Student Launch Flight Readiness Review (FRR)

Carbon Dioxide Analysis in Troposphere with Autonomous Air Brakes

Mailing Address:

15 Wyoming
Irvine, CA 92606

AIAA OC Section

3/4/17

Table of Contents

1. Summary of FRR Report

1.1 Team Summary

1.1.1 Team Name and Mailing Address

The official 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

1.2.1 Size and Mass

- Length - 101.5 in
- Diameter - 4 in
- Semi Span of Fins - 4.5 in
- Total Mass, -10891.8868 g or 24.0125 lbs

1.2.2 Final Motor Choice

We have chosen the Cesaroni K555 motor to help us with our flight.

1.2.3 Recovery System

The recovery electronics will be in the avionics bay, a 12.2.5" tube coupler with a 3" collar made of 4" G10 fiberglass body 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.

1.2.4 Rail Size

The rail will be 8 ft long with a 4 ft extension. This would make the rail a total length of 12 ft.

1.2.5 Milestone Review Flysheet

The Milestone Review Flysheet provides further specifics and is available under the tab **SL 2016-2017 > Documents** at verticalprojectile.org.

1.3 Payload Summary

1.3.1 Payload Title

K30 CO_2 sensor

1.3.2 Summarize Experiment

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. Changes made since CDR

2.1 Changes Made to Vehicle Criteria

- Addition of fiberglass tape to reinforce rocket fins
- Aluminum bulkheads sealed with silicon gel and O-rings to prevent black powder gas from affecting electronics
- MG Chemicals SuperShield spray added to prevent RF interference
- Main chute deployment changed to 500 ft to reduce drift
- Rail extended to 12 ft to help rocket meet minimum rail exit velocity

2.2 Changes Made to Payload Criteria

No changes were made to the payload.

2.3 Changes Made to Project Plan

No changes were made to the project plan.

3 Vehicle Criteria

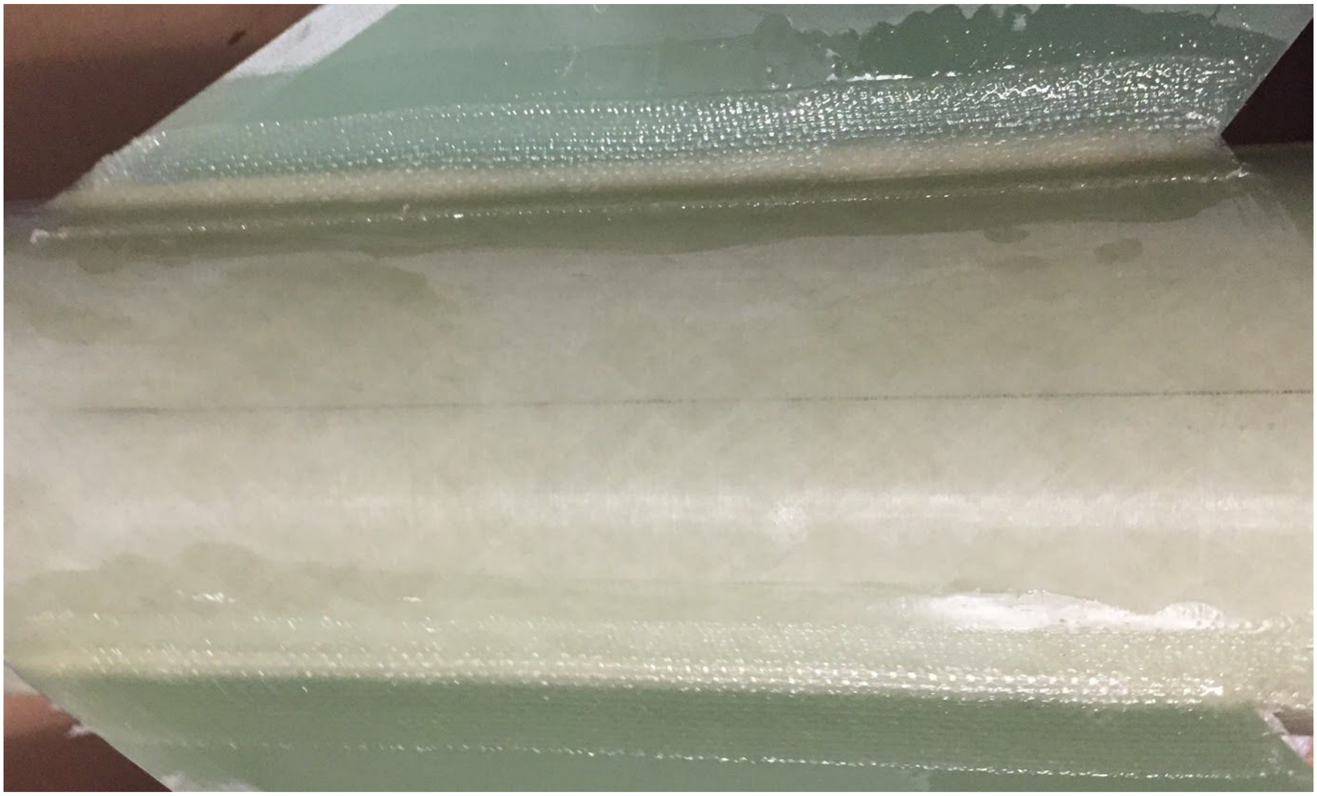
3.1 Design and Construction of Vehicle

3.1.1 Description of Changes in the Launch Vehicle Design from CDR

3.1.1.1 Fiberglass Tape

Fiberglass tape is a mix of West Systems 24-hour epoxy and fiberglass fabric. These are placed at the junction between the body tube and fins to prevent the fillets from breaking.

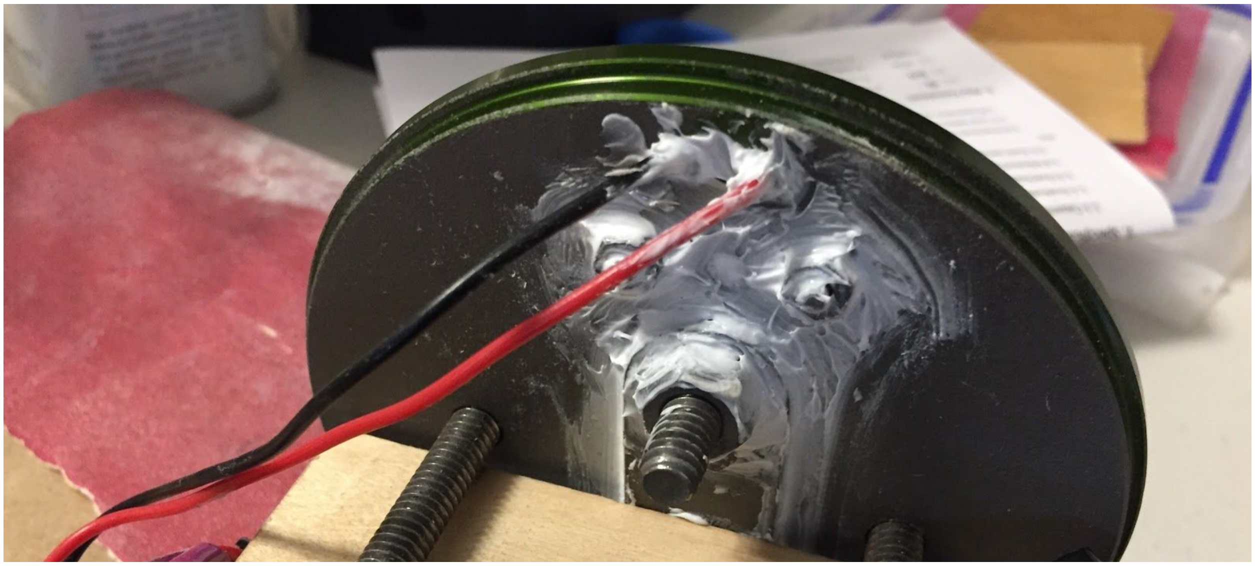
The addition of fiberglass tape became necessary after a fin broke after our first launch of the full scale rocket. We placed the fiberglass tape on the rocket after we had sanded and put the broken-off fin back inside the right place. The tape has a noticeably different texture than the fiberglass tube.



3.1.1.2 Silicon Gel

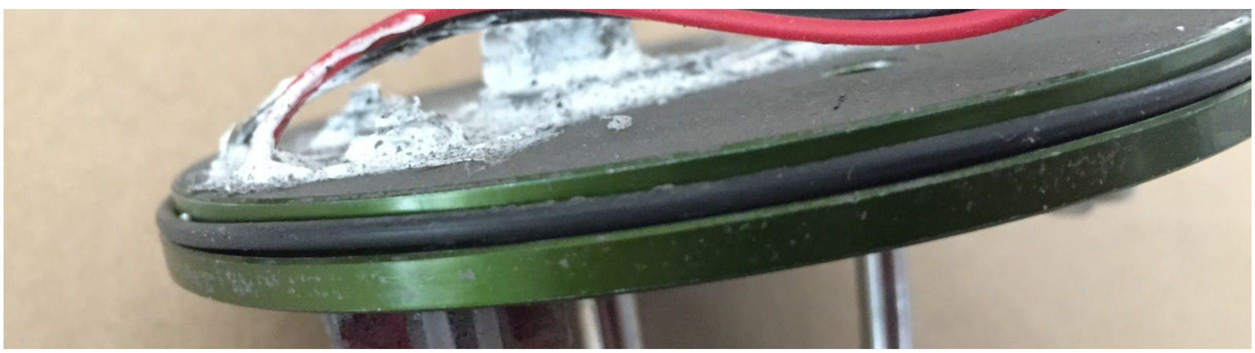
We noticed a significant spike in the avionics electronics in our subscale flight, but this was a result of the enclosure's numerous holes we had not plugged with epoxy. We did not make excess holes in our full scale rocket's avionics enclosure, but we still noticed a significant change in altitude after observing our avionics' electronic data.

Having large spikes in altitude are particularly concerning, as the electronics can mistake the rocket's current altitude for the altitude at which it ejects the main chute, leading to an early main chute ejection and significant drift.



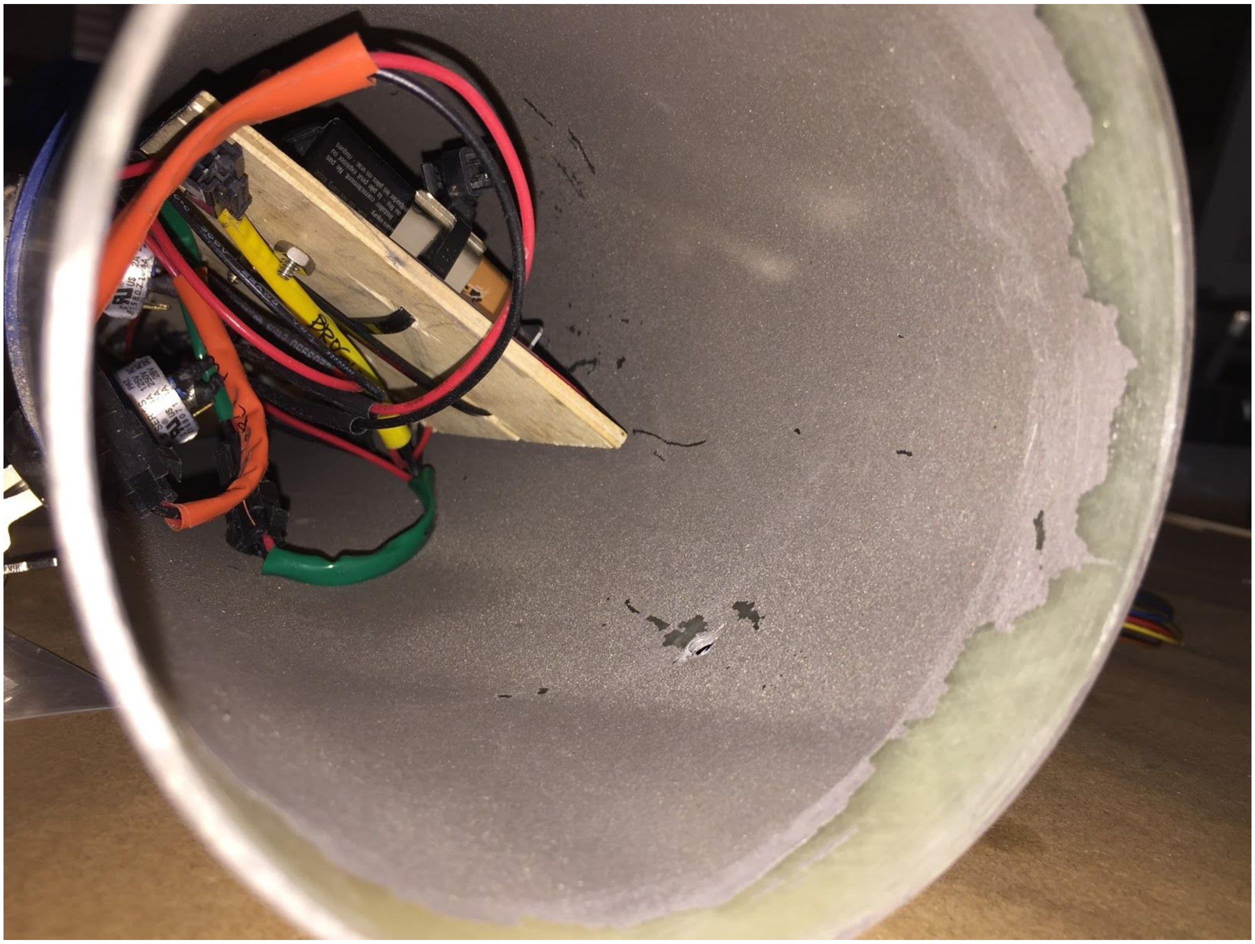
3.1.1.3 O-Rings

To further address completely sealing the flight computers, we added a black rubber lining, O-rings, around the aluminum bulkheads.



3.1.1.4 MG Chemicals SuperShield

This gray spray helps to prevent radio frequency waves from interfering with the data collection of the flight computers.



3.1.2 Description of Features that Enables the Vehicle to be Launched and Recovered

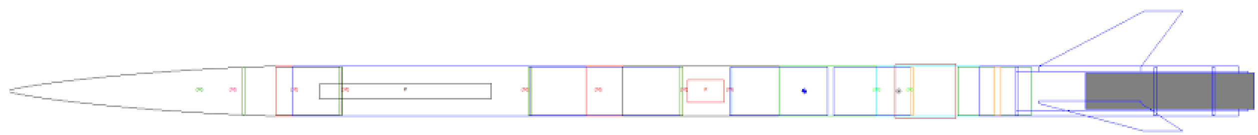
- Launch Rail - The launch rail is a tall, upright structure that is used to aim the rocket at an acute or zero angle of attack
- Parachute - The parachute is a large fabric that is connected to the rocket with shroud lengths that can be choked manually or as in our rocket, with a linear actuator that uses a code to adjust based on descent rate and optimal time.
- GPS - We use a dog tracking device that is inputted into the nose cone that is connected wirelessly to an app on our phone which allows for quick recovery as long as the rocket remains within the whistle zone (radius that is able to pick up the rocket's location).

3.1.2.1 Structural Elements

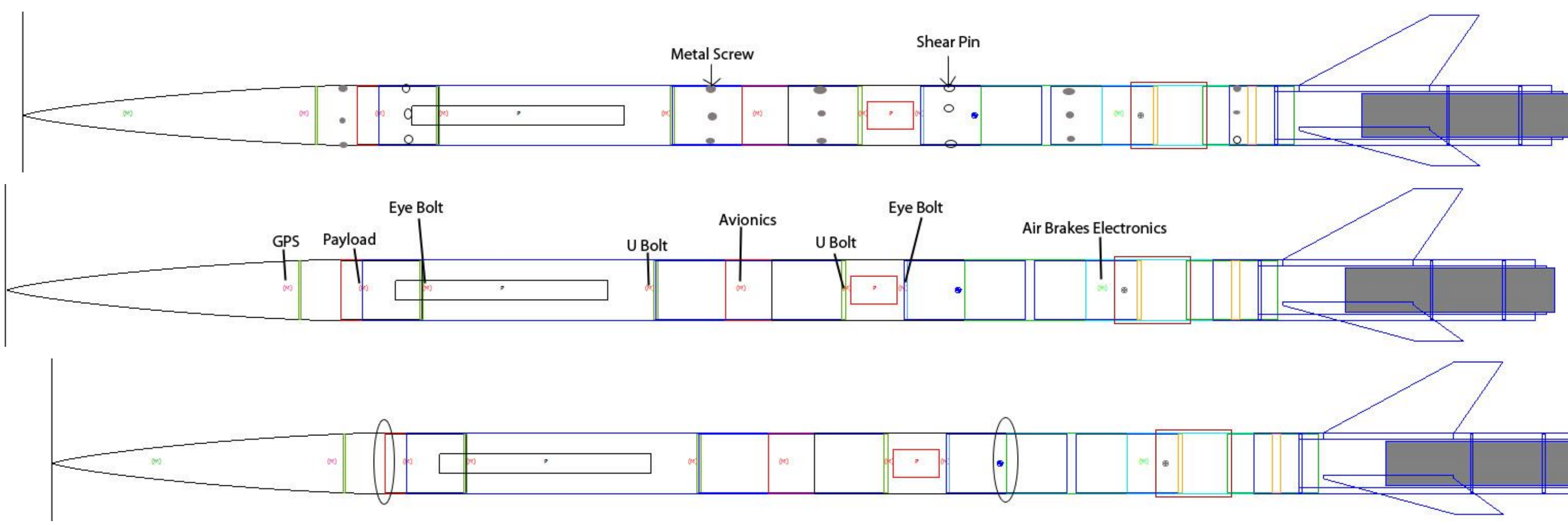
- Fiberglass - Fiberglass is the primary structural material used in the building of this rocket besides the nose cone which uses polystyrene. The other materials included in the rocketry the 24-hour epoxy as well as a fiberglass tape used to help keep the fins in position and firm.

