Student Launch Preliminary Design Review (PDR)

Carbon Dioxide Analysis in Troposphere with Autonomous Air Brakes

Mailing Address:
15 Wyoming
Irvine, CA 92606

AIAA OC Section

11/4/2016

Contents

1 Summary of PDR Report

1.1 Team Summary

1.1.1 Team Name and Mailing Address

The team name is AIAA OC Section. The mailing address is:

15 Wyoming
Irvine, CA 92606

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

Robert has been co-leading TARC teams for eight years and a part of the STEM outreach for AIAA for seven years. He has a BS degree in Electrical Engineering from USC and has worked as an electronics designer, programmer, and now the manager of the software department for Honeywell. 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 and Indian Princesses and Indian Guides.

1.1.2.2 Jann Koepke (Artist, Mom, Level 1 NAR)

Jann has been co-leading TARC teams for eight 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 also led 4H projects in livestock including lambs, goats, and beef.

1.2 Launch Vehicle Summary

- Length - 77.5 in
- Diameter - 4 in
- Semi Span of Fins - 3.25 in
- Total Mass - 9486.096 g
- Motor Choice - Cesaroni K661

- Recovery System -The recovery electronics will be in the avionics bay, a 10.2” tube coupler with a 1” band made of fiberglass body (4” diameter) tube to separate the upper and middle body tubes. It is a redundant dual deploy system with an 84” main parachute and 18” drogue parachute.
- The Milestone Review Flysheet provides further specifics and is available here.

1.3 K30 CO_2 Sensor Summary

Our payload, the K30 CO_2 sensor, has the sole purpose of collecting carbon dioxide samples from different altitudes. Our scientific experiment is to test the effect of altitude on carbon dioxide levels, hoping to find a strong correlation and regression (exponential, linear, or parabolic) within the explanatory and response variables. Our goal is to establish some sort of trend between the two variables, so it therefore follows that a successful experiment constitutes of a well defined correlation between altitude and carbon dioxide levels.

2.1 Changes to Vehicle Criteria

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

2.1.1 Dimensions

- Length adjusted from 91.75” to 77.50” to improve stability margin
- Overall mass reduced, from 9975.619 g to 9486.096 g; was a result of taking in more realistic masses
- Less room for servo rotation to move center of gravity toward fin area of rocket to improve stability margin, had to shorten rocket as a whole, , still operational to be effective
- Length of airbrakes enlarged from 5” to 6” to increase the drag and be more effective in meeting target altitude
- Payload mass reduced from 500 g to 189.2 g; more realistic as a result of more details factored into design
- Stability margin on launchpad reduced from 2.716 calibers to 1.717 calibers; See reason for below change
- Stability margin at rail exit reduced from 3.066 calibers to 2.033 calibers to meet section 1.15 in the Statement of Work (“The launch vehicle shall have a static stability margin of 2.0 at the point of rail exit.”)
- Semi span of fins cut from 4.5” to 3.25” to move center of pressure up to improve static stability margin

2.1.2 Recovery

- Parachute changed from 108” diameter to 84” diameter; change was result of mass reduction, so larger parachute no longer needed
- Mass of recovery electronics changed from 1000 g to 98 g
    - Needed more realistic mass of recovery electronics in avionics bay
- Drogue parachute is above the main parachute
    - Needed to move center of gravity down to improve stability margin, switched parachute positions
- Three, not four, independent sections tethered together after ejection

- Four would have required another tube coupler in upper body tube, needed to move center of gravity down to improve stability margin

2.1.3 Mass Placements

- GPS moved further down nose cone, from 6.625” to 4” shoulder
  - Needed to save space and shorten rocket, placing GPS around same area as payload more effective use of space
- Payload mounted on 3.9” x 10” board, placed 5” inside nose cone
  - Needed to shorten rocket, placed part of payload into nose cone as effective use of space
- 785 g added in back of rocket
  - Needed to move center of gravity down

2.1.4 Motor

- Changed motor from Aerotech K560W to Cesaroni K661
  - K661 had “spike” in thrust curve, improved stability of rocket overall and still within reasonable error of target altitude for air brakes to be effective

2.2 Changes made to payload criteria

The payload was originally estimated to be 500 g, but now it is 149.2 g. It will be attached to a 40 g wooden circuit board.
We changed our original power source from a Lithium Polymer battery to a 9 Volt battery.
There were no other changes.

2.3 Changes to Project Plan

2.3.1 Budget

We edited the following on our budget sheet:

Removed extended costs because it was unclear
Added a comments section for any notes
Added quantity column to avoid writing numbers in descriptions
Renamed “extended costs” to “subtotal” to make things more clear

2.3.2 Timeline

We added dates for purchasing parts, educational engagement events, test days, and milestones for the timeline and readjusted other dates if they were unrealistic or inaccurate.

3 Vehicle Criteria

3.1 Selection, Design, and Rationale of Launch Vehicle

3.1.1 Mission Statement

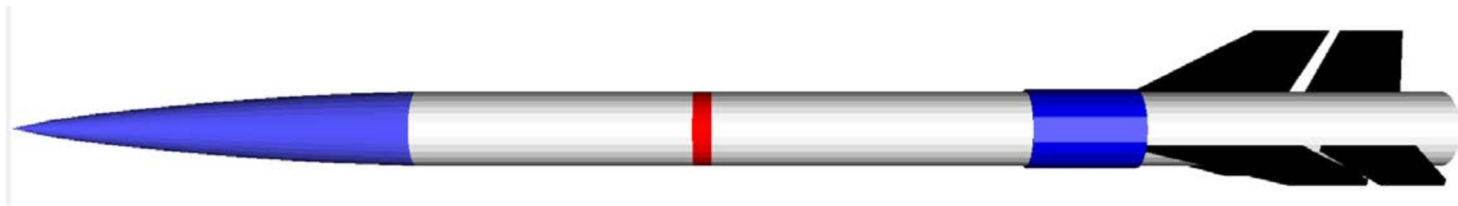
The AIAA OC Section team will construct a rocket that controls its ascent with air brakes to collect data on carbon dioxide levels one mile into the troposphere down to the lithosphere.

3.1.2 Mission Success Criteria

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 utilizes its air brakes to increase drag and achieve its target altitude of one mile, 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.

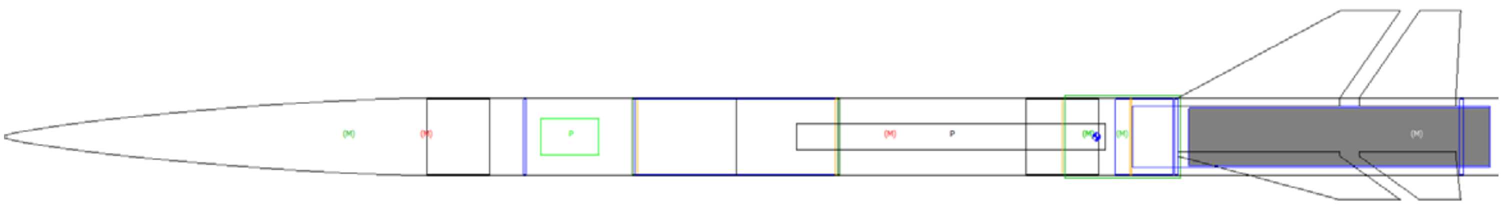
3.1.3 Vehicle Design

The launch vehicle is a single stage rocket that separates into three independent sections, all of which are tethered together. This launch vehicle will be a modified Frenzy XL kit designed by Michael Stoop and purchased from Mad Cow Rocketry. Modifying a kit instead of designing an original flight vehicle would be a more efficient use of time and be less difficult.



The red band indicates where the band on the avionics bay will be to separate the independent sections of the rocket.

The blue band on the lower body tube indicates the area where the air brakes will operate on the rocket.



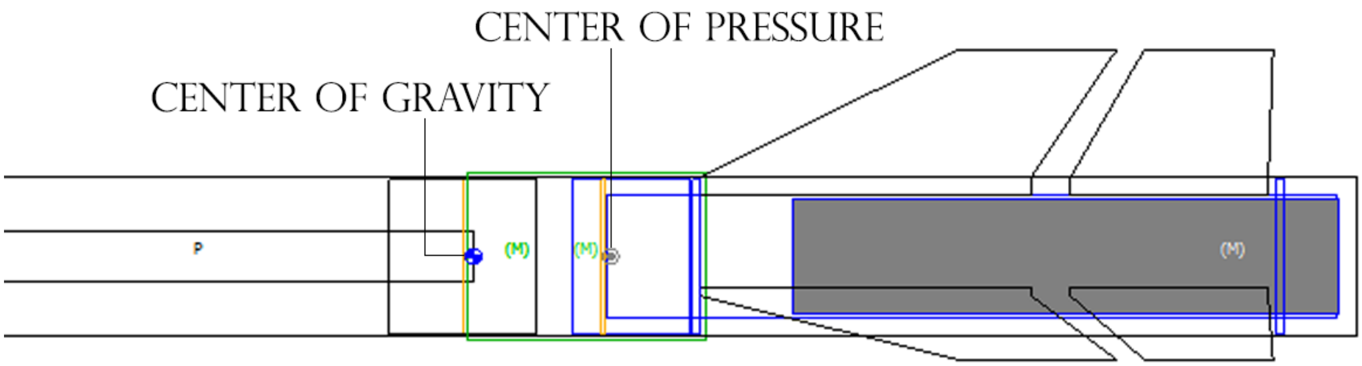
This is a view of the rocket's various components, designed on Apogee Components' RockSim 9. In this diagram, the green band surrounding the the lower body tube is the air brakes, and the yellow band is in the same place as the red band from the 3D diagram.

Dimensions of the rocket:

- Total Length: 77.5 in
- Diameter: 4 in
- Semi span of fin: 3.25 in
- Stability Margin at rail exit: 2.033 calibers
- Center of Gravity: 55.1429 in
- Center of Pressure: 58.6132 in

The Milestone Review Flysheet is available here.

3.1.3.1 Center of Gravity, Center of Pressure Before Ignition


CENTER OF PRESSURE
CENTER OF GRAVITY
P
(M)
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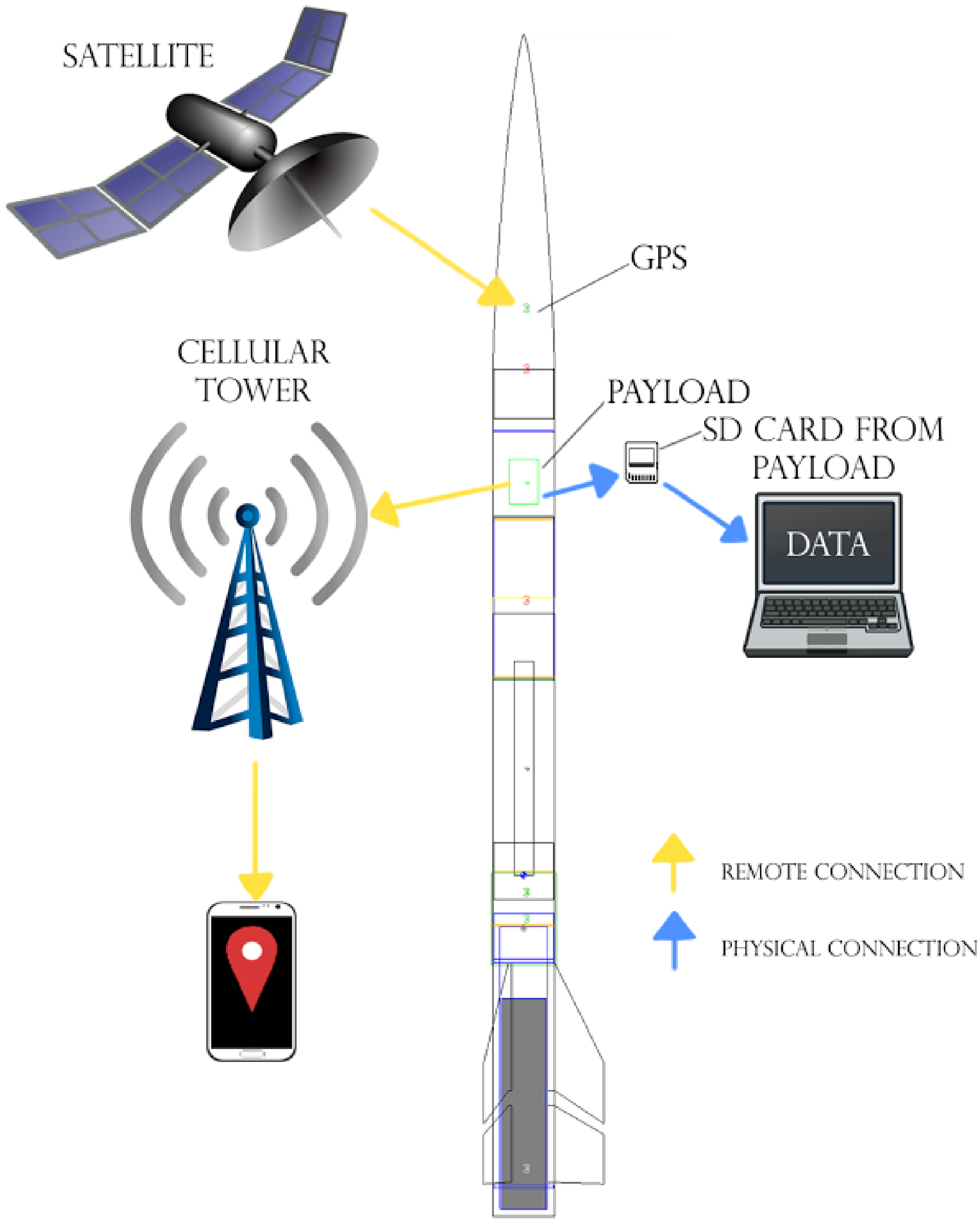
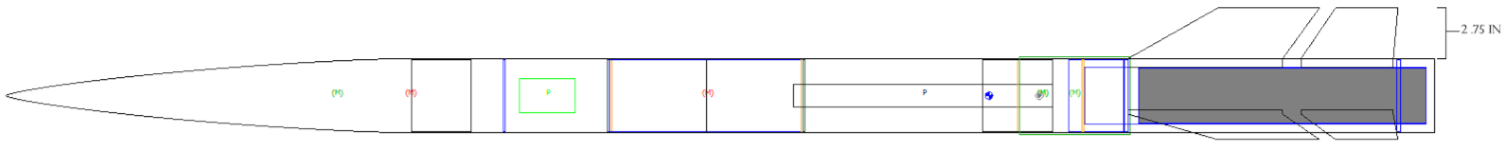
3.1.3.2 System Diagram



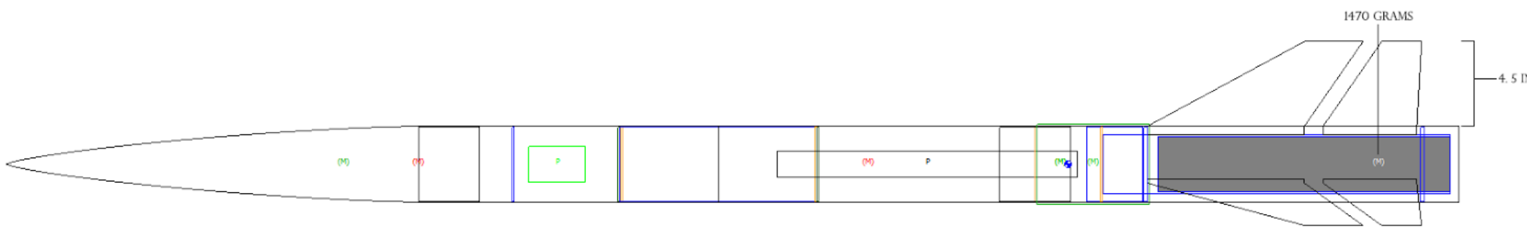
3.1.3.1 Alternatives Considered

The launch vehicle needed to retain a reasonable mass so that it would not present a significant danger to people and a burdensome cost. We experimented with different designs in RockSim to find a rocket that was most suited to our purposes and complied with SL rules.

