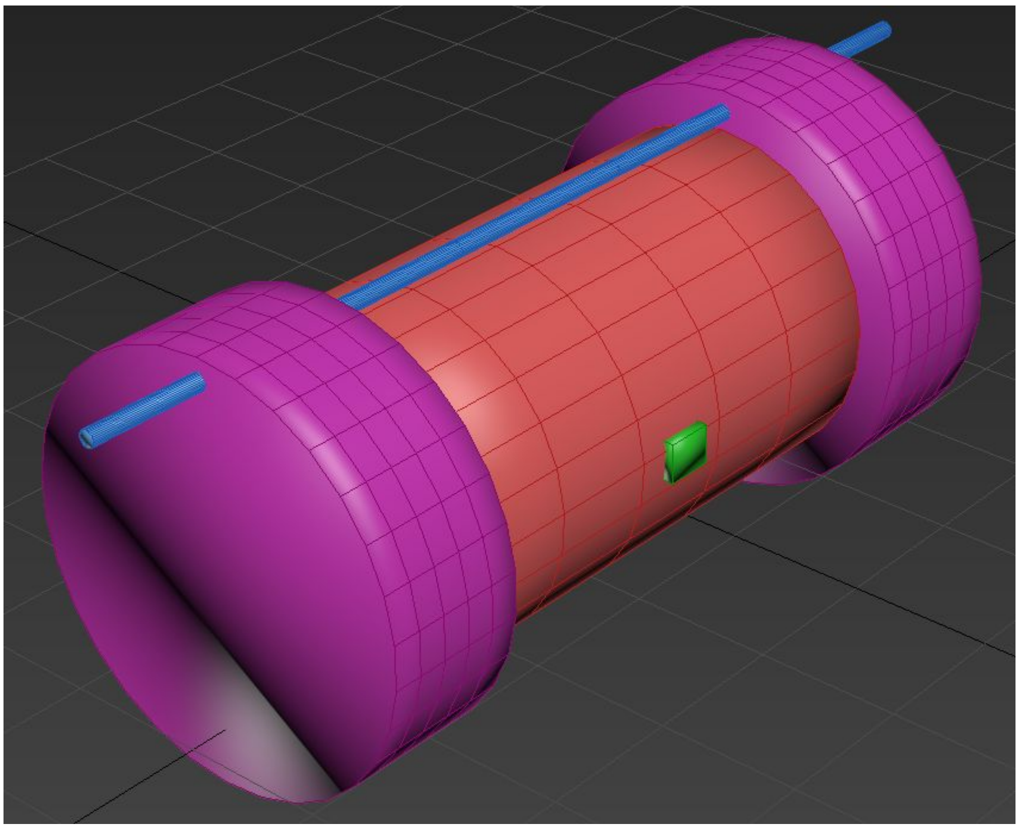
Student Launch Proposal

Rocket with Air Brakes containing Ground Rover with On-Board Camera



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AIAA OC Section

September 19, 2018

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1 Summary of PDR Report

1.1 Team Summary

1.1.1 Team Name & Mailing Address

American Institute of Aeronautics and Astronautics Orange County Section (AIAA OC Section)

7 Rosemary
Irvine, CA 92604

1.1.3 Name of Mentor, NAR/TRA Number and Certification Level and Contact Information

1.1.3.1 Robert Koepke (Electrical Engineer, Programmer, Level 2 NAR)

Robert can be contacted via rkoepke@socal.rr.com. His phone number is (714)-504-3591.

1.1.3.2 Jann Koepke (Artist, Mom, Level 2 NAR)

Jann can be contacted at jkoepke@socal.rr.com. Her phone number is (714)-504-3591.

1.2 Launch Vehicle Summary

Length: 122.5 in	Diameter: 4 inches
Mass: 10987.734 g or 24.224 lbs	Motor Choice: Cesaroni K1085WT
Target Altitude: 4600 feet	Recovery System: Recovery electronics are in the avionics bay where
Milestone Review Flysheet can be found:	http://www.verticalprojectile.org/documents-.html

1.3 Payload Summary

Our payload is a rover that uses computer vision to find and move to the designated area of the rocket marked by color code. The rover will be equipped with a Pixy2 for identifying the color code and a sensor to determine the distance between the rover and the designated part of the rocket. The rover will be released from the rocket and move five feet away, scanning the rocket for the color code, once it detects the color code, the sensor for distance will determine the distance and the rover will move to within 20 cm if the target to take a picture.

2 Changes Made Since Proposal

2.1 Changes Made to Vehicle Criteria

The majority of these changes take more realistic masses into account and provide for a more accurate rocket design. The proposal allowed for the worst case scenarios and we now have more accurate masses in the details of the design.

2.1.1 Dimensions

	RFP	PDR	Reasoning
Length	111.875 in	122.5 in	Increase in space allowed for Air Brake Subsystem Connection between Payload and Nose Cone was added as the Nose Cone didn't come with a shoulder, as stated in the design. Length in the Avionics band was decreased to prevent the rocket from becoming excessively long.
Mass	10780.392 g	10987.736 g	More mass was added to realistically simulate the masses of the subsystems.
Fins	2 sets	1 set	This change helped to lower the stability margin. The removal of the fins was approved by Mike Stoop from madcow in previous years as this kit (Frenzy XL) from madcow is the standard kit used in the last two years for this team.

2.2 Changes Made to Payload Criteria

The release mechanism for the deployment of the payload was changed from a sabot design to a piston design. The piston design has not been prototyped yet, but the reason for the change was due to safety concerns. The design of the sabot was meant for a UAV, meaning the sabot deploys when the main chute deploys. For this case, it would have to travel 500+ feet after deploying before the rover is released. This poses concern for if the rover were to fall out midair.

The rover design was changed to have the camera on top of the main body rather than inside. This helps to prevent the rover from having only one angle of perspective, which was forward. For the purpose of the rover's task, the camera will be angled towards the rocket.

2.3 Changes Made to Project Plan

The timeline and budget were adjusted to fit the schedule and track the progress of the team.

2.4 Changes Made to Air Brake Design

The current leading air brake design is greatly changed from the request for proposal air brakes, as it utilizes pneumatics instead of a solenoid to actuate the air brakes. This is because of the high power consumption of a solenoid (about 20W) that would provide an adequate braking force and sufficient travel. The solenoids tested were proved that they could be stopped with just the force of a finger, and therefore concluded that the force exerted from the upwards movement of the rocket would keep the air brakes closed during the flight.

3 Vehicle Criteria

3.1 Selection, Design and Rationale of Launch Vehicle

3.1.1 Mission Statement

The rocket must reach a target altitude of 4600 ft, deploy its drogue chute at apogee, descend to 600 ft, deploy its main chute, and then deploy the payload, a rover, once the rocket has landed. The rover will then angle its camera towards the rocket and take pictures of the length of the rocket. The pictures will be returned so damage after the flight can be documented via the rover.

3.1.2 Mission Success Criteria

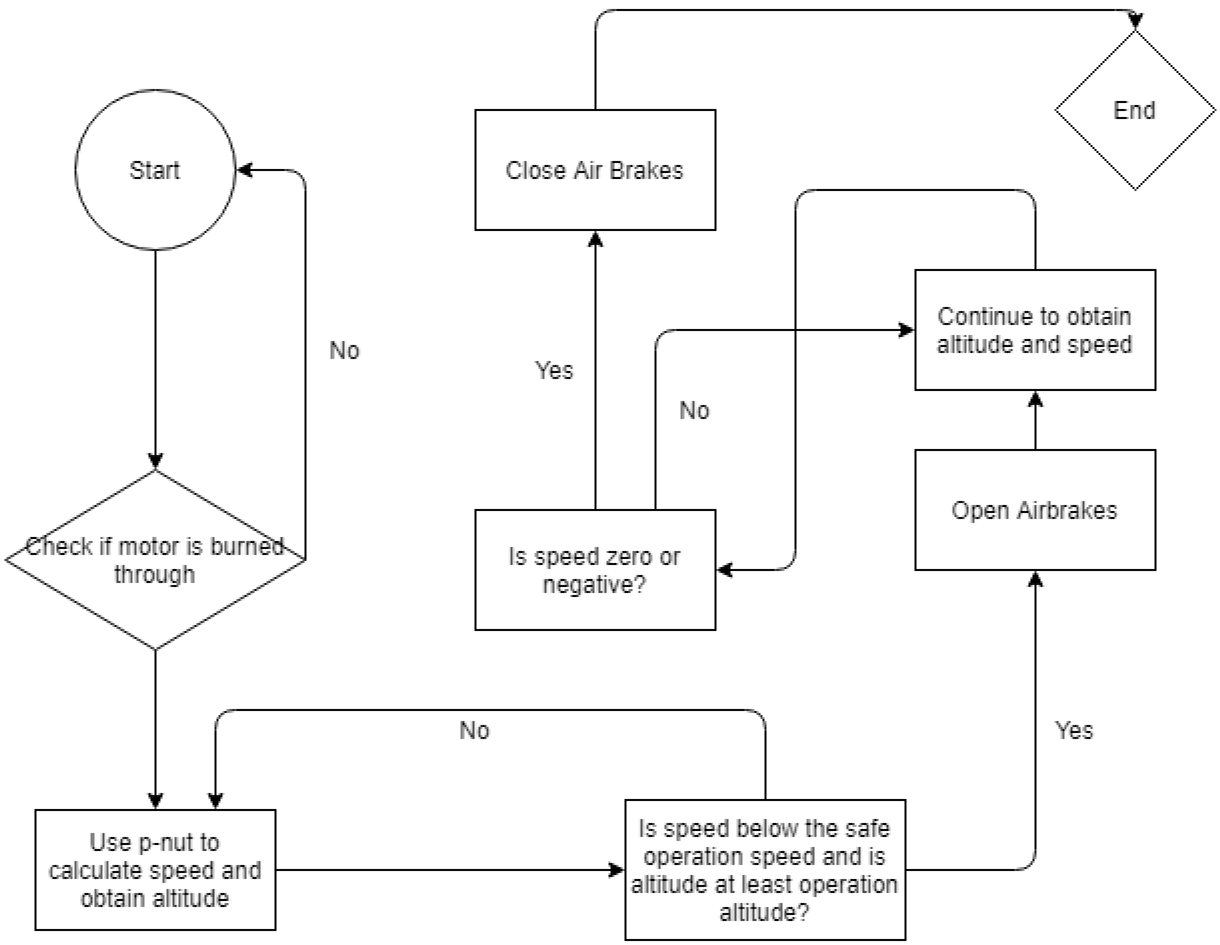
The vehicle must be reusable after launch and land within 1 mile of the launchpad.

3.1.3 System Level Review

3.1.3.1 Air Brake System

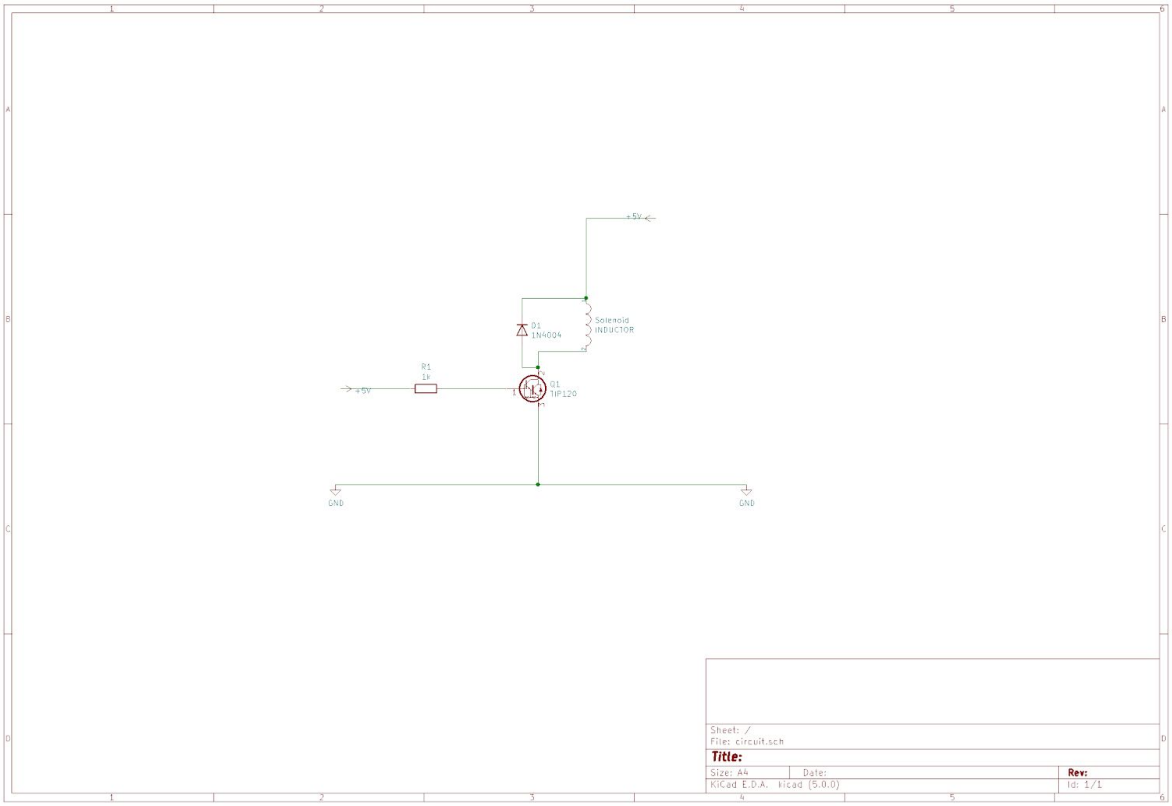
In the full-scale rocket, the air brake module will have a 10" long G10 fiberglass body tube, with an 8" long G10 fiberglass tube coupler, and it will have a 4" diameter.

Flow Chart of air brake actuation events:



3.1.3.1.1 Air Brake System Alternatives

One airbrake design considered was a rocker arm style solenoid actuated airbrake. The solenoid would pull on one side of a rocker, pushing on the airbrake and lifting it into the airstream, slowing the rocket down. The pros of this design are, low weight, quick actuation, and with a large solenoid, a high amount of lift. The cons are, difficult construction, a relatively low amount of braking force, and high power consumption. The reason this was not chosen was due to the difficult construction and low braking force, rendering it unusable for stopping the rocket effectively. The solenoid would have been powered by an external 11.7V battery, with the prototype's circuitry driven by 5V(shown below). However, the final design can substitute a solenoid for the air cylinder, with the solenoid directly replacing the air cylinder.



3.1.3.1.2 Leading Design

The main design is to utilize pneumatics to hold the airbrake up right after motor burn-out for a set amount of time, and then retracting the air brakes. The air brakes will be actuated through an umbrella style mechanism. The air brakes will be operated by the arduino and a p-nut altimeter to calculate velocity and measure altitude, with the arduino deciding when the air brakes open when conditions are met.

3.1.3.1.2.1 Description of Design

The design would utilize 3 bulkheads and a spider gear to actuate three air brakes with one cylinder. The bulkheads can be 3D printed out of ABS plastic, and the spider gear can be milled out of aluminium. The air valve would be operated by a servo, controlled by an arduino. The advantage to this design is that it has an incredibly high holding force, and can begin braking right after motor shut-off, and also is relatively easy to construct. The disadvantage to this design is that it is the air tank, which is rather large, and rather heavy, and has a risk of explosion. A balanced design that is compact enough to fit inside the rocket can be created with a ⅜ inch cylinder and 3 extra small air tanks to achieve. Huntsville is located at 600 feet above sea level with a pressure of 14.37psi, and the maximum flight altitude will be 4600 ft, with a pressure of 12.4psi. The difference in pressure is 1.97psi. The 90g Refillable Airsource CO2 cylinder is rated for a maximum pressure of 1500psi, and according to 2.15.1, the maximum pressure will be 100 psi in all three tanks. The three tanks will each have one pressure release valve, in compliance to

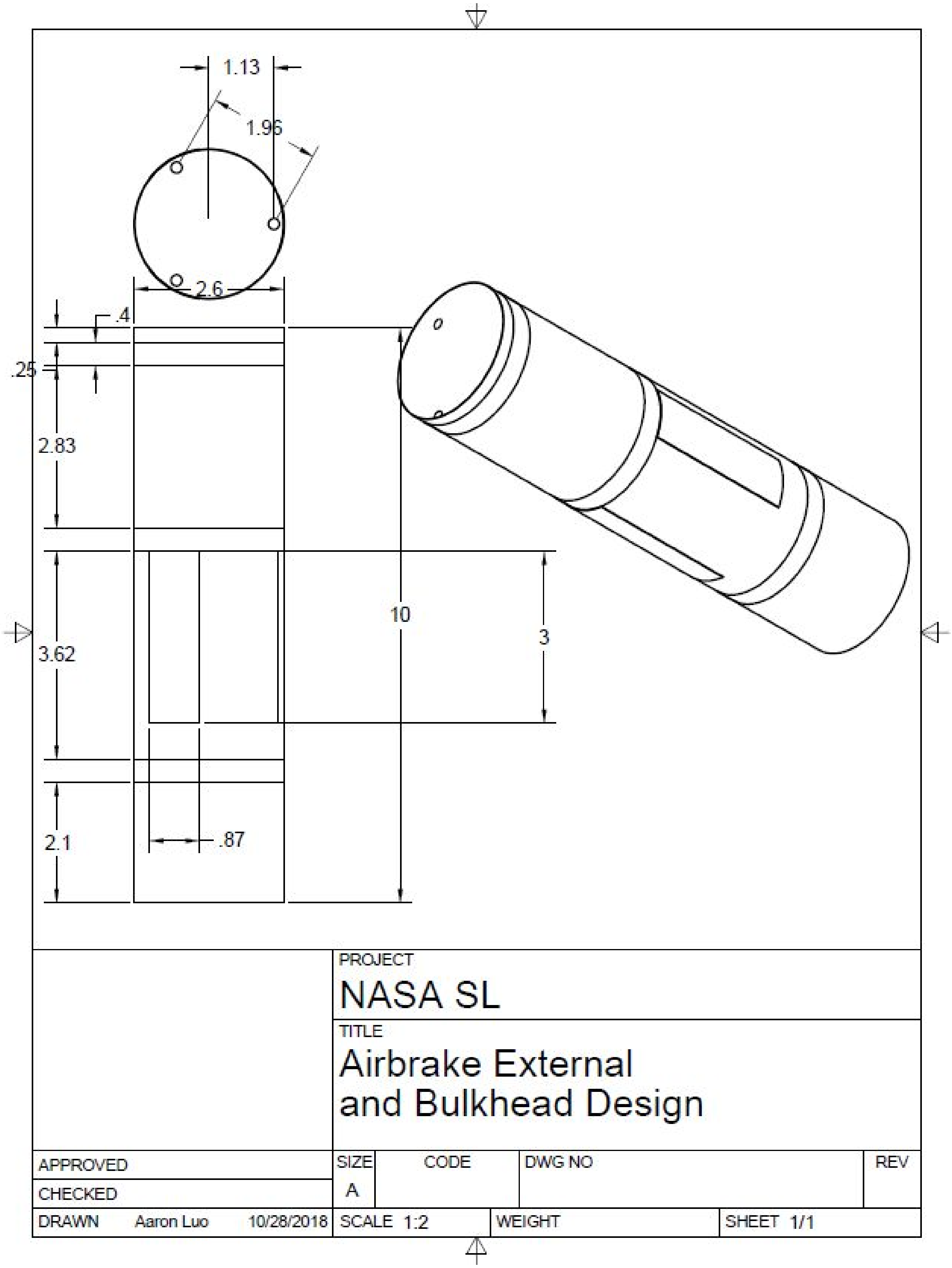
2.15.2, as the entire system is effectively one vessel. The tank will be bought new, which complies with 2.15.3.

