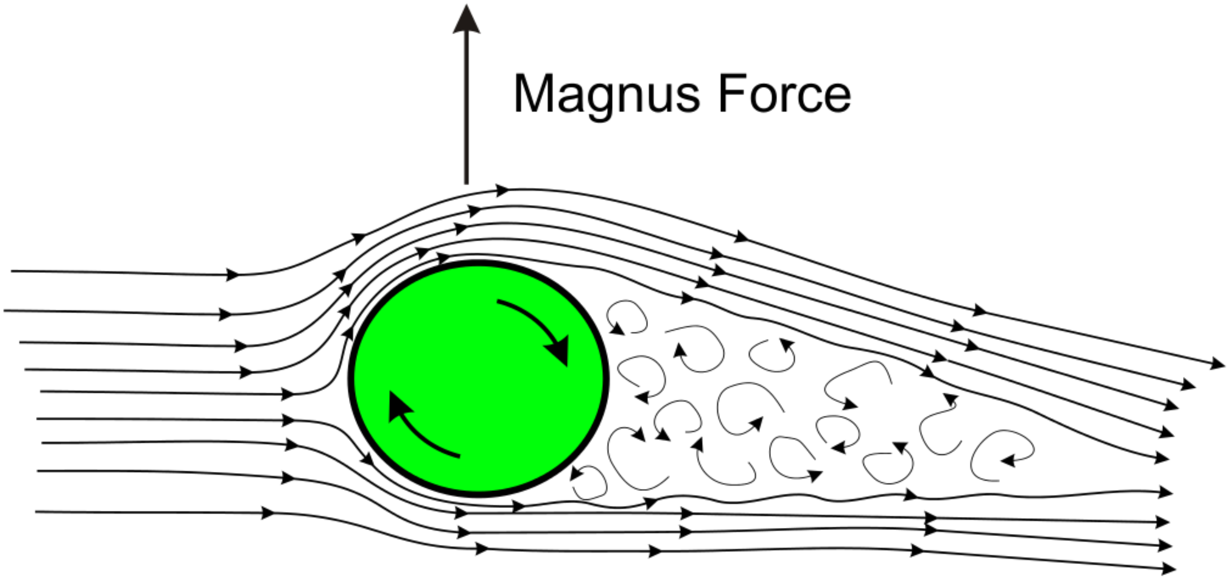
Flight Readiness Review (FRR)

Unmanned Aerial Vehicle with Experimental Magnus Force Lift



Mailing Address:
15 Wyoming
Irvine, CA 92606

AIAA OC Section
3/5/18

Albert (team leader)
Allison; Brenda; Kushagra; Sahil

Table of Contents

1 Summary of FRR 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

- Diameter: 4”
- Weight: 30.64 lbs
    - Mass: 13900 g
- Length: 144.75”

1.2.2 Motor Selection

Cesaroni K661

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 700 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 700 feet. The RRC3, which is the secondary flight computer, will blast out the drogue at two seconds after apogee and the main at 500 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

Unmanned Aerial Vehicle 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.
It will also feature a ballast arm to generate a torque to prevent the UAV from rotating around itself.

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.

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 release the sabot at no lower than 500 ft. Once the payload is below 400 ft, per the RSO's approval, the UAV will be released. The payload and rocket must land within 2500 ft of the launchpad.

2 Changes Made Since CDR

2.1 Changes to Vehicle Criteria

- Body tube extension
    - To accommodate the new payload length, which has been cut down for the sake of stability
- Vehicle is heavier as a result of the new mass of UAV and sabot
- Switched to a 12' 15 15 rail to achieve the minimum rail exit velocity

2.2 Changes to Payload Criteria

- Greater refinement of payload telemetry details
- The UAV will only have RC control as a failsafe, in the event the UAV poses a threat to bystanders
    - The UAV's lift motor can be turned off
- Sabot is released with a shorter elastic band

2.3 Changes to Project Plan

- Inclusion of dates for future flights and a balloon test

3 Vehicle Criteria

3.1 Design and Construction of the Vehicle

3.1.1 Changes in the Launch Vehicle

- The launch vehicle became heavier as a consequence of adding more realistic masses of the UAV and sabot, now that we had constructed the pair
    - The mass for the payload was greatly over what we had anticipated.

3.1.2 Features of Safe Launch and Recovery

Our recovery system has a redundant dual deploy system, which means that the electronics of the primary flight computer will not affect that of the secondary flight computer. The picture below shows the redundancy of our recovery electronics because the wiring of the Stratologger (in blue) is separate from the wiring of the RRC3 (in red).

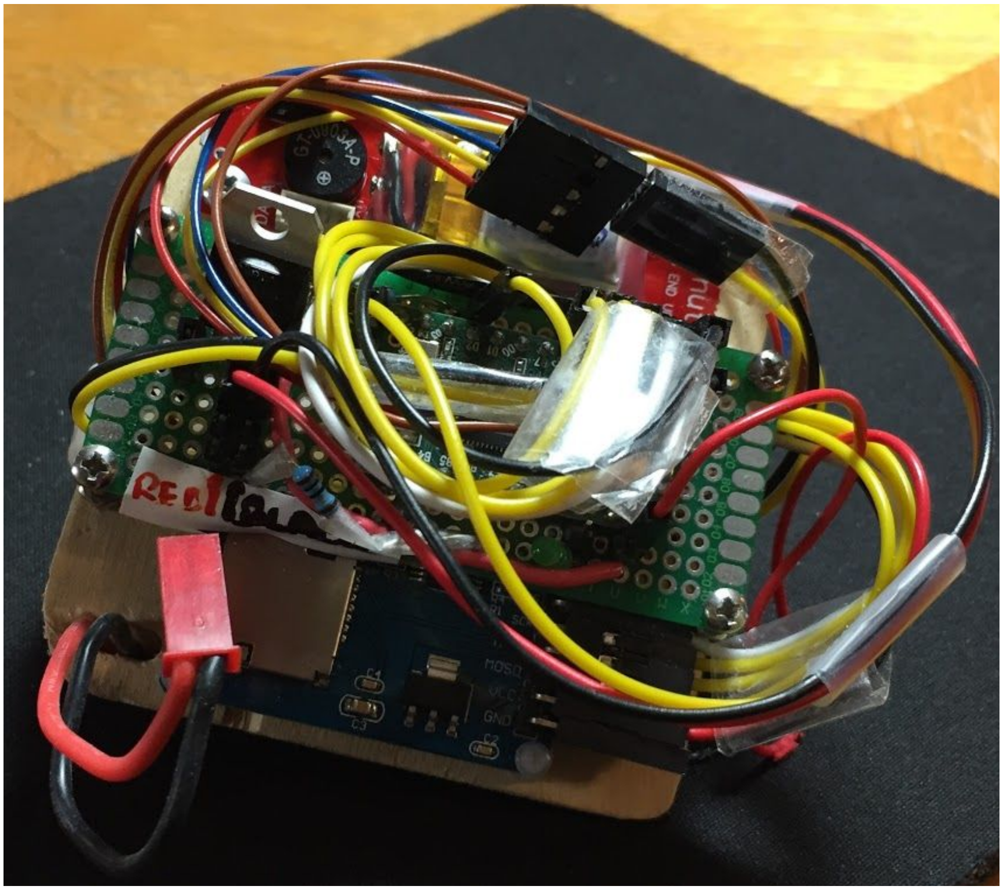
We are using two different types of recovery electronics in the event that one system has a bug and reads altitude incorrectly. If this is the case, then we can rely on the other recovery electronic to control the rest of the flight.

3.1.2.1 Structural Elements

The rocket comes from a MadCow Rocketry Frenzy XL kit, with some of our own additions. The launch vehicle's body is made of 4” G12 filament-wound fiberglass.

The rocket also has an AeroPack 75 mm motor retainer.

3.1.2.2 Electrical Elements



These are used to power the rocket's airbrakes. It contains a Teensy, a Pnut altitmeter, and a LiPo battery.

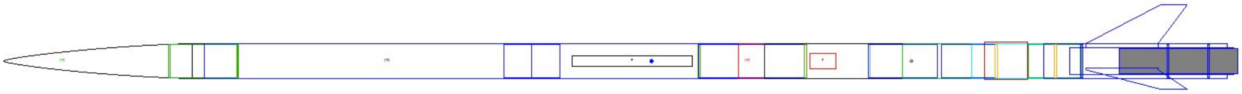
The Whistle GPS is used to track the launch vehicle's location. It hops frequencies, from this range: 850, 900, 1800, 1900 MHz.

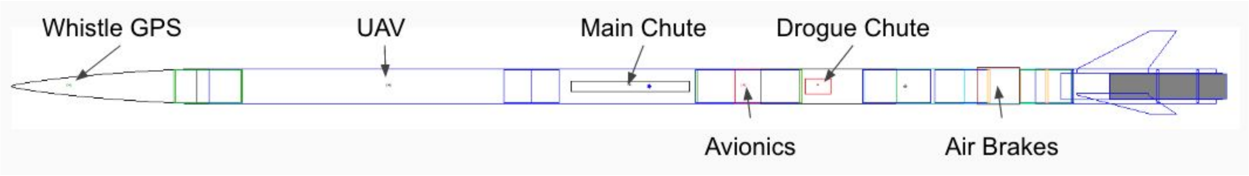
3.1.3 Flight Reliability

Most of this rocket has been flown before in our project from last year. There are a few new parts on the rocket, but they are mainly for holding new parts and extending the rocket to accomodate new recovery harness lengths.

3.1.4 Proof and Documentation of Vehicle Construction

3.1.5 Schematics of AS BUILT Rocket





3.1.6 Difference in Constructed Rocket as Compared to Previous Models

- More realistic mass, with the UAV and sabot masses included

3.2 Recovery Subsystem

3.2.1 Robustness of the Built and Tested Recovery System

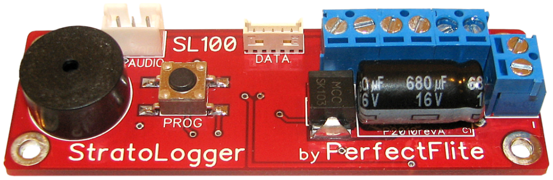
The recovery system is very robust because it is encased in a fiberglass avionics bay, which is structurally sound, and is redundant to reduce the chance of a failed recovery.