3.1.2.2 Electrical Elements

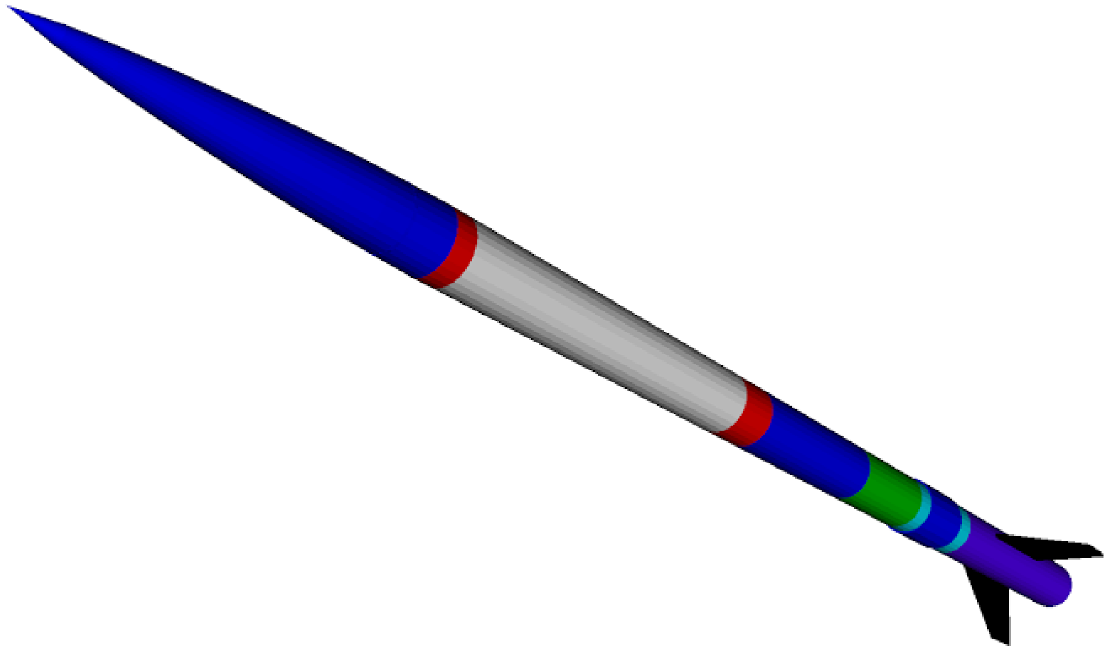
3.1.2.3 Drawings and Schematics of the Launch Vehicle to Describe the Assembly



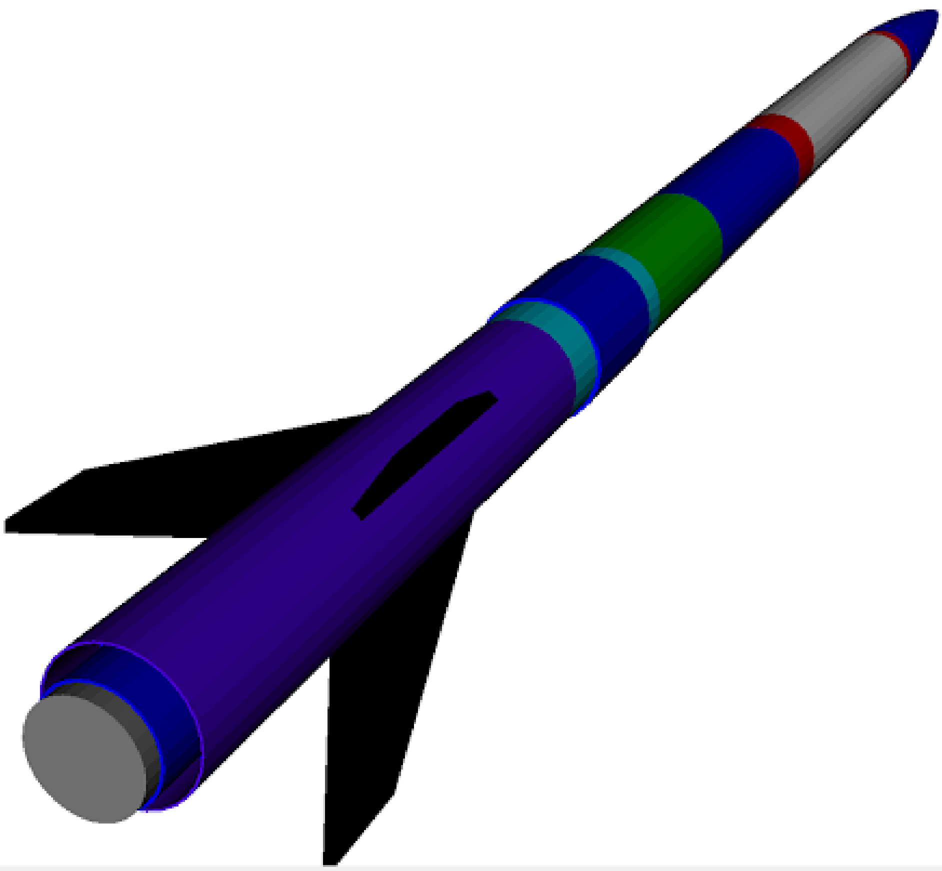
2D view



The circles above illustrate the separation points of the rocket.



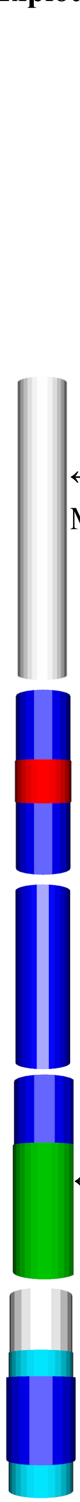
Front view



Rear view

The different colored body tubes of the above 3D rocket diagrams delineate a module.

Exploded Diagram (CAD)



The nose cone and payload module comprise one independent section.

The upper body tube, avionics bay, and middle body tube comprise one independent section.

The remaining modules comprise one independent section.

3.1.3 Flight Reliability Confidence

- Following our full-scale flight, the Student Launch team can say with absolute confidence that the design is functional and safe for the project. There was a successful dual deploy, and though we didn't use the air brakes, the flight reached 5451 feet which provides a healthy amount of altitude for the air brakes to cut down to (optimal height is 5280 feet, 1 mile).
- There was mild damage to one of the fins when the rocket was descending after the main chute deployment as it descended straight onto the fit and knocked it out of its placement but it was easily fixed and now has fillets as well as fiberglass tape for extra holding strength.

3.1.4 Construction Process Used to Assemble the Vehicle

- The construction process begins with cutting and sanding of all the correct body tubes as well as the creation of the inner portions of the rocket.
- Sanding of the fiberglass is required to make sure the epoxy can take a firm hold on both the tube you are gluing as well as the tube it is being glued onto.
- Next, the fins are set using a fin-jig as well as rubber bands to hold them in place. This is then set for a couple days to ensure that the fins are properly glued and are strong so they don't fall off inflight or in case of a hard landing.
- Next, two types of holes are drilled on the rocket called MS (metal screws) or SP (shear pins) with the MS providing support on the rocket and keeping everything attached correctly and firmly. The SP are used to keep the midsection together which are then ripped when the black powder charge is set off at apogee.
- Finally, once construction is complete including the avionics bay (recovery systems) the black powder test is done which then makes sure that the charge separates the body tube and fully expels the parachute which should be similar to conditions midflight.

3.2 Recovery Subsystem

3.2.1 Description of the Robustness of the Recovery System

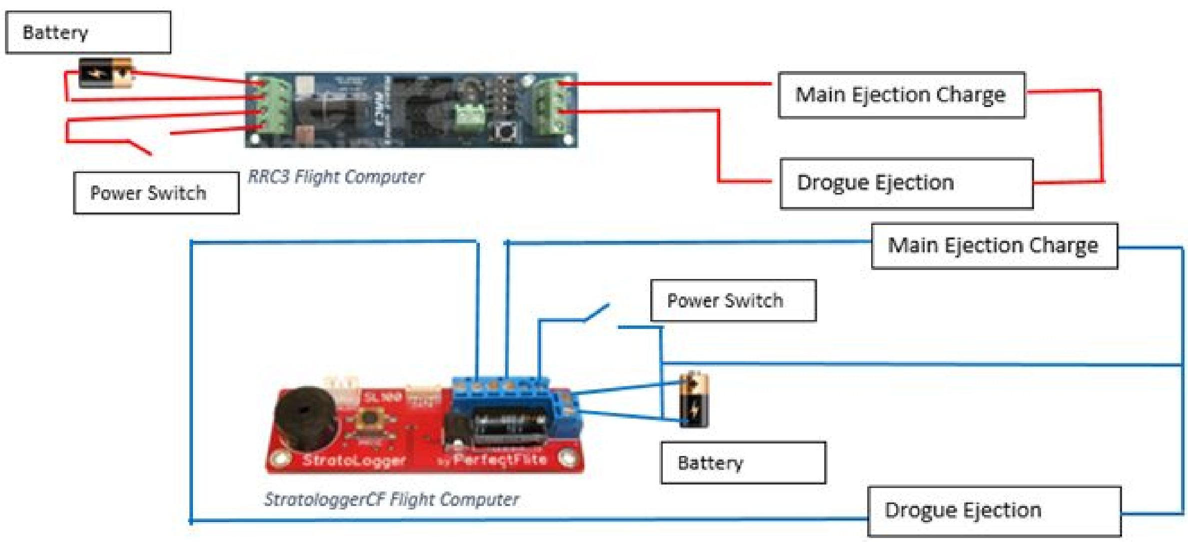
3.2.1.1 Structural Elements

The avionics bay is a wooden sled fit inside a tube coupler. Two metal rods provide most of the structural stability, as the necessary electronics (flight computers, batteries, etc) are screwed onto the sled.

3.2.1.2 Electrical Elements

The avionics bay has two main electrical elements: the flight computers and the batteries. The batteries are 9 V batteries and can last an entire day without being drained. The Stratologger CF is the primary flight computer, and the RRC3 is the secondary flight computer. Each flight computer also has a switch which can be accessed from the outside of the rocket, and it is used to turn on the avionics before launching the rocket. Finally, black powder ejection charges can be connected to each flight computer, which deploy the parachutes while the rocket is descending.

3.2.1.3 Redundancy Features



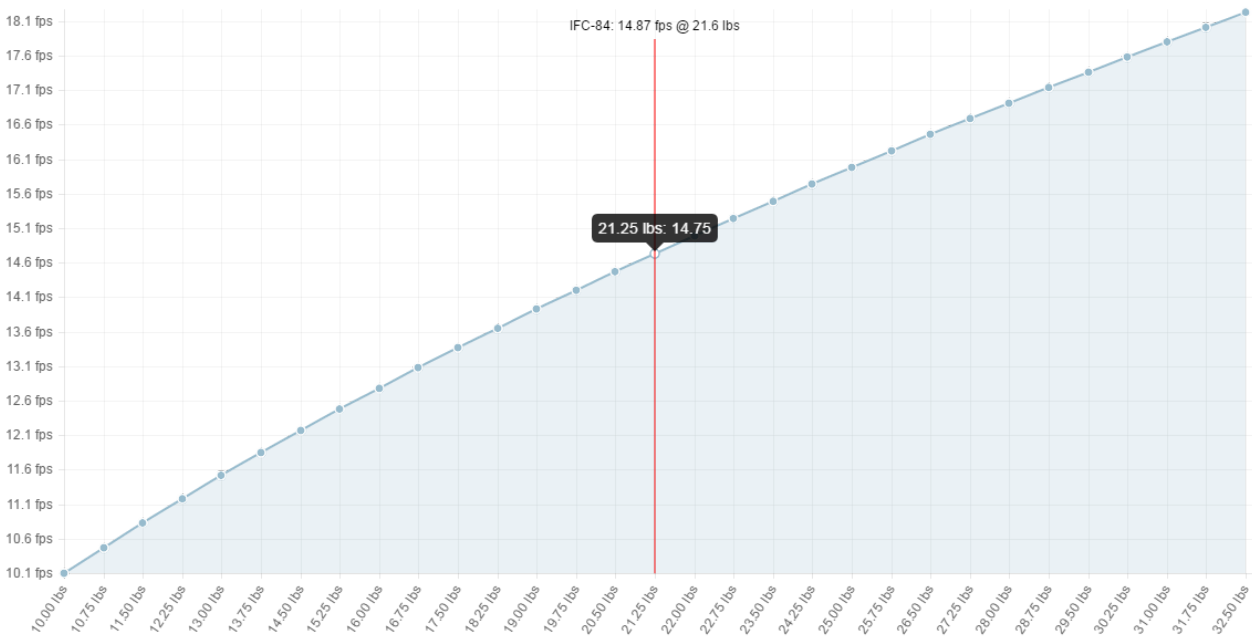
The fact that the wires of the stratologger and RRC3 do not get mixed together proves the redundancy of the dual-deploy system.

3.2.1.4 Parachute Sizes and Descent Rates

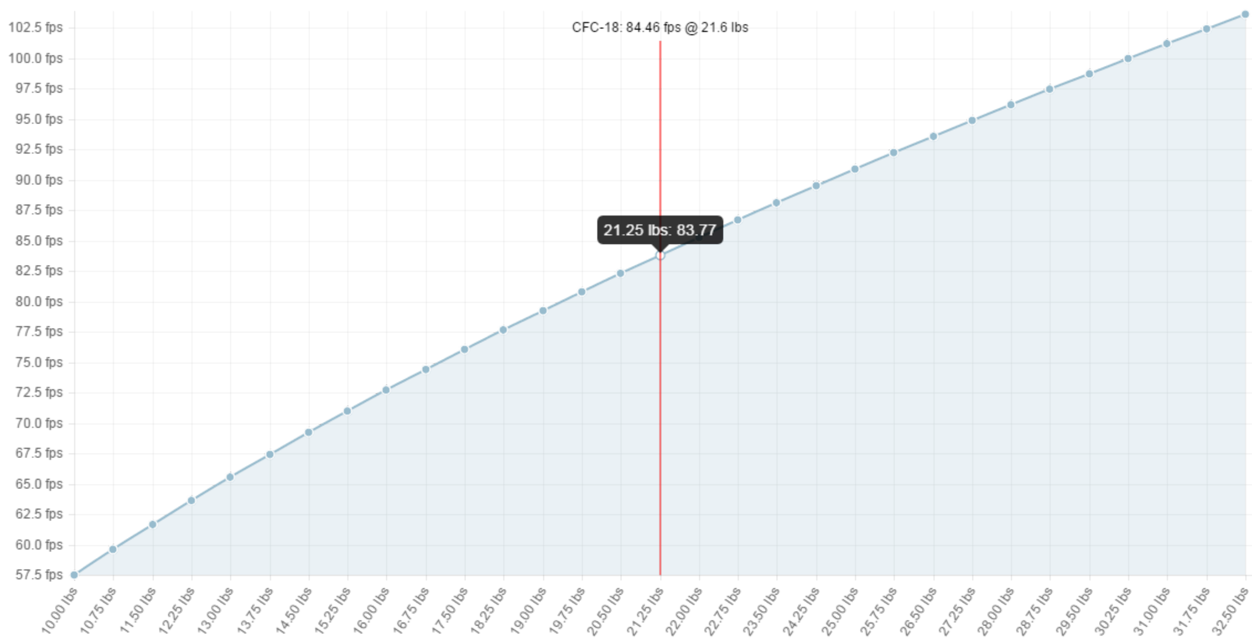
Our main chute is 84” in diameter, deployed at an altitude of 500 ft.
Our drogue chute is 18” in diameter, deployed at apogee

The following relates to the full scale rocket’s descent rate.

