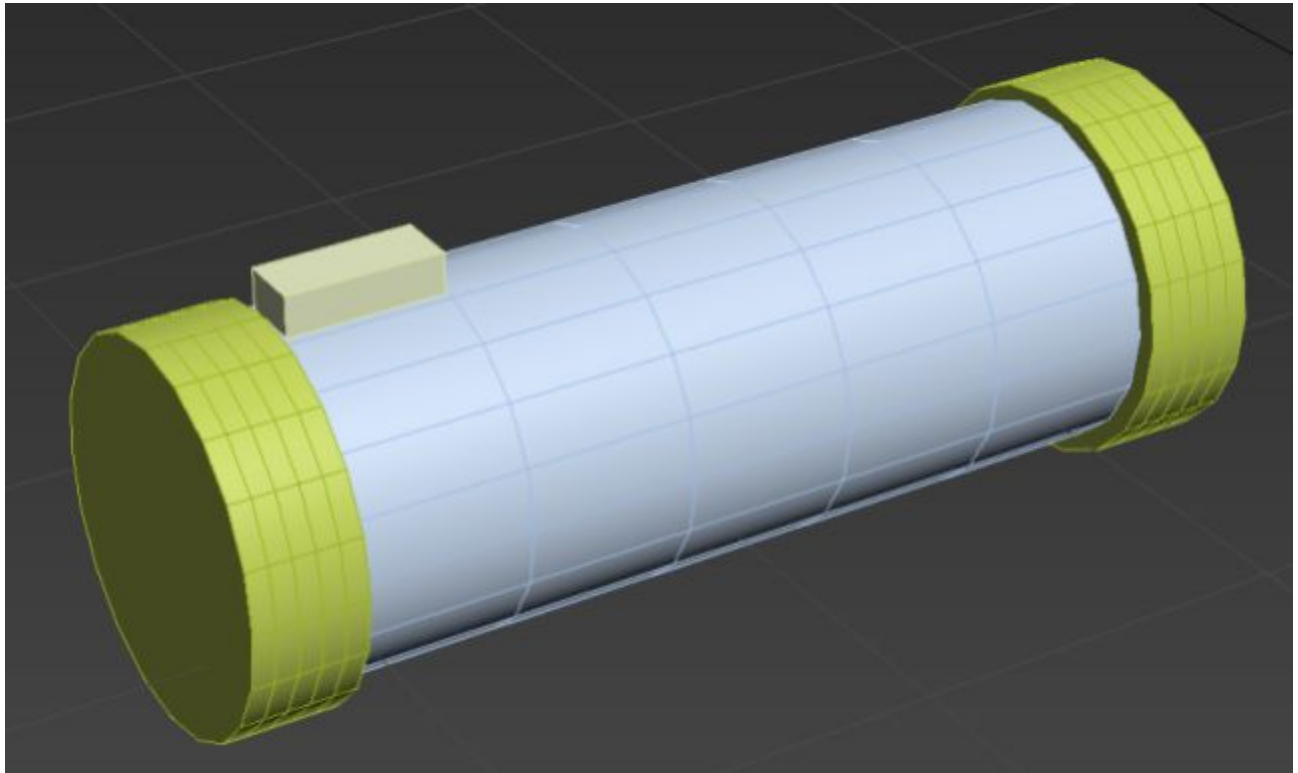


**Student Launch Proposal**

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



**Mailing Address:**

7 Rosemary  
Irvine, CA 92604

**AIAA OC Section  
September 19, 2018**

**Brenda (Project Manager)  
Aaron, Adelle, Catherine, Elsa, Ekas, Eric, Hugo, Jason, Joseph, Shelly**

# Table of Contents

<b>1 Summary of CDR Report</b>	<b>7</b>
1.1 Team Summary	7
1.1.1 Team Name and Mailing Address	7
1.1.2 Name of mentor, NAR/TRA number and certification level, and contact information	7
1.1.2.1 Robert Koepke (Electrical Engineer, Programmer, Level 2 NAR)	7
1.1.2.2 Jann Koepke (Artist, Mom, Level 2 NAR)	7
1.2 Launch Vehicle Summary	7
1.3 Payload Summary	7
<b>2 Changed Made Since PDR</b>	<b>8</b>
2.1 Changes Made to Vehicle Criteria	8
2.2 Changes Made to Payload Criteria	8
2.3 Changes Made to Project Plan	9
2.4 Changes Made to Air Brake Design	9
<b>3 Vehicle Criteria</b>	<b>9</b>
3.1 Design and Verification of Launch Vehicle: Flight Reliability and Confidence	9
3.1.1 Mission Statement	9
3.1.2 Mission Success Criteria	9
3.1.3 Vehicle Design	10
3.1.3.1 Airbrakes	10
3.1.3.1.1 Alternatives Considered	10
3.1.3.1.2 Final Choice	10
3.1.3.2 Payload	11
3.1.3.2.1 Alternatives Considered	11
3.1.3.2.2 Final Choice	12
3.1.3.3 Avionics	12
3.1.3.3.1 Alternatives Considered	12
3.1.3.3.2 Final Choice	13
3.1.3.4 Final Components of the Launch Vehicle	13
3.1.4 Illustrations and CAD Drawings	13
3.1.4.1 Final Launch Vehicle	13
3.1.4.2 Subsystems	13
3.1.4.3 Components	14
3.1.6 Design Integrity	14
3.1.6.1 Suitability of Shape and Fin Style for Mission	14
3.1.6.2 Proper Use of Materials in Fins, Bulkheads, and Structural Elements	14
3.1.6.2.1 Fins	14

3.1.6.2.2 Bulkheads	14
3.1.6.2.2.1 Additional Insulation	15
3.1.6.2.3 Fiberglass Tape	17
3.1.6.3 Sufficient Motor Mounting and Retention	17
3.1.6.4 Estimated Final Mass of the Vehicle and Individual Subsystems	18
3.1.7 Justification for Material Selection, Dimensioning, Component Placement, and Other Design Aspects	19
3.2 Subscale Flight Results	19
3.2.1 Flight Data	19
3.2.2 Scaling Factors in Subscale Rocket	19
3.2.3 Launch Day Conditions	19
3.2.4 Analysis of Flight	20
3.2.4.1 Predicted Flight Model	20
3.2.4.2 Actual Flight Model	22
3.2.4.3 Results	23
3.2.4.4 Error Between Predicted and Actual Flight Models	24
3.2.4.5 Estimated Drag Coefficient of Full Scale based on Subscale	24
3.2.4.6 Impacts of Subscale Flight Data on Full Scale Launch Vehicle	24
3.3 Recovery Subsystem	24
3.3.1 Design Alternatives	25
3.3.2 Final Choice	26
3.3.3 Parachutes	26
3.3.4 Harnesses	26
3.3.5 Bulkheads	26
3.3.6 Attachment Hardware	27
3.3.7 Electrical Components	27
3.3.8 Proof of Dual Redundancy	27
3.3.9 Drawings and Schematics	28
3.3.10 Operating Frequency of Tracker(s)	28
3.4 Mission Performance Predictions	28
3.4.1 Flight Profile Simulations	28
3.4.1.1 Altitude Predictions with Simulated Data	28
3.4.1.2 Component Weights	31
3.4.1.3 Simulated Motor Thrust Curve	31
3.4.2 Verification of Robust Design	31
3.4.3 Stability Margin	32
3.4.4 Center of Gravity	32
3.4.5 Center of Pressure	32
3.4.5.1 Diagram of CP and CG	32

3.4.6 Kinetic Energy of Independent Sections	33
3.4.6.1 Independent Section 1	33
3.4.6.2 Independent Section 2	33
3.4.6.3 Independent Section 3	34
3.4.6.4 Differences Between Calculations	34
3.4.7 Expected Descent Time	34
3.4.7.1 Differences in Calculations	35
3.4.7.2 Simulations	35
3.4.8 Drift Calculations	35
3.4.8.1 0 MPH Wind	35
3.4.8.2 5 MPH Wind	35
3.4.8.3 10 MPH Wind	35
3.4.8.3 15 MPH Wind	36
3.4.8.4 20 MPH Wind	36
3.4.8.5 Differences in Calculations	36
3.4.8.6 Simulations	37
3.4.8.6.1 5 MPH	37
3.4.8.6.2 10 MPH	38
3.4.8.6.3 15 MPH	39
3.4.8.6.4 20 MPH	40
<b>4 Safety</b>	<b>40</b>
4.1 Launch Concerns and Operation Procedures	40
4.1.1 Recovery Preparation Final Assembly and Launch Procedure	40
4.1.2 Motor Preparation Final Assembly and Launch Procedure	41
4.1.3 Setup on Launch Pad Final Assembly and Launch Procedure	42
4.1.4 Igniter Installation Final Assembly and Launch Procedure	43
4.1.5 Troubleshooting Final Assembly and Launch Procedure	44
4.1.6 Post-Flight Inspection Final Assembly and Launch Procedure	44
4.2 Safety and Environment (Vehicle and Payload)	44
4.2.1 Personal Hazard Analysis	47
4.2.2 Failure Modes and Effects Analysis	47
4.2.3 Environmental Hazard Analysis	48
<b>5 Payload Criteria</b>	<b>50</b>
5.1 Design of Payload Equipment	51
5.1.1 Alternative Designs	51
5.1.2 Final Selection	51
5.1.3 System Level Review	52
5.1.3.1 Payload Assembly	52

5.1.3.2 Component Interactions	52
5.1.3.3 Integration of Payload into Launch Vehicle	52
5.1.4 Release Mechanism	52
5.1.4.1 Alternatives Considered	52
5.1.4.2 Final Choice	54
5.1.5 Demonstration of Complete Design	55
5.1.6 Payload Electronics	55
5.1.7 Justification for Unique Aspects	56
<b>6 Project Plan</b>	<b>56</b>
6.1 Testing	57
6.1.1 Test Result Effects on Launch Vehicle and Payload	57
6.1.2 Vehicle Test Plan	57
6.1.2.1 Test Objective	57
6.1.2.2 Success Criteria	57
6.1.2.3 Testing Variable and Methodology	57
6.1.2.4 Proof of Integrity	58
6.1.2.5 Justification of Necessity to Validation of the Vehicle and Payload	58
6.1.2.6 Effects of Results	58
6.1.3 Energetics Test Plan	58
6.1.3.1 Test Objective	61
6.1.3.2 Success Criteria	61
6.1.3.3 Testing Variable and Methodology	61
6.1.3.4 Proof of Integrity	61
6.1.3.5 Justification of Necessity to Validation of the Vehicle and Payload	61
6.1.3.6 Effects of Results	61
6.1.4 Air Brakes Test Plan	61
6.1.4.1 Test Objective	61
6.1.4.2 Success Criteria	61
6.1.4.3 Testing Variable and Methodology	61
6.1.4.4 Proof of Integrity	62
6.1.4.5 Justification of Necessity to Validation of the Vehicle and Payload	62
6.1.4.6 Effects of Results	62
6.1.5 GPS Test Plan	62
6.1.5.1 Test Objective	63
6.1.5.2 Success Criteria	63
6.1.5.3 Testing Variable and Methodology	63
6.1.5.4 Proof of Integrity	63
6.1.5.5 Justification of Necessity to Validation of the Vehicle and Payload	63

6.1.5.6 Effects of Results	63
6.1.6 Payload Test Plan	63
6.1.6.1 Test Objective	63
6.1.6.2 Success Criteria	63
6.1.6.3 Testing Variable and Methodology	63
6.1.6.4 Proof of Integrity	63
6.1.6.5 Justification of Necessity to Validation of the Vehicle and Payload	63
6.1.6.6 Effects of Results	63
6.1.7 Effects of Tests on Overall Vehicle and Payload Design	63
6.2 Requirements Compliance	63
6.2.1 Verification Plans	63
6.2.1.1 General Verification Plan	63
6.2.1.2 Vehicle Verification Plan	63
6.2.1.3 Recovery System Verification Plan	64
6.2.1.4 Experiment Verification Plan	64
6.2.1.5 Safety Verification Plan	64
6.2.2 Team Derived Requirements	65
6.2.2.1 Vehicle Requirements	65
6.2.2.2 Recovery Requirements	65
6.2.2.3 Payload Requirements	65
6.3 Budgeting and Timeline	65
6.3.1 Budget	65
6.3.1.1 Funding Plan	69
6.3.2 Timeline	69
<b>Appendix A: Statement of Work Cross-Reference</b>	<b>70</b>
<b>Appendix B: Shop Safety Rules</b>	<b>80</b>
<b>Appendix C: Launch Safety Rules</b>	<b>82</b>

# 1 Summary of CDR Report

## 1.1 Team Summary

### 1.1.1 Team Name and Mailing Address

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

7 Rosemary  
Irvine, CA 92604

### 1.1.2 Name of mentor, NAR/TRA number and certification level, and contact information

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

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

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

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

## 1.2 Launch Vehicle Summary

Size	149.325 inches	Target Altitude	4700 feet
Mass	11.074951 kg	Recovery System	Redundant Dual Deploy System
Motor Choice	<a href="#">CTI K1085WT</a>	Rail Size	96"

Milestone Review Flysheet:

[https://docs.google.com/spreadsheets/d/1dhYAt0sxtJZV4au79lD\\_I4Ut478piXhAKLnZhtMtPfM/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1dhYAt0sxtJZV4au79lD_I4Ut478piXhAKLnZhtMtPfM/edit?usp=sharing)

## 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 of the target to take a picture.

## 2 Changed Made Since PDR

### 2.1 Changes Made to Vehicle Criteria

	PDR	CDR	Reasoning
Length	122.5 in	149.325 in	<p>Payload Bay was increased to fit the rover and the linear actuator.</p> <p>The piston mechanism was moved from between the nose cone and payload to be between the main chute body and the payload. This is so that the payload now comes out of the nose cone and the bulkhead that is attached to the parachute is not at risk of being pushed out.</p> <p>Air Brake module was lengthened to allow for space for the new servo air brakes, adapted and improved from previous designs.</p>
Mass	10.987736 kg	11.074951 kg	<p>Masses were changed to realistically simulate the masses of the subsystems.</p> <p>Change in length added to the change in mass</p> <p>Removal of the sabot and all the sabot mechanisms.</p>
Air Brake	6 in	12.5 in	<p>The air brakes were designed as an adaptation and improvement from last year. Due to this, the length was increased to allow for space for the change in design.</p>

### 2.2 Changes Made to Payload Criteria

We discussed over email that we would be switching the design to a door design. After consulting Mike Kramer, we have decided to pursue using the piston mechanism again. The door mechanism was



discarded because we discovered that the rover would be too large to fit through a door unless we cut the body tube in half. However, if we did that the structural integrity of the body tube would be severely compromised and so it had a high chance of collapsing in on itself.

For the piston, we have switched the location of the piston and the payload so that the payload will be ejected from the nose cone, hence the added length in the rocket. The active retention system to ensure that rover isn't prematurely released is created by using a solenoid to act as a screw and keep the nose cone attached to the tube coupler. Once it receives a signal, the solenoid will retract, allowing the linear actuator on the other end to then extend and push the rover out from the nose cone.

## 2.3 Changes Made to Project Plan

The timeline and budget were adjusted to fit the schedule and track the progress of the team. We also started using ProjectLibre to track the progress of the team.

## 2.4 Changes Made to Air Brake Design

Due to the solenoid air brakes not being able to meet the time requirements, we settled on improving the air brake design featured in last year's rocket design.

# 3 Vehicle Criteria

## 3.1 Design and Verification of Launch Vehicle: Flight Reliability and Confidence

### 3.1.1 Mission Statement

The rocket must reach a target altitude of 4700 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. The rover must have traveled out of the rocket body and turned around towards the colored bands. A picture needs to have been taken of the colored bands. Lastly, the rover must still be functional and reusable after it's task is complete.

