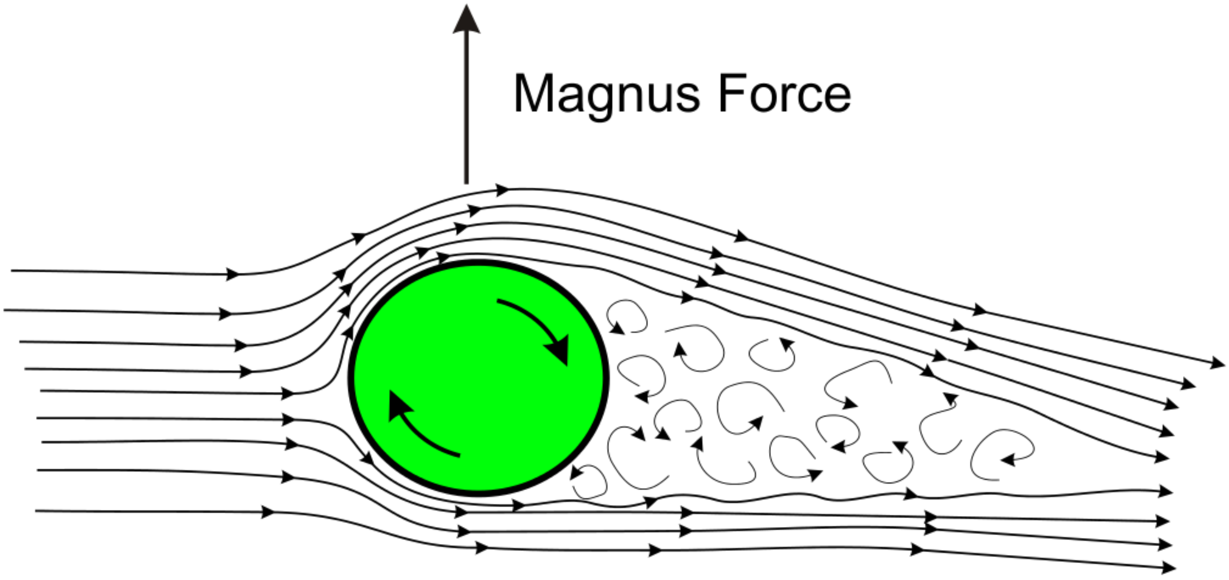
# Preliminary Design Review (PDR)

## Unmanned Aerial Vehicle with Experimental Magnus Force Lift



Mailing Address:
15 Wyoming
Irvine, CA 92606

**AIAA OC Section**
**11/3/17**
Albert (team leader)
Allison; Annabel; Brenda; Kushagra; Sahil

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# 1 Summary of PDR Report

## 1.1 Team Summary

### 1.1.1 Team Name and Mailing Address

Team Name:
AIAA OC Section

Mailing Address:
15 Wyoming
Irvine, CA 92606

### 1.1.2 Mentor Information

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

Robert has been co-leading TARC teams for eight years and 4H rocketry projects for 13 years. He has a BS degree in Electrical Engineering from USC and has worked as an electronics designer, programmer, and now a director of the software department doing embedded programming for thermal printers. Robert worked on the F-20 Tigershark while at Northrop. Robert launched his first rockets shortly after Sputnik in 1957 and has continued in rocketry with his own children and grandchildren, Indian Princesses and Indian Guides, and 4H.

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

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

Jann has been co-leading TARC teams for eight years and 4-H rocketry projects for 11 years. She has a bachelor's degree in Fine Arts from Cal State University Los Angeles in 1979. She has worked in electronic business as an assembler and in the accounting office. Now she is retired. She has been doing Rocketry for 25 years with her husband children and grandchildren. Jann is the AIAA OC Section Council member in charge of education. She has been in 4-H for 11 years and has been doing rocketry in 4-H for 11 years. She has also led 4-H projects in livestock including lambs, goats, and beef.

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

# 1.2 Launch Vehicle Summary

## 1.2.1 Size and Mass

- Dimater: 4”
- Mass: 11501 g
- Length: 139.5”

## 1.2.2 Motor Choice

Cesaroni K2000

## 1.2.3 Recovery System

The rocket will contain two parachutes. The drogue, the smaller one below the avionics bay, will deploy at apogee (theoretically a mile high) and will be used to slow down the descent of the rocket until 500 feet, when the main parachute is deployed. To ensure redundancy, there will be 2 different flight computers to blast out the parachutes for each height. The stratologger, which will be the primary flight computer, will blast out the drogue at apogee and the main at 500 feet. The RRC3, which is the secondary flight computer, will blast out the drogue at two seconds after apogee and the main at 300 feet.

## 1.2.4 Milestone Review Flysheet

The milestone review sheet will be available at
http://www.verticalprojectile.org/documents18.html

# 1.3 Payload Summary

## 1.3.1 Payload Title

Sub-Orbital Satellite with Experimental Magnus Force Lift

## 1.3.2 Summary of Payload Experiment

The payload will utilize two cylindrical drums on a single rod and rotate to generate lift. This is an exploitation of the Magnus Effect to generate lift in an aircraft.

The engineering payload is to fly to a specified GPS coordinate on Bragg Farms. The coordinate must be within 0.25 mi of the launchpad.

# 2 Changes Made Since Proposal

## 2.1 Changes made to Vehicle Criteria

- Body tube extension
    - To accommodate the new payload length

## 2.2 Changes made to Payload Criteria

- Narrowed down alternatives for deployment methods
- Addition of slingshot system
    - Utilizes linear actuators, telemetry
    - Provides constant force against nose cone, pushes nose cone and payload out simultaneously
- Addition of linear actuators
    - Will pull the pins in the nose cone to make sure

## 2.3 Changes made to Project Plan

- Timeline adjusted, includes backup flight days

# 3 Vehicle Criteria

## 3.1 Selection, Design, and Rationale of Launch Vehicle

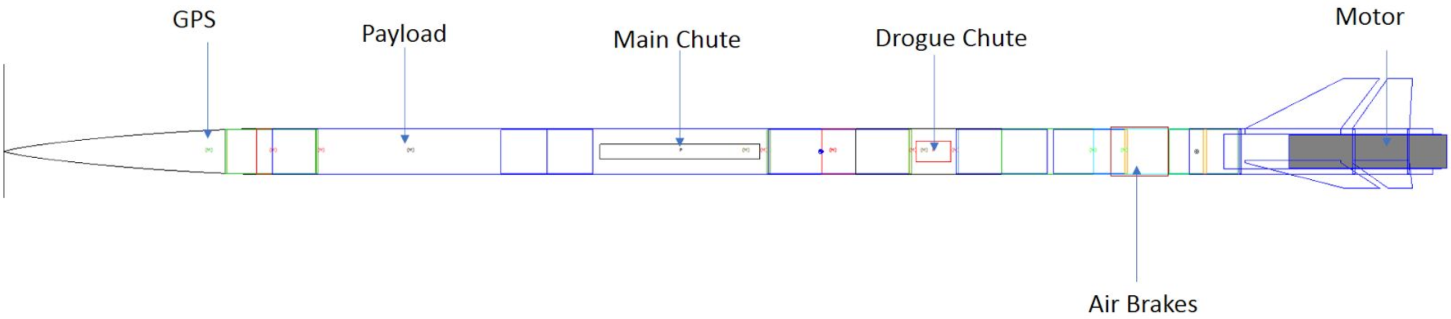
### 3.1.1 Mission Statement

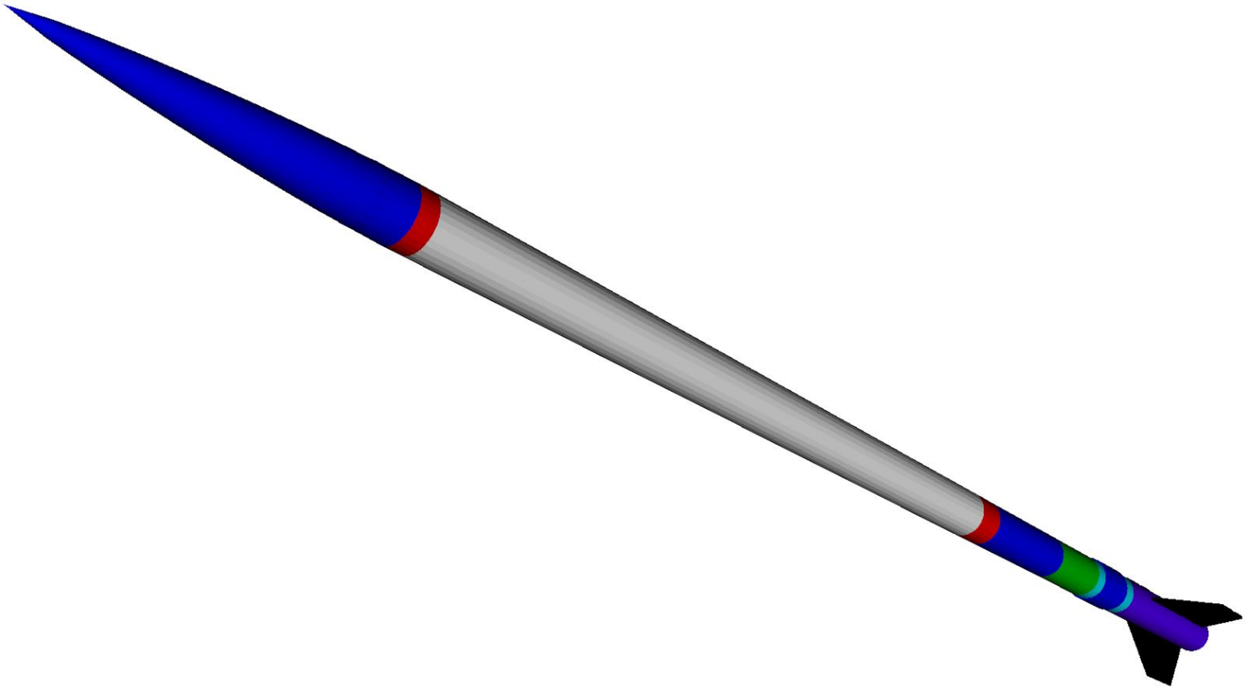
The rocket must transport its payload safely to a target altitude of exactly 5280 ft, deploy its drogue chute at apogee, descend to 700 ft, deploy its main chute, and then deploy the payload at or below 400 ft, per the RSO's approval. The rocket and payload must land within 2500 ft of the launchpad.

### 3.1.2 Mission Success Criteria

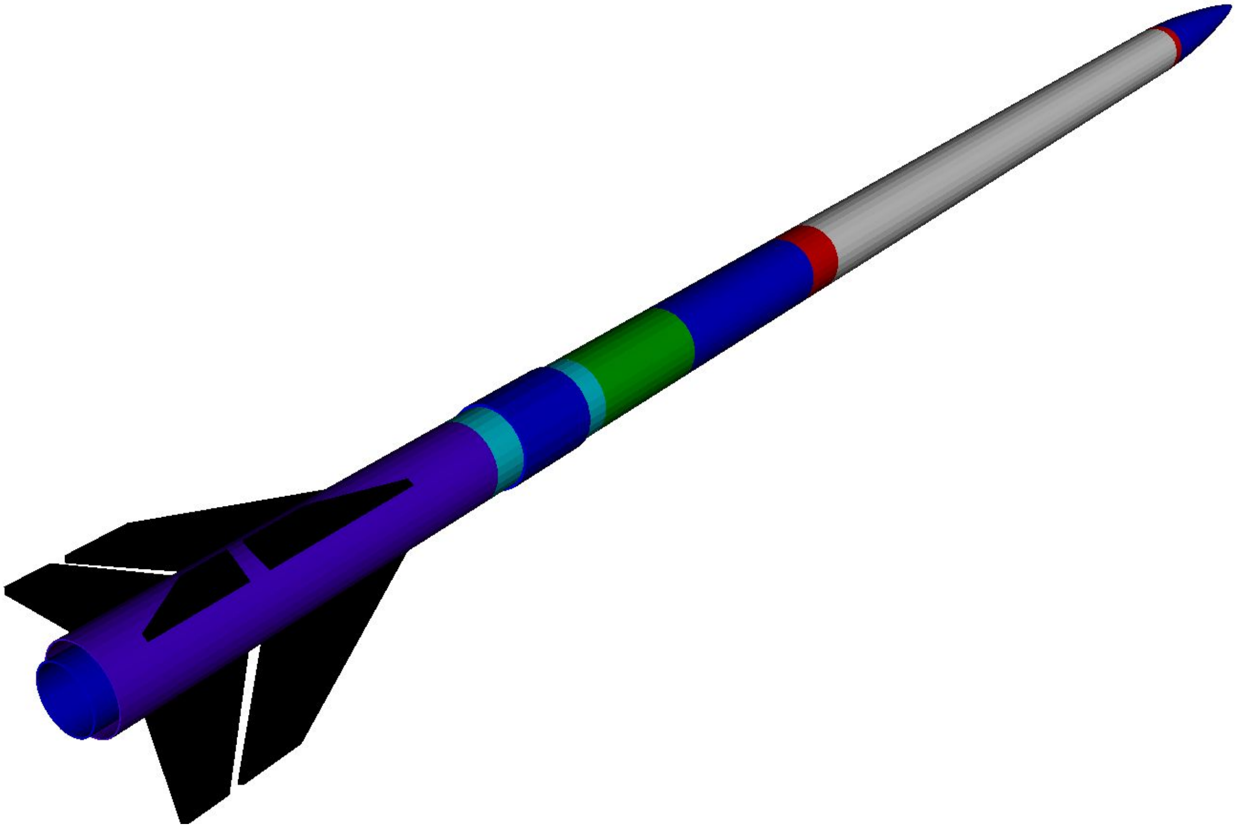
The vehicle must be reusable after launch and must land within 0.25 miles of the launchpad.

### 3.1.3 Vehicle Design

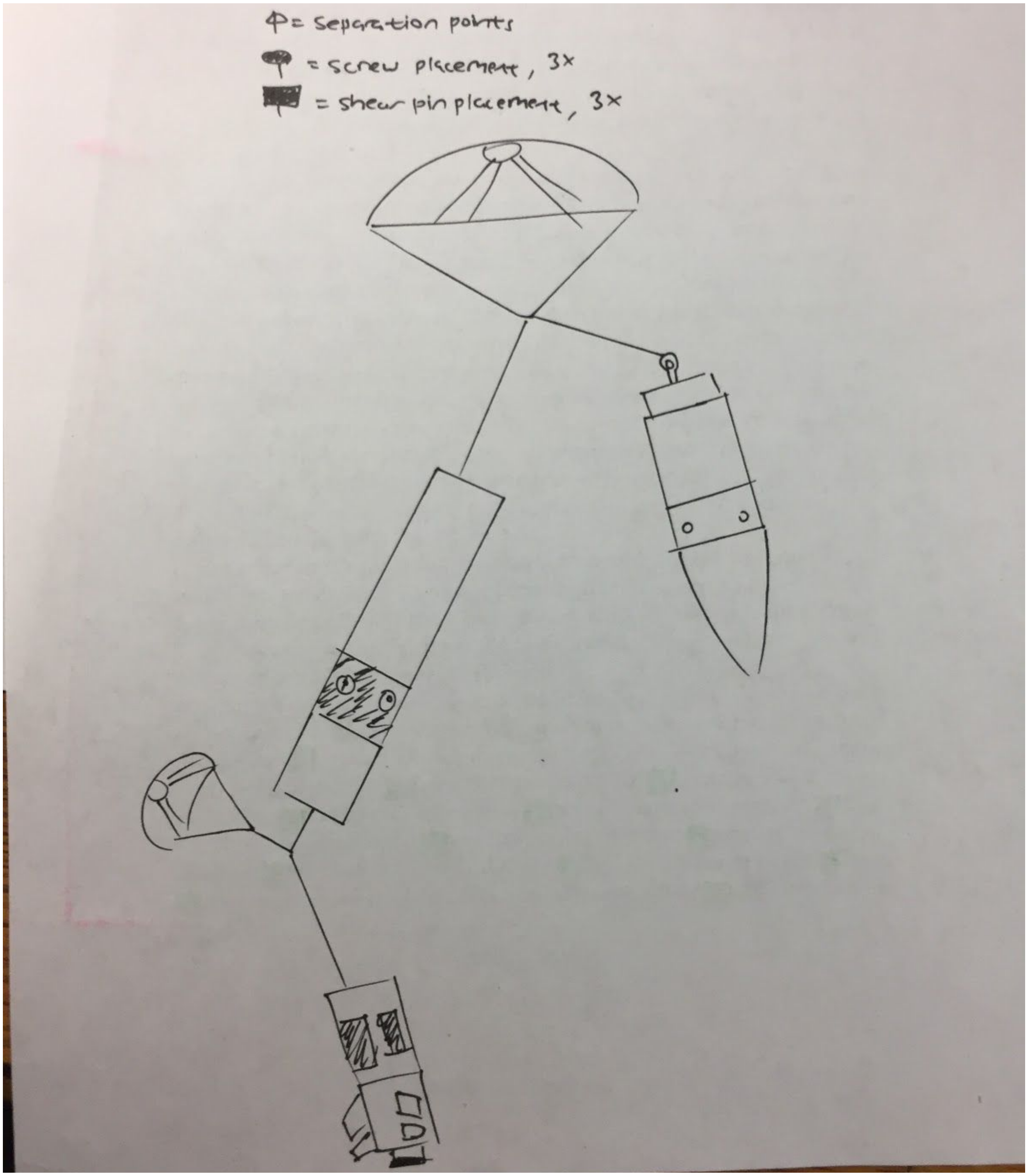




**Fore View**



**Aft View**



In total, there are four independent sections of the rocket, all of which are tethered via flat nylon cords.