Full Scale Descent Rate vs Weight, Main



Full Scale Descent Rate vs Weight, Drogue

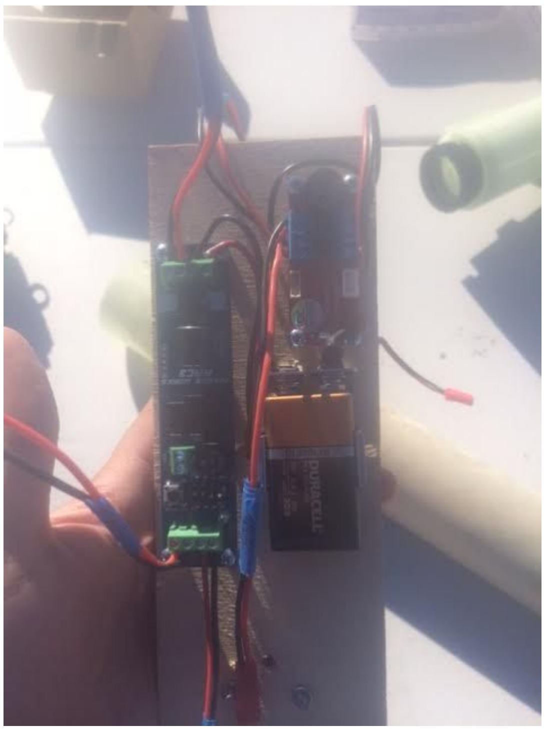


Graphs from the parachute manufacturer: Fruity Chutes. This is their descent rate calculator.

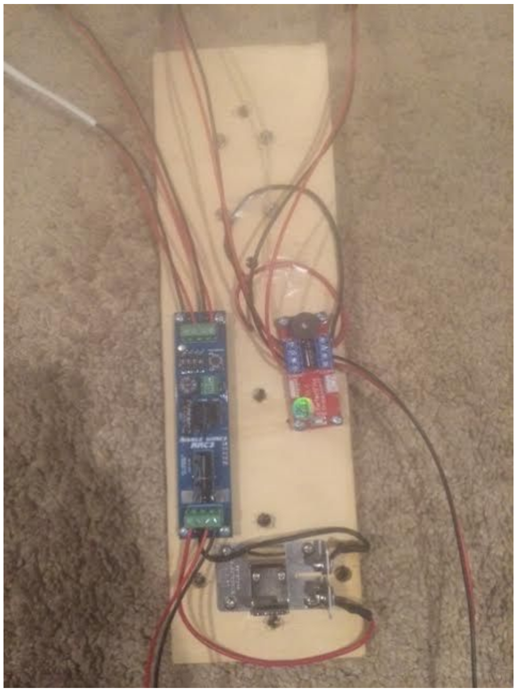
3.2.1.5 Drawings and Schematics of Electrical and Structural Assemblies

As of now there are no electric schematics for the avionics bay. The following are diagrams associated with the recovery electronics.

Subscale:



Full Scale:



3.2.1.6 Rocket-locating Transmitters (Frequency, Wattage, Range)

The recovery electronics don't have a unique tracking feature but rather uses the general tracker for the rocket. See the GPS whistle dog tracker for information on the rocket's GPS.

3.2.1.7 Sensitivity of Recovery System

The recovery subsystem is extremely accurate in predicting the altitude of the rocket, as both the stratologger and RRC3 can deploy the parachute at any height with the increment of one foot. Both use a variety of physics formulas to achieve such accuracy.

3.3. Mission Performance Predictions

3.3.1 Mission Performance Criteria

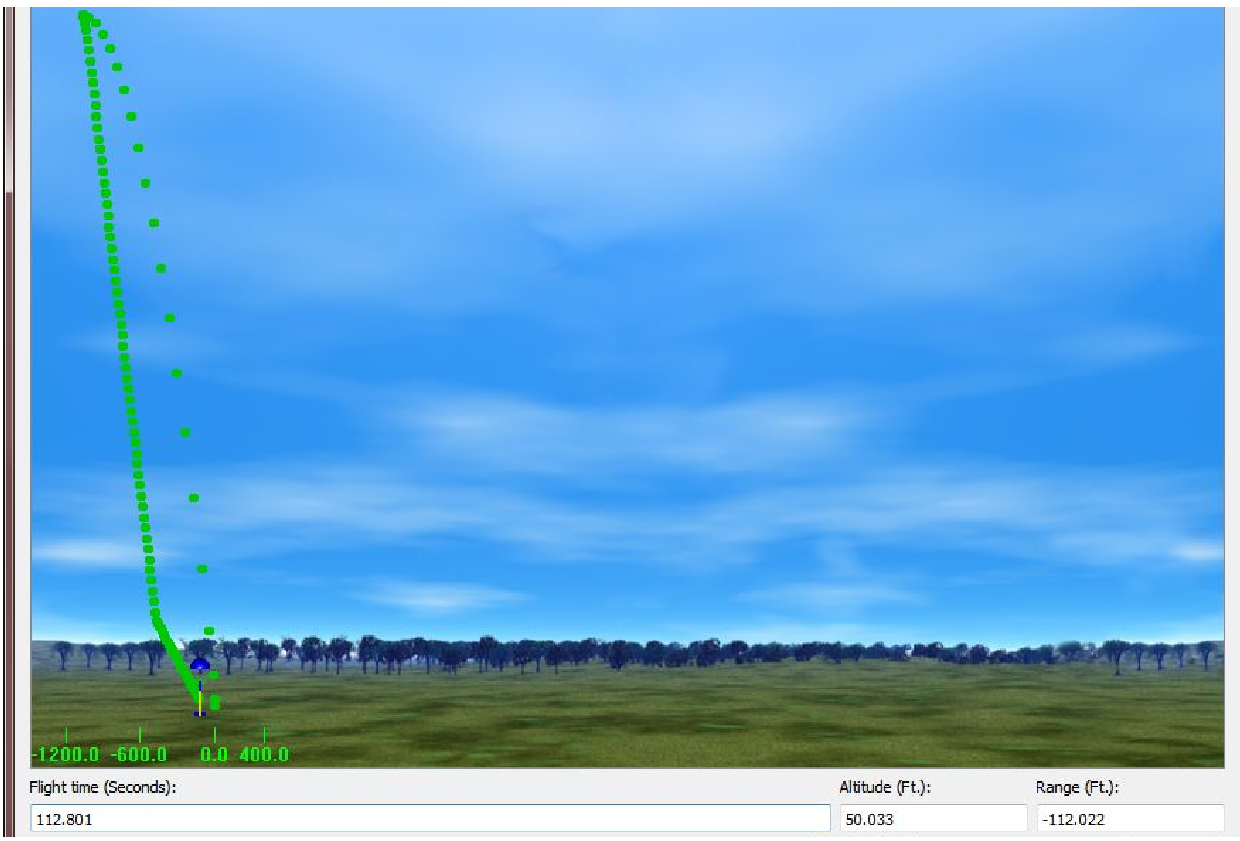
A successful mission is determined by the vehicle's success in the following areas: data collected, ascent, altitude reached, descent.

- 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 per independent section, returns data from the payload, and can be reused again, then the mission is a success in this aspect.

3.3.2 Simulation Data

3.3.2.1 Flight Profile Simulations



3.3.2.2 Altitude Predictions

	Simulation	Results	Engines loaded	Max. altitude Feet
1	0		[2406-K555-WH-P-N	5459.48
2	1		[2406-K555-WH-P-N	5465.19
3	2		[2406-K555-WH-P-N	5432.28
4	3		[2406-K555-WH-P-N	5465.19
5	4		[2406-K555-WH-P-N	5457.12
6	5		[2406-K555-WH-P-N	5435.17
7	6		[2406-K555-WH-P-N	5462.89
8	7		[2406-K555-WH-P-N	5465.19
9	8		[2406-K555-WH-P-N	5437.14
10	9		[2406-K555-WH-P-N	5464.67
11	10		[2406-K555-WH-P-N	5446.52

These are all simulations made without the aid of air brakes. Overshooting will work in the air brakes' favor, as the algorithm will be able to make the necessary corrections to reach the target altitude. It is better to be over the target altitude rather than under.

If necessary, we can add more weight to the rocket. Or we can correct the algorithm and have the air brakes extend outward for a longer period of time during the first five seconds of the flight.

3.3.2.3 Component Weights

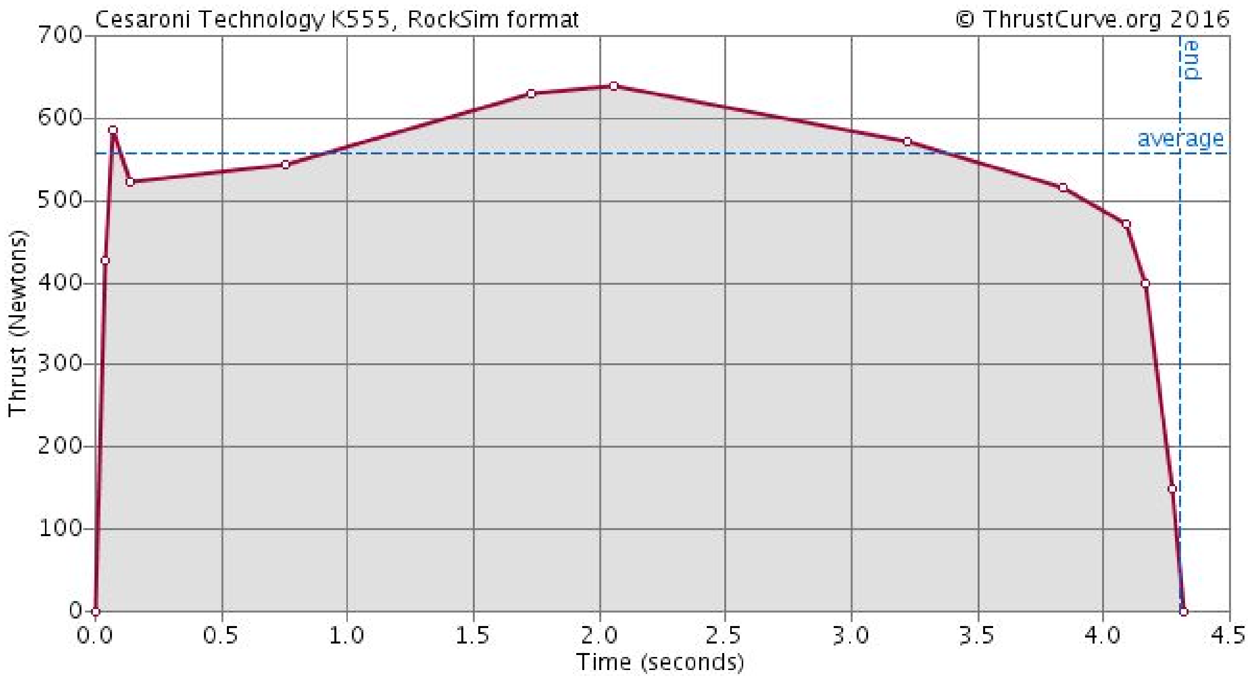
Component Name	Mass (g)	Length (in)	Thickness, if applicable (in)
Nose Cone	638.4	22	0.2
Whistle GPS	240		
Payload Collar	40	1.375	
Payload Enclosure	309	8	
Aluminum	100	0.25	0.25

Bulkhead			
Payload	142		
Aluminum Bulkhead	100	0.25	0.25
Eye Bolt	30		
Upper Body Tube	725	26	
84” Main Chute, swivel	540		
Blast Cloth	125		
Shock Cord	250		
Avionics Collar	60	1.5	
U Bolt	50		
Aluminum Bulkhead	100	0.25	0.25
Recovery Electronics (Avionics)	240		
2 Key Slots	160		
Electronics Bay (TC)	410	12.25	
Aluminum Bulkhead	100	0.25	0.25
U Bolt	50		
Middle Body Tube	387	12.75	
Shock Cord	200		
Drogue Chute	60		
Extension	250	8	
Eye Bolt	30		

2 Fiberglass Bulkheads	72	0.25	0.25
Tube Coupler	210	8	
Airbrake Module	235	8.375	
Tube Coupler	200	6.75	
Birch Bulkhead	87	0.25	0.25
Air Brakes	160	5	
Air Brakes Electronics	240		
Servo	285		
Booster	290	21.25	
Tube Coupler	250	7	
2 Fiberglass Bulkheads	50	0.25	0.25
Centering Ring	52.289	0.188	0.188
75 mm Motor Mount	550	19	
Fin Set	326	Semi-span: 4.5	0.3785
Centering Ring	52.289	0.188	0.188
Centering Ring	52.289	0.188	0.188
Motor Retainer	135.237		
Total	8586.504	101.5*	

*Some of the lengths were not included because they are inside. For example, a tube coupler does not contribute to the overall length of the rocket.

3.3.2.4 Motor Thrust Curve



Name	Total impulse (Ns)	Total Mass (g)	Max Altitude (ft), no air brake function	Max velocity (ft/s)	Max acceleration (ft/s^2)
K555	2400.688	2759.0	5451	661.14	615.88

3.3.3 Validity of Analysis

3.3.3.1 Drag Assessment

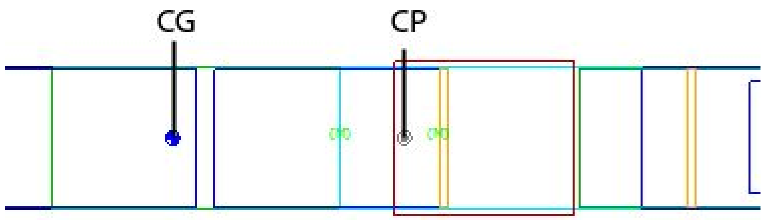
For us to evaluate the coefficient of drag of the rocket, we flew the rocket without the air brakes. This was also a good way for us to assess the rocket's maximum altitude to see if we would break the 5600 ft FAA waiver NASA has obtained at Marshall Space Flight Center. Our maximum alt

After simulating the rocket during its launch day conditions (Feb. 4, 2017), we found that the coefficient of drag for the rocket was 0.30.

3.3.3.2 Scale Modeling Results

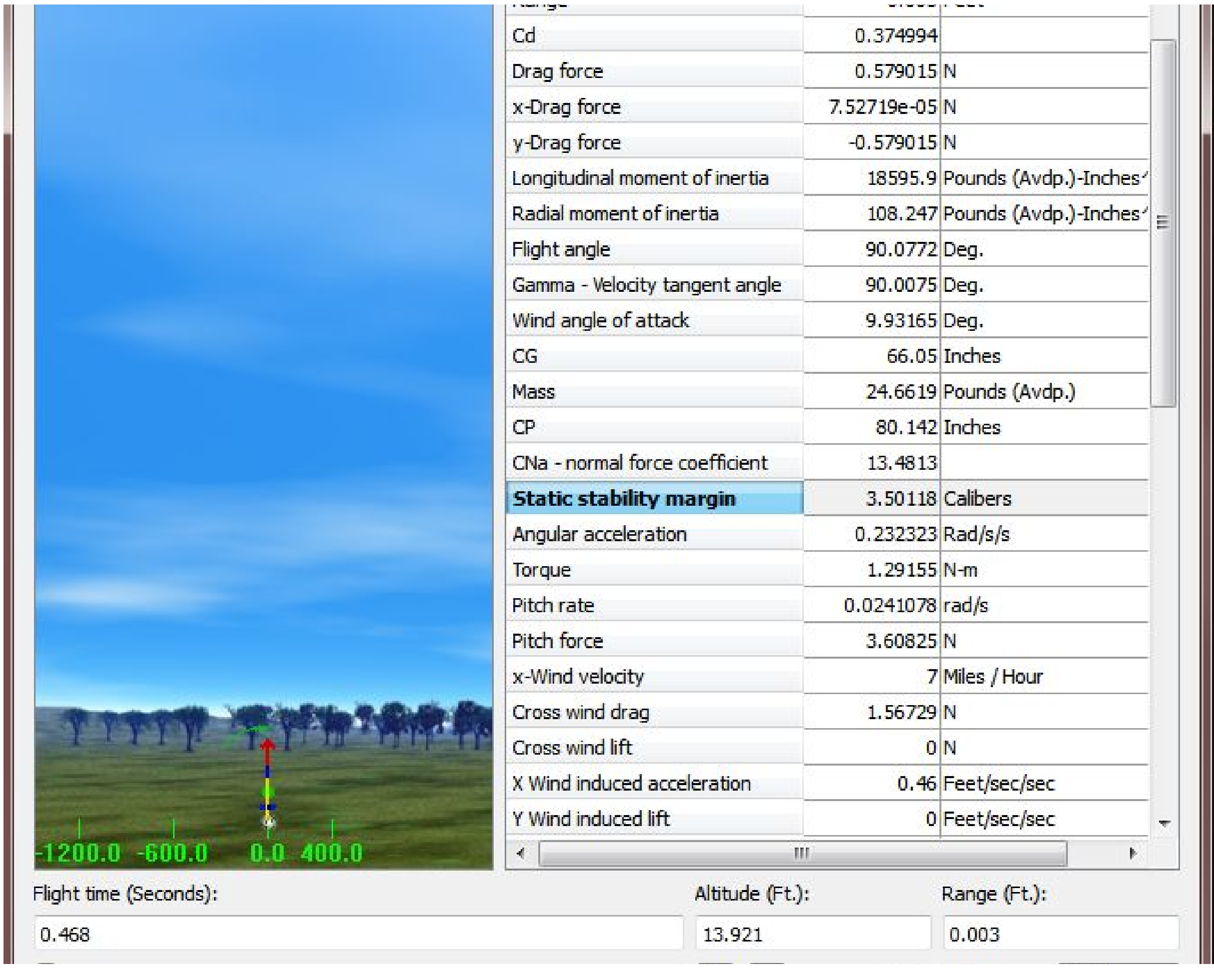
The scale model we used is 3:4. We came very close to creating rockets that were exactly similar in terms of scale.