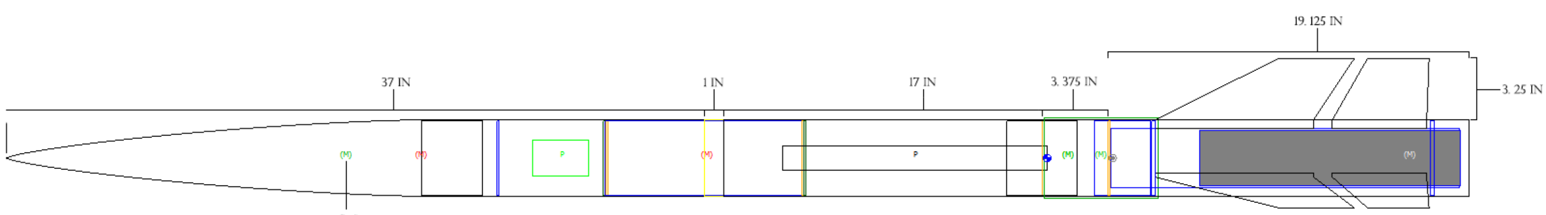
We attempted three different designs that used parts from the Frenzy XL rocket kit.



The first option had smaller fins than the fins provided by the kit.



The second option had a heavier bottom.



The third option had both features - small fins and heavier bottom - to create an even balance.

The white mass near the motor area is 785 g.

Comparison Diagram

Viable Rocket Designs

	Smaller Fins	Heavier Bottom	Smaller Fins, Heavier Bottom
Mass (g)	8797.648	10747.203	9486.098
Kinetic energy (lb-ft)	55.96*	84.20*	75.788
Parachute Diameter (in)	84	96	84
Total Length (in)	77.5	77.5	77.5
Semi span of fin (in)	2.75	4.5	3.25
Motor	Aerotech K560W	Aerotech K560W	Cesaroni K661
Altitude (ft) with no air brakes in action	6356	5217	5869
Static Stability Margin (calibers)	0.66	1.40	0.86
Stability Margin at Rail Exit (calibers)	1.946	2.105	1.97
Mass Addition in Back (g)	N/A	1470.0	785.0

Pugh matrix

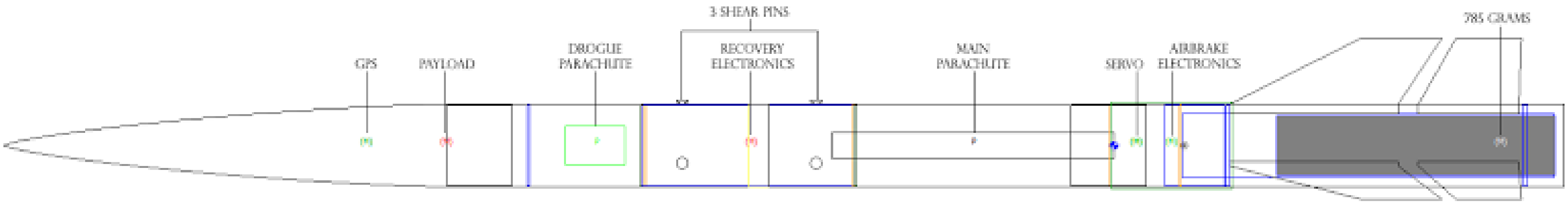
	Smaller Fins	Heavier Bottom	Smaller Fins, Heavier Bottom
Functionality	-	-	+
Free Space Available for Parachute*	+	-	+
Cost-Effectiveness	0	-	0
Conclusion: Usability	-	-	+

*This calculation was verified using the Fruity Chutes Online Descent Rate Calculator. We will purchase our drogue and main parachutes from Fruity Chutes.

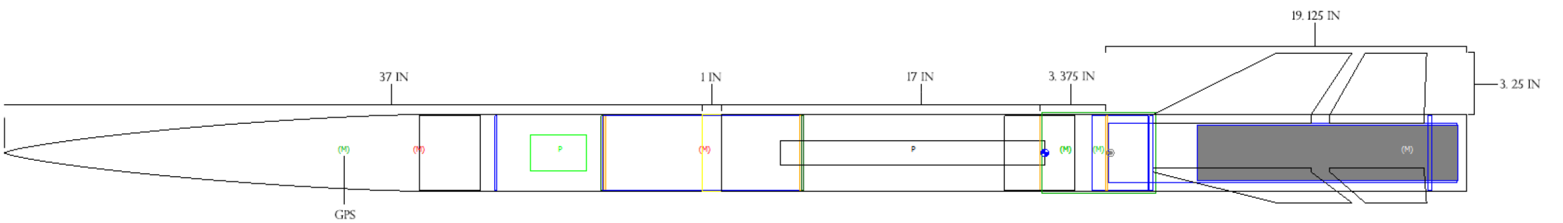
*This factor is based on how much space a certain packed parachute could take up. We allowed an 84” parachute in the middle body tube, but any larger would have required us to spend more money and make major adjustments to the rocket (i.e. lengthening the rocket) to accommodate the stability margin

3.1.3.2 Leading Design

Based on the comparisons we have made above, we have determined that the third design is the



best alternative.



3.1.2 GPS Subsystem

3.1.2.1 GPS Alternatives

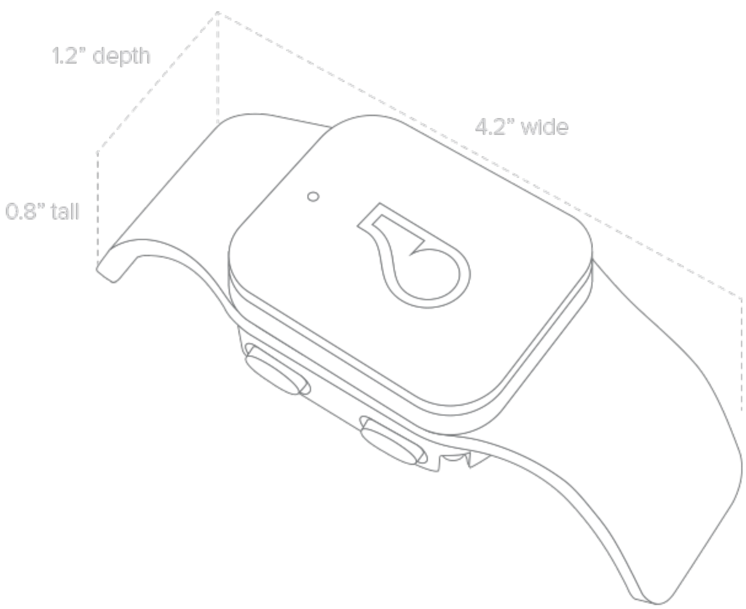
GPS system	Pros	Cons
Whistle GPS dog tracker	Easy to use because it requires knowledge of using a smartphone app. It can be recharged easily using the base station and is not dependent on any other external electronics. No additional telemetry required.	Only works where there is cellular coverage. Bigger than the other GPS options. More expensive because of money needed for cellular service.
EM-506 GPS Receiver	Really small, really accurate in rough geographical conditions like canyons, relatively cheap.	Relatively difficult to use compared to dog tracker. Also not as durable. Additional telemetry may be required.
Arduino GPS tracker	Small and easy to set up. It will be easy for us to use because of our experience with Arduino in TARC.	Additional space required for battery, really expensive, will require use to use a new and unfamiliar version of Arduino. Additional telemetry may be required, making it relatively harder to use.

3.1.2.2 Final Decision

We decided to use the Whistle GPS dog tracker because of ease of usage. Even though it costs more than the other options, we will use it because unlike the other options, handling the Whistle GPS is simply the matter of using an app rather than getting technical. Although the dog tracker will only work in areas with cellular coverage, we have confirmed that it will work in Lucerne Dry Lake (our launch site) and Huntsville (the official launch site).

3.1.2.3 Subsystems and Components

There are three main subsystems to the Whistle GPS dog tracker: the dog collar, the base station, and the phone app. The dog collar, or the actual GPS device that will go inside the rocket, has the following dimension diagram:



It has the dimensions of 4.2” x 0.8” x 1.2” with a mass of 35.44 g, with a battery life of up to 10 days of continuous use. The dog collar will simply be placed into the rocket after being charged from the base station, and no other technical interference is necessary to activate it. The base station, or the charging station of the Whistle GPS, is seen in the following diagram:

The base station, pictured above with the Whistle GPS dog tracker piece, has an estimated mass of 300 grams but will not be inside the rocket. In addition to being the charging station of the dog collar, the base station also serves as the telemetry for the GPS. The user (our team) has to set up a whistle zone (the "safe" range) such that when the dog collar leaves the whistle zone the device will start tracking it. The final component of the Whistle GPS dog tracker is the smartphone app. The app will collect the data from the base station wirelessly using cellular networks and will display the position of the rocket in real time.

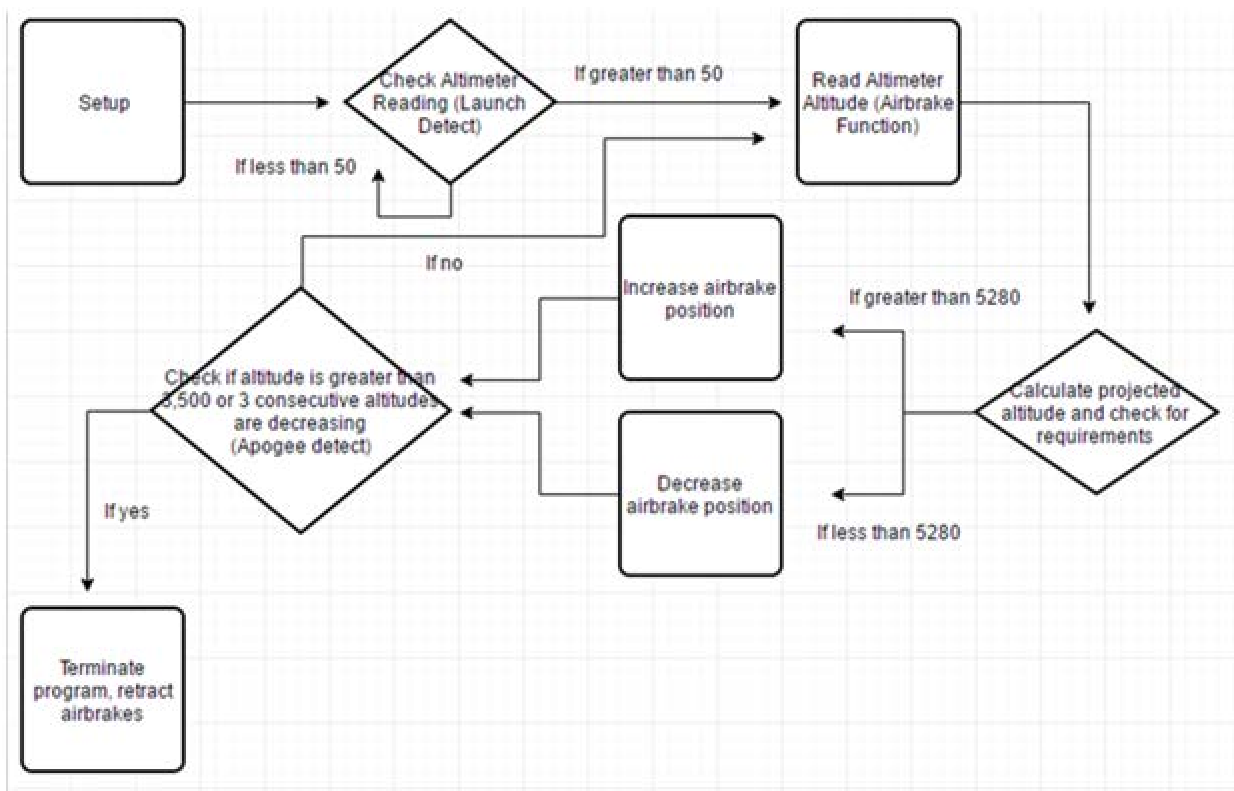
3.1.3 Air Brakes Subsystem

The body tube of the air brake module will be 3.375 in, and the air brakes will be made of a 6 in long fiberglass tube coupler with a 3.9" diameter. It will be independently powered by a Lithium Polymer battery, meaning it will not have any connection with the recovery subsystem or the K30 CO_2 payload.

3.1.3.1 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 Arduino'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.

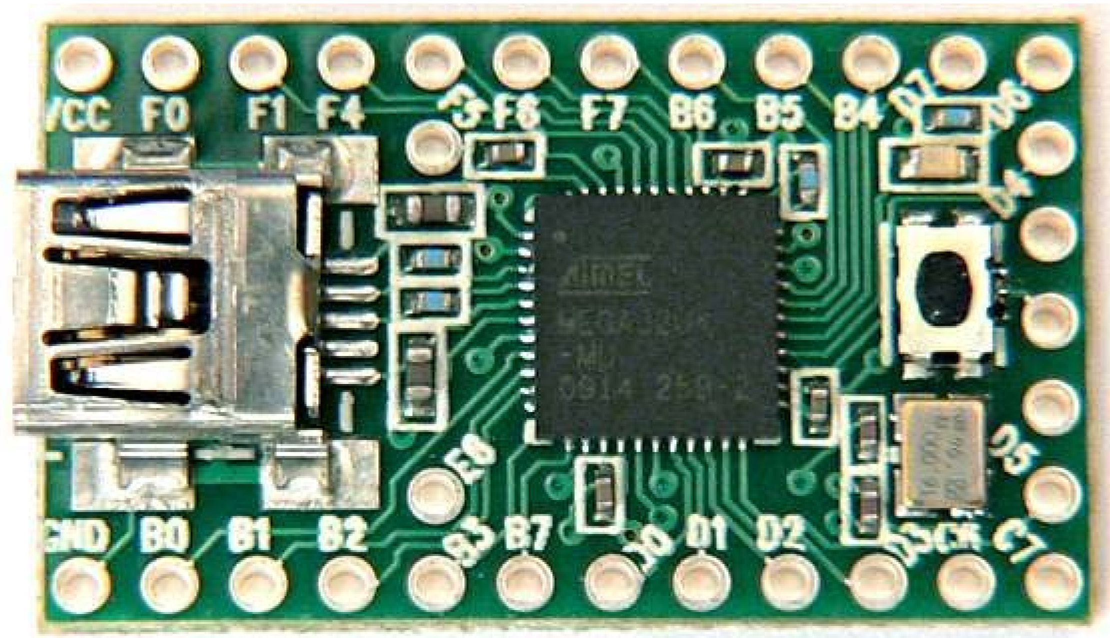
3.1.3.2 Algorithm Flowchart



3.1.3.2 Components of Air Brakes

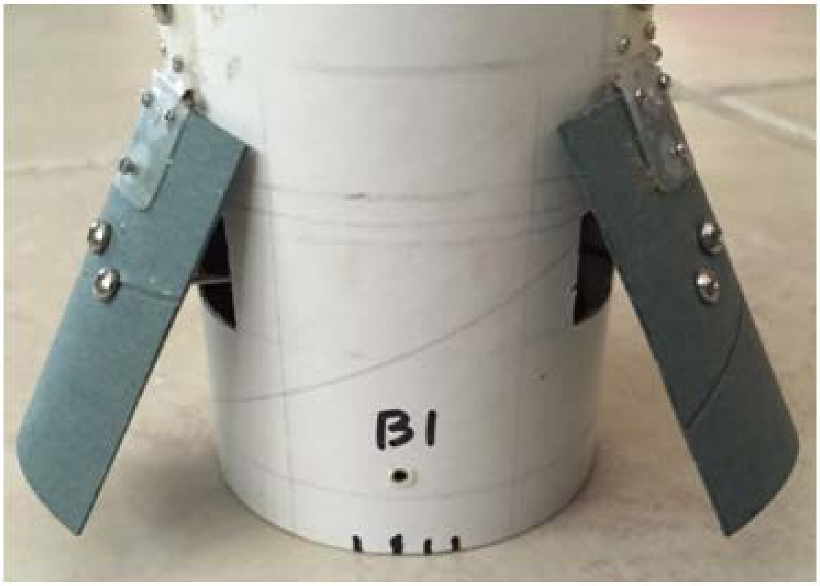
For the 2017 Team America Rocketry Challenge (TARC), we developed an air brake system. The current model pushes the air brakes through holes that we carved into the body tube. After testing the design ten times, recording the air brakes in flight with an on-board flight camera, and

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.