3.2.1.1 Structural Elements

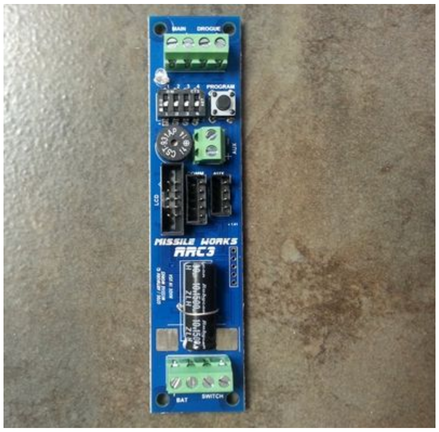
The flight computers are placed on a board with launch lugs. This is a sled.
There are two threaded rods that run through the avionics bay, which are used to keep the sled in place.
We also feature O-rings and silicon insulation, which help to keep excess gases from the ejection charges from entering the bay.
Either side of the avionics bay is covered by MadCow Rocketry 4” Aluminum Bulkplates. Wing nuts help to keep the threaded rods in place.
U-bolts are also put into the place of the bulkheads.
There are two terminals on each bulkplate. They respectively belong to the Stratologger and RRC3 Flight computers.
MG Chemicals Supershield is used to prevent against RF interference coming from the transmitters on the launch vehicle.

3.2.1.2 Electrical Elements

We are using a Stratologger CF Flight Computer from PerfectFlite to detonate the primary ejection charges. The RRC3 Flight Computer is for secondary charges.



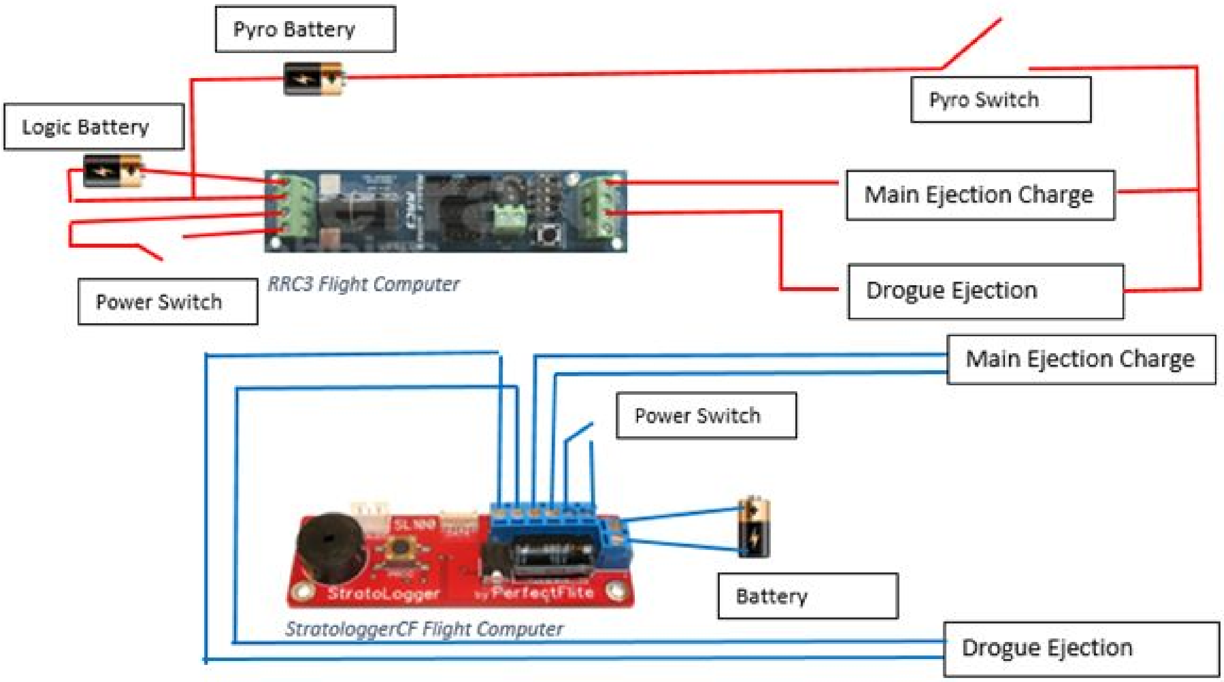
Stratologger



RRC3

Each is powered by a 9V battery.

3.2.1.3 Redundancy Features



3.2.1.4 Parachute Sizes and Descent Rates

3.2.1.4.1 Main Chute

Fruity Chutes 60” Iris Ultra Parachute

- Total weight upon descent: 28.36 lbs
- Descent rate: 23.6 fps

3.2.1.4.1 Drogue Chute

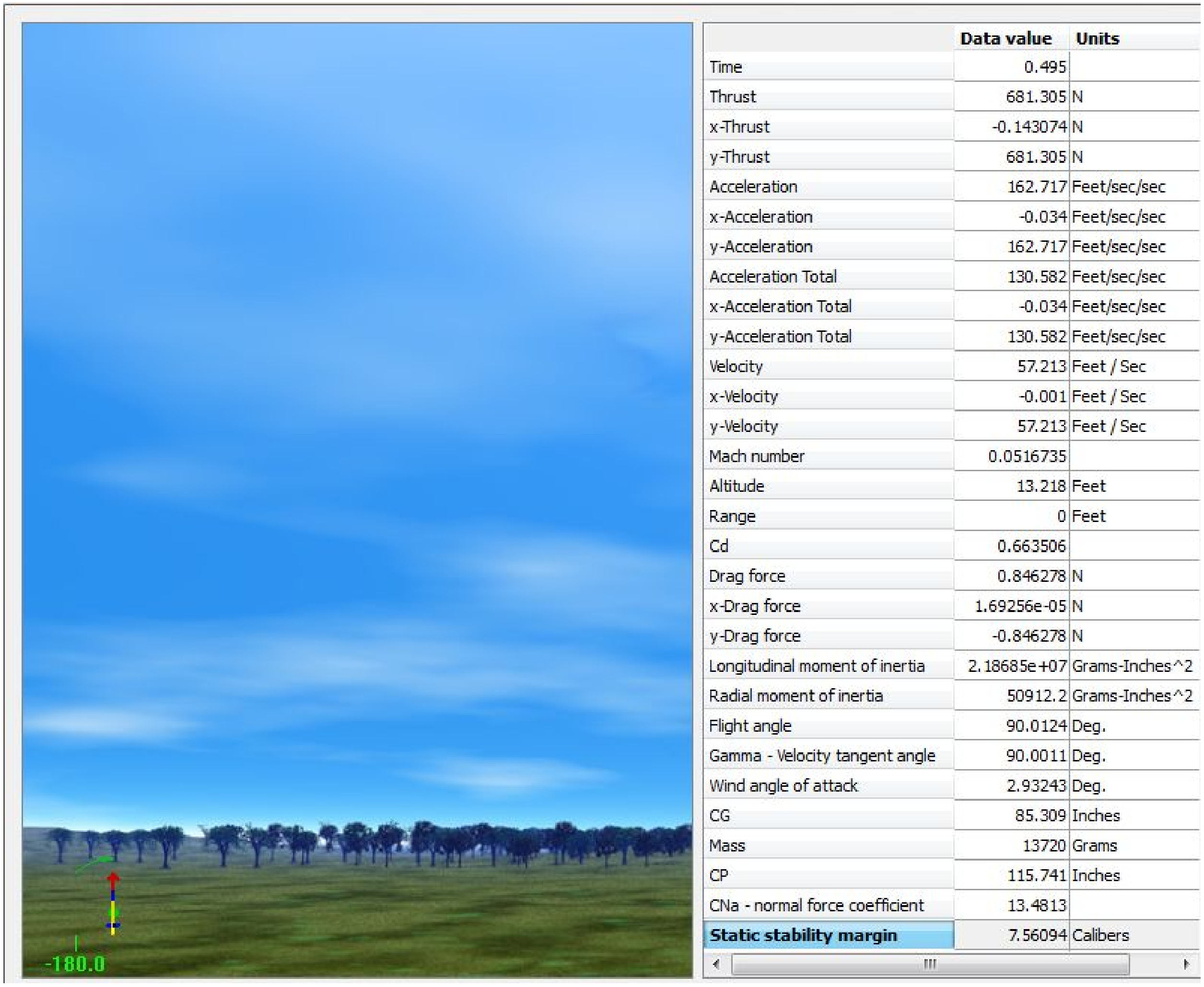
Fruity Chutes 18” Classic Elliptical Parachute

- Total weight upon descent: 28.36 lbs
- Descent rate: 96.77 fps

3.3 Mission Performance Predictions

3.3.1 Robustness of Vehicle

3.3.1.1 Flight Profile Simulations



	Data value	Units
Time	0.495	
Thrust	681.305	N
x-Thrust	-0.143074	N
y-Thrust	681.305	N
Acceleration	162.717	Feet/sec/sec
x-Acceleration	-0.034	Feet/sec/sec
y-Acceleration	162.717	Feet/sec/sec
Acceleration Total	130.582	Feet/sec/sec
x-Acceleration Total	-0.034	Feet/sec/sec
y-Acceleration Total	130.582	Feet/sec/sec
Velocity	57.213	Feet / Sec
x-Velocity	-0.001	Feet / Sec
y-Velocity	57.213	Feet / Sec
Mach number	0.0516735	
Altitude	13.218	Feet
Range	0	Feet
Cd	0.663506	
Drag force	0.846278	N
x-Drag force	1.69256e-05	N
y-Drag force	-0.846278	N
Longitudinal moment of inertia	2.18685e+07	Grams-Inches^2
Radial moment of inertia	50912.2	Grams-Inches^2
Flight angle	90.0124	Deg.
Gamma - Velocity tangent angle	90.0011	Deg.
Wind angle of attack	2.93243	Deg.
CG	85.309	Inches
Mass	13720	Grams
CP	115.741	Inches
CNa - normal force coefficient	13.4813	
Static stability margin	7.56094	Calibers

The rail exit stability margin has met the minimum 2.0.