The longest body tube is directly under the nose cone at 38” long. This is to accommodate the large payload.

### 3.1.3.1.1 GPS Subsystem

The main rocket, which is all tethered together, will contain a Whistle GPS dog tracker for the GPS. It will be located in the nose cone of the rocket, and it operates through cellular connection and can transmit the location of the rocket through a smartphone app. The payload, our UAV, will have it's own separate GPS via an Arduino Uno.

### 3.1.3.1.2 Alternatives

| GPS system | Pros | Cons |
|---|---|---|
| Whistle GPS dog tracker | Easy to use because it requires knowledge of using a smartphone app. It can be recharged easily using the base station and is not dependent on any other external electronics. No additional telemetry required. | Only works where there is cellular coverage. Bigger than the other GPS options. More expensive because of money needed for cellular service.telemetr Sometimes has trouble locating and turning on. |
| Parallax GPS Receiver | Arduino compatible | |

### 3.1.3.1.3 Leading Design

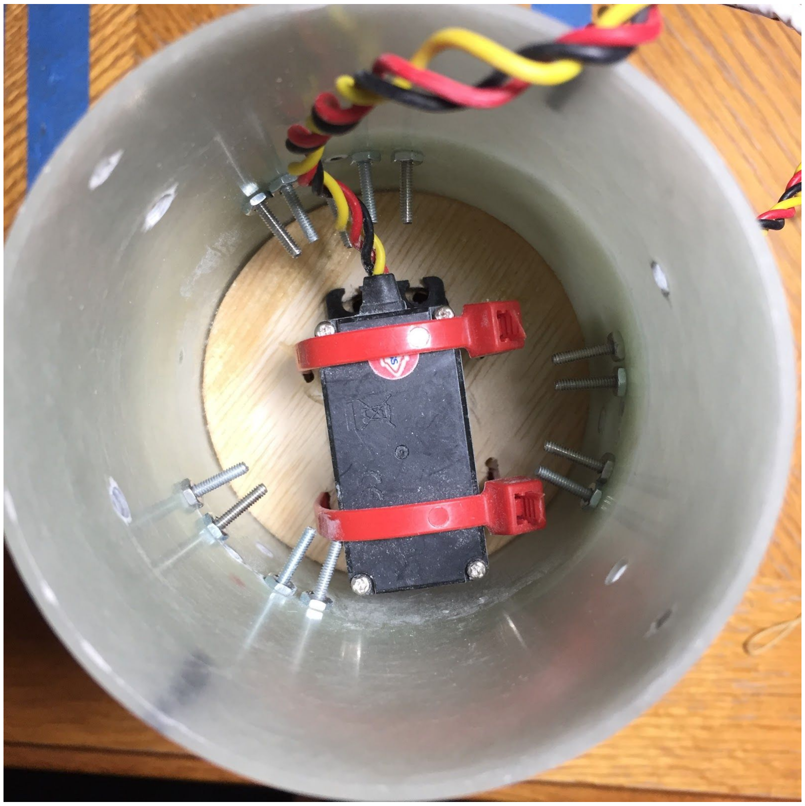
We will continue using Whistle GPS dog tracker because we can visually find the rocket and have an exact location based on satellite images. These images can be shown through the mobile app.

## 3.1.3.2 Airbrakes Subsystem

In the full-scale rocket, the air brake module will have an 8.25” long G10 fiberglass body tube, with a 6.5” long G10 fiberglass tube coupler, and. It will have a 4” diameter. It will be independently powered by a Lithium Polymer battery, meaning it will not have any connection with the recovery subsystem or the payload.

Both are constructed to be modular and have an opening for repairing electronics. The wooden bulkhead will not undergo any stress from the explosion of the ejection charge or sustain the rocket via attachment of an eyebolt.

After constructing the air brakes module, we found that the joints that connected the servo to the air brakes required more flexibility. Originally, we used shortened servo horns and snap-on connectors to create the braking mechanism. We purchased ball-bearing swivels at a hobby store to add more flexibility to the rotational points. This swivel provides an additional hinge for the arm to turn on, so the air brake wing will come out.



The above pictures are of the rocket's subscale air brake module, which are from last year's Student Launch project. We will continue using the same design.

We tested the air brakes to run continuously for one minute to account for any problems. We did not find any. The rocket's ascent lasts for less than 20 seconds, depending on weather conditions. If the air brakes can function without fail for longer than that time, then they are safe to fly. The battery is strong enough to last the designated standstill time on the launchpad prior to launch. We also tested the airbrakes with varied servo speeds to see if they would open and close systematically, regardless of torque, and function was normal.

### 3.1.3.2.1 Algorithm Development

The overall algorithm we will use to automate our airbrakes has four major facets: the initial setup, the launch detect function, the actual airbrake function, and the apogee detect function. The initial setup, or void setup, initializes the Teensy's serial monitor to a baud rate of 9600 Bd, along with blinking a built in LED light to indicate to the user that the system was functional. Next, the launch detect function is perhaps the most vital piece of the code. It is a boolean function which analyzes the readings from the altimeter, and when it sees a value which is greater than 50 feet, it starts the main airbrake program. The airbrake function then checks the altimeter values and uses basic physics formulas (factoring in air resistance, pressure, etc) to determine velocity and projected altitude. If this projected altitude is greater than the actual altitude, the airbrake will expand to a certain angle (where 120 degrees was the maximum) using a fairly linear formula. The airbrake function works simultaneously with the apogee detect formula, which analyzes the altitudes from the Pnut and checks to see whether the rocket reaches apogee. Since this is a boolean function, it has to satisfy 2 conditions in order to be true. First, three consecutive altitudes has to be descending, as this will indicate a descending rocket and thus the arrival of apogee. However, we have to account for errors in the Pnut readings, so the second condition is that the altitude has to be at least 3,500 feet. If the detect apogee function satisfies these two conditions, it will terminate the airbrake function and stop the overall program, retracting the airbrakes to zero position. There is no use of the airbrakes after apogee.

### 3.1.3.2.2 Algorithm Flowchart

The algorithm also uses this equation, which we derived from our understanding of the Law of Conservation of Energy. *U* and *K* denote potential and kinetic energy, respectively.

$$U_0 + K_0 = U_f + K_f$$

$$mgh_0 + \tfrac{1}{2}mv_0{}^2 = mgh_f + \tfrac{1}{2}mv_f{}^2;\ v_f = 0\ mph\ at\ apogee;\ v_0,\ h_0 > 0$$

$$mgh_0 + \tfrac{1}{2}mv_0{}^2 = mgh_f$$

$$h_f = h_0 + \tfrac{v_0{}^2}{2g}$$

If the difference between the predicted altitude and the target altitude is greater than or equal to 20 ft, then the air brakes will use coarse tuning. Coarse tuning involves opening the air brakes at a greater angle for a longer period of time.

If the difference between the predicted altitude and the target altitude is less than 20 ft, then the air brakes will use fine tuning. Fine tuning opens the air brakes at a reduced angle for a shorter period of time.

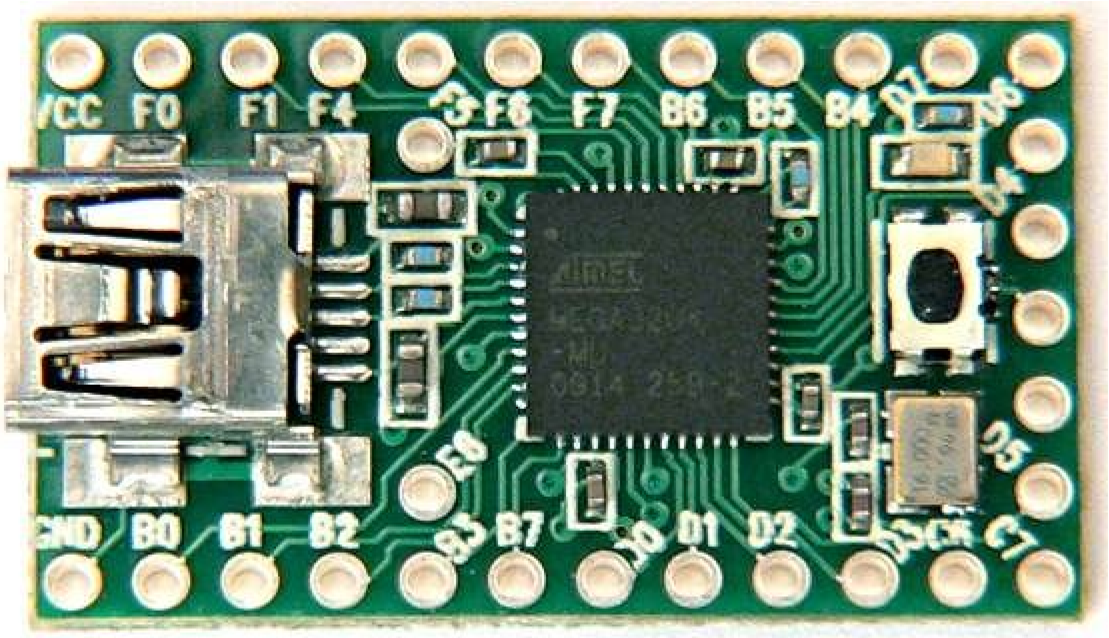
The above calculations do not account for air friction because air density decreases as the rocket ascends and becomes negligible as the rocket ascends.

### 3.1.3.2.3 Components of Air Brakes

For the 2017 Team America Rocketry Challenge (TARC), we developed an air brake system. The current model pushes the air brakes through holes that we carved into the body tube. After testing the design ten times, recording the air brakes in flight with an on-board flight camera, and examining post-flight data, we determined that the air brake system was reliable and applicable for our purposes in Student Launch. The air brakes will use similar but stronger materials that we have used in our TARC rocket for the 2017 season.

Due to space, we will use a Teensy 2.0, which is Arduino compatible but smaller than an Arduino Uno. The dimensions of the Teensy are 1.2”x 0.7”x 0.125”. We have experience with the Teensy because we used it for air brake control in our TARC rockets.

The Teensy can also carry an SD card, so we will use this to determine how the Teensy predicted the velocity of its ascent, how many times the air brakes opened, and how much our rocket decelerated.



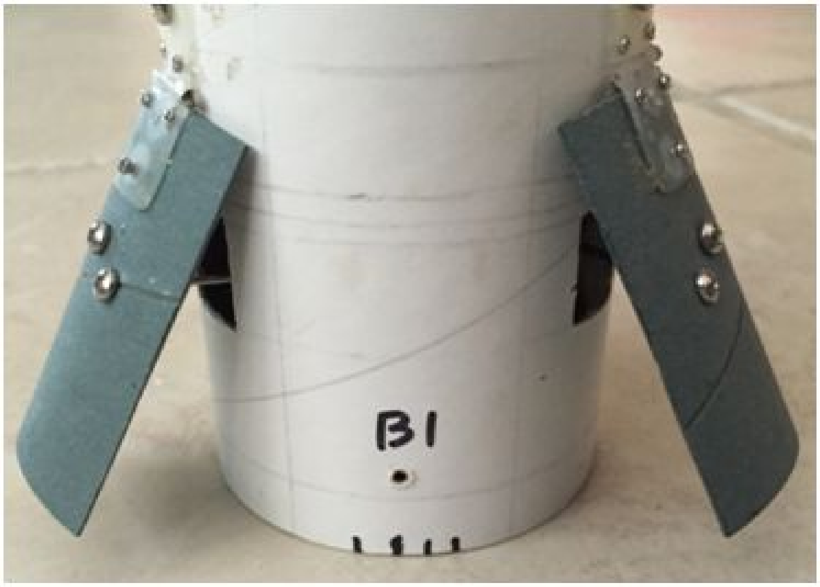
To make the legs on our airbrake system to push and pull the air brakes, we used strong dental wire and dental tools from Albert’s father, who is a dentist. Our system required flexibility around the rotational points, like a ball and socket joint on the human shoulder. We cut and bent the wires into hooks and attached them to loops we made ourselves to accomplish this design.

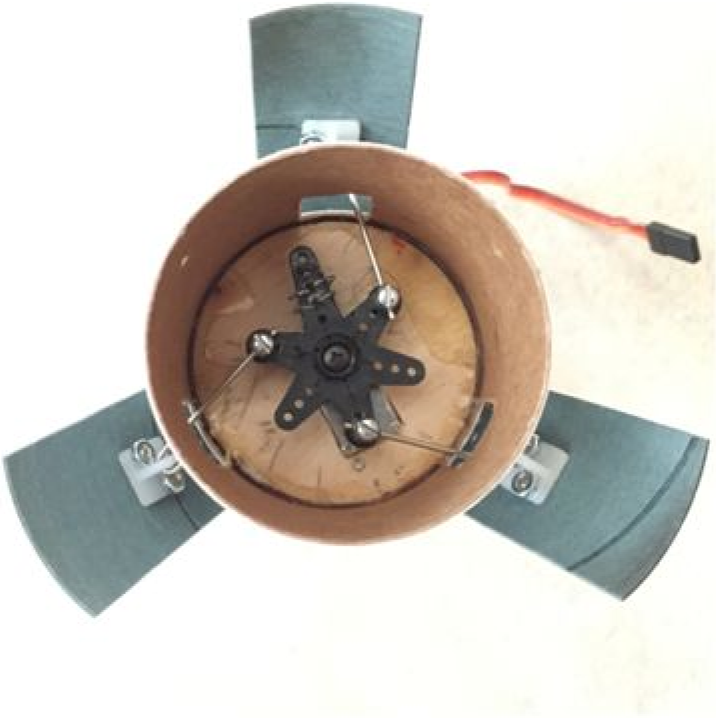
We first made a proof of concept of the mechanism on June 27, 2016, which can be found here. Our current design can be found here.

We have not yet decided upon a horn, so the length of the wire used has not yet been finalized. We will use stronger wire or rods to accommodate this new design.

A Teensy will be used to control the mechanism and run the algorithm. Its small size and processing power is capable of controlling the rocket.

To make the air brakes we will evenly cut the tube coupler into sixths and place three of the pieces equally apart in a specified area. The air brakes will extend beyond the air brake module. The air brakes will be used for controlling the altitude of the rocket through drag rather than relying on the variable thrust of the motor as a result of manufacturing.





The above three pictures are of the TARC rocket's air brake module.

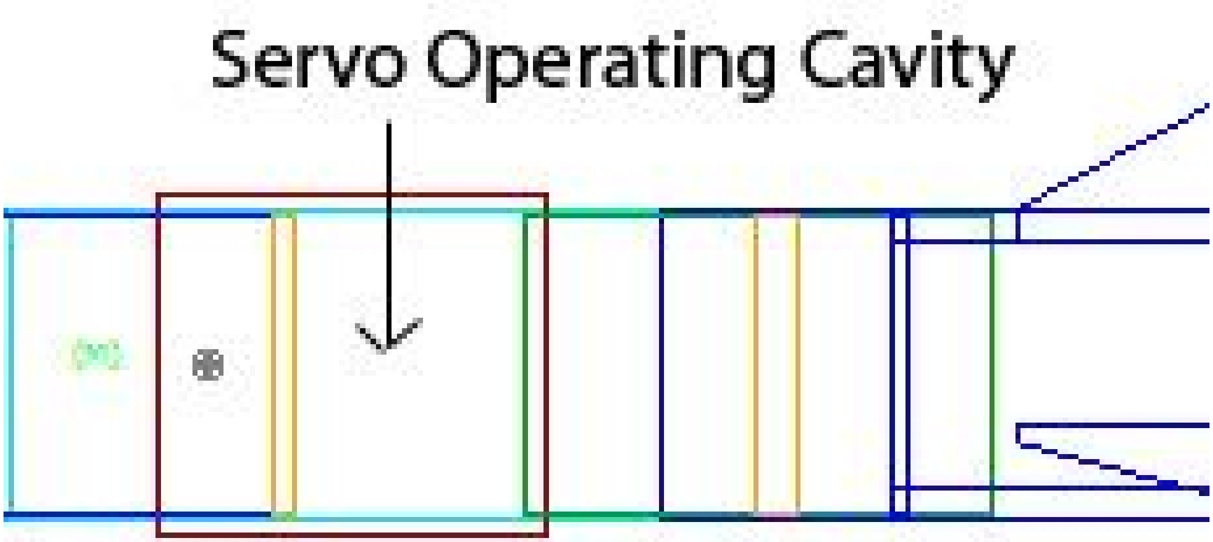
The air brakes will use a Hitec HS-7890T circular servo, which have the following statistics:

| | |
|---|---|
| Dimensions | 1.72" x 0.88" x 1.57" (43.8 x 22.4 x40 mm) |
| Product Weight | 2.76 oz (78.2g) |
| No-Load Speed (6.0V) | 0.21 sec/60° |
| No-Load Speed (7.4 V) | 0.17 sec/60° |
| Stall Torque (6.0V) | 500oz/in (26 kg.cm) |
| Stall Torque (7.4V) | 611oz/in (44kg.cm) |
| Travel per µs (out of box) | .080°/µsec |
| Travel per µs (reprogrammed high res) | .132°/µsec |

We received our inspiration from a YouTube video of a mechanical flower. A student from the University of Twente used this flower for a bachelor thesis.