## 3.1.3 Vehicle Design

### 3.1.3.1 Airbrakes

#### 3.1.3.1.1 Alternatives Considered

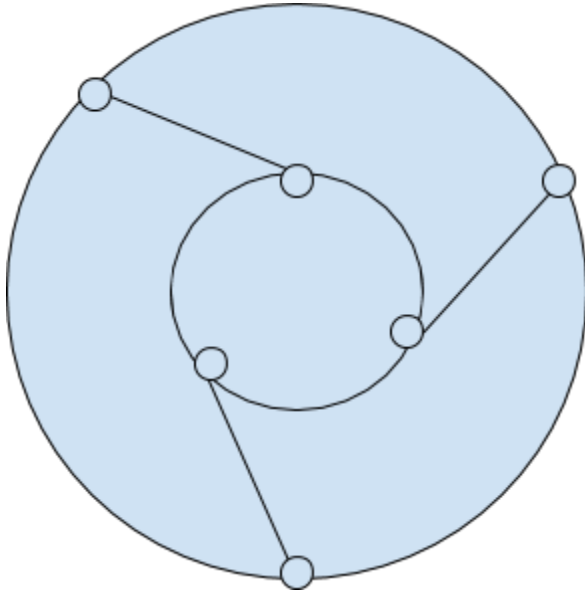
An alternative air brake design was considered, a design using a solenoid and a spider gear, with the solenoid pulling on the spider gear, actuating all three air brakes at once in an umbrella like fashion. The air brakes will be operated by the arduino and a p-nut altimeter to calculate velocity and measure altitude, with the arduino deciding when the air brakes open when conditions are met. The design would utilize 2 bulkheads and 2 endplates. The bulkheads can be milled out of aluminium, as can the endplates and the spider gear. The solenoid would be controlled by a relay, which would be controlled by an arduino. The advantage to this design is the linear actuation of the solenoid more efficiently applying force to the air brakes than the previous year's design. The disadvantage is the design's high weight and complexity, along with the solenoid's nonlinear force curve, as well as the solenoid's high power draw and inability to adjust the degree to which the air brakes open.

Another alternative would be to use the same design as the solenoid, but to replace the solenoid with a motor actuated linear actuator, which would solve the nonlinear force curve issue of the solenoid, as well as the solenoid's high power draw and inability to adjust the degree to which the air brakes open, but would still be incredibly heavy and complex to build relative to the design chosen.

#### 3.1.3.1.2 Final Choice

In the end, the decision to refine last year's design was made. A motor, mounted to a bulkhead, would rotate a disk with holes drilled into it, actuating the air brakes through three pushrods. The difference between this year and last year is the potential degree to which the air brakes can open. The hinges are now parallel to one another, via very heavy sanding of the body tube and air brake, as well as the addition of the appropriate supporting structure to ensure maximum structural rigidity. The advantages of this design are: the larger amount of lift, low power draw, adjustable air brake position, light weight, and low complexity. The disadvantage is the low efficiency of the force application of the motor, with some of the force initially being applied sideways. In the end, this design was mostly chosen due to its low power draw and low complexity, making it easier to construct in a short time.

Diagrams:



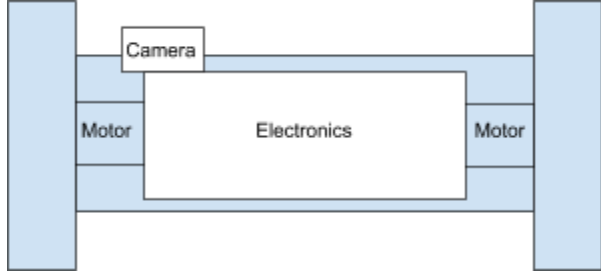
This is the top down view of the spider gear and pushrod system that will actuate the three air brakes.

### 3.1.3.2 Payload

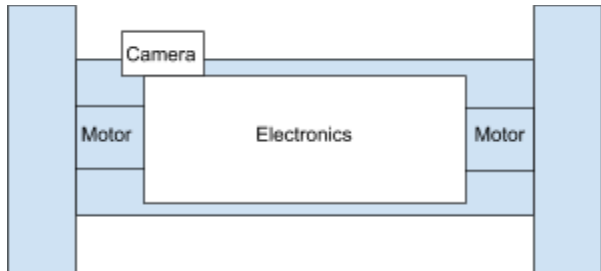
The payload is designed as a rover with an onboard camera. It will be ejected out of the nose cone rather than the aft end. Therefore, the bulkhead of which the nylon shock cord is attached will not be detached at any time from the rocket.

#### 3.1.3.2.1 Alternatives Considered

<p>Shorter rover body          Pros: effectively utilizing the space in the rocket for the payload section          Cons: Not enough space between the body and the edges of the wheels to allow for the rover to efficiently move across the ground.</p>	
---	--

<p>Longer rover body          Pros: more gaps between bottom and top of wheels and the body, allowing for overcoming obstacles          Cons: Requiring more space in the rocket for the payload section</p>	
--	--

### 3.1.3.2.2 Final Choice

<p>Longer rover body          Pros: more gaps between bottom and top of wheels and the body, allowing for overcoming obstacles          Cons: Requiring more space in the rocket for the payload section</p>	
--	--

### 3.1.3.3 Avionics

#### 3.1.3.3.1 Alternatives Considered

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.
<a href="#">Stratologger CF</a>	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.

<a href="#">RRC3 Sport</a>	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).
<a href="#">TeleMega Altimeter</a>	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).
<a href="#">Raven Flight Computer</a>	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).

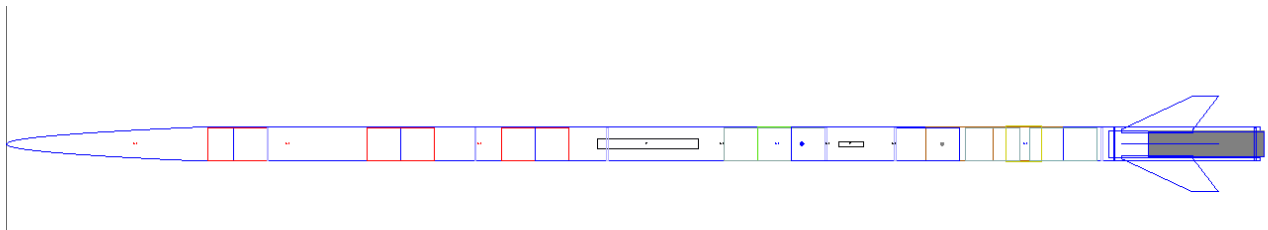
### 3.1.3.3.2 Final Choice

We chose to use the Stratologger CF Flight Computer as our main flight computer and the RRC3 Sport Flight Computer as our backup.

### 3.1.3.4 Final Components of the Launch Vehicle

## 3.1.4 Illustrations and CAD Drawings

### 3.1.4.1 Final Launch Vehicle



### 3.1.4.2 Subsystems

The subsystems include the Recovery Subsystem, the GPS Subsystem, and the Air Brakes Subsystems.

### 3.1.4.3 Components

Components of the rocket include the GPS, the Payload Bay, the Main Chute, the Avionics Bay, the Drogue Chute, the Air Brake Module and the Motor. 3.1.5 Completion of Design and Preparation for Manufacture

## 3.1.6 Design Integrity

### 3.1.6.1 Suitability of Shape and Fin Style for Mission

The fins used for both the full scale and subscale are the fins that came with the model kits for the Frenzy XL 4" and 3" respectively. We were given permission to remove the lower set of fins to maintain a reasonable stability margin.

### 3.1.6.2 Proper Use of Materials in Fins, Bulkheads, and Structural Elements

#### *3.1.6.2.1 Fins*

The fins used for both the full scale and the subscale are the fins that came with the model kits for the Frenzy XL 4" and 3" respectively. The fins are made of fiberglass, the same kind of fiberglass the rest of our rocket is made out of.

#### 3.1.6.2.2 Bulkheads

Bulkheads are either aluminum or fiberglass. Those that are aluminum are 0.25" thick.



The aluminum bulkheads were purchased from Mad Cow Rocketry.

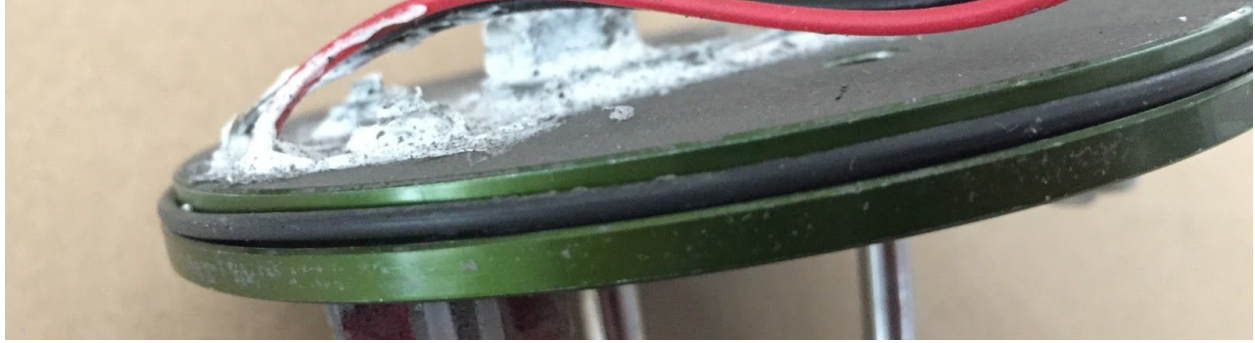
The two holes that are not in the center of the bulkhead are used to hold the rails to the electronics boards. These rails run through 0.25" launch lugs that are glued to the back of the electronics board for easy access when the rocket is not on the launch pad and security during the rocket's flight

Those that are fiberglass tend to be made of two individual fiberglass bulkheads that are stuck together with West Systems epoxy, providing additional reinforcement to withstand the shock of ejection and ejection charge force. Together, the two fiberglass bulkheads are 0.25" thick. These were purchased from Mad Cow Rocketry.

G10 fiberglass can withstand the force the rocket will experience in-flight. Body tubes are 0.118" thick and tube couplers are 0.2" thick.

#### 3.1.6.2.2.1 Additional Insulation

Because there are pyrotechnic charges involved in the ejection of the rocket's parachutes, the bulkheads will have O-rings around their inner diameter.



All possible openings, save the holes where the threaded rods go through the bulkheads, are covered in silicon gel.



We will use an MG Chemical Supershield spray on the inside of the avionics bay. This will allow the flight computers to collect data without RF interference.





#### 3.1.6.2.3 Fiberglass Tape

Both the full scale and subscale will utilize fiberglass tape to reinforce the epoxy fillets. This will prevent the fins from displacing themselves from the body tube upon landing.

#### 3.1.6.3 Sufficient Motor Mounting and Retention

The motor mount was sanded down so we could dry-fit the retainer. Once we confirmed that the motor retainer fit the mount, we used JB Weld glue to attach the retainer to the rocket. We used AeroPack Fiberglass 54mm and 75mm Motor Tube Retainers, purchased from [Madcow Rocketry](#).

## Aero Pack 75mm Retainer (Fiberglass Motor Tubes) (RA75P)



## Aero Pack 54mm Retainer (Fiberglass Motor Tubes) (RA54P)



### 3.1.6.4 Estimated Final Mass of the Vehicle and Individual Subsystems

Subsystem	Estimated Mass (g)	Estimated Weight (lbs)
Gross Liftoff	11074.951	24.41608751047

Air Brakes	857	1.889362
Avionics	670.5	1.4781995
Payload	1200	2.645547
Piston	800	1.7637

### 3.1.7 Justification for Material Selection, Dimensioning, Component Placement, and Other Design Aspects

## 3.2 Subscale Flight Results

### 3.2.1 Flight Data

The flight was performed on January 5th, 2019. It successfully deployed both of its parachutes at their respective times during the flight. The drogue deployed at apogee, and the main deployed at 600 ft.

### 3.2.2 Scaling Factors in Subscale Rocket

Because the subscale as a 3” diameter, and the full scale as a 4” diameter, the scale factor is 3 to 4, subscale to full scale.

We tried to keep the masses consistent, but we should expect some error in the scale factor before and after building.

### 3.2.3 Launch Day Conditions

#### Summary January 5, 2019

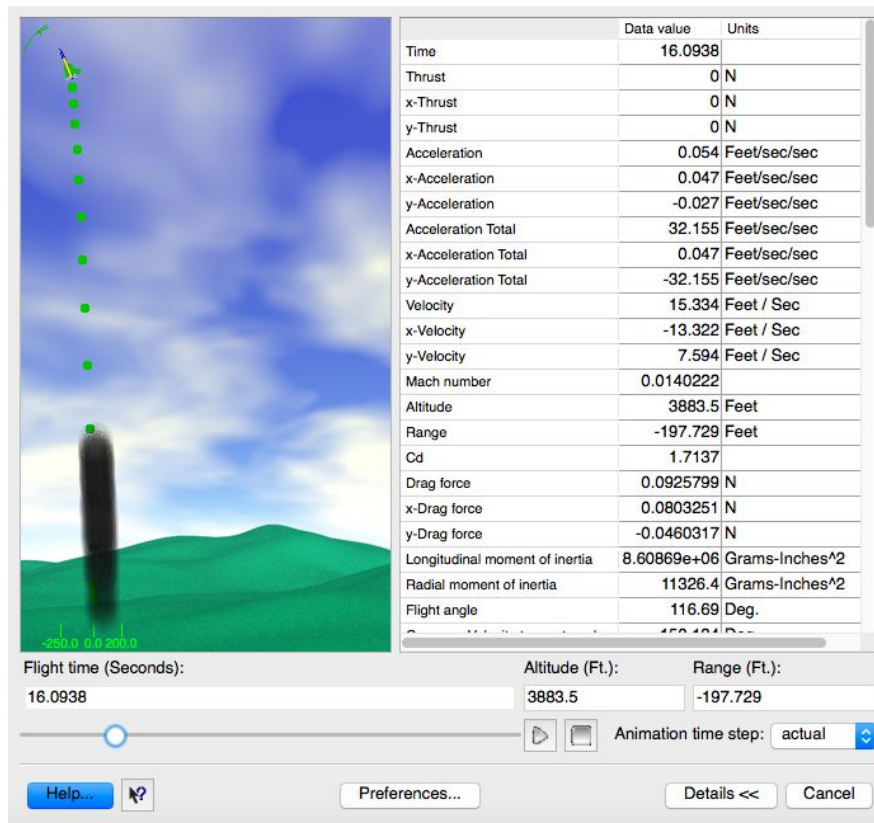
	High	Low	Average
Temperature	44.7 °F	33.9 °F	39.3 °F
Dew Point	35.9 °F	14.8 °F	21.1 °F
Humidity	81%	38%	48%
Precipitation	0.01 in	--	--

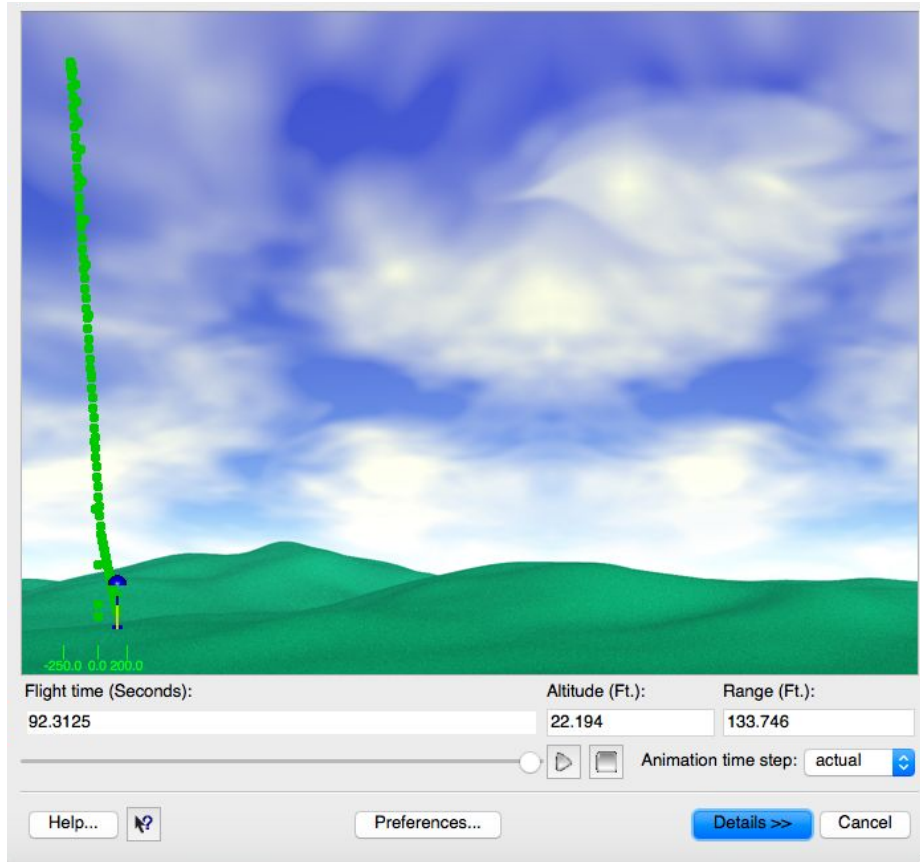
	High	Low	Average
Wind Speed	6 mph	--	1 mph
Wind Gust	11 mph	--	--
Wind Direction	--	--	West
Pressure	30.04 in	29.93 in	--

<b>Temperature</b>	39.3° F
<b>Wind conditions</b>	6 mph
<b>Humidity</b>	48%

### 3.2.4 Analysis of Flight

#### 3.2.4.1 Predicted Flight Model





Simulation	Δ	Results	Engines loaded	Max. altitude Feet	Max. velocity Feet / Sec	Max. acceleration Feet/sec/sec	Time to apogee	Velocity at deployment Feet / Sec	Altitude at deployment Feet	Total flight time	Time to burnout	Velocity at Feet / Sec
1	0		[J295-None]	4054.69	493.38	261.82	16.76	0.04	4054.69	90.42	4.15	
2	1		[J295-None]	4054.69	493.38	261.82	16.76	0.04	4054.69	90.42	4.15	
3	2		[J295-None]	3884.38	487.51	261.86	16.33	13.31	3884.40	93.34	4.15	

Rocksim - simulation details

### Recovery system data

- P: Main (4.1 in) Deployed at : 66.246 Seconds
- Velocity at deployment: 66.2798 ft/s
- Altitude at deployment: 599.97004 Ft.
- Range at deployment: 19.05409 Ft.
- P: Drogue (3.5 in) Deployed at : 16.331 Seconds
- Velocity at deployment: 13.3115 ft/s
- Altitude at deployment: 3884.39506 Ft.
- Range at deployment: -200.57190 Ft.