3.3.1.2 Altitude Predictions with Simulated Vehicle Data

- Predicted altitude: 3878.71’
- Achieved altitude, as of March 4, 2018: 3730’

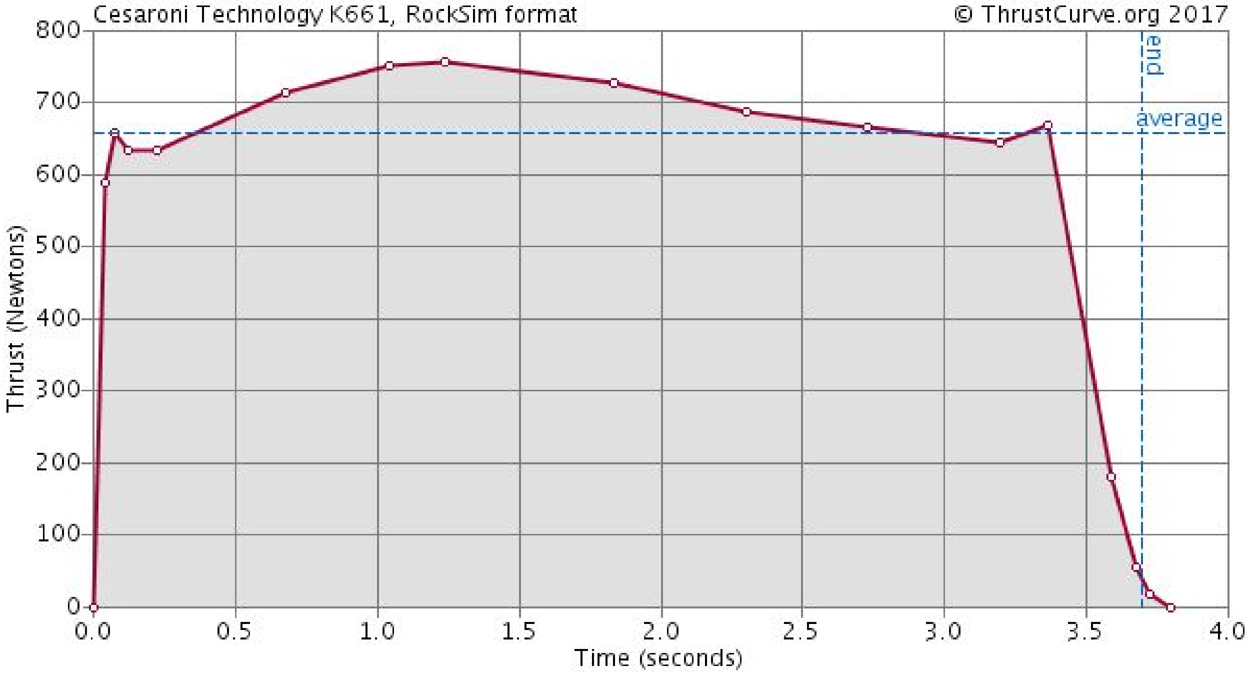
- Predicted coefficient of drag: 0.69
- Determined coefficient of drag: 0.61

3.3.1.3 Component Weights

IND SECT 1		
Nose Cone	560	g
Sabot housing	412	g
Sabot	705	g
Payload	900	g
Shock Cord	25	g
Total Mass	2602	g
Total Weight	5.73642124	lbs
IND SECT 2		
Payload Tube	988	g
Payload Coupler	512	g
Slingshot system	50	g
Total Mass	1550	g
Total Weight	3.417161	lbs
IND SECT 3		
Main Chute Tube	754	g
Avionics	1320	g
Drogue Chute Tube	342	
Drogue Chute + Harness	410	g
Main Chute + Harness	740	g
Charges	15	g
Total Mass	3581	g

Total Weight	7.89474422	lbs
IND SECT 4 Pre-Burnout		
Extension	630	g
Air Brakes	725	g
Booster	1912	g
Motor	2900	g
Total Mass	6167	g
Total Weight	13.59589154	lbs
Gross Liftoff Mass	13900	g
Gross Liftoff Weight	30.64	lbs

3.3.1.4 Simulated Motor Thrust Curve



Average Thrust: 641.6 N or 144.24 lbs

Also the first peak of this thrust curve

3.3.2 Stability Margin

CG: 85.9246 in from nose cone

CP: 116.4851 in from nose cone

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

$$=\ \frac{106.9598"-85.9246"}{4"}$$

$$=\ 5.23\ calibers$$

3.3.3 Kinetic Energy Calculations

3.3.3.1 With Drogue Chute Out

Section 1:

$$Kinetic\ energy\ =\ \frac{1}{2}mv^2$$

$$=\frac{1}{2}(5.74\ lbs)(95.1ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$

$$=806.1\ lbf$$

Section 2:

$$Kinetic\ energy\ =\ \frac{1}{2}mv^2$$

$$=\frac{1}{2}(3.42\ lbs)(95.1ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$

$$=480.29\ lbf$$

Section 3:

$$Kinetic\ energy\ =\ \frac{1}{2}mv^2$$

$$=\frac{1}{2}(7.89\ lbs)(95.1ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$

$$=1108.03\ lbf$$

Section 4:

$$Kinetic\ energy\ =\ \frac{1}{2}mv^2$$

$$=\frac{1}{2}(11.31\ lbs)(95.1ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$

$$=1588.32\ lbf$$

3.3.3.2 With Main Chute out:

Section 1:

$$Kinetic\ energy\ =\ \frac{1}{2}mv^2$$

$$=\frac{1}{2}(5.74\ lbs)(23.45ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$

$$=49.01\ lbf$$

Section 2:

$$Kinetic\ energy\ =\ \frac{1}{2}mv^2$$

$$=\frac{1}{2}(3.42\ lbs)(23.45ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$

$$= 29.2\ lbf$$

Section 3:

$$Kinetic\ energy\ =\ \frac{1}{2}mv^2$$
$$= \frac{1}{2}(7.89\ lbs)(23.45ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 67.37\ lbf$$

Section 4:

$$Kinetic\ energy\ =\ \frac{1}{2}mv^2$$
$$= \frac{1}{2}(11.31\ lbs)(23.45ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 96.57\ lbf$$

3.3.4 Drift Calculations

3.3.4.1 No Wind

Drogue

$$Drift = 47.3s \times (0)$$
$$= 0\ miles$$
$$= 0\ ft$$

Main

$$Drift = 29.7\ s \times (0)$$
$$= 0\ miles$$
$$= 0\ ft$$

3.3.4.2 5-mph Wind

Drogue

$$Drift = 47.3\ s \times (\frac{5\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds})$$
$$= 0.0657\ miles$$
$$= 347\ ft$$

Main

$$Drift = 29.7\ s \times (\frac{5\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds})$$
$$= 0.04125\ miles$$
$$= 218\ ft$$

3.3.4.3 10-mph Wind

Drogue

$$Drift = 47.3\ s \times (\frac{10\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds})$$
$$= 0.1314\ miles$$

$$= 694\,ft$$

Main

$$Drift = 29.7\ s \times \left(\frac{10\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds}\right)$$
$$= 0.0825\ miles$$
$$= 436\,ft$$

3.3.4.4 15-mph Wind

Drogue

$$Drift = 47.3\ s \times \left(\frac{15\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds}\right)$$
$$= 0.2102\ miles$$
$$= 1110\,ft$$

Main

$$Drift = 29.7\ s \times \left(\frac{15\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds}\right)$$
$$= 0.12375\ miles$$
$$= 653\,ft$$

3.3.4.5 20-mph Wind

Drogue

$$Drift = 47.3\ s \times \left(\frac{20\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds}\right)$$
$$= 0.2628\ miles$$
$$= 1388\,ft$$

Main

$$Drift = 29.7\ s \times \left(\frac{20\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds}\right)$$
$$= 0.165\ miles$$
$$= 871\,ft$$

3.3.5 Calculation Verifications

3.3.6 Differences in Calculations

3.3.7 Simulations

3.4 Full Scale Flight

The full demonstration of the full scale flight is here.

The flight took place on March 4, 2018.

3.4.1 Launch Day Conditions

3.4.1.1 Simulation with Launch Day Conditions

Altitude (ft)	44
Humidity (%)	15
Wind Speed (mph)	5-10
Latitude (°)	32.840
Temperature (°F)	77

- Altitude Achieved: 3734 ft
- Center of Gravity (in from nose cone): 87.1962”
- Center of Pressure (in from nose cone): 105.3845”

3.4.2 Analysis of Flight

3.4.2.1 Comparison of Predicted Flight Model to Actual Flight Data

Prior to the flight, we had originally estimated the gross liftoff mass to be 25.6 lbs, but we had underestimated that. It was actually 30.64 lbs.

We had also estimated the stability margin to be 7.46 calipers, but that was also inaccurate. The Center of Gravity was found to be close to the center of pressure than we had anticipated.

This threw off the thrust to weight ratio we had anticipated. Instead of a 5.65:1 ratio, we dealt with a 4.70:1 ratio instead.

3.4.2.2 Errors Between Predicted and Actual Flight Data

The calculated coefficient of drag with the design on RockSim was 0.69. This was not too far off from our empirically tested CD, which we found to be 0.61 after inputting the value into the simulation.

With the calculated CD, the simulation found the rocket could achieve a maximum altitude of 3853’. The maximum altitude with our empirical CD was 3734’, which is close to the apogee we obtained on March 4, 2018.

3.4.2.3 Estimated of Drag Coefficient

The calculated coefficent of drag is 0.61.
The CD we used to recreate the flight was 0.69.