We also have video of us testing the air brakes.

The area for the servo to operate will be in this area:

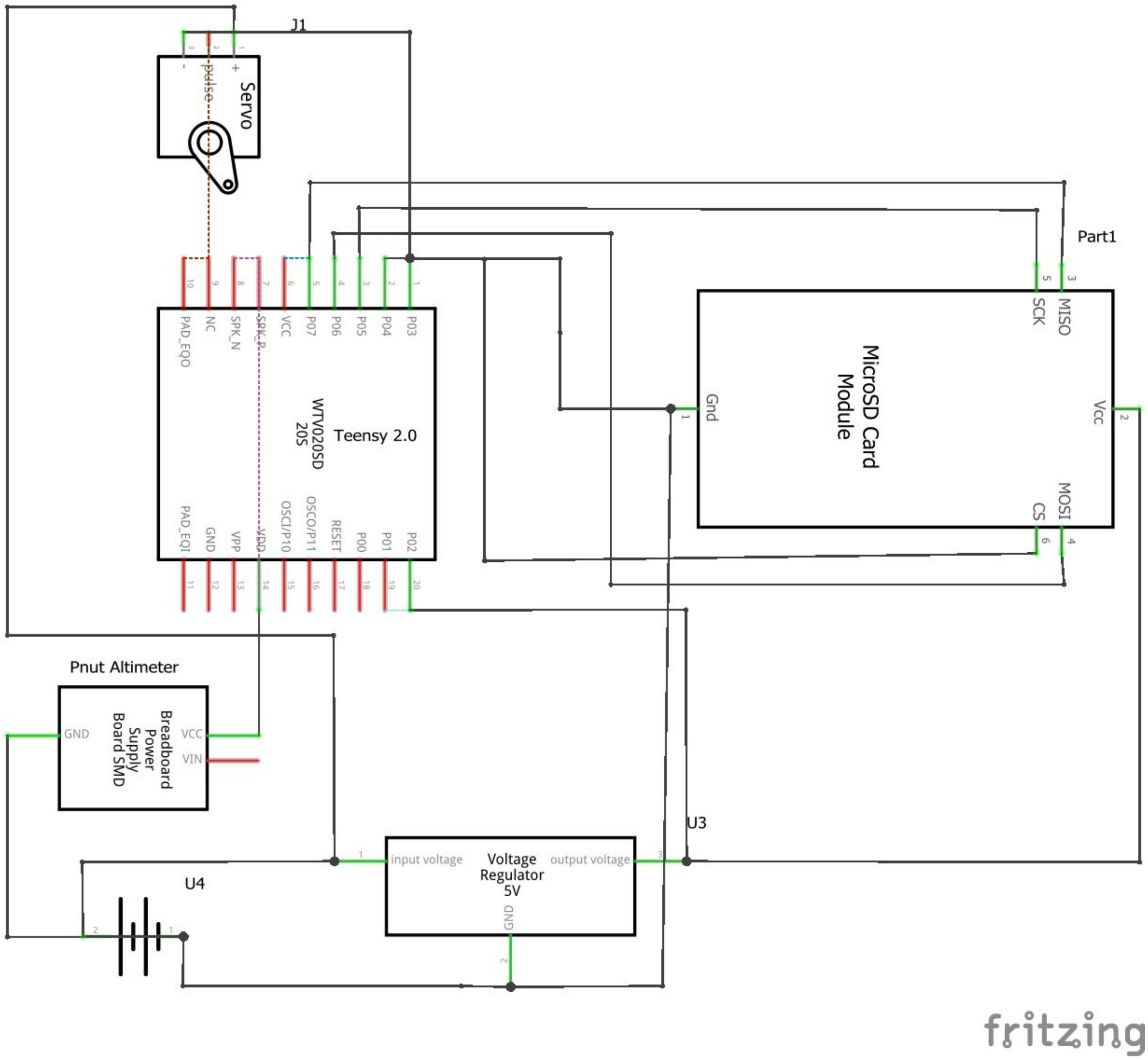


The Lithium Polymer battery will run a 5 Volt current to power the servo. Its dimensions are 2.17”x1.22”x0.79”.

The length of body tube where the servo can rotate is 1.25 in, which allows for the air brakes to rotate. The green mass object closest to the center of gravity represents the servo that will operate the air brakes. The volume where the servo and its electronics, including the battery will be placed is a 3.9”d x 2”h, inside a 4” long tube coupler. The diameter is large enough to fit the Teensy and servo in one place. We will cut a 0.115” thick bulkhead to fit the rectangular shape of the servo and position the servo so that it can operate the air brakes, as seen in the TARC air brake module pictures above. The bulkhead will fit snugly in the specified tube coupler.

The estimated mass of this subsystem is 815 g.

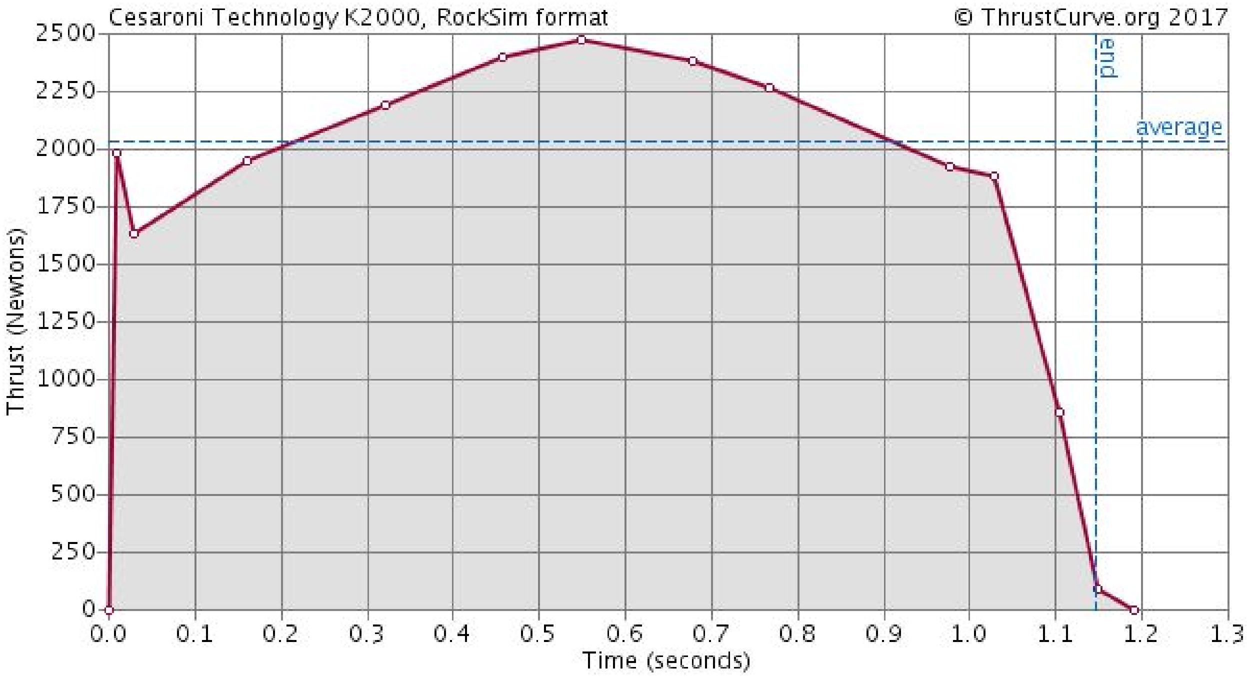
### 3.1.3.2.4 Air Brakes Schematic



## 3.1.5 Motor

### 3.1.5.1 Motor Selected

The K2000 looks like it is the best choice. All of the selected alternatives display a spike in their thrust curves, but we have decided to use the K2000 because it has a higher rail exit velocity, allowing the rocket to have a straighter and more stable flight on its initial ascent.



### 3.1.5.2 Motor Alternatives

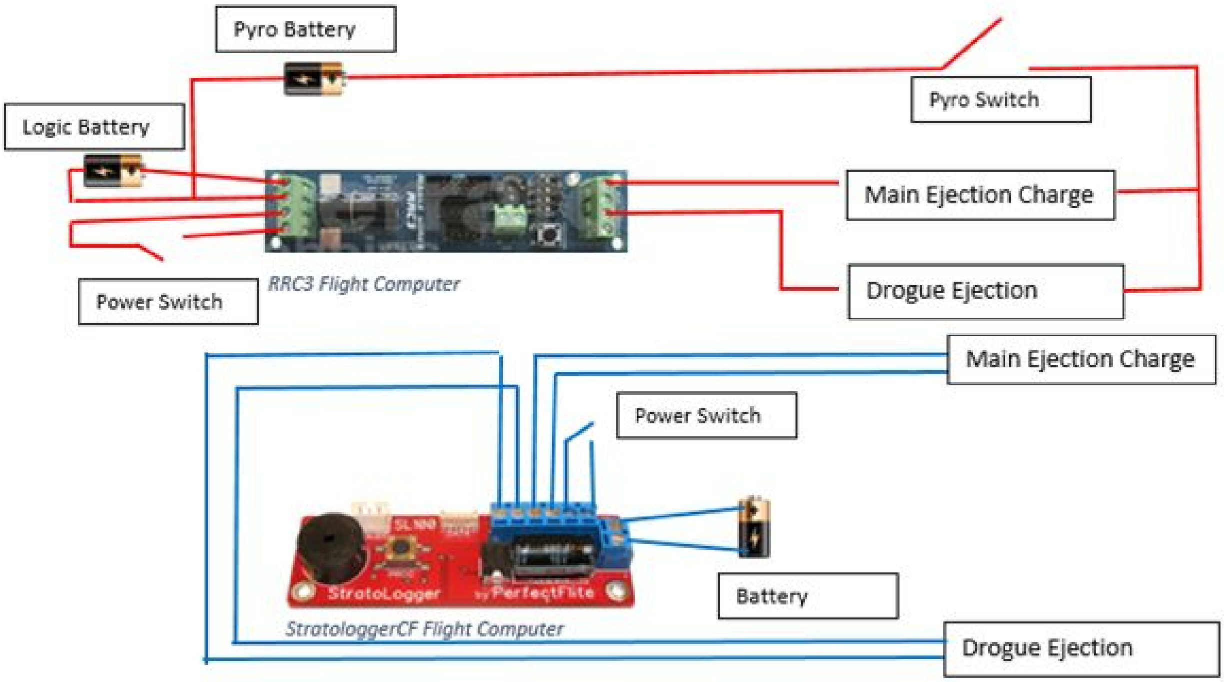
The table below contains data taken from both thrustcurve.org and our RockSim simulations.

| **Cesaroni Engines** | **Total Impulse (Ns)** | **Total Mass (g)** | **Max Altitude (ft), no air brake function** | **Max Velocity (ft/s)** | **Max Accel (ft/s$^2$)** | **Velocity at Rail Exit (ft/s, altitude ≈ 8 ft)** |
|---|---|---|---|---|---|---|
| **K1085 (75 mm)** | 2378.7 | 2430 | 5413.85 | 653.11 | 616.23 | 61.73 |
| **K2000 (75 mm)** | 2331.5 | 2464.5 | 5363.22 | 380.05 | 734.17 | 90.328 |
| **K661 (75 mm)** | 2436.5 | 2527.8 | 5383.20 | 609.43 | 616.24 | 47.315 |

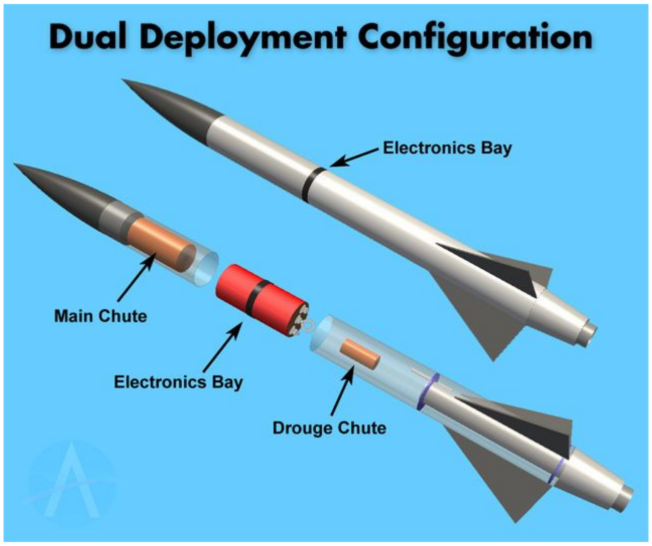
## 3.2 Recovery Subsystem

### 3.2.1 Avionics Subsystem

The recovery electronics will be in the avionics bay, a 10.2” tube coupler with a 1” band made of fiberglass body (4” diameter) tube to separate the upper and middle body tubes. It is a redundant system that will deploy an 18” drogue parachute at apogee and an 84” main parachute at 900 feet. Removable shear pins (# 2 nylon shear pins that require 35 lbs of force to tear) will be used for the main and drogue compartment such that the pins will hold the rocket together while the rocket is ascending but the ejection charge will rip them off to deploy the parachutes.



The two mass objects represents the recovery electronics, which are 50 g total. The primary flight system, the Stratologger CF, weighs 11 grams while the backup flight computer, the RRC3, weighs 17 grams. They will be mounted on a 4” x 12” wooden board, which weighs 48 g. The green bulkheads are 0.115” thick fiberglass, while the orange bulkheads are 0.115” birch. Both recovery electronics will be powered by commercially available batteries, and there will be a power switch for both flight computers to increase safety. Together, the parachutes and the avionics bay will ensure that the flight is recoverable and reusable. This is a sample configuration of our recovery electronics and parachutes:



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

## 3.2.2 Subsystems and Components

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

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

### 3.2.3 Alternatives

| Flight Computer | Pros | Cons |
|---|---|---|
| G-Wiz HCX | Easily programmable, dual deployment can be set in 100 foot increments. Comes with an SD card to record flights. Can also be used with 2 batteries to optimize safety. | Not available for sale anymore. |
| Stratologger CF | Easy to program, reliable manufacturer (PerfectFlite). It can record altitudes up to 100,000 feet, and stores 20 flights a second. Main deployment can be set in 1 foot increments for more precision. | Can only launch drogue at certain altitudes. Doesn't allow two batteries for increased safety. |
| RRC3 Sport | Easy to program and is pre set up at drogue deployment at apogee and main deployment at 500 feet. Reliable manufacturer (Mad Cow Rocketry) which we used in TARC. Allows two batteries. | Bigger than the stratologger and heavier (17g). |
| TeleMega Altimeter | Has an on board integrated GPS receiver (eliminating need for dog collar). Has accelerometer. Pyro events like dual deploy can be configured to specific heights and times to increase accuracy. | Really expensive (costs $500). Relatively heavy (25g). |
| Raven Flight Computer | Really small (saves space). High quality data (accelerometer, barometric pressure, etc). Main deployment at 700 feet (fits with our deployment plan). | Hard to program. No flexibility with main deployment (can't change the altitude). Really expensive ($155). |

## 3.2.4 Leading Design

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 84” diameter main chute.  Both of them are from Fruity Chutes.

## 3.2.5 Analysis of Parachute

Our main chute is 84” in diameter, deployed at an altitude of 500 ft.