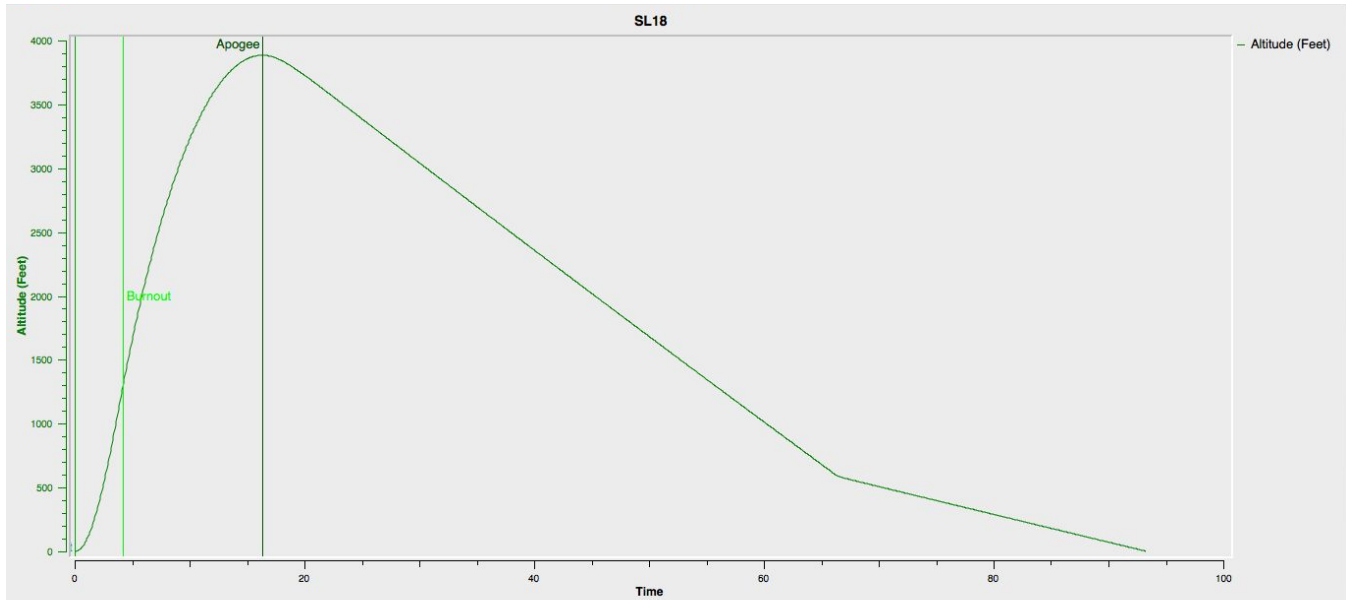
### Time data

- Time to burnout: 4.150 Sec.
- Time to apogee: 16.331 Sec.
- Optimal ejection delay: 12.181 Sec.

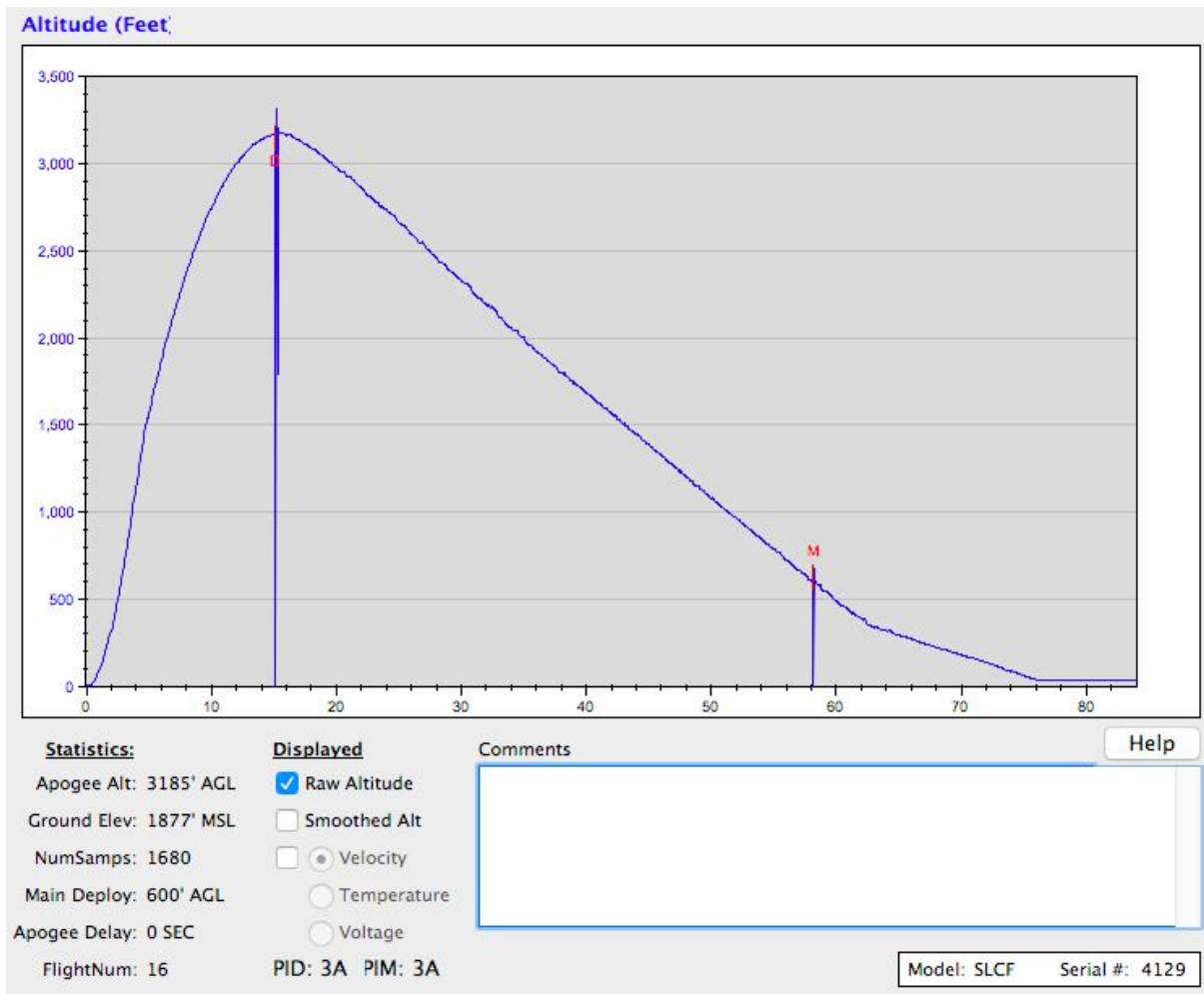
### Landing data

- Successful landing
- Time to landing: 93.337 Sec.
- Range at landing: 133.25559
- Velocity at landing: Vertical: -21.6671 ft/s , Horizontal: 4.4000 ft/s , Magnitude: 22.1094 ft/s

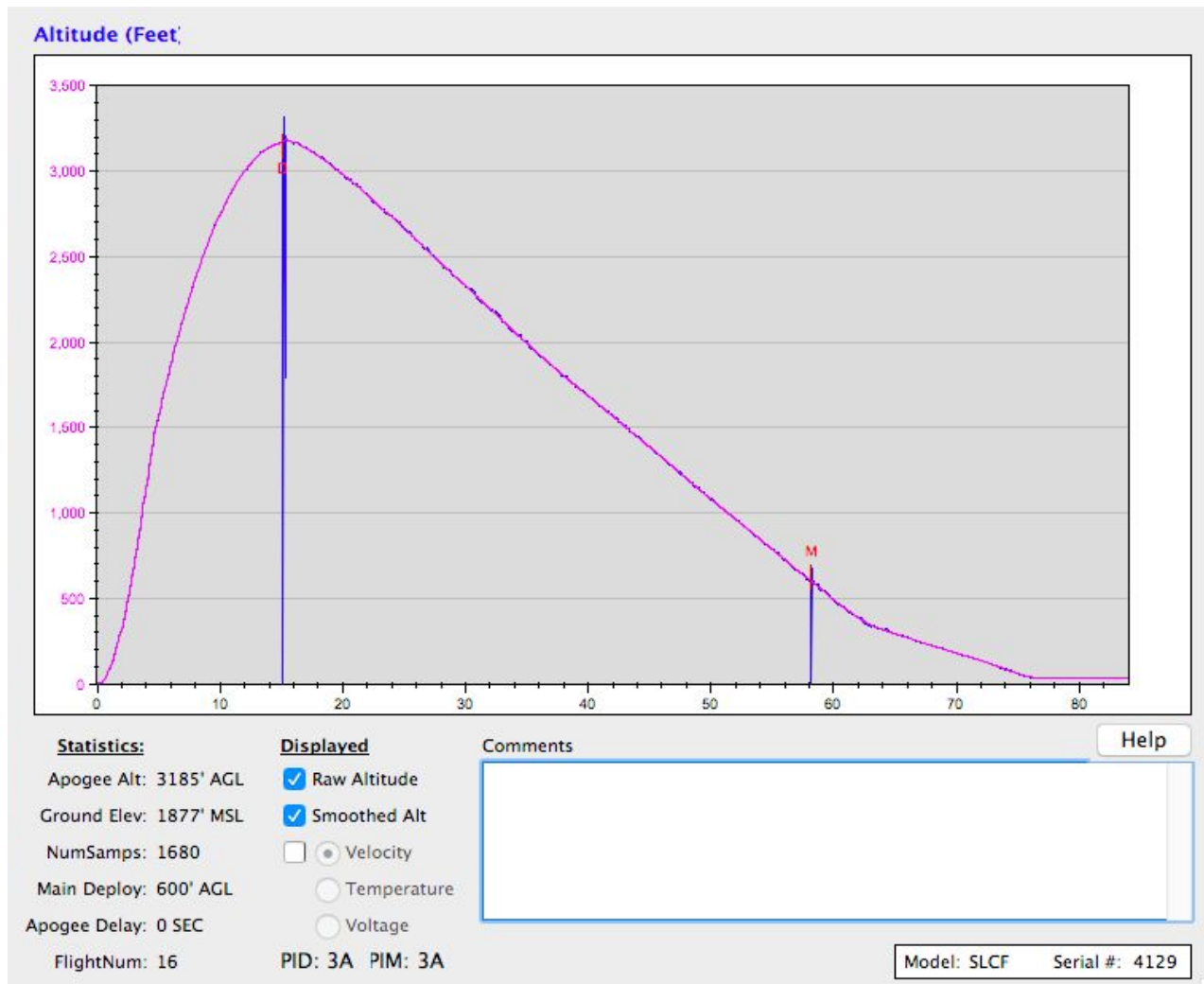
### Competition settings



### 3.2.4.2 Actual Flight Model



The sudden decrease in altitude during the drogue and main deployment is assumed to be a result of pressure from the ejection charges entering the avionics bay. This will be negated using O-rings for the next subscale launch with air brakes and the full scale launches.



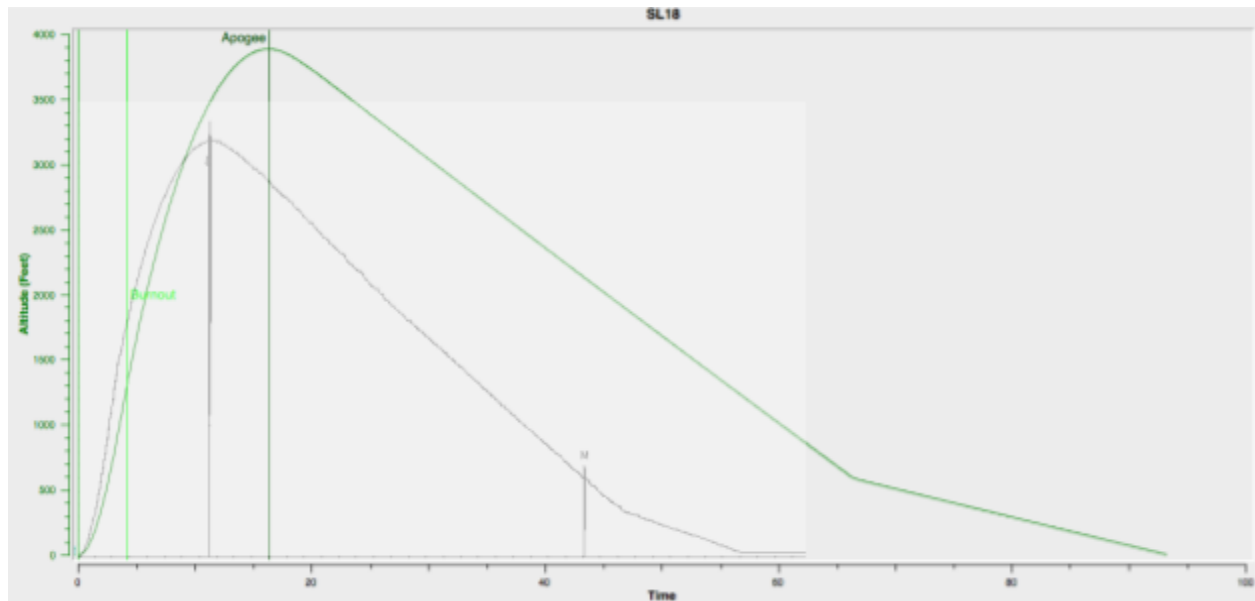
The purple altitude measurements are the smoothed altitude data points.

### 3.2.4.3 Results

Max Altitude: 3185 feet

Motor Used: CTI J295

#### 3.2.4.4 Error Between Predicted and Actual Flight Models



The green line depicted is the Flight Model and the grey line is the actual flight data. As shown, the flight model flew significantly higher than the actual flight data.

#### 3.2.4.5 Estimated Drag Coefficient of Full Scale based on Subscale

#### 3.2.4.6 Impacts of Subscale Flight Data on Full Scale Launch Vehicle

The success of the subscale indicates that the omission of the aft fins will work well for the rocket on quiet days, with little to no wind.

### 3.3 Recovery Subsystem

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 600 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. The 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.

### 3.3.1 Design 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.
<a href="#">Stratologger CF</a>	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.