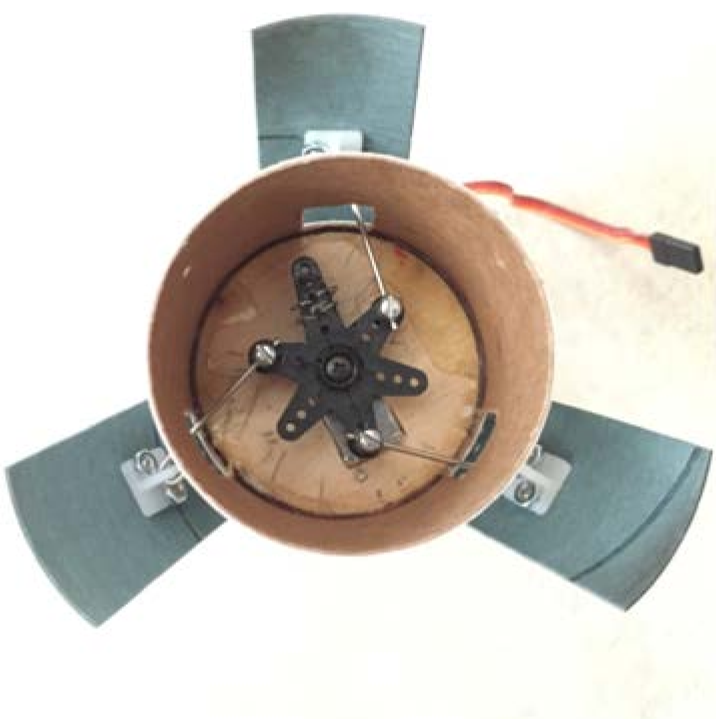


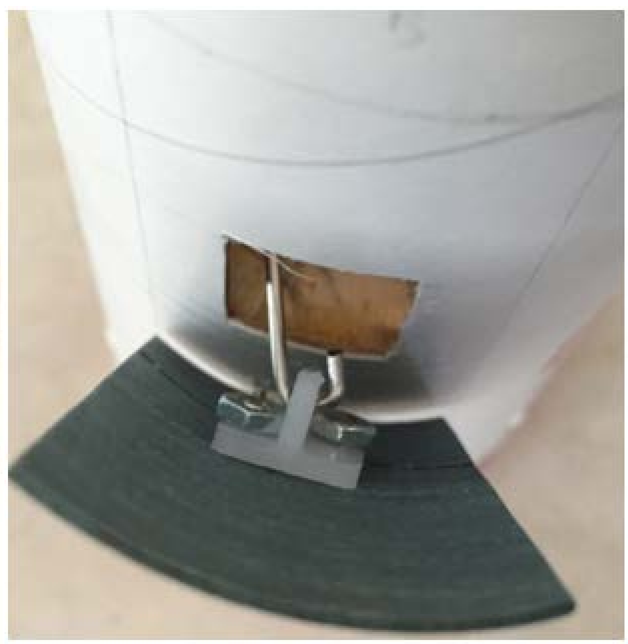
To make the legs on our airbrake system to push and pull the air brakes, we used strong dental wire and dental tools from Albert’s father, who is a dentist. Our system required flexibility around the rotational points, like a ball and socket joint on the human shoulder. We cut and bent the wires into 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. The complete dimensions of the air brakes will be ready by the Critical Design Review.
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.

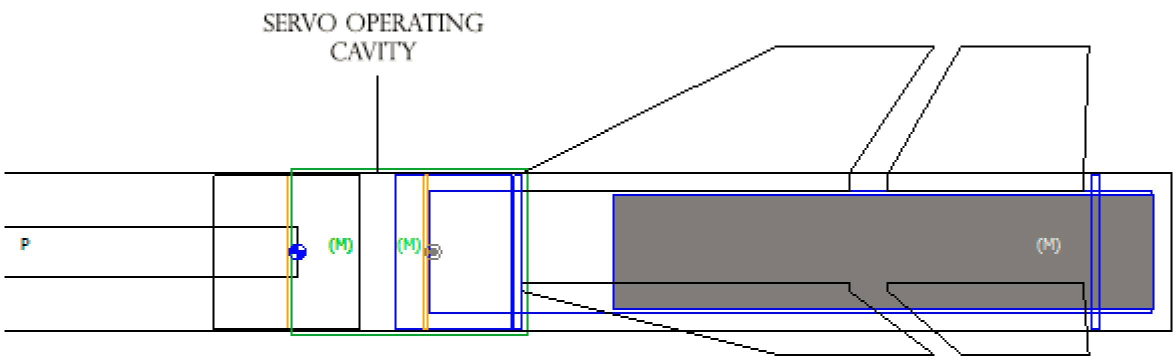
The air brakes will use a Hitec HS-7890T circular servo, which have the following statistics:

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.

3.1.3.3 Conclusion

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 434.393 g.

3.2 Motor

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

Aerotech Engines	**Total Impulse (Ns)**	**Total Mass (g)**	**Max Altitude (ft), no air brake function**	**Max Velocity (ft/s)**	**Max Accel (ft/s^2)**
K560 (75 mm)	2417.0	2744.0	5889.30	657.09	1864.32
K1050W* (54 mm)	2522.0	2259.0	6354.49	820.41	1863.57
K780R (75 mm)	2,361.1	2934.4	5286.35	674.52	640.38
K1000T (75 mm)	2496.6	2575.0	6072.80	772.36	1864.45
Cesaroni Engines	**Total Impulse (Ns)**	**Total Mass (g)**	**Max Altitude (ft), no air brake function**	**Max Velocity (ft/s)**	**Max Accel (ft/s^2)**
K570 (75 mm)	2070.3	1685.0	5213.09	639.91	1863.41
K590 (75 mm)	2415.3	1994.0	6240.62	693.69	1844.53
K661 (75 mm)	2436.5	2527.8	5869.09	707.01	1864.27

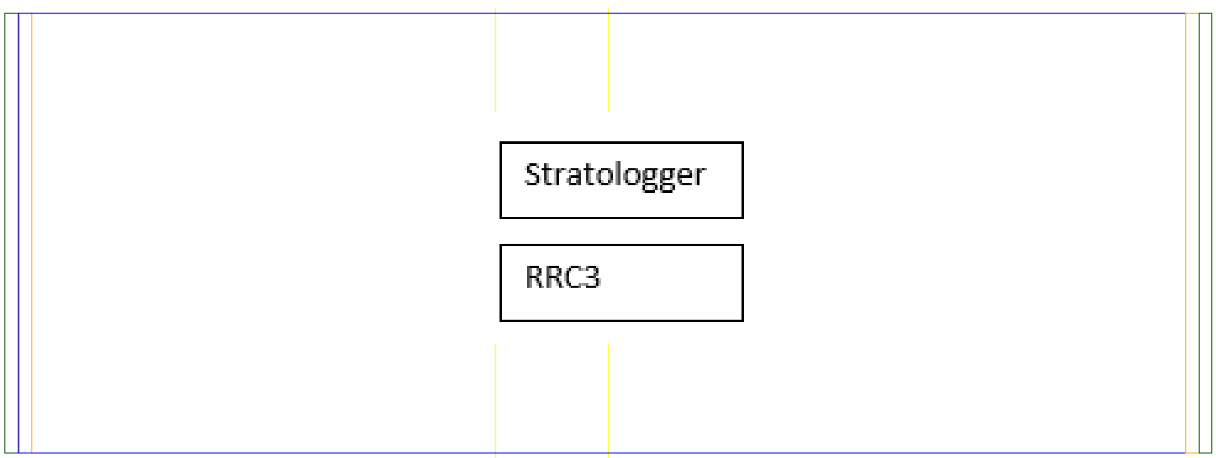
*The average thrust on this RockSim engine file differed from the data given by thrustcurve.org. The average thrust that thrustcurve.org gave was 1062.3 N. The average thrust given by the RockSim engine file is 1025.218 N. The burn time also differed: 2.46 sec on the file, 2.4 sec on thrustcurve.org

3.2.1 Motor Selected

Based on the simulations of the following motors, we have decided that we will use a Cesaroni K661 because it is still within a reasonable distance for the air brakes to be effective. However, we will empirically test the efficacy of the air brakes to see how much the drag affects the altitude. More data and rationale for the motor can be found in section 3.4.1.3.

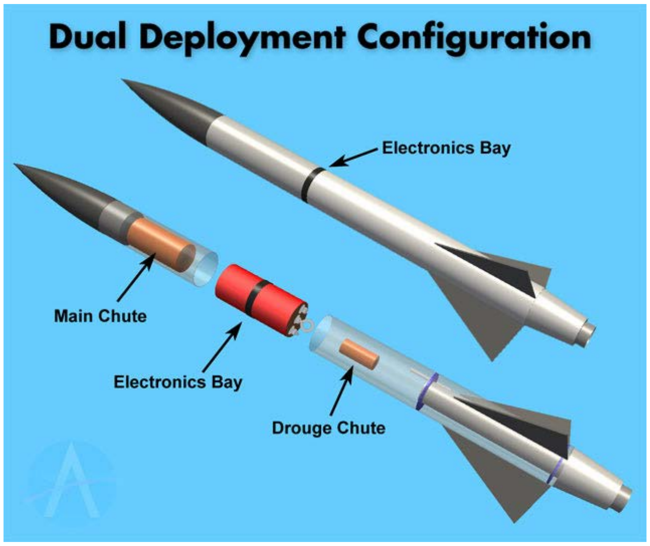
3.3 Recovery Subsystem

The recovery electronics will be in the avionics bay, a 10.2” tube coupler with a 1” band made of fiberglass body (4” diameter) tube to separate the upper and middle body tubes. It is a redundant system that will deploy an 18” drogue parachute at apogee and an 84” main parachute at 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 rocket and its payload are recoverable and reusable. This is a sample configuration of our recovery electronics and parachutes:



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

3.3.1 Parachute Arrangement Alternatives

Parachute Arrangement				
	Option #1	Option #2	Option #3	Option #4
	Main above Drogue	Main and Drogue Chutes in same place	Drogue placed above main	Single parachute with controlled diameter change*
Compliance with SL rules	+	+	+	-
Efficacy	+	-	+	+
Reliability	+	-	+	0
Safety	+	-	+	+
Space	0	+	0	+
Effect on stability	-	-	-	+

margin				
Conclusion	-	-	+	-

*To clarify, we had considered using the Jolly Logic Chute Release to eliminate the need for a second parachute. The main parachute could act as a drogue chute with the Releaser restricting its diameter, and then expand to its full diameter at a specified altitude.

3.3.2 Recovery Plan

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

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

3.3.3 Recovery Electronic Alternatives Considered

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

3.3.4 Conclusion

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.

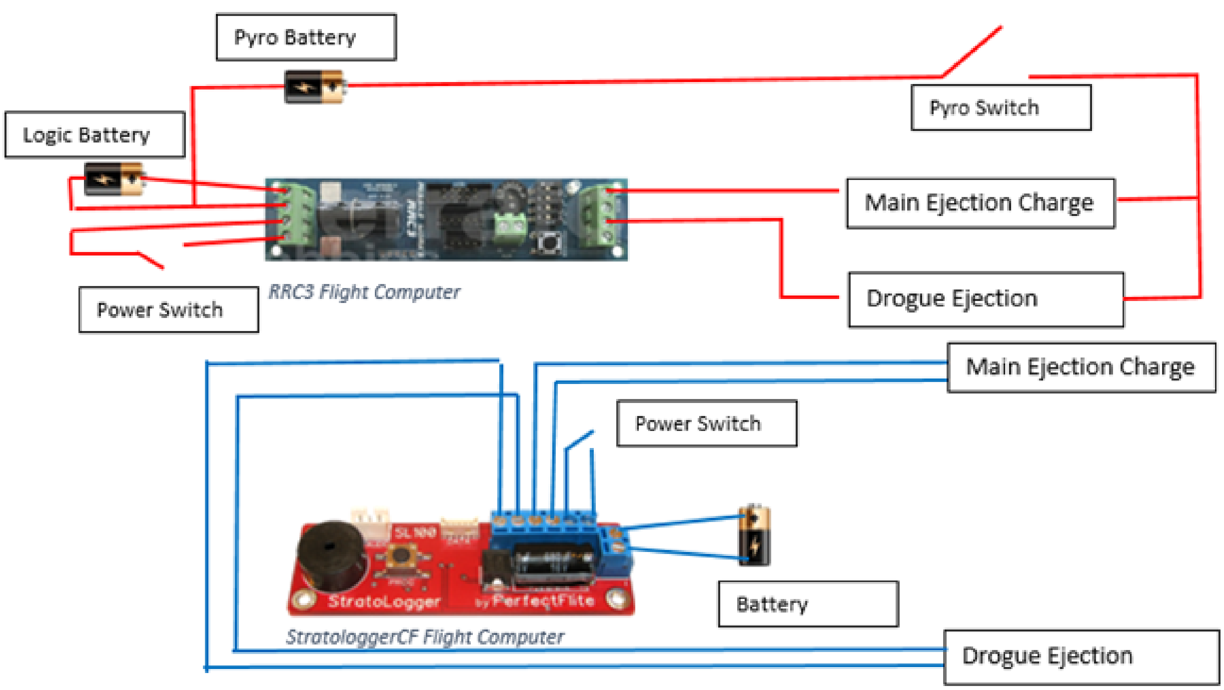
The estimated mass of the subsystem is 660.382 g.

We will use an 18” diameter drogue chute and 84” diameter main chute. Both of them are from Fruity Chutes. Rationale for selecting this main chute will be in section 3.5.