3.3.4 Stability Margin (CP and CG locations)



CG: 66.4569 in from nose cone
CP: 72.8941 in from nose cone

$$Static\ stability\ margin = \frac{CP - CG}{Body\ Tube\ Diameter}$$
$$= \frac{72.8491'' - 66.4569''}{3''}$$
$$= 1.60\ calibers$$



The stability margin at rail exit is 3.50 calibers. The stability margin on the launch pad is 2.85.

3.3.5 Management of Kinetic Energy

To clarify, the weight of the rocket is 21.73 lbs after the motor has burned out.

3.3.5.1 With Drogue Chute Out

Section 1:

$$Kinetic\ energy = \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(2.9375\ lbs)(81 ft/s)^2\left(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}\right)$$
$$= 299.27\ lbf$$

Section 2:

$$Kinetic\ energy = \tfrac{1}{2}mv^2$$
$$= \tfrac{1}{2}(7.9125\ lbs)(81 ft/s)^2\left(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}\right)$$
$$= 806.12\ lbf$$

Section 3:

$$Kinetic\ energy\ =\ \frac{1}{2}mv^2$$
$$= \frac{1}{2}(10.8865\ lbs)(81 ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 1109.10\ lbf$$

3.3.5.2 With Main Chute Out

Section 1:

$$Kinetic\ energy\ =\ \frac{1}{2}mv^2$$
$$= \frac{1}{2}(2.9375\ lbs)(10\ ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 4.56\ lbf$$

Section 2:

$$Kinetic\ energy\ =\ \frac{1}{2}mv^2$$
$$= \frac{1}{2}(7.9125\ lbs)(10\ ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 12.29\ lbf$$

Section 3:

$$Kinetic\ energy\ =\ \frac{1}{2}mv^2$$
$$= \frac{1}{2}(10.8865\ lbs)(10\ ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft})$$
$$= 16.90\ lbf$$

3.3.6 Altitude and Drift for Winds of 0, 5, 10, 15, 20 mph

The rocket achieved an altitude of 5451 ft for its first launch. Its altitude for the second launch was 5359 ft, with the aid of air brakes.

The following drift calculations shall be performed under the assumption that the rocket will be launched straight up, or at a zero degree launch angle.
The subscale and full scale deploy their drogue chutes at apogee, and their main chutes at 500 ft AGL.

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

Drift in No Wind

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

Drift in 5-mph Wind

$$Drift = 113\ s \times (\frac{5\ miles}{1\ hour} \times \frac{1\ hour}{3600\ seconds})$$
$$= .157\ miles$$
$$= 829\ ft$$

Drift in 10-mph Wind

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

Drift in 15-mph Wind:

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

Drift in 20-mph Wind

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

3.4. Full Scale Flight

A video of our second full scale flight is available here.

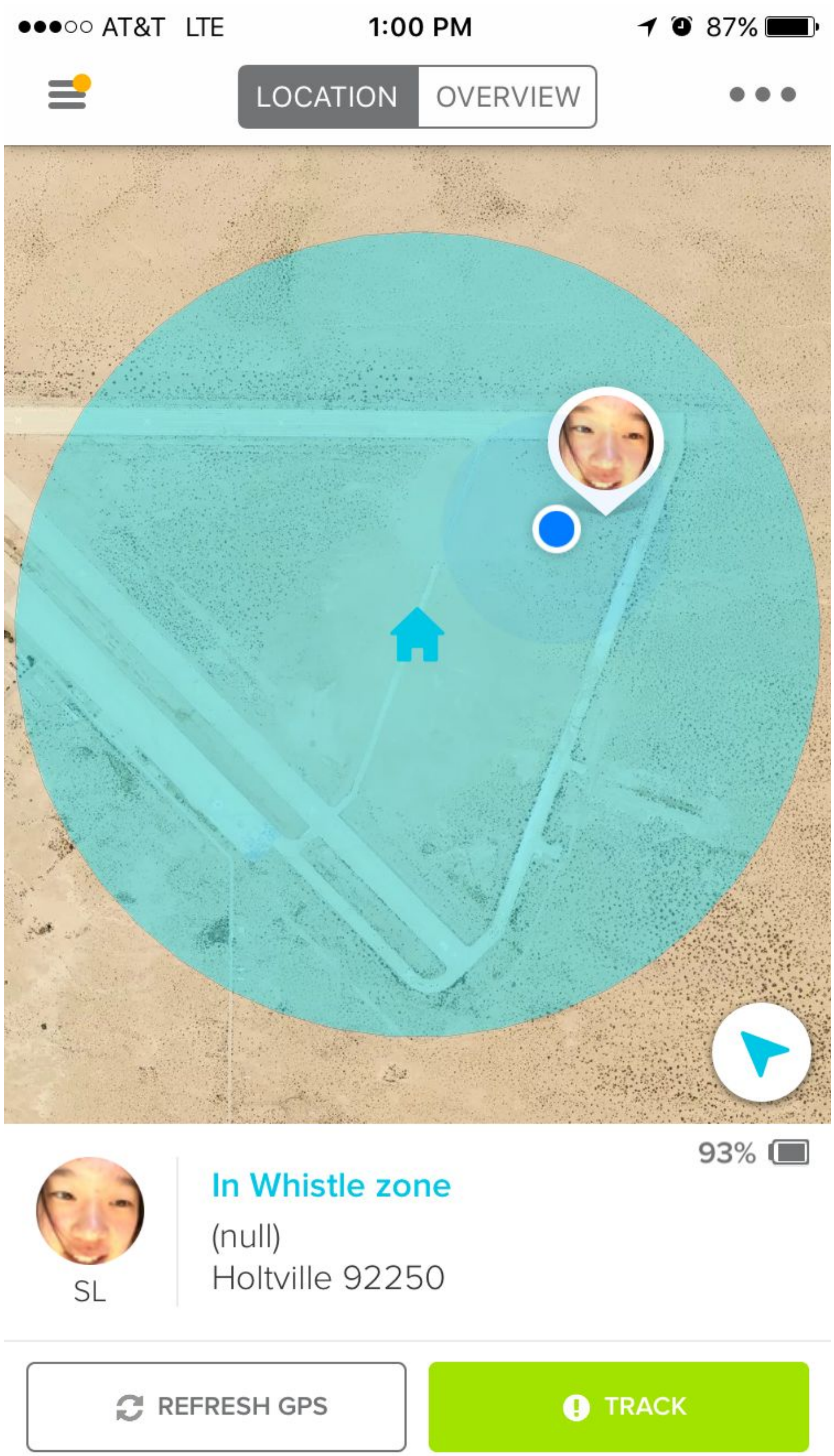
3.4.1 Description of Launch Day Conditions and Simulation Based on Conditions

Actual Flight Conditions

February 4, 2017 Flight

Temperature	73° F
Wind conditions	2-3 mph
Cloud coverage	0-5%
Barometric pressure	30.01 in Hg

Humidity	33%
Elevation	54 ft
Latitude	32.91° N
Longitude	115.4° W

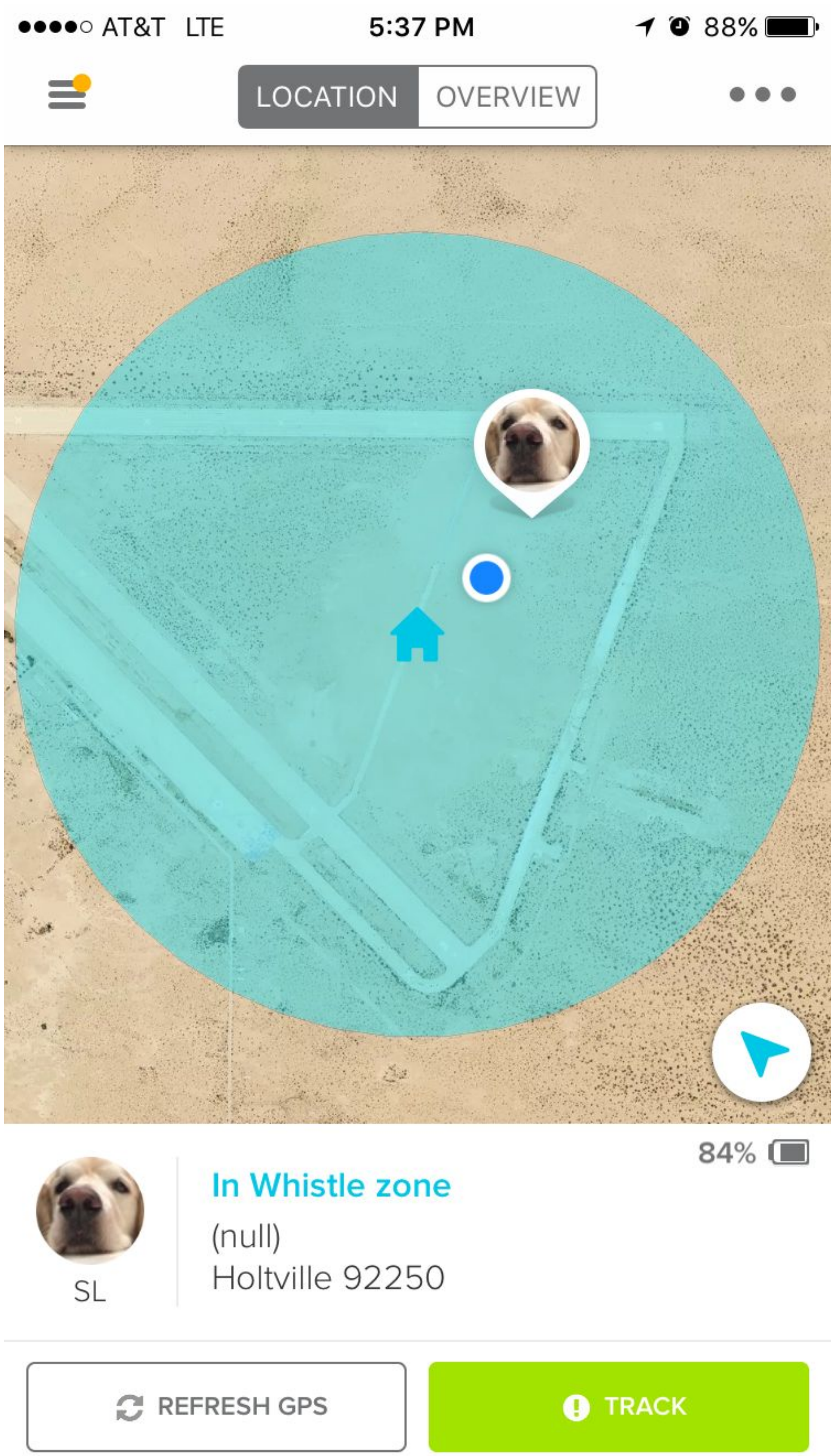


The home icon represents the launchpad. The blue dot represents the position of the smartphone tracking the GPS, and the (unflattering) picture with Allison represents the rocket's location.

A major limitation of the Whistle GPS is its inability to give exact distance. However, the circle has a 1-mile radius,indicating the rocket has drifted approximately 0.75 miles.

March 4, 2017 Flight

Temperature	70° F
Wind conditions	7-10 mph
Cloud coverage	95%
Barometric pressure	30.05 in Hg
Humidity	10%
Elevation	54 ft
Latitude	32.91° N
Longitude	115.4° W



In this instance, the rocket has drifted 0.5 miles from the launchpad.

3.4.2 Analysis of Full-scale Flight

3.4.2.1 Comparison of Predicted Flight Model to Actual Flight Data

Predicted Flight Model

Vehicle Properties	
Total Length (in)	101.5”
Diameter (in)	4”
Gross Lift Off Weigh (lb)	25.0125 lb
Airframe Material	Fiberglass
Fin Material	Fiberglass
Coupler Length	Payload Bay: 8.25” Avionics Bay: 12.25” Extension TC: 8” Air Brake Module TC: 6.75” Booster TC: 7”

Stability Analysis	
Center of Pressure (in from nose)	72.8491”
Center of Gravity (in from nose)	63.9729”
Static Stability Margin	2.22 calibers
Static Stability Margin (off launch rail)	3.25 calibers
Thrust-to-Weight Ratio	6:1
Rail Size and Length (in)	12”
Rail Exit Velocity	57

Ascent Analysis	
Maximum Veloxity (ft/s)	567 ft/sec
Maximum Mach Number	0.51
Maximum Acceleration (ft/s^2)	156.464
Target Apogee (From Simulations)	5400
Stable Velocity (ft/s)	567
Distance to Stable Velocity (ft)	1267

Recovery System Properties	
Drogue Parachute	
Manufacturer/Model	Fruity Chutes
Size	18”
Altitude at Deployment (ft)	Apogee
Velocity at Deployment (ft/s)	81
Terminal Velocity (ft/s)	
Recovery Harness Material	Tubular Nylon
Harness Size/Thickness (in)	1”

Recovery Harness Length (ft)			16	
Harness/Airframe Interfaces		Eyebolt		
Kinetic Energy of Each Section (Ft-lbs)	Section 1	Section 2	Section 3	Section 4
	$Kinetic\ energy = \frac{1}{2}mv^2 = \frac{1}{2}(2.9375\ lbs)(81ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}) = 299.27\ lbf$	$Kinetic\ energy = \frac{1}{2}mv^2 = \frac{1}{2}(7.9125\ lbs)(81ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}) = 806.12\ lbf$	$Kinetic\ energy = \frac{1}{2}mv^2 = \frac{1}{2}(10.8865\ lbs)(81ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}) = 1109.10\ lbf$	

Recovery System Properties				
Main Parachute				
Manufacturer/Model		Fruity Chutes		
Size		84”		
Altitude at Deployment (ft)			500 ft	
Velocity at Deployment (ft/s)			10	
Terminal Velocity (ft/s)				
Recovery Harness Material			Tubular Nylon	
Harness Size/Thickness (in)			1”	
Recovery Harness Length (ft)			21	
Harness/Airframe Interfaces		Eyebolt		
Kinetic Energy of Each Section (Ft-lbs)	Section 1	Section 2	Section 3	Section 4
	$Kinetic\ energy = \frac{1}{2}mv^2 = \frac{1}{2}(2.9375\ lbs)(10\ ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}) = 4.56\ lbf$	$Kinetic\ energy = \frac{1}{2}mv^2 = \frac{1}{2}(7.9125\ lbs)(10\ ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}) = 12.29\ lbf$	$Kinetic\ energy = \frac{1}{2}mv^2 = \frac{1}{2}(10.8865\ lbs)(10\ ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}) = 16.90\ lbf$	

Actual Flight Data

Vehicle Properties	
Total Length (in)	101.5”
Diameter (in)	4”
Gross Lift Off Weigh (lb)	25.0125
Airframe Material	Fiberglass
Fin Material	Fiberglass
Coupler Length	Payload Bay: 8.25” Avionics Bay: 12.25” Extension TC: 8” Air Brake Module TC: 6.75” Booster TC: 7”

Stability Analysis	
Center of Pressure (in from nose)	72.8491”
Center of Gravity (in from nose)	63.9729”
Static Stability Margin	2.22 calibers
Static Stability Margin (off launch rail)	3.25 calibers
Thrust-to-Weight Ratio	6:1