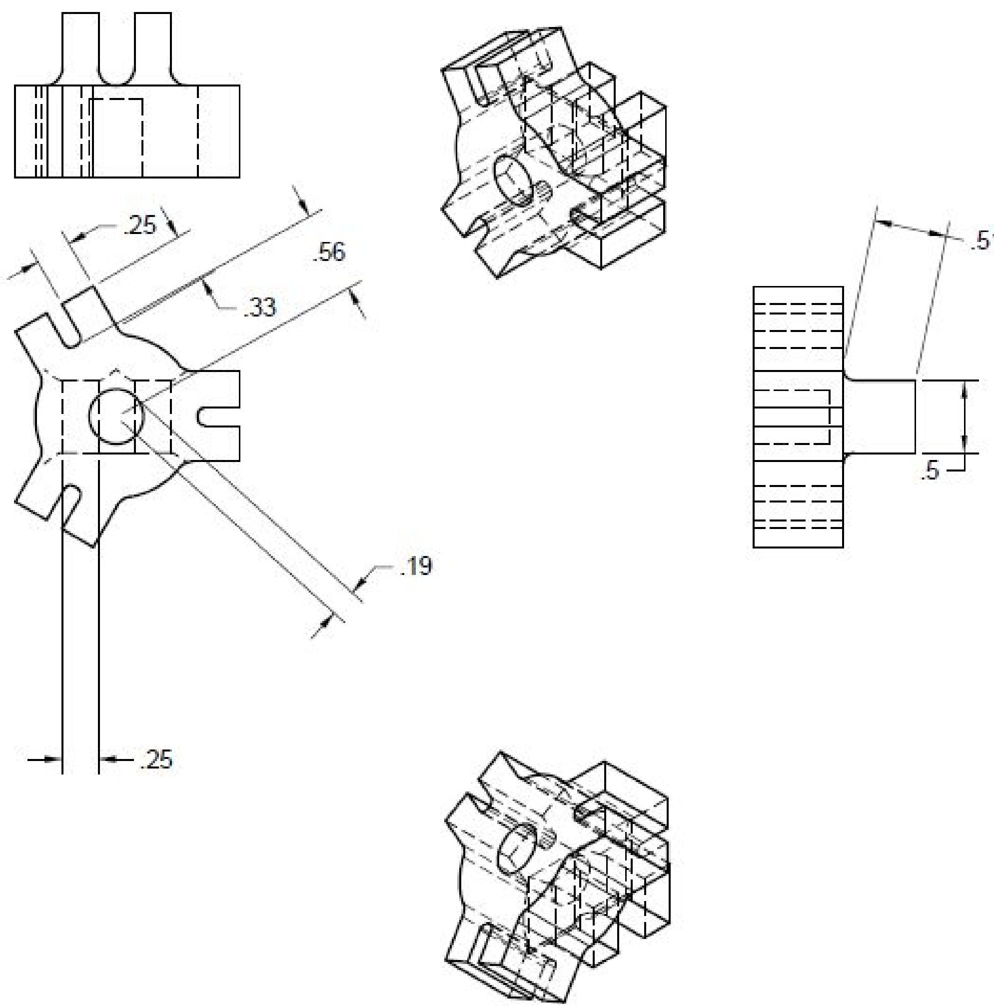
3.1.3.1.2.2 Components

The components are as follows:

- (3) 11 inch threaded steel rods
- (9) aluminium spacer tubes
- (6) lock nuts
- (1) 0.4 inch ABS bulkhead with pushrod hole
- (1) 0.4 inch ABS bulkhead with cylinder hole
- (1) 0.4 inch ABS cylinder holder with hole drilled to allow for tubing
- (3) control horns
- (3) aluminium control arms
- (3) hinges
- (1) aluminium spider gear, ⅝ inch thick
- (1) body tube with 3 air brakes
- (1) proportioning valve, air hoses
- (3) extra small air tanks
- (1) servo motor
- (1) fill valve
- (1) arduino
- (1) pressure relief valves
- (2) t - junctions.

3.1.3.1.2.3 Dimensional Drawing

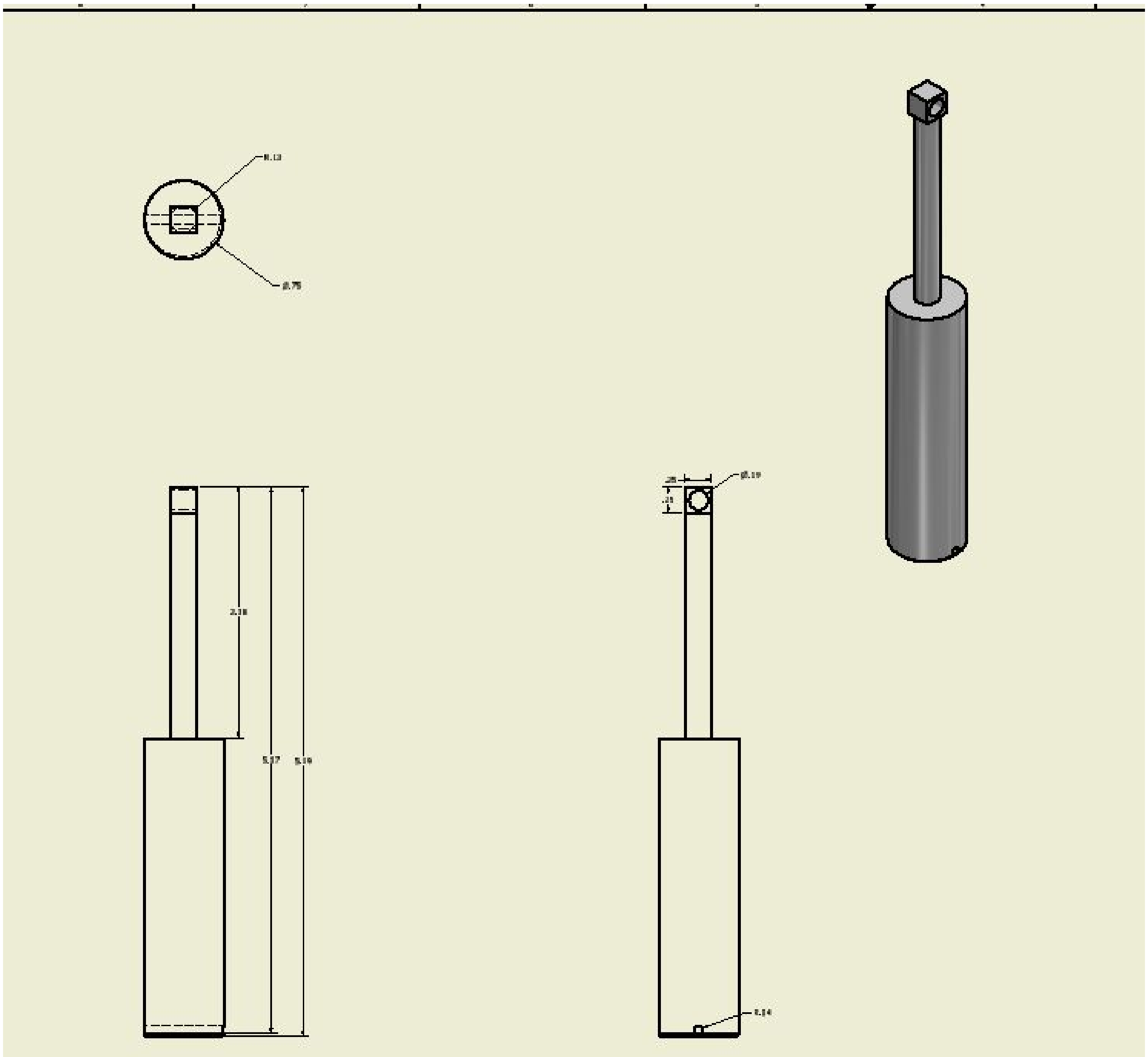




PROJECT
NASA SLI

TITLE
Spider

APPROVED	SIZE	CODE	DWG NO	REV
CHECKED	A			
DRAWN Aaron Luo 10/28/2018	SCALE 1:1	WEIGHT	SHEET 1/1	



3.1.3.1.2.4 Estimated Masses

The 2.6 inch prototype assembly should weigh around 1-2 pounds, with the 3 inch assembly weighing 3-4 pounds, and the 4 inch assembly weighing about the same.

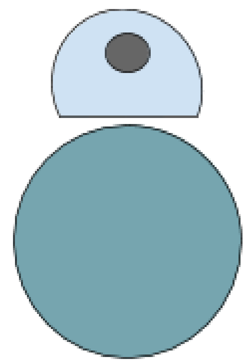
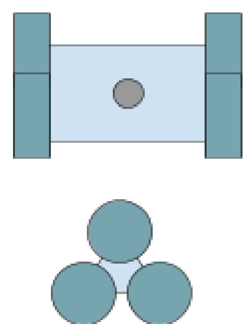
3.1.3.1.2.5 Justification

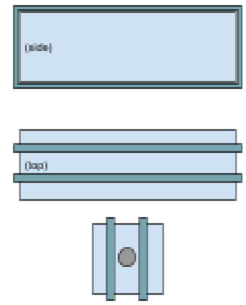
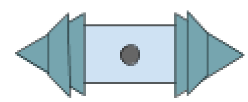
The air brake design is to increase drag momentarily to slow down the rocket in order to reach the target altitude of 4600 feet. The design change was a result of prototyping the solenoid and realizing that the force that can be placed on them for them to properly actuate was far too small to utilize for the rocket's purposes.

3.1.3.3 Payload System

3.1.3.3.1 Payload System Alternatives

The team considered 5 different rover ideas and considered the positives and negatives per design. Below is a comparison chart briefly explaining the 5 different rovers and the reasoning some choices were not discussed further. The grey on the diagram is the camera location and the teal represents the wheel(s).

Rover Designs	Description	Positives	Negatives	Diagram
BB-8 Inspired	A spherical wheel with a magnet that allows a "head" to attach to the top, yet not physically touch and allow it to move freely as the sphere below it rolls	A design liked by the team, meaning increased enthusiasm toward building it A mechanical challenge for the team	The surface of the farmland that the final launch will be on is not suitable for this specific rover design.	
[Long Beach Rover]	California State University: Long Beach created a triangular rover for the 2018 SLI featuring a total of 6 wheels, three per corner.	Allows for freedom of movement disregarding its orientation. The rover design also makes it optimal for traversing the terrain of the farm It can easily roll out of the rocket/sabot regardless of the orientation of the rocket/sabot	If the rover were to flip onto another of the 3 sides, how would the camera be able to work?	

“The Tank”	A rectangular rover with 2 tracks running the longer length of the rover.	It can easily move over the tilled farmland we anticipate the rover will be traveling across.	If the rover wasn’t deployed out a certain way, it would risk the rover landing on the side without tracks and cause the rover to fail. If the dirt on the farmland sticks to the tracks, it can obstruct the camera.	
“The IDC”	This is a cylindrical rover with cone wheels.	This can easily roll out of the rocket/sabot regardless of the orientation of the rocket/sabot		

3.1.3.3.2 Leading Design

Rover Designs	Description	Positives	Negatives	Diagram
“Mr. Beaver”	A cylindrical rover with large tractor like wheels and a “beaver” tail to ensure that the cylinder holding the camera and electronics don’t spin with the wheels The camera is on the top of the rover, and there are two cylinder wheels. Inside the rover, there is a box	The rover can easily roll out of the rocket/sabot regardless of the orientation of the rocket. The beaver-tail mechanism helps to stabilize the camera	Possibly an issue with crossing the tilled farmland?	(below in dimensional drawings)

	that contains all the electronic component. The box will be hanged on a rod, which is used to connect two major motors.			

3.1.3.3.2.1 Description of Design

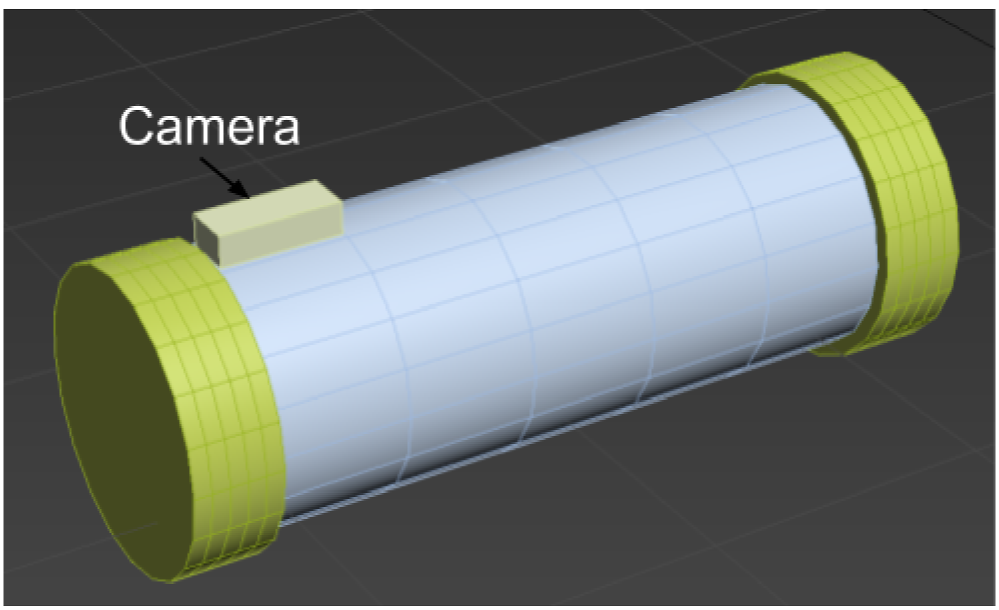
A cylindrical rover with large tractor like wheels and a "beaver" tail to ensure that the cylinder holding the camera and electronics don't spin with the wheels

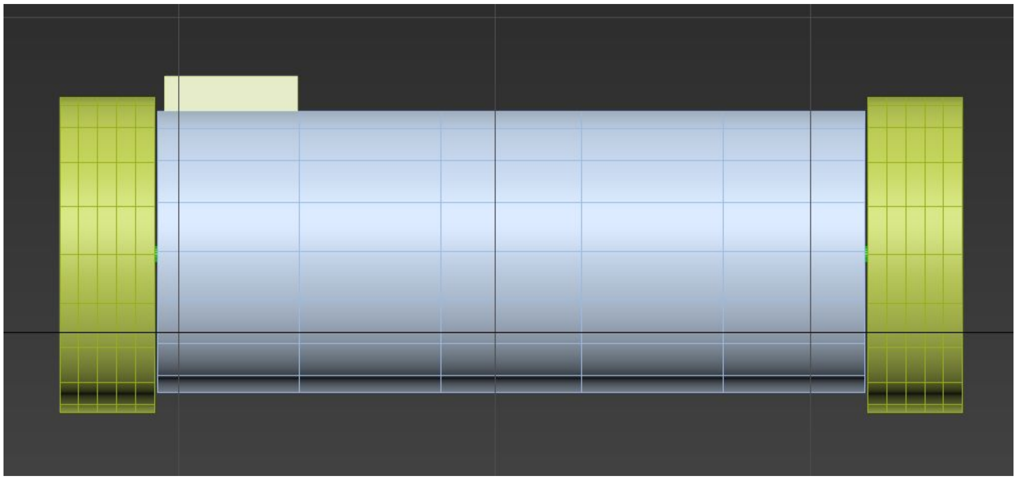
3.1.3.3.2.2 Components

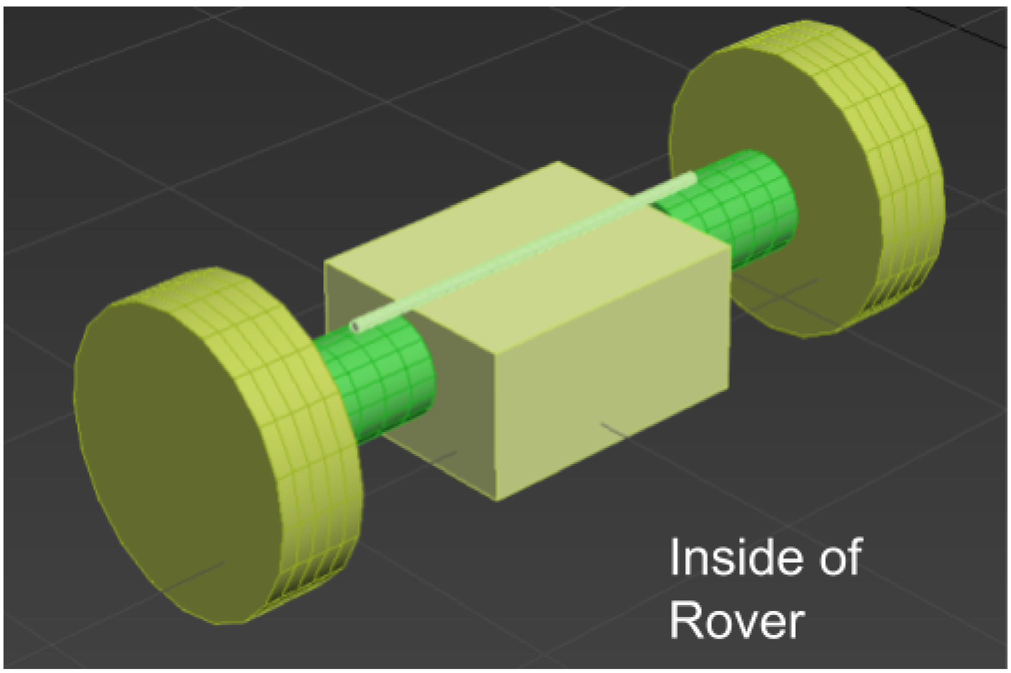
The materials that are speculated to be necessary in building the rover payload.

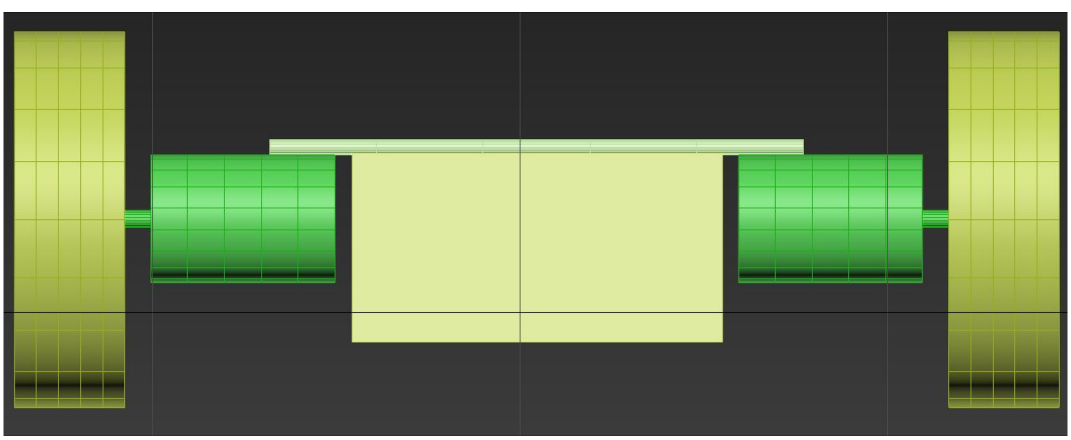
- GPS
- Small camera capable of transmitting live video and taking picture.
- 3D printer for printing the components of the rover body.
- Gears, wheels, etc.