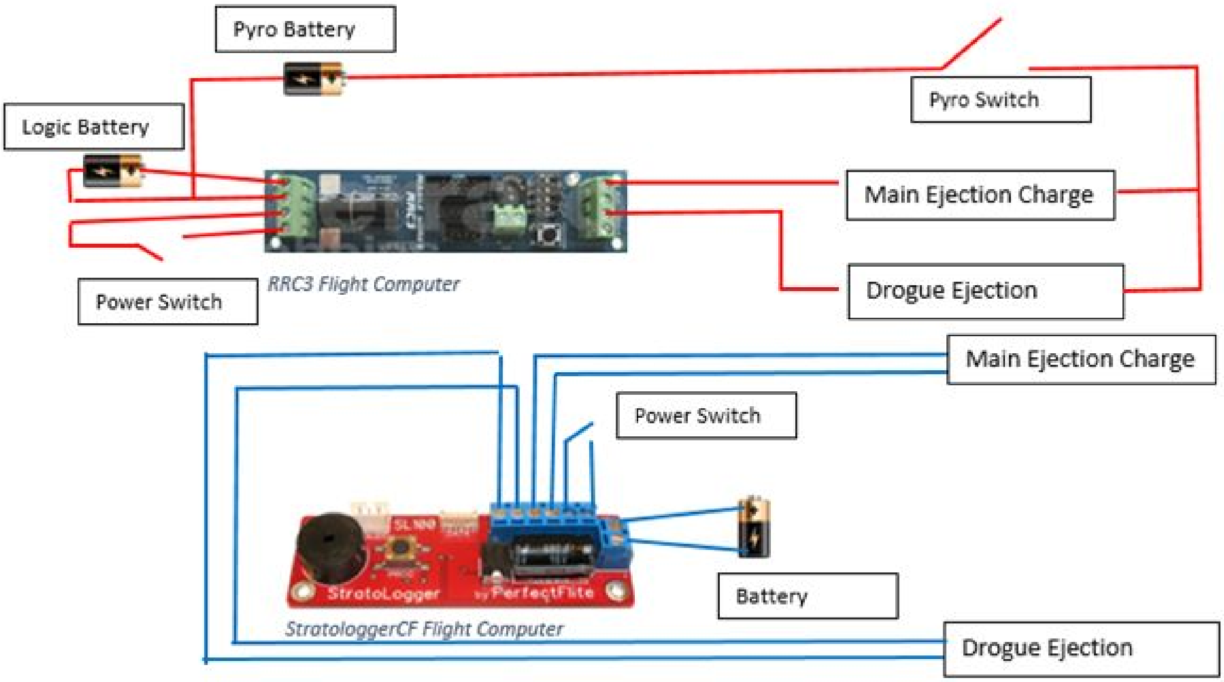
| **84” Iris Ultra Standard Information** | |
|---|---|
| **Parachute Material** | Rip-stop nylon |
| **Shroud Line Material** | 400lb Flat tubular Nylon |
| **Mass** | 539 g |
| **OD** | 84” |
| **ID** | 36” |
| **Shroud line length** | 84” |
| **Shape** | Toroidal |
| **Coefficient of drag** | 2.2 |
| **Colors** | Red, White |

Our drogue chute is 18” in diameter, deployed at apogee.

| **18” Classical Elliptical Information** |
|---|

| | |
|---|---|
| **Parachute Material** | 1.1 oz rip-stop nylon |
| **Shroud Line Material** | 220 lb tubular nylon |
| **Mass** | 49 g |
| **OD** | 18” |
| **ID** | 6” |
| **Shroud line length** | 24” |
| **Shape** | Elliptical |
| **Coefficient of drag** | 1.5-1.6 |
| **Colors** | Red, White |

## 3.2.6 Proof of Redundancy

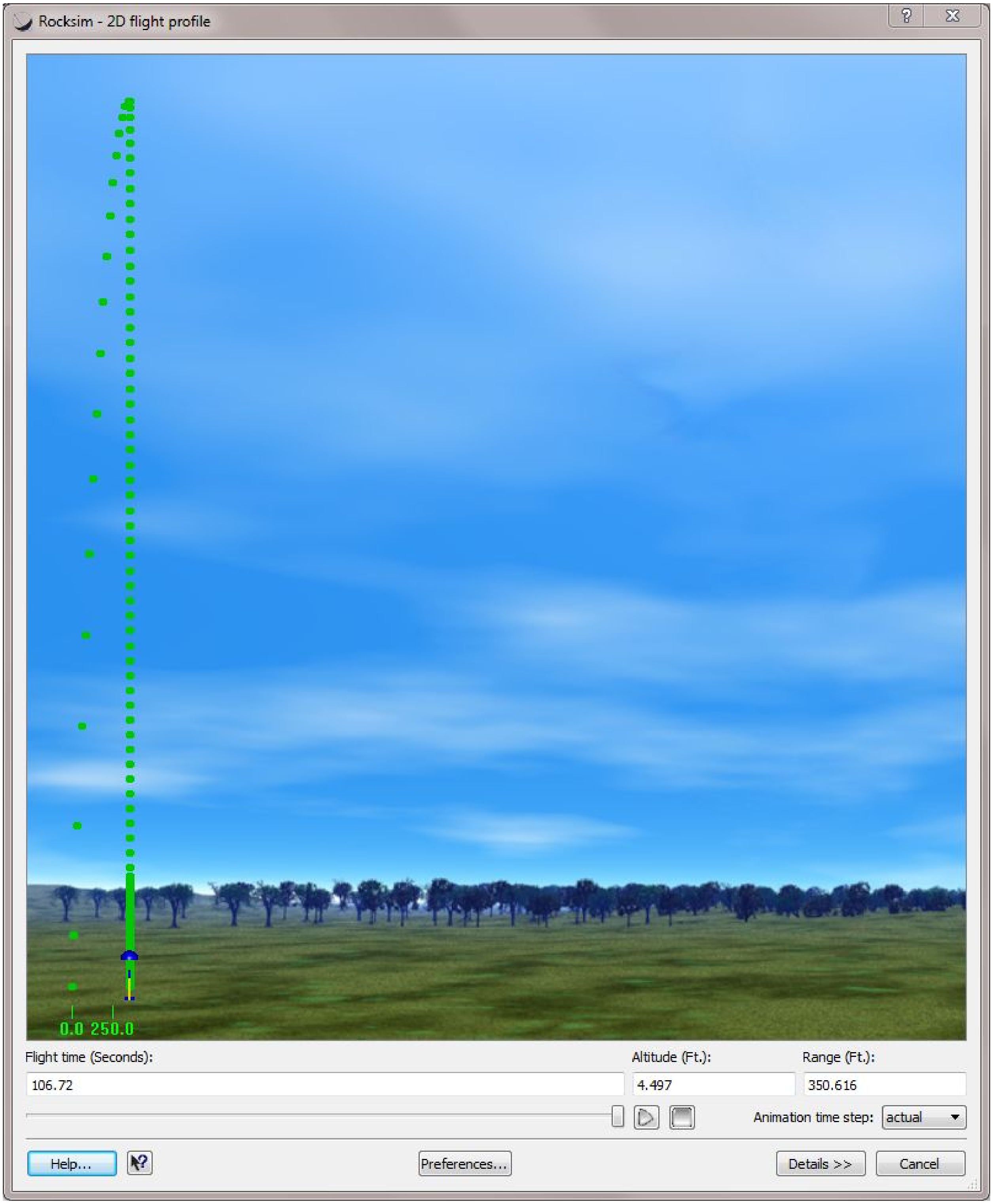


The fact that the wires of the stratologger and RRC3 do not get mixed together proves the redundancy of the dual-deploy system.

## 3.3 Mission Performance Prediction

### 3.3.1 Simulations - RockSim 9

#### 3.3.1.1 Flight Profile Simulations



Flight time (Seconds): 106.72

Altitude (Ft.): 4.497

Range (Ft.): 350.616

Animation time step: actual

### 3.3.1.2 Altitude Predictions with Simulated Vehicle Data

| Wind Condition (mph) | Max Altitude (ft, without air brakes assistance) |
|---|---|
| 0 | 5363.22 |
| 5 | 5368.37 |
| 10 | 5363.58 |
| 15 | 5348.88 |
| 20 | 5324.38 |
| 25 | 5290.39 |

Increasing wind speeds have no noticeable effect on the rocket until the wind exceeds 10 mph.

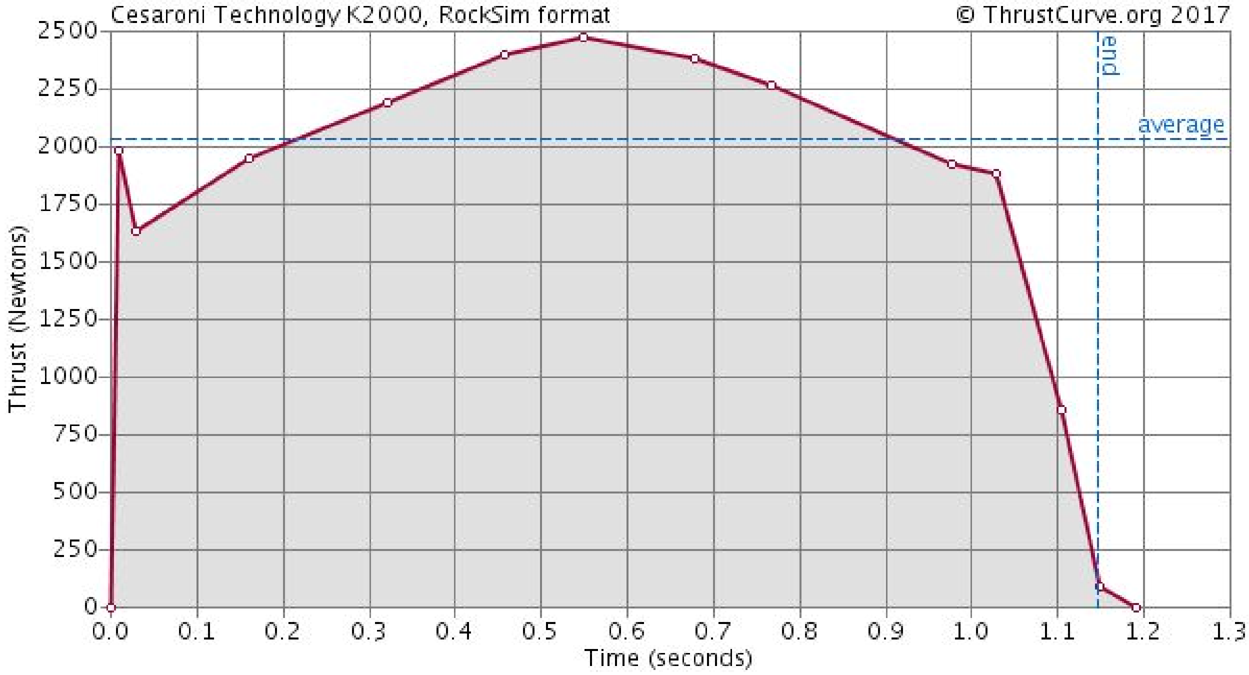
### 3.3.1.3 Component Weights

| Component Name | Mass (g) | Length (in) | Thickness, if applicable (in) |
|---|---|---|---|
| Nose Cone | 638.4 | 22 | 0.2 |
| Whistle GPS | 240 | | |
| Payload Collar | 40 | 1.375 | |
| Payload Enclosure | 309 | 8 | |
| Aluminum Bulkhead | 100 | 0.25 | 0.25 |
| Aluminum Bulkhead | 100 | 0.25 | 0.25 |
| Eye Bolt | 30 | | |
| Payload Bay | 1044 | 38 | |
| Tube Coupler | 195 | 6.5 | |
| Payload | .5 | 37.5 | |
| Upper Body Tube | 725 | 26 | |

| | | | |
|---|---|---|---|
| 84” Main Chute, swivel | 540 | | |
| Blast Cloth | 125 | | |
| Shock Cord | 250 | | |
| Avionics Collar | 60 | 1.5 | |
| U Bolt | 50 | | |
| Aluminum Bulkhead | 100 | 0.25 | 0.25 |
| Recovery Electronics (Avionics) | 240 | | |
| 2 Key Slots | 160 | | |
| Electronics Bay (TC) | 410 | 12.25 | |
| Aluminum Bulkhead | 100 | 0.25 | 0.25 |
| U Bolt | 50 | | |
| Middle Body Tube | 387 | 12.75 | |
| Shock Cord | 200 | | |
| Drogue Chute | 60 | | |
| Extension | 250 | 8 | |
| Eye Bolt | 30 | | |
| 2 Fiberglass Bulkheads | 72 | 0.25 | 0.25 |
| Tube Coupler | 210 | 8 | |
| Airbrake Module | 235 | 8.375 | |
| Tube Coupler | 200 | 6.75 | |
| Birch | 87 | 0.25 | 0.25 |

|  |  |  |  |
|---|---|---|---|
| Bulkhead |  |  |  |
| Air Brakes | 160 | 5 |  |
| Air Brakes Electronics | 240 |  |  |
| Servo | 285 |  |  |
| Booster | 290 | 21.25 |  |
| Tube Coupler | 250 | 7 |  |
| 2 Fiberglass Bulkheads | 50 | 0.25 | 0.25 |
| Centering Ring | 52.289 | 0.188 | 0.188 |
| 75 mm Motor Mount | 550 | 19 |  |
| Fin Set | 326 | Semi-span: 4.5 | 0.3785 |
| Centering Ring | 52.289 | 0.188 | 0.188 |
| Centering Ring | 52.289 | 0.188 | 0.188 |
| Motor Retainer | 135.237 |  |  |
| **Total** | 11051 | 139.5 | N/A |

### 3.3.1.4 Simulated Motor Thrust Curve



### 3.3.1.5 Verification of Robust Design

Based on past experience with fiberglass and fiberglass tape, a rocket with the proper resin and under careful supervision can be reusable.

### 3.3.2 Stability Margin

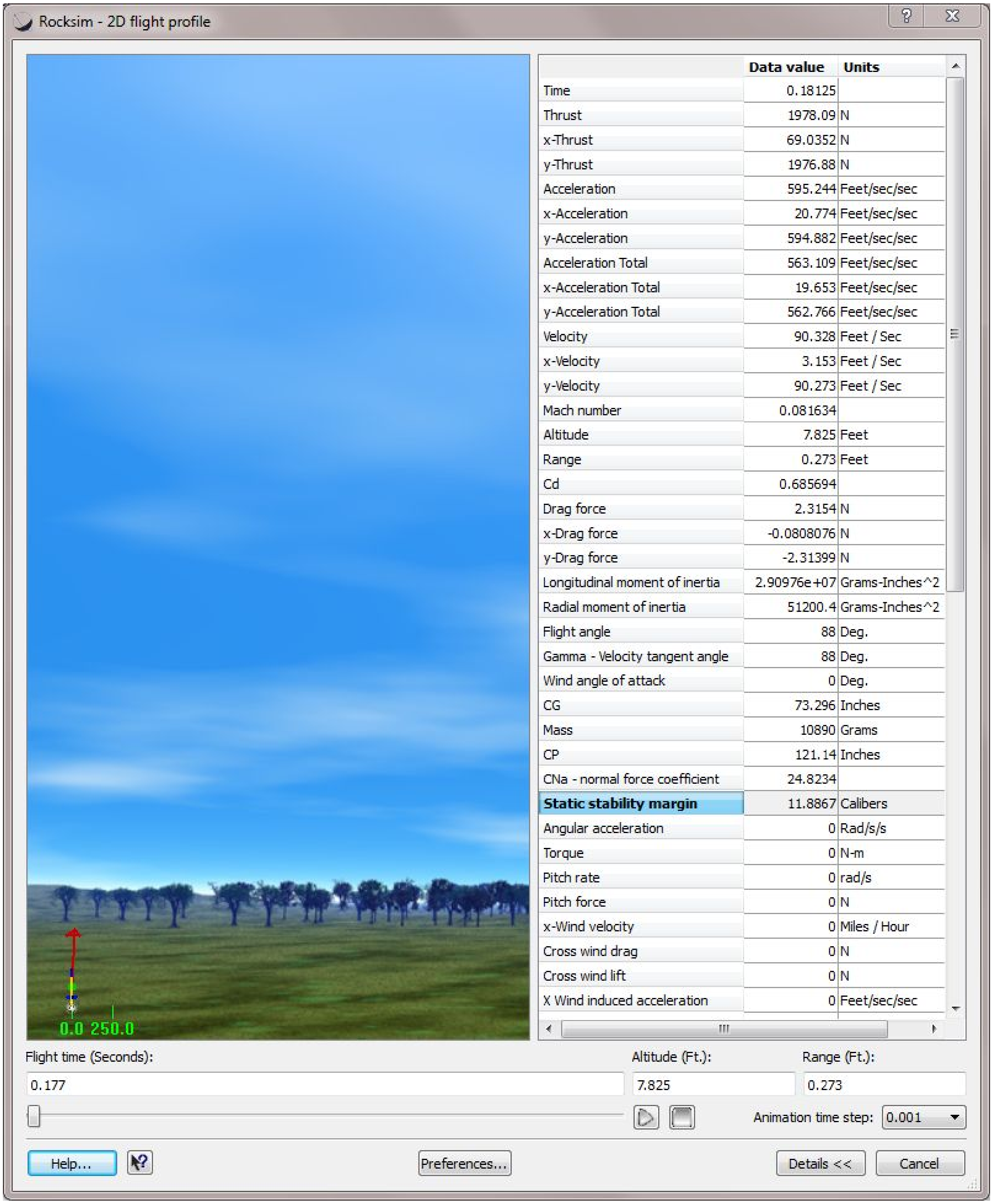
CG: 74.5034 in from nose cone

CP: 116.4851 in from nose cone

$$\text{Static stability margin} = \frac{CP - CG}{\text{Body Tube Diameter}}$$

$$= \frac{116.4851'' - 74.5034''}{3''}$$

$$= 10.43\ \text{calibers}$$



| | Data value | Units |
|---|---|---|
| Time | 0.18125 | |
| Thrust | 1978.09 | N |
| x-Thrust | 69.0352 | N |
| y-Thrust | 1976.88 | N |
| Acceleration | 595.244 | Feet/sec/sec |
| x-Acceleration | 20.774 | Feet/sec/sec |
| y-Acceleration | 594.882 | Feet/sec/sec |
| Acceleration Total | 563.109 | Feet/sec/sec |
| x-Acceleration Total | 19.653 | Feet/sec/sec |
| y-Acceleration Total | 562.766 | Feet/sec/sec |
| Velocity | 90.328 | Feet / Sec |
| x-Velocity | 3.153 | Feet / Sec |
| y-Velocity | 90.273 | Feet / Sec |
| Mach number | 0.081634 | |
| Altitude | 7.825 | Feet |
| Range | 0.273 | Feet |
| Cd | 0.685694 | |
| Drag force | 2.3154 | N |
| x-Drag force | -0.0808076 | N |
| y-Drag force | -2.31399 | N |
| Longitudinal moment of inertia | 2.90976e+07 | Grams-Inches^2 |
| Radial moment of inertia | 51200.4 | Grams-Inches^2 |
| Flight angle | 88 | Deg. |
| Gamma - Velocity tangent angle | 88 | Deg. |
| Wind angle of attack | 0 | Deg. |
| CG | 73.296 | Inches |
| Mass | 10890 | Grams |
| CP | 121.14 | Inches |
| CNa - normal force coefficient | 24.8234 | |
| **Static stability margin** | 11.8867 | Calibers |
| Angular acceleration | 0 | Rad/s/s |
| Torque | 0 | N-m |
| Pitch rate | 0 | rad/s |
| Pitch force | 0 | N |
| x-Wind velocity | 0 | Miles / Hour |
| Cross wind drag | 0 | N |
| Cross wind lift | 0 | N |
| X Wind induced acceleration | 0 | Feet/sec/sec |

Flight time (Seconds): 0.177

Altitude (Ft.): 7.825

Range (Ft.): 0.273

Animation time step: 0.001

The stability margin at rail exit is 11.8867 calibers. The stability margin on the launch pad is 11.6701.