3.4.2.3.1 Post Flight Simulation

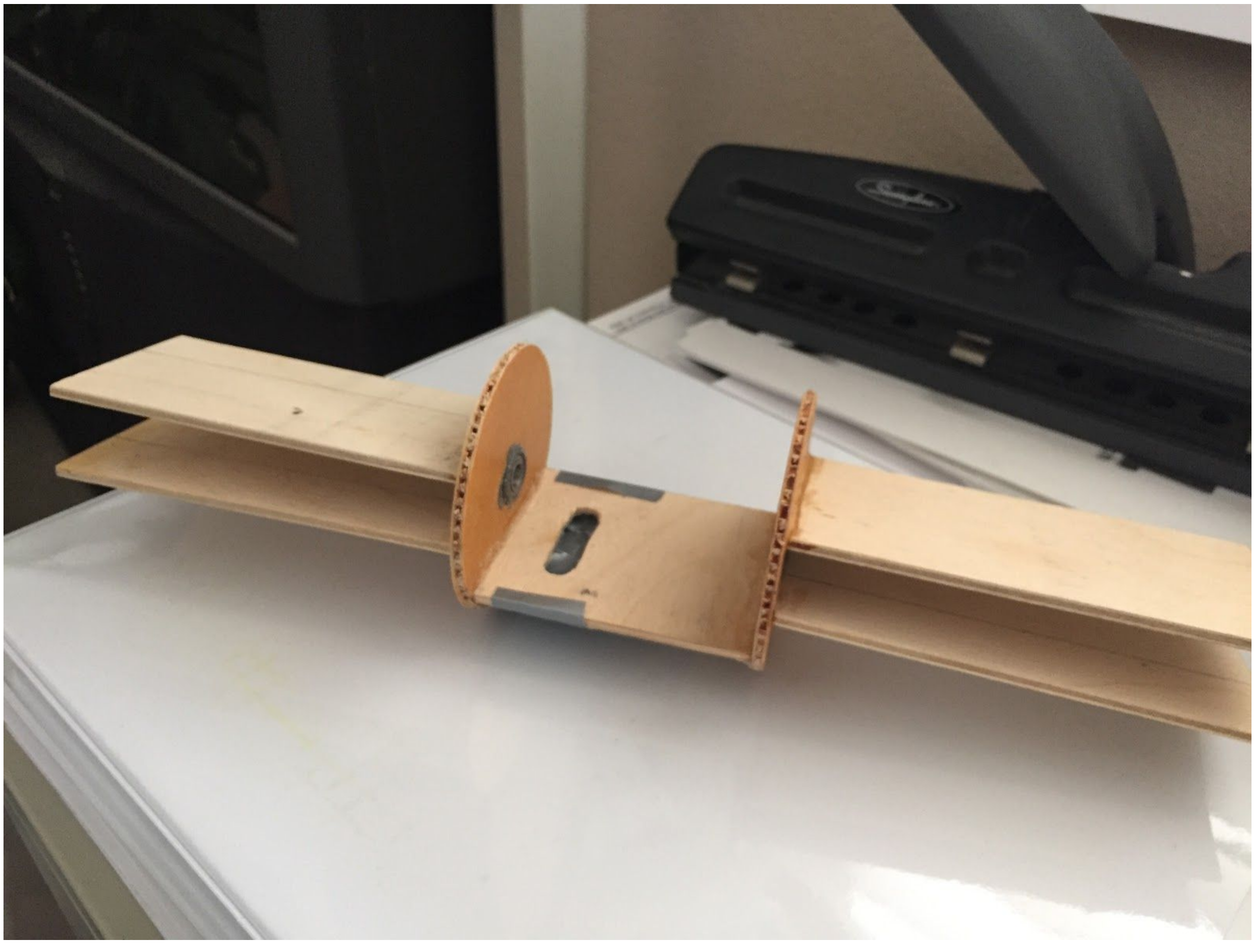
3.4.2.4 Similarities and Differences between Full Scale and SubScale Flight Results

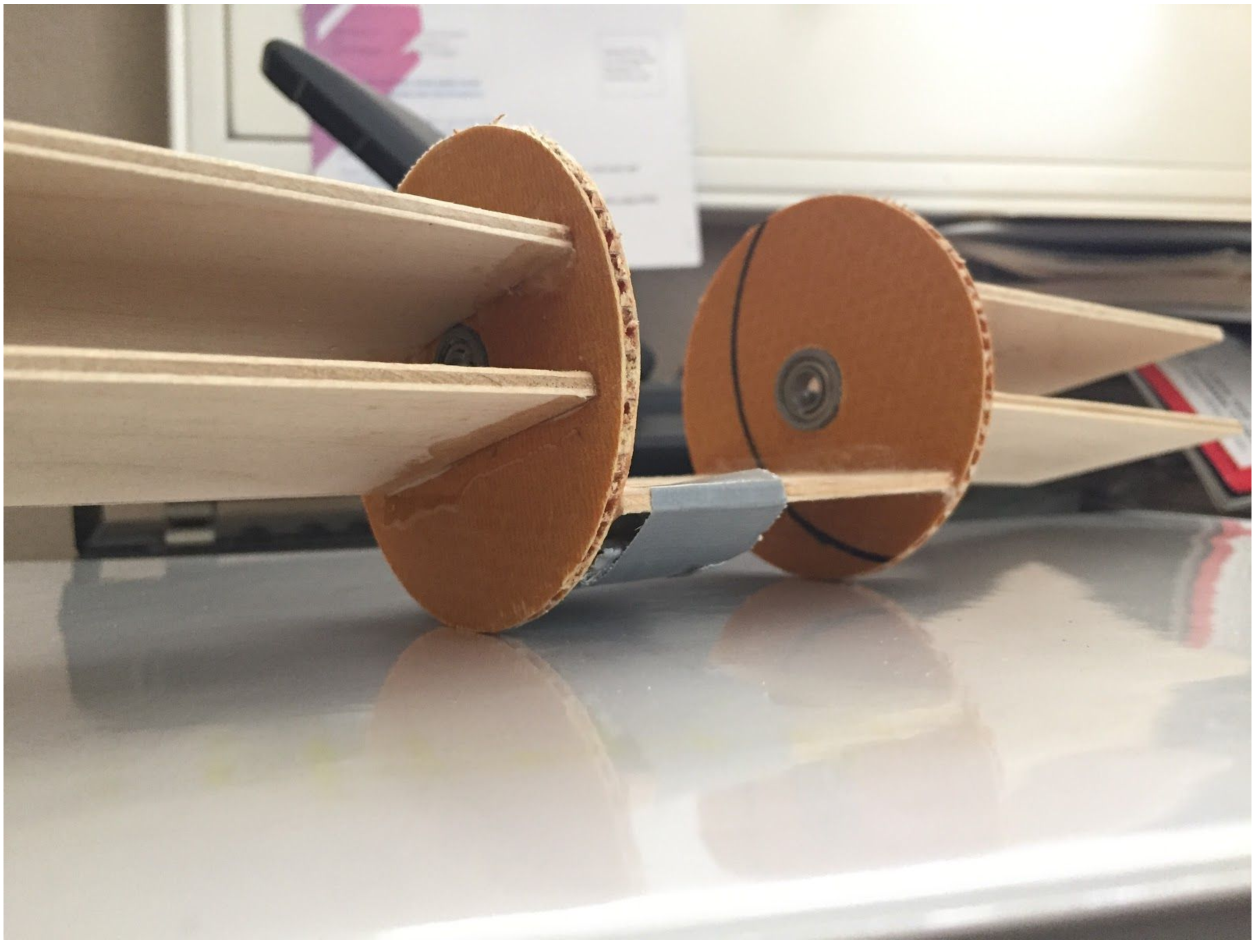
4 Payload Criteria

4.1 Payload Design

4.1.1 Changes in Payload Design

Addition of more detailed carriage





4.1.2 Payload Features

4.1.2.1 Structural Elements

- 6 mm x 5 mm 1000 mm carbon fiber rod
- 75-tooth gear
- 10000 Lift motor
- Precision bearings, with bore 0.250”
  - OD 0.625”, ID 0.4724”

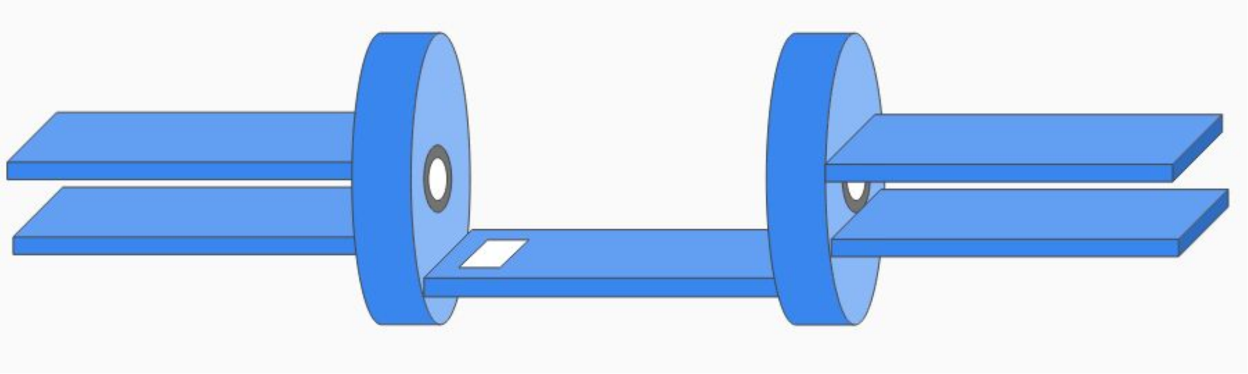
4.1.2.2 Electrical Elements

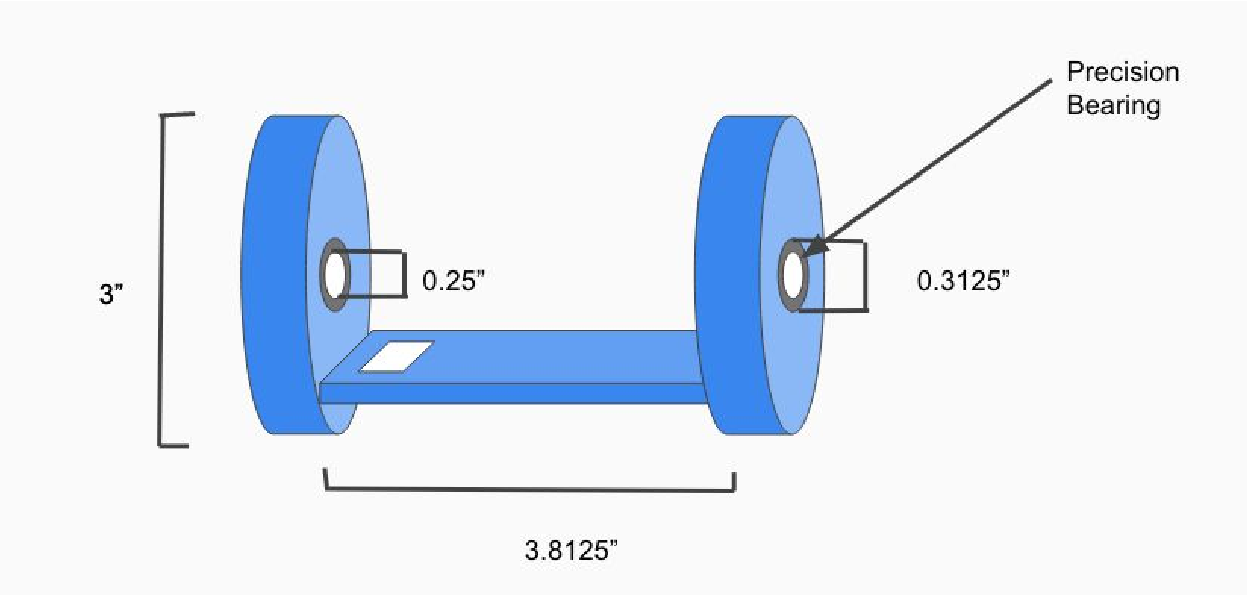
- Keyence A-07V Brushed Motor ESC W/reverse
- LiPo 7.4 V Battery
- DXe receiver
- DX8 receiver
- Arduino Mega
- LiPo Battery