3.1.3.3.2.3 Dimensional Drawing






Inside of
Rover



3.1.3.3.2.4 Estimated Masses

The entire rover is estimated currently to be 600 grams. There has been 800 gram on the rocket allotted for the payload.

3.1.3.3.2.5 Justification

The payload design was altered so that the rover would not have to move down the rocket and then turn to take the photo. Originally, the design stated that the camera would be located in the center body rather than on top. The change helps to simplify the tasks required of the rover, meaning less room for error.

3.1.4 Motor Choice

The final choice of the motor is the Cesaroni K1085. The reasons of the choice in motor includes the following:

- The CTI K1085 falls within NAR requirements for a K class motor where the max total impulse is 2560Ns and the K1085 has a total impulse of 2412Ns.
- The weight of the designed rocket for the past two years has been heavier than anticipated. Assuming that the rocket design is heavier than what will actually result, the increased altitude and velocity help to ensure the rocket will reach the target altitude.
- Assuming the rocket is heavier, the motor will account for the loss of a couple hundred feet altitude when the actual rocket is built versus on the simulation.
- The weight of the CTI K1085 motor is lighter than most of the other motors compared. At 2430 grams, this helps to ensure that the rocket will not end up too much heavier than anticipated.
- The burnout time of the K1085 motor is estimated to be about 2.1 (thrustcurve.org) and 2.28 (rocksim) seconds. Due to the burnout being so short, the vehicle will be able to put into use the air brake module the team will design
- The thrust curve graph shown by thrustcurve.org for the K1085 motor has a larger spike at the beginning of the flight, indicating a higher velocity at first and therefore a straighter flight. This also indicates greater force upon the vehicle and payload. However, we believe that our design will be able to withstand the force.

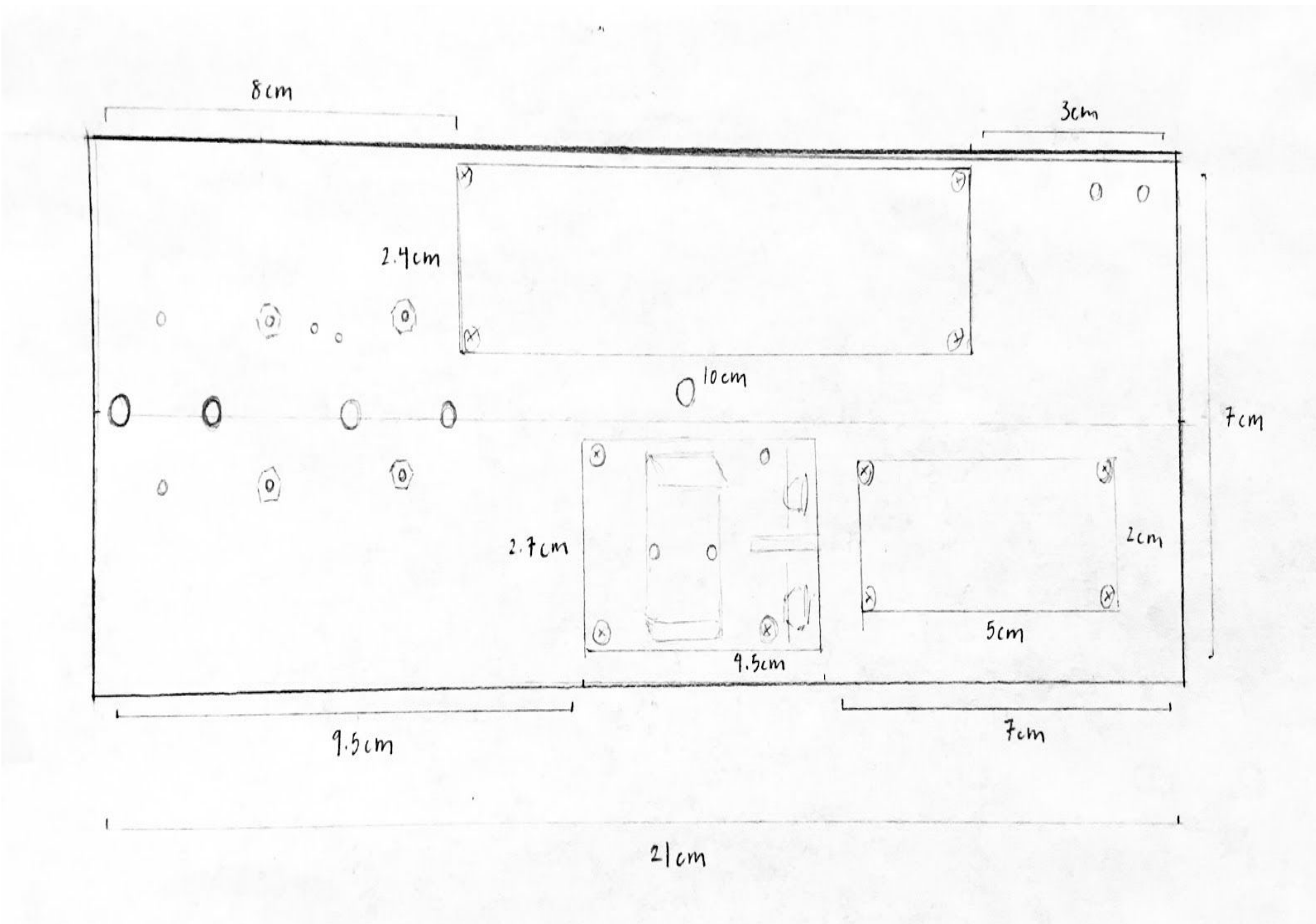
3.1.4.1 Motor Alternatives

Motor	**Total Impulse (Ns)**	**Total Mass (g)**	**Max Altitude (ft)**	**Max Velocity (ft/s)**	**Max Acceleration (ft/s^2)**
CTI K661	2430.4	2528	5164.4	614.5	693.99

CTI K555	2406.2	2759	4886.42	547.75	693.93
CTI K2000	2329.9	2465	5072.87	691.57	749.44
CTI K735	1955.2	2509	5149.74	661.51	693.92
CTI K1085	2412.0	2430.0	5080.44	653.06	974.61

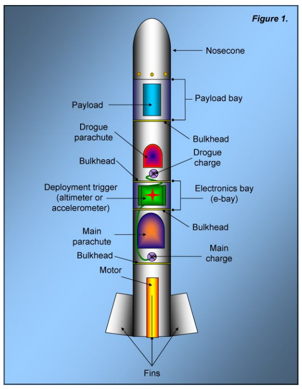
3.2 Recovery Subsystem

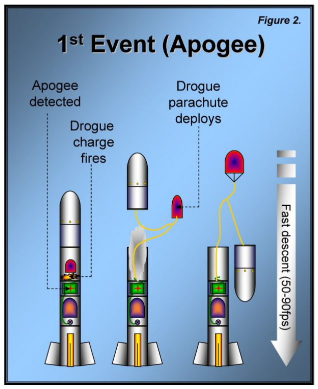
The recovery electronics will be in the avionics bay, a 10.2” tube coupler with a 1” band made of fiberglass body (4” diameter) tube to separate the upper and middle body tubes. It is a redundant system that will deploy an 18” drogue parachute at apogee and an 84” main parachute at 600 feet. Removable shear pins (# 2 nylon shear pins that require 35 lbs of force to tear) will be used for the main and drogue compartment such that the pins will hold the rocket together while the rocket is ascending but the ejection charge will rip them off to deploy the parachutes.

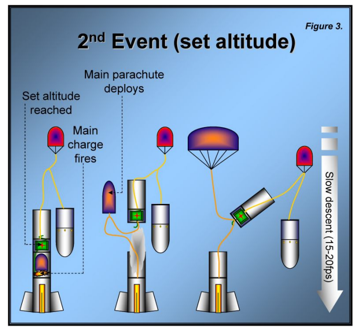


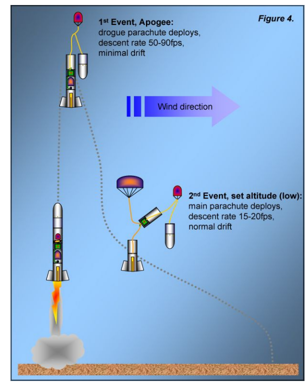
The two mass objects represents the recovery electronics, which are 50 g total. The primary flight system, the Stratologger CF, weighs 11 grams while the backup flight computer, the

RRC3, weighs 17 grams. They will be mounted on a 4” x 12” wooden board, which weighs 48 g. The green bulkheads are 0.115” thick fiberglass, while the orange bulkheads are 0.115” birch. Both recovery electronics will be powered by commercially available batteries, and there will be a power switch for both flight computers to increase safety. Together, the parachutes and the avionics bay will ensure that the rocket and its payload are recoverable and reusable. This is a sample configuration of our recovery electronics and parachutes:









On either side on the bulkheads is a 1” machine-pressed eye bolt. The independent sections will use 1” wide tubular nylon to tether them during descent. These cords will be protected by a 1” wide shock cord protector sleeve. The shock cord will be changed every five launches to maintain the design’s safety.

3.2.1 Components

There are four primary components of recovery: the parachutes, the harnesses, the bulkheads, and attachment hardware.

3.2.1.1 Component Alternatives

Flight Computer	Pros	Cons
G-Wiz HCX	Easily programmable, dual deployment can be set in 100 foot increments. Comes with an SD card to record flights. Can also be used with 2 batteries to optimize safety.	Not available for sale anymore.

Stratologger CF	Easy to program, reliable manufacturer (PerfectFlite). It can record altitudes up to 100,000 feet, and stores 20 flights a second. Main deployment can be set in 1 foot increments for more precision.	Can only launch drogue at certain altitudes. Doesn't allow two batteries for increased safety.
RRC3 Sport	Easy to program and is pre set up at drogue deployment at apogee and main deployment at 500 feet. Reliable manufacturer (Mad Cow Rocketry) which we used in TARC. Allows two batteries.	Bigger than the stratologger and heavier (17g).
TeleMega Altimeter	Has an on board integrated GPS receiver (eliminating need for dog collar). Has accelerometer. Pyro events like dual deploy can be configured to specific heights and times to increase accuracy.	Really expensive (costs $500). Relatively heavy (25g).
Raven Flight Computer	Really small (saves space). High quality data (accelerometer, barometric pressure, etc). Main deployment at 700 feet (fits with our deployment plan).	Hard to program. No flexibility with main deployment (can't change the altitude). Really expensive ($155).

3.2.1.2 Preliminary Analysis on Parachute Sizing for Safe Descent

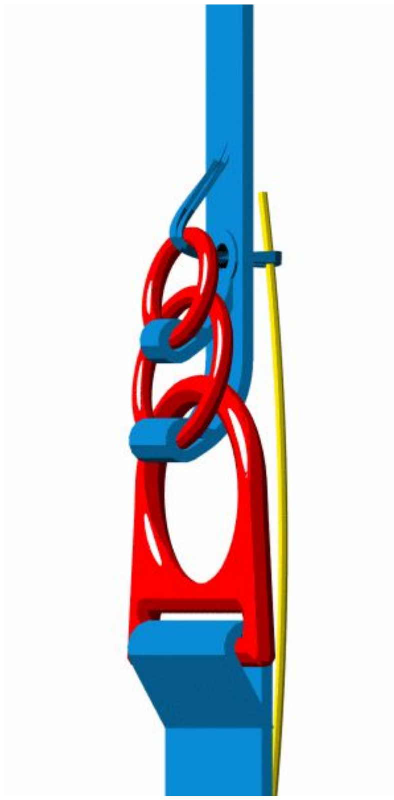
The recovery electronics will be in the avionics bay, a 10.2" tube coupler with a 1" band made of fiberglass body (4" diameter) tube to separate the upper and middle body tubes. It is a redundant dual deploy system with an 84" main parachute and 18" drogue parachute.

3.2.1.3 Recovery Plan

The vehicle will use redundant dual deployment for recovery. The top section will be connected to the parachutes via a nylon shock cord, and the avionics bay will also be connected via a nylon shock cord. Recovery will occur in three phases – near apogee a small drogue parachute will be deployed that is designed to slow the rocket for initial descent. Much later, at an altitude of 900 feet, the ejection charge will deploy the main, which is designated to drastically slow down ascent for the purpose of safety.

The primary set of recovery electronics will use a Stratologger CF Flight Computer, and the backup set will use an RRC3 Flight computer. In this way, if there is a bug in the design of either flight computer that would affect the recovery during our flight it will not be replicated in the other set of electronics. Each of the two recovery electronics has its own separate commercially available battery capable of powering the electronics for a minimum of 1 hour dwell time plus flight time. That battery is disconnected through an interlock key switch accessible on the outside of the rocket near the nose cone, and this is to ensure that the electronics are not powered on until it is safe to do so on the launch pad. They key can be removed only when the switch is locked ON. The recovery electronics will ignite a measured portion of gunpowder using an electric match. Recovery electronics are totally independent of the payload electronics and power. To assure that the radio frequency signals of other electronics do not interfere with recovery, use a MG Chemicals SuperShield. One to two mil coating provides 40dB - 50dB shielding across a frequency range of 5 to 1800MHz.

3.2.1.4 Leading Design



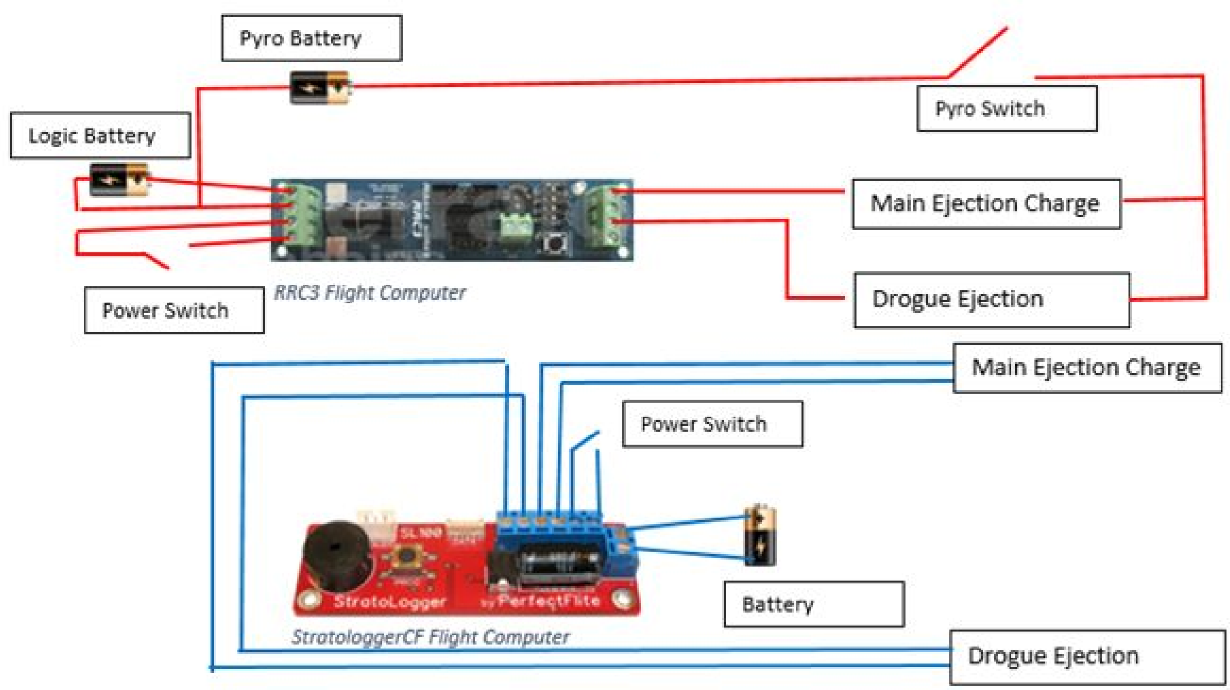
In order to detach the parachute, our team plans to use a 3-ring release system. Since the 3-ring release system is primarily used by sport skydivers and military free-fall parachutists, the design of this system is very reliable. The largest ring in this system is located on the bottom and attached to the harness. The middle ring is attached to the end of the parachute riser. The small ring is also attached to the parachute riser, above the middle ring. The middle ring will pass through the biggest ring and loop upward. Then the smallest ring, located above the middle ring, will pass through the middle ring and loop upward as well. A cord loop will pass through the small ring, loop upwards, and finally pass through a grommet to the opposing side of the parachute riser. A semi-rigid cable will stabilize this loop by passing through it. When released, the cable is removed with a tug and the rings will detach. The parachute will then detach.

This is a prototype describing the general idea of how this system works:
https://www.youtube.com/watch?v=T6pXytpAnZ0&feature=youtu.be

3.2.2 Proof of Redundancy

Our recovery system has a redundant dual deploy system, which means that the electronics of the primary flight computer will not affect that of the secondary flight computer. The picture below shows the redundancy of our recovery electronics because the wiring of the Stratologger (in blue) is separate from the wiring of the RRC3 (in red). We decided to use the Stratologger CF flight computer as our primary flight computer and the RRC3 as our secondary one, keeping in mind cost and ease of accessibility. These two were our cheapest options, since both sold for less than $100. Even though they only provided altitude data, they were also the easiest to program compared to the other options. Finally, we picked them because they had reliable manufacturers. Our team had experience working with Mad Cow Rocketry for TARC, as we got parts from them, and we saw the reliability of Perfect Flite on multiple forums and product reviews.
The estimated mass of the subsystem is 660.382 g.
We will use an 18” diameter drogue chute and 72” diameter main chute.

We are using two different types of recovery electronics in the event that one system has a bug and reads altitude incorrectly. If this is the case, then we can rely on the other recovery electronic to control the rest of the flight.