## 3.3.3 Calculations

### 3.3.3.1 Kinetic Energy

With Drogue Chute Out:

Section 1:

$$Kinetic\ energy\ =\ \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(2.9375\ lbs)(89ft/s)^2(\tfrac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 361.303\ lbf$$

Section 2:

$$Kinetic\ energy\ =\ \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(2.9075\ lbs)(89ft/s)^2(\tfrac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 357.613$$

Section 3:

$$Kinetic\ energy\ =\ \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(7.9125\ lbs)(89ft/s)^2(\tfrac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 973.213\ lbf$$

Section 4:

$$Kinetic\ energy\ =\ \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(10.8865\ lbs)(89ft/s)^2(\tfrac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 1339\ lbf$$

With Main Chute out:

Section 1:

$$Kinetic\ energy\ =\ \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(2.9375\ lbs)(16\,ft/s)^2(\tfrac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 11.677\ lbf$$

Section 2:

$$Kinetic\ energy\ =\ \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(2.9075\ lbs)(16ft/s)^2(\tfrac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 11.56$$

Section 3:

$$Kinetic\ energy\ =\ \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(7.9125\ lbs)(16\,ft/s)^2(\tfrac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 31.45\ lbf$$

Section 4:

$$Kinetic\ energy \;=\; \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(10.8865\ lbs)(16\ ft/s)^2(\tfrac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 43.28\ lbf$$

Each independent section has less than 75 lbf.

#### 3.3.3.1.1 Alternative Calculation

Fruity Chutes Descent Rate Calculator

### 3.3.3.2 Drift

#### 3.3.3.2.1 0 MPH Wind

$$Drift = 113\ s \;\times\; 0\ mph$$
$$= 0\ miles$$

##### 3.3.3.2.1.1 Alternative Calculation

#### 3.3.3.2.2 5 MPH Wind

$$Drift = 113\ s \times (\tfrac{5\ miles}{1\ hour} \times \tfrac{1\ hour}{3600\ seconds})$$

##### 3.3.3.2.2.1 Alternative Calculation

#### 3.3.3.2.3 10 MPH Wind

$$Drift = 113\ s \times (\tfrac{10\ miles}{1\ hour} \times \tfrac{1\ hour}{3600\ seconds})$$
$$= \; 0.314\ miles$$
$$= 1658\ ft$$

##### 3.3.3.2.3.1 Alternative Calculation

#### 3.3.3.2.4 15 MPH Wind

$$Drift = 113\ s \times (\tfrac{15\ miles}{1\ hour} \times \tfrac{1\ hour}{3600\ seconds})$$
$$= .471\ miles$$
$$= 2487\ ft$$

#### 3.3.3.2.4.1 Alternative Calculation

### 3.3.3.2.5 20 MPH Wind

$$Drift = 122.2\ s \times \left(\frac{20\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds}\right)$$
$$= .628\ miles$$
$$= 3316\ ft$$

#### 3.3.3.2.5.1 Alternative Calculation

## 3.3.4 Simulation of Results

“Perform multiple simulations to verify that results are precise.”

# 4 Safety

## 4.1 Components Needed to Complete the Project

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

### 4.1.1 Impacts of Risks/Delays in Project

| | | |
|---|---|---|
| 1. **Risk**: A team member is out sick or busy handling something else<br>**Mitigation**: Keep calm, divide duties accordingly. | 2. **Risk**: A launch severely damages a launch vehicle prior to PDR, CDR, or FRR submission.<br>**Mitigation**: Follow all safety checklists, with a special emphasis on recovery and motor loading | 3. **Risk**: Deliverables are not delivered on time<br>**Mitigation**: Strictly follow a well-thought-out timeline and create documents accordingly. |

## 4.2 Personnel Hazard Analysis

The SL team has developed a series of risk mitigation plans to reduce the risk of this project.

### 4.2.1 Identification of Hazards, Their Causes, and Resulting Effects

While completing the launch vehicle, team members will frequently come into contact with hazardous materials. These substances will not be dangerous to the team members as long as these rules are followed when handling. Concerning materials include adhesives, paints, and the

actual materials used to build the vehicle. The manufacturer of those materials knows best about the posed hazards. Each manufacturer and safety organizations publish MSDS for each product. Handling these materials will require the use of Personal Protective Equipment (PPE).
An MSDS (Material Safety Data Sheet) is available to provide an overview explaining how to work safely with and handle specific chemicals or materials. It is compiled by the manufacturer of the particular chemical. Although MSDS do not have a particular format, they are required to have certain information per OSHA (Occupational Safety and Health Administration) 29 CFR 1910.1200. A list of the required information can be found here on this website.
In the next sections, the team has listed hazards that must be accounted for.

## 4.2.2 Mitigations and Controls

Listed are some threats to team members' safety that must be accounted for (see details below the table):

| Risk | Mitigation |
|---|---|
| Impact to the body | Gloves, apron, goggles |
| Cut or puncture | Gloves and Apron |
| Chemicals – fumes and/or direct contact | Gloves, respirator, goggles |
| Heat/cold | Gloves |
| Harmful Dust and small particles | Mask and Goggles |
| Loud noises | Earplugs |

The team will keep a copy of the MSDS for all materials used in the making of the vehicle when an MSDS exists for a certain material. The following items will be present and available for team member use whenever they are working, constructing the vehicle or payload, or launching.

- Safety goggles
- Rubber gloves
- Protective aprons
- Ear Plugs
- Leather gloves
- Respirators / Dust Masks

Eye protection must be worn whenever there is a danger of:

- Dust, dirt, metal, or wood chips entering the eye. This can happen when sawing, grinding, hammering, or using power tools.
- Strong winds during a launch (common at Lucerne Dry Lake)
- Chemical splashes when using paints, solvents, or adhesives
- Cutting fiberglass, which can produce damaging fine particles
- Objects thrown (intentionally or inadvertently) or swinging into a team member

These types of gloves must be worn to protect the team member's hands whenever there is danger of contact with a hazardous material:

- Latex or rubber gloves for possible contact with hazardous chemicals such as adhesive, paint, or thinners, or dangerous solid materials.
- Leather gloves to protect against impact, cuts, or abrasions (e.g. in the use of some power tools such as grinders)

Team members will always work in a clean, well-ventilated area. Protection for a team member's lungs (dust mask or respirator) must be used when:

- Working with chemicals emitting fumes (e.g. paints and solvents). In this case, the team member must wear a respirator.
- Working in an environment where there is dust (e.g. sanding and working with power tools). The team member must wear a dust mask.

Body protection, such as an apron must be worn whenever there is danger of:

- Splashes or spills from chemicals
- Possible impact from tools

Ear protection (plugs or ear muffs) must be worn whenever there are loud noises present, which include:

- Using loud power tools or hammers
- Launching larger rocket motors at launches

When creating documents that require work with potentially hazardous materials including chemicals, that section will be marked with the following:

"HAZARDOUS MATERIAL - SEE MSDS"

A sample MSDS is included in the next appendix to show what is included. As materials are identified during the research and design phases of this project, suitable MSDS for those materials used will be gathered and made available to all team members in hard copy form at the work area as well as on the web site.

## 4.3 Failure Modes and Effects Analysis (FMEA)

| Potential Issues/ Failure Mode | Potential Failure Effects | Severity (1-10) | Potential Causes | Occurrence (1-10) | Mitigation |
|---|---|---|---|---|---|
| Battery for the payload explodes or fail. | The rocket or payload 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 payload fails to work during the launch after it is deployed.. | Experiment cannot be conducted. Sparking could occur within the payload. | 5 | Wiring is incorrect. Battery was not activated, or no connection in the payload circuitry. | 1 | A checklist will be followed during construction and when preparing the rocket to launch. The payload will be tested at ground level and simulated at manageable height(from a building). |
| The rocket does not fly in a stable manner. | Altitude might not be met. Damage to the rocket can occur. The rocket will fly uncontrollably, possible hurting someone. | 6 | While constructing the rocket, mass change might have occurred. During the design process, stability margin might not have been considered. Weather conditions also influence instability. | 3 | Stability margin is always looked at when designing the rocket and when making any changes to that design. Weather conditions will be monitored, and the rocket will not be launched in unsafe conditions. |
| Rocket components and pieces are not | When launched, inconsistent flights could take | 7 | Team members are not paying attention and | 2 | Checklists will be made and each team member working on a certain part of the |

|  |  |  |  |  |  |
|---|---|---|---|---|---|
| constructed properly (Right length is not cut, epoxy is not well applied, screws are not screwed in properly, electronics are not wired correctly, etc.). | place, rocket electronics will not function properly, and rocket could combust. |  | giving close detail during the construction process. Team members are unclear of proper process of construction or the putting together of the rocket. |  | rocket will be checked by another member to ensure safety and proper execution. |

## 4.4 Environmental Concerns

| Potential Issues/ Failure Mode | Potential Failure Effects | Severity (1-10) | Potential Causes | Occurrence (1-10) | Mitigation |
|---|---|---|---|---|---|
| Wind speeds are unsuitable for launching the rocket. | If rocket is launched, rocket will fly in an unstable manner, making it difficult for performing proper tasks. | 6 | Environmental conditions are not suitable and worsen as the day proceeds at Lucerne Dry Lake. | 6 | Launch rail can be tilted at an angle that is with the wind in correlation with the speed of the wind. If wind speeds are too strong, the team will wait for conditions to improve. |
| Rain falls when the rocket is on the launch pad or in preparation. | Drag increases, resulting a possible lower altitude for the rocket. Stability also decreases. | 5 | Weather conditions are not suitable. | 4 | Rocket will be launched if rain is light; if rain is too strong, the team will wait for conditions to improve. |
| A fire can spread to the surrounding environment. | The launch site can catch on fire, resulting in damage to the nature. | 9 | Rocket can malfunction and once it lands, a fire can begin. Malfunction of the motor, sparks or ignition can set the rocket on fire. | 0 | If the rocket does catch on fire in any way, no parts of the environment will catch on fire. There is only dirt at Lucerne Dry Lake for miles. No grass is near the launch site. |

| | | | | | |
|---|---|---|---|---|---|
| The rocket will affect trees, power lines, buildings, or people not involved in the launch. | The rocket could hurt people near the launch site who are not aware. It may cause additional damage to the surrounding environment. | 9 | If the rocket is not stable, if may go off in the wrong path. Instability can be caused by the weather or rocket design. | 1 | There are no power lines, trees, or buildings within miles of the launch site. People nearby will be warned prior to the launching of the rocket. Stability margin of rocket will be made sure to be within safe limits during the design process. |
| Rocket components are harmful to the environment in terms of air and land pollution. | The team will be contributing to pollution and its harmful effects on the surrounding nature and the earth's population. | 1 | During the construction of the rocket, the team may come across disposable material such as electronics, batteries, and other rocket parts. After launching the rocket, the motor cannot be used again and must be disposed. | 1 | The team will dispose batteries and motors at Higgins Environmental in Huntington Beach to promote environmental awareness. |
| Ammonium perchlorate composite motors that are not disposed of safely pose a threat to human and environmental safety. | The team will contribute to the pollution of the ground and affect surrounding ecosystems by leaving used up motors in the environment. This can release hydrogen chloride, which, mixed in water, can create | 1 | After a motor has been used, the team could leave a motor behind without noticing. | 3 | The team will promptly remove the motor and place it in a designated bag to take to a nearby disposal center that will properly dispose of the motor. The team will also scout the area they occupied for any trash and dispose of the trash as well. |

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

*Source: wikipedia.org

[#] Source: westsystem.com

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

## 4.5 Risks and Mitigation

The following tables have been made to address potential catastrophes. All risks in the red columns are considerably dangerous, while risks in the green columns are not necessarily dangerous but warrant steady caution.

| Risk | Likelihood | Impact | Mitigation Technique |
|---|---|---|---|
| Time | M | H | If we do not have enough time, then there is nothing to do other than to work harder and reduce quality. To prevent this, we will create a coherent work schedule, divide the work evenly, and clearly delineate the formatting of the deliverables for uniformity in advance.<br>Failing to meet deadlines in time may result in the termination of the SL team's participation. |
| Budget | M | M | If we run out of funds, we can either fundraise or gather money from within the team. The first method would guarantee a minimum $100 profit. The second would guarantee a minimum $700. |

|  |  |  |  |
|---|---|---|---|
| Functionality | L | H | If functionality within the project decreases, then we can mitigate this risk by providing clear work schedules and creating team activities to relax. |
| Resources | L | M | If we run out of resources, we can buy more and use our funds. |

### 4.5.1 Vehicle Risk Mitigation

|  |  |  |
|---|---|---|
| 1. **Risk** - The engine does not ignite while conducting the launch of the rocket.<br>**Mitigation** - Prior to launch, multiple team members will check to make sure the igniter is properly inserted in the engine to its full length, ensuring ignition of the motor. | 4. **Risk** - The rocket body caves in, or collapses on itself.<br>**Mitigation** - The team will use fiberglass for the body tube, a material capable of withstanding outside forces. Inside, flight boards, bulkheads, and centering rings will help to maintain the circular frame of the body tube. | 7. **Risk** - The electronic matches fall out of their designated place.<br>**Mitigation** - Before placing the shear pins, the matches will be checked to ensure that they have been tightened down to remain in place. This task will be placed on a checklist that members will go through while preparing the rocket for launch. |
| 2. **Risk** - The engine does not fit (too loose or tight) in the motor casing.<br>**Mitigation** - The team will make sure the engine is inserted in the proper motor casing, and cannot be shaken or pulled out with ease. The team will also check when the motor casing is inserted into the motor mount. | 5. **Risk** - The quick links are not attached properly.<br>**Mitigation** - The team will double check all connections to ensure that the rocket is assembled completely before preparing the rocket for launch. These tasks will be written on a checklist, which members who checked the task will sign off to take responsibility. | 8. **Risk**: Motor explodes<br>**Mitigation**: Detailed instructions will be followed step by step when building the motor. Team members will be required to maintain focus and detail while putting together the motor. We will make sure the igniter is inserted without folding in on itself to prevent it from catching on its way out of the nozzle after ignition. |
| 3. **Risk**: Airbrakes do not function while in flight. | 6. **Risk** - The shear pins do not shear due the ejection charge. | 9. **Risk** - Parachute was not packed correctly and does not deploy |

| | | |
|---|---|---|
| **Mitigation**: When electronics, are activated at ground level, a test for airbrake function will be performed. The airbrake motors will checked prior to assembling the whole rocket. | **Mitigation** - When purchasing the pins, the team will note the force required to shear them. The team will perform black powder ground tests to make sure the ejection charges exert more force than the pins can withstand. To ensure shearing, the backup charge will have a greater amount of black powder. | **Mitigation**: The team will check to make sure the parachuted is fitted correctly into the body of the rocket prior to launch. However, if the primary ejection charge does not separate the rocket, backup ejection charges with greater amounts of black powder will allow the parachute to deploy. |