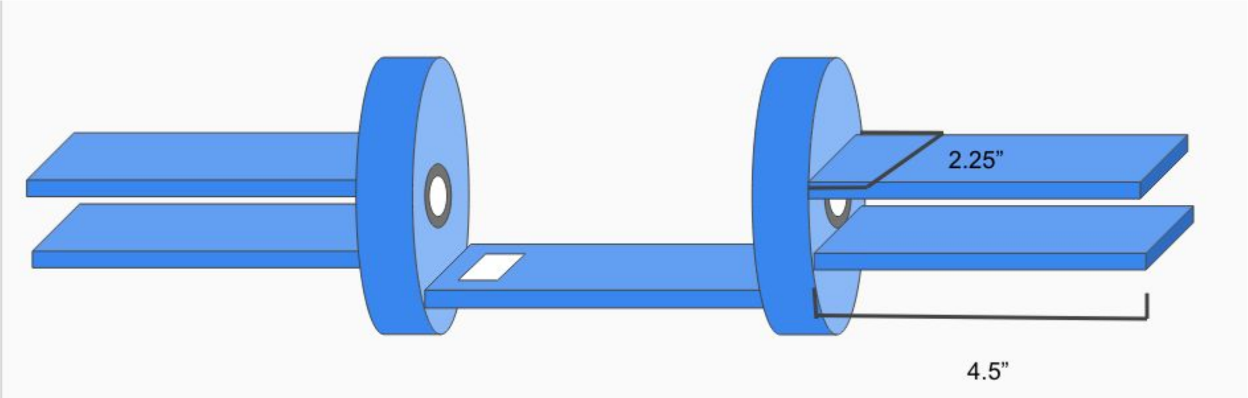
- 9V battery

4.1.2.3 Drawings and schematics

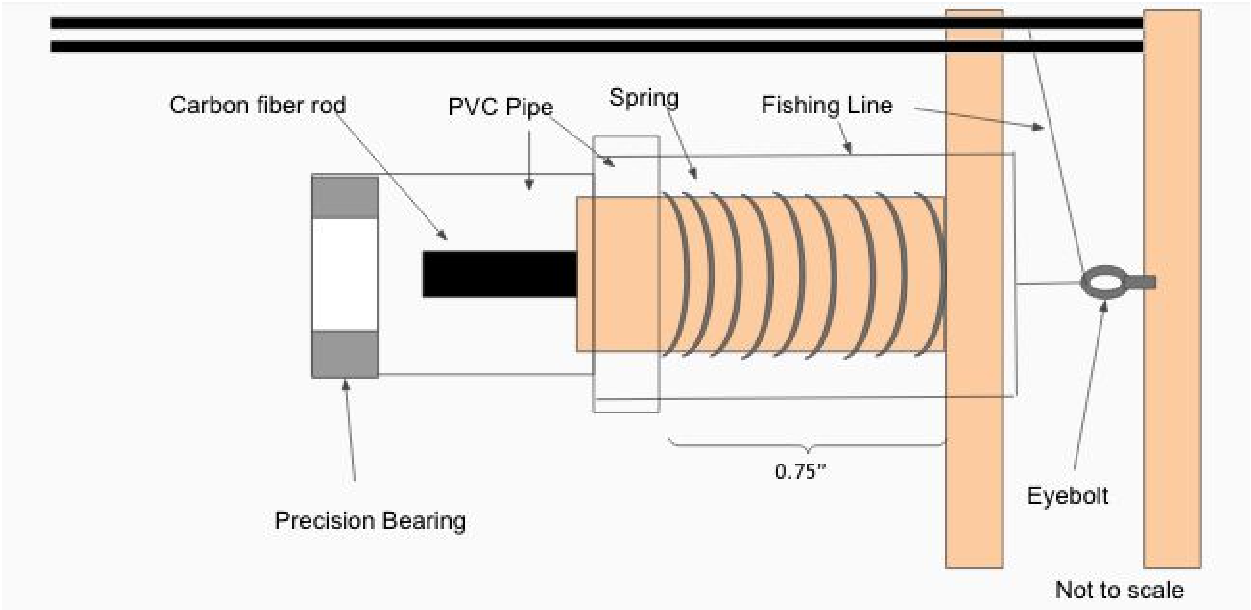
4.1.2.3.1 UAV

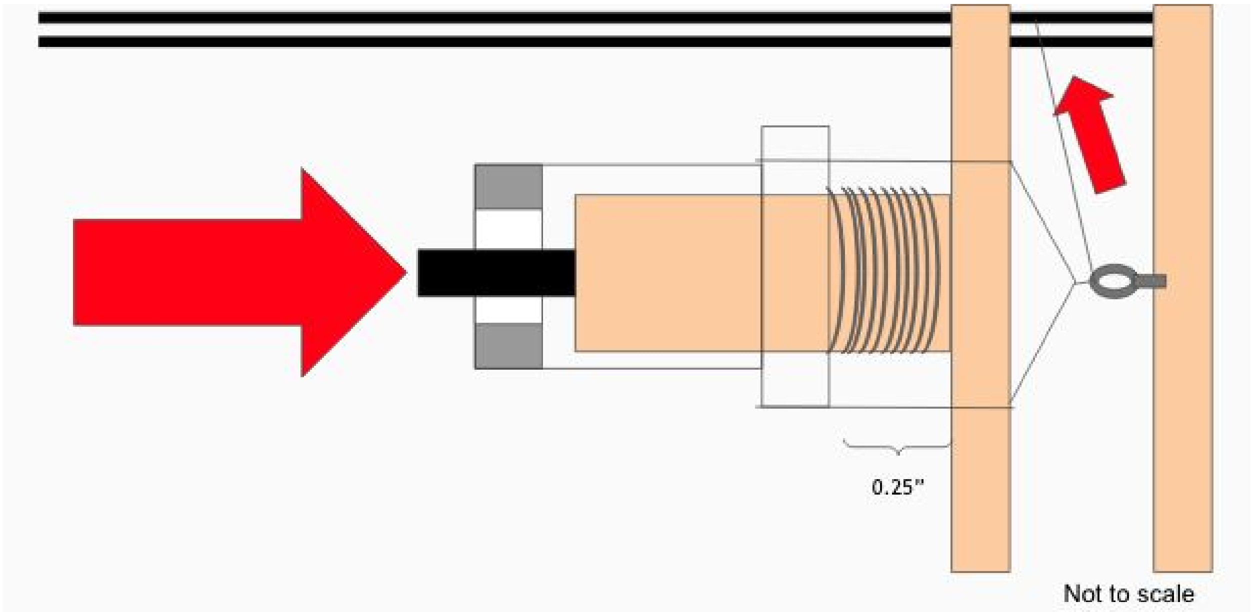






4.1.2.3.2 Sabot (UAV Release Mechanism)

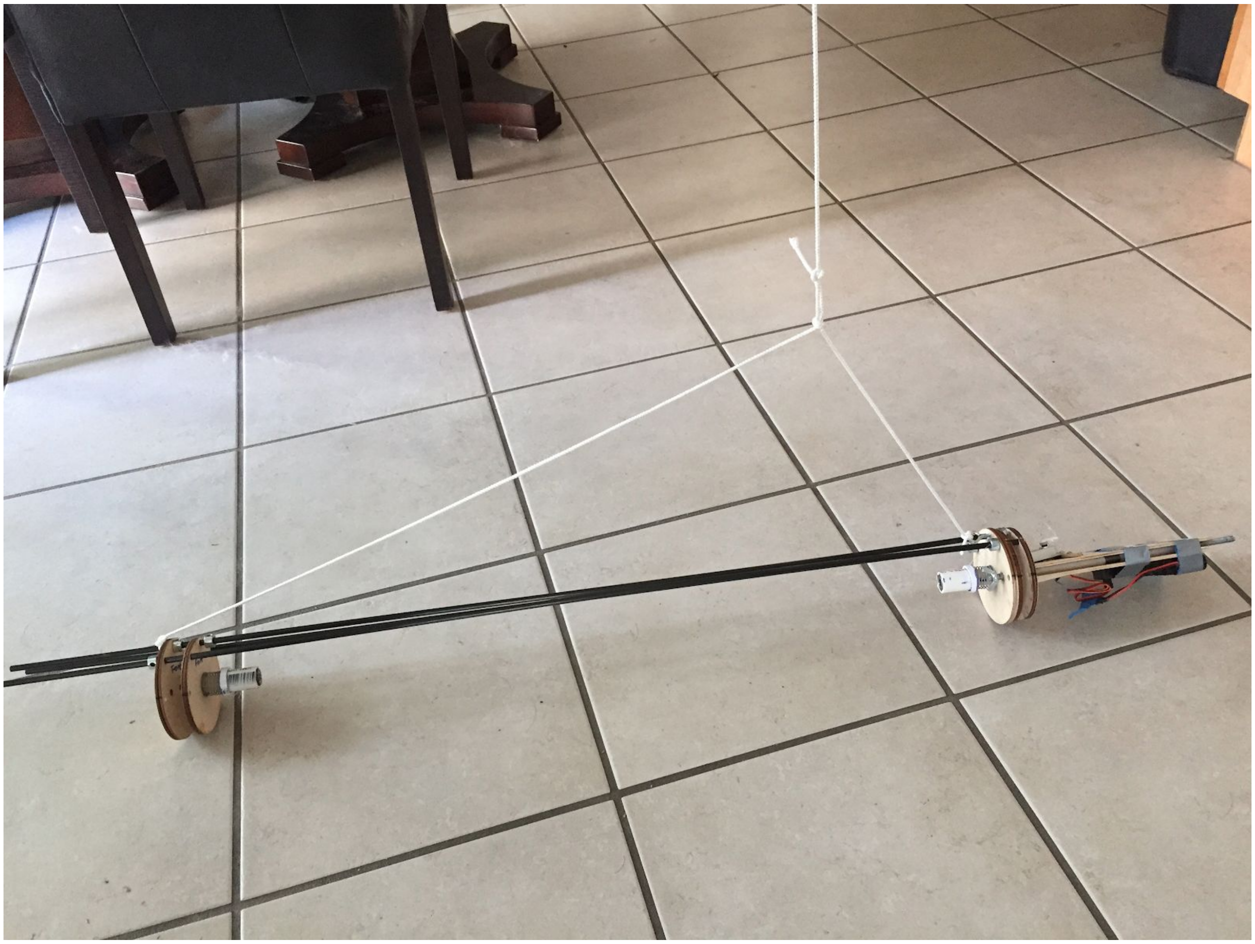




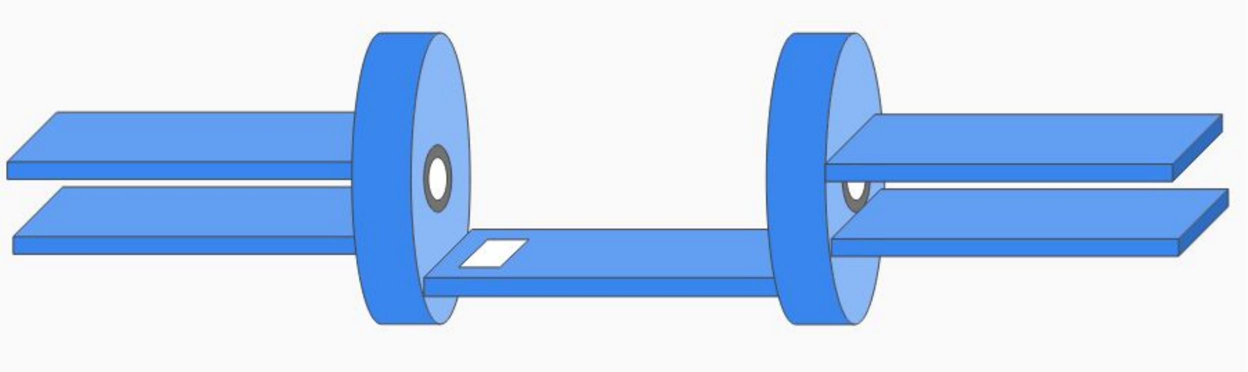