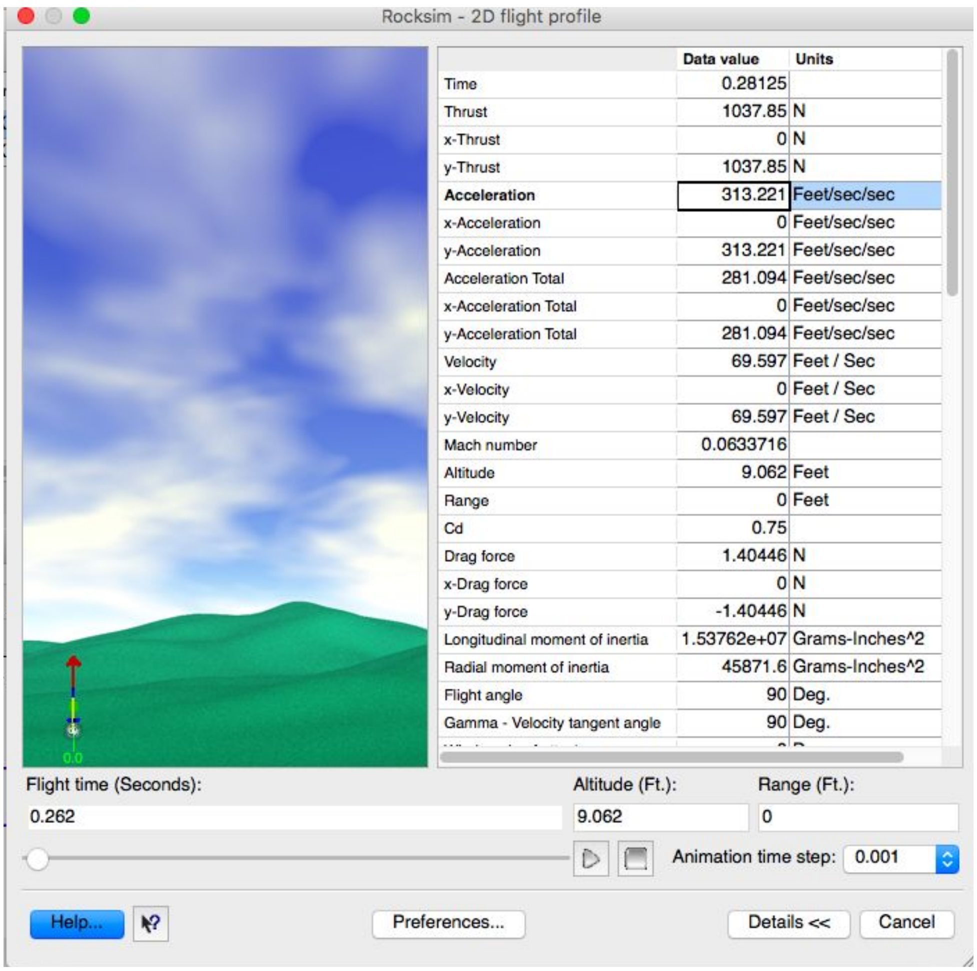
3.3 Mission Performance Predictions

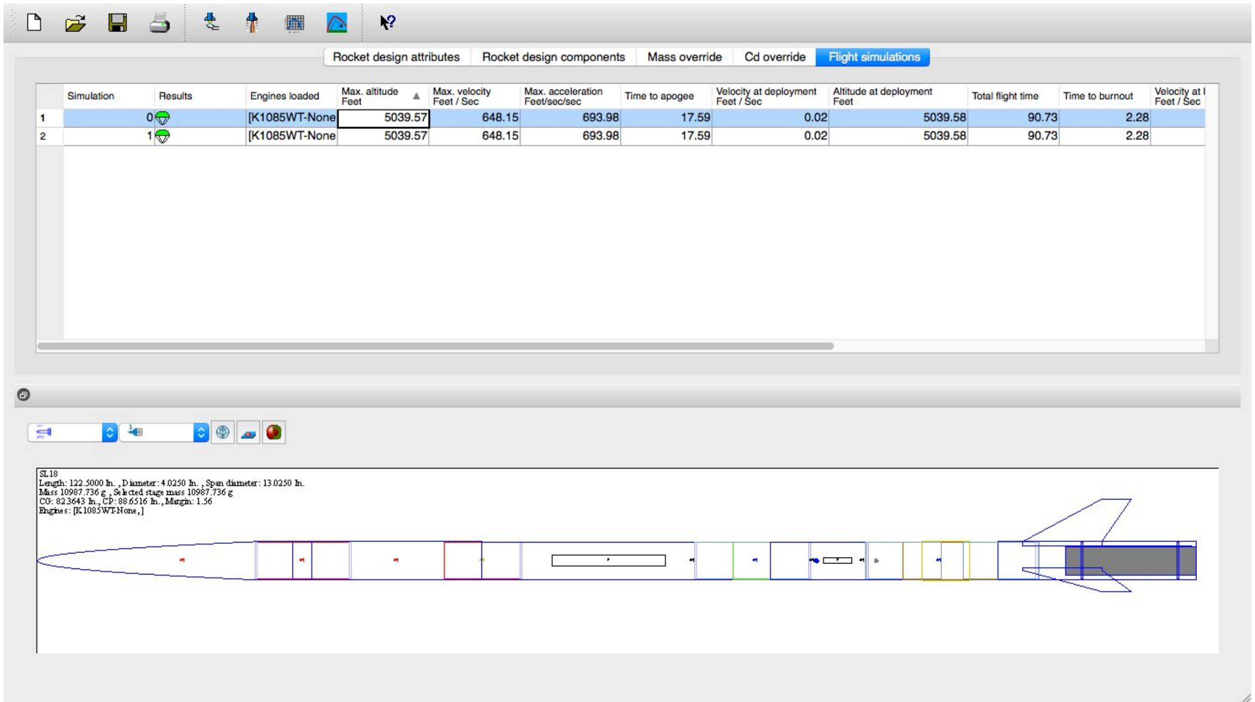
3.3.1 Official Launch Day Target Altitude (ft)

The official launch day target altitude is 4600 ft.

3.3.2 Simulations

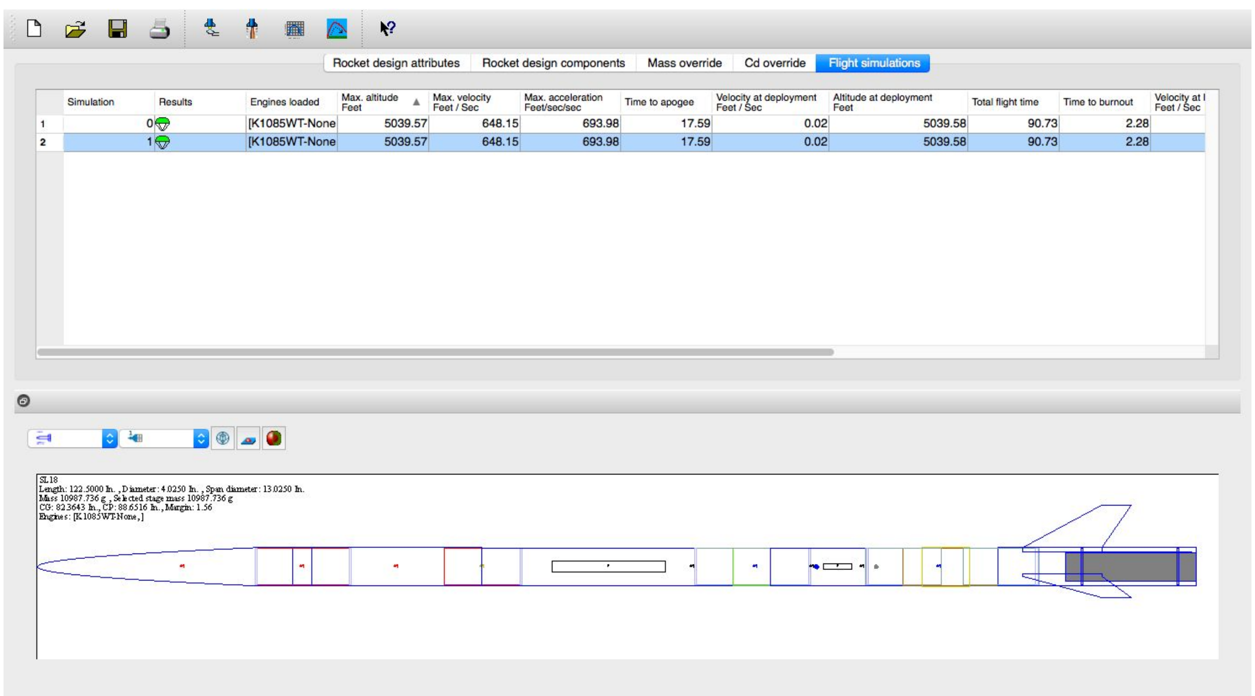
3.3.2.1 Flight Profile Simulation

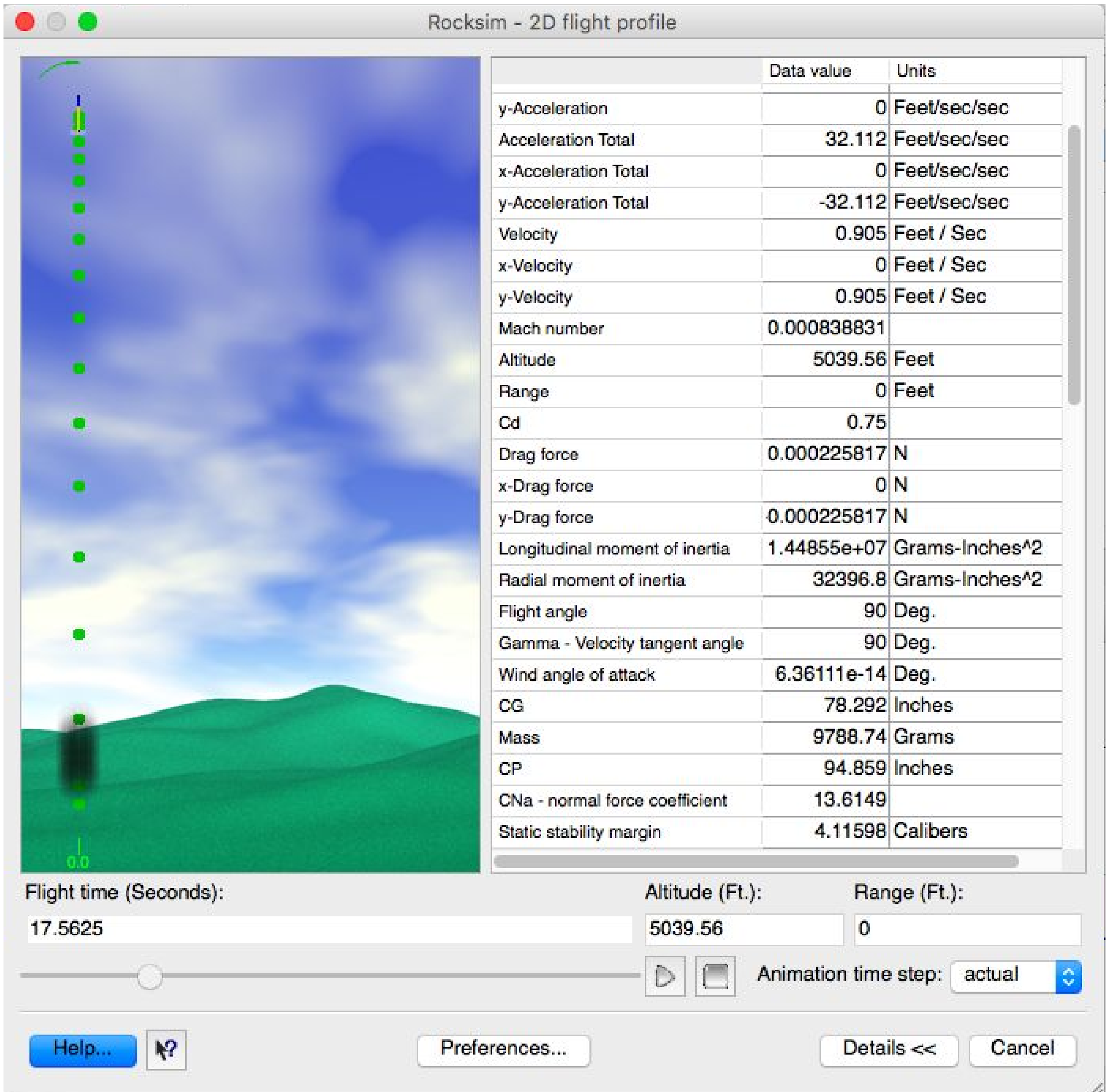




3.3.2.2 Altitude Predictions with Simulated Vehicle Data

The current projected altitude of the rocket with a CTI K1085 motor is 5039 ft. This is at conditions of “no wind” according to rocksim.

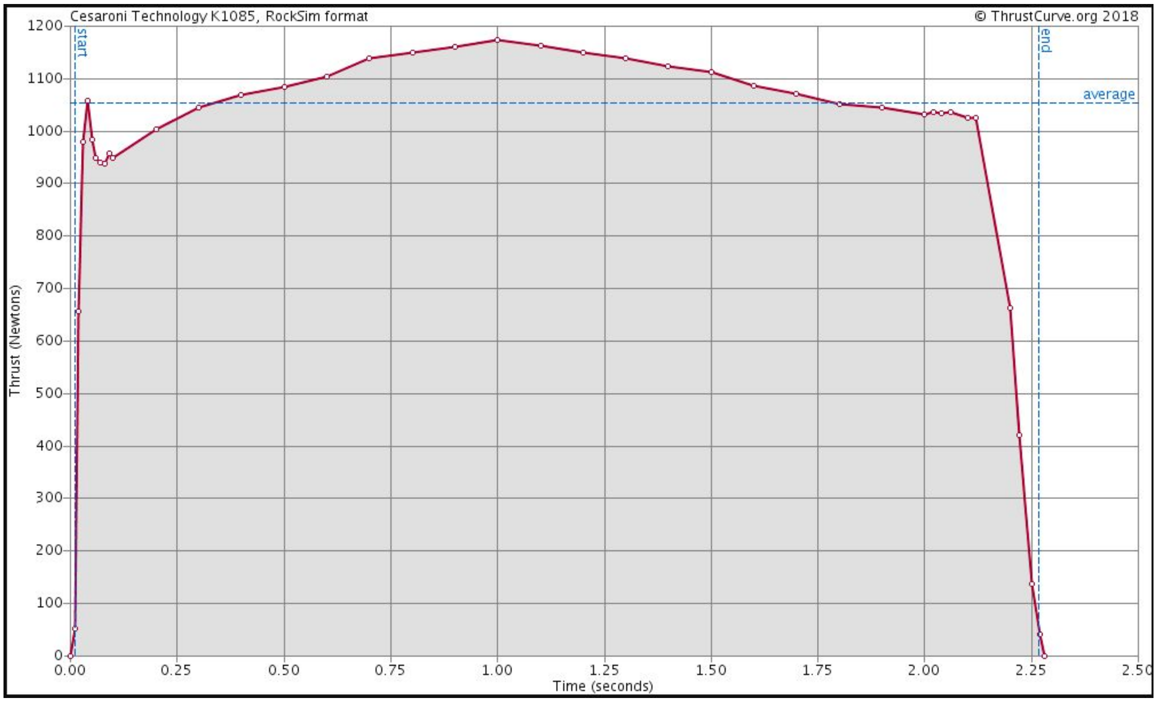




The use of on board air brakes will ensure that the altitude of the rocket will reach the specified target of 4600 feet. Even without the air brakes, the max altitude is 5039 ft, which is within the the airspace license for this project.

3.3.2.3 Component Weights

3.3.2.4 Simulated Motor Thrust Curve

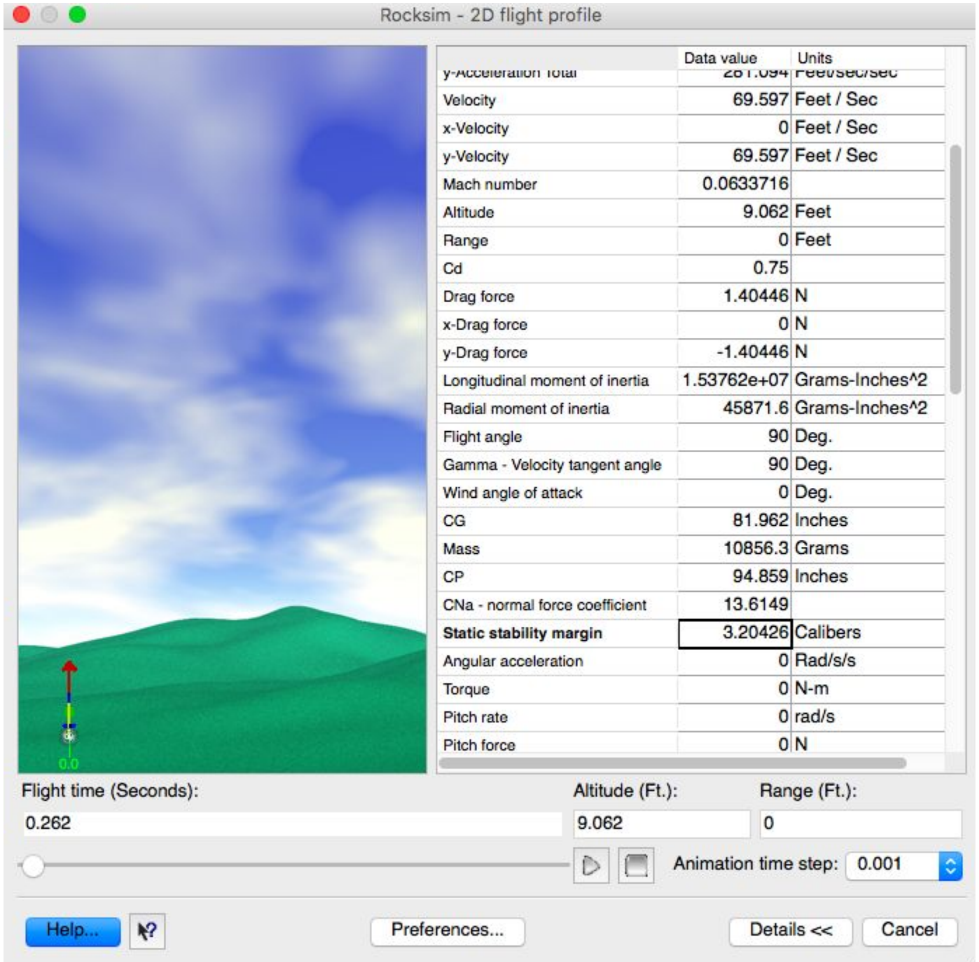


The above thurst curve graph was provided by thurstcurve.org for the CTI K1085WT motor.

3.3.3 Verification of Robust Design

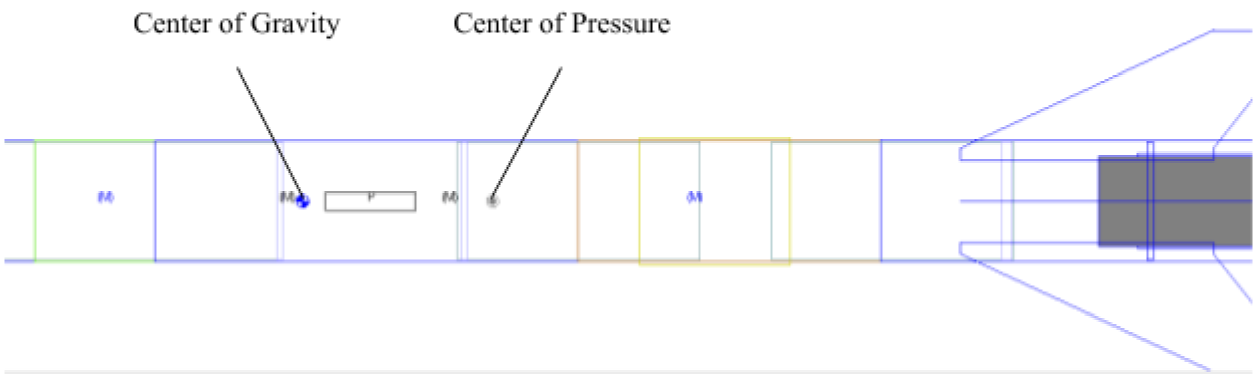
We will use a scale model to test the robustness of the design. The scale model will be a predictor of how the full scale model will perform. The scale model has a 3” diameter.

3.3.4 Stability Margin



The above shows the static stability margin upon rail exit. Due to the program not being the most user friendly, the closest value to rail exit was at 9.062 ft. As shown, the estimation is 3.2 calibers. The requirement is a minimum of 2 calibers.