<a href="#">RRC3 Sport</a>	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).
<a href="#">TeleMega Altimeter</a>	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).
<a href="#">Raven Flight Computer</a>	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).

### 3.3.2 Final Choice

We chose to use the Stratologger CF Flight Computer as our main flight computer and the RRC3 Sport Flight Computer as our backup.

### 3.3.3 Parachutes

The main parachute is a 72" Iris Ultra Compact Parachute manufactured by Fruity Chutes  
The drogue parachute is an 18" Classic Elliptical Parachute manufactured by Fruity Chutes

### 3.3.4 Harnesses

The harnesses are purchased from Madcow Rocketry. The harnesses selected are the 1" tubular nylon cords and they have been measured out to be about 27 feet in length for each harness (2 per rocket)

### 3.3.5 Bulkheads

The bulkheads for the harnesses are either double fiberglass bulkheads with machine shouldered eye bolts secured with nuts, or aluminum bulkheads with o-rings between it and the tube once again with machine shouldered eye bolts secured with nuts

### 3.3.6 Attachment Hardware

The harnesses are attached via machine shouldered eye bolts that are secured on tightly by nuts. The harnesses are tied to the eye bolts with a 60" shock cord blast protector that will be pulled over both the cord and the eyebolt as much as possible to protect it from the black powder charges.

### 3.3.7 Electrical Components

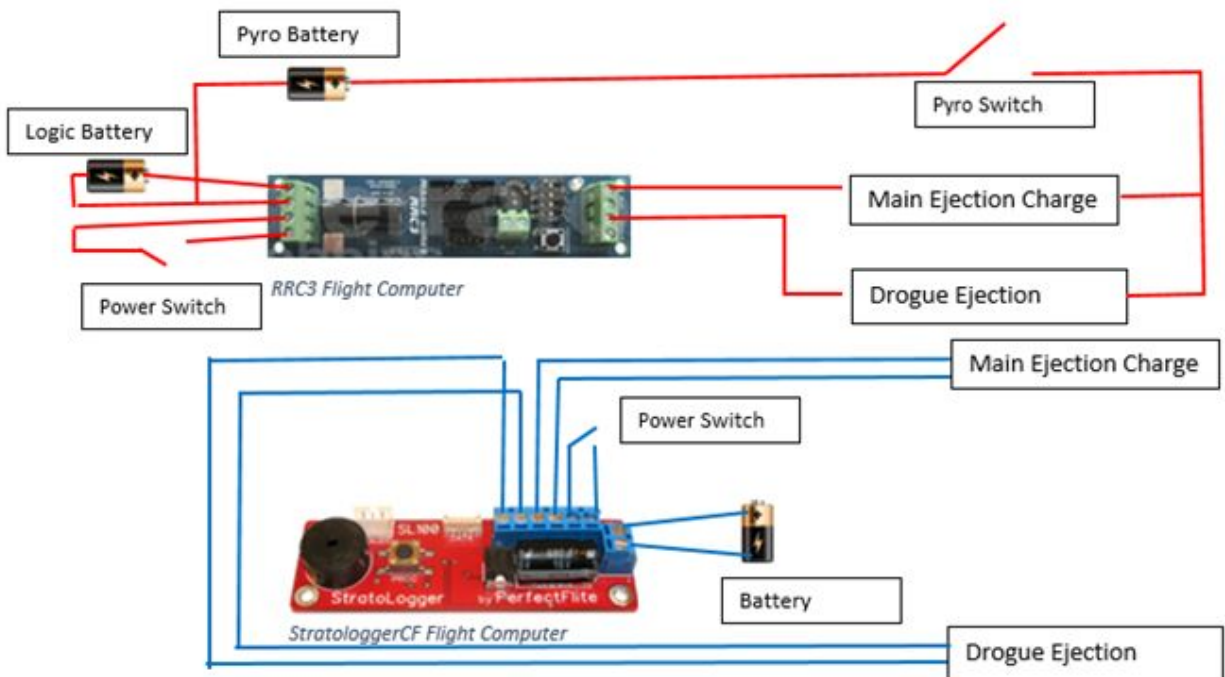
#### 3.3.8 Proof of Dual Redundancy

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.



### 3.3.9 Drawings and Schematics

#### 3.3.10 Operating Frequency of Tracker(s)

The trackers that the rocket and rover will have are the Big Red Bee trackers. They transmit at 433MHz but the frequency can easily be changed.

## 3.4 Mission Performance Predictions

### 3.4.1 Flight Profile Simulations

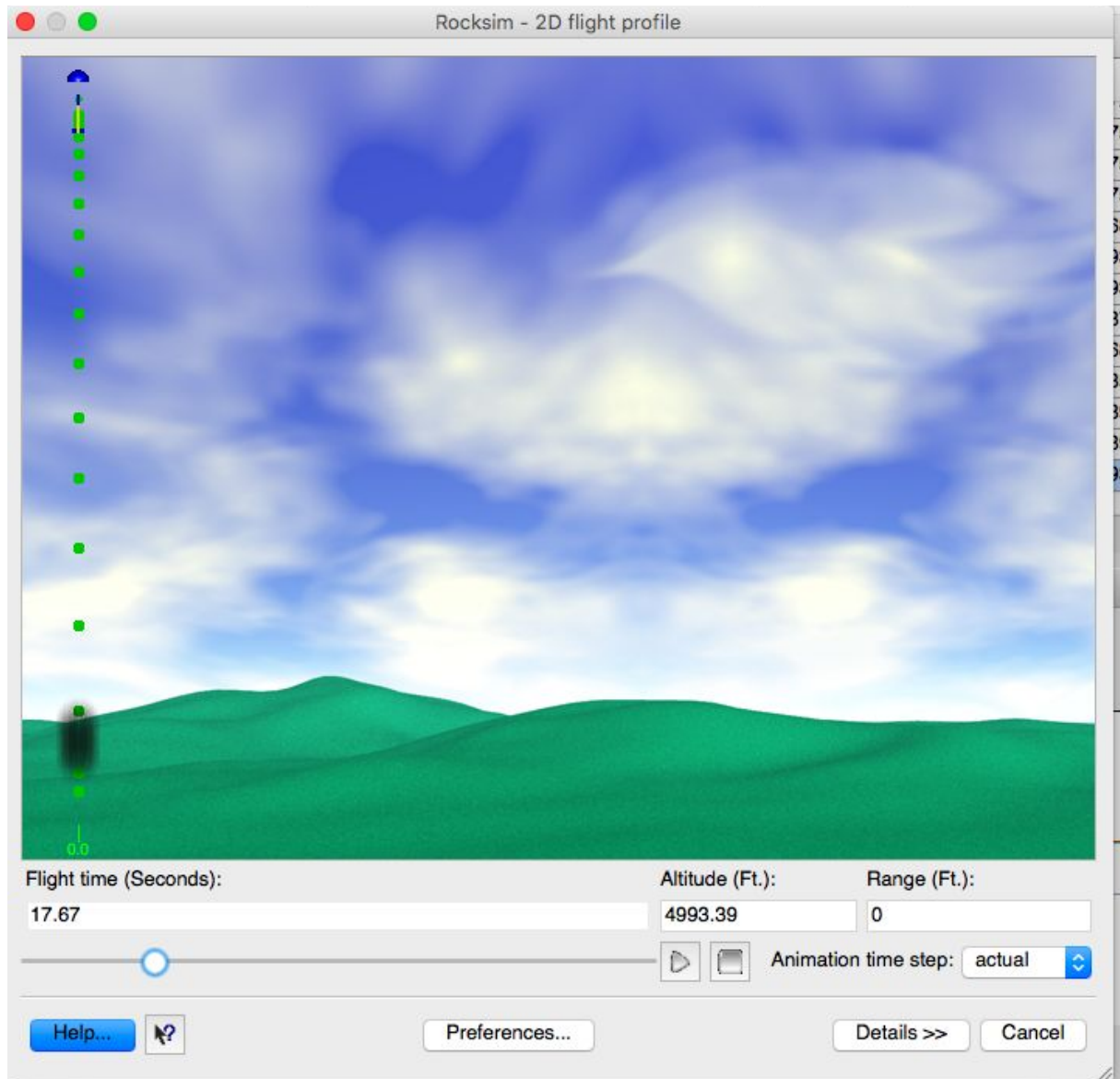
#### 3.4.1.1 Altitude Predictions with Simulated Data

The current projected altitude of the rocket with a CTI K1085 motor is 4993.67 ft. This is at conditions of “no wind” according to rocksim.

Rocket design attributes    Rocket design components    Mass override    Cd override    **Flight simulations**

Simulation	A	Results	Engines loaded	Max. altitude Feet	Max. velocity Feet / Sec	Max. acceleration Feet/sec/sec	Time to apogee	Velocity at deployment Feet / Sec	Altitude at deployment Feet	Total flight time	Time to burnout	Velocity at 1 Feet / Sec
8	7		[K1085WT-None]	4975.10	640.48	694.20	17.52	0.00	4975.10	81.43	2.28	
9	8		[K1085WT-None]	4975.10	640.48	694.02	17.52	0.00	4975.10	89.58	2.28	
10	9		[K1085WT-None]	4975.10	640.48	694.02	17.52	0.00	4975.10	89.58	2.28	
11	10		[K1085WT-None]	4975.10	640.48	694.02	17.52	0.00	4975.10	89.58	2.28	
12	11		[K1085WT-None]	4468.27	583.27	694.32	16.86	0.00	4468.27	80.91	2.28	
13	12		[K1085WT-None]	4993.67	642.67	694.01	17.54	0.02	4993.67	89.92	2.28	
14	13		[K1085WT-None]	4993.67	642.67	694.01	17.54	0.02	4993.68	89.92	2.28	
15	14		[K1085WT-None]	4987.40	642.57	694.01	17.52	14.95	4987.41	89.84	2.28	
16	15		[K1085WT-None]	4968.18	642.23	700.10	17.49	30.14	4968.19	89.03	2.28	
17	16		[K1085WT-None]	4935.70	641.67	694.01	17.43	45.43	4935.68	89.23	2.28	
18	17		[K1085WT-None]	4889.96	640.89	694.01	17.34	60.64	4889.97	88.69	2.28	
19	18		[K1085WT-None]	4889.96	640.89	694.01	17.34	60.64	4889.97	88.69	2.28	
20	19		[K1085WT-None]	4993.67	642.67	694.01	17.54	0.02	4993.68	89.92	2.28	

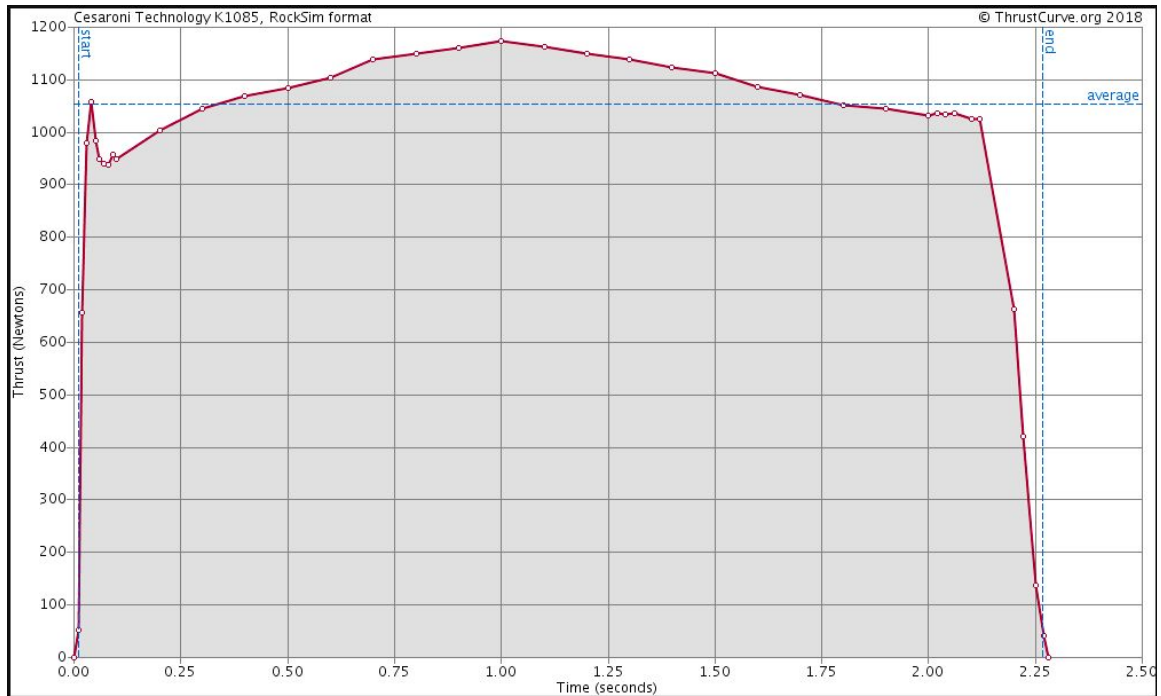
SL1819  
 Length: 149.3250 in., Diameter: 4.0250 in., Spin diameter: 13.0250 in.  
 Mass: 11074.921 g., Selected stage mass: 11074.921 g.  
 CP: 94.7272 in., CP: 111.4604 in., Margin: 4.16 Overstable  
 Engines: [K1085WT(Non...)]



The use of on board air brakes will ensure that the altitude of the rocket will reach the specified target of 4700 feet. Even without the air brakes, the max altitude is 4993.67 ft, which is within the the airspace license for this project.

### 3.4.1.2 Component Weights

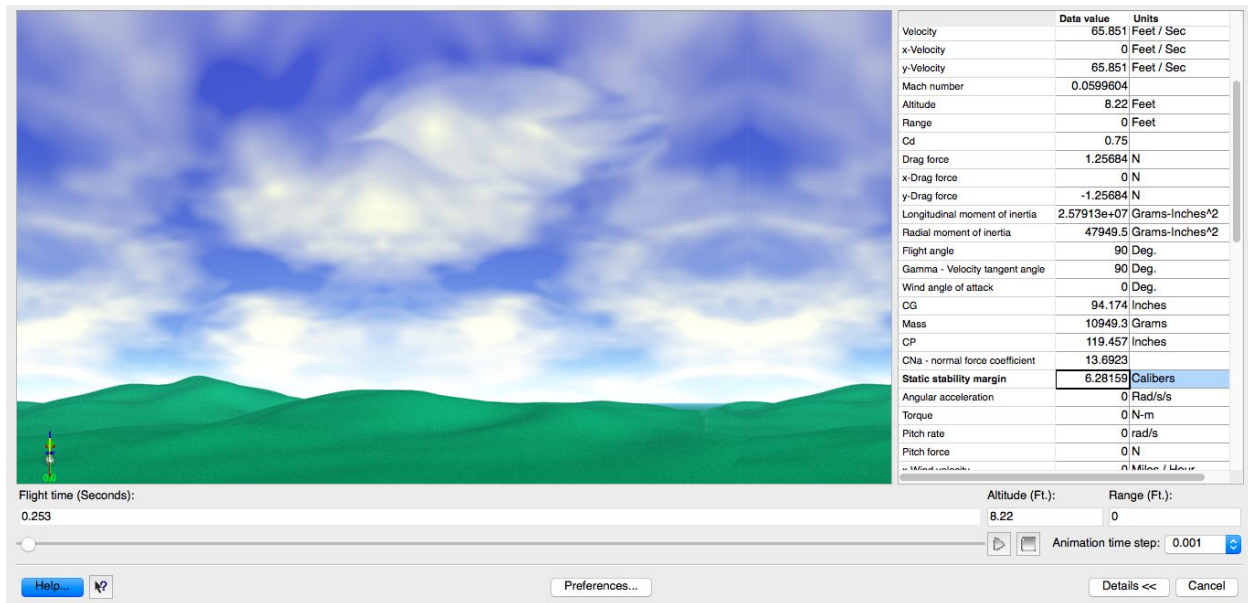
### 3.4.1.3 Simulated Motor Thrust Curve



### 3.4.2 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.

### 3.4.3 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 8.22 ft. As shown, the estimation is 6.28 calibers. The requirement is a minimum of 2 calibers.