4.1.3 Flight Reliability Confidence

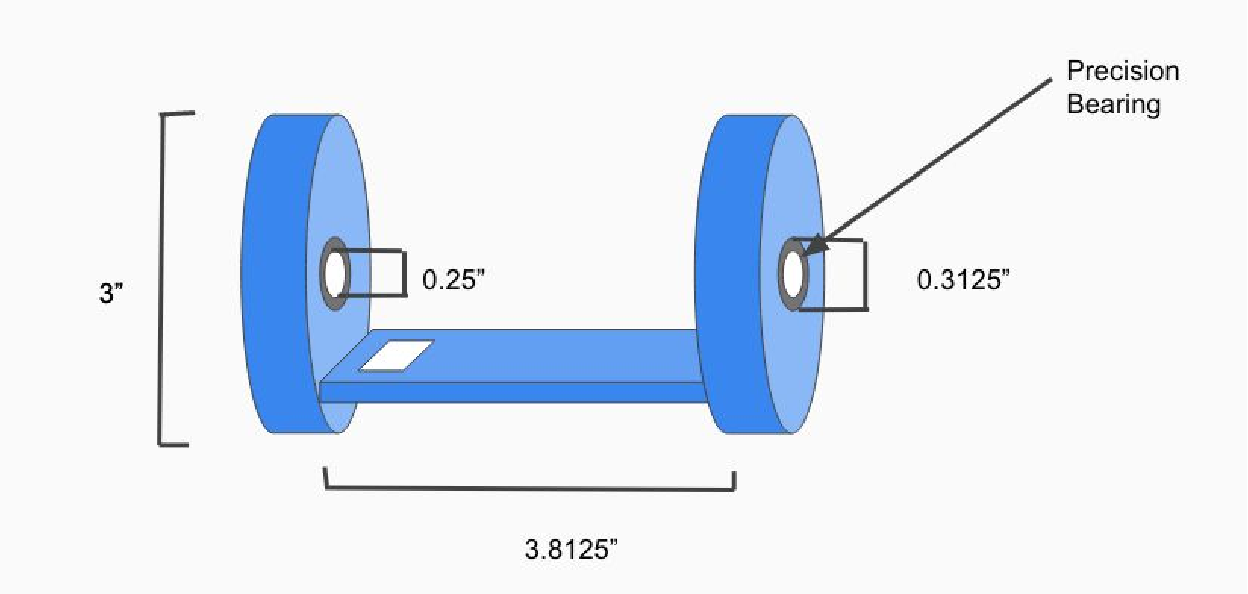
After our balloon test on March 11, 2018, we are not confident the Magnus effect UAV is ready for Huntsville at this time. Unless we further pursue the flyer and get it ready for a proposed reflight, on March 17, this UAV will remain grounded.