3.3.5 Simulated Center of Pressure (CP)/Center of Gravity (CG) Relationship and Locations



CG: 82.3643 in
CP: 88.6516 in

3.3.6 Calculations

3.3.6.1 Kinetic Energy Calculations

Overall Rocket: 9278.618 g (with burnt out motor) = 20.4559 lbs
Independent Section 1: 2716.338 g = 5.9885 lbs
Independent Section 2: 1476.888 g = 3.256 lbs
Independent Section 3: 5085.392 g (with burnt out motor) = 11.2114 lbs

$$kinetic\ energy = \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(20.4559lbs)(16.89ft/s)^2(\tfrac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 90.6133\ lbf$$

Independent Section 1 - Nose Cone, Payload Bay, Payload

$$kinetic\ energy = \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(5.9885lbs)(16.89ft/s)^2(\tfrac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 26.5272\ lbf$$

Independent Section 2 - Upper Body Tube, Avionics Bay

$$kinetic\ energy = \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(3.256lbs)(16.89ft/s)^2(\tfrac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$

$$= 14.4321\ lbf$$

Independent Section 3 - Lower Body Tube, Air Brake System, Booster

$$kinetic\ energy\ =\ \tfrac{1}{2}mv^2$$

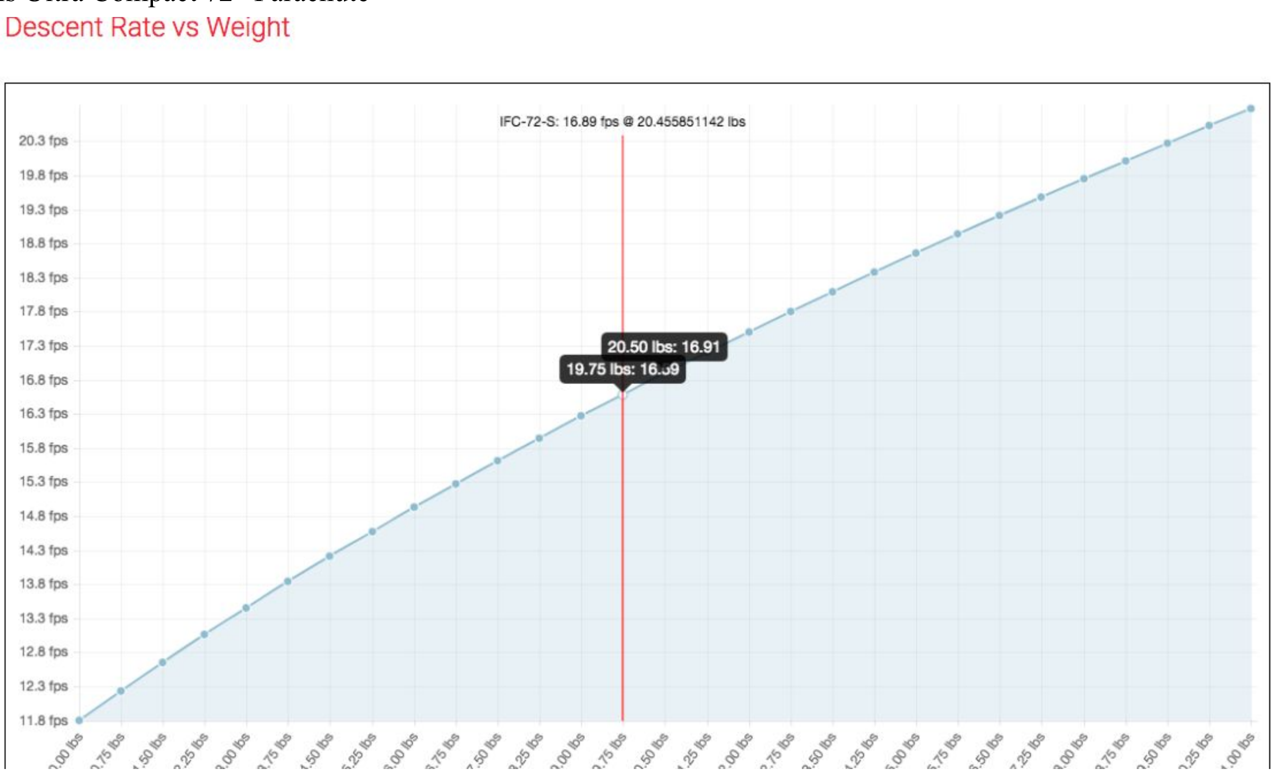
$$= \tfrac{1}{2}(11.2114lbs)(16.89ft/s)^2\left(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}\right)$$

$$= 49.663\ lbf$$

3.3.6.1.4 Verification of Calculation

The velocity of the kinetic energy calculations as well as the drift were calculated using the descent rate calculator provided by Fruity Chutes, the manufacturer the team is purchasing the parachutes from.

Iris Ultra Compact 72” Parachute



Classic Elliptical 18” Parachute

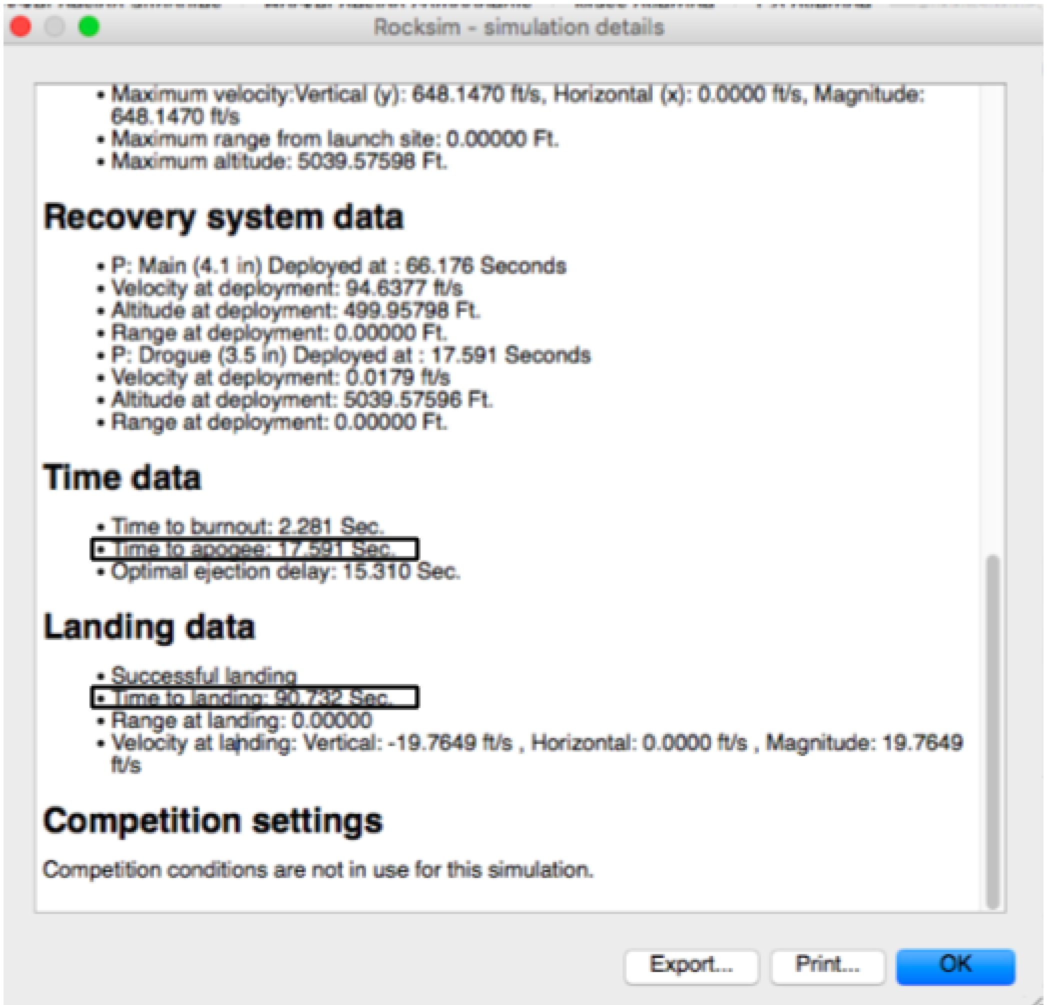
3.3.6.1.7 Differences in Calculations

No difference in calculations.

3.3.6.2 Expected Descent Time

Using a simulated flight profile, we found the time to apogee and subtracted that time from the total time of the simulation. The estimated descent time was 70.18 seconds.

3.3.6.2.1 Verification of Calculation



3.3.6.2.7 Differences in Calculations

The values given suggest a 3 second difference from the calculations done using the flight profile of rocksim. The second calculation for descent time equates to 73.141 seconds.

3.3.6.3 Drift

3.3.6.3.1 0 MPH Wind

$$[(\frac{1\ second}{82.19\ feet})(4600 - 600\ ft) + (\frac{1\ second}{16.89\ feet})(600\ ft)] \times (\frac{0\ miles}{1\ hour})(\frac{5280\ feet}{1\ mile})(\frac{1 hour}{3600\ seconds}) = 0\ ft$$

3.3.6.3.2 5 MPH Wind

$$[(\frac{1\ second}{82.19\ feet})(4600 - 600\ ft) + (\frac{1\ second}{16.89\ feet})(600\ ft)] \times (\frac{5\ miles}{1\ hour})(\frac{5280\ feet}{1\ mile})(\frac{1 hour}{3600\ seconds}) = 617.4058\ ft$$

3.3.6.3.3 10 MPH Wind

$$[(\frac{1\ second}{82.19\ feet})(4600 - 600\ ft) + (\frac{1\ second}{16.89\ feet})(600\ ft)] \times (\frac{10\ miles}{1\ hour})(\frac{5280\ feet}{1\ mile})(\frac{1 hour}{3600\ seconds}) = 1234.8116\ ft$$

3.3.6.3.4 15 MPH Wind

$$[(\frac{1\ second}{82.19\ feet})(4600 - 600\ ft) + (\frac{1\ second}{16.89\ feet})(600\ ft)] \times (\frac{15\ miles}{1\ hour})(\frac{5280\ feet}{1\ mile})(\frac{1 hour}{3600\ seconds}) = 1852.2174\ ft$$

3.3.6.3.5 20 MPH Wind

$$[(\frac{1\ second}{82.19\ feet})(4600 - 600\ ft) + (\frac{1\ second}{16.89\ feet})(600\ ft)] \times (\frac{20\ miles}{1\ hour})(\frac{5280\ feet}{1\ mile})(\frac{1 hour}{3600\ seconds}) = 2469.6232\ ft$$

3.3.6.3.6 Verification of Calculation

The calculations were done via graphing calculator and checked by multiple people

3.3.6.3.7 Differences in Calculations

Calculations were all the same.

4 Safety

4.1 Components Needed to Complete the Project

To complete this SL project, each member of the team needs to deliver the tasks asked from them. Overall, the rocket design, payload specifications, educational engagement, budget specifications, and safety plans are the basic measures necessary for the success of the project. Safety is a key consideration in every aspect of this project, as team members must be aware of certain risks and dangers while designing the rocket, physically constructing the rocket, launching the rocket, and recovering the rocket. Risks can be consequential for all components of the project, as it can create setbacks if the risks fail to meet requirements. To avoid this, project planning has been established, along with making sure that safety is not looked over when focusing on efficiency.

4.1.1 Analysis of Impacts of Risks and Delays

4.2 Preliminary Personnel Hazard Analysis

4.2.1 Hazardous Material Safety

Hazardous Materials	**Compliance**

Metal.	Team members will only use cardboard, fiberglass, with some wood, paper, and plastic as required for the rocket, and team members will not use steel to fabricate cases, front, or nozzles.
Flammable materials such as paper, cardboard, wood.	Team members will install a jet or blast deflector device to prevent the flammable material touch the motor exhaust directly.
Frangible materials such as plastic, glass.	Team members will not use glass or other frangible materials to fabricate cases, front, or nozzles.

4.2.2 MSDS

MSDS Outline

MSDS is an important document that states the health risks for an item in case an accident happens and the proper procedures that need to be undertaken just in case the health of the affected is at risk.

Fiberglass

Product Name(s): Woven Unidirectional Fiberglass Fabric (A-Style Warp Unidirectional), Stitchbonded Fiberglass Fabric, Woven Fiberglass Fabric
Manufacturer: Owens-Corning, World Headquarters, One Owens-Corning Parkway Attn. Product Stewardship, Toledo, OH, 43659, Telephone: 1-419-248-8234 (8am-5pm ET weekdays). OC Fabrics, 1851 S. Sequin Ave., New Braunfels, TX, 78130 Telephone: 1-210-629-4009 (8am-5pm CT weekdays).
Emergency Contacts: Emergencies ONLY (after 5pm ET and weekends): 1-419-248-5330, CHEMTREC (24 hours everyday): 1-800-424-9300, CANUTEC (Canada- 24 hours everyday): 1-613-996-6666. Health and Technical Contacts:
Health Issues Information: (8am-5pm ET):1-419-248-8234, Technical Product Information (8am-5pm ET): 1-800-GET-PINK.

Common Name	Chemical Name	CAS No.	Wt. %
Fiber Glass Continuous Filament (non respirable)	Fibrous Glass	65997-17-3	94-100
Size	Size	None	0-2
Polyester Yarn	Polyester Yarn	None	0-4

Appearance and Odor: White/off-white colored solid with no odor.

Primary Route(s) of Exposure: Inhalation, skin, eye
Potential Health Effects:

- **Acute (short term):** Fiber glass continuous filament is a mechanical irritant. Breathing dusts and fibers may cause short term irritation of the mouth, nose and throat. Skin contact with dust and fibers may cause itching and short term irritation. Eye contact with dust and fibers may cause short term mechanical irritation. Ingestion may cause short term mechanical irritation of the stomach and intestines. See Section 8 for exposure controls.
- **Chronic (long term):** There is no known health effects connected with long term use or contact with this product. See Section 11 of MSDS for more toxicological data.

Medical Conditions Aggravated by Exposure: Long term breathing or skin conditions that are aggravated by mechanical irritants may be at a higher risk for worsening from use or contact with this product.
Inhalation: Move person to fresh air. Seek medical attention if irritation persists.
Eye Contact: Flush eyes with running water for at least 15 minutes. Seek medical attention if irritation persists.
Skin Contact: Wash with mild soap and running water. Use a washcloth to help remove fibers. To avoid more irritation, do not rub or scratch affected areas. Rubbing or scratching may force fibers into skin. Seek medical attention if irritation persists.
Ingestion: Ingestion of this material is unlikely. If it does occur, watch the person for several days to make sure that intestinal blockage does not occur.
Flash Point and Method: None
Flammability Limits (%): None
Auto Ignition Temperature: Not Applicable
Extinguishing Media: Water, foam, CO2 or dry chemical.
Unusual Fire and Explosion Hazards: None known
Fire Fighting Instructions: Use self contained breathing apparatus (SCBA) in a sustained fire.
Hazardous Combustion Products: Primary combustion products are carbon monoxide, carbon dioxide and water. Other undetermined compounds could be released in small quantities.
Land Spill: Scoop up material and put into suitable container for disposal as a nonhazardous waste.
Water Spill: This material will sink and disperse along the bottom of waterways and ponds. It can not easily be removed after it is waterborne; however, the material is non-hazardous in water. **Air Release:** This material will settle out of the air. If concentrated on land it can then be scooped up for disposal as a non-hazardous waste.
Storage Temperature: Not applicable
Storage Pressure: Not applicable
General: No special storage or handling procedures are required for this material.

Black Powder 4F

Hazardous Components

Material or Component	%	CAS no.	TLV	PEL

Potassium Nitrate	70-76	007757-79-1	NE	NE
Sodium Nitrate	70-74	007631-99-4	NE	NE
Charcoal	8-18	N/A	NE	NE
Sulfur	9-20	007704-34-9	NE	NE
Graphite	Trace	007782-42-5	15 mppct (TWA)	2.5 mg/m^3

Physical Data

Boiling Point: N/A
Vapor Pressure: N/A
Vapor Density: N/A
Solubility in Water: Good
Specific Gravity: 1.70 - 1.82 (mercury method) andŠ 1.92 - 2.08 (pycnometer)
pH: 6.0-8.0
Evaporation Rate: N/A
Appearance and Odor: Black granular powder. No odor detectable.

Hazardous Reactivity

Instability: Keep away from heat, sparks, and open flame. Avoid impact, friction, and static electricity.
Incompatibility: When dry, black powder is compatible with most metals; however, it is hygroscopic, and when wet, attracts all common metals except stainless steel. Black powder must be tested for compatibility with any material not specified in the production/procurement package with which they may come in contact. Materials include other explosives, solvents, adhesives, metals, plastics, paints, cleaning compounds, floor and table coverings, packing materials, and other similar materials, situations, and equipment.
Hazardous Decomposition: Detonation produces hazardous overpressures and fragments (if confined). Gases produced may be toxic if exposed in areas with inadequate ventilation.
Polymerization: Will not occur.

Fire and Explosion Data

Flashpoint: N/A
Auto Ignition Temperature: Approximately 464 C (867 F)
Explosive Temperature (5sec): Ignites at approximately 427 C (801 F)
Extinguishing Media: Water
Special Fire Fighting Procedures: ALL EXPLOSIVES: DO NOT FIGHT EXPLOSIVES FIRES. Try to keep fire from reaching explosives. Isolate area. Guard against intruders.

- Division 1.1 Explosives (heavily encased): Evacuate the area for 5000 feet (1 mile) if explosives are heavily encased.
- Division 1.1 Explosives (not heavily encased): Evacuate the area for 2500 feet (½ mile) if explosives are not heavily encased.
- Division 1.1 Explosives (all): Consult the 2000 Emergency Response Guidebook, Guide 112 for further details.

Unusual Fire and Explosion Hazards: Black powder is a deflagrating explosive. It is very sensitive to flame and spark and can also be ignited by friction and impact. When ignited unconfined, it burns with explosive violence and will explode if ignited under even slight confinement.

Health Hazards

General: Black powder is a Division 1.1 Explosive, and detonation may cause severe physical injury, including death. All explosives are dangerous and must be handled carefully and used following approved safety procedures under the direction of competent, experienced persons in accordance with all applicable federal, state, and local laws, regulations, and ordinances.
Carcinogenicity: None of the components of Black powder are listed as a carcinogen by NTP, IARC, or OSHA.

First Aid

Inhalation: Not a likely route of exposure. If inhaled, remove to fresh air. If not breathing, give artificial respiration, preferably by mouth-to-mouth. If breathing is difficult, give oxygen. Seek prompt medical attention.
Eye and Skin Contact: Not a likely route of exposure. Flush eyes with water. Wash skin with soap and water.
Ingestion: Not a likely route of exposure.. If ingested, induce vomiting immediately by giving two glasses of water and sticking finger down throat.
Injury from Detonation: Seek prompt medical attention.

Spill or Leak Procedures

Spill/Leak Response: Use appropriate personal protective equipment. Isolate area and remove sources of friction, impact, heat, low level electrical current, electrostatic or RF energy. Only competent, experienced persons should be involved in cleanup procedures. Carefully pick up spills with non-sparking and non-static producing tools.
Waste Disposal: Desensitize by diluting in water. Open train burning, by qualified personnel, may be used for disposal of small unconfined quantities. Dispose of in compliance with federal regulations under the authority of the Resource Conservation and Recovery Act (40 CFR Parts 260-271).