3.3.5 Proof of Redundancy

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

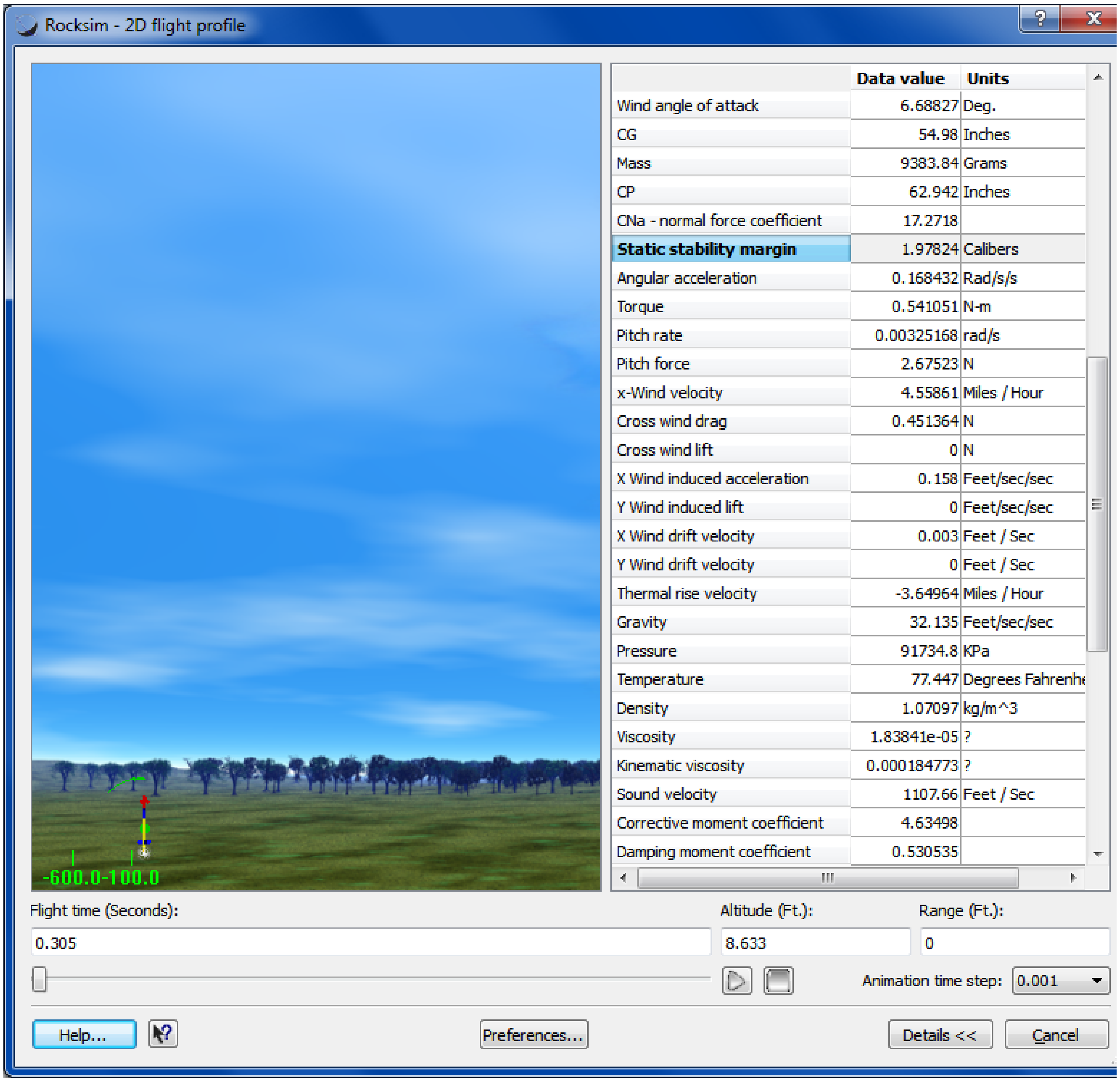
We are using two different types of recovery electronics in the event that one system has a bug and reads altitude incorrectly. If this is the case, then we can rely on the other recovery electronic to control the rest of the flight.



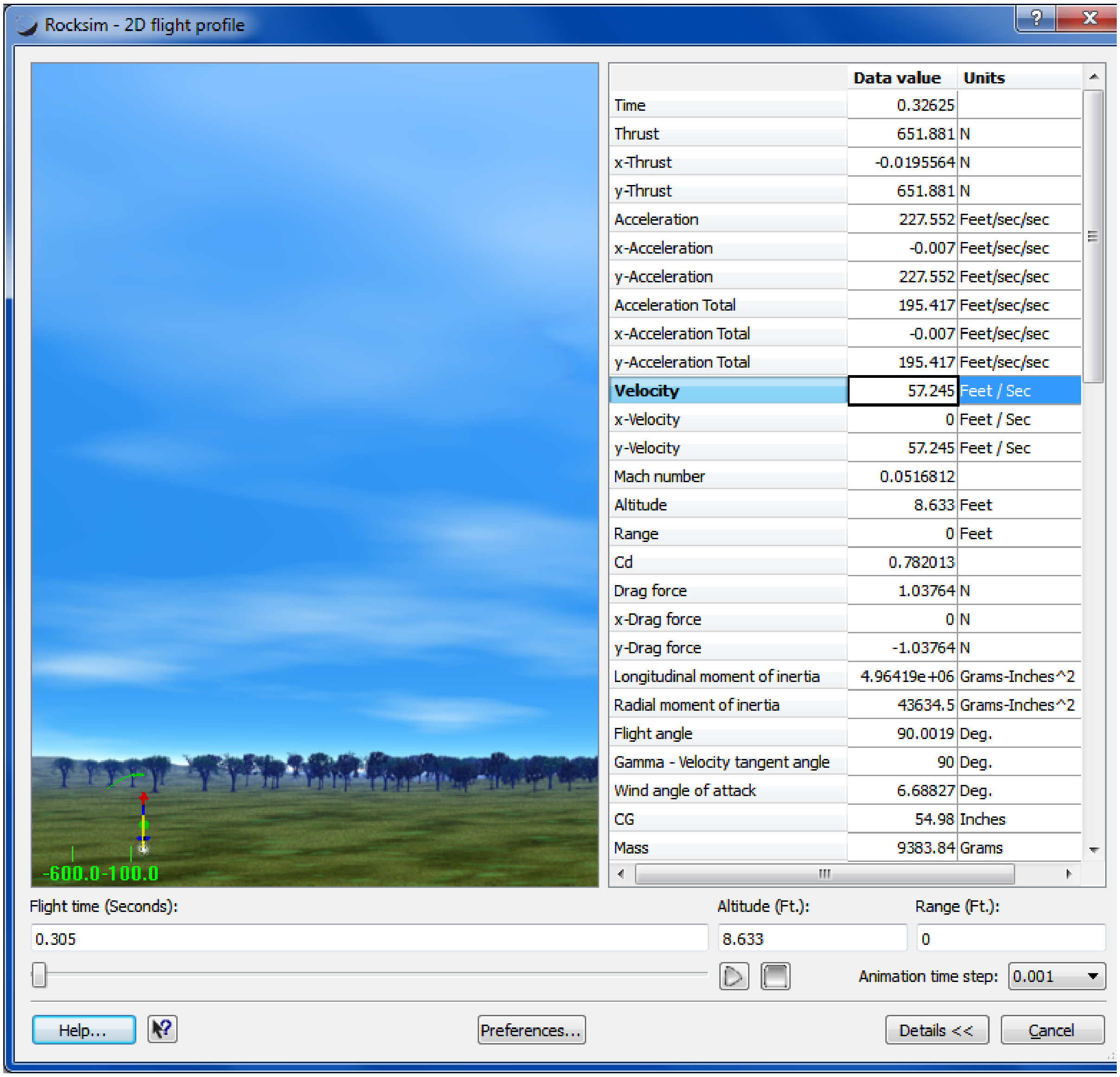
3.4 Mission Performance Predictions

3.4.1 RockSim 9 Data

3.4.1.1 Flight Profile Simulations



Because RockSim's software is not completely user-friendly, we have managed to record the stability margin of the rocket near rail exit. We cannot find a way on RockSim to pinpoint at what moment the rocket leaves its 96" rail. The stability margin of the rocket must be 2.0 at rail exit; ours is 1.978.



In section 1.15 of the Statement of Work, the minimum velocity of the rocket is required to be 52 ft/s at rail exit. Our rocket achieved 57.245 ft/s at, or near, rail exit.

3.3.1.2 Altitude Predictions with Simulated Vehicle Data

The predicted altitude of the rocket, without the aid of air brakes, is generally higher than the target altitude. We anticipate that the air brakes will be effective in bringing the altitude closer to the target altitude, but we must empirically test if the air brakes can lower the rocket by approximately 600 feet. If this altitude is determined to be too high, then we will select a different motor that will bring the rocket closer to the target altitude without air brakes and still overshoot. Or, we will change the air brakes' length to increase drag.

The rocket's maximum altitude, without the aid of air brakes, is 5869.09 ft.

	Simulation	Results	Engines loaded	Max. altitude Feet	Max. velocity Feet / Sec	Max. acceleration Feet/sec/sec	Time to apogee
1	0		[2430-K661-BS-P-Nc	5825.89	706.83	1864.27	18.96
2	1		[2430-K661-BS-P-Nc	5868.18	707.01	1864.27	19.04
3	2		[2430-K661-BS-P-Nc	5840.22	706.89	1864.27	18.99
4	3		[2430-K661-BS-P-Nc	5830.97	706.85	1873.55	18.97
5	4		[2430-K661-BS-P-Nc	5848.43	706.93	1864.27	19.00
6	5		[2430-K661-BS-P-Nc	5859.22	706.97	1864.27	19.02
7	6		[2430-K661-BS-P-Nc	5824.05	706.83	1864.27	18.96
8	7		[2430-K661-BS-P-Nc	5834.12	706.87	1864.27	18.98
9	8		[2430-K661-BS-P-Nc	5868.34	707.01	1851.47	19.04

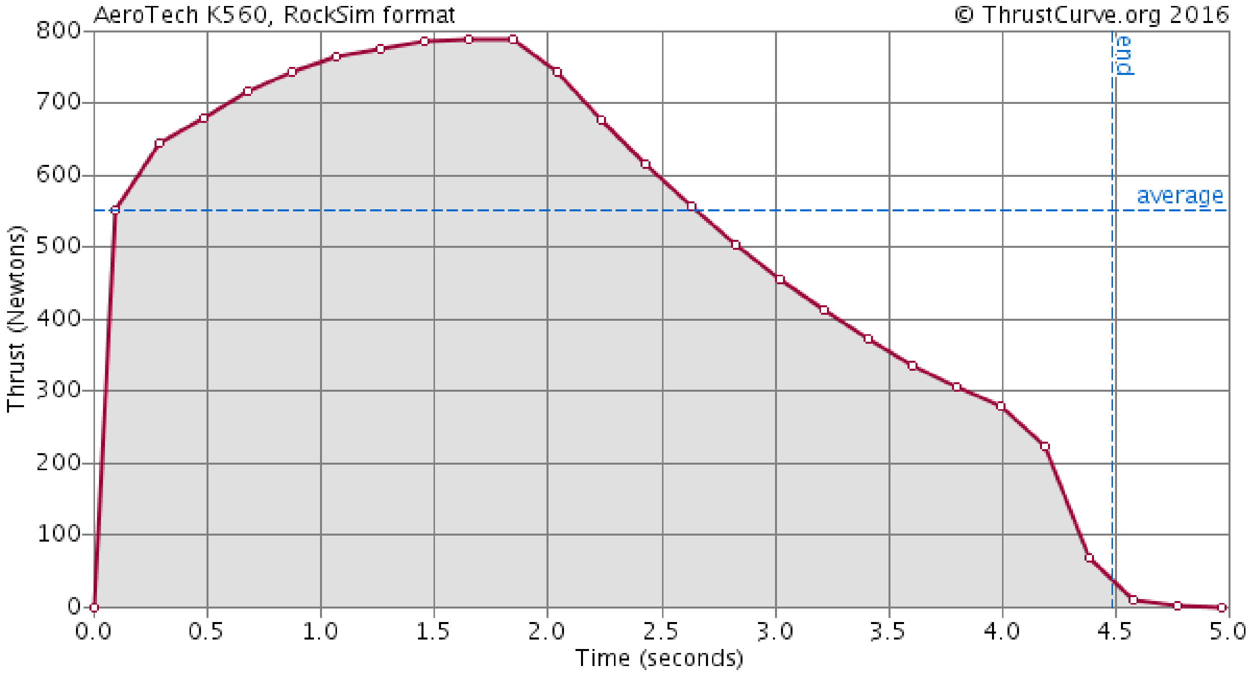
3.4.1.3 Component Weights - Total mass = 6958.296 g

Component Name	Mass (g)
Nose Cone	**1344.203**
Upper Body Tube	
Body Tube	364.369
Payload	149.2
3.9" x 10" Board for Mounting Payload	40 g
Fiberglass Bulkhead	2.885
Drogue Parachute	49.00
Avionics Bay	
Fiberglass Bulkhead	2.885
Birch Bulkhead	16.00
Tube Coupler (Acting as Housing for Recovery Electronics)	217.96
Body Tube (Band on Tube coupler, Separates Independent Sections	24.291
Recovery Electronics	98

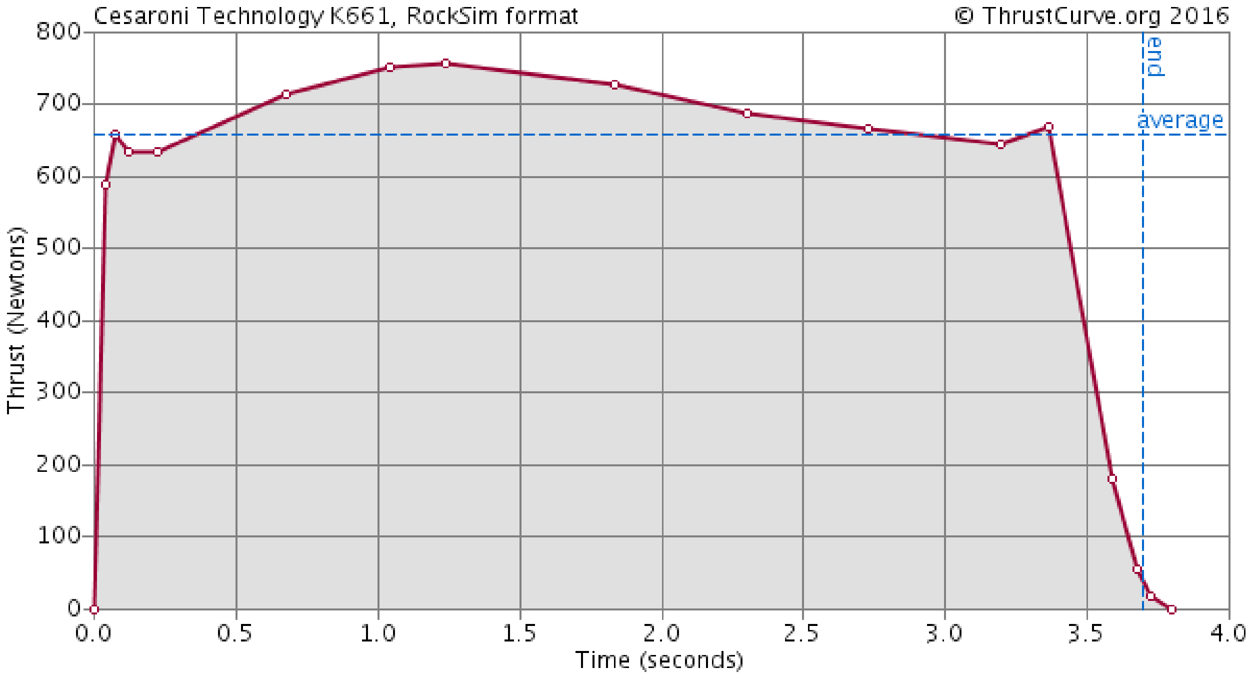
Birch Bulkhead	16.00
Fiberglass Bulkhead	2.885
Middle Body Tube	
Body Tube	412.951
Main Parachute	379.883
Tube Coupler	77.784
Bulkhead	2.885
Electronics + Additional Mass, for altitude adjustment	~100
Tube Coupler	77.784
Servo	78.2
Air Brakes made of Tube coupler	41.485
Air Brake Wires	~42.00
Lower Body Tube	
Body Tube	464.70
Tube Coupler	62.227
Fiberglass Bulkhead	2.885
`Motor Mount	474.782
Centering Ring	70.118
Fin Set 1	838.64
Fin Set 2	549.909

Centering Ring	70.118
Additional Mass	785

3.4.1.4 Simulated Motor Thrust Curve



Although the Aerotech K560W(thrust curve pictured above) was considerably closer to the altitude, it did not have this “spike” in its thrust curve. The below thrust curve of the Cesaroni K661 does.