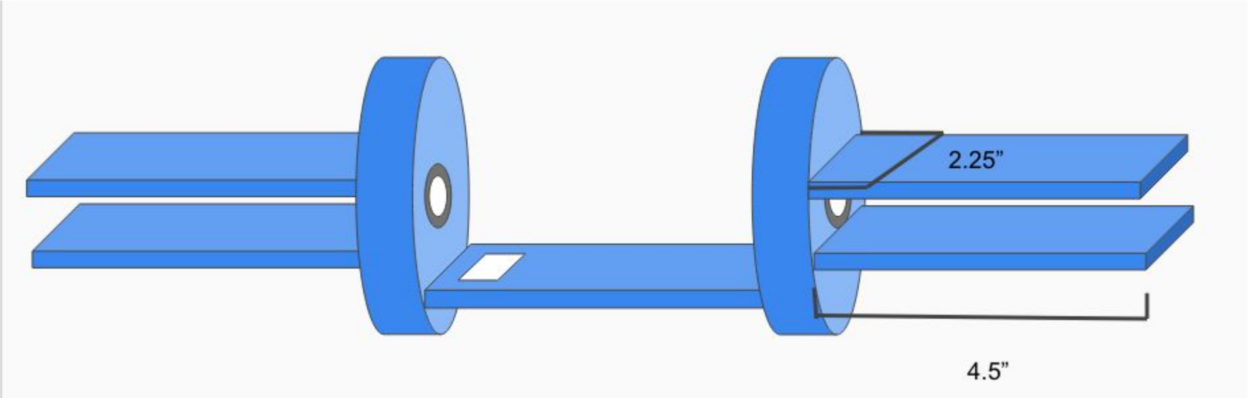
4.1.4 Payload Construction

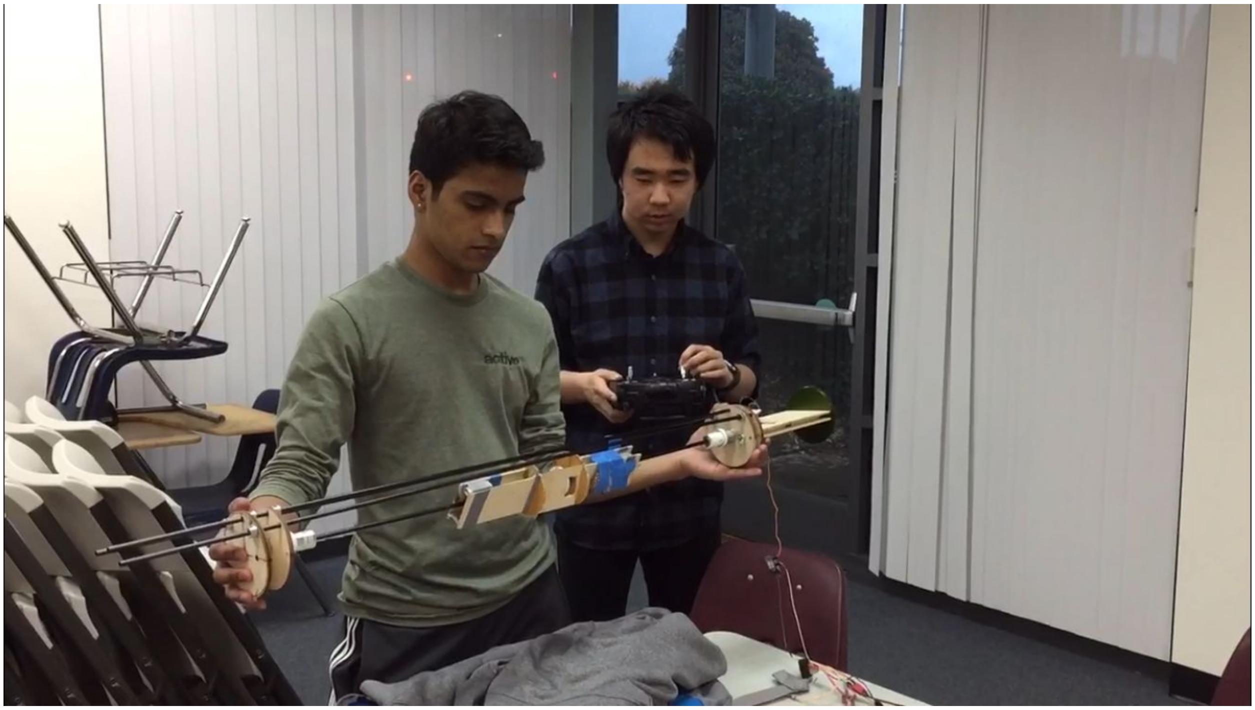


4.1.5 AS BUILT Payload Schematics

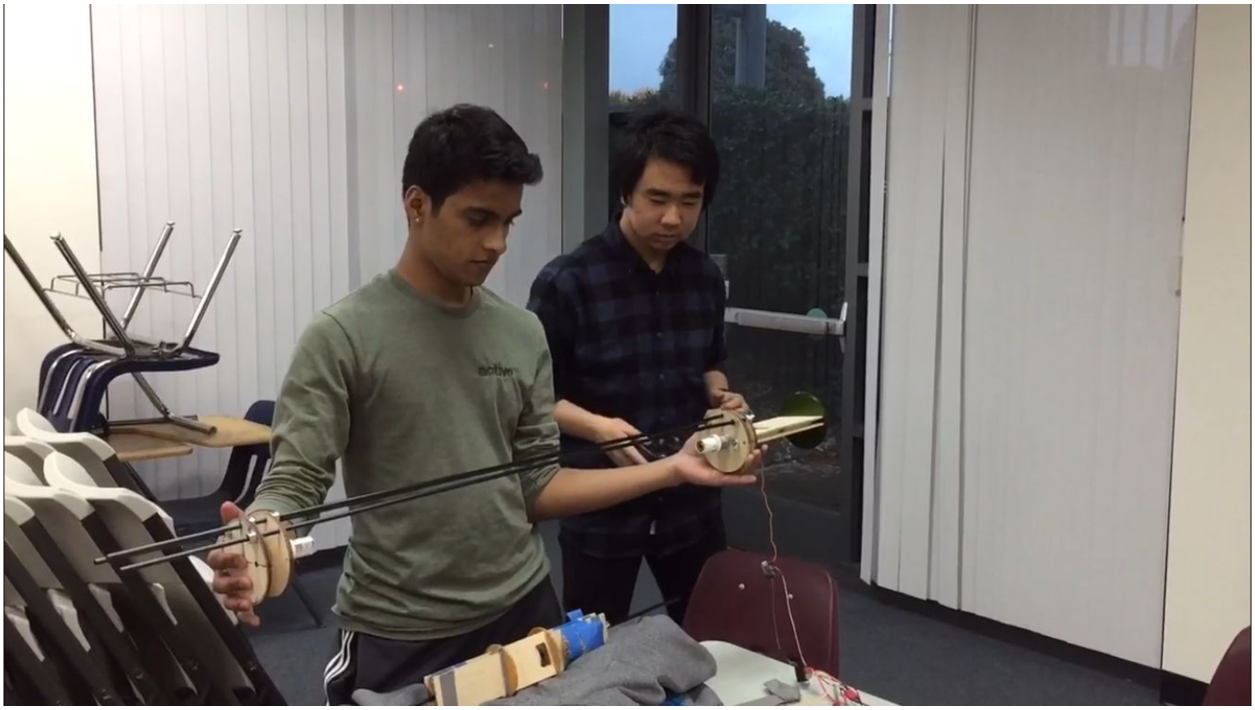



Precision Bearing
3"
0.25"
0.3125"
3.8125"


2.25"
4.5"



Before disengagement



After disengagement
See the video here.

5 Safety

5.1 Safety and Environment (Vehicle and Payload)

5.1.1 Personnel Hazard Analysis

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

5.1.1.1 Hazardous Materials Safety

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.

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
- 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 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.

5.1.1.2 Range Safety Officer (RSO) Duties

Based on the requirements set by the Statement of Work, Sahil, the RSO, must:

- Monitor team activities with an emphasis on Safety during:
    - Design of vehicle and launcher
    - Construction of vehicle and launcher
    - Assembly of vehicle and launcher
    - Ground testing of vehicle and launcher
    - Sub-scale launch test(s)
    - Full-scale launch test(s)
    - Launch day
    - Recovery activities
    - Educational Engagement Activities
    - Implement procedures developed by the team for construction, assembly, launch, and recovery activities
    - Manage and maintain current revisions of the team’s hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data
    - Assist in the writing and development of the team’s hazard analyses, failure modes analyses, and procedures.

5.1.2 Failure Modes and Effects Analysis

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	Experiment cannot be	5	Wiring is incorrect. Battery	1	A checklist will be followed during construction and

during the launch after it is deployed..	conducted. Sparking could occur within the payload.		was not activated, or no connection in the payload circuitry.		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 constructed properly (Right length is not cut, epoxy is not well applied, screws are not screwed in properly, electronics are not wired correctly, etc.).	When launched, inconsistent flights could take place, rocket electronics will not function properly, and rocket could combust.	7	Team members are not paying attention and giving close detail during the construction process. Team members are unclear of proper process of construction or the putting together of the rocket.	2	Checklists will be made and each team member working on a certain part of the rocket will be checked by another member to ensure safety and proper execution.

5.1.3 Environmental Hazard Analysis

6 Launch Operations Procedures

6.1 Recovery Preparation

6.2 Motor Preparation

- Attach the 2-grain hardware on the motor
- Apply grease to motor prior to fixture in casing
- Secure tightly with the motor retainer

6.2.1 Warnings and Hazards

- Do not take out the smoking agent
- Only remove the black powder in the ejection charge to prevent against an explosion in the motor tube

6.2.2 PPE

- Gloves
- Safety googles

6.2.3 Required Personnel

- NAR Level 2 personnel, at minimum - Robert Koepke

6.3 Setup on Launcher

6.3.1 Warnings and Hazards

6.3.2 PPE

6.3.3 Required Personnel

- Other teammates
- NAR Level 2 Personnel, at minimum

6.4 Igniter Installation

6.4.1 Warnings and Hazards

- Short the leads whenever possible

6.4.2 PPE

6.4.3 Required Personnel

6.5 Launch Procedure

6.5.1 Warnings and Hazards

- Ensure countdown
- Be at least 250’ away from the launchpad
- Check for nearby aircraft, people in the range

6.5.2 PPE

N/A

6.5.3 Required Personnel

6.6 Troubleshooting

6.6.1 Warnings and Hazards

6.6.2 PPE

6.6.3 Required Personnel

6.7 Post-Flight Inspection

6.7.1 Warnings and Hazards

6.7.2 PPE

6.7.3 Required Personnel

7 Project Plan

7.1 Testing

7.1.1 UAV’s Lift Testing

7.1.1.1.1 Test Methodology

The payload is made of the UAV and the sabot. We will attach the UAV and sabot to a weather balloon filled with helium and let it ascend to about 400’ before we remotely release the UAV from the sabot. This test will serve as a test of the UAV’s controlled descent.

7.1.1.1.2 Proof of Completion of Testing

We will include video and photo evidence for the documentation of this test here.

7.1.1.1.3 Criteria for Test

7.1.1.1.3.3 Controlled Deployment

The UAV must fall flat, and the sabot must have a simultaneous release.

7.1.1.1.3.2 Controlled Descent

The UAV must fall no faster than 17 ft/s. The goal is to lengthen the UAV's flight time, which would be indicative of the presence of dynamic lift.

7.1.1.1.3.3 Reusability

The UAV must not sustain damage from the test.

7.1.1.2 Test Results

7.1.1.2.1 Test Successfulness

The UAV fell straight down.

7.1.1.2.2 Lessons Learned from Test

- Allot more time to the UAV's development
- Plan ahead for more realistic mass of UAV
- Don't secure everything with duct tape
- Ensure contact with the gears to maintain axle's rotation

7.1.1.2.3 Differences Between Predicted and Actual Results of the Test

7.1.2 Recovery Testing

7.1.2.1.1 Test Methodology

The rocket will be prepared with the necessary parachutes wrapped in blast cloth. The rocket and avionics will be stored, sans flight computers, and remotely detonated with a 9 V battery. The rocket is typically pointed at an angle so that the rest of the rocket body can travel in the air in projectile motion.

7.1.2.1.2 Proof of Completion and Testing

Video of the main chute deployment is here.
Video of the drogue chute deployment is here.

7.1.2.1.3 Criteria for Test

The parachute must escape out of its tube, and the ejected body must travel the whole length of the shock cord. In other words, the shock cord must be fully extended after the detonation.

7.1.2.2 Test Results

7.1.2.2.1 Test Successfulness

The tests were successful, as shown by the video.

7.1.2.2.2 Lessons Learned from Test

The recovery still works, but testing was still necessary to affirm this.

7.2 Requirements Compliance

7.2.1 Verification Plans

7.2.1.1 General Verification Plan

7.2.1.2 Vehicle Verification Plan

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

7.2.1.3 Recovery 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.

7.2.1.4 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.

7.2.1.5 Safety Verification Plan

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

7.2.2 Team Derived Requirements

7.2.2.1 Vehicle Requirements

A successful mission is determined by the vehicle’s success in the following areas : data collected, ascent, altitude reached, descent. If the payload establishes some sort of trend between altitude and carbon dioxide levels and reads a three digit number, preferably near 350 ppm, which is the safe level of carbon dioxide in the atmosphere, the mission is a success in this aspect. If the rocket achieves a minimum velocity of 52 feet/s, achieves a static stability margin of 2.0 at rail exit, does not utilize a motor that exceeds 2560 Newton-seconds, and safely ascends to one mile, then the mission is a success in this aspect. If the rocket safely descends with a maximum kinetic energy of 75 ft-lbf, returns data from the payload, and can be reused again, then the mission is a success in this aspect.
To go outside of the handbook’s requirements, the rocket must land within a 1 mile radius of the launchpad and must utilize its air brakes to increase drag and achieve or almost achieve its target altitude of one mile.