### 3.4.4 Center of Gravity

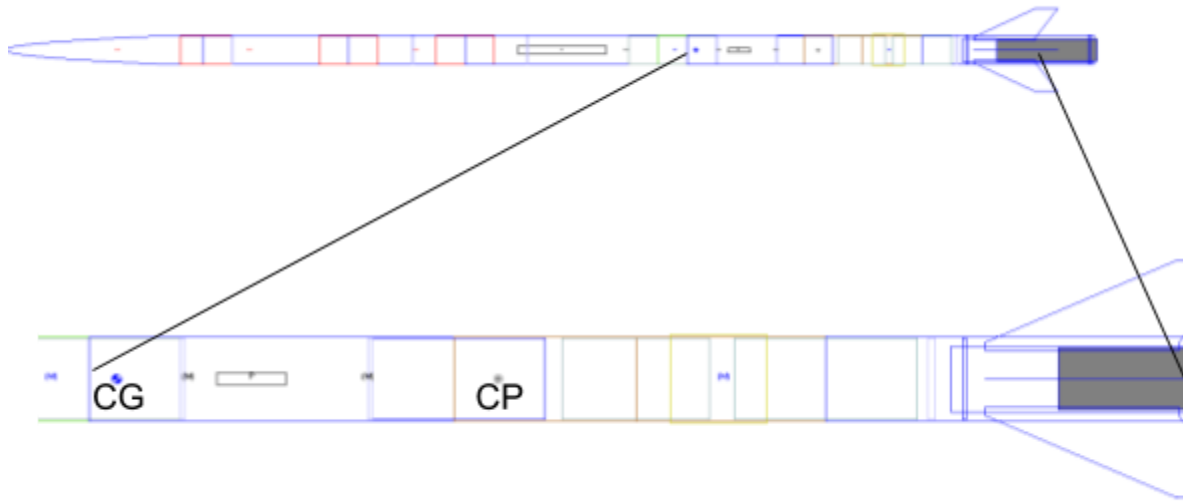
CG: 94.7272 in

### 3.4.5 Center of Pressure

CP: 111.4604 in

#### 3.4.5.1 Diagram of CP and CG





### 3.4.6 Kinetic Energy of Independent Sections

Overall Rocket: 9333.1485 g (with burnt out motor) = 20.5760871 lbs

Independent Section 1: 3524.672 g = 7.770577964 lbs

Independent Section 2: 1391.064 g = 3.066773664 lbs

Independent Section 3: 4417.4125 g (with burnt out motor) = 9.738735472 lbs

$$\begin{aligned}
 \text{kinetic energy} &= \frac{1}{2}mv^2 \\
 &= \frac{1}{2}(20.5760871\text{lbs})(16.94\text{ft/s})^2\left(\frac{1\text{ lbf s}^2}{32.2\text{ lbm ft}}\right) \\
 &= 91.68596568\text{ lbf}
 \end{aligned}$$

#### 3.4.6.1 Independent Section 1

Nose Cone, Payload Bay, Piston Bay

$$\begin{aligned}
 \text{kinetic energy} &= \frac{1}{2}mv^2 \\
 &= \frac{1}{2}(7.770577964\text{lbs})(16.94\text{ft/s})^2\left(\frac{1\text{ lbf s}^2}{32.2\text{ lbm ft}}\right) \\
 &= 34.62528814\text{ lbf}
 \end{aligned}$$

#### 3.4.6.2 Independent Section 2

Upper Body Tube, Avionics Bay, Lower Body Tube

$$\text{kinetic energy} = \frac{1}{2}mv^2$$

$$\begin{aligned} &= \frac{1}{2}(3.066773664\text{lbs})(16.94\text{ft/s})^2\left(\frac{1\text{ lbf s}^2}{32.2\text{ lbf ft}}\right) \\ &= 13.66538271\text{ lbf} \end{aligned}$$

### 3.4.6.3 Independent Section 3

Air Brake Extension, Air Brake, Booster

$$\begin{aligned} \text{kinetic energy} &= \frac{1}{2}mv^2 \\ &= 9.738735472\text{lbs}(16.94\text{ft/s})^2\left(\frac{1\text{ lbf s}^2}{32.2\text{ lbf ft}}\right) \\ &= 43.39529483\text{ lbf} \end{aligned}$$

### 3.4.6.4 Differences Between Calculations

### 3.4.7 Expected Descent Time

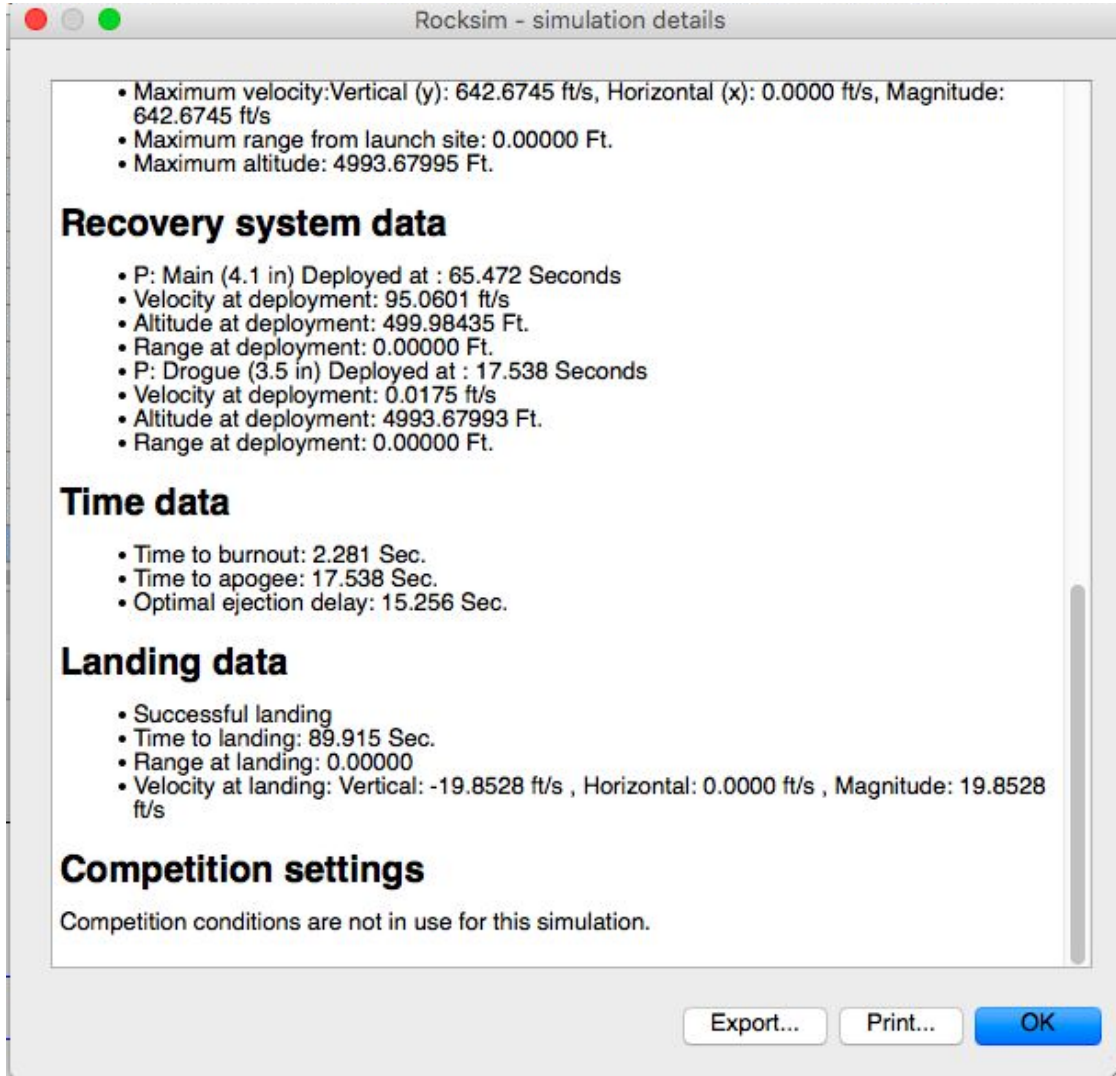
Total Flight Time: 89.92 Sec

Time to Apogee: 17.54 Sec

Expected Descent Time: 72.38 Sec

### 3.4.7.1 Differences in Calculations

### 3.4.7.2 Simulations



### 3.4.8 Drift Calculations

#### 3.4.8.1 0 MPH Wind

$$\left[ \left( \frac{1 \text{ second}}{82.43 \text{ feet}} \right) (4600 - 600 \text{ ft}) + \left( \frac{1 \text{ second}}{16.94 \text{ feet}} \right) (600 \text{ ft}) \right] \times \left( \frac{0 \text{ miles}}{1 \text{ hour}} \right) \left( \frac{5280 \text{ feet}}{1 \text{ mile}} \right) \left( \frac{1 \text{ hour}}{3600 \text{ seconds}} \right) = 0 \text{ ft}$$

#### 3.4.8.2 5 MPH Wind

$$\left[ \left( \frac{1 \text{ second}}{82.43 \text{ feet}} \right) (4600 - 600 \text{ ft}) + \left( \frac{1 \text{ second}}{16.94 \text{ feet}} \right) (600 \text{ ft}) \right] \times \left( \frac{5 \text{ miles}}{1 \text{ hour}} \right) \left( \frac{5280 \text{ feet}}{1 \text{ mile}} \right) \left( \frac{1 \text{ hour}}{3600 \text{ seconds}} \right) = 615.597755 \text{ ft}$$

### 3.4.8.3 10 MPH Wind

$$\left[\left(\frac{1 \text{ second}}{82.43 \text{ feet}}\right)(4600 - 600 \text{ ft}) + \left(\frac{1 \text{ second}}{16.94 \text{ feet}}\right)(600 \text{ ft})\right] \times \left(\frac{10 \text{ miles}}{1 \text{ hour}}\right)\left(\frac{5280 \text{ feet}}{1 \text{ mile}}\right)\left(\frac{1 \text{ hour}}{3600 \text{ seconds}}\right) = 1231.19551 \text{ ft}$$

### 3.4.8.3 15 MPH Wind

$$\left[\left(\frac{1 \text{ second}}{82.43 \text{ feet}}\right)(4600 - 600 \text{ ft}) + \left(\frac{1 \text{ second}}{16.94 \text{ feet}}\right)(600 \text{ ft})\right] \times \left(\frac{15 \text{ miles}}{1 \text{ hour}}\right)\left(\frac{5280 \text{ feet}}{1 \text{ mile}}\right)\left(\frac{1 \text{ hour}}{3600 \text{ seconds}}\right) = 1846.793265 \text{ ft}$$

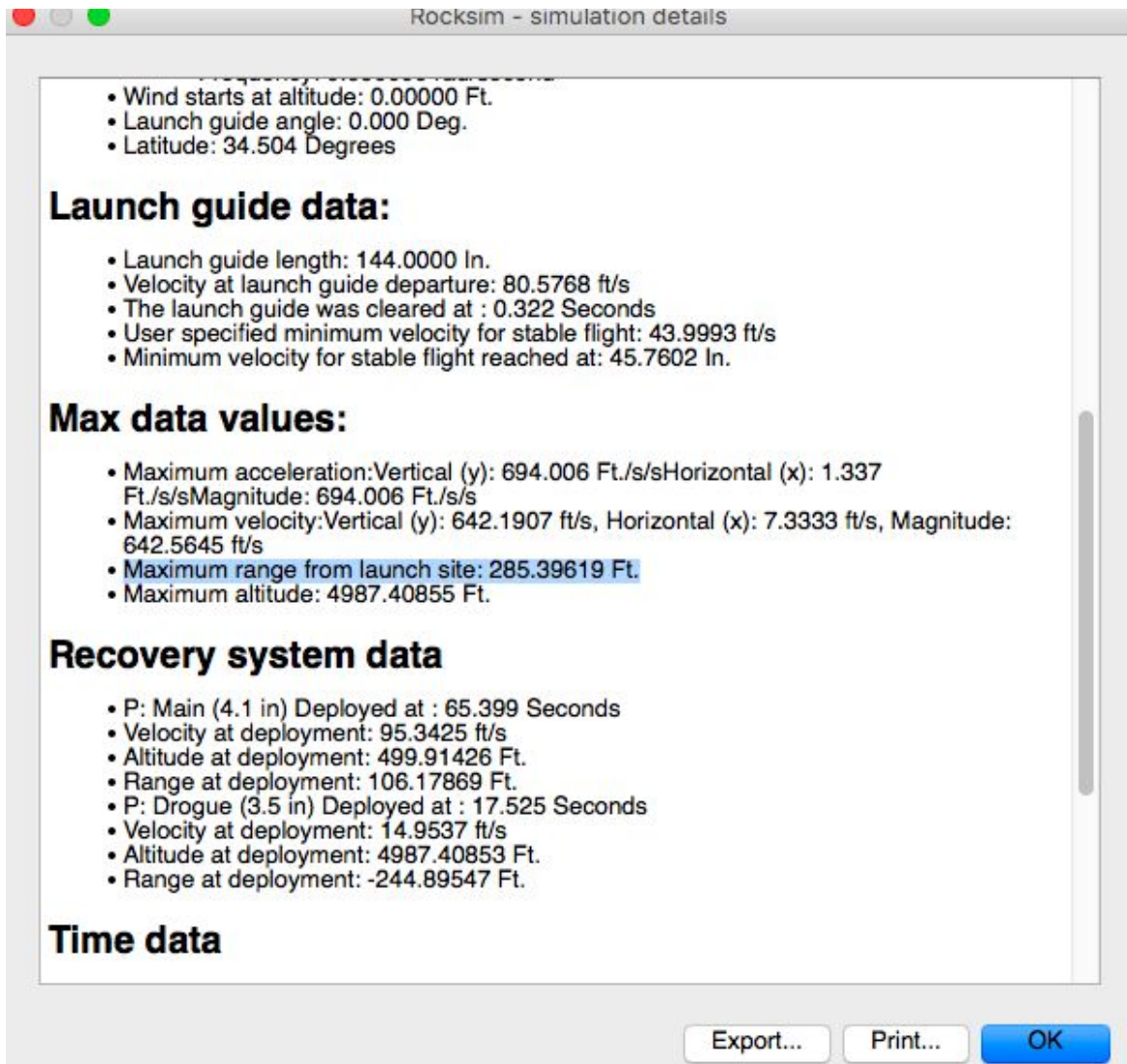
### 3.4.8.4 20 MPH Wind

$$\left[\left(\frac{1 \text{ second}}{82.43 \text{ feet}}\right)(4600 - 600 \text{ ft}) + \left(\frac{1 \text{ second}}{16.94 \text{ feet}}\right)(600 \text{ ft})\right] \times \left(\frac{20 \text{ miles}}{1 \text{ hour}}\right)\left(\frac{5280 \text{ feet}}{1 \text{ mile}}\right)\left(\frac{1 \text{ hour}}{3600 \text{ seconds}}\right) = 2462.39102 \text{ ft}$$

### 3.4.8.5 Differences in Calculations

### 3.4.8.6 Simulations

#### 3.4.8.6.1 5 MPH



Rocksim - simulation details

- Wind starts at altitude: 0.00000 Ft.
- Launch guide angle: 0.000 Deg.
- Latitude: 34.504 Degrees

**Launch guide data:**

- Launch guide length: 144.0000 In.
- Velocity at launch guide departure: 80.5768 ft/s
- The launch guide was cleared at : 0.322 Seconds
- User specified minimum velocity for stable flight: 43.9993 ft/s
- Minimum velocity for stable flight reached at: 45.7602 In.

**Max data values:**

- Maximum acceleration: Vertical (y): 694.006 Ft./s/s Horizontal (x): 1.337 Ft./s/s Magnitude: 694.006 Ft./s/s
- Maximum velocity: Vertical (y): 642.1907 ft/s, Horizontal (x): 7.3333 ft/s, Magnitude: 642.5645 ft/s
- Maximum range from launch site: 285.39619 Ft.
- Maximum altitude: 4987.40855 Ft.