Special Protection Information

Ventilation: Use only with adequate ventilation.
Respiratory: None
Eye: None
Gloves: Impervious rubber gloves
Other: Metal-free and non-static producing clothes

Ammonium Perchlorate Composite Propellant (APCP)

Product Name: Ammonium Perchlorate
Other/Generic Names: AP, ammonium salt of perchloric acid
Product Use: Analytical chemistry, oxidizer in various propellant or explosive mixtures, various industrial uses involving need for oxidizing or ionization in aqueous solution properties.

Manufacturer: American Pacific Corporation, Western Electrochemical Co. 10622 West 6400 North, Cedar City, UT 84721
For More Information Call: (435) 865-5000
In Case of Emergency Call: (435) 865-5044

Ingredient Name	CAS no.	Einecs no.	Wt. %
Ammonium Perchlorate	7790-98-9	232-235-1	100

OSHA Hazard Communication Standard: This product is considered hazardous under the OSHA Hazard Communication Standard. The stated hazards classifications are applicable to the ammonium perchlorate as manufactured by AMPAC and as delivered in the DOT/UN approved shipping containers. Any rework, modification, amending or additional processing of the ammonium perchlorate may change the hazards classification and may require further hazards classification testing to determine the appropriate classification. AMPAC will not be responsible for personnel or property damage caused by a failure to conduct or provide adequate safe measures needed due to any individual company's production activities.
Emergency Overview: An odorless white crystal material. Perchlorate is an Oxidizing Agent; there is a risk of explosion if heated under confinement. As with any toxicant, dose and exposure are critically important variables to understand any potential treatment. Harmful if swallowed or inhaled in large doses.
Potential Health Effects:

- **Acute (short term):** Eye contact causes irritation, redness, and tearing. Skin contact causes irritation to mucous membranes and skin. Inhalation may cause respiratory tract irritation such as coughing, and shortness of breath; high concentrations may cause more significant respiratory effects. Ingestion: may cause gastrointestinal irritation; larger doses may cause nausea and vomiting.
- **Chronic (long term):** Perchlorates act to reversibly and competitively inhibit iodine uptake by the thyroid gland. Perchlorate is soluble in water, so exposure to ammonium perchlorate can be via water contaminated with ammonium perchlorate or inhalation in the workplace. With chronic exposure given sufficient dose (see NRC, 2005) and duration, ammonium perchlorate can cause thyroidal stores of iodine to be reduced, which may lead to hypothyroidism. For those individuals that live in areas of the world where endemic iodine deficiency occurs, it is important that these people receive adequate iodine in the diet or are supplemented with iodine.

May be explosive when mixed with combustible material. Risk of explosion if heated under confinement.

Routes of Exposure	Signs and Symptoms of Exposure:	Emergency and First Aid Procedures:

Skin:	May cause local irritation or stinging effect.	Wash exposed area immediately with plenty of water. Remove contaminated clothing and footwear.
Inhalation:	Airborne concentrations of ammonium perchlorate can aggravate pre-existing respiratory problems.	If experiencing breathing difficulties, move to fresh air. Administer oxygen if exposed person is unconscious such as mouth to mouth resuscitation. Never give anything by mouth to an unconscious person.
Ingestion:	Ingestion of large quantities has been reported to cause staggering in small mammals. Chronic ingestion of sufficient quantities may interfere with uptake of iodine by the thyroid.	Give water. Induce vomiting, keep airway clear. Seek medical attention.
Eyes:	Irritation of the eyes will cause stinging effect.	Flush eyes with fresh water for at least 15 minutes and move exposed person to a non-contaminated area.

Flash Point: Not flammable
Flash Point Method: Not applicable
Autoignition Temperature: Not applicable. Ammonium perchlorate decomposes spontaneously at 300o C in its pure state. Contaminants may cause decomposition at lower temperatures typically down to 2700C but decomposition temperature has been listed as low as 240oC in one case
Upper Flammability Limit (volume % in air): Not applicable.
Lower Flammability Limit (volume % in air): Not applicable.
Extinguishing Media: Water - other extinguishing materials are ineffective
Unusual Fire and Explosion Hazards: Ammonium perchlorate is an oxidizing agent and may cause rapid combustion or explosions if mixed with fuels, including organic materials or powdered metals. This does not include DOT shipping containers if intimate mixtures are not present and the shipping container is not inordinately contaminated. Plastic containers have been observed to burn and leave standing cylinders of ammonium perchlorate. Molten metal from aluminum containers may contribute fuel in an instance hot enough to melt aluminum.
Special Fire Fighting Precautions/Instructions: Do not fight fires involving mixtures of ammonium perchlorate and fuels. Ammonium perchlorate is an oxidizing agent and may cause rapid combustion or explosions if mixed with fuels. Burning ammonium perchlorate may produce chlorine, chlorine dioxide, hydrogen chloride, and oxides of nitrogen as well as mixtures with any other compounds involved in the combustion. These are common by-products of

combustion and are likely to be serious health concern; thus, keep upwind or wear self-contained breathing apparatus when attempting to rescue.

In Case of Spill or Other Release: (See section 8 for recommended personal protective equipment.) Sweep up material and containerize. Clean contaminated floor surface with water. Ammonium perchlorate is water soluble; thus, manage water to avoid release into the environment. Dispose of in accordance with local, state, and federal regulations.

Normal Handling: (See section 8 for recommended personal protective equipment.) Avoid contact with skin, eyes and clothing. Avoid breathing dust. Wash thoroughly after handling and follow good personal hygiene and good housekeeping practices. Keep containers closed. Handle in a manner to minimize dusting. Use of containers that meet the requirements to be DOT approved shipping containers which are managed in a manner to inhibit intimate mixtures of the container material with the product is recommended. Materials such as plastic drums, steel drums, flexible intermediate bulk containers, and fiberboard containers approved or constructed to the same specifications as DOT requirements are normally safe. FIBC are normally constructed of plastic materials in which intimate contamination soaked into the plastic is difficult to achieve. If in doubt wet and wash the FIBC and manage the water used to wash in accordance with good environmental principles to avoid contaminating drinking water sources or organic materials more subject to intimate mixtures.

Storage Recommendations: Store away from combustibles and flammables. Keep container closed when not in use. Control static electricity and other ignition sources. Store in dry areas away from sources of extreme heat.

Special Mixing and Handling Instructions: Ground and bond process equipment. Mixing ammonium perchlorate with fuels of any type may result in rapid combustion or explosions. When handling materials contaminated with ammonium perchlorate such as dust collector bags or any other combustible material, thoroughly wet the bags with water before handling, keep the bags wet while handling, and use non-sparking tools or tools coated with non-sparking material if non-sparking tools are not available. AVOID friction, impact, or static electricity ignition sources when organic materials are contaminated with ammonium perchlorate. Fire resistant fabrics do not reduce the hazard. Finely powdered metals are frequently as combustible with ammonium perchlorate as are organics.

Engineering Controls: Ventilate as necessary to minimize dust exposures. Inspect and clean ventilation systems regularly.

Personal Protective Equipment Skin Protection: Wear impervious aprons or rain gear to reduce contamination of cotton or other fiber clothing. Plastic, rubber or latex gloves are recommended. Leather or cotton gloves should not be used unless a management program is implemented to ensure detection of contamination and immediate cleaning and change in case of contamination. Cotton clothing may be used if chance of contact is minimal or if clothing is monitored for contamination and changed if contamination occurs. In any case where combustible protection is used, a strong management system must be in place to monitor contamination and ensure appropriate removal and cleaning or severe risk of fire and personal injury or death exists. There are no known cloth materials that will not combust vigorously with perchlorates including nomex, Kevlar based materials, or clothing that is normally considered fire retardant or resistive. Observation and management of contamination is the only practicable safety measure. See additional recommendations below.

- **Eye Protection:** Under normal conditions, wear safety glasses. Under dusty conditions, wear chemical safety goggles.
- **Respiratory Protection:** Under normal conditions, not required. Where dusty conditions develop, use a NIOSH approved respirator for dusts.
- **Additional Recommendations:** Avoid contamination of cotton or other absorbent material. As in any industrial working environment, workers should routinely wear clean clothes to work. Do not wear any work clothing that has become contaminated with ammonium perchlorate. Remove contaminated clothing immediately and keep wet until thoroughly washed. Keeping contaminated clothing wet minimizes hazards until the laundering is completed. Showering is recommended after handling any industrial chemical. Smoking of tobacco should not be permitted while wearing contaminated clothing. Leather boots may become contaminated and could be a source of combustion damaging feet. Rubber boots are recommended unless a very strict management program to detect contaminated leather boots is in place much as listed on the glove section above.

Appearance: White Crystal	**Physical State:** Solid	**Molecular Weight:** 117.50	**Chemical Formula:** NH_4ClO_4	**Odor:** None
Specific Gravity (water = 1.0): 1.95	**Solubility in Water (weight %):** 20.8 g/100 ml at 20 C	**pH:** Materials is a solid however, dissolved in water the pH is slightly acidic	**Boiling Point:** None, rather it decomposes	**Melting Point:** Decomposes at 300 C in its pure state, impurities may lower the decomposition temperature significantly.
Vapor Pressure: Solid, none	**Vapor Density (air = 1.0):** At 20 C, None	**Evaporation Rate:** None		
Flash Point: Not flammable				

Normally Stable (Conditions To Avoid): Stable under normal conditions. Do not mix with organic materials, reducing agents, metal powders or powdered carbon. Avoid elevated temperatures over 270°C, which can cause spontaneous exothermic decomposition. Cloth fabric of any type including dust collector bags intimately contaminated with ammonium perchlorate is subject to ignition through friction or impact. High-energy static electricity may also serve as an ignition source when contamination or combustibles are intermixed.
Incompatibilities: Sulfuric acid, powdered metals, and intimate mixtures with organics.
Hazardous Decomposition Products: Chlorine, chlorine dioxide, oxygen, nitrogen oxides, hydrogen chloride.
Hazardous Polymerization: Will not occur.

As with any toxicant, dose and exposure are critically important variables to understand any potential toxicity. It is always advisable to minimize dusting and use respiratory protection for environments where substantial dust is generated or where there may be exposure to water with high concentrations of perchlorate. Ammonium perchlorate acts to reversibly and competitively inhibit iodine uptake by the thyroid gland. The half-life of ammonium perchlorate ranges from 8 to 12 hours. Ammonium perchlorate does not bioaccumulate. Perchlorate is not metabolized and is excreted from the kidneys. Harmful if swallowed or inhaled in large doses. In the early 1960s another salt of perchlorate, potassium perchlorate, given in very high doses for weeks of exposure as an oral therapeutic agent to treat hyperthyroidism was reported to be associated with a few cases of aplastic anemia and agranulocytosis (National Research Council, 2005). Since that time, there have been no known reports of aplastic anemia. There have been no reports of ammonium perchlorate associated with aplastic anemia or agranulocytosis.
Immediate (Acute) Effects: Oral LD50: rat; 4200 mg/kg Rat-par-LDLo = 3500 mg/kg Oral LD50: rabbit; 1900 mg/kg Rabbit-par-LDLo = 750 mg/kg Inhalation LC50: No references found. Skin sensitization: not reported to be a skin sensitizer
Delayed (Subchronic And Chronic) Effects:

- **Thyroid:** No long-term health effects have been reported with exposure to ammonium perchlorate. Perchlorate is water soluble, so exposure to ammonium perchlorate can be via water contaminated with ammonium perchlorate or inhalation in the workplace. With chronic exposure, sufficient dose, and duration, ammonium perchlorate may cause thyroidal stores of iodine to be reduced, which may lead to goiter (enlarged thyroid gland) and hypothyroidism. Occupational studies indicated no adverse health effects on workers exposed for 3 years or more to perchlorate. These studies also demonstrate that blood chemistry and hormone values are not altered with occupational exposures as high as 0.48 mg per kilogram body weight (Braverman et al., 2005; Lamm et al., 1999). In 2005, a National Academies of Science Committee reviewed the literature and oral exposures to perchlorate and identified a no-observable-adverse-effect-level 0.4 mg/kg/day in humans. That dose is inhibits iodide uptake by nearly 70 percent without effecting thyroid hormones or thyroid stimulating hormone. The NAS also identified a no-observed-effect-level of 0.007 mg/kg/day in humans, based on Greer, et. al. 2002, which is a dose that does not cause inhibition of iodide uptake. For those individuals that live in areas of the world where endemic iodine deficiency occurs, it is important that these people receive adequate iodine in the diet or are supplemented with iodine.

4.3 Preliminary Failure Modes and Effects Analysis

Battery for the rover (payload) explodes or fail.	The rocket can be damaged, forcing a complete redesign and new	9	Incorrect wiring or the battery cannot withstand certain	1	The team decided to switch to a 9 volt battery to better suit the payload. A checklist will be followed when

	construction process.		malfunctions in the coding.		constructing the rocket so no incorrect actions will occur.
The Rover fails to deploy after landing	Experiment cannot be conducted. Sparking could occur within the rocket.	5	Wiring is incorrect. Battery was not activated, or no connection in the circuit.	1	A checklist will be followed during construction and when preparing the rocket to launch.
The rocket does not fly in a stable manner.	Altitude might not be met. Damage to the rocket can occur. The rocket will fly uncontrollably, possible hurting someone.	6	While constructing the rocket, mass change might have occurred. During the design process, stability margin might not have been considered. Weather conditions also influence instability.	3	Stability margin is always looked at when designing the rocket and when making any changes to that design. Weather conditions will be monitored, and the rocket will not be launched in unsafe conditions.
Rocket components and pieces are not constructed properly (Right length is not cut, epoxy is not well applied, screws are not screwed in properly, electronics are not wired correctly, etc.).	When launched, inconsistent flights could take place, rocket electronics will not function properly, and rocket could combust.	7	Team members are not paying attention and giving close detail during the construction process. Team members are unclear of proper process of construction or the putting together of the rocket.	2	Checklists will be made and each team member working on a certain part of the rocket will be checked by another member to ensure safety and proper execution.

4.4 Environmental Concerns

Potential Issues/ Failure Mode	Potential Failure Effects	Severity (1-10)	Potential Causes	Occurrence (1-10)	Mitigation
Wind speeds are unsuitable for launching the rocket.	If rocket is launched, rocket will fly in an unstable manner, making it difficult for performing proper tasks.	6	Environmental conditions are not suitable and worsen as the day proceeds at Lucerne Dry Lake.	6	Launch rail can be tilted at an angle that is with the wind in correlation with the speed of the wind. If wind speeds are too strong, the team will wait for conditions to improve.
Rain falls when the rocket is on the launch pad or in preparation.	Drag increases, resulting a possible lower altitude for the rocket. Stability also decreases.	5	Weather conditions are not suitable.	4	Rocket will be launched if rain is light; if rain is too strong, the team will wait for conditions to improve.
A fire can spread to the surrounding environment.	The launch site can catch on fire, resulting in damage to the nature.	9	Rocket can malfunction and once it lands, a fire can begin. Malfunction of the motor, sparks or ignition can set the rocket on fire.	0	If the rocket does catch on fire in any way, no parts of the environment will catch on fire. There is only dirt at Lucerne Dry Lake for miles. No grass is near the launch site.
The rocket will affect trees, power lines, buildings, or people not involved in the launch.	The rocket could hurt people near the launch site who are not aware. It may cause additional damage to the	9	If the rocket is not stable, if may go off in the wrong path. Instability can be caused by the weather or rocket design.	1	There are no power lines, trees, or buildings within miles of the launch site. People nearby will be warned prior to the launching of the rocket. Stability margin of rocket will be made sure to be within safe limits during the design process.

	surrounding environment.				
Rocket components are harmful to the environment in terms of air and land pollution.	The team will be contributing to pollution and its harmful effects on the surrounding nature and the earth's population.	1	During the construction of the rocket, the team may come across disposable material such as electronics, batteries, and other rocket parts. After launching the rocket, the motor cannot be used again and must be disposed.	1	The team will dispose batteries and motors at Higgins Environmental in Huntington Beach to promote environmental awareness.
Ammonium perchlorate composite motors that are not disposed of safely pose a threat to human and environmental safety.	The team will contribute to the pollution of the ground and affect surrounding ecosystems by leaving used up motors in the environment. This can release hydrogen chloride, which, mixed in water, can create hydrochloric acid. The acid is corrosive and can acidify soil and water.*	1	After a motor has been used, the team could leave a motor behind without noticing.	3	The team will promptly remove the motor and place it in a designated bag to take to a nearby disposal center that will properly dispose of the motor. The team will also scout the area they occupied for any trash and dispose of the trash as well.

More epoxy resin than necessary is left out in the environment or disposed of improperly.	The epoxy could result in dermatitis, chemical burns, respiratory irritation, and environmental pollution. #	1	The team overestimated how much epoxy they could use.	1	The team must consistently underestimate the total volume of epoxy resin they will use during the construction of the rocket. To prevent pollution, the team will take excess epoxy resin and the supplies that were used in mixing the resin to a nearby waste disposal center.

*Source: wikipedia.org
#Source: westsystem.com

The nearby waste disposal center in Irvine is the Irvine Collection Center.

4.5 Risks and Mitigations

4.5.1 Vehicle Risks and Mitigations

Possible Hazards/Accidents	Mitigations
The engine fails to ignite when launching the rocket.	Team members will make sure that the igniter is inserted into the engine completely, securing the connection between the engine and the igniter.
The engine is too loose or tight for the motor casing.	Team members will make sure the motor casing matches the corresponding engine size and that the motor casing fits into the motor mount without being too loose or too tight.
The air brakes don't function in flight.	Electronics will be activated at ground level for a test of the air brakes functions. Before the assembly of the whole rocket, the motor for the air brakes will be checked for its functions.
The rocket body bends inward on itself.	The materials used for the body tubes is fiberglass, which can stand against considerable amounts of outside forces. The flight boards, bulkheads, and centering rings on the inside of the body tubes will also support the circular structure of the body tube.
The quick links are not attached securely.	Team members will ensure that all connections between the body tubes and other parts of the rocket are assembled correctly before launching.

	A checklist will be written for the above tasks, members will be checking and signing off each of the tasks when completed.
The ejection charge does not have enough force to shear the shear pins.	The force required to shear the pins will be accurately noted when they are purchased. Black powder ground tests will be performed to make sure that the force provided from the ejections charges exceeds the force that the pin can withstand. To further make sure that the pin will shear, the backup charge will provide a greater force.
The electronic matches move outside of their specified area.	Team members will make sure that the matches are tightened in their specified area before attaching the shear pins. This task will be placed on the pre-launch checklist.
The motor explodes.	As a high school team, we are not allowed to build the motor and the construction of said motor will be done by a certified individual. The team will ensure that while the motor is in our hands, assuming that it has been assembled correctly, the motor will not be damaged nor will we alter the motor in a way that could cause a malfunction.
Parachute does not deploy because of packing issues.	Team members will check that the parachute is packed correctly into the body tube before launch and make sure the ejection charges will separate the body tubes when parachute is ready to deploy via black powder tests.

4.5.2 Payload Risks and Mitigations

Possible Hazards/Accidents	Mitigations
The camera malfunctions.	Team members will make sure the camera is turned on and functions correctly before the launch.
Batteries are not fully charged.	Team members will make sure to charge battery to max capacity before launch

Batteries fail.	Before launch, team members will use a voltmeter to check if the battery is functional and fully charged.
Payload doesn’t deploy	Before launch, the release mechanism of the sabot will be checked by team members to see if the payload can be released.
The wheels don’t move.	The payload will be tested by team members before the launch to see if the wheels can spin freely and move the rover on ground.
Payload unable to move on ground due to dirt.	The payload is equipped with a mechanism that scoops the dirt of the wheels after ever rotation, however, it will still be tested before the launch to see if the mechanism is capable of clearing the dirt of the wheels.
Payload deploys early due to loose sabot.	Team members will make sure that the sabot is not damaged or loose before the launch to ensure the rover doesn't drop from the rocket.