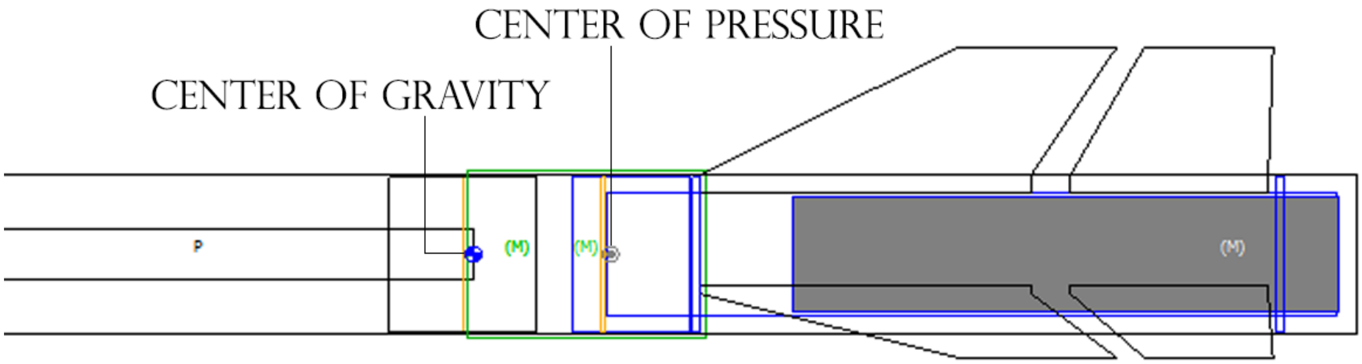


Even though the simulated altitude with a Cesaroni K661 is well over 5280 ft, the air brakes should adjust to bring the rocket down. Other motors were eliminated because they did not fit the 75 mm diameter motor mount and/or caused the rocket to fly too high.

3.4.1.5 Verification of Robust Design

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

3.4.2 Static Stability Margin



- Center of Gravity: 55.1429 in
- Center of Pressure: 58.6132 in

$$Static\ stability\ margin = \frac{distance\ between\ CG\ and\ CP}{diameter\ of\ body\ tube}$$

$$= \frac{|55.1429\ in - 58.6132\ in|}{4.0\ in}$$

$$\approx 0.87$$

Please note that the calculated stability margin in the design's overview is not the same as the stability margin of the rocket in the flight profile. We will assume that the static stability margin of the rocket in the flight profile is more accurate.

3.4.3 Calculation: Kinetic Energy at Landing

$$Kinetic\ Energy = \frac{1}{2} mass\ \times velocity^2$$

Kinetic energy with drogue chute only out

Terminal velocity with drogue chute out only is

$$\frac{122\ feet}{1\ second} \times \frac{0.305\ meters}{1\ feet} = 37.21\ m/s$$

Independent Section one: 1949.657 g

$$1949.657\ g\ \times \frac{1\ kg}{1000\ g} = 1.949657\ kg$$

$$Kinetic\ energy = \frac{1}{2} \times 1.949657\ kg\ \times (37.21\frac{m}{s})^2\ = 1349.73\ J$$

$$= 995.510 ft - lbf$$

Independent Section two: 353.73 g

$$353.73\ g\ \times \frac{1\ kg}{1000\ g} = 0.35373\ kg$$

$$Kinetic\ energy = \frac{1}{2} \times 0.35373\ kg\ \times (37.21\frac{m}{s})^2\ = 244.884\ J$$

$$= 180.617\ ft - lbf$$

Independent Section three 5920.213 g

$$5920.213\ g\ \times \frac{1\ kg}{1000\ g} = 5.920213\ kg$$

$$Kinetic\ energy = \frac{1}{2} \times 5.920213\ kg\ \times (37.21\frac{m}{s})^2\ = 4098.516\ J$$

$$= 3022.910\ ft - lbf$$

Total burnout mass: 8223.6 g

$$8223.6\ \ g\ \times \frac{1\ kg}{1000\ g} = 8.2236\ kg$$

$$Kinetic\ energy = \frac{1}{2} \times 8.2236\ kg\ \times (37.21\frac{m}{s})^2\ = 5693.133\ J$$

$$= 419.039\ ft - lbf$$

Kinetic energy at landing, with drogue and main chutes out

Velocity at landing is

$$\frac{16\ feet}{1\ second} \times \frac{0.305\ meters}{1\ feet} = 4.999\ m/s$$

Independent Section one: 1949.657 g

$$1949.657\ g\ \times \frac{1\ kg}{1000\ g} = 1.949657\ kg$$

$$Kinetic\ energy = \frac{1}{2} \times 1.949657\ kg\ \times (4.999 \frac{m}{s})^2\ = 24.361\ J$$

$$= 17.968\ ft - lbf$$

Independent Section two: 353.73 g

$$353.73\ g\ \times \frac{1\ kg}{1000\ g} = 0.35373\ kg$$

$$Kinetic\ energy = \frac{1}{2} \times 0.35373\ kg\ \times (4.999 \frac{m}{s})^2\ = 4.420\ J$$

$$= 3.620\ ft - lbf$$

Independent Section three 5920.213 g

$$5920.213\ g\ \times \frac{1\ kg}{1000\ g} = 5.920213\ kg$$

$$Kinetic\ energy = \frac{1}{2} \times 5.920213\ kg\ \times (4.999 \frac{m}{s})^2\ = 73.973\ J$$

$$= 54.560\ ft - lbf$$

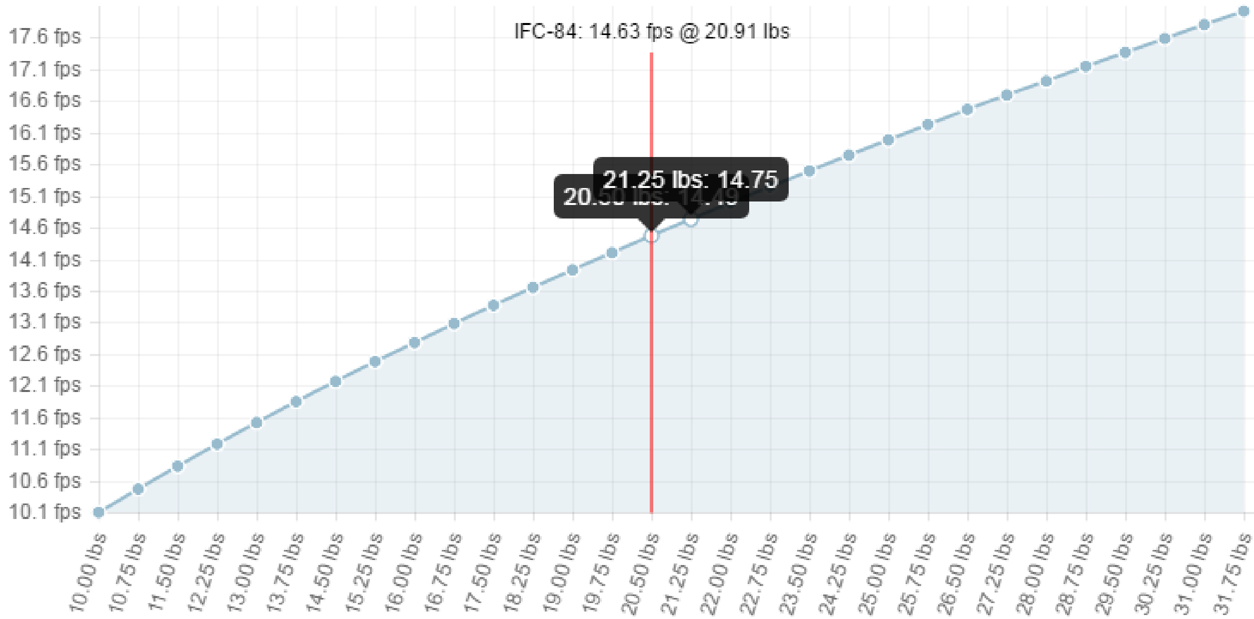
Total burnout mass: 8223.6 g

$$8223.6\ \ g\ \times \frac{1\ kg}{1000\ g} = 8.2236\ kg$$

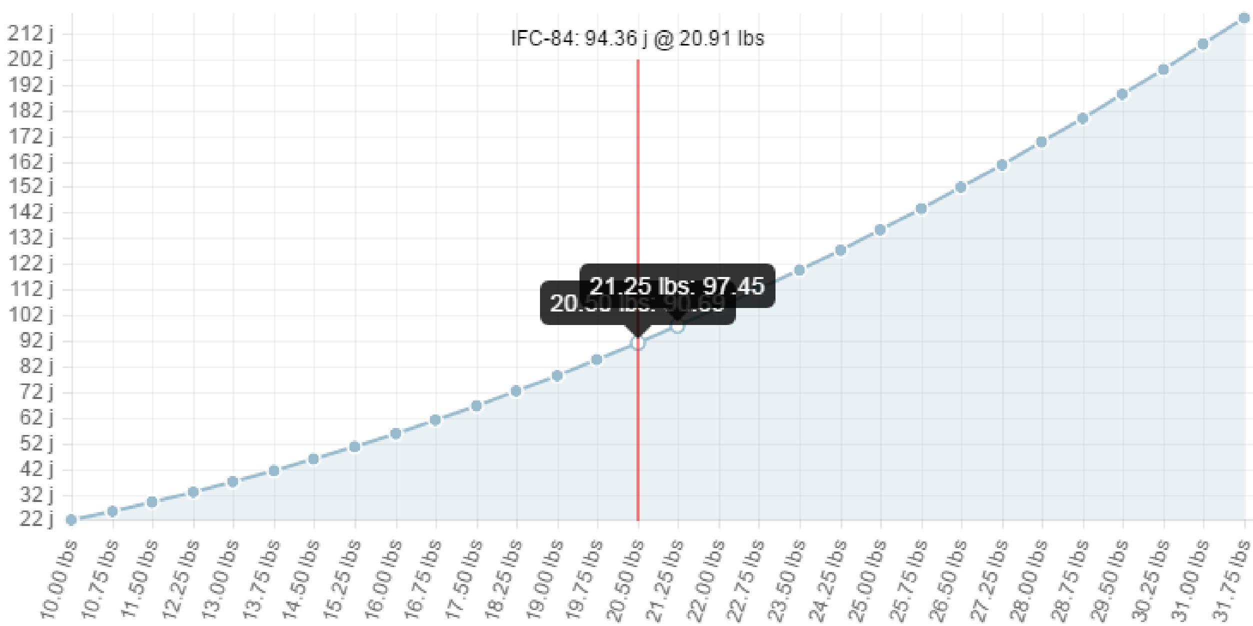
$$Kinetic\ energy = \frac{1}{2} \times 8.2236\ kg\ \times (4.999 \frac{m}{s})^2\ = 102.754\ J$$

$$= 75.788\ ft - lbf$$

Our calculations of the kinetic energy at landing were verified using the parachute manufacturer’s descent rate calculator.



The above graph indicated the associated weight, in lbs, to the descent rate, in ft/s, depending on the type of parachute and the weight of the rocket.



We noted that our calculated kinetic energy was 75.788 ft-lbf, but the estimated range given by the graph above was between 66.890 ft-lbf and 71.875.

3.4.4 Calculation: Drift

Drift is calculated as

$$Drift = descent\ time\ \times velocity\ of\ wind$$

Descent time with drogue chute out = 58 sec

Descent time with main chute out = 43 sec

Because we want to find the total drift following each ejection,

$$\sum drift = descent\ time\ with\ drogue\ chute\ out\ \times velocity\ of\ wind + descent\ time\ with\ main\ chute\ out\ \times velocity\ of\ wind$$

When velocity of wind = 0 mph,

$$\frac{0\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds} = 0\ ft/s$$

$$Drift = 58\,\text{sec} \times 0\ ft/s + 43\,\text{sec} \times 0\ ft/s$$

$$= 0\ ft$$

When velocity of wind = 5 mph

$$\frac{5\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds} = 7.3\ ft/s$$

$$Drift = 58\,\text{sec} \times 7.3\ ft/s + 43\,\text{sec} \times 7.3\ ft/s$$

$$= 737.38\ ft$$

When velocity of wind = 10 mph

$$\frac{10\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds} = 14.6\ ft/s$$

$$Drift = 58\,\text{sec} \times 14.6\ ft/s + 43\,\text{sec} \times 14.6\ ft/s$$

$$= 1515\ ft$$

When velocity of wind = 15 mph

$$\frac{15\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds} = 22\ ft/s$$

$$Drift = \ 58\,\sec \times \ 22\ ft/s + 43\,\sec \times 22\ ft/s$$

$$= 2222\ ft$$

When velocity of wind = 20 mph

$$\frac{20\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds} = 29.33\ ft/s$$

$$Drift = \ 58\,\sec \times \ 29.33\ ft/s + 43\,\sec \times 29.33\ ft/s$$

$$= 2962.33\ ft$$

3.3.5 Black Powder Calculations

Using these equations:

$$N = 0.00052\ F \times L$$

$$F = A * P + force\ needed\ to\ shear\ a\ shear\ pin\ \times number\ of\ shear\ pins$$

Where N is grams needed, F is the force of the black powder's explosion, and L is the length of the body tube. A is the area of the bulkplate, and P is the pressure that is produced by the gas from the ignited black powder.

In the upper body tube, where the drogue chute is stored, the cavity is 10.9 in long.

$$N = 0.00052\ \times \left(A\ \times P + \sum shear\ pin\ force\right) \times L$$

$$= 0.00052 \times ((\frac{Diameter}{2})^2 \pi \times 15\ psi + \sum shear\ pin\ force)\ \times L$$

$$= 0.00052\ \times \left(15\ psi\ \times \left(\frac{4\ in}{2}\right)^2 \pi + 3(\frac{35 lbs}{shear\ pin}\right) \times 10.9\ in$$

$$\approx 1.664\ g$$

In the middle body tube, where the main chute is stored, the cavity is 16 in long.

$$N = 0.00052\ \times \left(A\ \times P + \sum shear\ pin\ force\right) \times L$$

$$= 0.00052 \times ((\frac{Diameter}{2})^2 \pi \times 15\ psi + \sum shear\ pin\ force) \times L$$

$$= 0.00052 \times \left(15\ psi \times \left(\frac{4\ in}{2}\right)^2 \pi + 3(\frac{35lbs}{shear\ pin}\right) \times 16\ in$$

$$\approx 2.442\ g$$

4 Safety

4.1 Components needed to complete 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.

4.2 Preliminary Checklist

Our team will create a checklist for launch preparation, which should take less than 4 hours. The checklist will guide the team through safe and complete preparations for launch. The final checklist will include all of the necessary details.