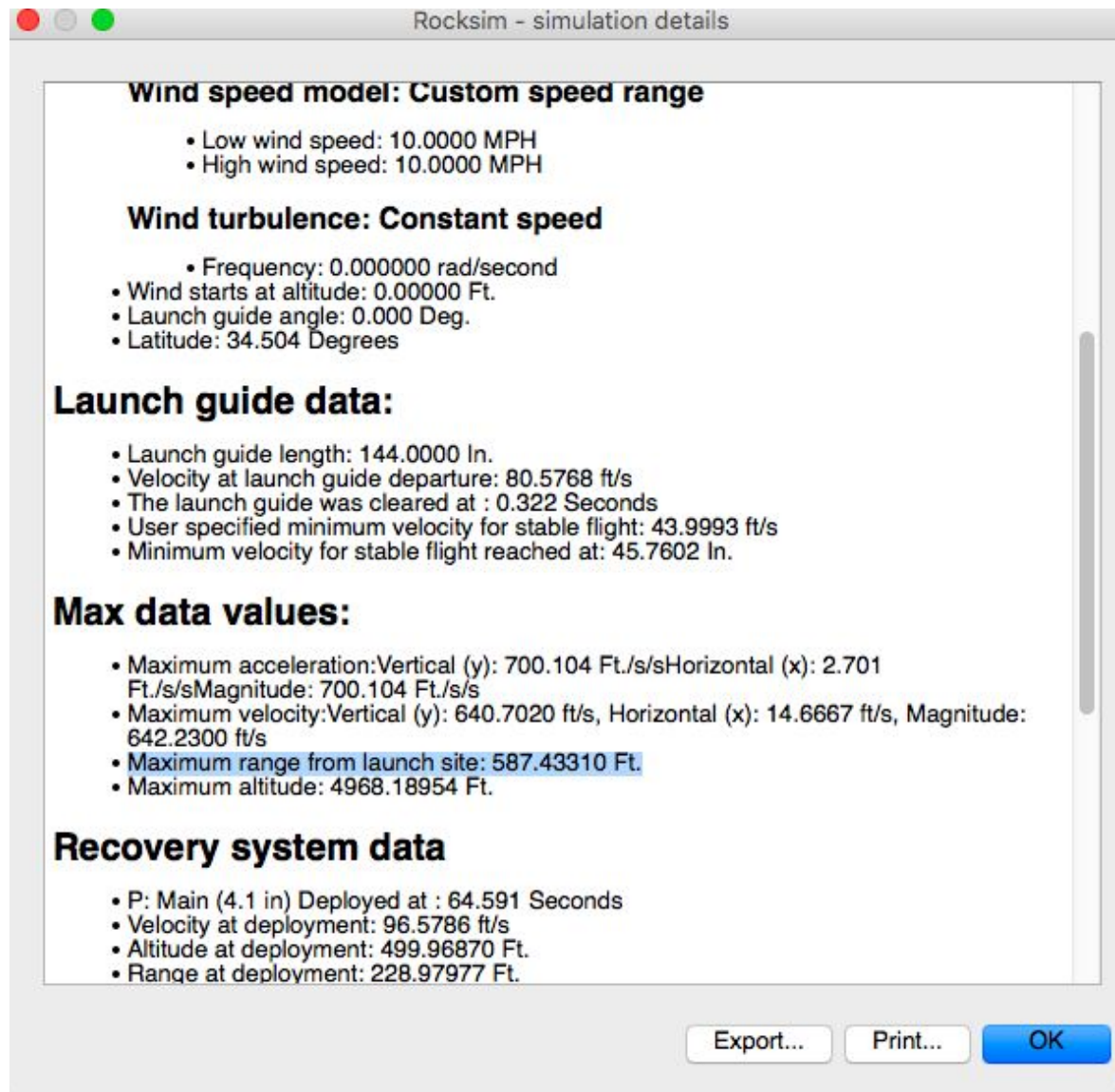
**Recovery system data**

- P: Main (4.1 in) Deployed at : 65.399 Seconds
- Velocity at deployment: 95.3425 ft/s
- Altitude at deployment: 499.91426 Ft.
- Range at deployment: 106.17869 Ft.
- P: Drogue (3.5 in) Deployed at : 17.525 Seconds
- Velocity at deployment: 14.9537 ft/s
- Altitude at deployment: 4987.40853 Ft.
- Range at deployment: -244.89547 Ft.

**Time data**

Export... Print... OK

### 3.4.8.6.2 10 MPH



The screenshot shows a window titled "Rocksim - simulation details" with a standard macOS-style title bar (red, yellow, green buttons). The window contains several sections of simulation data:

- Wind speed model: Custom speed range**
  - Low wind speed: 10.0000 MPH
  - High wind speed: 10.0000 MPH
- Wind turbulence: Constant speed**
  - Frequency: 0.000000 rad/second
  - Wind starts at altitude: 0.00000 Ft.
  - Launch guide angle: 0.000 Deg.
  - Latitude: 34.504 Degrees
- Launch guide data:**
  - Launch guide length: 144.0000 In.
  - Velocity at launch guide departure: 80.5768 ft/s
  - The launch guide was cleared at : 0.322 Seconds
  - User specified minimum velocity for stable flight: 43.9993 ft/s
  - Minimum velocity for stable flight reached at: 45.7602 In.
- Max data values:**
  - Maximum acceleration: Vertical (y): 700.104 Ft./s/s Horizontal (x): 2.701 Ft./s/s Magnitude: 700.104 Ft./s/s
  - Maximum velocity: Vertical (y): 640.7020 ft/s, Horizontal (x): 14.6667 ft/s, Magnitude: 642.2300 ft/s
  - Maximum range from launch site: 587.43310 Ft.
  - Maximum altitude: 4968.18954 Ft.
- Recovery system data**
  - P: Main (4.1 in) Deployed at : 64.591 Seconds
  - Velocity at deployment: 96.5786 ft/s
  - Altitude at deployment: 499.96870 Ft.
  - Range at deployment: 228.97977 Ft.

At the bottom right of the window, there are three buttons: "Export...", "Print...", and "OK".

### 3.4.8.6.3 15 MPH

The screenshot shows a window titled "Rocksim - simulation details" with a standard macOS-style title bar (red, yellow, green buttons). The main content area is a scrollable list of simulation parameters and results, organized into sections. At the bottom right, there are three buttons: "Export...", "Print...", and "OK".

**Simulation Parameters:**

- Frequency: 0.000000 rad/second
- Wind starts at altitude: 0.00000 Ft.
- Launch guide angle: 0.000 Deg.
- Latitude: 34.504 Degrees

**Launch guide data:**

- Launch guide length: 144.0000 In.
- Velocity at launch guide departure: 80.5768 ft/s
- The launch guide was cleared at : 0.322 Seconds
- User specified minimum velocity for stable flight: 43.9993 ft/s
- Minimum velocity for stable flight reached at: 45.7602 In.

**Max data values:**

- Maximum acceleration: Vertical (y): 694.006 Ft./s/s Horizontal (x): 4.078 Ft./s/s Magnitude: 694.006 Ft./s/s
- Maximum velocity: Vertical (y): 638.1740 ft/s, Horizontal (x): 22.0000 ft/s, Magnitude: 641.6697 ft/s
- Maximum range from launch site: 913.15582 Ft.
- Maximum altitude: 4935.68479 Ft.

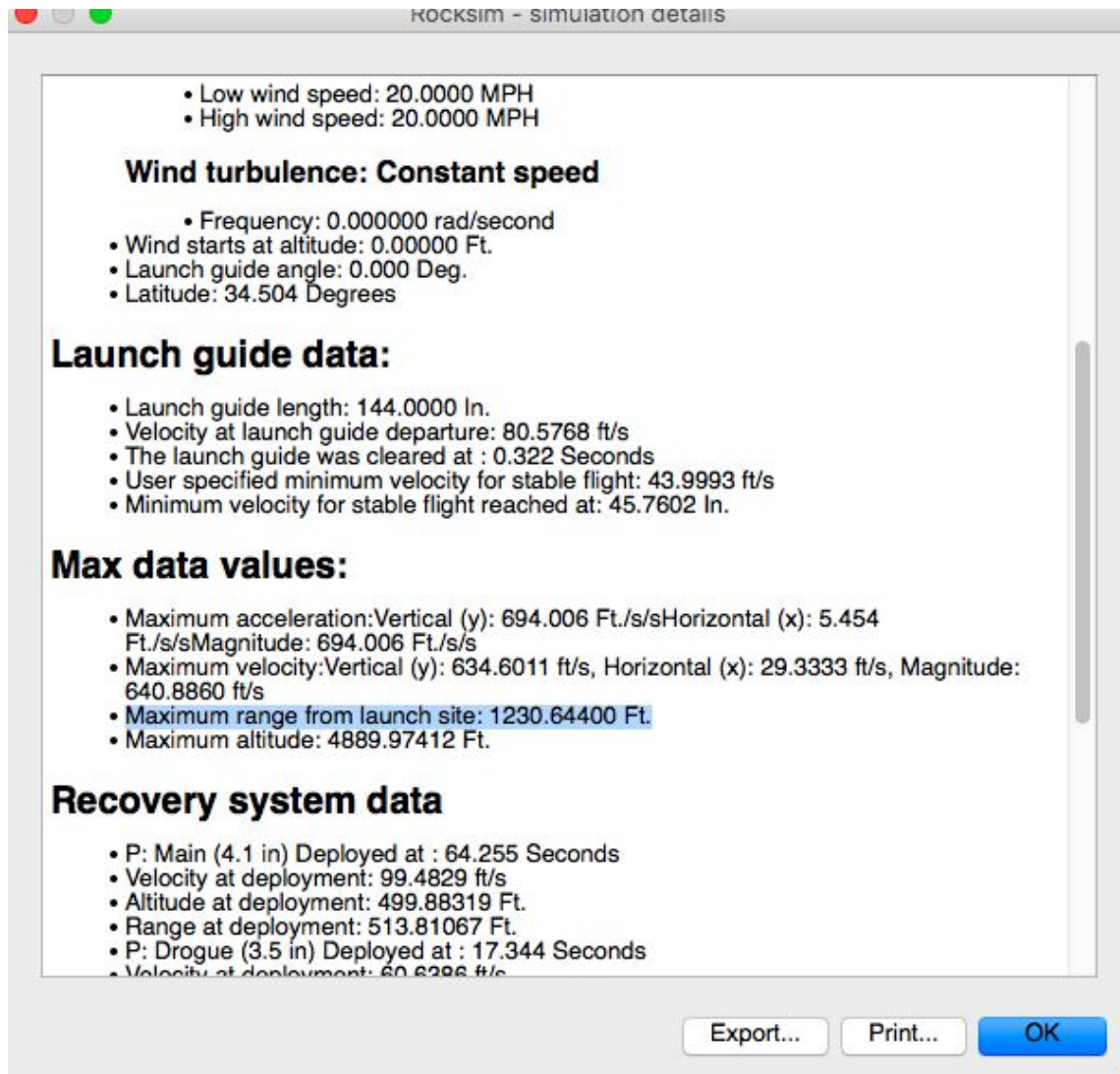
**Recovery system data**

- P: Main (4.1 in) Deployed at : 64.791 Seconds
- Velocity at deployment: 97.5726 ft/s
- Altitude at deployment: 499.89697 Ft.
- Range at deployment: 375.50332 Ft.
- P: Drogue (3.5 in) Deployed at : 17.429 Seconds
- Velocity at deployment: 45.4334 ft/s
- Altitude at deployment: 4935.68475 Ft.
- Range at deployment: -666.47168 Ft.

**Time data**

Export... Print... OK

### 3.4.8.6.4 20 MPH



## 4 Safety

### 4.1 Launch Concerns and Operation Procedures

#### 4.1.1 Recovery Preparation Final Assembly and Launch Procedure

<b>Recovery Preparation Checklist</b>
---------------------------------------



	<p>Replace the battery, then ziptie them</p> <ul style="list-style-type: none"> <li>● <b>Risk:</b> Battery falls out</li> </ul>
	<p>Attach the wires according to color (green to green, white to white, etc)</p> <ul style="list-style-type: none"> <li>● <b>Risk:</b> Drogue or main is ejected at the wrong time</li> <li>● <b>Note:</b> Attach orange and green wires first, and have orange, green, blue, and yellow in the same side.</li> <li>● <b>Note:</b> The bulkhead with blue and yellow is at the bottom, and the bulkhead with white and purple is at the top.</li> </ul>
	<p>Attach ejection charges</p> <ul style="list-style-type: none"> <li>● <b>Risk:</b> Parachutes don't go eject</li> <li>● <b>PPE:</b> goggles</li> </ul>
	<p>Unlock the keys for stratologger and check the beeps according to key card</p> <ul style="list-style-type: none"> <li>● <b>Risk:</b> What if something is wrong with the stratologger?</li> </ul>
	<p>Unlock the keys for RRC3 and check the beeps according to key card</p> <ul style="list-style-type: none"> <li>● <b>Risk:</b> What if something is wrong with the RRC3?</li> </ul>

#### 4.1.2 Motor Preparation Final Assembly and Launch Procedure

Motor Preparation Checklist	
	<p>Remove the motor from its package.</p> <ul style="list-style-type: none"> <li>● <b>Risk:</b> There will be no motor to fly the rocket!</li> </ul>
	<p>Remove the ejection charge from the motor.</p> <ul style="list-style-type: none"> <li>● <b>Risk:</b> The explosion may cause internal and irreparable damage to rocket.</li> </ul>
	<p>Scrape out all ejection charge powder.</p> <ul style="list-style-type: none"> <li>● <b>Risk:</b> may cause internal and irreparable damage to rocket.</li> <li>● <b>PPE:</b> work gloves, safety goggles</li> </ul>
	<p>Replace the ejection charge (now with no powder) back onto the motor.</p> <ul style="list-style-type: none"> <li>● <b>Risk:</b> The motor will not fit properly in its casing and will not have enough pressure to propel the rocket.</li> <li>● <b>Note:</b> It is helpful to have sanded down the charge so more of it fits inside the motor. This will help with extracting the motor after its launch. Insufficient</li> </ul>

	sanding will cause the ejection charge to catch in the casing and lead to spilling out waste inside of the casing.
	<p>Apply a thin layer of grease all around the motor.</p> <ul style="list-style-type: none"> <li>● <b>Risk:</b> It will be difficult to extract the motor after the launch if no grease is applied.</li> <li>● <b>PPE:</b> a disposable glove to spread grease, soap, water</li> </ul>
	<p>Push the motor into the engine casing and screw tightly.</p> <ul style="list-style-type: none"> <li>● <b>Risk:</b> A loose motor will not retain pressure inside the rocket and lead to flight inconsistency and lower altitudes.</li> <li>● <b>Note:</b> Have other people tighten the casing to make sure it is tight.</li> </ul>
	<p>Screw in the motor retainer as tightly as possible</p> <ul style="list-style-type: none"> <li>● <b>Risk:</b> A loose motor may pose safety hazard to bystanders, will not retain pressure inside of rocket and lead to flight inconsistency and lower altitude.</li> <li>● <b>Note:</b> Have other people tighten the retainer to make sure it is tight.</li> </ul>

#### 4.1.3 Setup on Launch Pad Final Assembly and Launch Procedure

Setup on Launcher Checklist	
	<p>Tilt the rail back</p> <ul style="list-style-type: none"> <li>● <b>Risk:</b> Beware of not catching it before it falls too fast! Lower it slowly so the launchpad and people aren't damaged.</li> <li>● <b>Note:</b> If necessary, use hard hats.</li> </ul>
	<p>Mount the rocket and slide it all the way down.</p> <ul style="list-style-type: none"> <li>● <b>Note:</b> Make sure the rail buttons align and are in the right place. Also check to make sure no screws conflict with the rail.</li> </ul>
	<p>Tilt the rail back up.</p>
	<p>Level the launch pad accordingly.</p> <ul style="list-style-type: none"> <li>● <b>Note:</b> The rocket must not point toward people in the proximity of the launchpad.</li> </ul>

#### 4.1.4 Igniter Installation Final Assembly and Launch Procedure

Igniter Installation Checklist	
	<p>Twist the igniter leads.</p> <ul style="list-style-type: none"><li>● <b>Risk:</b> Accidental ignition can damage rocket during launch if the rocket is not fully set up and poses a risk to Student Launch members. Twist the leads!</li><li>● <b>Note:</b> Wear clothing that does not generate static electricity. An accidental discharge of static electricity may cause the igniter to ignite. This is much more dangerous around the black powder charges.</li></ul>
	<p>Mark how far up the igniter should be prior to installation</p> <ul style="list-style-type: none"><li>● <b>Risk:</b> The rocket will not launch even if the igniter goes off.</li><li>● <b>Note:</b> The igniter must be as far up the motor as possible in order to have contact with the solid fuel.</li></ul>
	<p>Install the rocket on the launch pad before placing the igniter.</p> <ul style="list-style-type: none"><li>● <b>Risk:</b> accidental ignition when transporting the rocket, which can lead to injuries and rocket damage</li></ul>
	<p>Coil the igniter after it is pushed in all the way.</p> <ul style="list-style-type: none"><li>● <b>Risk:</b> The igniter must be as far up the motor as possible in order to have contact with the solid fuel.</li><li>● <b>Note:</b> The coil will help maintain how far the igniter is inside the motor.</li></ul>
	<p>Replace the plug</p> <ul style="list-style-type: none"><li>● <b>Risk:</b> The igniter will fall out and the rocket won't launch</li></ul>
	<p>Untwist igniter leads and attach the alligator clips.</p> <ul style="list-style-type: none"><li>● <b>Risk:</b> If skipped, the rocket will not launch.</li></ul>
	<p>Check for continuity.</p> <ul style="list-style-type: none"><li>● <b>Risk:</b> If skipped, the rocket may not launch.</li></ul>

#### 4.1.5 Troubleshooting Final Assembly and Launch Procedure

#### 4.1.6 Post-Flight Inspection Final Assembly and Launch Procedure

Post-Flight Inspection Checklist	
	Once the rocket has landed, approach carefully and inspect any major issues, dangers, or damages done to the rocket.
	Each team member should grab a section of the rocket or the parachute and bring back to the team table where the rocket was constructed.
	Hear the altitude of the rocket with the beeps from the avionics bay.
	Open avionics bay, payload bay, and airbrake module and check for any visible issues.
	Cut the power source and retrieve data from the rover and air brakes.
	Wrap the parachutes and place them back into their respective body tubes to avoid damage.

