.53	1	SUBSCALE
75mm G12 Fiberglass Tube 4 ft.	$93.38	1	SUBSCALE
Plastic Nosecone	$21.23	1	SUBSCALE
Phenolic Coupler Tube	$3.69	3	SUBSCALE
2.0" Bulkhead	$1.90	4	SUBSCALE
L1112BT Motor	$195.00	2	SUBSCALE
54mm 1400Ns - complete motor	$145.00	1	SUBSCALE
54 mm Retainer Assembly	$38.00	1	SUBSCALE
Baltic Birch 3 SQ FT	$8.17	1	SUBSCALE
Phenolic Airframe Tubing	$14.99	1	SUBSCALE
Strap Nylon Shock Cords 2"	$2.49	7	SUBSCALE
Tubular Nylon Shock Cords 1" x 7 yards	$2.49	7	SUBSCALE
Cert 3 Large Parachute	$145.00	1	SUBSCALE
RRC3 Altimeters	$69.95	2	SUBSCALE
Nomex Chute Protector 9x9 for 3" Tube	$6.95	2	SUBSCALE
Cert 3 Drogue	$27.50	2	SUBSCALE
Hardware	$38.40	1	SUBSCALE

Table 15: AGSE Budget plan

Tetrix Max	$595.00	1	AGSE
Tetrix Prime	$329.00	1	AGSE
Tetrix Gripper	$9.95	1	AGSE
Servos	$22.95	5	AGSE
Lynx Motion Arm	$300.00	1	AGSE
Microcontrollers	$15.00	3	AGSE
worm shaft	$21.10	1	AGSE
gear shaft	$18.27	1	AGSE
worm shaft key	$15.00	1	AGSE
gear shaft key	$15.00	2	AGSE
worm	$43.13	1	AGSE
worm gear	$196.10	1	AGSE
bearings 1	$65.70	2	AGSE
bearings 2	$11.78	2	AGSE
3ft extruded aluminum	$21.78	2	AGSE
10ft extruded aluminum	$61.94	5	AGSE
6ft extruded aluminum	$39.31	1	AGSE
brackets and joints	$50.00	1	AGSE
plywood	$24.92	1	AGSE
Nuts/bolts/screws	$30.00	1	AGSE

5.2 Funding Plan

To complete this project our organization shall rely primarily on funding allocated to us through the USF student government, sponsorships, and fundraising. We already have sponsorships from the USF STEM Education Society, funding achieved through the Florida Space Grant Consortium’s Hybrid Rocket Motor Competition, and from organization allocations internally, such as USF student government.

5.3 Timeline

Table 16: Timeline as established in Gaant Chart

Proposal Due	8/7	9/11
Design		
Website Established	10/23	10/23
Rocket Design	10/2	10/14
Rocket Models Developed	10/15	10/21
AGSE Design	10/2	10/14
AGSE Models Developed	10/15	10/21
Budget Estabished	10/21	10/28
Subteams Establish	10/14	10/21
Subteam Budgets Established	10/21	10/28
Subscale Materials Ordering	10/21	10/28
Subscale Materials Shipping	10/28	11/6
PDR		
First Draft	10/21	10/28
Editing	10/29	11/4
Completion	11/5	11/5
Powerpoint	10/29	11/4
Presentation	11/23	11/23
Subscale Rocket		
Vehicle Design	10/21	10/28
OpenRocket Simulation	10/28	11/6
Motor Can Fabrication	11/8	11/13
Altimeter Bay Fabrication	11/14	11/16
Recovery Systems Fabrication	11/16	11/18
Payload/Nosecone Fabrication	11/14	11/16
Vehicle Assembly	11/16	11/20
Subscale Launch	11/21	11/21
CDR		
First Draft	12/14	12/27
Editing	12/28	1/14
Completion	1/15	1/15
Powerpoint	12/14	12/27
Presentation	TBA	TBA

Full Scale Rocket		
Vehicle Design	12/14	12/27
OpenRocket Simulation	12/28	1/8
Motor Can Fabrication	1/22	2/4
Altimeter Bay Fabrication	2/5	2/11
Recovery Systems Fabrication	2/5	2/11
Payload/Nosecone Fabrication	2/5	2/11
Vehicle Assembly	2/12	2/19
Test Launch	2/20	2/20
AGSE		
Overall System Design	10/28	11/6
Vision System Development	11/8	11/29
Arm Design	11/8	11/29
Launch Rail Design	11/8	11/29
Rover Design	11/8	11/29
Containment Design	11/8	11/29
Systems Fabrication	1/8	1/29
Prototyping	1/30	2/12
Testing	2/13	3/5
Educational Outreach		
Great American Teach In	11/19	11/19
USF Engineering Expo	2/19	2/20
Local High School Outreach	1/21	1/21
FRR		
First Draft	2/15	2/1
Editing	3/1	3/13
Completion	3/14	3/14
Powerpoint	2/15	2/19
Presentation	TBA	TBA
Competition	4/12	4/17
PLAR		
First Draft	4/18	4/25
Editing	4/25	4/28
Completion	4/29	4/29

5.4 Educational Engagement Plan and Status

5.4.1 Engagement at Local Schools

We maintain that one of the simplest and most effective methods of engaging students is to visit the schools and personally speak to students about STEM. These meetings will be established by contacting local schools and requesting permission to speak in the classroom as well as give demonstrations. This will be organized by the Education Engagement Officer. One of the major visits will occur as part of the Great American Teach-In in November, in which university students, professors, and others are encouraged to come give presentations and demonstrations about STEM to local primary education schools. In addition we will also be visiting Young Middle Magnet school in the Spring to share with them our work on the AGSE. This will serve to further inspire the students at this school, which is geared toward STEM education and specifically robotics.

5.4.2 Engagement at the University of South Florida

Our team will be participating in the Engineering Expo hosted by the University of South Florida. This event is designed for campus organizations to showcase a STEM related project to both the USF community and local schools. This will serve as a platform for us to share STEM and rocketry with other students in an education and engaging way. The Engineering Expo is set to occur in February of 2016.

5.4.3 Online Engagement

In addition to sharing our events online such as our presentation from the Great American Teach-In, we will host videos and presentations online that look at the different STEM fields. These will allow our team to engage a wider audience outside of the immediate Hillsborough County area. These will be hosted on our organization's website, along with interactive forums and chat boxes where individuals may ask questions of our group or start discussions.

6. Conclusion

The Society of Aeronautics and Rocketry at USF is a group of aspiring scientists and engineers seeking to further mankind's pursuit of space exploration, and inspire an appreciation for STEM in the local community. The NASA Student Launch and the Centennial Challenge are opportunities for SOAR to work toward these goals in the form of designing vehicles which could one day be used to send samples of Martian soil back to Earth, and of community educational outreach. The skills gained by our team in the completion of the Centennial Challenge goals will prove invaluable for helping the progress the world towards a brighter future.