## 4.5.2 Payload Risks and Mitigations

| | | |
|---|---|---|
| 1. **Risk**: The automation of the payload stops working<br>**Mitigation**: Switch to RC | 4. **Risk**: RC is still not safe in presence of crowd<br>**Mitigation**: Deploy emergency parachute | 7. **Risk**: Payload fails to have controlled descent.<br>**Mitigation**: Immediately deploy parachute with autonomous sensor |
| 2. **Risk**: Batteries are not fully charged<br>**Mitigation**: Charge the batteries to max before the flight. | 5. **Risk**: Steering rotor fails, resulting in loss of control of payload.<br>**Mitigation**: Deploy parachute remotely | 8. **Risk**: Payload ejects above 400 ft, which is illegal for RC aircraft<br>**Mitigation**: Immediately deploy parachute, turn off auto and RC controls. |
| 3. **Risk**: Payload does not eject<br>**Mitigation**: Check if the supply wire is securely attached from the 5 volt pin of the teensy to the Sensor. | 6. **Risk**: Batteries fail<br>**Mitigation**: Use Voltmeter to check if the battery is fully charged before the flight. | 9. **Risk**: Power fails entirely despite charging; power disconnect mid-flight<br>**Mitigation**: Keep an independent power source and receiver for emergency parachute deployment for redundancy |

### 4.5.3 Recovery Risks and Mitigations

| | | |
|---|---|---|
| 1. **Risk**: Backup ejection charges do not ignite.<br>**Mitigation**: Check to make sure the RRC3 is beeping in the specific sequence as denoted in the manual. | 4. **Risk**: Drogue chute flies at wrong altitude<br>**Mitigation**: Double check that the Stratologger and RRC3 both are beeping in their specific sequences. | 7. **Risk**: Main chute doesn't deploy<br>**Mitigation**: Backup Flight Computer and ejection charges should take care of this. |
| 2. **Risk**: The Batteries of Backup Electronics Fall out<br>**Mitigation**: Use battery holders and zip ties to ensure that the batteries do not fall out, and double check the sturdiness of these before every launch. | 5. **Risk**: Airbrakes fail to close, interfering with recovery<br>**Mitigation**: Double check that the LED light is blinking on the Arduino. Also, make sure the most recent code is uploaded in the Arduino. | 8. **Risk**: Stratologger CF Flight Computer is not turned on<br>**Mitigation**: The team will have three members check the Stratologger to see if it is beeping in its specific sequence, and they will affirm its status by signing their name in the checklist. |
| 3. **Risk**: The Backup RRC3 Flight Computer is not turned on<br>**Mitigation**: The team will have three members check the Flight Computer to see if it's beeping and affirm its status by signing their name in the checklist. | 6. **Risk**: Drogue doesn't deploy<br>**Mitigation**: Double check that the electronics are turned on and beeping, and have three people sign the checklist to affirm. Also, back up ejection charges will take care of this. | 9. **Risk**: Main batteries fail<br>**Mitigation**: Use fresh batteries and make sure the electronics will power up first in a test second before flight. |

# 5 Payload Criteria

## 5.1 Selection, Design, and Rationale of Payload

### 5.1.1 Objective

The goal of this payload is to utilize the Magnus Effect to generate lift and land at a specified GPS coordinate.

The payload is a UAV, so it must comply with federal law regarding the airspace. It will be flown at or below 400 ft AGL.

### 5.1.2 Success Criteria

If the payload is ejected successfully and within legal limits and lands within a 50-foot radius of its intended landing position, this is considered a success.

The payload must also be reusable after its landing.

### 5.1.3 System Design Review

#### 5.1.3.1 UAV GPS

The payload will have various devices installed to send data down to the receiver on the ground allowing information such as the rotation of the payload when being ejected and most importantly, the location of the payload. This will be located in the center console of the UAV and will be transmitting real time.

#### 5.1.3.2 UAV GPS Alternatives

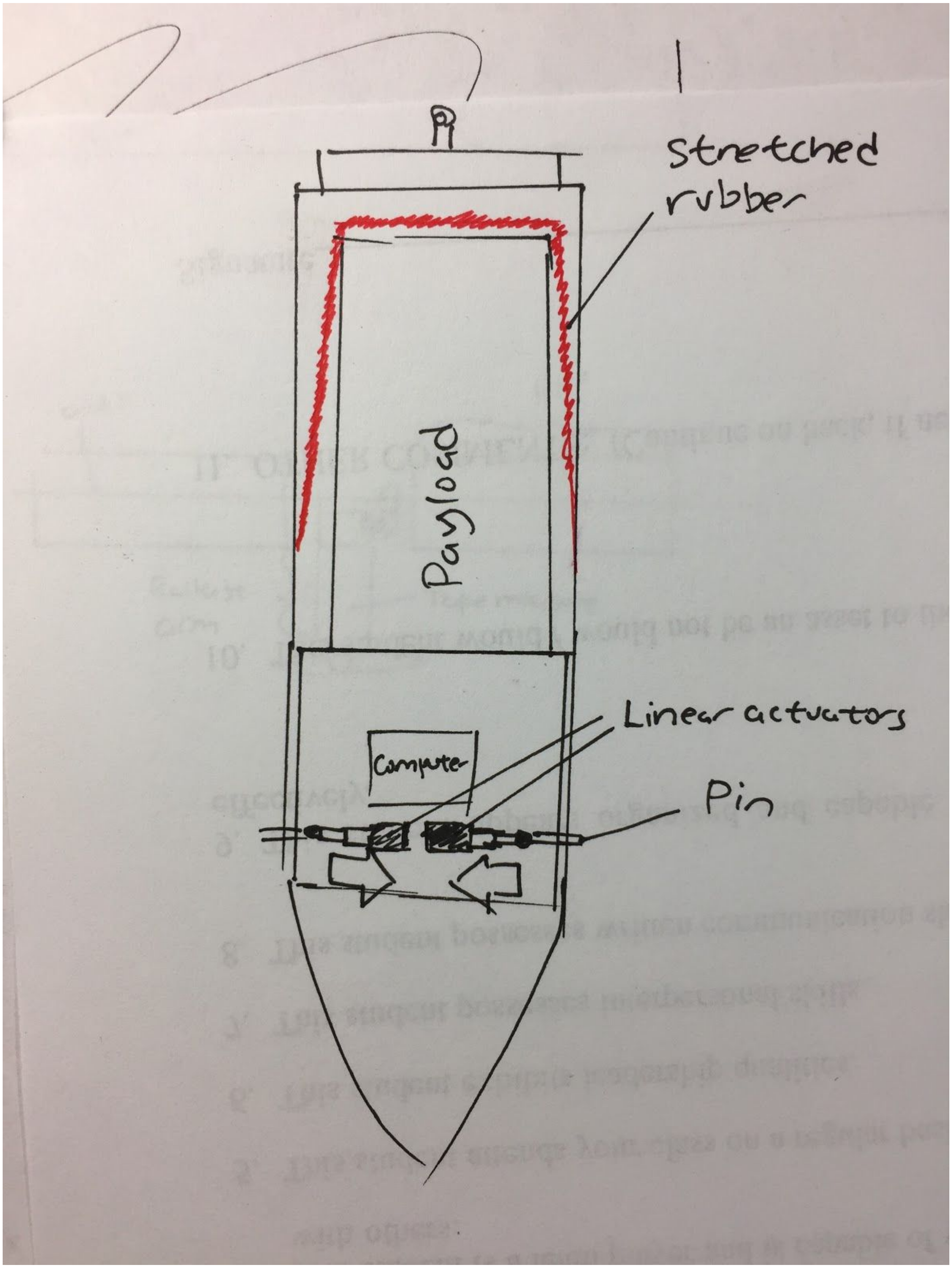
| Device | Pros | Cons |
|---|---|---|
| Mobilinkd | Easily reprogrammable. Works with variety of devices that supports KISS protocol. Accessible without mobile/wifi network. No extra wires or large setups | Doesn't work with iPhones/Apple products due to iOS not supporting KISS protocol. 11mm thick. About $70 |

| | | |
|---|---|---|
| | required. ≥ 40g. | |
| Radio Shield 2 for Arduino | $36 each. Operational with VHF APRS network. Can transmit and receive packets. Programmable. 17g | Will not send telemetry unless it knows its location. |
| APC220<br>Manual | $40 each. Highly sensitive. Has an embedded watchdog. Size: 37 x 17 x 6.5 mm. Eliminates need for packetizing and data encoding. ≥ 30g. | Only works at a distance of up to 1200m at 9600 bps. |

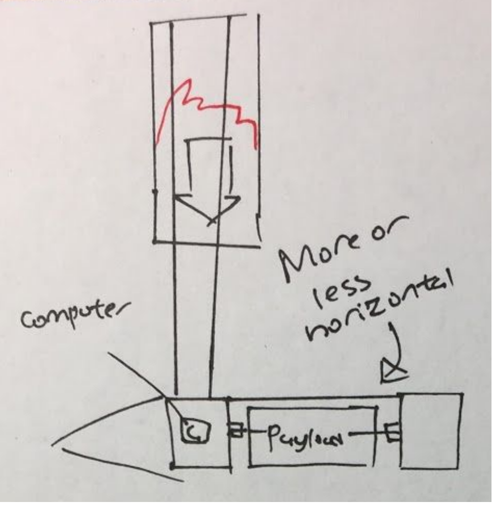
### 5.1.3.3 Leading Design

We will use Mobilnkd for the payload. This will help us locate the UAV in case it gets lost, and it is easily reprogrammable.

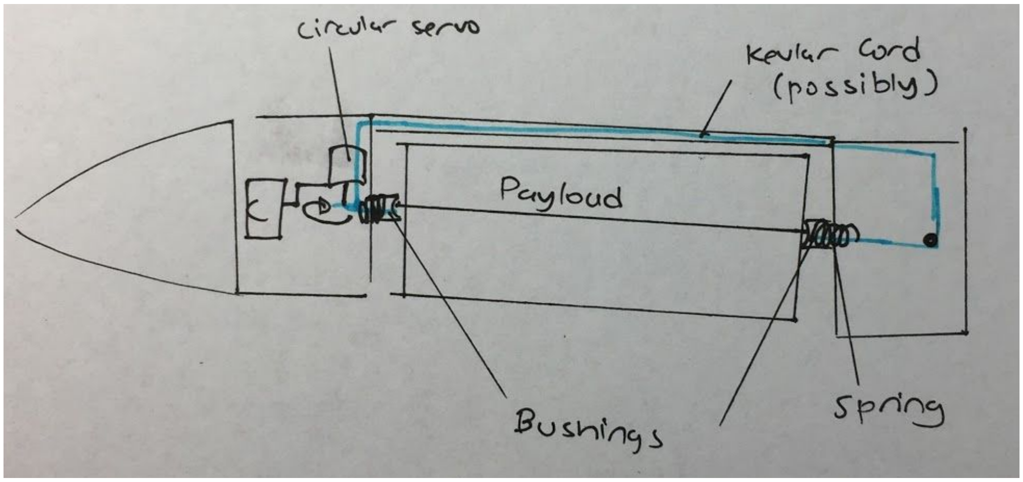
### 5.1.4 System Diagrams and Schematics

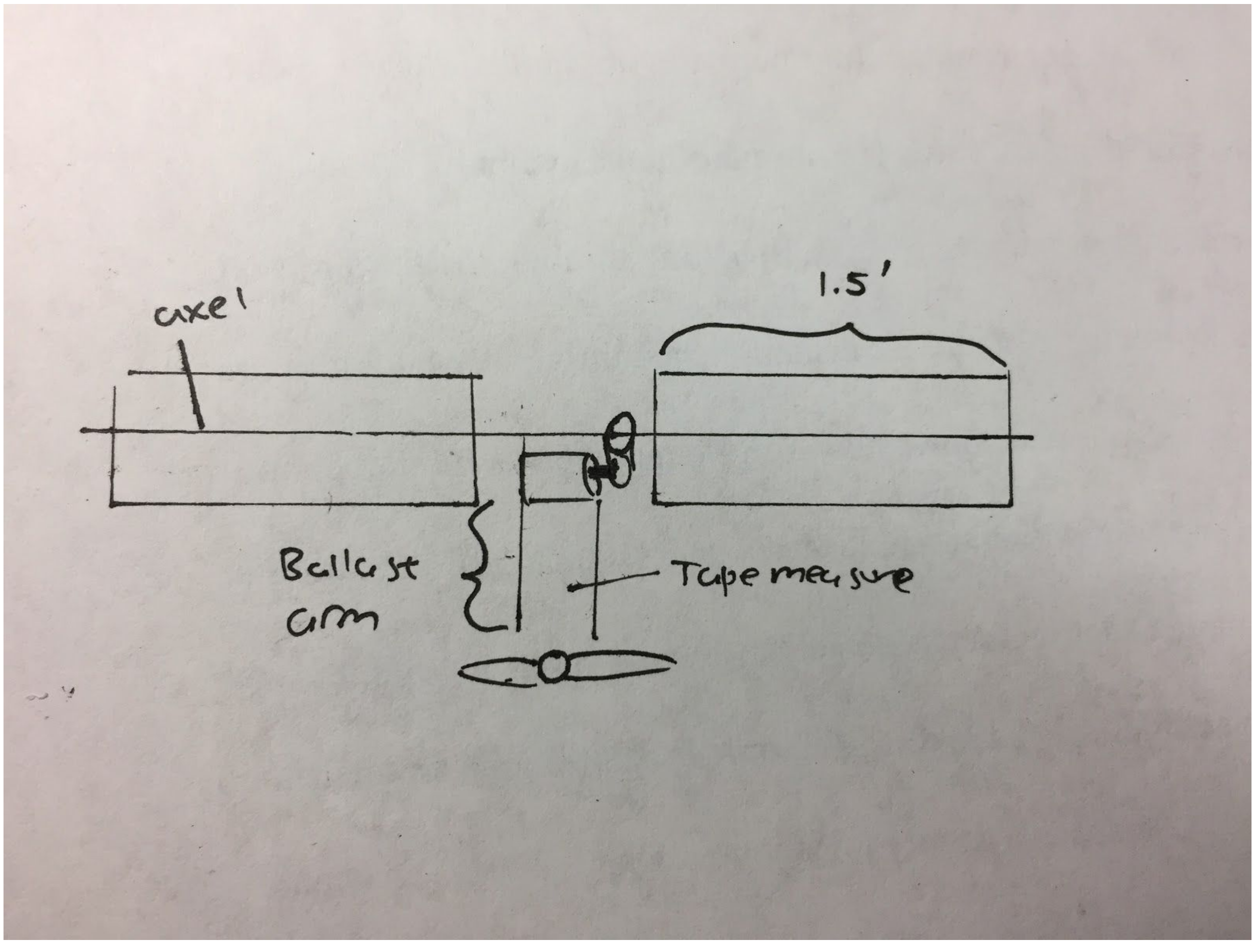

Stretched rubber
Payload
Linear actuators
Computer
Pin

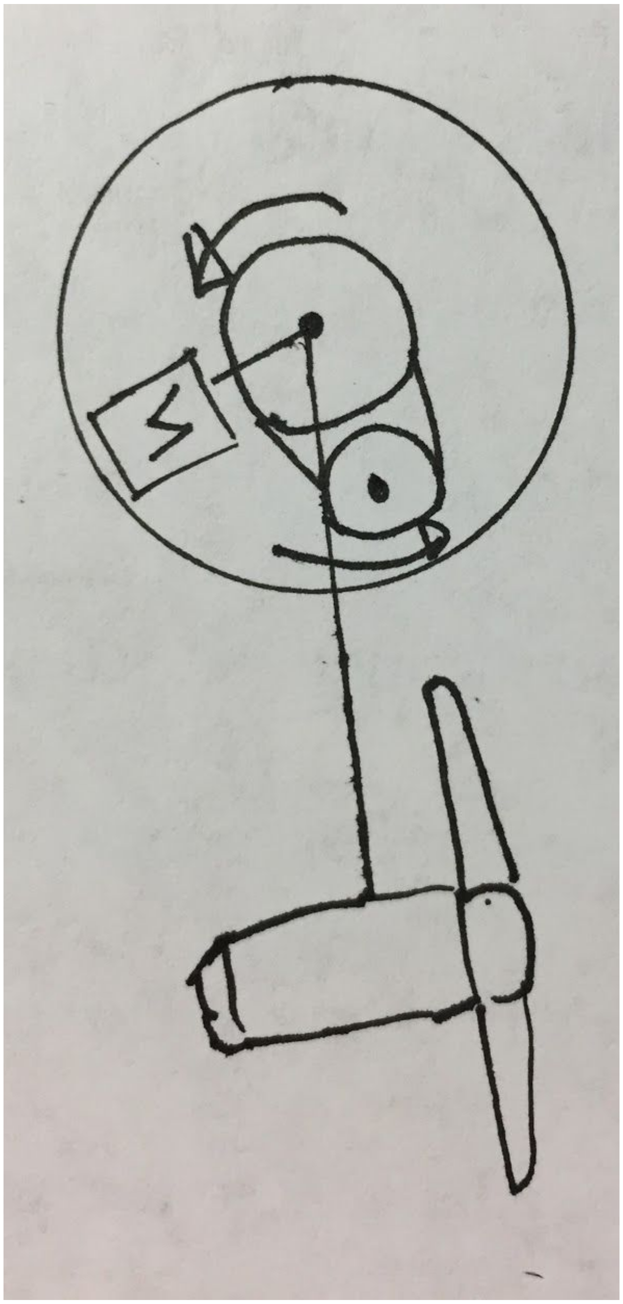
The main electronics regarding ejecting the payload will be through the nose cone. There will be a computer, along with its own transmitter and receiver, within the nose cone. There will also be two linear actuators that will pull on the metal pins to release the nose cone, thus allowing the elastic inside of the body tube (depicted in red) to force the payload out.