7.2.2.2 Payload Requirements

7.2.2.3 Recovery Requirements

7.2.2.4 Safety Requirements

7.2.2.5 General Requirements

Teamwork Dynamics

Risk	Mitigation
Consecutive long work days	Update the Gantt chart frequently, schedule hourly breaks
Uneven distribution of work	Update the Gantt chart frequently

Avionics bay not assembled in time	Give the person in charge of avionics (Kush) more time to practice

Rocket Construction

Risk	Mitigation
Finding the right parachutes	Simulate, calculate drift and kinetic energy, and fit the parachutes and their respective shock cords
Finding the right way to mount masses	Use zipties and duct tape, cut boards
Couplers that are too short or do not have enough body tube length	All tube couplers should be halfway inside. For the full scale, tube couplers must be a minimum of 3” inside a body tube. For the subscale, tube couplers must be a minimum of 2.5” inside a subscale rocket body tube and 3” inside a full-scale rocket body tube
Metal screws tearing	Screw in more delicately, designate a few people to use screws

Other team dynamics goals:

- Develop clear goals for each day we meet
- Present individual roles and progress to the team
    - I.e. inform them on how to make the avionics work
- Bring plenty of shock cord to launches
- Figure out how to pack shock cord better
- Fill old holes with epoxy and then drill new ones
- Develop checklists in the event the person in charge of a specific aspect is unable to come to an event
- Stay focused while building. Don’t get distracted by animals
    - DO NOT engage Parbo the Macaw. Except for spraying.
- Schedule hourly break times

7.3 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*	
Body Tubes and Bulkheads	$134.69	1	$134.69	
Cesaroni J210	$68.00	2	$136.00	
Total Scale Vehicle Cost				$270.69
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*	
Body Tube and Bulkhed	$144.39	1	$144.39	
Eyebolts	$80.78	1	$80.78	
4" Coupler Bulkhead		4	$21.81	
Launch Rail	$29.63	1	$29.63	
Tape Measure/Tweezers	$28.47	1	$28.47	
Cesaroni K2661	$133.00	2	$301.00	$35 shipping
Total Vehicle Cost				$696
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*	
Locing Connectors, Housing Kit, Shunts, Heat Shrink Tubing	$42.47	1	$42.47	
100 3mm Led Lights	$3.99	1	$3.99	
Voltage Regulator	$5.03	1	$5.03	
Capacitors, Cables, Breadboard Diode	$11.67	1	$11.67	
Total Recovery Cost				$63.16
Payload				
Arduino Uno kit (includes LED, resistors, regulators, etc)	$35.00	1	$0.00*	
SD card + Adapter + Teensies + Headers	$102.09	1	$102.09	
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	
Gimbal	$11.68	2	$23.36	
Adafruit Battery	$6.40 for 10	10	$6.40	
Arduino Mega	$44.95	1	$44.95	

Carbon Fiber Round Tubes (6mm x 5mm 1000mm)	$27.44	1	$27.44	
two-chanel Transceiver and Receiver	$120.00	1	$120.00	
40PCS Dupont 10cm Male to Female Jumper Wire	$1.24	1	$1.24	
HP-PRO Short-167 Low-Profie HV Digital Servo	$67.99	1	$67.99	
Gears/Rod/Bearing/Fasteners/Fishing Lines	$129.36	1	$129.36	
Stretching Band	$7.53	1	$7.53	
Resistance Rubber Loop Bands	$14.00	1	$14.00	
Linear Actuator 30 mm 50-6	$228.61	1	$228.61	Express Shipping
Motors - 10000 RPM	$11.92	1	$11.92	
3.7" Body Tube	$11.00	2	$36.88	14.88 Shipping
KST x 12-508 Micro Corelss HV Servo	$68.48	1	$68.48	
Transmitters and Receivers - Argent	$181.07	1	$181.07	
100 pack 4.7K ohm 1/4W Metal Film Resistor	$2.29	1	$2.29	
Standoff Spacer for PCB	$24.17	1	$24.17	
Swivel Pulleys	$18.30	1	$18.30	
Double Indulator Single Row Header Strip	$9.98	1	$9.98	
5 mm Drill Bit	$9.97	1	$9.97	
Solder Wire	$14.99	1	$14.99	
18 AWG Cables	$10.98	1	$10.98	

Heat Gun/Super Lube/Laminator	$52.03	1	$52.03	
Weather Balloon	$28.45	1	$28.45	
Total Payload Cost				$1,260.54
GPS System				
Whistle GPS Dog Tracker Kit	$75.00	1	$0.00*	
Whistle Monthly Charge-Jan	$9.95	1	$9.95	
Whistle Monthly Charge- Feb	$9.95	1	$9.95	
Cellular Service Fee (3 months free, 5 months to pay)	$40.00	1	$40.00	
Total GPS Cost				$59.90
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	6	$1,992.00	
Food (2 meals a day, 6 days)	$10.00	728	$720.00	
Hotel (2 people per room, 6 days)	$120.00	18	$2,160.00	
El Centro Hotel	$99.18	7	$694.26	
Total Travel Cost (Estimated)				$5,566.26
Total Estimated Project Expenses				$8,086.63

7.4 Timeline

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

Appendix A: Statement of Works

No.	Requirement in SOW	CDR 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 post and make available for download, the required deliverables to the team Web site by the due dates specified in the project timeline.	
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) Subpart B-Technical Standards (http://www.section507.gov): ● 1194.21 Software applications and operating systems	

	● 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.	
2.1	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.	
3.1	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.	
4.1	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.	
5.1	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 FRR

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.

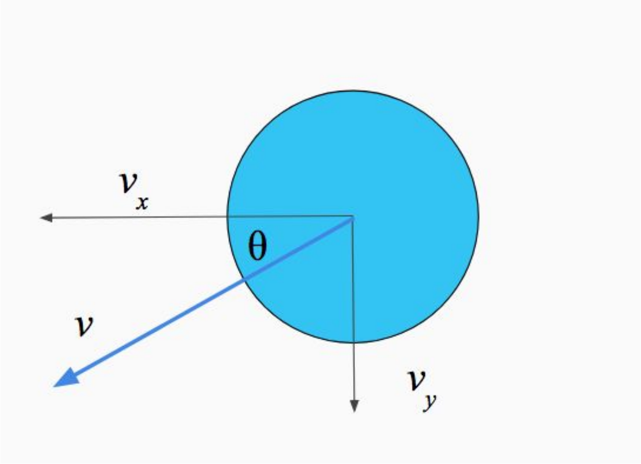
Mike Stoop (Fiberglassing, Programming, Design)
Mike Stoop is currently the CTO of PriceDoc, Inc, a healthcare related web services company. Mike has been in the software industry for 30 years and an avid rocketeer for 40 years. Mike achieved his level 3 certification in 2002 and has participated in 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.

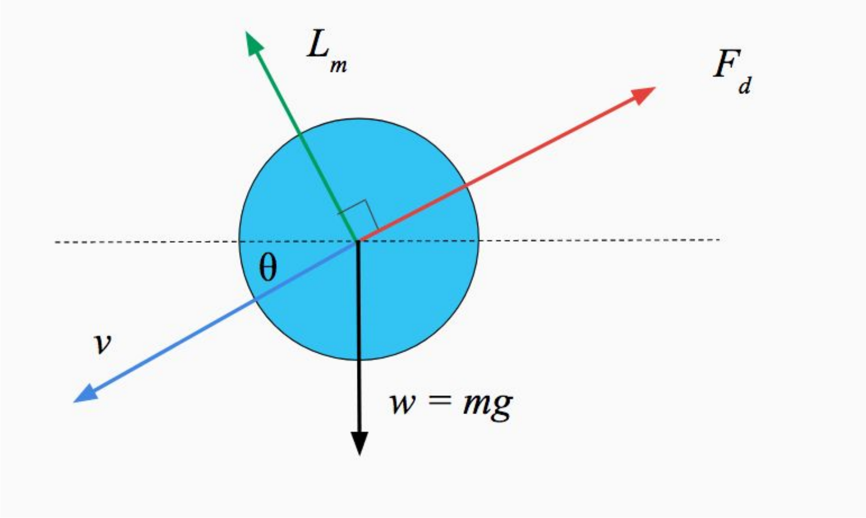
Drew, SpaceX (Fiberglassing, Programming, Design)
Mr. Drew Beckett holds BS and MS degrees in aerospace engineering from the Dwight Look College of Engineering at Texas A&M University at College Station. Mr. Beckett developed and operated unmanned aircraft technology demonstrators for the Texas A&M Flight 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.

Matt Kuhn (Mechanical Engineer)
Matt has a MS in Mechanical Engineering from CMU and a MS in Aerospace Systems Engineering from UAH. He worked on the Space Launch System and the 777X propulsion systems as a fuel analyst. He currently works as a service engineer on the 787 program. Matt's father purchased Matt his first rocket for his 10th birthday. After building and launching that

initial rocket, he has run with propulsion systems and never looked back. He is currently active in after school STEM volunteering.

Appendix D: Determination of Magnus Effect





Lift of Rotating Cylinder:Kutta-Joukowski Lift Theorem

$$L = \rho G V$$
$$G = 2\pi b V_r$$
$$V_r = 2\pi b s$$

Sum of Y Forces

$$\sum F_y = L_m \cos\theta + F_d \sin\theta - mg$$
$$mg = L_m \cos\theta + F_d \sin\theta$$

Magnus Force Calculation

$$\frac{L_m}{L} = \rho G V$$
$$L_m = \rho G V L$$

$L_m = \rho(2\pi b V_r) V L$
$L_m = \rho(2\pi r[2\pi r\omega]) V L$
$L_m = \rho(4\pi^2 \omega r^2) V L$
$L_m = \rho 4\pi^2 \omega r^2 V L$

Force of Drag Calculation
$A = 2rL$
$F_d = \frac{1}{2}\rho V^2 c_d A$
$F_d = 2\rho r L V^2 c_d$

Governing Equation
$mg = L_m \ \cos\theta + F_d \sin\theta$
$L_m = \rho 4\pi^2 \omega r^2 V L$
$F_d = 2\rho r L V^2 c_d$
$mp = (\rho 4\pi^2 \omega r^2 V L)\cos\theta + (2\rho r L V^2 c_d)\sin\theta$
$m = \frac{2\rho L r V}{g}[2\pi^2 \omega r * \cos\theta + V c_d * \sin\theta]$

Appendix E: Flight Diagram