- Preparation for launch and assurance that all safety interlock switches are off and batteries uninstalled.
    - The safety interlock switches will be verified as “OFF” and batteries for the recovery electronics will be installed.
- The battery for the GPSs and payload will be installed but will remain off.
    - The Whistle GPS will be placed in a foam cutout and secured to the shock cord. The parachutes will both be located in the sustainer section of the rocket, with the drogue parachute packed first and the main parachute in a parachute bag that is attached to the Tender Descenders. The payload will be turned on throughout the entire flight, and since there is no telemetry but rather an SD card to store the payload data, the SD card will start recording the moment the Arduino’s battery is turned on in the ground.
- Four ejection charges will be prepared and installed (1 for the drogue and 1 for the main for each of the redundant and backup electronics).
    - The two ejection charges for the main will be in two separate Tender Descenders from Fruity Chutes, and will be in series. The shear pins can be put into place holding the vehicle sections above and below the avionics bay. The GPS device for the upper section will also be encased in a foam cut out and secured to the shock cord. The rocket can then be placed on the pad (standard launch rail), electronics armed, igniter installed and connected to the electronics launch

system. It is necessary only to apply power to the igniter for the launch. The total time should take less than 2 hours.

- Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.
    - There will be shear pins (2mm nylon screws) at all separation points. The shear pins will keep all points of separation attached while the rocket is moving upwards, and this is mainly to make sure that the rocket does not separate before necessary. The primary and backup ejection charges will have enough force to break through the shear pins, ensuring that the main and drogue parachutes deploy.
- Folding and protecting the parachutes
    - The drogue and main parachutes must be placed inside blast protectors so that they are not damaged by the black powder charges and remain functional for a safe descent.
- Listening to the beeps of the avionics electronics
- Checking electronic programming and functionality
- Checking for continuity
- Igniter installed correctly
- Check if range and sky are clear

Launch procedures and waivers will be taken care of by the Rocketry Organization of California in Lucerne Dry Lake, where we plan to have our full-scale model and scale model flights.

4.3 Personnel Hazard Analysis

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

4.3.1 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.

4.3.2 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.

4.3.3 Vehicle Risk Mitigation

1. Risk - The engine does not ignite while conducting the launch of the rocket. 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. 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. 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. 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. 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 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.
3. Risk: Airbrakes do not function while in flight. 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.	6. Risk - The shear pins do not shear due the ejection charge. 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.	9. Parachute was not packed correctly and does not deploy 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.

4.3.4 Payload Risks and Mitigations

1. Risk: SD card is defective Mitigation: Test run before the actual flight.	4. Risk: SD card is not plugged in Mitigation: Double check that the SD card is properly placed in its socket.	7. Risk: Arduino fails to start. Mitigation: Program an LED light to blink when the Arduino is connected to the power supply.
2. Risk: Batteries are not fully charged Mitigation: Charge the batteries to max before the flight.	5. Risk: Wires detach from the Teensy Mitigation: Securely strap the wires to the circuit board using Velcro or other adhesives.	8. Risk: Defective CO2 Sensor Mitigation: Test run before the actual flight.
3. Risk: The VCC is not connected to the sensor, so the sensor does not work Mitigation: Check if the supply wire is securely attached from the 5 volt pin of the teensy to the Sensor.	6. Risk: Batteries fail Mitigation: Use Voltmeter to check if the battery is fully charged before the flight.	9. Risk: The supply and ground wires are switched. Mitigation: Have two other people keep an eye on the wire connections.

4.3.5 Recovery Risks and Mitigations

1. Risk: Backup ejection charges do not ignite. 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 Mitigation: Double check that the Stratologger and RRC3 both are beeping in their specific sequences.	7. Risk: Main chute doesn’t deploy Mitigation: Backup Flight Computer and ejection charges should take care of this.
2. Risk: The Batteries of Backup Electronics Fall out Mitigation: Use battery holders and zip ties to ensure	5. Risk: Airbrakes fail to close, interfering with recovery Mitigation: Double check	8. Risk: Stratologger CF Flight Computer is not turned on Mitigation: The team will

that the batteries do not fall out, and double check the sturdiness of these before every launch.	that the LED light is blinking on the Arduino. Also, make sure the most recent code is uploaded in the Arduino.	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 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 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 Mitigation: Use fresh batteries and make sure the electronics will power up first in a test second before flight.

4.4 Failure Mode Effects Analysis of Design

Potential Issues/ Failure Mode	Potential Failure Effects	Severity (1-10)	Potential Causes	Occurrence (1-10)	Mitigation
Battery for the CO_2 Sensor (payload) explodes or fail.	The rocket can be damaged, forcing a complete redesign and new construction process.	9	Incorrect wiring or the battery cannot withstand certain malfunctions in the coding.	1	The team decided to switch to a 9 volt battery to better suit the payload. A checklist will be followed when constructing the rocket so no incorrect actions will occur.
The CO_2 Sensor fails to work during the launch.	Experiment cannot be conducted. Sparking could occur within the rocket.	5	Wiring is incorrect. Battery was not activated, or no connection in the circuit.	1	A checklist will be followed during construction and when preparing the rocket to launch.
The rocket does not fly in a stable manner.	Altitude might not be met. Damage to the rocket can occur. The rocket will fly	6	While constructing the rocket, mass change might have occurred.	3	Stability margin is always looked at when designing the rocket and when making any changes to that design. Weather conditions will be

	uncontrollably, possible hurting someone.		During the design process, stability margin might not have been considered. Weather conditions also influence instability.		monitored, and the rocket will not be launched in unsafe conditions.
Rocket components and pieces are not constructed properly (Right length is not cut, epoxy is not well applied, screws are not screwed in properly, electronics are not wired correctly, etc.).	When launched, inconsistent flights could take place, rocket electronics will not function properly, and rocket could combust.	7	Team members are not paying attention and giving close detail during the construction process. Team members are unclear of proper process of construction or the putting together of the rocket.	2	Checklists will be made and each team member working on a certain part of the rocket will be checked by another member to ensure safety and proper execution.

4.5 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	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.

	rocket. Stability also decreases.				
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	The team will contribute to the pollution of the ground and affect surrounding	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

threat to human and environmental safety.	ecosystems by leaving used up motors in the environment. This can release hydrogen chloride, which, mixed in water, can create hydrochloric acid. The acid is corrosive and can acidify soil and water.*				occupied for any trash and dispose of the trash as well.
More epoxy resin than necessary is left out in the environment or disposed of improperly.	The epoxy could result in dermatitis, chemical burns, respiratory irritation, and environmental pollution. #	1	The team overestimated how much epoxy they could use.	1	The team must consistently underestimate the total volume of epoxy resin they will use during the construction of the rocket. To prevent pollution, the team will take excess epoxy resin and the supplies that were used in mixing the resin to a nearby waste disposal center.

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

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

4.6 Risk Identification

Key	
L	Low
M	Medium
H	High

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. 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.

5 Payload Criteria

5.1 Selection, Design, and Rationale of payload

Our payload, the K30 CO_2 sensor, has the sole purpose of collecting carbon dioxide samples from different altitudes. Our scientific experiment is to test the effect of altitude on carbon dioxide levels, hoping to find a strong correlation and regression (exponential, linear, or parabolic) within the explanatory and response variables. Our goal is to establish some sort of trend between the two variables, so it therefore follows that a successful experiment constitutes of a well defined correlation between altitude and carbon dioxide levels. If the sensor reads a three digit number, preferably near 350 ppm, which is the safe level of carbon dioxide in the atmosphere, the experiment was successful.

The payload consists of multiple parts, and will be attached to either side of a rectangular piece of plywood board, which will fit inside a 4 inch diameter body tube near the nose cone. One side of the board will carry the Arduino and SD card while the other side will hold the CO2 Sensor, Pnut altimeter, and the 9V battery.

5.1.1 Alternatives Considered

Alternative	Pros	Cons
Arduino Uno	Easily programmable and comes with wires, breadboard, resistors, and other accessories.	Slow software processing speed.
Raspberry Pi	Easily programmable and has a software processing speed about 60 times faster than that of Arduino.	Slow hardware response time.
K30 CO2 Sensor SE-0018	High measurement range: 0-10,000 ppm. Very accurate and simple to program.	Requires holes in the rocket around the sensor to ensure air flow. More expensive too
TMP36 Temperature Sensor	Very small and light. Easily assembled and simple to program.	Outputs voltage proportional to the temperature so doesn’t give exact temperature.
Micro SD Storage Board	Easy to program and very cheap. Perfect small size for the electric control board.	Has a 2-200mA current range which is high.
Breakout Board for MicroSD	Simple to control and very small	More costly.

RB-Spa-197	too.	
Pnut Altimeter	Very precise: yields a 0.1% accuracy. Reports battery voltage and immune to false triggering.	More expensive.
Firefly Altimeter	Cheap and has a large battery life	Too simple. Not as many features as Pnut.
9v Battery	Easily used through the Arduino’s built in regulator when the battery is placed in its battery casing that attaches to the Arduino.	Not rechargeable
Two cell Lipo Battery	500mAH and rechargeable.	Requires regulator to make energy usable for the Arduino.

5.1.2 Conclusion

We decided to choose the Arduino Uno because we use it for our TARC rocket and are more familiar with it than other single-board computers. We did not use Raspberry Pi because, although its software processing speed is about 60 times faster than Arduino, its hardware response time is much slower.

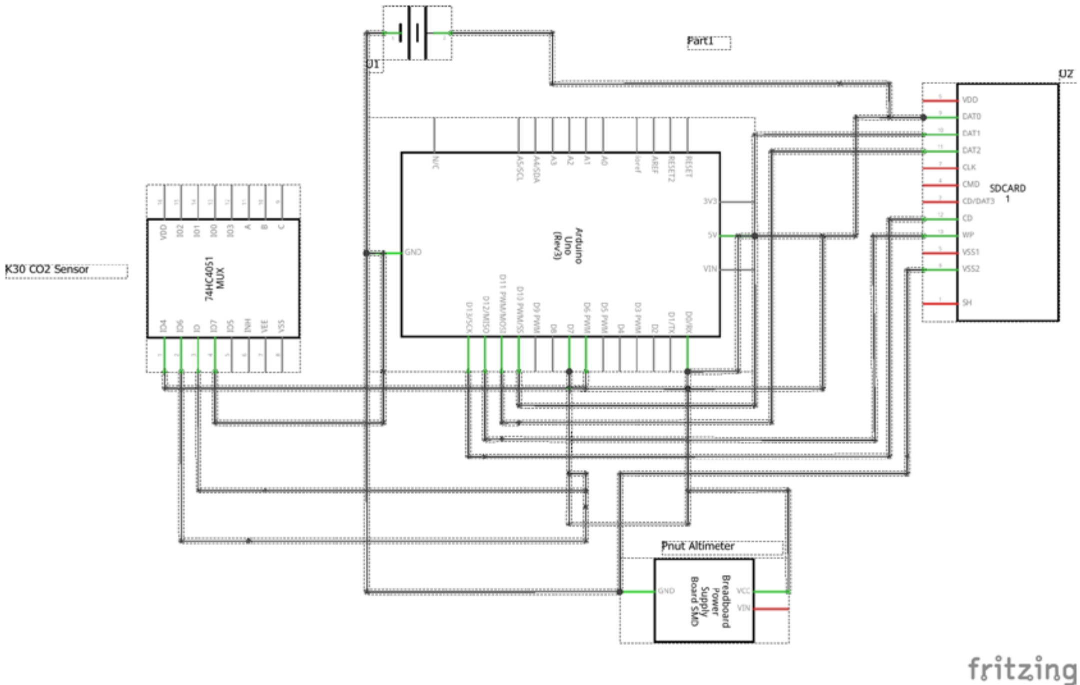
We also decided to test the levels of carbon dioxide for our payload because besides the fact that carbon dioxide is a widely known greenhouse gas, we were also curious to experiment for ourselves how far the calculated level of carbon dioxide is from the safe level of carbon dioxide in the atmosphere. The CO2 Sensor also has a 9600 baud rate and runs on 5 volts.

We use the Micro SD Card Module and Pnut for the altimeter because we are more familiar with them, since we use them for TARC. Both of these devices have a 9600 baud rate and run on 5 volts. We will also use the 9v battery because it is safer because its current is more dense than that of the lipo battery.

5.1.3 Precision of Instrumentation

The Sensor has a response time of 2 seconds and a diffusion time of 20 seconds. Its measurement range is from 0 to 10,000 ppm and its repeatability is ± 20 ppm ± 1 % of measured value within specifications.

We will do most data processing on Microsoft Excel at the ground station because it saves time.


U1
Part1
U2
K30 CO2 Sensor
74HC4051 MUX
Arduino Uno (Rev3)
SDCARD 1
Pnut Altimeter
Breadboard Power Supply Board SMD
fritzing

6 Project Plan

6.1 Requirements Compliance

Requirement in PDR	**PDR Section**
I) Summary of PDR report	
Team Summary	**1.1**
• Team name and mailing address	1.1.1
• Name of mentor, NAR/TRA number and certification level	1.1.1.1
Launch Vehicle Summary	1.2
• Size and mass	1.2
• Motor Choice	1.2
• Recovery System	1.2
• Milestone Review Flysheet	Appendix A, 1.2
Payload Summary	1.3
• Payload Title	1.3
• Summarize payload experiment	1.3
II) Changes made since Proposal	2.1
Highlight all changes made since the proposal and the reason for those changes	2.1
• Changes made to vehicle criteria	2.1.1
• Changes made to payload criteria	2.2
• Changes made to project plan	2.3
III) Vehicle Criteria	Section 3
Selection, Design, and Rationale of Launch Vehicle	3.1

• Include unique mission statement, and mission success criteria.	3.1.1, 3.1.2
• Review the design at a system level, going through each systems' alternative designs, and evaluating the pros and cons of each alternative.	3.1.3
• For each alternative, present research on why that alternative should or should not be chosen.	3.1.3.1
• After evaluating all alternatives, present a vehicle design with the current leading alternatives, and explain why they are the leading choices.	3.1.3.2
• Describe each subsystem, and the components within those subsystems	3.1.3
• Provide a dimensional drawing using the leading design	3.1.3.2
• Provide estimated masses for each subsystem	3.1.3
• Review different motor alternatives, and present data on each alternative.	3.2
Recovery Subsystem	
• Review the design at a component level, going through each components' alternative designs, and evaluating the pros and cons of each alternative.	3.3.3
• For each alternative, present research on why that alternative should or should not be chosen.	3.3.3
• Using the estimated mass of the launch vehicle, perform a preliminary analysis on parachute sizing, and what size is required for a safe descent.	3.3.1
• Choose leading components amongst the alternatives, present them, and explain why they are the current leaders.	3.3.1
• Prove that redundancy exists within the system.	3.3.5
Mission Performance Predictions	
• 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.	3.4
• Show stability margin, simulated Center of Pressure (CP)/Center of Gravity (CG) relationship and locations.	3.4.2
• Calculate the kinetic energy at landing for each independent and tethered section of the launch vehicle.	3.4.3