4.5.3 Recovery Risks and Mitigations

Possible Hazards/ Accidents	Mitigations
The backup charges do not go off.	Team members will check if the RRC3 is beeping in the sequence that is shown on the manual.
The backup electronics batteries disconnect.	Battery holders and zip ties will be used to secure the battery in its position. The sturdiness of the battery holder and zip ties will be check before every launch by team members.
The backup RRC3 flight computers are shut down.	Team members will check if the flight computers are beeping and and signing their names on the checklist.
The drogue chute deployed at the incorrect altitude.	Team members will check that RRC3 and the Stratologger are both beeping in their respective sequences as shown on their manuals.
The air brakes not closing during descent and influencing the recovery.	Team members will upload the most recent code from the computer to the arduino and check if the arduino’s respective LED light is blinking.

The drogue chute doesn't deploy.	Team members will make sure the electronics are turned on and check if they are beeping, and members who checked will sign on the checklist. The backup ejection charge can also resolve this issue.
The main chute doesn't deploy.	Solutions include both the backup Flight Computer and the backup ejection charges.
The Stratologger CF Flight Computer is shut down.	Team members will check the Stratologger is beeping in its respective sequence as shown on the manuals, they will sign their names on the checklist after.
The main battery disconnect.	Brand new batteries will be used, and a test will be contacted right before the launch to see if all of the electronics can be powered up correctly.

5 Payload Criteria

5.1 Selection, Design, and Rationale of Payload

5.1.1 Objective

The objective of this rover is tog scan the vehicle for damage that can prevent us from continuing our launch or can inform us of what needs to be fixed before the next launch. Through this we will be upholding the safety of our project by making sure that our rocket is intact for future flight and if it isn't the problem area can be identified and repaired before we continue with our launches.

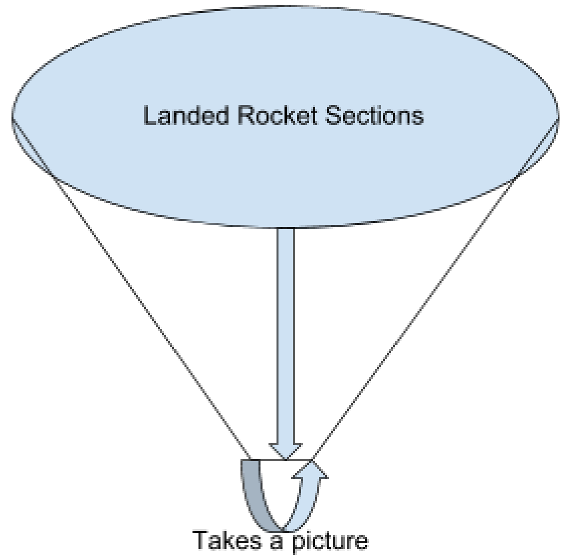
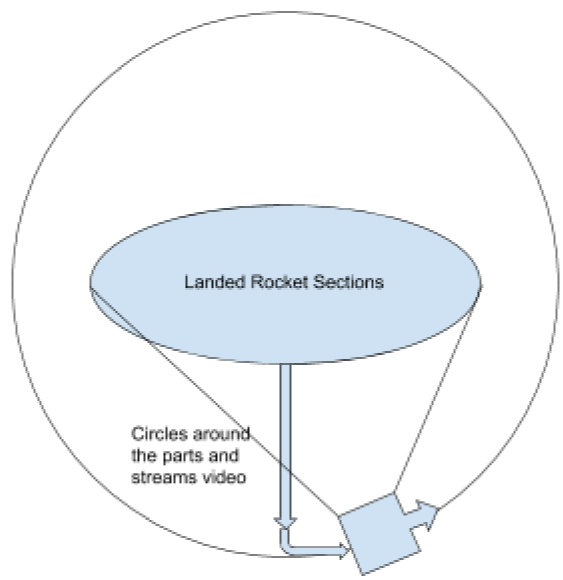
5.1.2 Success Criteria

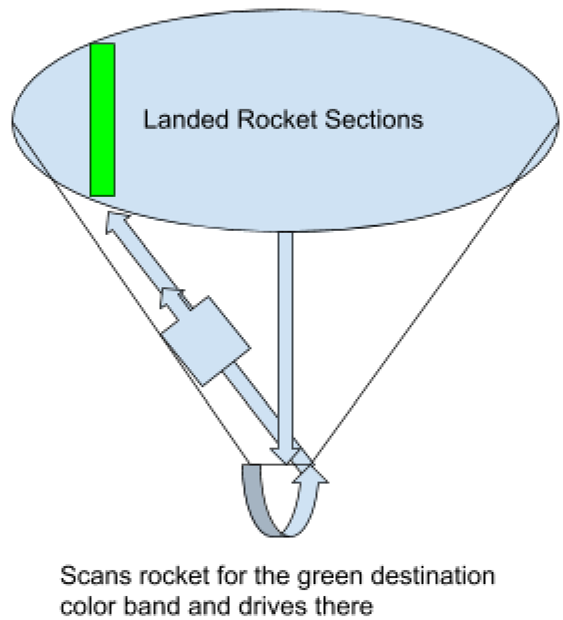
The rover must stop within one feet of the color band at the end of its run.

5.1.3 System Design Review

5.1.3.1 Alternative Designs

All the rover task designs will start with the rover being released from the sabot, move five feet from the sabot, and finally making a 180 degree turn. Below is a table with the alternate task options that we considered for the rover after making its U-turn.

Alternate Task Description	Diagram
Rover snaps a picture of the remaining rocket parts.	
Rover circles around the rocket parts with the camera pointing at the parts. The live video will be relayed back to ground stations.	

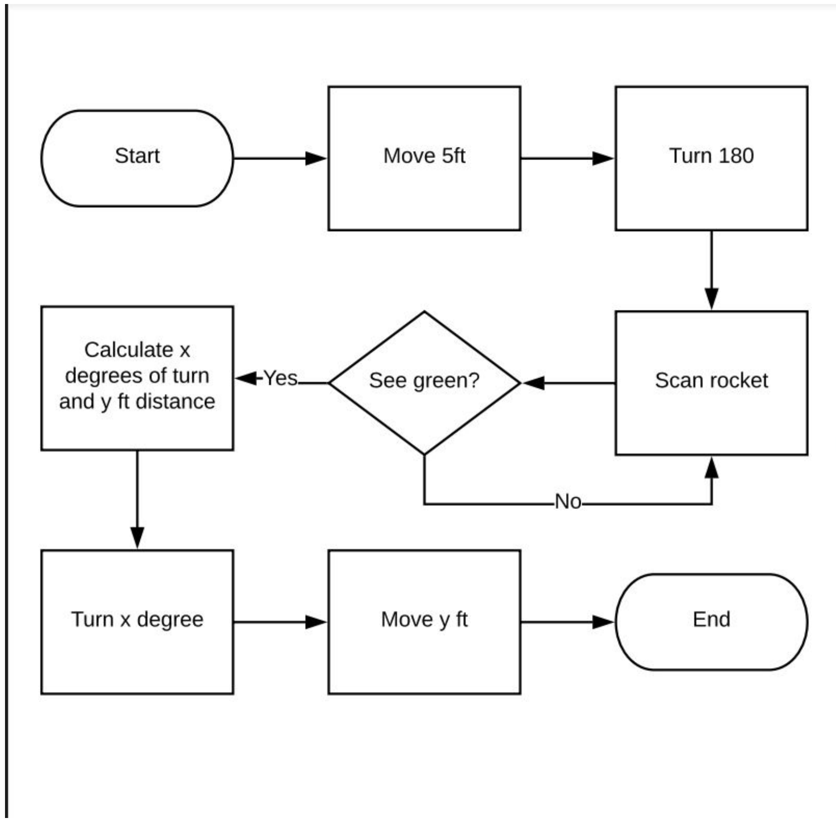
Rover scans rocket for green color band and moves to it by calculating the angle it needs to turn and the distance it needs to travel.	

5.1.3.1.1 Alternative Design Research

5.1.3.2 Current Leading Alternatives

The final chosen task for the rover that we are building is going to be scanning the landed rocket parts for a color band and driving to that part as the destination. A raspberry pi and a camera will be equipped and the computer vision element of the design will be coded using the OpenCV library.

5.1.4 System Diagrams and Schematics



5.1.5 Justification of Design Selections

The payload needed to be challenging but doable. The rover that only takes a picture of the separated parts after the rocket lands was the initial design, but after multiple considerations, the payload team decided that it was too simple. Therefore instead of only taking a picture, the payload team decided to scan the entirety of the rocket parts using the rover by having it loop around the rocket after it lands and stream the video back to the team. This seemed like a good idea at first, but there existed too many uncontrollable factors. The way that the rocket lands is random and unpredictable, which requires us to maximize the radius of the circular course that the rover will take, thus also increasing the risk of encountering obstacles such as plants, rocks, and bumps, which can easily lead to the rover going off track. The task that the team finally decided on was to have color band on one of the tubes of the rocket and will incorporate computer vision to identify the color and have the rover move in front of that specific body tube. Although it seems like an easy concept, it is quite hard to accomplish with team members having little to no experience with the raspberry pi and computer vision, which poses a decent amount of challenge to the team.

5.1.6 Interfaces Between Payload and Launch Vehicle

The rover will stay inside the body tube next to the nose cone during flight and will be secured in a sabot. When the main parachutes deploy, the sabot that holds the rover payload would be pulled out from the body tube but still connected to the body tube via the tether. Once the rocket lands, the sabot will release the rover, and the rover will roll out to perform its task.

6 Project Plan

6.1 Requirements Verification

6.1.1 Verification Plans

6.1.1.1 General Verification Plan

6.1.1.2 Vehicle Verification Plan

To test the vehicle, we shall perform a series of analyses to ensure that it works properly. To make sure that the rocket is designed properly, we will place the design in RockSim 9 to predict the rocket's behavior, such as its velocity at rail exit. We will also calculate the drift of the design, its kinetic energy at which it lands, and, and its stability margin.
If the rocket is unable to perform correctly in simulation or fails to meet the SL requirements for safe ascent and descent, then we will continue adjusting the rocket until it reaches SL requirements.

6.1.1.3 Recovery System Verification Plan

Testing for the avionics bay is fairly straightforward, as it requires the teammates to listen to a specific series of beeps from the flight computers to ensure their functionalities. For the stratologger, there should be seven sets of beeps, in the following manner:

Present number - 1 through 9
Main Deploy Altitude
Long beep if Apogee delay set
Altitude of last flight (Warble = Power lost)
Battery Voltage
Continuity beeps (repeats every 0.8 seconds)
    Zero beeps = no continuity
    One beep = Drogue OK

Two beeps = Main OK
Three beeps = Drogue + Main OK (ideal scenario)

For the RRC3, the continuity check is the following:

5 second long beep (init mode)
10 second baro history init time (silence)
Settings beep (when enabled) or POST fault code beep (if a fault, see POST fault codes)
10 second launch commit test time (silence)
Launch Detect mode (continuity beeps)
A long beep indicates no continuity on any event terminal.
One short beep indicates continuity on only the drogue terminal.
Two short beeps indicate continuity on only the main terminal.
Three short beeps indicate continuity on the main and drogue terminals.

6.1.1.4 Payload Verification Plan

6.1.1.5 Safety Verification Plan

To ensure safety, all guidelines and plans will be followed.

6.1.2 Team Derived Requirements

6.1.2.1 Vehicle Requirements

For the vehicle to be successful, the rocket must fly up to 4700 feet and return successfully and safely within a mile of the launch pads.

6.1.2.2 Recovery Requirements

For the recovery to be successful, the parachutes must deploy at their designated times and the main chute must deploy after the rocket has descended to at least 1000 feet. The parachutes must also detach via the 3-ring method after the rocket lands to ensure the payload will not get caught.

6.1.2.3 Payload Requirements

For the rover payload the team selected to be successful, it must deploy only after the rocket has landed. It then must move 5 feet from the rocket and be able to determine which direction it must face and move as well as take images of the rocket.

6.2 Budget

Description	Unit Cost	Qty	Subtotal	
Subscale Vehicle				
3" Fiberglass Frenzy XL	$226.95	1	$226.95	
3" Aluminum Bulkplate	$15.00	2	$30.00	
3" / 75 mm Black G10 Airframe Bulkplate	$5.00	12	$60.00	
3" / 75 mm Black G10 Coupler Bulkplate	$5.00	12	$60.00	
3" G12 Airframe (30")	$50.00	2	$100.00	
3" G12 Coupler (9")	$22.00	4	$88.00	
Total				**$564.95**
Fullscale Vehicle				
4" Fiberglass Frenzy XL	$369.95	1	$369.95	
4" Aluminum Bulkplate	$20.00	2	$40.00	
4" / 98 mm Black G10 Airframe Plate	$6.00	12	$72.00	
4" / 98 mm Black G10 Coupler Bulkplate	$6.00	12	$72.00	
4" G12 Airframe (30")	$58.00	2	$116.00	
4" G12 Coupler (12")	$32.00	2	$64.00	
4" G12 Coupler (9")	$24.00	3	$72.00	
Total				**$805.95**
Avionics/Recovery				
RRC3 Flight Computer	$69.95	1	$69.95	
StratologgerCF Flight Computer	$57.50	1	$57.50	
1" Tubular Nylon Green	$0.55	100	$55.00	
Iris Ultra 72" Compact Parachute - 28lbs @ 20fps; 15lbs @ 15fps	$265.00	1	$265.00	
18" Elliptical Parachute - 1.2 lb @ 20fps	$53.00	1	$53.00	
Key Switch - Type 3	$6.00	5	$30.00	

RBF4B Remove Before Flight	$6.00	5	$30.00	
Chute Blast Protector 12” x 12”	$8.95	1	$8.95	
Chute Blast Protector 18” x 18”	$11.95	3	$35.85	
Chute Blast Protector 6” x 6”	$6.95	1	$6.95	
Chute Blast Protector 9” x 9”	$7.95	3	$23.85	
Shock Cord Protector	$23.95	4	$95.80	
Parts Express 9V Battery Holder Metal Clip	$10.93	5	$54.65	
Total				**$786.50**
Payload				
Carbon Fiber Tube (hollow) 3x2x750mm	$2.10	5	$10.50	
4" Airframe A-Bay Bulkplate	$4.05	8	$32.40	
4" Couple A-Bay Bulkplate	$4.05	6	$24.30	
Total				**$67.20**
GPS				
Whistle GPS	$70.00	1	$70.00	
Cellular Service Fee (3 months free, 5 months to pay)	$40.00	1	$40.00	**$110.00**
Total				
Educational Outreach				
Facility Use	$30	1		
Materials for Outreach Event	$90	1		
Total				**$120**
Travel Fees (11 Members) (Estimated)				
Trips to Lucerne Dry Lake ($3.25/gallon, 128 mi)				
Trip to Huntsville (Roundtrip)	$380	11	$4,180	
Hotel at Huntsville ($120/night, 2 people per room, 6 days)	$120	36	$4,320	
Food ($25/day, 6 days)	$25	11	$1,650	

Total Travel Costs				**$10,150**
TOTAL ESTIMATED SLI PROJECT COSTS				**$12,604.30**

6.2.1 Funding Plan

Our goal this year is to obtain our funds from a variety of sources. One method will be through fundraising, such as fundraising via selling items such as boba milk tea from Lollicup or donuts from Krispy Kreme. Other methods also include, but are not limited to, asking for donations, requesting financial aid from local businesses and companies through explaining the goal of the team, and appealing for discounts from vendors relating to the project plan.

6.3 Timeline

Timeline can be found on the following sheets:
https://drive.google.com/open?id=1odzwu1sL2n5n08fKEGrLZkw3e2bZnt5_3HeKFwJZhsI

Appendix A: Statement of Work Cross-Reference

Section	Requirement in SOW	PDR Section
General Requirements		
1.1	Students on the team will do 100% of the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder or any variant of ejection charges, or preparing and installing electric matches (to be done by the team's mentor).	
1.2	The team will provide and maintain a project plan to include, but not limited to the following items: project milestones, budget and community support, checklists, personnel assignments, STEM engagement events, and risks and mitigations.	
1.3	Foreign National (FN) team members must be identified by the Preliminary Design Review (PDR) and may or may not have access to certain activities during launch week due to security restrictions. In addition, FN's may be separated from their team during certain activities.	
1.4	The team must identify all team members attending launch week	

	activities by the Critical Design Review (CDR). Team members will include:	
1.4.1	Students actively engaged in the project throughout the entire year.	
1.4.2	One Mentor (see requirement 1.13)	
1.4.3	No more than two adult educators.	
1.5	The team will engage a minimum of 200 participants in educational, hands-on science, technology, engineering, and mathematics (STEM) activities, as defined in the STEM Engagement Activity Report, by FRR. To satisfy this requirement, all events must occur between project acceptance and the FRR due date and the STEM Engagement Activity Report must be submitted via email within two weeks of the completion of the event. A sample of the STEM Engagement Activity Report can be found on page 33 of the handbook.	
1.6	The team will establish a social media presence to inform the public about team activities.	
1.7	Teams will email all deliverables to the NASA project management team by the deadline specified in the handbook for each milestone. In the event that a deliverable is too large to attach to an email, inclusion of a link to download the file will be sufficient.	
1.8	All deliverables must be in PDF format.	
1.9	In every report, teams will provide a table of contents including major sections and their respective sub-sections.	
1.10	In every report, the team will include the page number at the bottom of the page	
1.11	The team will provide any computer equipment necessary to perform a video teleconference with the review panel. This includes, but is not limited to, a computer system, video camera, speaker telephone, and a sufficient Internet connection. Cellular phones should be used for speakerphone capability only as a last resort.	
1.12	All teams will be required to use the launch pads provided by Student Launch's launch services provider. No custom pads will be permitted on the launch field. Eight foot 1010 rails and 12 foot 1515 rails will be provided. The launch rails will be canted 5 to 10 degrees away from the crowd on launch day. The exact cant will depend on launch day wind conditions.	
1.13	Each team must identify a "mentor." A mentor is defined as an adult who is included as a team member, who will be supporting the team	

	(or multiple teams) throughout the project year, and may or may not be affiliated with the school, institution, or organization. The mentor must maintain a current certification, and be in good standing, through the National Association of Rocketry (NAR) or Tripoli Rocketry Association (TRA) for the motor impulse of the launch vehicle and must have flown and successfully recovered (using electronic, staged recovery) a minimum of 2 flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to launch week. One travel stipend will be provided per mentor regardless of the number of teams he or she supports. The stipend will only be provided if the team passes FRR and the team and mentor attend launch week in April.	
	Vehicle Requirements	
2.1	The vehicle will deliver the payload to an apogee altitude between 4,000 and 5,500 feet above ground level (AGL). Teams flying below 3,500 feet or above 6,000 feet on Launch Day will be disqualified and receive zero altitude points towards their overall project score.	
2.2	Teams shall identify their target altitude goal at the PDR milestone. The declared target altitude will be used to determine the team's altitude score during launch week	
2.3	The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the Altitude Award winner. The Altitude Award will be given to the team with the smallest difference between their measured apogee and their official target altitude on launch day.	
2.4	Each altimeter will be armed by a dedicated mechanical arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	
2.5	Each altimeter will have a dedicated power supply	
2.6	Each arming switch will be capable of being locked in the ON position for launch (i.e. cannot be disarmed due to flight forces).	
2.7	The launch vehicle will be designed to be recoverable and reusable. Reuseable is defined as being able to launch again on the same day without repairs or modifications.	
2.8	The launch vehicle will have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute.	