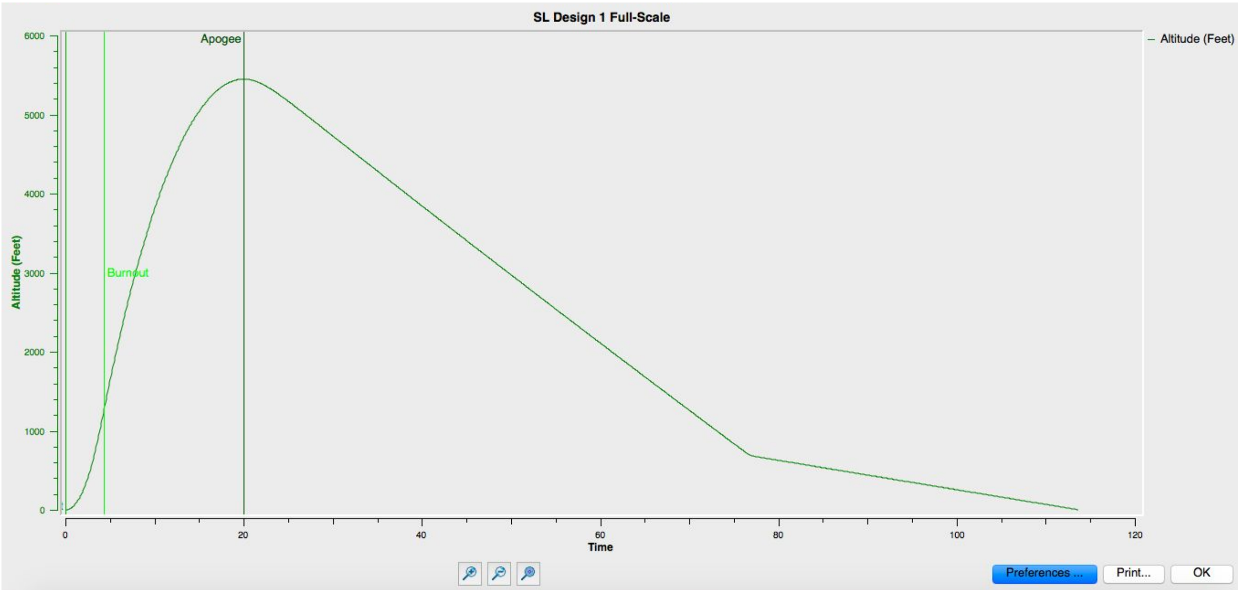
Rail Size and Length (in)	12”
Rail Exit Velocity	57

Ascent Analysis	
Maximum Veloxity (ft/s)	636
Maximum Mach Number	0.51
Maximum Acceleration (ft/s^2)	156.464
Target Apogee (From Simulations)	5400
Stable Velocity (ft/s)	636
Distance to Stable Velocity (ft)	1124

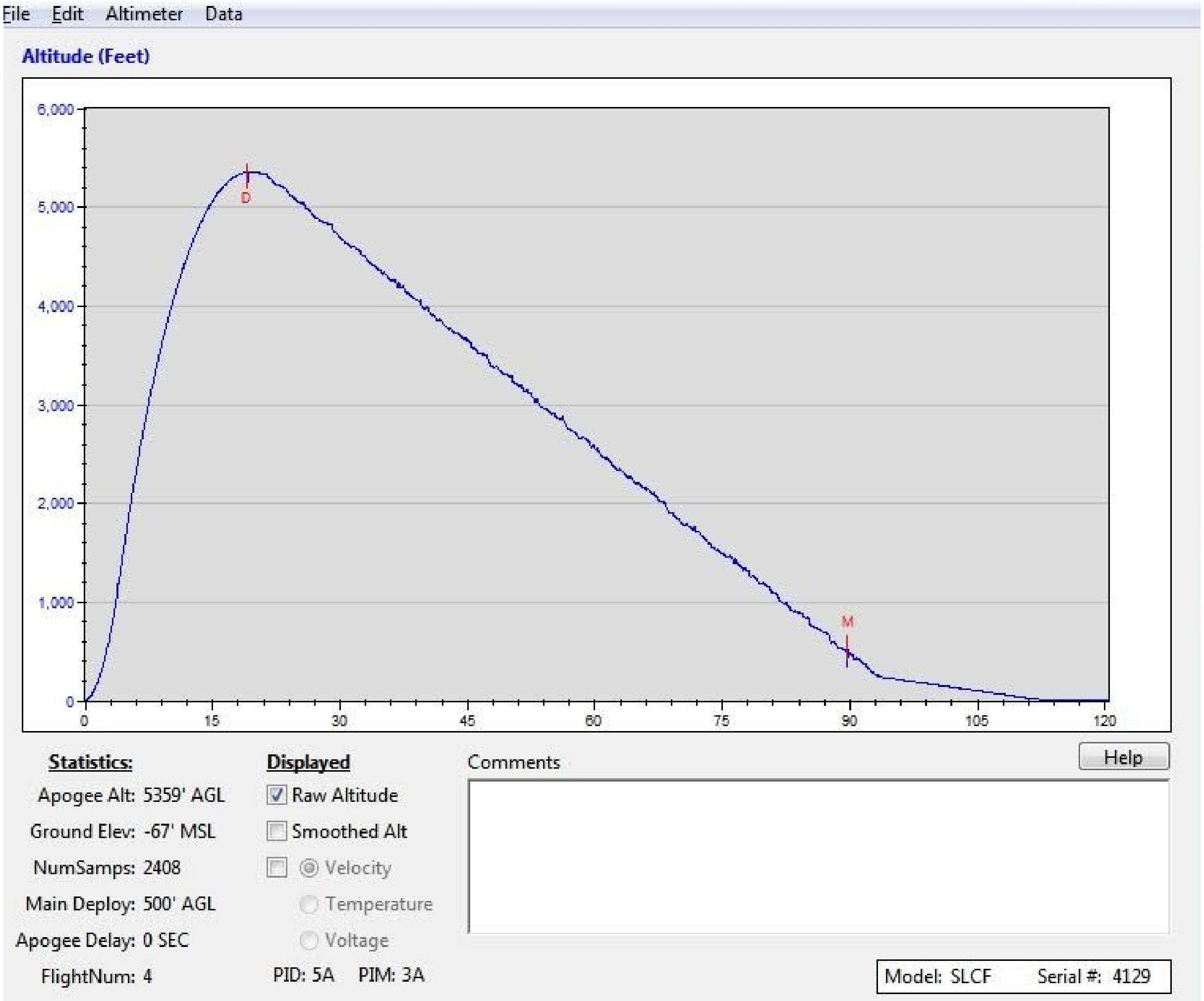
Recovery System Properties				
Drogue Parachute				
Manufacturer/Model	Fruity Chutes			
Size	18”			
Altitude at Deployment (ft)			Apogee (5451 ft)	
Velocity at Deployment (ft/s)			81	
Terminal Velocity (ft/s)				
Recovery Harness Material			Tubular Nylon	
Harness Size/Thickness (in)			1”	
Recovery Harness Length (ft)			16 ft	
Harness/Airframe Interfaces	Eyebolt			
Kinetic Energy of Each Section (Ft-lbs)	Section 1	Section 2	Section 3	Section 4
	$Kinetic\ energy = \frac{1}{2}mv^2 = \frac{1}{2}(2.9375\ lbs)(81 ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}) = 299.27\ lbf$	$Kinetic\ energy = \frac{1}{2}mv^2 = \frac{1}{2}(7.9125\ lbs)(81 ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}) = 806.12\ lbf$	$Kinetic\ energy = \frac{1}{2}mv^2 = \frac{1}{2}(10.8865\ lbs)(81 ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}) = 1109.10\ lbf$	

Recovery System Properties				
Main Parachute				
Manufacturer/Model	Fruity Chutes			
Size	84”			
Altitude at Deployment (ft)			500 ft	
Velocity at Deployment (ft/s)			63	
Terminal Velocity (ft/s)				
Recovery Harness Material			Tubular Nylon	
Harness Size/Thickness (in)			1”	
Recovery Harness Length (ft)			21 ft	
Harness/Airframe Interfaces	Eyebolt			
Kinetic Energy of Each Section (Ft-lbs)	Section 1	Section 2	Section 3	Section 4
	$Kinetic\ energy = \frac{1}{2}mv^2 = \frac{1}{2}(2.9375\ lbs)(10 ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}) = 4.56\ lbf$	$Kinetic\ energy = \frac{1}{2}mv^2 = \frac{1}{2}(7.9125\ lbs)(10 ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}) = 12.29\ lbf$	$Kinetic\ energy = \frac{1}{2}mv^2 = \frac{1}{2}(10.8865\ lbs)(10 ft/s)^2(\frac{1\ lbf\ s^2}{32.2\ lbm\ ft}) = 16.90\ lbf$	

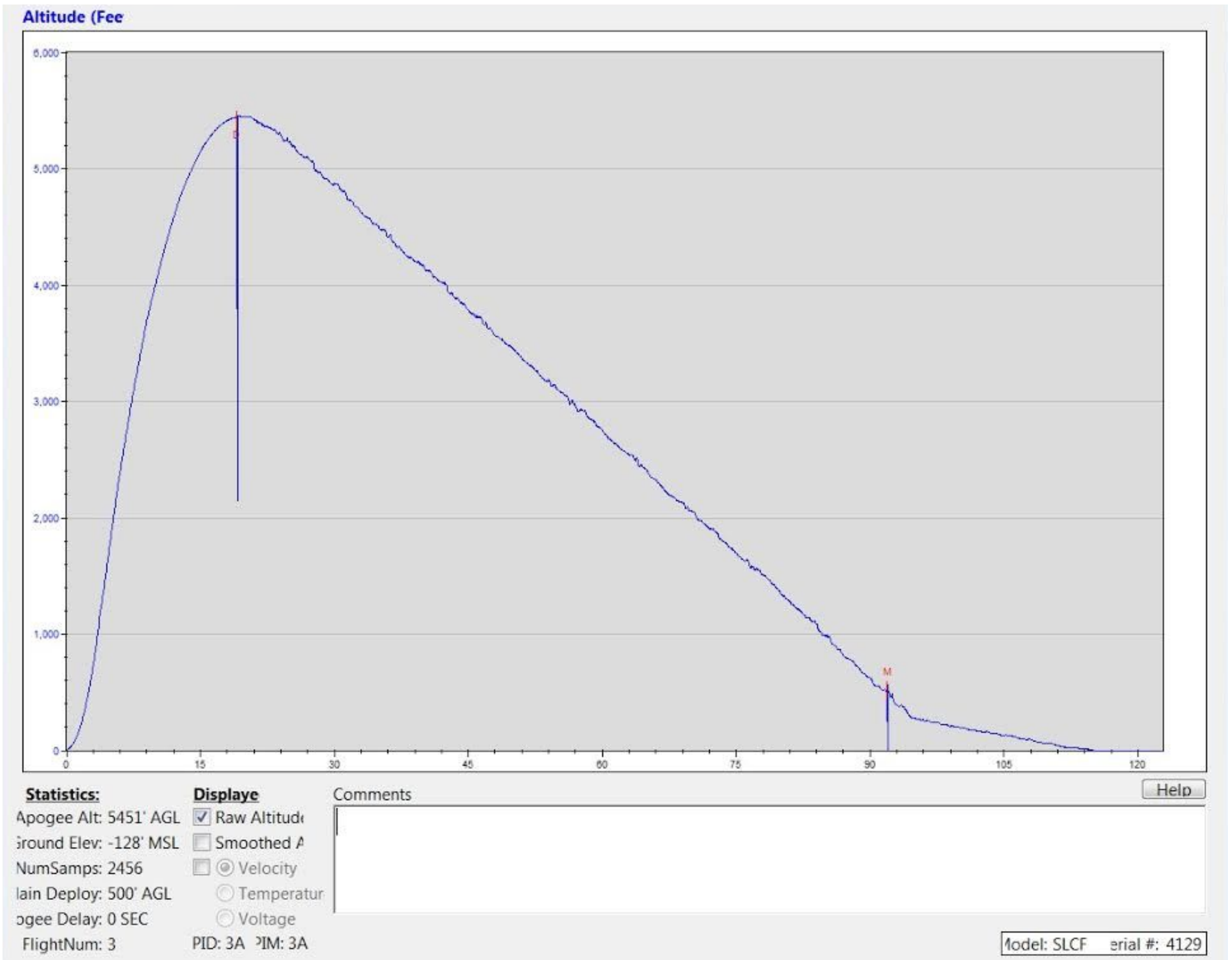
3.4.2.2 Error Between Actual and Predicted Flight Data



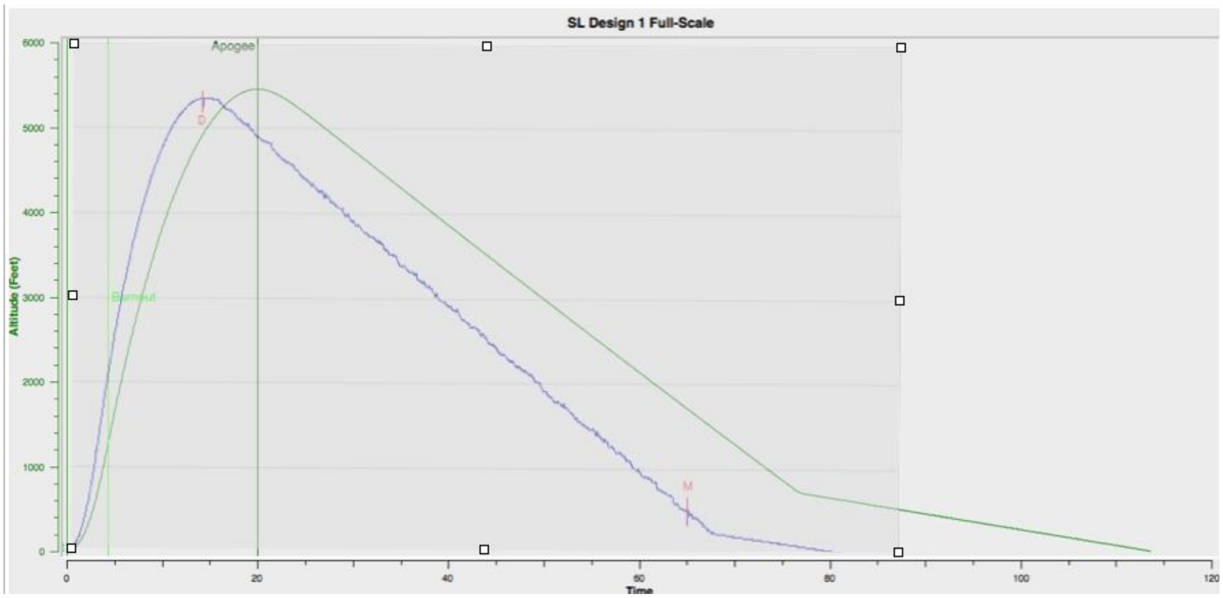
The above graph is a graph of the simulated flight in RockSim using launch day conditions



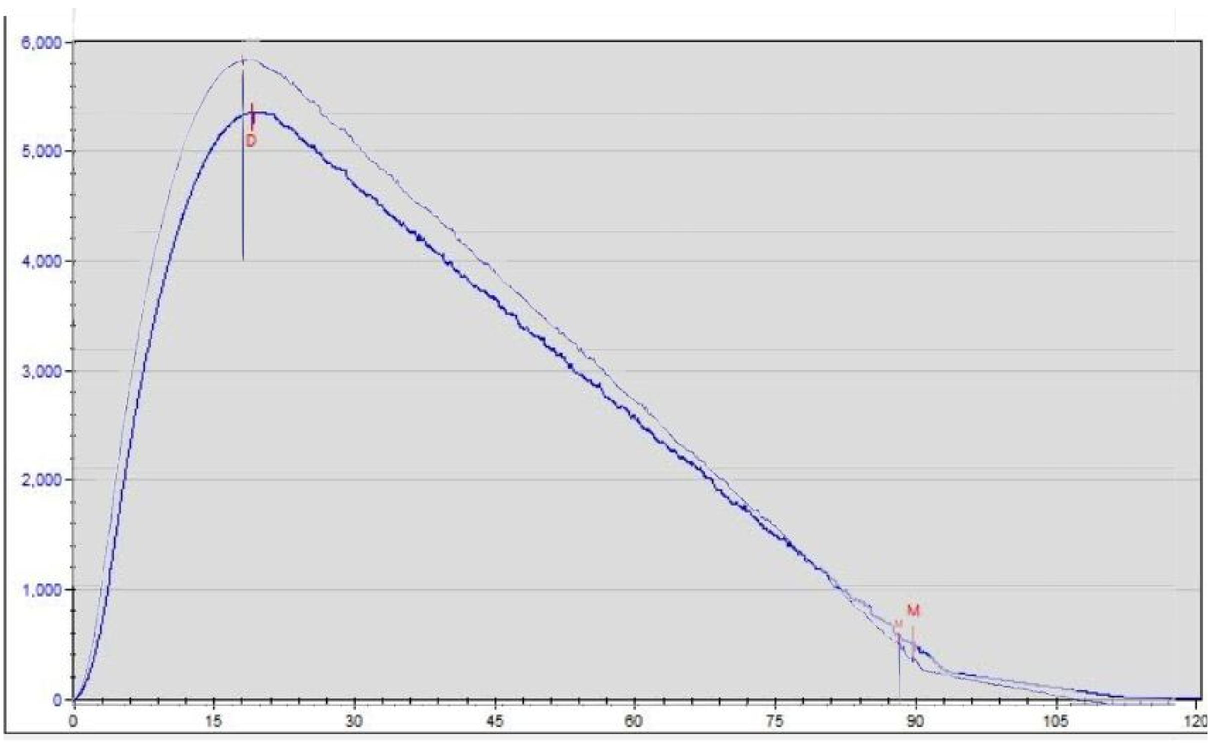
The above graph is the graph of the actual flight performed on March 4th, 2017, with the use of air brakes



The above graph is the graph of the actual flight performed on Feb 4, 2017, without the use of air brakes



The above graph is a graph of the graphs of the simulation and the March 4th launch overlaid, the green being the simulation graph, and the blue being the actual flight graph.