• 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).	3.4.4
IV) Safety	
• Demonstrate an understanding of all components needed to complete the project, and how risks/delays impact the project.	4.1
• Develop a preliminary checklist of final assembly and launch procedures.	4.2
• 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 (ie cost, schedule, personnel availability). Rank the risk of each Hazard for both likelihood and severity.	4.3
• Include data indicating that the hazards have been researched (especially personnel). Examples: NAR regulations, operator's manuals, MSDS, etc.	4.3
• 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.	4.4
• Discuss any environmental concerns using the same format as the Personnel Hazard Analysis and FMEA.	4.5
• This should include how the vehicle affects the environment, and how the environment can affect the vehicle.	5.4
• 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.	4.6

V) Payload Criteria	
Selection, Design, and Rationale of payload	5.1
• Describe what the objective of the payload is, and what experiment it will perform. What results will qualify as a successful experiment.	5.1
• Review the design at a system level, going through each systems' alternative designs, and evaluating the pros and cons of each alternative.	5.1.1
• For each alternative, present research on why that alternative should or should not be chosen.	5.1.1
• After evaluating all alternatives, present a payload design with the current leading alternatives, and explain why they are the leading choices.	5.1.2
• Include drawings and electrical schematics for all elements of the preliminary payload.	5.1.3
• Describe the preliminary interfaces between the payload and launch vehicle.	5.1.3
• Determine the precision of instrumentation, repeatability of measurement, and recovery system.	5.1.3
VI) Project Plan	
Requirements Compliance	
• 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
• Create a set of team derived requirements. 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.	6.1
Budgeting and Timeline	
• Line item budget with market for individual components values	6.3.1
• Funding plan describing sources of funding, and allocation of funds	6.3.1.1
• Timeline including all team activities, and activity duration. GANTT charts are encouraged	6.3.2

No.	Requirement in SOW	PDR Section
Vehicle Requirements		
1.1	The vehicle shall deliver the science or engineering payload to an apogee altitude of 5,280 feet above ground level (AGL).	**3.1.2**
1.2	The vehicle shall 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 (5,280) 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.	**3.3.1.2**
1.3	All recovery electronics shall be powered by commercially available batteries.	**3.3**
1.4	The launch vehicle shall be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.	**3.1, 3.3**
1.5	The launch vehicle shall 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.	**2.1.2**
1.6	The launch vehicle shall be limited to a single stage.	**3.1.3**
1.7	The launch vehicle shall be capable of being prepared for flight at the launch site within 4 hours, from the time the Federal Aviation Administration flight waiver opens.	**4.2**
1.8	The launch vehicle shall 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 component.	
1.9	The launch vehicle shall 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.	
1.10	The launch vehicle shall require no external circuitry or special ground support equipment to initiate launch (other than what is provided by Range Services).	

1.11	The launch vehicle shall 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).	**3.2.1**
1.12	Pressure vessels on the vehicle shall be approved by the RSO and shall meet the following criteria	
1.12.1	The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) shall be 4:1 with supporting design documentation included in all milestone reviews	
1.12.2	The low-cycle fatigue life shall be a minimum of 4:1.	
1.12.3	Each pressure vessel shall include a solenoid pressure relief valve that sees the full pressure of the tank.	
1.12.4	Full pedigree of the tank shall 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.	
1.13	The total impulse provided by a Middle and/or High School launch vehicle shall not exceed 2,560 Newton-seconds (K-class).	**3.1.2, 3.2**
1.14	Any team who wishes to apply for a larger motor impulse limit may include a section within the proposal detailing why the larger motor is necessary. Educator and mentor experience in high power rocketry should also be included in this section. Motor impulses may increase to a maximum of 6,120 Newton-seconds (L-class). If, during the design review process, the rocket design does not safely allow for use of an L motor, the Student Launch office reserves the right to revoke the increased impulse limit.	**3.2**
1.15	The launch vehicle shall have a minimum static stability margin of 2.0 at the point of rail exit.	**3.1.3**
1.16	The launch vehicle shall accelerate to a minimum velocity of 52 fps at rail exit	**3.2**
1.17	All teams shall successfully launch and recover a subscale model of their rocket prior to CDR	
1.17.1	The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale shall not be used as the subscale model.	

1.17.2	The subscale model shall carry an altimeter capable of reporting the model's apogee altitude	
1.18	All teams shall 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 to be 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 a lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full scale demonstration flight:	
1.18.1	The vehicle and recovery system shall have functioned as designed.	**1.2**
1.18.2	The payload does not have to be flown during the full-scale test flight. The following requirements still apply:	**Appendix A**
1.18.2.1	If the payload is not flown, mass simulators shall be used to simulate the payload mass.	**Appendix A**
1.18.2.2	The mass simulators shall be located in the same approximate location on the rocket as the missing payload mass.	**Appendix A**
1.18.3	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 shall be active during the full-scale demonstration flight.	
1.18.4	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.	
1.18.5	The vehicle shall 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.	
1.18.6	After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components shall not be modified without the concurrence of the NASA Range Safety Officer (RSO)	
1.18.7	Full scale flights must be completed by the start of FRRs (March 6th, 2016). If the Student Launch office determines that a re-flight is	

	necessary, than an extension to March 24th, 2016 will be granted. This extension is only valid for re-flights; not first time flights.	
1.19	Any structural protuberance on the rocket shall be located aft of the burnout center of gravity	**3.1.3.2**
1.20	Vehicle Prohibitions	
1.20.1	The launch vehicle shall not utilize forward canards.	**1.2**
1.20.2	The launch vehicle shall not utilize forward firing motors.	**3.2**
1.20.3	The launch vehicle shall not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)	**3.2**
1.20.4	The launch vehicle shall not utilize hybrid motors.	**3.2**
1.20.5	The launch vehicle shall not utilize a cluster of motors.	**3.2**
1.20.6	The launch vehicle shall not utilize friction fitting for motors.	**3.2**
1.20.7	. The launch vehicle shall not exceed Mach 1 at any point during flight.	**3.2**
1.20.8	Vehicle ballast shall not exceed 10% of the total weight of the rocket.	**N/A**
Recovery System Requirements		
2.1	The launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude. Tumble recovery or streamer recovery from apogee to main parachute deployment is also permissible, provided that kinetic energy during drogue-stage descent is reasonable, as deemed by the Range Safety Officer.	**3.3.2**
2.2	Each team must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full scale launches.	**6.1.3**
2.3	At landing, each independent sections of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf.	**3.1.3.1**
2.4	The recovery system electrical circuits shall be completely independent of any payload electrical circuits.	**3.3.2**

2.5	The recovery system shall contain redundant, commercially available altimeters. The term “altimeters” includes both simple altimeters and more sophisticated flight computers.	**3.3.2**
2.6	Motor ejection is not a permissible form of primary or secondary deployment.	**N/A**
2.7	Each altimeter shall 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.	**3.3, 3.3.2**
2.8	Each altimeter shall have a dedicated power supply.	**3.3**
2.9	Each arming switch shall be capable of being locked in the ON position for launch	**3.3, 3.3.2**
2.10	Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.	**3.3**
2.11	An electronic tracking device shall be installed in the launch vehicle and shall transmit the position of the tethered vehicle or any independent section to a ground receiver.	**3.1.2**
2.11.1	Any rocket section, or payload component, which lands untethered to the launch vehicle, shall also carry an active electronic tracking device.	**3.1.2**
2.11.2	. The electronic tracking device shall be fully functional during the official flight on launch day.	**3.1.2**
2.12	The recovery system electronics shall not be adversely affected by any other on-board electronic devices during flight (from launch until landing).	**3.3.2**
2.12.1	The recovery system altimeters shall be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.	**3.3.2**
2.12.2	The recovery system electronics shall be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system electronics	**3.3.2**
2.12.4	The recovery system electronics shall be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.	**3.3.2**
Payload Requirements		

3.1	The launch vehicle shall carry a science or engineering payload. The payload may be of the team's discretion, but shall 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.	**5**
3.2	`Data from the science or engineering payload shall be collected, analyzed, and reported by the team following the scientific method.	**5.1**
3.3	Unmanned aerial vehicle (UAV) payloads of any type shall be tethered to the vehicle with a remotely controlled release mechanism until the RSO has given the authority to release the UAV.	
3.4	Any payload element that is jettisoned during the recovery phase, or after the launch vehicle lands, shall receive real-time RSO permission prior to initiating the jettison event.	
3.5	The payload shall 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.	**3.3**
Safety Requirements		
4.1	Each team shall use a launch and safety checklist. The final checklists shall be included in the FRR report and used during the Launch Readiness Review (LRR) and any launch day operations.	**4.2**
4.2	Each team must identify a student safety officer who shall be responsible for all items in section 4.3	**4.3.2**
4.3	The role and responsibilities of each safety officer shall include, but not limited to:	**4.3.2**
4.3.1	Monitor team activities with an emphasis on Safety during:	**4.3.2**
4.3.1.1	Design of vehicle and launcher	**4.3.2**
4.3.1.2	Construction of vehicle and launcher	**4.3.2**
4.3.1.3`	Assembly of vehicle and launcher	**4.3.2**
4.3.1.4	Ground testing of vehicle and launcher	**4.3.2**
4.3.1.5	Sub-scale launch test(s)	**4.3.2**

4.3.1.6	Full-scale launch test(s)	**4.3.2**
4.3.1.7	Launch day	**4.3.2**
4.3.1.8	Recovery activities	**4.3.2**
4.3.1.9	Educational Engagement Activities	**4.3.2**
4.3.2	Implement procedures developed by the team for construction, assembly, launch, and recovery activities	**4.3.2**
4.3.3	Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data	**4.3.2**
4.3.4	Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.	**4.3.2**
4.4	Each team shall 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 shall 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 the rocketeer shall have flown and successfully recovered (using electronic, staged recovery) a minimum of 2 flights in this or a higher impulse class, prior to PDR. The mentor is designated as the individual owner of the rocket for liability purposes and must travel with the team to launch week. One travel stipend will be provided per mentor regardless of the number of teams he or she supports. The stipend will only be provided if the team passes FRR and the team and mentor attends launch week in April.	**1.1.2.1**
4.5	During test flights, teams shall abide by the rules and guidance of the local rocketry club's RSO. The allowance of certain vehicle configurations and/or payloads at the NASA Student Launch 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.	
4.6	Teams shall abide by all rules set forth by the FAA.	
General Requirements		

5.1	Students on the team shall 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).	
5.2	The team shall provide and maintain a project plan to include, but not limited to the following items: project milestones, budget and community support, checklists, personnel assigned, educa tional engagement events, and risks and mitigations.	**6.1**
5.3	Foreign National (FN) team members shall be identified by the Preliminary Design Review (PDR) and may or may not have access to certain activities during launch week due to security restrictions. In addition, FN's may be separated from their team during these activities.	
5.4	The team shall identify all team members attending launch week activities by the Critical Design Review (CDR). Team members shall include:	
5.4.1	Students actively engaged in the project throughout the entire year.	
5.4.2	One mentor (see requirement 4.4).	**1.1.2.1, 1.1.2.2**
5.4.3	No more than two adult educators.	**1.1.2.1, 1.1.2.2**
5.5	The team shall engage a minimum of 200 participants in educational, hands-on science, technology, engineering, and mathematics (STEM) activities, as defined in the Educational Engagement Activity Report, by FRR. An educational engagement activity report shall 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 28 of the handbook.	
5.6	The team shall develop and host a Web site for project documentation	
5.7	Teams shall post, and make available for download, the required deliverables to the team Web site by the due dates specified in the project timeline.	
5.8	All deliverables must be in PDF format	
5.9	In every report, teams shall provide a table of contents including major sections and their respective sub-sections.	

5.10	In every report, the team shall include the page number at the bottom of the page.	
5.11	The team shall provide any computer equipment necessary to perform a video teleconference with the review board. This includes, but not limited to, a computer system, video camera, speaker telephone, and a broadband Internet connection. If possible, the team shall refrain from use of cellular phones as a means of speakerphone capability	
5.12	All teams will 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.	
5.13	Teams must implement the Architectural and Transportation Barriers Compliance Board Electronic and Information Technology (EIT) Accessibility Standards (36 CFR Part 1194) Subpart B-Technical Standards (http://www.section508.gov): § 1194.21 Software applications and operating systems. § 1194.22 Web-based intranet and Internet information and applications.	

6.1.1 Vehicle Test 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.

6.1.2 Recovery Test 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.

6.1.3 Energetics Test Plan

We will perform ground tests to verify our calculations of how much black powder is safe to use on a rocket. In an isolated area, we will test different masses of black powder changes and remotely detonate these charges with a 9 Volt current.

If the rocket deploys its respective parachutes without exploding the body tubes, then we will have found the correct mass of the black powder that is safe to use on the flight. If the rocket is unable to deploy a parachute, then we will increase the mass of the black powder used and check to see if there is continuity with the recovery electronics and the electric match that detonates the black powder.

We will find the minimum amount of black powder that is safe for use.

This ground test will be used on the full-scale and scale model of the rocket.

6.1.4 Air Brakes Test Plan

To test the functionality of the air brakes, we will first create the module for it. We will power the Teensy and link it to its battery. Once powered, the air brakes are expected to open and close fully in unison.

Once we have deemed the air brakes mechanically sound, we will check the battery's power to see if there is enough. If the air brakes are unable to open and close quickly, it is likely due to low battery. We will recharge the battery and regularly check its voltage to ensure that it functions.

To test efficacy and durability, we will place simulate the air brakes in flight by using an electric leaf blower. The propelled air will simulate the air friction that results from the rocket's ascent. The leaf blower propels air at approximately 200 ft/s.

See section 4.3.1 Vehicle Risk Mitigation to see how air brake malfunction affect the launch vehicle's flight.

6.1.5 GPS Test Plan

Once we purchase the Whistle GPS, we will test its range by setting up our base station at Lucerne Dry Lake (our launch site) and having one person walk 2 miles to check its range. We will also test the dog tracker's battery life by leaving it on and recording when it completely discharges. Ideally, it should be able to run for a couple of days without stopping but this test will be just to make sure of this.

6.1.6 Payload Test Plan

To test if all devices are working correctly, we will first check if the LED light is blinking on the CO2 Sensor and Arduino after we link them to the battery. Then we will make sure the SD card is securely placed in its socket and the Pnut is beeping. Then after the flight, we will connect the SD card to a computer and analyze the readings.

6.2 Team Derived Requirements

The following is a list of minimum requirements for mission success. These requirements are outside of the scope of the Student Launch 2017 Handbook.

6.2.1 Payload Success

Our goal is to establish some sort of trend between the two variables, so it therefore follows that a successful experiment constitutes of a well defined correlation between altitude and carbon dioxide levels. If the sensor reads a three digit number, preferably near 350 ppm, which is the safe level of carbon dioxide in the atmosphere, the experiment was successful.

6.2.2 Team Expenditure

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

6.2.3 Team Functionality

The team must not become divided over insignificant issues. They must regularly meet, with ideas planned ahead of time, to work effectively. The team will also divide parts of each report evenly and complete their written parts on time.
On the launch site, the team must assign specific roles that they must fulfill. It is the job of the Range Safety Officer to insure their safety as they operate.