### 4.2 Safety and Environment (Vehicle and Payload)

#### Vehicle Hazards

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.

#### Payload Hazards

Possible Hazards/Accidents	Mitigations
----------------------------	-------------

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.
The camera malfunctions.	Team members will make sure the camera is turned on and functions correctly before the launch.
Payload deploys early	Team members will make sure that the solenoid is keeping the nose cone attach to the payload body tube before launch.

#### Recovery Hazards

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 airbrakes 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.

#### 4.2.1 Personal Hazard Analysis

#### 4.2.2 Failure Modes and Effects Analysis

Battery for the rover (payload) explodes or fail.	The rocket can be damaged, forcing a complete redesign and new construction process.	9	Incorrect wiring or the battery cannot withstand certain malfunctions in the coding.	1	The team decided to switch to a 9 volt battery to better suit the payload. A checklist will be followed when 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	6	While constructing the rocket, mass change might have occurred.	3	Stability margin is always looked at when designing the rocket and when making any changes to that design. Weather conditions will be

	uncontrollably, possible hurting someone.		During the design process, stability margin might not have been considered. Weather conditions also influence instability.		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.

### 4.2.3 Environmental Hazard Analysis

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 surrounding environment.	9	If the rocket is not stable, it 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.
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.

<p>Ammonium perchlorate composite motors that are not disposed of safely pose a threat to human and environmental safety.</p>	<p>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.*</p>	<p>1</p>	<p>After a motor has been used, the team could leave a motor behind without noticing.</p>	<p>3</p>	<p>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.</p>
<p>More epoxy resin than necessary is left out in the environment or disposed of improperly.</p>	<p>The epoxy could result in dermatitis, chemical burns, respiratory irritation, and environmental pollution. #</p>	<p>1</p>	<p>The team overestimated how much epoxy they could use.</p>	<p>1</p>	<p>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.</p>

\*Source: [wikipedia.org](http://wikipedia.org)

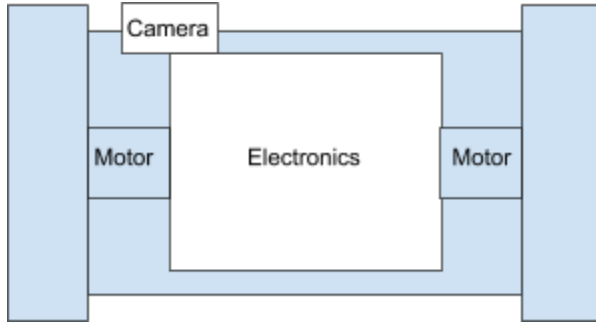
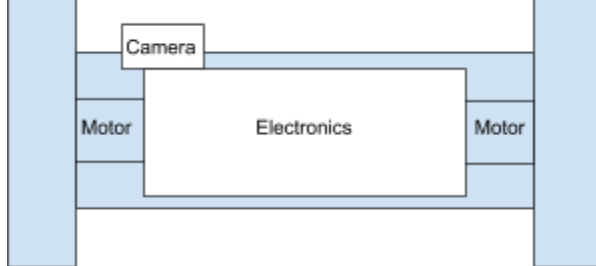
#Source: [westsystem.com](http://westsystem.com)

The nearby waste disposal center in Irvine is the [Irvine Collection Center](#).

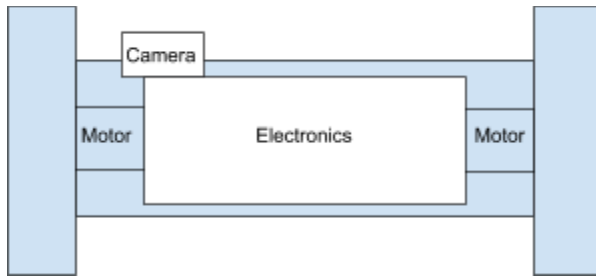
# 5 Payload Criteria

## 5.1 Design of Payload Equipment

### 5.1.1 Alternative Designs

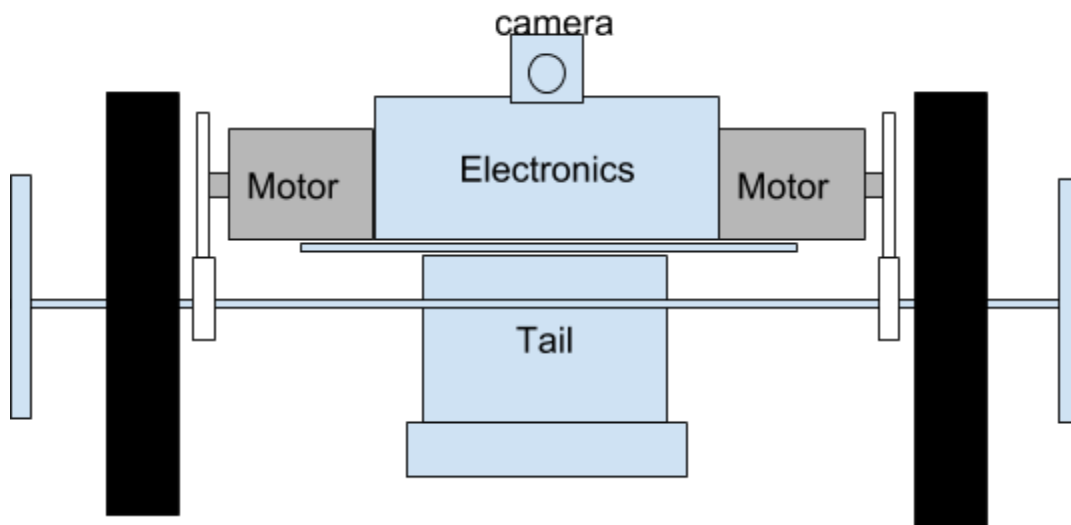
<p>Shorter rover body Pros: effectively utilizing the space in the rocket for the payload section Cons: Not enough space between the body and the edges of the wheels to allow for the rover to efficiently move across the ground.</p>	
<p>Longer rover body Pros: more gaps between bottom and top of wheels and the body, allowing for overcoming obstacles Cons: Requiring more space in the rocket for the payload section</p>	

### 5.1.2 Final Selection

<p>Longer rover body Pros: more gaps between bottom and top of wheels and the body, allowing for overcoming obstacles Cons: Requiring more space in the rocket for the payload section</p>	
--	--

### 5.1.3 System Level Review

#### 5.1.3.1 Payload Assembly



#### 5.1.3.2 Component Interactions

The motors, the ultrasonic sensor, and the pixy2 are all connected to the Arduino Uno. The motors will respond to the data taken in by the pixy2 and the ultrasonic to determine if it needs to move more to reach its destination.

#### 5.1.3.3 Integration of Payload into Launch Vehicle

The rover will be secured with the solenoid acting as a pin to connect the nose cone and the payload body tube.

### 5.1.4 Release Mechanism

#### 5.1.4.1 Alternatives Considered

A release mechanism that allows the main parachute to pull the entire sabot out. The servo is connected to two bearings via fishing wire. When given the signal, the servo will turn and pull the bearings back, allowing the rover to drop out of the sabot.

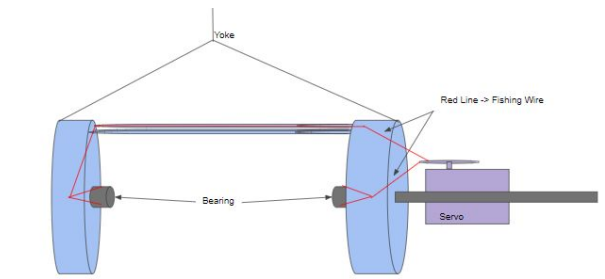
Pros:

- Easy release system that doesn't require extending the length of the rocket

Cons:

- High risk of rover falling out midair while descending on the main parachute.
- No active retention

Decision: Rejected due to safety concern.



A 3-step mechanism controlled via RC that releases the payload by using a linear actuator as a piston. First step is to have the servo that controls the hook that keeps the rover in the body tube. Second step is for the linear actuator by the nose cone and push out the sabot and rover from the aft end. Last step is for the servo on the sabot to allow the bearings to retract and release the rover.

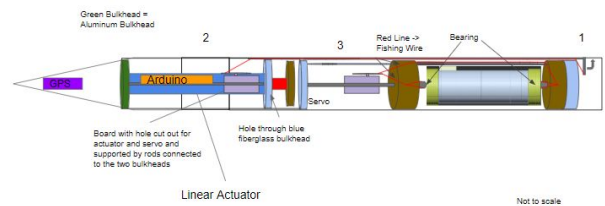
Pros:

- Actuator in the nose cone allows the actuator to partially sit in the nose cone, reducing the length of the rocket.

Cons:

- Retention system has a high risk of failing. Slack can cause the hook to release the sabot and rover.
- The aft end is connected to the tube coupler and bulkhead that is tied to the parachute. If the system were somehow to be pushed out there would be a section that is not tethered together

Decision: Rejected due to safety concern



A door mechanism that allows the rover to drive out the side of the rocket tube. The body tube will be strengthened by gluing a tube coupler to the areas where the body tube doesn't open up. Extra rods and bulkheads were designed to help increase the structural integrity and strength of the body tube.

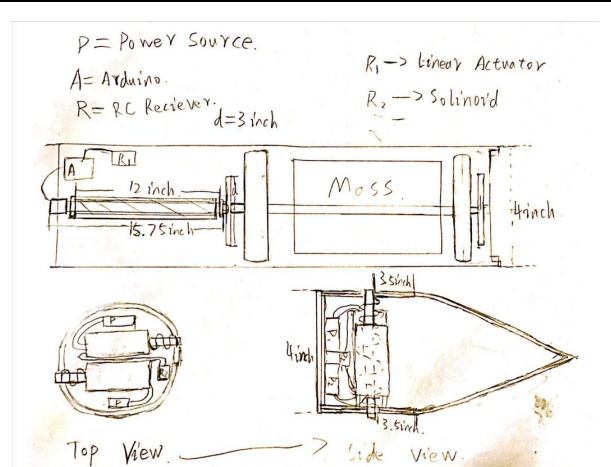
Pros:

- No risk of the parachute detaching from the entire independent section
- No extra length needed to house the linear actuators

Cons:

- The tube would essentially need to be cut in half to allow the rover to roll out of the body tube, severely compromising the structural integrity.
- If the door were to be under the rover, or above the rover, there is no guarantee the rover will be able to make its way out of the body tube.

Decision: Rejected due to risk of the body tube collapsing in on itself.



### 5.1.4.2 Final Choice

A linear actuator that pushes a rod out with 320N.

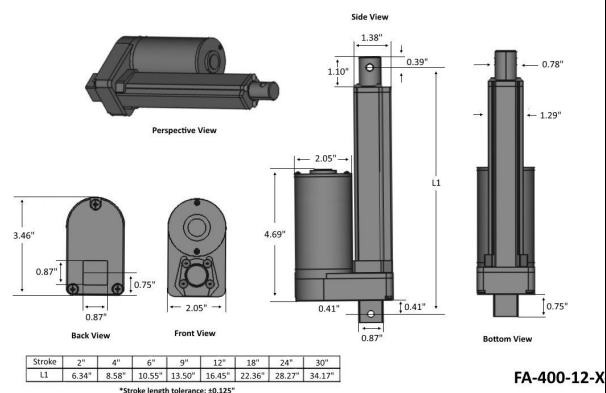
Pros:

- Pushes rod out.
- Easy to incorporate to the designed system.
- Large enough force.

Cons:

- Has a mass of almost 1.6 kg

Decision: Rejected due to the weight and size.



A track linear actuator that moves a piece along the track.

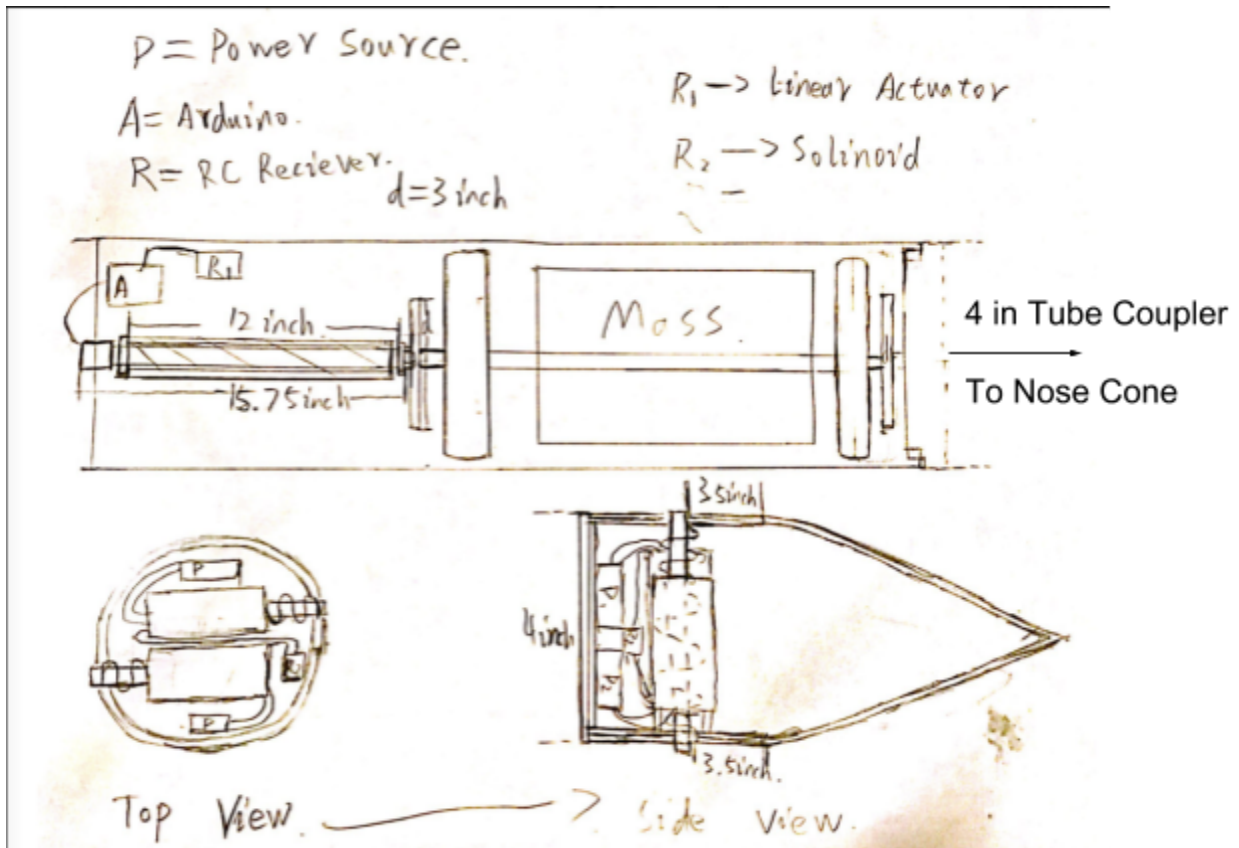
Pros:

- Small but still provides enough force.