The above graph is a graph of the graphs of the February 4th launch (without air brakes) and the March 4th launch (with air brakes) overlaid, the fainter blue graph being the February launch graph, and the blue being the March launch graph.

3.4.2.3 Estimation of the Drag Coefficient of Full Scale Rocket with Launch Data and Comparison to that of CDR

We had predicted that our coefficient of drag would have been 0.658 based on our subscale launch, but our subscale rocket utilized air brakes, which did not create a consistent coefficient of drag during that flight.

We flew the full scale rocket on February 4, 2017 to verify the coefficient of drag. After simulating the rocket in launch conditions to attain the actual apogee, 5451 ft and adjusted the Coefficient of Drag of the simulated rocket in RockSim. The rocket is estimated to have a 0.30 coefficient of drag.

4. Payload Criteria

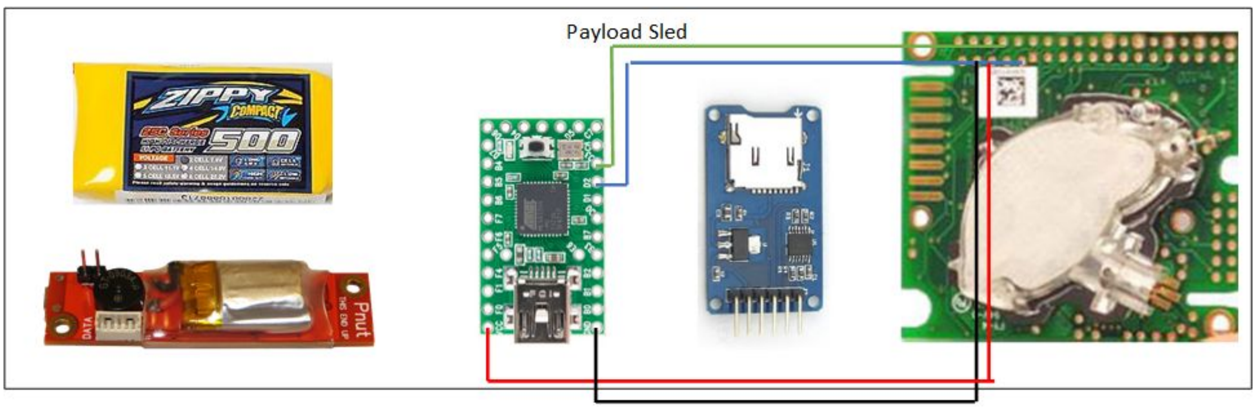
4.1 Payload Design

4.1.1 Design and Construction

4.1.1.1 Structural Elements

The payload sled is supported by two bulkheads on both sides with metal rods connecting these parts together.

4.1.1.2 Drawings and Schematics

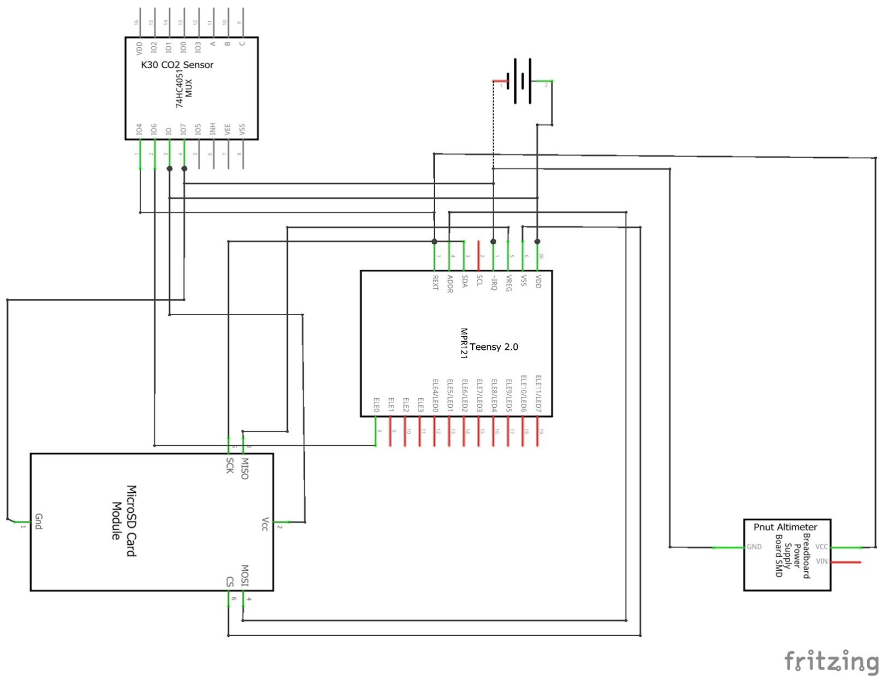


4.1.2 Precision of Instrumentation and Repeatability of Measurement

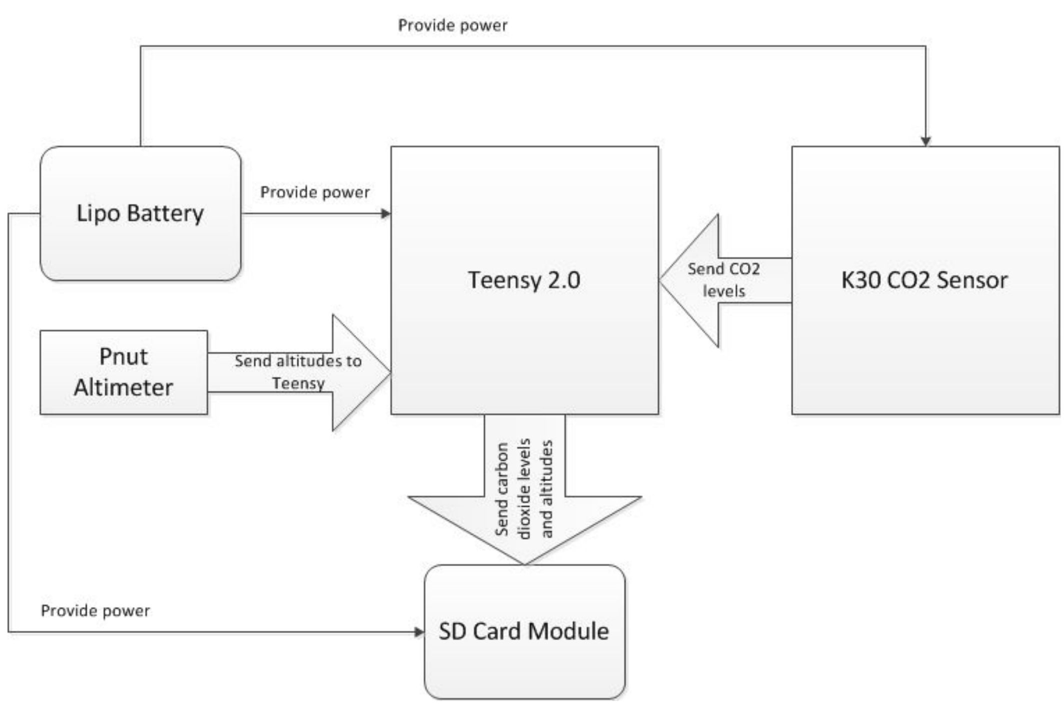
The Sensor has a response time of 2 seconds and a diffusion time of 20 seconds. Its measurement range is from 0 to 10,000 ppm and its repeatability is ± 20 ppm ± 1 % of measured value within specifications.
We will do most data processing on Microsoft Excel at the ground station because it saves time.

4.1.3 Payload Electronics

4.1.3.1 Drawings and Schematics



4.1.3.2 Block Diagrams



4.1.3.3 Batteries/Power

We will have one lipo battery controlling the entire payload system. Although the 9v battery does not have the risk of exploding or catching fire when remained at low power and does not need too much care when storing and handling, it is harder to make connections to the Teensy and requires a battery holder.

4.1.3.4 Switch and Indicator Wattage and Location

There will be no need for switches because it is easy to access the top of the rocket to connect or disconnect the battery. Unlike the recovery subsystem, the payload does not contain explosives and is not a safety hazard when handling the battery and other electronics.

5. Safety

5.1 Safety and Environment (Vehicle and Payload)

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.

5.1.1 Updated Personnel Hazard Analysis, Failure Modes and Effects Analysis, and Environmental Hazard Analysis

In this section we have addressed and finalized our analysis of hazards for the team members, the rocket, and the environment and their mitigations.

5.1.1.1 Finalized Hazard Descriptions, Causes, and Effects for Rocket

See 6.1.6 Troubleshooting and 7.1 Testing Plan for possible issues and hazards that may occur in individual sections of the rocket and the mitigations for them.

5.1.1.1.1 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	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

	circular frame of the body tube.	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: air brakes do not function while in flight. Mitigation: When electronics, are activated at ground level, a test for air brake function will be performed. The air brake 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.

5.1.1.1.2 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.

5.1.1.1.3 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 that the batteries do not fall out, and double check the sturdiness of these before every launch.	5. Risk: air brakes fail to close, interfering with recovery Mitigation: Double check that the LED light is blinking on the Arduino. Also, make sure the most recent code is uploaded in the Arduino.	8. Risk: Stratologger CF Flight Computer is not turned on Mitigation: The team will have three members check the Stratologger to see if it is beeping in its specific sequence, and they will affirm its status by signing their name in the checklist.
3. Risk: The Backup RRC3 Flight Computer is not turned	6. Risk: Drogue doesn't deploy	9. Risk: Main batteries fail

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.	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.	Mitigation: Use fresh batteries and make sure the electronics will power up first in a test second before flight.

5.1.1.1.4 Failure Modes and Effects Analysis for the Rocket

The FMEA table below highlights some of the issues the team might encounter during the design, construction, and launch of the rocket. Other issues are displayed in the previous mitigation charts, and checklists in Section 6 Launch Operation Procedures as well.

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 uncontrollably, possible hurting someone.	6	While constructing the rocket, mass change might have occurred. During the design process, stability margin might not have been	3	Stability margin is always looked at when designing the rocket and when making any changes to that design. Weather conditions will be monitored, and the rocket will not be launched in unsafe conditions.

			considered. Weather conditions also influence instability.		
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.

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.

5.1.1.2 Completed List of Mitigations, Addressing the Hazards and/or their Causes

In this section, we have addressed the mitigations for hazards that might affect our team members.

5.1.1.2.1 Personnel Hazard Analysis

While completing the launch vehicle, team members will frequently come into contact with hazardous materials. These substances will not be dangerous to the team members as long as these rules are followed when handling. Concerning materials include adhesives, paints, and the actual materials used to build the vehicle. The manufacturer of those materials knows best about the posed hazards. Each manufacturer and safety organizations publish MSDS for each product. Handling these materials will require the use of Personal Protective Equipment (PPE).
An MSDS (Material Safety Data Sheet) is available to provide an overview explaining how to work safely with and handle specific chemicals or materials. It is compiled by the manufacturer of the particular chemical. Although MSDS do not have a particular format, they are required to have certain information per OSHA (Occupational Safety and Health Administration) 29 CFR 1910.1200. A list of the required information can be found here on this website.
Listed are some threats to team members' safety that must be accounted for (see details below the table):

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

Loud noises	Earplugs

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

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

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

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

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

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

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

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

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

- Splashes or spills from chemicals
- Possible impact from tools

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

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

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

"HAZARDOUS MATERIAL - SEE MSDS"

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

5.1.1.2.2 Environmental Hazard Analysis

Below we have compiled potential environmental hazards that could hinder our progress in launching the rocket. The FMEA chart displays which events are most severe, and how we plan to mitigate their possible occurrence.

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

power lines, buildings, or people not involved in the launch.	the launch site who are not aware. It may cause additional damage to the surrounding environment.		go off in the wrong path. Instability can be caused by the weather or rocket design.		launch site. People nearby will be warned prior to the launching of the rocket. Stability margin of rocket will be made sure to be within safe limits during the design process.
Rocket components are harmful to the environment in terms of air and land pollution.	The team will be contributing to pollution and its harmful effects on the surrounding nature and the earth's population.	1	During the construction of the rocket, the team may come across disposable material such as electronics, batteries, and other rocket parts. After launching the rocket, the motor cannot be used again and must be disposed.	1	The team will dispose batteries and motors at Higgins Environmental in Huntington Beach to promote environmental awareness.
Ammonium perchlorate composite motors that are not disposed of safely pose a threat to human and environmental safety.	The team will contribute to the pollution of the ground and affect surrounding ecosystems by leaving used up motors in the environment. This can release hydrogen chloride, which, mixed in water, can create hydrochloric acid. The acid is	1	After a motor has been used, the team could leave a motor behind without noticing.	3	The team will promptly remove the motor and place it in a designated bag to take to a nearby disposal center that will properly dispose of the motor. The team will also scout the area they occupied for any trash and dispose of the trash as well.

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

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

5.1.1.3 Completed List of Verifications for the Identified Mitigations

See Sections 6.1 Detailed Procedure and Checklists and 7.1 Testing. All the mitigations have been addressed prior to our subscale, and two full scale launches. The mitigations for the rocket are verified, as our design complies with NASA specification and criteria while the construction of the rocket was completed under the safety precautions in this section.

5.2 Discuss Any Concerns

No concerns are present with regard to the rocket and its design, the team members, or safety overall. The successful flight of the subscale rocket with the air brakes activated and the two successful flights of the full scale rocket with/without the air brakes activated convey the safety in the design and construction of the rocket. The rocket design meets the required criteria by NASA. Team members also practiced safety during the construction and launch of the rocket.

6. Launch Operations Procedures

6.1 Detailed Procedure and Checklists

NOTE: list warning of hazards in missing a step, PPE required for a step in the procedure (BEFORE the step), and required personnel to complete a step or to witness and sign off

6.1.1 Recovery Preparation

- Before launch, both the main chute and the drogue chute have to be properly and tightly folded so that the pounds/in^2 doesn't exceed 2-3 pounds. The blast cloth has to be wrapped around the parachute correctly and in a manner that protects the parachute from the blunt ejection charge as in facing the bottom of the rocket.

6.1.2 Motor Preparation

- The ejection charge for the motor must be removed. So, we will scrape out all ejection charge gunpowder. After removing the ejection charge, we will insert the motor into its Cesaroni motor casing, secure the motor inside of the casing and screw the motor retainer tightly over the motor casing. The motor should not slide further into the rocket's motor mount.

6.1.3 Setup on Launcher

- When placing the rocket on the launch rail, we will make sure the igniter is out of the rocket. The avionics must be turned off during the preparation stage. If the battery voltage is around 9.2 V-9.3 V, we will proceed with the launch. If otherwise, we will terminate the launch immediately. The SL team will make sure the igniter is placed in last so that in case of a unexpected launch, the recovery systems are armed and ready to deploy in flight. The following sections will also describe our troubleshooting for each section of the rocket, and our inspection plan after the flight as well.

6.1.4 Igniter Installation

- Remove the igniter from its antistatic package and twist the leads. Run it all the way up the nozzle until it reaches the end. Mark the location on the igniter's wires where the match head stops. This mark should indicate how far the igniter should be inside the motor.

6.1.5 Launch Procedure

- Arm the pad.
- Check to make sure there are no people or pets in the range. Call loudly and clearly, “Range is clear!” if there are no people pets in the range.
- Check to make sure there is no aircraft over the launchpad or headed toward the launchpad. Call loudly and clearly, “Sky is clear!” if there are no aircraft in immediate danger.
    - **Note:** Birds flying overhead do not warrant a delayed launch.

6.1.6 Troubleshooting

Troubleshooting Checklist	
	GPS Troubleshooting: Run down the GPS troubleshooting mitigation table in section 6.1.6.1
	Payload Troubleshooting: Run down the payload troubleshooting mitigation table in section 6.1.6.2
	Parachute Troubleshooting: Run down the parachute troubleshooting mitigation tables of either section 6.1.6.3 or section 6.1.6.5. Both tables are identical.
	Avionics Troubleshooting: Run down the avionics troubleshooting mitigation table in section 6.1.6.4
	Air Brakes Troubleshooting: Run down the air brakes troubleshooting mitigation table in section 6.1.6.6
	Motor Troubleshooting: Run down the motor troubleshooting mitigation table in section 6.1.6.7

6.1.6.1 GPS Troubleshooting

Our Whistle GPS uses an iPhone app. To see if the GPS is ready for launch, we will check the Whistle GPS app.