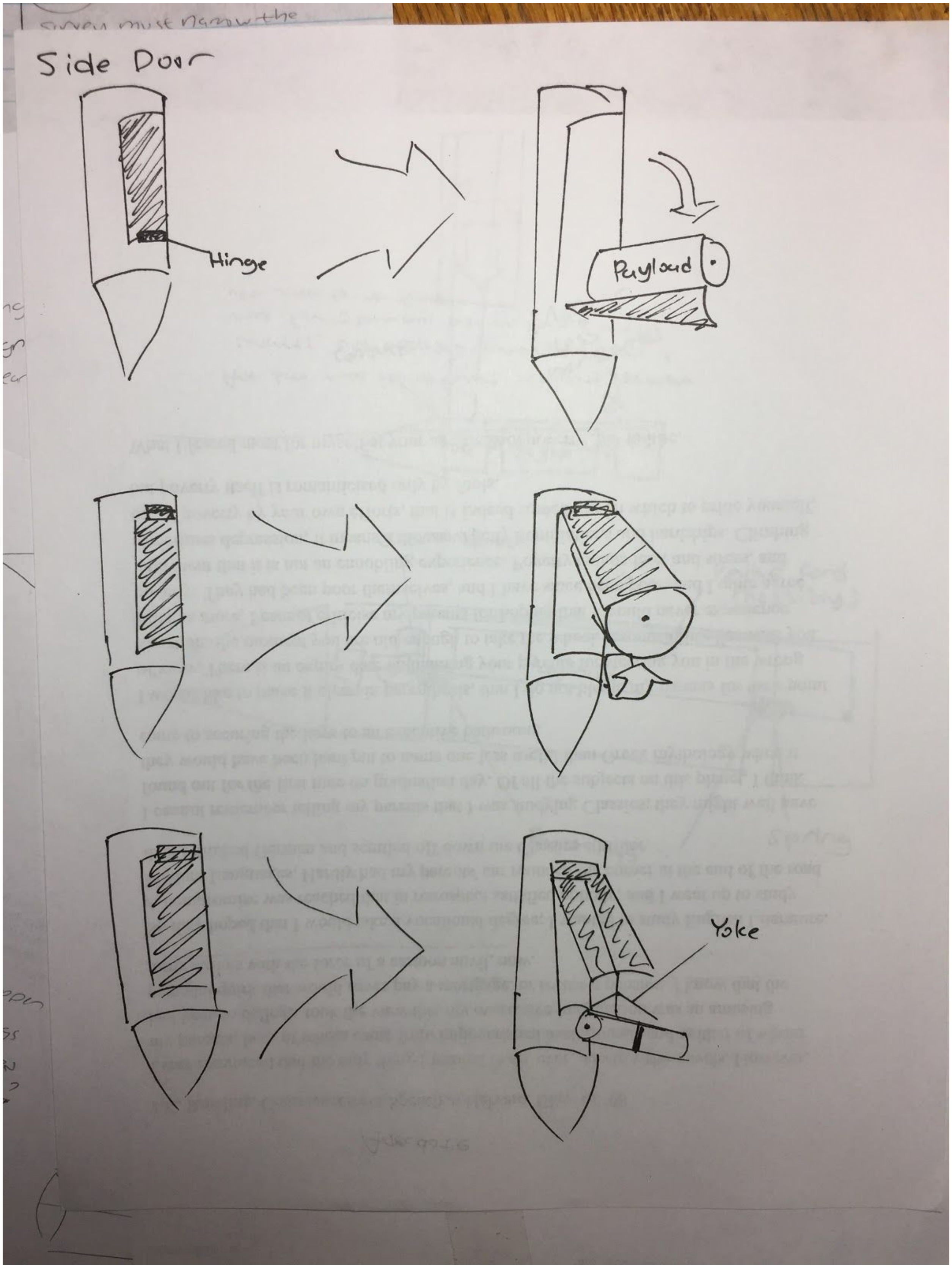


With the tethers attached, the payload, attached to the nose cone, will deploy and stop horizontally.




axel
1.5'
Ballast arm
Tape measure


S


Side Door
Hinge
Payload
Yoke

We had also considered using a side door, but we realized it was possible this design could not act fast enough for us.

## 5.1.5 Justification of Design Selections

We will use a vertical gravitational dump with elastic-assisted deployment to deploy the UAV.

## 5.1.6 Interfaces Between Payload and Launch Vehicle

The payload will fit within its own body tube, which is above the main chute. There will be shear pins attached to this area.

### 5.1.6.1 Slingshot System

#### 5.1.6.1.1 Linear Actuator

**L12-I Micro Linear Actuator with Internal Controller**

| | | | |
|---|---|---|---|
| Gearing | 50:1 | Mass | 34 g |
| Stroke | 30 mm | Repeatability | ±0.2 mm |
| Voltage | 6VDC | Max Side Load (extended) | 40 N |
| Peak Power Point | 17 N @ 14 mm/s | Closed Length (hole to hole) | 82 mm |
| Peak Efficiency Point | 10 N @ 19 mm/s | Potentiometer | 3kΩ±50% |

| | | | |
|---|---|---|---|
| Max Speed (no load) | 25 mm/s | Max Input Voltage | 7.5V |
| Max Force (lifted) | 22 N | Stall Current | 460mA |
| Back Drive Force (static) | 12 N | Standby Current | 7.2mA |

The linear actuators are responsible for pulling out stainless steel pins. By releasing the resisting force against the tension of the rubber band, the nose cone and the payload accelerate out of the rocket as one mass and then hang until the RSO gives the all-clear.

# 6 Project Plan

## 6.1 Requirements Verification

### 6.1.1 Verification Plans

We will use a cross reference table to make sure we have met all of sections 1-5 within the NASA Student Launch handbook.

#### 6.1.1.1 General Verification Plan

#### 6.1.1.2 Vehicle Verification Plan

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

#### 6.1.1.3 Recovery System Verification Plan

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

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

For the RRC3, the continuity check is the following:

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

#### 6.1.1.4 Experiment Verification Plan

We will bring a measuring tape with us and a GPS to verify that the payload landed within 50 ft of its intended landing position.

#### 6.1.1.5 Safety Verification Plan

Safety of the team and of anyone around is managed by the safety officer.

### 6.1.2 Team Derived Requirements

#### 6.1.2.1 Vehicle Requirements

#### 6.1.2.2 Payload Requirements

#### 6.1.2.3 Recovery Requirements

#### 6.1.2.4 Safety Requirements

#### 6.1.2.5 General Requirements

The SL team should complete the project within its set budget, finalized by the Critical Design Review

## 6.2 Budget

*Will be reusing last year’s materials

| Description | Unit Cost | Qty | Subtotal | |
|---|---|---|---|---|
| **Scale Vehicles and Engines** | | | | |
| 3" Fiberglass Frenzy XL | $200.00 | 1 | $0.00* | |
| 3" G12 Thin-Wall Airframe (12" length) | $20.00 | 1 | $0.00* | |
| 3" G12 Coupler (6" length) | $14.00 | 2 | $0.00* | |
| 3" G12 Coupler (9" length) | $21.00 | 1 | $0.00* | |
| HS-7980TH | $190.00 | 1 | $0.00* | |
| 2-56 wire | $10.00 | 1 | $0.00* | |
| 1/4" Machine Closed Eye Bolt | $18.00 | 4 | $0.00* | |
| Heavy unit easy connector | $5.00 | 1 | $0.00* | |
| Iris Ultra 72" Compact parachute | $265.00 | 1 | $0.00* | |
| 12" Elliptical Parachute | $47.00 | 1 | $0.00* | |
| Cesaroni J240RL | $85.00 | 1 | $85.00 | |
| **Total Scale Vehicle Cost** | | | | $85.00 |
| | | | | |
| **Vehicle** | | | | |
| 4" G12 Coupler (12" length) | $31.00 | 3 | $0.00* | |
| 4" G12 Coupler (8" length) | $21.00 | 2 | $0.00* | |
| 4" Fiberglass Frenzy XL | $300.00 | 1 | $0.00* | |
| 4" G12 Airframe (12" length) | $23.00 | 1 | $0.00* | |
| 2-56 wire | $10.00 | 1 | $0.00* | |
| Heavy unit easy connector | $5.00 | 1 | $0.00* | |
| Aero Pack 75mm Retainer (Fiberglass Motor Tubes) | $44.00 | 1 | $0.00* | |
| Shock Cord Protector Sleeves of Kevlar | $10.00 | 3 | $0.00* | |
| 1 Inch Black Climbing Spec Tubular Nylon Webbing | $12.00 | 2 | $0.00* | |
| 3/8" Machine Closed Eye Bolt | $30.00 | 4 | $0.00* | |
| 4" G10 Airframe Plate | $6.00 | 8 | $0.00* | |
| 3" G10 Airframe Bulkplate | $5.00 | 8 | $0.00* | |
| 3" Aluminum Bulkplate | $15.00 | 4 | $0.00* | |
| 4" Aluminum Bulkplate | $20.00 | 4 | $0.00* | |
| 4" Coupler Bulkplate | $4.00 | 4 | $0.00* | |
| 3" Coupler Bulkplate | $3.50 | 4 | $0.00* | |

| | | | | |
|---|---|---|---|---|
| Electric Matches | $1.50 | 60 | $90.00 | |
| Aero Pack 54mm Retainer (Fiberglass Motor Tubes) | $29.00 | 1 | $0.00* | |
| Cesaroni K2000 | $30.00 | 5 | $150 | |
| **Total Vehicle Cost** | | | | $240 |
| | | | | |
| **Recovery** | | | | |
| Iris Ultra 120" Compact Parachute | $504.00 | 1 | $0.00* | |
| 24" Elliptical Parachute | $60.00 | 1 | $0.00* | |
| 4F Black Powder | Kept by mentor | | | |
| Batteries (9v, 2 pack) | $7.00 | 3 | $0.00* | |
| Battery Holder | $1.00 | 5 | $0.00* | |
| Stratologger CF Flight Computer | $55.00 | 1 | $0.00* | |
| RRC3 Flight Computer | $70.00 | 1 | $0.00* | |
| PerfectFlite Pnut (2 units) | $55.00 | 2 | $0.00* | |
| **Total Recovery Cost** | | | | $0.00 |
| | | | | |
| **Payload** | | | | |
| Arduino Uno kit (includes LED, resistors, regulators, etc) | $35.00 | 1 | $0.00* | |
| SD card + Adapter | $10.00 | 1 | $0.00* | |
| PerfectFlite Pnut Altimeter | $50.00 | 2 | $0.00* | |
| Lithium Ion Battery (rechargeable) | $100.00 | 1 | $0.00* | |
| DC 12v 10000RPM Mini Magnetic Motor | $5.53 | 2 | $10.06 | |
| 16” Paper parachute | $4.00 | 2 | $8.00 | |
| Teensy | | | | |
| Gimbal | $11.68 | 2 | $23.36 | |
| Adafruit Battery | $6.40 for 10 | 10 | $6.40 | |
| **Total Payload Cost** | | | | $47.82 |
| | | | | |
| **GPS System** | | | | |
| Whistle GPS Dog Tracker Kit | $75.00 | 1 | $0.00* | |
| Cellular Service Fee (3 months free, 5 months to pay) | $40.00 | 1 | $40.00 | |

| | | | | |
|---|---|---|---|---|
| **Total Payload Cost** | | | | $40.00 |
| | | | | |
| **Educational Outreach** | | | | |
| Color fliers (250 copies) | $170.00 | | | |
| **Total Educational Outreach Cost** | | | | $170.00 |
| | | | | |
| **Travel (4 Members)** | | | | |
| Trips to Lucerne ($2.80/gal, 112mi; $21.00 per trip per car) | | | | |
| Huntsville, Alabama (roundtrip plane ticket) | $332.00 | 4 | $1328.00 | |
| Food (2 meals a day, 6 days) | $10.00 | 48 | $480.00 | |
| Hotel (2 people per room, 6 days) | $120.00 | 12 | $1440.00 | |
| **Total Travel Cost (Estimated)** | | | | $3248.00 |
| | | | | |
| **Total Estimated Project Expenses** | | | | $3830.82 |

### 6.2.1 Funding Plan

The team will procure funds from various sources. Action plans include the following: go around the community to collect items for a garage sale and also ask for donations, explain to them what the team's goal is, send letters to local businesses and aerospace companies requesting financial aid, and speak to vendors involved in rocketry and other supplies for discounts and donations. Additionally, opportunities such as fundraising support from local restaurants and stores will be used to gain more funding for the team.

## 6.3 Timeline

The development timeline will be available on verticalprojectile.org under the NASA SL tab.

# Appendix A: Statement of Work Cross-Reference

Grayed out areas indicate requirements that are not mentioned/fulfilled in the PDR because they are larger in scope than is required for the PDR itself.

| **No.** | **Requirement in SOW** | **PDR Section** |
|---|---|---|

| **1. General Requirements** | | |
|---|---|---|
| 1.1 | Students on the team will do 100% of the project, including design, construction, written reports, presentations, and flight preparation with the exception of assembling the motors and handling black powder or any variant of ejection charges, or preparing and installing electric matches (to be done by the team's mentor) | |
| 1.2 | The team will provide and maintain a project plan to include, but not limited to, the following items: project milestones, budget and community support, checklists, personnel assigned, educational 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 the team during these 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 4.4.) | |
| 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 Education Engagement Activity Report, by FRR. An educational engagement activity report will be completed and submitted within two weeks after completion of an event. A sample of the educational engagement activity report can be found on page 29 of the handbook. | |
| 1.6 | The team will develop and host a Web site for project documentation | |
| 1.7 | Teams will post, and make available for download, the | |

| | | |
|---|---|---|
| | required deliverables to the team Web site by the due dates specified in the project timeline. | |
| 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 ever 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 broadband Internet connections. Cellular phones can be used for speakerphone capability as a last resort. | |
| 1.12 | All teams must be required to use the launch pads provided by Student Launch's launch service provider. No custom pads will be permitted on the launch field. Launch services will have 8 ft. 1010 rails, and 8 and 12 ft 1515 rails available for use. | |
| 1.13 | Teams must implement the Architectural and Transportation Barriers Compliance Board Electronic and Information Technology (EIT) and Accessibility Standards (36 CFR Part 1194)<br>Subpart B-Technical Standards<br>(http://www.section507.gov):<br>● 1194.21 Software applications and operating systems<br>● 1194.22 Web-based intranet and Internet information and applications | |
| 1.14 | 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 t2 flights in this or a higher impulse class, prior to the 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 only be provided if the team passes the FRR and the team and mentor attends launch week in April. | |
| **2. Vehicle Requirements** | | |
| 2.1 | The vehicle will deliver the payload to an apogee altitude of 5, 280 feet above ground level (AGL). | |
| 2.2 | The vehicle will carry one commercially available, barometric altimeter for recording the official altitude used in determining the altitude award winner. Teams will receive the maximum number of altitude points if the official scoring altimeter reads a value of exactly 5280 feet AGL. The team will lose one point for every foot above or below the required altitude. | |
| 2.3 | Each altimeter will be armed by a dedicated arming switch that is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad. | |
| 2.4 | Each altimeter will have a dedicated power supply. | |
| 2.5 | Each arming switch will be capable of being locked in the ON position for the launch. | |
| 2.6 | The launch vehicle will be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications. | |
| 2.7 | The launch vehicle will have a maximum of four (4) independent sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute. | |
| 2.8 | The launch vehicle will be limited to a single stage. | |
| 2.9 | The launch vehicle will be capable of being prepared for flight at the launch site within 3 hours of the time the Federal Aviation Administration flight waiver opens. | |

| | | |
|---|---|---|
| 2.10 | The launch vehicle will be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board components. | |
| 2.11 | The launch vehicle will be capable of being launched by a standard 12-volt direct current firing system. The firing system will be provided by the NASA-designated Range Services Provider. | |
| 2.1.2 | The launch vehicles will require no external circuitry or special ground support equipment to initiate a launch (other than what is provided by Range Services). | |
| 2.13 | The launch vehicle will use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR). | |
| 2.13.1 | Final motor choices must be made by the Critical Design Review (CDR). | |
| 2.13.2 | Any motor changes must be approved by the NASA Range Safety Officer (RSO), and will only be approved if the changes is for the sole purpose of increasing the safety margin. | |
| 2.14 | Pressure vessels on the vehicle will be approved by the RSO and will meet the following criteria: | |
| 2.14.1 | The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) will be a 4:1 with supporting design documentation included in all milestone reviews. | |
| 2.14.2 | Each pressure vessel will include a pressure relief valve that sees the full pressure of the tank. | |
| 2.14.3 | Full pedigree of the tank will be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank, by whom, and when. | |
| 2.15 | The total impulse provided by a Middle and/or High | |