Cons:

- Harder to implement and need modification.

Decision: Chosen because of its size and weight, and easier to modify.

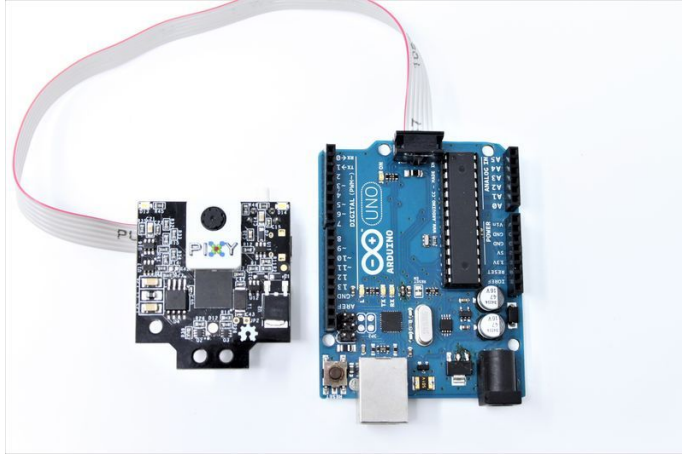


The above diagram is the final design of the system. As shown, the piston mechanism is moved between the rover and the main chute body. This means that the bulkhead that secures the nylon harness will not be detached at any point of the rocket/rover's tasks out on the field. (We attach the pipe with the linear actuator by using glue.)

### 5.1.5 Demonstration of Complete Design

### 5.1.6 Payload Electronics

Pixy2 and Arduino UNO



Ultrasonic sensor



### 5.1.7 Justification for Unique Aspects

We did not place the motors in the middle of the wheel is because our release mechanism need a rod to pass through the rover to push out both rover and nose cone. We kept the rover to 12ft to fit the dimension of the linear actuator. For the release mechanism, we are pushing the rover out of the nose cone, so we use the solenoid to prevent the chance that the nose cone might be pushed out before the it land.



# 6 Project Plan

## 6.1 Testing

### 6.1.1 Test Result Effects on Launch Vehicle and Payload

### 6.1.2 Vehicle Test Plan

To verify that the vehicle is ready, it is necessary to design a subscale model of it. We used a 3” subscale rocket and verified that the design and its subsystems are safe for the flight of the full scale.

#### 6.1.2.1 Test Objective

To verify the functionality and safety of the rocket

#### 6.1.2.2 Success Criteria

The rocket has a suitable stability margin (greater than or equal to 2 calibers), was flown and recovered successfully, Set the minimum rail exit velocity (52 ft/s), and flew the avionics and air brakes subsystems.

#### 6.1.2.3 Testing Variable and Methodology

1. Design a full-scale and subscale rocket. Simulate. If the rockets do not meet the Student Launch handbook’s criteria, then revise and simulate again.
2. Pick suitable motors for each rocket.
3. Build the subscale rocket. Measure for:
  - a. Center of Gravity, relative to nose cone
  - b. Total Mass

These details should be inputted in RockSim to receive a better prediction of the subscale’s flight.

This should also include the rocket’s air brakes and avionics.

4. Test the recovery system and air brakes.
5. Fly the subscale, with the air brakes and avionics on board and active.
6. The following depends on the flight’s results
  - a. If the rocket has crashed, diagnose what went wrong, redesign if necessary, rebuild, and fly again.

- b. If a subsystem did not function at all, diagnose what went wrong, redesign if necessary, and fly again.
- c. If the rocket is successful, then record the results in the Critical Design Review.

#### 6.1.2.4 Proof of Integrity

#### 6.1.2.5 Justification of Necessity to Validation of the Vehicle and Payload

#### 6.1.2.6 Effects of Results

### 6.1.3 Energetics Test Plan

To verify that the energetics charges to deploy the parachutes are sufficient and are connected correctly to the avionics bay. The energetics testing will be used on both the subscale and full scale rocket before launching.

Energetics was tested on December 9th for the subscale vehicle.







#### 6.1.3.1 Test Objective

To ensure that the parachutes will deploy successfully in flight.

#### 6.1.3.2 Success Criteria

The rocket deploys its drogue parachute at apogee and its main chute no higher than 1000 feet above ground. During the deployment, the rocket should not be damaged by the blast to the point it explodes, nor should the parachutes be damaged during the blast.

#### 6.1.3.3 Testing Variable and Methodology

1. Calculate the amount of black powder to be used for both the main chute and the drogue chute. There should be a backup charge that is 1.4 times as much as the regular charge for both the drogue and main chute.
2. Test the charges to make sure they fully eject each parachute by packing the rocket as if preparing for launch, checking for continuity, and inserting and remotely detonating one charge at a time with a 9V current.
3. If the parachute is not ejected fully, recalculate/increase the charge and test again. If the parachute or rocket gets damaged, recalculate/decrease the charge, fix the damages, and test again.
4. Test all four charges (main charge for drogue and main, backup charge for drogue and main) to find the minimum amount of black powder that is safe to use for flight.

#### 6.1.3.4 Proof of Integrity

#### 6.1.3.5 Justification of Necessity to Validation of the Vehicle and Payload

#### 6.1.3.6 Effects of Results

### 6.1.4 Air Brakes Test Plan

#### 6.1.4.1 Test Objective

#### 6.1.4.2 Success Criteria

#### 6.1.4.3 Testing Variable and Methodology

1. Check the module to see any possible structural damages.
2. Tighten all screws, from the hinges of the airbrakes to the arms of the servo.
3. If not already uploaded, the airbrake test code should be uploaded to the Teensy via laptop

4. Connect the servo cable to the respective wire on the airbrake electronics. Once the battery is connected, the simple code should just open and close the airbrakes continuously.
5. Team members in charge of the airbrakes will look for any improper functionality in the rocket.
6. After one minute of running the code, remove the battery connection from the Teensy and upload the flight code.
7. Connect the servo cable to the respective wires on the airbrake electronics.
8. Connect the other respective cable to the Pnut altimeter
9. Place the Pnut in the vacuum chamber and connect the Lipo battery source to the designated location on the Teensy board.
10. Turn on the vacuum chamber. As pressure changes in the chamber, the airbrakes should open and close irregularly to adjust the simulated altitude.
11. If the airbrakes and servo do respond, the airbrake module is ready for flight.

#### 6.1.4.4 Proof of Integrity

#### 6.1.4.5 Justification of Necessity to Validation of the Vehicle and Payload

#### 6.1.4.6 Effects of Results

### 6.1.5 GPS Test Plan

To test the GPS, one must turn on the Whistle GPS app and set up the Whistle Zone, a circle with a one mile radius. After the Whistle Zone is set up and the base station is in place, a team member can drive up to a mile with the GPS, and the phone should be able to track the pathway of the car.

Refreshing location is useful in checking to see if the GPS has changed its position. The GPS will only update the phone if the GPS has left the designated Whistle Zone. The update provides the location of the GPS before it left the Whistle Zone.

6.1.5.1 Test Objective

6.1.5.2 Success Criteria

6.1.5.3 Testing Variable and Methodology

6.1.5.4 Proof of Integrity

6.1.5.5 Justification of Necessity to Validation of the Vehicle and Payload

6.1.5.6 Effects of Results

## 6.1.6 Payload Test Plan

6.1.6.1 Test Objective

Check to see if payload is secured inside the body tube.

6.1.6.2 Success Criteria

6.1.6.3 Testing Variable and Methodology

6.1.6.4 Proof of Integrity

6.1.6.5 Justification of Necessity to Validation of the Vehicle and Payload

6.1.6.6 Effects of Results

6.1.7 Effects of Tests on Overall Vehicle and Payload Design

## 6.2 Requirements Compliance

6.2.1 Verification Plans

6.2.1.1 General Verification Plan

6.2.1.2 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.

#### 6.2.1.3 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.

#### 6.2.1.4 Experiment Verification Plan

#### 6.2.1.5 Safety Verification Plan

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



## 6.2.2 Team Derived Requirements

### 6.2.2.1 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

### 6.2.2.2 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, no earlier.

### 6.2.2.3 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.

## 6.3 Budgeting and Timeline

### 6.3.1 Budget

Description	Cost Per	Qty	Total *Tax Separated	
<b>Subscale Vehicle</b>				
3" Fiberglass Frenzy XL	\$226.95	1	\$226.95	
3" Aluminum Bulkplate	\$15.00	2	\$30.00	
3" G12 Airframe (Thin Wall)	\$50.00	2	\$100.00	
3" G12 Coupler 9"	\$22.00	3	\$66.00	
3" G12 Coupler 9.75"	\$22.00	1	\$22.00	
Aero Pack 54mm Retainer	\$29.00	1	\$29.00	
P54-3G-CL	\$86.00	3	\$0.00	
Cesaroni - P54-3G Classic (J295)	\$115.14	3	\$345.42	
3" G12 Coupler 9"	\$22.00	1	\$22.00	
<b>Total SubScale Cost</b>				\$898.45

<b>Full Scale Vehicle</b>				
4" Aluminum Bulkplate	\$20.00	2	\$40.00	
4" Fiberglass Frenzy XL	\$369.95	1	\$369.95	
4" G12 Airframe	\$58.00	2	\$116.00	
4" G12 Coupler 9"	\$24.00	3	\$72.00	
4" G12 Coupler 12"	\$32.00	1	\$32.00	
4" G12 Coupler 13"	\$32.00	1	\$32.00	
4" / 98 mm Black G10 Airframe Plate	\$6.00	4	\$24.00	
4" / 98 mm Black G10 Coupler Bulkplate	\$6.00	3	\$18.00	
Aero Pack 75mm Retainer	\$44.00	1	\$44.00	
P75-2G-WT	\$140.00	4	\$560.00	
<b>Total Full Scale Cost</b>				<b>\$1,307.95</b>
<b>Avionics/Recovery</b>				
1" Tubular Nylon Green (Per Inch)	\$0.55	100	\$55.00	
Shock Cord Protector 60"	\$23.95	4	\$95.80	
Chute Blast Protector 9" x 9"	\$7.95	3	\$23.85	
Chute Blast Protector 6" x 6"	\$6.95	1	\$6.95	
Chute Blast Protector 18" x 18"	\$11.95	3	\$35.85	
Chute Blast Protector 12" x 12"	\$8.95	1	\$8.95	
Launch Lug Pack	\$2.50	1	\$2.50	
Machinery Shoulder Eye Bolt, 1/4" x 1"	\$3.75	3	\$11.25	
Rod-316SS Threaded 1/4-20x2ft	\$8.49	1	\$8.49	
Eye Bolt-SS 1/4x2-3/16	\$17.99	2	\$35.98	
Threadlock-Gel Blue .20 oz	\$9.99	1	\$9.99	
Eye Nut-SS 1/4-20	\$27.99	2	\$55.98	
Key Switch - Type 3	\$6.00	5	\$30.00	
RBF4B Remove Before Flight	\$6.00	5	\$30.00	
2 of Parts Express 9V Battery Holder Metal Clip	\$10.93	5	\$54.65	
8" NRTL/BLK Cable Tie Set 200PK	\$9.21	1	\$9.21	
Duracell 9V Batteries 4 Pack	\$15.79	1	\$15.79	
Duracell 9V Batteries 8 Pack	\$16.99	1	\$16.99	

M2.5 Male Female Hex Brass PCB Threaded Motherboard Standoff Pillar Hexagonal Spacer Bolt Screw Nut Assortment Kit 160Pcs	\$11.99	1	\$11.99	
			\$0.00	
			\$0.00	
			\$0.00	
<b>Total Avionics Cost</b>				\$519.22
<b>Payload</b>				
T16-S Mini Track Actuator with Limit Switches	\$80.00	2	\$160.00	
Pixy2 Smart Vision Sensor - Object Tracking Camera for Arduino, Raspberry Pi, BeagleBone Black	\$59.90	1	\$59.90	
Samsung 32GB 95MB/s (U1) MicroSD EVO Select Memory Card with Adapter (MB-ME32GA/AM)	\$5.99	1	\$5.99	
Pan/Tilt2 Servo Motor Kit for Pixy2 - Dual Axis Robotic Camera Mount	\$29.90	1	\$29.90	
SainSmart InstaBots 2-Wheels Self-Balancing Upright Rover Car V3 for Arduino with Step-by-step Instructions	\$99.99	1	\$99.99	
Ultimate Hobbies (Payload Material)	\$53.83	1	\$53.83	
HobbyPark 3/4/5/6/7/8mm Wheels Tires Flexible DC Gear Motor Coupling Coupler Connector Adapter Nuts 12mm Hex 30mm Length for RC Car Robot DIY (4-Pack) (Fit 3mm Motor Shaft)	\$12.98	1	\$12.98	
HobbyPark 3/4/5/6/7/8mm Wheels Tires Flexible DC Gear Motor Coupling Coupler Connector Adapter Nuts 12mm Hex 30mm Length for RC Car Robot DIY (4-Pack) (Fit 4mm Motor Shaft)	\$12.98	1	\$12.98	
Premium High Force Linear Actuators 400lbs/12"	\$139.99	2	\$279.98	
3"x38mm G10 CR	\$6.00	8	\$48.00	
<b>Total Payload Cost</b>				\$763.55
<b>GPS</b>				
Whistle GPS	\$70.00	1	\$70.00	
Whistle GPS - December Month	\$9.95	1	\$9.95	

			\$0.00	
	<b>Total GPS Cost</b>			\$79.95
	<b>Educational Outreach</b>			
			\$0.00	
	<b>Total Outreach Cost</b>			\$0.00
	<b>Supplies</b>			
	Large Plastic Storage Bin 10071296	\$6.99	1	\$6.99
	Large Tarnish Inhibitor C 10043286	\$13.49	1	\$13.49
	Small Plastic Storage Bin 10071294	\$3.19	2	\$6.38
	<b>Total Supply Cost</b>			\$26.86
	<b>Travel Fees (11 Members) (Estimated)</b>			
	Trips to Lucerne Dry Lake (\$3.25/gallon, 128 mi)			
	Trip to Huntsville (Roundtrip)	\$380.00	11	\$4,180.00
	Hotel at Huntsville (\$120/night, 2 people per room, 6 days)	\$120.00	30	\$3,600.00
	Food (\$30/day, 6 days)	\$30.00	66	\$1,980.00
	FAR Launch Member Fee (12/15)	\$10.00	6	\$60.00
	<b>Total Travel Costs</b>			\$9,820.00
	<b>Tax Fees (Order Number)</b>			
	66510669937			\$0.87
	16687			\$81.58
	16694			\$21.78
	17328			\$5.86
	17876			\$4.14
	112-1341414-3920226			\$0.00



## Appendix A: Statement of Work Cross-Reference

Section	Requirement in SOW	CDR Section
<b>General Requirements</b>		
1.1	Students on the team will do 100% of the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder or any variant of ejection charges, or preparing and installing electric matches (to be done by the team's mentor).	
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.	
<b>Vehicle Requirements</b>		
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. Subscalers 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.	
<b>Recovery System Requirements</b>		
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.	
<b>Payload Experiment Requirements</b>		
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 <a href="https://www.faa.gov/uas/faqs">https://www.faa.gov/uas/faqs</a> ).	
4.5.7	Any UAV weighing more than .55 lbs. will be registered with the FAA and the registration number marked on the vehicle.	
<b>Safety Requirements</b>		
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

### AIAA OC Section Shop Safety Rules For all rocketry activities (Youth – TARC – modified for SLI)

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

## AIAA OC Section Launch Safety Rules For all rocketry activities (Youth – TARC – modified for SL)

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 battery 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.