Problem	**Mitigation**
The battery percentage is not displayed.	The Whistle GPS will be turned on, and we will check the Whistle GPS app to see that its battery is turned on. We should now see a percentage and the location of the GPS.

The GPS is not inside of its "Whistle Zone," the designated 1-mile radius area where the rocket will be launching.	We will reset the Whistle Zone to the current location of the launch or to a different location of our choosing via the Whistle GPS app. Now we will be able to monitor the GPS's movement during the rocket's ascent and descent.
The GPS is out of battery.	We will return the GPS to its base station and have it sufficiently charged. The base station will alert us through the app if the GPS is charging. Charging must be done before the launch to prevent this scenario from being realized.
The GPS is not mounted on its board.	We will use zipties and loop them through the holes we drilled on the board. We will secure the GPS by tightening the zipties until the GPS is unable to move. We will cut the zipties when we need to remove the GPS.

6.1.6.2 Payload Troubleshooting

Problem	**Mitigation**
Battery is not plugged in	We will make sure the light on the Teensy and CO_2 Sensor are on to confirm that the battery is plugged in.
Battery is low	Always check the battery voltage using a voltmeter to see if it is at least 7 volts before every flight. Otherwise, replace the battery.
Wires are loose	We will be sure that the wires connecting the electronics are securely tightened around the pins before every launch. If some become loose, we will either tape the wires or replace them.
Any electronic device isn't securely mounted on the sled	Tighten the zipties around the Teensy, battery, and CO_2 Sensor to keep it attached on the board during the flights.

6.1.6.3 Main Chute Troubleshooting

Problem	Mitigation
Parachute is too bulky	Refold the parachute, and wrap the shroud lengths tighter around the parachute to shrink the space needed in the body tube for the parachute.
Blast cloth wrapped insufficiently	Before placing the folded parachute and blast cloth into the body tube, have another person check that the blast cloth is facing towards the blast with the cleaner side on the inside (holding the parachute) and the darker side facing the blast.
Tangled shroud lengths	Refold the parachute by starting completely from the beginning and have another person pull on all of the shroud lengths while you turn the parachute in your hands right or left to untangle.

6.1.6.4 Avionics Troubleshooting

Problem	Mitigation
Flight computers are not turning on.	Check to see if the power switch wires and battery wires on the sled are connected. 99% of the time, this will be the problem. Otherwise, don't launch.
Flight computers beep different from what is expected.	Reprogram the flight computer according to the manual. If it is still showing different than what you would expect, then the flight computer is probably broken.
Battery Voltage is not over 9.	Replace the batteries.
The board is not fitting inside the coupler.	Check to see if the wires are all in the right sides. The power switch wires should be on the other side of the board, as well as one of

	the main wires and one of the drogue wires.

6.1.6.5 Drogue Chute Troubleshooting

Problem	Mitigation
Parachute is too bulky	Refold the parachute, and wrap the shroud lengths tighter around the parachute to shrink the space needed in the body tube for the parachute.
Blast cloth wrapped insufficiently	Before placing the folded parachute and blast cloth into the body tube, have another person check that the blast cloth is facing towards the blast with the cleaner side on the inside (holding the parachute) and the darker side facing the blast.
Tangled shroud lengths	Refold the parachute by starting completely from the beginning and have another person pull on all of the shroud lengths while you turn the parachute in your hands right or left to untangle.

6.1.6.6 Air Brakes Troubleshooting

Problem	Mitigation
A team member putting together the air brake electronics does not know which wires connect to which pins.	The pins and wires are color coded, and the pins are labeled. For the battery input, red and black pins are clearly labeled.
The battery is not connected correctly, with reverse polarity.	The battery wire will be attached last and the work done by one person will be closely checked by the other. Labels should also prevent this from occurring,
When the battery is connected, the Teensy does not flash red.	The battery will be disconnected and all the connections will be checked.

air brakes might not function during the flight of the rocket.	Prior to launch, a vacuum test will be performed. By putting the altimeter in the vacuum, a height will be simulated, and air brakes will be checked to see if they open.
The air brake breaks, whether it is the arm, the wing, the hinge, or horn.	The air brake wings will need to be taken off to reattach the broken part. Construction is required.

6.1.6.7 Motor Troubleshooting

Problem	Mitigation
The motor still has its ejection charge.	We will scrape out all of the ejection charge and add a plug to prevent an internal explosion. This is so the rocket does not damage itself after the motor finishes burning.
The motor retainer is very loose.	We will tighten the retainer until it is secure. If the retainer falls during flight, it could pose a lethal hazard to bystanders and could also impede the rocket's flight should the motor fall out.

6.1.7 Post-flight Inspection

Areas	Data to cull
Overall Rocket	Inspect for damage, scraping, and missing parts
Black powder charges	Check to make sure all four charges (backup charges included) were detonated.
Payload	Check to make sure all switches were still turned on and the SD card still in place. Turn off the Pnut altimeter and disconnect the LiPo battery.
Air Brakes	Check to make sure the air brakes are still on.

	This should be observable by the high-pitched sound the circular servo emits on standby. The SD card should still be in place.
Avionics	Check to make sure the avionics are reporting data. Disarm them with their keys.

7. Project Plan

7.1 Testing

7.1.1 Vehicle Test Plan

7.1.1.1 Vehicle Test Impact on Launch Vehicle and Payload Design

If problems arise from the launch vehicle during its subscale test, it will become necessary to make the necessary changes to the launch vehicle. The payload will not be affected.

7.1.1.2 Vehicle Test Operating Procedures

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

    These details should be inputted in RockSim to receive a better prediction of the subscale's flight.
    This should also include the rocket's air brakes and avionics.
4. Test the recovery system and air brakes.
5. Fly the subscale, with the air brakes and avionics on board and active.
6. The following depends on the flight's results
    a. If the rocket has crashed, diagnose what went wrong, redesign if necessary, rebuild, and fly again.
    b. If a subsystem did not function at all, diagnose what went wrong, redesign if necessary, and fly again.
    c. If the rocket is successful, then record the results in the Critical Design Review.
7. After the subscale's flight, build and fly the full-scale rocket. Aim for the 5280 ft target altitude and avoid exceeding 5600 ft.
    a. See 6a-6c. Record results in the Flight Readiness review

7.1.1.3 Test Plan Results

The rocket successfully flew and was recovered. In general, it was a straight flight. The rocket did not sustain any damage. Both subsystems on the rocket performed well. There was ballast to simulate the payload on the rocket.

The rocket after its flight

The results of the subscale's flight will help us predict the coefficient of drag on the rocket, which is useful for predicting the full-scale rocket's apogee. It also indicates that the rocket's design is functional, so we will continue with this design in the full scale.

The full scale flight was tested twice--once with air brakes on and once without. The rocket performed its flight safely.

7.1.2 Recovery Test Plan

7.1.2.1 Recovery Test Plan Impact on Launch Vehicle and Payload Design

Testing for the avionics bay is fairly straightforward, as it requires the team 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 (needs to be about 9V)
Continuity beeps (repeats every 0.8 seconds)

Zero beeps = no continuity
One beep = Drogue OK
Two beeps = Main OK
Three beeps = Drogue + Main OK (ideal scenario)

For the RRC3, the continuity check is the following:

5 second long beep (init mode)
10 second baro history init time (silence)
Settings beep (when enabled) or POST fault code beep (if a fault, see POST fault codes)
10 second launch commit test time (silence)
Launch Detect mode (continuity beeps)

A long beep indicates no continuity on any event terminal.
One short beep indicates continuity on only the drogue terminal.
Two short beeps indicate continuity on only the main terminal.
Three short beeps indicate continuity on the main and drogue terminals.

7.1.2.2 Recovery Test Operating Procedures

Please see section 7.1.3.2, as these tests are intertwined.

7.1.3 Energetics Test Plan

Drogue: 1.1 g black powder (fail) 1.4 (pass)
Main: 3.8 g black powder

In the body tube, where the main chute is stored, the cavity is 18.5 in long.

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

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

$$= \left(\frac{Diameter}{2}\right)^2 \times P + \textit{force needed to shear a shear pin} \times \textit{number of shear pins}$$

$$N = 0.00052\,(A \times P + \sum \textit{shear pin force}) \times L$$

$$= 0.00052\,\left(\left(\frac{4\,in}{2}\right)^2 \pi \times 24\,psi + (3\,pins)(35 lbs/pin)\right) \times 188 in$$

$$\approx 3.81\,g$$

In the body tube, where the drogue chute is stored, the cavity is 4 in long.

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

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

$$= (\frac{Diameter}{2})^2 \times P \ + \ force\ needed\ to\ shear\ a\ shear\ pin\ \times number\ of\ shear\ pins$$

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

$$= 0.00052\ ((\frac{4\ in}{2})^2 \pi\ \times 24\ psi\ + (3\ pins)(35 lbs/pin)) \times 5\ in$$
$$\approx 1.06\ g$$

7.1.3.1 Energetics Test Plan Impact on Launch Vehicle and Payload Design

The testing of black powder is done to ensure that there is enough black powder to tear the shear pins and to eject the parachutes. If there was an insufficient amount of black powder, the rocket would not separate properly, and the parachutes would not eject properly.

We were able to conclude through the testing that the calculated measurement of 1.1 grams of black powder for the drogue chute was insufficient. Therefore, we raised the amount of black powder to 1.4 grams. Similarly, we were able to conclude that 3.8 grams of black powder was sufficient for the main chute through the same test procedure.

7.1.3.2 Energetics Test Operating Procedures

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.

If we have calculated the correct mass, then it doesn’t pop out, we need to find out why. Account for nylon screws and the force of the black powder and the friction that results from the avionics bay rubbing against the body tube.

7.1.4 Air Brakes Test Plan

In the sections below, the testing plan for the air brakes has been outlined.

7.1.4.1 Air Brakes Test Impact on Launch Vehicle and Payload Design

The testing of the air brakes is crucial prior to the launch of our rocket, as it controls the apogee of the rocket during its flight. Without testing, we will not be able to discover if there is an issue with the air brake code, or if there is constructional issue. The team will always conduct the two code tests prior to any launch with the air brakes activated.

The air brakes do not directly affect the payload design, so there is no impact of the air brakes on the payload. However, since data is being collected regarded the levels of CO_2 at different altitudes, the function of the air brakes limits the altitude at which CO_2 can be detected.

7.1.4.2 Air Brakes Test Operating Procedures

First, check the module to see any possible structural damages. Tighten all screws, from the hinges of the air brakes to the arms of the servo. If not already uploaded, the air brakes test code should be uploaded to the Teensy via laptop. We then perform two tests with two codes.

Connect the servo cable to the respective wire on the air brake electronics. Once the battery is connected, the simple code should just open and close the air brakes continuously. During this preliminary test, team members in charge of the air brakes will look for any improper functionality in the rocket. If no issues have come up after one minute of running the code, remove the battery connection from the Teensy and upload the flight code.

Test the air brakes at least once on the full scale flight. Attach a video camera to see if they function at all during the flight and make sure they do not fall off after landing.

7.1.5 GPS Test Plan

7.1.5.1 GPS Test Plan Impact on Launch Vehicle and Payload Design

The GPS test plan does not significantly affect the vehicle and has no effect on the payload. The GPS had to be placed in an area where it would not affect the avionics.

71.1.5.2 GPS Test Plan Operating Procedures

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

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

7.1.6 Payload Test Plan

7.1.6.1 Payload Test Plan Impact on Launch Vehicle and Payload Design

The Payload test plan does not affect the vehicle because the payload is placed under the nose cone, away from the avionics.

7.1.6.2 Payload Test Operating Procedures

To test the payload, one must plug in the battery and plug in the jumper of the Pnut to activate the Teensy, CO_2 Sensor, and altimeter. Then the Pnut must be placed into a closed plastic container, which contains small holes along the circumference and has the nozzle of a vacuum chamber stuck inside of it. Turn on the vacuum chamber and slowly cover up holes using tape to simulate the flight. Then check the SD card to see if the CO_2 levels and altitudes are displayed.

7.2 Requirements Compliance

7.2.1 Verification Plan for every requirement from sections 1-5

Handbook Number	Section Description	FRR Report Section
I)	**Summary of FRR Report**	1
	Team Summary ● Team name and mailing address ● Name of mentor	1.1
	Launch vehicle Summary ● Size and mass ● Final motor choice ● Recovery System ● Rail size ● Milestone Review Flysheet	1.2
	Payload Summary ● Payload Title ● Summarize Experiment	1.3

II)	**Changes made since CDR**	2
	Highlight all changes made since PDR and the reason for those changes	
	● Changes made to vehicle criteria	2.1
	● Changes made to payload criteria	2.2
	● Changes made to project plan	2.3
III)	**Vehicle Criteria**	3
	Design and Construction of Vehicle	3.1
	● Describe any changes in the launch vehicle design from CDR, and why those changes were necessary	3.1.1
	● Describe features that will enable the vehicle to be launched and recovered safely	3.1.2
	❏ Structural elements (such as airframe, fins, bulkheads, attachment hardware, etc.)	3.1.1
	❏ Electrical elements (wiring, switches, battery retention, retention of avionics board, etc.)	3.1.2.1
	❏ Drawings and schematics of the as built launch vehicle to describe the assembly	3.1.2.2
	● Discuss flight reliability confidence. Demonstrate that the design can meet mission success criteria	3.1.3
	● Describe the construction process used to assemble the vehicle. Include photos of all interior and exterior components throughout the entire construction life cycle	3.1.4
	Recovery Subsystem	3.2

	● Describe and defend the robustness of the as-built and as-tested recovery system	3.2.1
	❏ Structural elements (such as bulkheads, harnesses, attachment hardware, etc.)	3.2.1.1
	❏ Electrical elements (such as altimeters/computers, switches, connectors, etc.)	3.2.1.2
	❏ Redundancy features	3.2.1.3
	❏ As built parachute sizes and descent rates	3.2.1.4
	❏ Drawings and schematics of the as-built electrical and structural assemblies	
	❏ Discuss the sensitivity of the recovery system to onboard devices that generate electromagnetic fields (such as transmitters). This topic should also be included in the Safety and Failure Analysis	
	Mission Performance Predictions	
	● State mission performance criteria	
	● Provide flight profile simulations, altitude prediction with as built vehicle data, component weights, and actual motor thrust curve. Include real values with optimized design for altitude	
	● Thoroughness and validity of analysis, drag assessment, and scale modeling results. Compare analyses and simulations to measure values from ground and/or flight tests	
	●	

IV)	**Safety**	
	Launch concerns and operation procedures	
	● Submit a draft of final assembly and launch procedures including:	
	❏ Recovery preparation	
	❏ Motor preparation	
	❏ Setup on launcher	
	❏ Igniter installation	
	❏ troubleshooting	
	❏ Post-flight inspection	
	Safety and Environment	
	● Update the Personnel Hazard Analysis, the Failure Mode and Effects Analysis, and the Environmental Hazard Analysis to include:	
	❏ Finalized hazard descriptions, causes and effects	
	❏ A near-complete list of mitigations, addressing the hazards and/or their causes	
	❏ A preliminary list of verifications for the identified mitigations	
V)	**Payload Criteria**	
	Design of Payload Equipment	
	● Identify which of the design alternatives from PDR is chosen as the final components for the payload. Describe why that alternative is the best choice.	
	● Review the design at a system level	

	❏ Include drawings and specifications for each component of the payload, as well as the entire payload assembly	
	❏ Describe how the payload components interact with each other	
	❏ Describe how the payload integrates within the launch vehicle	
	• Demonstrate that the design can meet all team derived functional requirements within acceptable levels of risk	
	• Discuss the payload electronics with special attention to given safety switches and indicators	
	❏ Drawings and schematics	
	❏ Block diagrams	
	❏ batteries/power	
	❏ Switch and indicator wattage and location	
VI)	**Launch Operations and Procedures**	
	Provide preliminary procedures for the following (as a minimum)	
	• Recovery Preparation	
	• Motor Preparation	
	• Setup on launcher	
	• Igniter installation	
	• Launch Procedure	

	● Troubleshooting	
	● Post-flight inspection	
	These procedures should include specially demarcated steps related to safety. Examples include:	
	● Warnings of hazards that result from missing a step	
	● PPE required for a step in the procedure (identified BEFORE the step)	
	● Required personnel to complete a step or to witness and sign off verification of a step	
VII)	**Project Plan**	
	Testing	
	● Identify all tests required to prove the integrity of the design	
	● For each test, present the test objective and success criteria, as well as testing variable and methodology	
	● Present results of any completed tests	
	● Describe the tests plan, and whether or not the test was a success	
	● How do the results drive the design of the launch vehicle and/or payload	
	Requirements Compliance	
	● Create a verification plan for every requirement from sections 1-5 of this handbook. Identify if test, analysis, demonstration, or inspection are required to verify the requirement. After identification, describe the association plan needed for verification. Provide a	

	status update for each requirement, and mention the part of the document that includes the testing or analysis used to verify	
	● 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 and status	
	Budgeting and timeline	
	● Line item budget with accurate market values for individual components	
	● Funding plan describing sources of funding, and allocation of funds	
	● Timeline including all team activities, and activity duration. Gantt charts are encouraged	

7.2.1.1 Identify if Test, Analysis, Demonstration, or Inspection are Required

Section one did not need any further tests. For section two, we focused on the changes made since the PDR and analyzed the reasons for changing our criteria, making sure that we improved. Section three was vehicle criteria, and for the subsection of design and verification of launch vehicle, we analyzed our design and weighed the pros and cons of using different materials for our rocket. With subscale flight results, we compared the predictions to the actual outcomes and made estimations for the full scale rocket. In recovery subsystems, we discussed ideas of components to use within recovery and had to gather information for each option and compare it with others. Section four contained safety, and for launch concerns and operation procedures, we created a draft of final and launch procedures. During this, we had to go over our work and look for any discrepancies that could cause problems. For the subsection safety and environment, we updated all the different types of hazard analysis to include mitigations, making us analyze each possible hazardous situation. Section five was payload criteria. The first subsection was design of payload equipment in which we thought of different payload ideas and listed the pros and cons of each. We also had to demonstrate that the design was able to meet all requirements.