6.3 Budgeting and Timeline

6.3.1 Line Budget

Description	Unit Cost	Quantity	Subtotal		Comments
Scale Vehicles and Engines					
3" Fiberglass Frenzy XL	$200.00	1	$200.00		
3" G12 Thin-Wall Airframe (12" length)	$20.00	1	$20.00		
3" G12 Coupler (6" length)	$14.00	2	$28.00		
3" G12 Coupler (9" length)	$21.00	1	$21.00		
HS-7980TH	$190.00	1	$190.00		
2-56 wire	$10.00	1	$10.00		
1/4" Machine Closed Eye Bolt	$18.00	4	$72.00		
Heavy unit easy connector	$5.00	1	$5.00		
Iris Ultra 72" Compact parachute	$265.00	1	$265.00		
12" Elliptical Parachute	$47.00	1	$47.00		
Cesaroni J240RL	$85.00	1	$85.00		
Total Scale Vehicle Cost				$943.00	
Vehicle					
4" G12 Coupler (12" length)	$31.00	3	$93.00		
4" G12 Coupler (8" length)	$21.00	2	$42.00		
4" Fiberglass Frenzy XL	$300.00	1	$300.00		

4" G12 Airframe (12" length)	$23.00	1	$23.00		
75mm Aerotech K560	$70.00	3	$210.00		
HS-7980TH	$190.00	1	$190.00		
2-56 wire	$10.00	1	$10.00		
Heavy unit easy connector	$5.00	1	$5.00		
Aero Pack 75mm Retainer (Fiberglass Motor Tubes)	$44.00	1	$44.00		
Shock Cord Protector Sleeves of Kevlar	$10.00	3	$30.00		
1 Inch Black Climbing Spec Tubular Nylon Webbing	$12.00	2	$24.00		
3/8" Machine Closed Eye Bolt	$30.00	4	$120.00		
4" G10 Airframe Plate	$6.00	8	$48.00		
3" G10 Airframe Bulkplate	$5.00	8	$40.00		
3" Aluminum Bulkplate	$15.00	4	$60.00		
4" Aluminum Bulkplate	$20.00	4	$80.00		
4" Coupler Bulkplate	$4.00	4	$16.00		
3" Coupler Bulkplate	$3.50	4	$16.00		
Electric Matches	$1.50	60	$90.00		
Aero Pack 54mm Retainer (Fiberglass Motor Tubes)	$29.00	1	$29.00		
Cesaroni K661	$150.00	5	$150.00		
Total Vehicle Cost				$1,620.00	
Recovery					
Iris Ultra 120" Compact Parachute	$504.00	1	$504.00		
24" Elliptical Parachute	$60.00	1	$60.00		
4F Black Powder	Kept by mentor				
Batteries (9v, 2 pack)	$7.00	3	$21.00		
Battery Holder	$1.00	5	$5.00		
Stratologger CF Flight Computer	$55.00	1	$55.00		
RRC3 Flight Computer	$70.00	1	$70.00		

PerfectFlite Pnut (2 units)	$55.00	2	$110.00		
Total Recovery Cost				$825.00	
Payload					
K30 CO2 Sensor	$85.00	1	$85.00		
Arduino Uno kit (includes LED, resistors, regulators, etc)	$35.00	1	$35.00		
SD card + Adapter	$10.00	1	$10.00		
PerfectFlite Pnut Altimeter	$50.00	2	$100.00		
Lithium Ion Batter (rechargable)	$100.00	1	$100.00		
Total Payload Cost				$330.00	
GPS System					
Whistle GPS Dog Tracker Kit	$75.00	1	$75.00		
Cellular Service Fee (3 months free, 5 months to pay)	$40.00	1	$40.00		
Total Payload Cost				$115	
Educational Outreach					
Color fliers (250 copies)	$170.00				
Total Educational Outreach Cost				$170	
Travel (7 Members)					
Trips to Lucerne ($2.80/gal, 112mi; $21.00 per trip per car)					
Huntsville, Alabama (roundtrip plane ticket)	$332.00	7	$2,324.00		
Hotel (4 rooms, 6 days)	$130.00	24	$3,120.00		
Hotel (2 people per room, 6 days)	$25.00	6	$1,050.00		
Total Travel Cost (Estimated)				$6,494.00	

6.3.1.1 Funding Plan

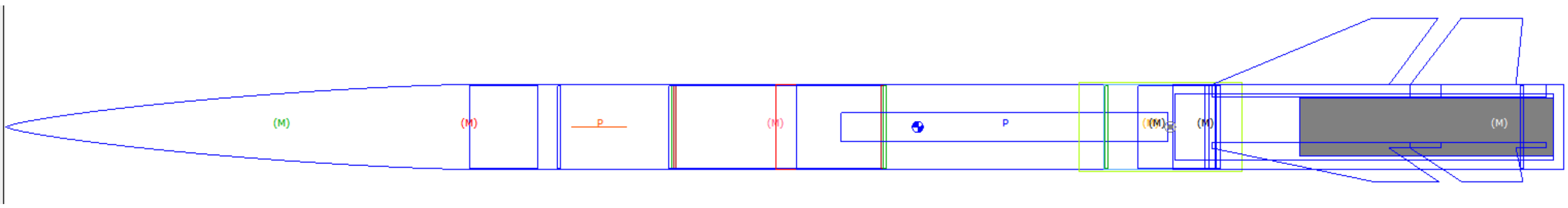
Our rocket team will procure funds from various sources. Action plans include the following: sell See’s candies and Mary Kay cosmetics to fundraise, go around the community to collect items for a garage sale and also ask for donations, explain to them what the team’s goal is, send letters to local businesses and aerospace companies requesting financial aid, and speak to vendors involved in rocketry and other supplies for discounts and donations. We have already obtained funds from selling artwork to art patrons and will continue doing so. Some the sponsors we have currently are Apex Desks, Pegasus Management, and Yogurtland.

6.3.2 Timeline

We haven't figured out how to combine the two PDFs, so the timeline will be here.

Appendix A: Scale Model

We will use a scale model of the designed rocket to verify that the subsystems are operational in



flight.

The diameter is 3” and the length is 57.125”. The scale factor should be ¾. We have decided to use a Cesaroni J240 to test the scale model. The scale model can achieve an altitude of 3094 ft, which will be just high enough for us to test our redundant recovery system and observe the success of this subsystem from a distance at which the rocket will still be visible.

Appendix B: Material Safety Data Sheet

MSDS Outline

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

Fiberglass

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

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

Appearance and Odor: White/off-white colored solid with no odor.
Primary Route(s) of Exposure: Inhalation, skin, eye
Potential Health Effects:

- **Acute (short term):** Fiber glass continuous filament is a mechanical irritant. Breathing dusts and fibers may cause short term irritation of the mouth, nose and throat. Skin contact with dust and fibers may cause itching and short term irritation. Eye contact with dust and fibers may cause short term mechanical irritation. Ingestion may cause short term mechanical irritation of the stomach and intestines. See Section 8 for exposure controls.

- **Chronic (long term):** There is no known health effects connected with long term use or contact with this product. See Section 11 of MSDS for more toxicological data.

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

Black Powder 4F

Hazardous Components

Material or Component	%	CAS no.	TLV	PEL
Potassium Nitrate	70-76	007757-79-1	NE	NE

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

Physical Data

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

Hazardous Reactivity

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

Fire and Explosion Data

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

- Division 1.1 Explosives (heavily encased): Evacuate the area for 5000 feet (1 mile) if explosives are heavily encased.
- Division 1.1 Explosives (not heavily encased): Evacuate the area for 2500 feet (½ mile) if explosives are not heavily encased.

- Division 1.1 Explosives (all): Consult the 2000 Emergency Response Guidebook, Guide 112 for further details.

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

Health Hazards

General: Black powder is a Division 1.1 Explosive, and detonation may cause severe physical injury, including death. All explosives are dangerous and must be handled carefully and used following approved safety procedures under the direction of competent, experienced persons in accordance with all applicable federal, state, and local laws, regulations, and ordinances.

Carcinogenicity: None of the components of Black powder are listed as a carcinogen by NTP, IARC, or OSHA.

First Aid

Inhalation: Not a likely route of exposure. If inhaled, remove to fresh air. If not breathing, give artificial respiration, preferably by mouth-to-mouth. If breathing is difficult, give oxygen. Seek prompt medical attention.

Eye and Skin Contact: Not a likely route of exposure. Flush eyes with water. Wash skin with soap and water.

Ingestion: Not a likely route of exposure.. If ingested, induce vomiting immediately by giving two glasses of water and sticking finger down throat.

Injury from Detonation: Seek prompt medical attention.

Spill or Leak Procedures

Spill/Leak Response: Use appropriate personal protective equipment. Isolate area and remove sources of friction, impact, heat, low level electrical current, electrostatic or RF energy. Only competent, experienced persons should be involved in cleanup procedures. Carefully pick up spills with non-sparking and non-static producing tools.

Waste Disposal: Desensitize by diluting in water. Open train burning, by qualified personnel, may be used for disposal of small unconfined quantities. Dispose of in compliance with federal regulations under the authority of the Resource Conservation and Recovery Act (40 CFR Parts 260-271).

Special Protection Information

Ventilation: Use only with adequate ventilation.

Respiratory: None

Eye: None

Gloves: Impervious rubber gloves

Other: Metal-free and non-static producing clothes

Ammonium Perchlorate Composite Propellant (APCP)

Product Name: Ammonium Perchlorate
Other/Generic Names: AP, ammonium salt of perchloric acid
Product Use: Analytical chemistry, oxidizer in various propellant or explosive mixtures, various industrial uses involving need for oxidizing or ionization in aqueous solution properties.
Manufacturer: American Pacific Corporation, Western Electrochemical Co. 10622 West 6400 North, Cedar City, UT 84721
For More Information Call: (435) 865-5000
In Case of Emergency Call: (435) 865-5044

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

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

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

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

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

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

Special Fire Fighting Precautions/Instructions: Do not fight fires involving mixtures of ammonium perchlorate and fuels. Ammonium perchlorate is an oxidizing agent and may cause rapid combustion or explosions if mixed with fuels. Burning ammonium perchlorate may produce chlorine, chlorine dioxide, hydrogen chloride, and oxides of nitrogen as well as mixtures with any other compounds involved in the combustion. These are common by-products of combustion and are likely to be serious health concern; thus, keep upwind or wear self-contained breathing apparatus when attempting to rescue.
In Case of Spill or Other Release: (See section 8 for recommended personal protective equipment.) Sweep up material and containerize. Clean contaminated floor surface with water. Ammonium perchlorate is water soluble; thus, manage water to avoid release into the environment. Dispose of in accordance with local, state, and federal regulations.
Normal Handling: (See section 8 for recommended personal protective equipment.) Avoid contact with skin, eyes and clothing. Avoid breathing dust. Wash thoroughly after handling and follow good personal hygiene and good housekeeping practices. Keep containers closed. Handle in a manner to minimize dusting. Use of containers that meet the requirements to be DOT approved shipping containers which are managed in a manner to inhibit intimate mixtures of the container material with the product is recommended. Materials such as plastic drums, steel drums, flexible intermediate bulk containers, and fiberboard containers approved or constructed to the same specifications as DOT requirements are normally safe. FIBC are normally constructed of plastic materials in which intimate contamination soaked into the plastic is difficult to achieve. If in doubt wet and wash the FIBC and manage the water used to wash in accordance with good environmental principles to avoid contaminating drinking water sources or organic materials more subject to intimate mixtures.
Storage Recommendations: Store away from combustibles and flammables. Keep container closed when not in use. Control static electricity and other ignition sources. Store in dry areas away from sources of extreme heat.
Special Mixing and Handling Instructions: Ground and bond process equipment. Mixing ammonium perchlorate with fuels of any type may result in rapid combustion or explosions. When handling materials contaminated with ammonium perchlorate such as dust collector bags or any other combustible material, thoroughly wet the bags with water before handling, keep the bags wet while handling, and use non-sparking tools or tools coated with non-sparking material if non-sparking tools are not available. AVOID friction, impact, or static electricity ignition sources when organic materials are contaminated with ammonium perchlorate. Fire resistant fabrics do not reduce the hazard. Finely powdered metals are frequently as combustible with ammonium perchlorate as are organics.
Engineering Controls: Ventilate as necessary to minimize dust exposures. Inspect and clean ventilation systems regularly.
Personal Protective Equipment Skin Protection: Wear impervious aprons or rain gear to reduce contamination of cotton or other fiber clothing. Plastic, rubber or latex gloves are recommended. Leather or cotton gloves should not be used unless a management program is

implemented to ensure detection of contamination and immediate cleaning and change in case of contamination. Cotton clothing may be used if chance of contact is minimal or if clothing is monitored for contamination and changed if contamination occurs. In any case where combustible protection is used, a strong management system must be in place to monitor contamination and ensure appropriate removal and cleaning or severe risk of fire and personal injury or death exists. There are no known cloth materials that will not combust vigorously with perchlorates including nomex, Kevlar based materials, or clothing that is normally considered fire retardant or resistive. Observation and management of contamination is the only practicable safety measure. See additional recommendations below.

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

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

Normally Stable (Conditions To Avoid): Stable under normal conditions. Do not mix with organic materials, reducing agents, metal powders or powdered carbon. Avoid elevated temperatures over 270°C, which can cause spontaneous exothermic decomposition. Cloth fabric of any type including dust collector bags intimately contaminated with ammonium perchlorate is subject to ignition through friction or impact. High-energy static electricity may also serve as an ignition source when contamination or combustibles are intermixed.
Incompatibilities: Sulfuric acid, powdered metals, and intimate mixtures with organics.
Hazardous Decomposition Products: Chlorine, chlorine dioxide, oxygen, nitrogen oxides, hydrogen chloride.
Hazardous Polymerization: Will not occur.
As with any toxicant, dose and exposure are critically important variables to understand any potential toxicity. It is always advisable to minimize dusting and use respiratory protection for environments where substantial dust is generated or where there may be exposure to water with high concentrations of perchlorate. Ammonium perchlorate acts to reversibly and competitively inhibit iodine uptake by the thyroid gland. The half-life of ammonium perchlorate ranges from 8 to 12 hours. Ammonium perchlorate does not bioaccumulate. Perchlorate is not metabolized and is excreted from the kidneys. Harmful if swallowed or inhaled in large doses. In the early 1960s another salt of perchlorate, potassium perchlorate, given in very high doses for weeks of exposure as an oral therapeutic agent to treat hyperthyroidism was reported to be associated with a few cases of aplastic anemia and agranulocytosis (National Research Council, 2005). Since that time, there have been no known reports of aplastic anemia. There have been no reports of ammonium perchlorate associated with aplastic anemia or agranulocytosis.
Immediate (Acute) Effects: Oral LD50: rat; 4200 mg/kg Rat-par-LDLo = 3500 mg/kg Oral LD50: rabbit; 1900 mg/kg Rabbit-par-LDLo = 750 mg/kg Inhalation LC50: No references found. Skin sensitization: not reported to be a skin sensitizer
Delayed (Subchronic And Chronic) Effects:

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

Appendix C: Written Statement from Team Members Regarding Safety

We, the team members of the Student Launch team of the AIAA OC Section will understand and abide by the following safety regulations:

- Range safety inspections of each rocket before it is flown. Each team shall comply with the determination of the safety inspection or be removed from the program.
- The Range Safety Officer has the final say on all rocket safety issues. Therefore, the Range Safety Officer has the right to deny the launch of any rocket for safety reasons.
- Any team that does not comply with the safety requirements will not be allowed to launch their rocket.

No.	Date	Name	Signature
1	8/20/16	Albert Wen	
2	8/20/16	Norman Chu	
3	8/20/16	David Chang	
4	8/20/16	Kushagra Pandey	
5	8/20/16	Claire Chang	
6	8/20/16	Sahil Patne	
7	8/20/16	Allison Chen	

Appendix D: Shop Safety

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

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

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

Generally:

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

Electrical Tools

- Do not work with power tools unless there is at least one other person in proximity.

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

Appendix E: Flight Diagram