2.8.1	Coupler/airframe shoulders which are located at in-flight separation points will be at least 1 body diameter in length	
2.8.2	Nosecone shoulders which are located at in-flight separation points will be at least ½ body diameter in length	
2.9	The launch vehicle will be limited to a single stage	
2.10	The launch vehicle will be capable of being prepared for flight at the launch site within 2 hours of the time the Federal Aviation Administration flight waiver opens.	
2.11	The launch vehicle will be capable of remaining in launch-ready configuration on the pad for a minimum of 2 hours without losing the functionality of any critical on-board components.	
2.12	The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system. The firing system will be provided by the NASA-designated launch services provider.	
2.13	The launch vehicle will require no external circuitry or special ground support equipment to initiate launch (other than what is provided by the launch services provider).	
2.14	The launch vehicle will use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).	
2.14.1	Final motor choices will be declared by the Critical Design Review (CDR) milestone	
2.14.2	Any motor change after CDR must be approved by the NASA Range Safety Officer (RSO) and will only be approved if the change is for the sole purpose of increasing the safety margin. A penalty against the team's overall score will be incurred when a motor change is made after the CDR milestone, regardless of the reason.	
2.15	Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria:	
2.15.1	The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be 4:1 with supporting design documentation included in all milestone reviews.	
2.15.2	Each pressure vessel will include a pressure relief valve that sees the full pressure of the tank and is capable of withstanding the maximum pressure and flow rate of the tank	

2.15.3	Full pedigree of the tank will be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank, by whom, and when.	
2.16	The total impulse provided by a College or University launch vehicle will not exceed 5,120 Newton-seconds (L-class). The total impulse provided by a High School or Middle School launch vehicle will not exceed 2,560 Newton-seconds (K-class).	
2.17	The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit. Rail exit is defined at the point where the forward rail button loses contact with the rail.	
2.18	The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit.	
2.19	All teams will successfully launch and recover a subscale model of their rocket prior to CDR. Subscales are not required to be high power rockets	
2.19.1	The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale will not be used as the subscale model.	
2.19.2	The subscale model will carry an altimeter capable of recording the model's apogee altitude.	
2.19.3	The subscale rocket must be a newly constructed rocket, designed and built specifically for this year's project.	
2.19.4	Proof of a successful flight shall be supplied in the CDR report. Altimeter data output may be used to meet this requirement.	
2.20	All teams will complete demonstration flights as outlined below;	
2.20.1	Vehicle Demonstration Flight - All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown must be the same rocket to be flown on launch day. The purpose of the Vehicle Demonstration Flight is to validate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight. A successful flight is defined as a launch in which all hardware is functioning properly (i.e. drogue chute at apogee, main chute at the intended lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full-scale demonstration flight:	
2.20.1.1	The vehicle and recovery systems will have functioned as designed	

2.20.1.2	The full-scale rocket must be a newly constructed rocket, designed and built specifically for this year’s project.	
2.20.1.3	The payload does not have to be flown during the full-scale Vehicle Demonstration Flight. The following requirements still apply:	
2.20.1.3.1	If the payload is not flown, mass simulators will be used to simulate the payload mass	
2.20.1.3.2	The mass simulators will be located in the same approximate location on the rocket as well as the missing payload mass	
2.20.1.4	If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale Vehicle Demonstration Flight.	
2.20.1.5	Teams shall fly the launch day motor for the Vehicle Demonstration Flight. The RSO may approve use of an alternative motor if the home launch field cannot support the full impulse of the launch day motor or in other extenuating circumstances.	
2.20.1.6	The vehicle must be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during the launch day flight. Additional ballast may not be added without a re-flight of the fullscale launch vehicle	
2.20.1.7	After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components will not be modified without the concurrence of the NASA Range Safety Officer.	

2.20.1.8	Proof of a successful flight shall be supplied in the FRR report. Altimeter data output is required to meet this requirement.	
2.20.1.9	Vehicle Demonstration flights must be completed by the FRR submission deadline. If the Student Launch office determines that a Vehicle Demonstration Re-flight is necessary, then an extension may be granted. This extension is only valid for re-flights, not first-time flights. Teams completing a required re-flight must submit an FRR Addendum by the FRR Addendum deadline.	

2.20.2	Payload Demonstration Flight - All teams will successfully launch and recover their full-scale rocket containing the completed payload prior to the Payload Demonstration Flight deadline. The rocket flown must be the same rocket to be flown on launch day. The purpose of the Payload Demonstration Flight is to prove the launch vehicle’s ability to safely retain the constructed payload during flight and to show that all aspects of the payload perform as designed. A successful flight is defined as a launch in which the rocket experiences stable ascent, the payload is fully retained during ascent and descent, and the payload is safely deployed on the ground. The following criteria must be met during the Payload Demonstration Flight:	
2.20.2.1	The payload must be fully retained throughout the entirety of the flight, all retention mechanisms must function as designed, and the retention mechanism must not sustain damage requiring repair.	
2.20.2.2	The payload flown must be the final active version.	
2.20.2.3	If the above criteria is met during the original Vehicle Demonstration Flight, occurring prior to the FRR deadline and the information is included in the FRR package, the additional flight and FRR Addendum are not required.	
2.20.2.4	Payload Demonstration Flights must be completed by the FRR Addendum deadline. No extensions will be granted.	
2.21	An FRR Addendum will be required for any team completing a Payload Demonstration Flight or NASA-required Vehicle Demonstration Re-flight after the submission of the FRR Report.	
2.21.1	Teams required to complete a Vehicle Demonstration Re-Flight and failing to submit the FRR Addendum by the deadline will not be permitted to fly the vehicle at launch week.	
2.21.2	Teams who successfully complete a Vehicle Demonstration Flight but fail to qualify the payload by satisfactorily completing the Payload Demonstration Flight requirement will not be permitted to fly the payload at launch week.	
2.21.3	Teams who complete a Payload Demonstration Flight which is not fully successful may petition the NASA RSO for permission to fly the payload at launch week. Permission will not be granted if the RSO or the Review Panel have any safety concerns.	
2.22	Any structural protuberance on the rocket will be located aft of the burnout center of gravity.	

2.23	The team's name and launch day contact information shall be in or on the rocket airframe as well as in or on any section of the vehicle that separates during flight and is not tethered to the main airframe. This information shall be included in a manner that allows the information to be retrieved without the need to open or separate the vehicle.	
2.24	Vehicle Prohibitions	
2.24.1	The launch vehicle will not utilize forward canards. Camera housings will be exempted, provided the team can show that the housing(s) causes minimal aerodynamic effect on the rocket's stability.	
2.24.2	The launch vehicle will not utilize forward firing motors.	
2.24.3	The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)	
2.24.4	The launch vehicle will not utilize hybrid motors.	
2.24.5	The launch vehicle will not utilize a cluster of motors.	
2.24.6	The launch vehicle will not utilize friction fitting for motors.	
2.24.7	The launch vehicle will not exceed Mach 1 at any point during flight.	
2.24.8	Vehicle ballast will not exceed 10% of the total unballasted weight of the rocket as it would sit on the pad (i.e. a rocket with and unballasted weight of 40 lbs. on the pad may contain a maximum of 4 lbs. of ballast)	
2.24.9	Transmissions from onboard transmitters will not exceed 250 mW of power.	
2.24.10	Excessive and/or dense metal will not be utilized in the construction of the vehicle. Use of lightweight metal will be permitted but limited to the amount necessary to ensure structural integrity of the airframe under the expected operating stresses.	
Recovery System Requirements		
3.1	The launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue-stage descent is reasonable, as deemed by the RSO.	

3.1.1	The main parachute shall be deployed no lower than 500 feet.	
3.1.2	The apogee event may contain a delay of no more than 2 seconds.	
3.2	Each team must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full-scale launches.	
3.3	At landing, each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf.	
3.4	The recovery system electrical circuits will be completely independent of any payload electrical circuits.	
3.5	All recovery electronics will be powered by commercially available batteries.	
3.6	The recovery system will contain redundant, commercially available altimeters. The term “altimeters” includes both simple altimeters and more sophisticated flight computers.	
3.7	Motor ejection is not a permissible form of primary or secondary deployment.	
3.8	Removable shear pins will be used for both the main parachute compartment and the drogue parachute compartment.	
3.9	Recovery area will be limited to a 2,500 ft. radius from the launch pads.	
3.10	Descent time will be limited to 90 seconds (apogee to touch down).	
3.11	An electronic tracking device will be installed in the launch vehicle and will transmit the position of the tethered vehicle or any independent section to a ground receiver.	
3.11.1	Any rocket section or payload component, which lands untethered to the launch vehicle, will contain an active electronic tracking device.	
3.11.2	The electronic tracking device(s) will be fully functional during the official flight on launch day.	
3.12	The recovery system electronics will not be adversely affected by any other on-board electronic devices during flight (from launch until landing).	

3.12.1.	The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.	
3.12.2	The recovery system electronics will be shielded from all onboard transmitting devices to avoid inadvertent excitation of the recovery system electronics.	
3.12.3	The recovery system electronics will be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.	
3.12.4	The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.	
Payload Experiment Requirements		
4.1	High School/Middle School Division – Teams may design their own science or engineering experiment or may choose to complete one of the College/University Division experiment options.	
4.5.1	Team-designed payloads must be approved by NASA. NASA reserves the authority to require a team to modify or change a payload, as deemed necessary by the Review Panel, even after a proposal has been awarded.	
4.5.2	Data from the science or engineering experiment will be collected, analyzed, and reported by the team following the scientific method.	
4.5.3	The experiment must be designed to be recoverable and reusable. Reusable is defined as being able to be launched again on the same day without repairs or modifications.	
4.5.4	Any experiment element that is jettisoned during the recovery phase will receive real-time RSO permission prior to initiating the jettison event.	
4.5.5	Unmanned aerial vehicle (UAV) payloads, if designed to be deployed during descent, will be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given permission to release the UAV.	
4.5.6	Teams flying UAVs will abide by all applicable FAA regulations, including the FAA's Special Rule for Model Aircraft (Public Law 112-95 Section 336; see https://www.faa.gov/uas/faqs).	

4.5.7	Any UAV weighing more than .55 lbs. will be registered with the FAA and the registration number marked on the vehicle.	
Safety Requirements		
5.1	Each team will use a launch and safety checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any launch day operations.	
5.2	Each team must identify a student safety officer who will be responsible for all items in section 5.3.	
5.3	The role and responsibilities of each safety officer will include, but are not limited to:	
5.3.1	Monitor team activities with an emphasis on Safety during:	
5.3.1.1	Design of vehicle and payload	
5.3.1.2	Construction of vehicle and payload	
5.3.1.3	Assembly of vehicle and payload	
5.3.1.4	Ground testing of vehicle and payload	
5.3.1.5	Subscale launch test(s)	
5.3.1.6	Full-scale launch test(s)	
5.3.1.7	Launch day	
5.3.1.8	Recovery activities	
5.3.1.9	STEM Engagement Activities	
5.3.2	Implement procedures developed by the team for construction, assembly, launch, and recovery activities.	
5.3.3	Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data.	
5.3.4	Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data.	

5.4	During test flights, teams will abide by the rules and guidance of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch does not give explicit or implicit authority for teams to fly those vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch.	
5.5	Teams will abide by all rules set forth by the FAA.	

Appendix B: Shop Safety Rules

<u>AIAA OC Section Shop Safety Rules</u>
<u>For all rocketry activities (Youth – TARC – modified for SLI)</u>

In an emergency, dial 911
California Poison Control Center: 1-800-222-1222

There is always a risk when someone is handling shop tools or is near another who is handling shop tools. Great precaution measures should always be taken. The following are the AIAA Orange County Section shop rules:

Generally:

- Keep work area orderly and clean; neatly arrange all equipment and material. Put all tools and materials back where they belong.
- Always think through an entire task before starting it, and never rush a process or take chances.
- If you are unsure about safety operation or process, ask for assistance from a program manager or mentor.
- At all times when using chemicals, X-Acto knives, electrical tools, or any tool that creates a danger of fumes or particles entering your eyes, wear safety glasses.
- Flammable liquids such as paints, solvents, and thinners must be stored in their original containers or in approved safety cans with flame arresters.
- If there are any unsafe conditions, report them to a program manager or mentor right away. Rely on the best of your own judgment and knowledge of safety to guide you.
- When lifting a heavy object, lift with your legs and not with your back; keep your back straight.
- Do not use an air hose for cleaning or dusting yourself off. Never point it towards anyone.
- If you have long hair, you must tie it back or keep it from falling down so it won't be caught in rotating tools.
- Horseplay of any kind is not allowed.

- Heavy glues and household chemicals should only be used in well ventilated areas; heavy sanding, painting, and use of chemicals are to be done outdoors.
- For documents that require work with potentially hazardous tools or operations, specific sections will be marked with the following: HAZARDOUS OPERATION – SEE SAFETY PLAN

Electrical Tools

- Do not work with power tools unless there is at least one other person in proximity.
- Before operating any machine or equipment, make sure that all safety guards are in place. The guards must be replaced as soon as repairs or servicing on a machine has been completed and put into operation.
- Never oil, remove guards, or attempt to repair machinery while it is on or in motion.
- Never use a rag near moving machinery.
- It is prohibited to tie down, block out, or otherwise make inoperative of any type of safety device, attachment method, or guard.
- Before energizing or operating any equipment, be sure to verify the safety of all personnel.
- When a machine is de-energizing for the purpose of changing the setup or making a minor adjustment, turn off the machine and pull the plug. Allow the machine to come to a complete stop before proceeding with your task.
- Do not handle electrical equipment while standing on damp or wet surfaces or when your hands are wet.
- Wear suitable clothing for the work that you are doing. Loose clothing, neckties, rings, watches, and even gloves can create a hazard when operating tools. Long sleeves or non-synthetic clothes should be worn when sparks or hot metal is present.

Appendix C: Launch Safety Rules

<u>AIAA OC Section Launch Safety Rules</u>
<u>For all rocketry activities (Youth – TARC – modified for SL)</u>

In an emergency, dial 911
California Poison Control Center: 1-800-222-1222

Our team rules completely comply with the rules stated above. The AIAA Orange County Sections rules are stated below and contain a table similar to the one included above.

- The lightweight materials that will be used are; paper, wood, rubber, plastic, fiberglass or only when it’s necessary, metal.
- The motors that will be used will be certified for commercially made rocket motors. They will not be tampered with or used for anything except for what is recommended by the manufacturer. Under no circumstances will there be smoking, open flames or any other heat sources within 25 feet of the motors.
- The rocket will be launched with an electrical launch system, and with electrical motor igniters that are installed when the rocket is on the launch pad or in the designated

prepping area. The launch system will have a safety interlock that is in series with the unactivated launch switch until the rocket is ready for launch and will use a launch switch that returns to the off position when released. If the rocket has an onboard ignition system for motors and or recovery devices, they will have safety interlock that interrupts the current path until the rocket is at the launch pad. If the ignition systems have a second battery and relay at the pad, then the batter will be disconnected while the rocket is placed on the launch pad, and the igniter will be connected to the launch system.

- The launcher that is used will be a stable device that provides rigid guidance until the rocket has gotten to a speed that ensures it will be stable in flight. It is also pointed within twenty degrees of vertical. If the wind is over five miles per hour, then the launcher length will permit the rocket to attain safe velocity before separating from the launcher. In addition, blast deflector will be used to prevent the motor's exhaust from hitting the ground. In accordance with the minimum distance table, there will be no dry grass around each launch pad.
- If the rocket does not launch, then the launcher's safety will interlock or disconnect the battery. After the launch attempt, we will wait sixty seconds before allowing anyone to approach the rocket. If the ignition system includes a second battery and relay at the pad, that battery will be disconnected before approaching the rocket.
- The rocket will be verified for stability, sound construction, and any previous damage before it is allowed to fly. The rocket will not have a total thrust more than 40,960 N-Sec.

- The launch pad area will be reviewed to make sure there is no one closer to the launch pad than the minimum distance table states. The sky will be checked above the launch site to make sure that there are no airplanes, helicopters, or aircrafts in the area before launching. Someone will state: “range is clear” and “sky is clear” before proceeding to launch. These statements will be followed by a five second countdown to warn anyone in the launch area.
- The rocket will not be launched between the hours of sunset and sunrise or in the dark.
- The rocket will be launched outdoors in opens area where trees, power lines, buildings and person(s) not involved in the launch do not represent a hazard. The lot side must be at least, on its smallest dimension, as one-half of the maximum altitude for which rockets are allowed to be flown at that site, or 1500 feet, whichever is greater.
- The rocket will not be launched at targets into clouds or obscuring phenomena, near airplanes or on trajectories that make it fly directly over the heads of spectators, or beyond the boundaries of the launch site. It will not have a flammable or explosive payload in the rocket.
- The rocket will not be launched to an altitude where the horizontal visibility is less than five miles or if winds exceed twenty miles an hour. The person(s) launching the rocket will fully comply with the Federal Aviation Administration airspace regulations when flying and will make sure our rocket does not exceed any applicable altitude limit in effect at the launch site.
- The launching location will be at least 1500 feet away from any inhabited building or public highway on which traffic flow exceeds ten vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.

- All spectators shall remain behind the person launching the rocket. No person(s) shall be closer to the launch that the minimum safe distance table. Additionally, no person(s) shall be closer to the launch of our rocket than the person who is actually flying the rocket.
- The rocket will use a recovery system so that all parts of the rocket return safely and undamaged and can be flown again. Only flame-resistant or fireproof recovery system wadding and heat shields will be used in our rocket.
- No person(s) will attempt to recover the rocket from power lines, tall trees, or other dangerous places. The rocket must be flown under conditions where it is likely to recovery in spectators areas or outside the launch site. No one will attempt to catch the rocket as it approaches the ground.
- The two jobs that exist to ensure safety are the range safety officer and the launch control officer.
- The RSO (Range Safety Officer): has the overall control and responsibility for the safety of the range and can shut down the launch site if is thought to be necessary. They are responsible to make sure that each rocket flown is safe to fly before it is launched. They make certain the fins and launch lug are present and securely fastened to the body tube. They make sure that the recovery system is functional and the engine is installed properly. Although all persons responsible for designing and building a rocket need to make certain it is safe to fly, the range safety officer has the ultimate responsibility.

  The RSO reserves the right to stop a launch for safety reasons.
- The LCO (Launch Control Officer) is responsible for supervising the actual launching of the rockets and that all conditions are safe to do so. This includes making sure that the launch pads are not armed when people are close to them. Before each launch they must check for people, including spectators, that might be in an unsafe location and check for nearby aircrafts. For the first launch of a rocket, or if the launch includes any unusual risks, the flight will be announced as a “Heads-Up” flight. This person must track each flight until the rocket returns to ground level. Again, although all persons are responsible for designing and building the rocket and need to take these same precautions, the launch control officer has the ultimate responsibility.