| | | |
|---|---|---|
| | School launch vehicle will not exceed 2560 Newton-seconds (K-class.) | |
| 2.16 | The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit | |
| 2.17 | The launch vehicle will accelerate to a minimum velocity of 52 fps at rail exit. | |
| 2.18 | All teams will successfully launch and recover a subscale model of their rocket prior to CDR. Subscales are not required to be a high power rockets. | |
| 2.18.1 | The subscale model should resemble and perform as similarly as possible to the full scale model, however, the full-scale will not be used as the subscale model. | |
| 2.18.2 | The subscale model will carry an altimeter capable of reporting the model's apogee altitude | |
| 2.19 | All teams will successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown at FRR must be the same rocket flown on launch day. The purpose of the full-scale demonstration flight is to demonstrate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for 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 lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full scale demonstration flight: | |
| 2.19.1 | The vehicle and recovery system will have functioned as designed. | |
| 2.19.2 | The payload does not have to be flown during the full-scale test flight. The following requirements still apply: | |
| 2.19.2.1 | If the payload is not flown, mass simulators will be used to simulate the payload mass. | |
| 2.19.2.1.1 | The mass simulators will be located in the same approximate location on the rocket as the missing payload mass. | |

| | | |
|---|---|---|
| 2.19.3 | If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems will be active during the full-scale demonstration launch. | |
| 2.19.4 | The full-scale motor does not have to be flown during the full-scale test flight. However, it is recommended that the full-scale motor be used to demonstrate full flight readiness and altitude verification. If the full-scale motor is not flown during the full-scale flight, it is desired that the motor simulate, as closely as possible, the predicted maximum velocity and maximum acceleration of the launch day flight. | |
| 2.19.5 | 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. | |
| 2.19.6 | 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 (RSO) | |
| 2.19.7 | Full scale flights must be completed by the start of the FRRs (March 6th, 2018). If the Student Launch office determines that a re-flight is necessary, then an extension to March 28th, 2018 will be granted. This extension is only valid for re-flights; not first time flights. | |
| 2.20 | Any structural protuberance on the rocket will be located aft of the burnout center of gravity. | |
| 2.21 | Vehicle Prohibitions | |
| 2.21.1 | The launch vehicle will not utilize forward canards. | |
| 2.21.2 | The launch vehicle will not utilize forward firing motors. | |
| 2.21.3 | The launch vehicle will not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.). | |
| 2.21.4 | The launch vehicle will not utilize hybrid motors. | |
| 2.21.5 | The launch vehicle will not utilize a cluster of motors. | |
| 2.21.6 | The launch vehicle will not utilize friction fitting for | |

| | | |
|---|---|---|
| | motors. | |
| 2.21.7 | The launch vehicle will not exceed Mach 1 at any point during the flight. | |
| 2.21.8 | Vehicle ballast will not exceed 10% of the total weight of the rocket. | |
| **3. Recovery System requirements** | | |
| 3.1 | The launch vehicle will stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a lower altitude. Tumble or streamer recovery from apogee to main parachute is also permissible, provided that kinetic energy during drogue-stage descent is reasonable, as deemed by the RSO. | |
| 3.2 | Each team must perform a successful ground ejection test for both drogue and main parachutes. This must be done prior to the initial subscale and full scale launches | |
| 3.3 | At landing, each independent sections 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 electronic 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 2500 ft. radius from the launch pads. | |

| | | |
|---|---|---|
| 3.10 | An electronics 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. | |
| 3.10.1 | Any rocket section, or payload component, which lands untethered to the launch vehicle, will also carry an active electronic tracking device. | |
| 3.10.2 | The electronic tracking device will be fully functional during the official flight on launch day. | |
| 3.11 | The recovery system electronics will not be adversely affected by an other on-board electronic devices during flight (from launch until landing). | |
| 3.11.1 | The recovery system altimeters will be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device. | |
| 3.11.2 | The recovery system electronics will be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system electronics. | |
| 3.11.3 | The recovery 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. | |
| 3.11.4 | The recovery system electronics will be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics. | |
| **4. Payload requirements** | | |
| 4.1 | The launch vehicle will carry a science or engineering payload. The payload may be of the team’s discretion, but 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. | |
| 4.2 | Data from the science or engineering payload will be collected, analyzed, and reported by the team following the scientific method. | |

| | | |
|---|---|---|
| 4.3 | Unmanned aerial vehicle (UAV) payloads of any type will be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given the authority to release the UAV. | |
| 4.4 | Any payload element that is jettisoned during the recovery phase, or after the launch vehicle lands, will receive real-time RSO permission prior to initiating the jettison event. | |
| 4.5 | The payload 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. | |
| **5. Safety Requirements** | | |
| 5.1 | Each team will use a launch and safety checklist. The final checklists will be included in the FRR report and used during the Launch Readiness Review (LRR) and any launch day operations. | |
| 5.2 | Each team must identify a student safety officer who will be responsible for all items in section 5.3 | |
| 5.3 | The roles and responsibilities of each safety officer will include, but not limited to: | |
| 5.3.1 | Monitor team activities with an emphasis on Safety during: | |
| 5.3.1.1 | Design and vehicle 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 | Sub-scale launch test(s) | |
| 5.3.1.6 | Full-scale launch test(s) | |
| 5.3.1.7 | Launch day | |
| 5.1.3.8 | Recovery activities | |
| 5.3.1.9 | Educational Engagement Activities | |

| | | |
|---|---|---|
| 5.3.2 | Implement procedures developed by the team for construction, assembly, launch, and recovery activities | |
| 5.3.4 | Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures | |
| 5.4 | During test flights, teams will abide by the rules and guidances of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch Initiative does not give explicit or implicit authority for teams to fly those certain vehicle configurations and/or payloads at other club launches. Teams should communicate their intentions to the local club's President or Prefect and RSO before attending any NAR or TRA launch. | |
| 5.5 | Teams will abide by the rules set forth by the FAA. | |

# Appendix B: Summary of PDR Report

| **Summary of PDR report (1 page maximum)** | | |
|---|---|---|
| 1. | Team Summary | 1.1 |
| 1.1 | Team name and mailing address | 1.1.1 |
| 1.2 | Name of mentor, NAR/TRA number and certification level, and contact information | 1.1.2 |
| 2 | Launch Vehicle Summary | 1.2 |
| 2.1 | Size and mass | 1.2.1 |
| 2.2 | Motor choice | 1.2.2 |
| 2.3 | Recovery System | 1.2.3 |
| 2.4 | Milestone Review Flysheet | 1.2.4 |
| 3 | Payload Summary | 1.3 |
| 3.1 | Payload title | 1.3.1 |

|  |  |  |
|---|---|---|
| 3.2 | Summarize Payload Experiment | 1.3.2 |
| **Changes Made Since Proposal (1-2 Pages maximum)** |  |  |
| 1 | Highlight all changes made since the proposal and the reason for those changes | 2 |
| 1.1 | Changes made to vehicle criteria | 2.1 |
| 1.2 | Changes made to payload criteria | 2.2 |
| 1.3 | Changes made to project plan | 2.3 |
| **Vehicle Criteria** |  |  |
| 1 | Selection, Design, and Rationale of Launch Vehicle | 3 |
| 1.1 | Include unique mission statement, and mission success criteria | 3.1.1 |
| 1.2 | Review the design at a system level, going through each systems' alternative design | 3.1.3 |
| 1.3 | For each alternative, present on why that alternative should or should not be chosen | 3.1.3.1.2 |
| 1.4 | After evaluating all alternatives, present a vehicle design with the current leading alternatives, and explain why they are the leading choices | 3.1.3.1.3 |
| 1.4.1 | Describe each subsystem, and the components within those subsystems | 3.1.3.1.2 |
| 1.4.2 | Provide a dimensional drawing using the leading design | 3.1.3 |
| 1.4.3 | Provide estimated masses for each subsystem | 3.1.3.1.1,<br>3.1.3.2 |
| 1.4.4 | Provide sufficient justification for design selections | 3.1.3.1.3 |
| 1.5 | Review different motor alternatives, and present data for each alternative | 3.1.6 |
| 2 | Recovery Subsystem | 3.2 |
| 2.1 | Review the design at a component level, going through each components' alternative designs, and evaluating the pros and cons of each alternative | 3.2.1 |

| | | |
|---|---|---|
| 2.2 | For each alternative, present research on why that alternative should or should not be chosen. | 3.2.3 |
| 2.3 | Using the estimated mass of the launch vehicle, perform a preliminary analysis on parachute sizing, □and what size is required for a safe descent. | 3.2.4, 3.2.5 |
| 2.4 | Choose leading components amongst the alternatives, present them, and explain why they are the □current leaders. □ | 3.2.4 |
| 2.5 | Prove that redundancy exists within the system. □ | 3.2.6 |
| 3 | Mission Performance Predictions | 3.3 |
| 3.1 | Show flight profile simulations, altitude predictions with simulated vehicle data, component weights, and simulated motor thrust curve, and verify that they are robust enough to withstand the expected loads. □ | 3.3.1,<br>3.3.1.2,<br>3.3.1.3,<br>3.3.1.4,<br>3.3.1.5 |
| 3.2 | Show stability margin, simulated Center of Pressure (CP)/Center of Gravity (CG) relationship and locations. | 3.3.1.5 |
| 3.3 | Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle. | 3.3.3.1 |
| 3.4 | Calculate the drift for each independent section of the launch vehicle from the launch pad for five □different cases: no wind, 5-mph wind, 10-mph wind, 15-mph wind, and 20-mph wind. The drift calculations should be performed with the assumption that the rocket will be launch straight up (zero-degree launch angle). | 3.3.3.2 |
| 3.5 | Present data from a different calculation method to verify that original results are accurate. | 3.3.3.1.1,<br>3.3.3.2.1.1,<br>3.3.3.2.2.1,<br>3.3.3.2.3.1,<br>3.3.3.2.4.1,<br>3.3.3.2.5.1 |
| 3.6 | Discuss any differences between the different calculations. □ | 3.3.3.1.1,<br>3.3.3.2.1.1,<br>3.3.3.2.2.1,<br>3.3.3.2.3.1,<br>3.3.3.2.4.1,<br>3.3.3.2.5.1 |

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|---|---|---|
| 3.7 | Perform multiple simulations to verify that results are precise. ☐ | 3.3.4 |
| **Safety** |  |  |
| 1 | Demonstrate an understanding of all components needed to complete the project, and how risks/delays impact the project. ☐ | 4.1 |
| 2 | Provide a preliminary Personnel Hazard Analysis. The focus of the Hazard Analysis at PDR is identification of hazards, their causes, and the resulting effects. Preliminary mitigations and controls can be identified, but do not need to be implemented at this point unless they are specific to the construction and launching of the sub-scale rocket or are hazards to the success of the SL program (i.e. cost, schedule, personnel availability). Rank the risk of each Hazard for both likelihood and severity. | 4.2 |
| 2.1 | Include data indicating that the hazards have been researched (especially personnel). Examples: NAR regulations, operator's manuals, MSDS, etc. | 4.2 |
| 3 | Provide a preliminary Failure Modes and Effects Analysis (FMEA) of the proposed design of the rocket, payload, payload integration, launch support equipment, and launch operations. Again, the focus for PDR is identification of hazards, causes, effects, and proposed mitigations. Rank the risk of each Hazard for both likelihood and severity. | 4.3 |
| 4 | Discuss any environmental concerns using the same format as the Personnel Hazard Analysis and FMEA. | 4.4 |
| 4.1 | This should include how the vehicle affects the environment, and how the environment can affect the vehicle. | 4.4 |
| 5 | Define the risks (time, resource, budget, scope/functionality, etc.) associated with the project. Assign a likelihood and impact value to each risk. Keep this part simple i.e. low, medium, high likelihood, and low, medium, high impact. Develop mitigation techniques for each risk. Start with the risks with higher likelihood and impact, and work down from there. If possible, quantify the mitigation and impact. For example; including extra hardware to increase safety will have a quantifiable impact on budget. Including this information in a table is highly encouraged. | 4.5 |
| **Payload Criteria** |  |  |
| 1 | Selection, Design, and Rationale of payload | 5.1 |

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|---|---|---|
| 1.1 | Describe what the objective of the payload is, and what experiment it will perform. What results will qualify as a successful experiment? | 5.1.1, 5.1.2 |
| 1.2 | Review the design at a system level, going through each systems' alternative designs, and evaluating the pros and cons of each alternative. □ | 5.1.3 |
| 1.3 | For each alternative, present research on why that alternative should or should not be chosen. □ | 5.1.3 |
| 1.4 | After evaluating all alternatives, present a payload design with the current leading alternatives, and □explain why they are the leading choices. □ | 5.1.4 |
| 1.5 | Include drawings and electrical schematics for all elements of the preliminary payload with estimated □masses. □□ | 5.1.4 |
| 1.6 | Describe the justification used when making design selections. | 5.1.5 |
| 1.7 | Describe the preliminary interfaces between the payload and launch vehicle. □ | 5.1.6 |
| **Project Plan** | | |
| 1 | Requirements Verification | 6.1 |
| 1.1 | Create a verification plan for every requirement from sections 1-5 in this handbook. Identify if test, analysis, demonstration, or inspection are required to verify the requirement. After identification, describe the associated plan needed for verification. □ | 6.1.1 |
| 1.2 | Create a set of team derived requirements in the following categories: Vehicle, Payload, Recovery, Safety, and General. These are a set of minimal requirements for mission success that are ideally beyond the minimum success requirements presented in this handbook. Like before, create a verification plan identifying whether test, analysis, demonstration, or inspection is required with an associated plan. Demonstrate the requirements are not arbitrary, and are required for teams unique project. □ | 6.1.1,<br>6.1.1.1,<br>6.1.1.2,<br>6.1.1.3,<br>6.1.1.4,<br>6.1.1.5, 6.1.2 |
| 2 | Budgeting and Timeline | 6.2 |
| 2.1 | Line item budget with market values for individual components, material vendors, and applicable taxes or shipping/handling fees. □ | 6.2 |
| 2.2 | Funding plan describing sources of funding, allocation of funds, and material acquisition plan. □ | 6.2.1 |

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|---|---|---|
| 2.3 | Timeline includes all team activities, and activity duration. Schedule appears complete, and encompasses the full term of the project. Deliverables are defined with reasonable activity duration. GANTT charts are encouraged.  | 6.3 |

# Appendix C: Partners in Industry

**Dr. James Martin**
Dr. Martin holds degrees from West Virginia University, Massachusetts Institute of Technology, and George Washington University. He has worked at the NASA Langley Research Center, The University of Alabama, and Boeing. His work has mostly involved the design and evaluation of reusable launch vehicles. Some recent work has been on crew escape for the Shuttle, the Space Launch Initiative, and a robotic lander on the moon. Dr. Martin retired from Boeing when the Launch vehicle business was sold. He continues to be active in aerospace doing consulting, as an Associate Editor for AIAA J. Spacecraft and Rockets, and as Chair of the local AIAA Orange County Section.

**Jonathan Mack (Electrical Engineer and Programmer)**
Jonathan graduated with a Bachelor of Science from Long Beach State. Currently he is an electronics design engineer involved in hardware and software development including diverse fields such as toys, audio, and currently printing. He has led a 4H project in mechanical, electrical and software design areas in robotics. At home his hobbies mainly focus on improving DIY (Do It Yourself) knowledge, including everything from mad science projects to more mundane things like welding and cooking (usually not at the same time.)

**Guy Heaton (Mechanical Engineer)**
Guy graduated with a Bachelor of Science from Pepperdine University. Currently he is a Senior Mechanical Engineer and has been working on printing solutions for 12 years. Responsibilities include designing for injection and blow molding and extrusions. He also does mechanical systems, drive trains, cabling, durability testing, and sheet metal design. When not designing new printers he does manufacturing time analysis, line balancing, and documentation.

**Mike Stoop (Fiberglassing, Programming, Design)**
Mike Stoop is currently the CTO of PriceDoc, Inc, a healthcare related web services company. Mike has been in the software industry for 30 years and an avid rocketeer for 40 years. Mike achieved his level 3 certification in 2002 and has participated in many individual and team 'M" class and above rocket projects. He has launched K and larger engines with electronic dual

deploy many more than 15 times. Mike is also the owner of Madcow Rocketry, a mid/high power rocket kit manufacturer.

**Drew, SpaceX (Fiberglassing, Programming, Design)**
Mr. Drew Beckett holds BS and MS degrees in aerospace engineering from the Dwight Look College of Engineering at Texas A&M University at College Station. Mr. Beckett developed and operated unmanned aircraft technology demonstrators for the Texas A&M Flight Mechanics Laboratory (later Unmanned Flight Laboratory) while employed by the Texas Engineering Experiment Station. More recently, Mr. Beckett has been in the employ of Space Exploration Technologies where he is responsible for the inertial guidance, navigation, and control sensors for the Falcon 9 launch vehicle and Dragon spacecraft as well as navigating Dragon on-orbit as a mission operator.

# Appendix D: Determination of the Magnus Effect