In sum, tests for the following were necessary:
- Vehicle
- Energetics and recovery
- Payload
- Air Brakes
- GPS

Analyses for the following were necessary:
- Vehicle alternatives
- Safety, risk mitigation

7.2.1.2 Describe Associated Plan Needed for Verification

We can verify all of our sections by going over each subsection and making sure they follow the guidelines in our handbook. For different subsections, we will have varied types of test plans. The detailed description of our verification plan can be found in section 7.1.

7.2.1.3 Prove that all Requirements have been Verified

We have verified all the requirements, which can be seen in our reports and the rocket itself. The verification plan will also prove that the requirements have been fulfilled, and it can be found in section 7.1.

7.2.2 Set of Team Derived Requirements

Teamwork Dynamics

Risk	Mitigation
Consecutive long work days	Update the Gantt chart frequently, schedule hourly breaks
Uneven distribution of work	Update the Gantt chart frequently
Avionics bay not assembled in time	Give the person in charge of avionics (Kush) more time to practice

Rocket Construction

Risk	Mitigation

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

Vehicle

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

Payload

Risk	**Mitigation**
The Teensy isn’t loaded with the appropriate code.	Sometimes we would load the Teensy with the test codes of individual electronic devices to see if they work. It is important that we switch back to the main code before launch.

The Teensy and CO2 sensor are not powered up because the battery wasn't connected.	A few team members must confirm that they saw the Teensy and sensor blink their lights, which shows that the battery was connected.
We are not able to receive any data of our flight because the SD card wasn't in its socket.	A few team members must confirm that they see the SD card lock in place so that we are sure that all data sent to the Teensy can be viewed after the flight.

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.

Other team dynamics goals:

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

7.3 Budgeting and Timeline

7.3.1 Line item budget with accurate market values for individual components

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		

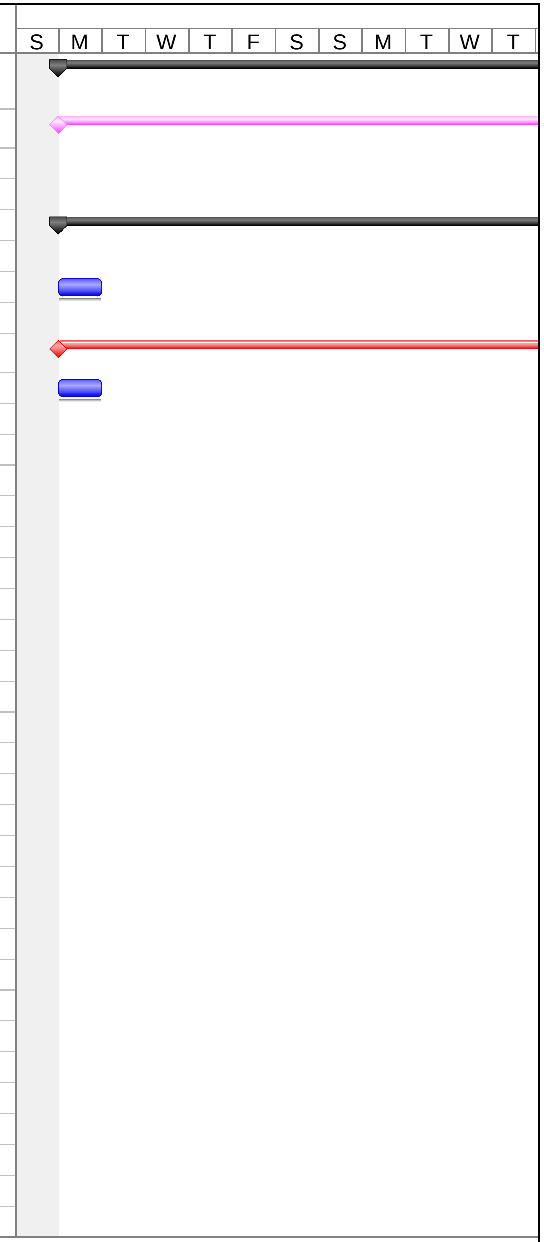
Arduino Uno kit (includes LED, resistors, regulators, etc)	$35.00	1	$35.00		
SD card + Adapter	$10.00	1	$10.00		
PerfectFlite Pnut Altimeter	$50.00	2	$100.00		
Lithium Ion Batter (rechargable)	$100.00	1	$100.00		
Total Payload Cost				$330.00	
GPS System					
Whistle GPS Dog Tracker Kit	$75.00	1	$75.00		
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 (8 Members)					
Trips to Lucerne ($2.80/gal, 112mi; $21.00 per trip per car)					
Huntsville, Alabama (roundtrip plane ticket)	$332.00	8	$2,656.00		
Food (2 meals a day, 6 days)	$10.00	96	$960.00		
Hotel (2 people per room, 6 days)	$120.00	24	$2,880.00		
Total Travel Cost (Estimated)				$6,496.00	
Total Estimated Project Expenses				$10,499	

7.3.2 Funding plan describing sources of funding, and allocation of funds

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. The sponsors we have currently are Apex Desks, Pegasus Management, Yogurtland, IvyMax, and Velur Enterprises, Inc.

7.3.3 Timeline including all team activities, and activity duration

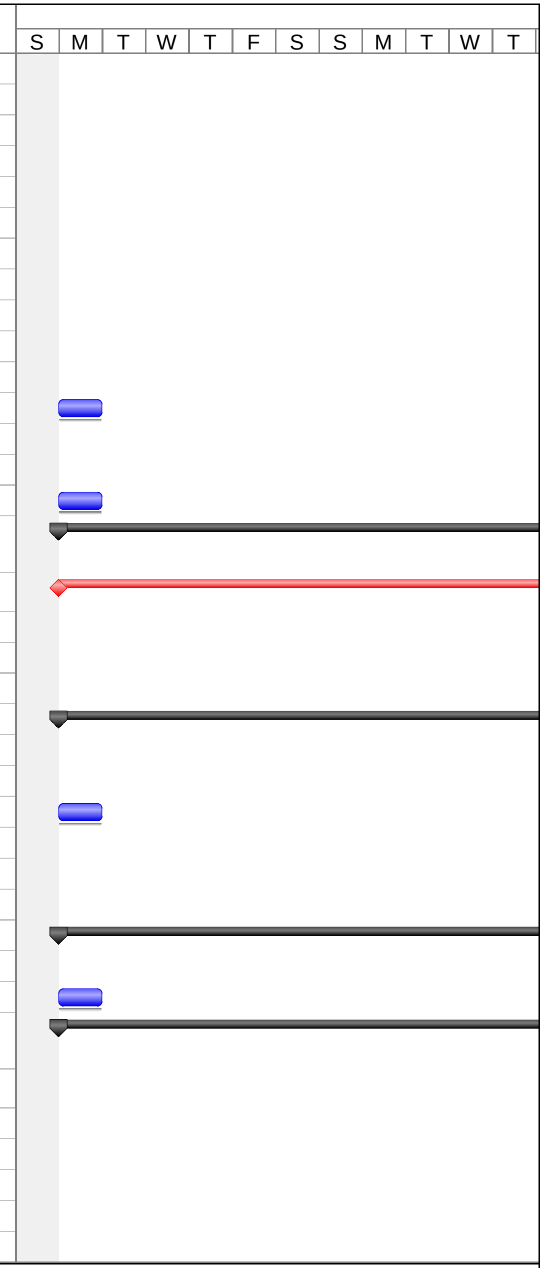
ID		Task Name	Physical % Complete	Duration	Start	Finish	Predecessors
1		**Proposal**	**0%**	**85 days?**	**Mon 7/11/16**	**Ved 10/12/16**	
2		**Summer 2016**	**0%**	**46 days?**	**Mon 7/11/16**	**Mon 8/29/16**	
3		**First Draft**	**0%**	**1 day**	**Wed 8/17/16**	**Wed 8/17/16**	
4		Completed First Draft	70%	1 day	Wed 8/17/16	Wed 8/17/16	
5		**Work on Second Draft**	**0%**	**46 days?**	**Mon 7/11/16**	**Mon 8/29/16**	
6		Completed Second Draft	0%	8 days?	Sat 8/20/16	Mon 8/29/16	4
7			0%	1 day?	Mon 7/11/16	Mon 7/11/16	
8		School Opens in IUSD	100%	1 day	Wed 8/24/16	Wed 8/24/16	
9		**Fall 2016**	**0%**	**85 days?**	**Mon 7/11/16**	**Ved 10/12/16**	
10			0%	1 day?	Mon 7/11/16	Mon 7/11/16	
11		**Work on Third Draft**	**0%**	**19 days**	**Mon 8/29/16**	**Sat 9/17/16**	
12		**General information**	**0%**	**17 days**	**Wed 8/31/16**	**Sat 9/17/16**	
13		General Information	90%	17 days	Wed 8/31/16	Sat 9/17/16	
14		**Facilities and Equipment**	**0%**	**17 days**	**Wed 8/31/16**	**Sat 9/17/16**	
15		Facilities and Equipment	95%	17 days	Wed 8/31/16	Sat 9/17/16	
16		**Safety**	**0%**	**17 days**	**Wed 8/31/16**	**Sat 9/17/16**	
17		Vehicle Risk Mitigation	95%	17 days	Wed 8/31/16	Sat 9/17/16	
18		Recovery Risk Mitigation	95%	17 days	Wed 8/31/16	Sat 9/17/16	
19		Payload Risk Mitigation	95%	17 days	Wed 8/31/16	Sat 9/17/16	
20		Launch Safety Rules	95%	17 days	Wed 8/31/16	Sat 9/17/16	
21		**Technical Design**	**0%**	**17 days**	**Wed 8/31/16**	**Sat 9/17/16**	
22		Vehicle Design	20%	17 days	Wed 8/31/16	Sat 9/17/16	
23		Preparation and Launch	80%	17 days	Wed 8/31/16	Sat 9/17/16	
24		Recovery Electronics	90%	17 days	Wed 8/31/16	Sat 9/17/16	
25		Motor Type and Design	95%	17 days	Wed 8/31/16	Sat 9/17/16	
26		Science/Engineering Payloa	95%	17 days	Wed 8/31/16	Sat 9/17/16	
27		Requirements for Rocket an	90%	17 days	Wed 8/31/16	Sat 9/17/16	
28		Testing	0%	17 days	Wed 8/31/16	Sat 9/17/16	
29		**Educational Engagement**	**0%**	**17 days**	**Wed 8/31/16**	**Sat 9/17/16**	
30		Educational Engagement	80%	17 days	Wed 8/31/16	Sat 9/17/16	
31		**Project Plan**	**0%**	**17 days**	**Wed 8/31/16**	**Sat 9/17/16**	
32		Project Plan	95%	17 days	Wed 8/31/16	Sat 9/17/16	
33		Plan for Sustainability	95%	17 days	Wed 8/31/16	Sat 9/17/16	
34		**Deliverables**	**0%**	**17 days**	**Wed 8/31/16**	**Sat 9/17/16**	
35		Flight Card?	0%	17 days	Wed 8/31/16	Sat 9/17/16	
36		Budget	99%	17 days	Wed 8/31/16	Sat 9/17/16	
37		**Appendices**	**0%**	**17 days**	**Wed 8/31/16**	**Sat 9/17/16**	



Project: v4 Student Launch 2017 Gant
Date: Mon 10/24/16

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

ID	Indicators	Task Name	Physical % Complete	Duration	Start	Finish	Predecessors
38		MSDS	95%	17 days	Wed 8/31/16	Sat 9/17/16	
39		NAR and TRA Safety Comp	15%	17 days	Wed 8/31/16	Sat 9/17/16	
40		Hazardous Materials Safety	95%	17 days	Wed 8/31/16	Sat 9/17/16	
41		Shop Safety Rules	95%	17 days	Wed 8/31/16	Sat 9/17/16	
42		Timeline	25%	17 days	Wed 8/31/16	Sat 9/17/16	
43		Safety Statement	16%	17 days	Wed 8/31/16	Sat 9/17/16	
44		Technical Requirements Cr(	0%	17 days	Wed 8/31/16	Sat 9/17/16	
45		Proposal Requirements Cro	0%	17 days	Wed 8/31/16	Sat 9/17/16	
46		Major Challenges	0%	17 days	Wed 8/31/16	Sat 9/17/16	
47		Comprehensive budget	0%	19 days	Mon 8/29/16	Sat 9/17/16	
48		Completed Third Draft	0%	1 day	Sat 9/17/16	Sat 9/17/16	
49			0%	1 day?	Mon 7/11/16	Mon 7/11/16	
50		Submitted Third Draft	0%	1 day	Fri 9/30/16	Fri 9/30/16	
51		Proposals awarded	0%	1 day	Wed 10/12/16	Ved 10/12/16	
52			0%	1 day?	Mon 7/11/16	Mon 7/11/16	
53		**PDR**	**0%**	**132 days?**	**Mon 7/11/16**	**Sun 12/4/16**	
54		**Fall 2016**	**0%**	**132 days?**	**Mon 7/11/16**	**Sun 12/4/16**	
55		Kickoff and Q & A	0%	14 days	Fri 11/4/16	Thu 11/17/16	
56		Web Presence Established	100%	14 days	Tue 11/1/16	Mon 11/14/16	
57		**PDR Document**	**0%**	**14 days**	**Fri 11/18/16**	**Sun 12/4/16**	
77		**Testing**	**0%**	**126 days?**	**Mon 7/11/16**	**Mon 11/28/16**	
78		Black Powder Testing	0%	14 days	Sat 11/12/16	Mon 11/28/16	
79		GPS Testing	0%	1 day	Sat 11/12/16	Sat 11/12/16	
80			0%	1 day?	Mon 7/11/16	Mon 7/11/16	
81		Payload Assembly	0%	5 days?	Sat 11/5/16	Wed 11/9/16	
82		Scale Model Assembly	0%	7 days	Sun 11/13/16	Sat 11/19/16	
83		Launch Day	0%	1 day?	Mon 11/21/16	Mon 11/21/16	
84		**PDR reports, presentation slides, fl**	**0%**	**119 days?**	**Mon 7/11/16**	**Fri 11/18/16**	
85		PDR web teleconference	0%	16 days	Thu 11/3/16	Fri 11/18/16	
86			0%	1 day?	Mon 7/11/16	Mon 7/11/16	
87		**CDR**	**0%**	**178 days?**	**Mon 7/11/16**	**Tue 1/31/17**	
88		**Winter 2016**	**0%**	**36 days**	**Wed 11/30/16**	**Tue 1/10/17**	
89		CDR Q & A	0%	1 day	Wed 11/30/16	Ved 11/30/16	
90		CDR Document	0%	32 days	Sun 12/4/16	Tue 1/10/17	
91		Payload Revisions and Assembly	0%	6 days	Mon 12/12/16	Sun 12/18/16	
92		Launch Vehicle Assembly	0%	11 days	Tue 12/13/16	Sat 12/24/16	
93		Launch Day	0%	1 day	Sat 12/31/16	Sat 12/31/16	



Project: v4 Student Launch 2017 Gant
Date: Mon 10/24/16

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

ID		Task Name	Physical % Complete	Duration	Start	Finish	Predecessors
94		**CDR reports, presentation slides, fly sh**	**0%**	**178 days?**	**Mon 7/11/16**	**Tue 1/31/17**	
95		CDR teleconference	0%	11 days	Tue 1/17/17	Tue 1/31/17	
96			0%	1 day?	Mon 7/11/16	Mon 7/11/16	
97		**FRR**	**0%**	**34 days**	**Wed 2/8/17**	**Fri 3/24/17**	
98		**Winter 2016**	**0%**	**15 days**	**Wed 2/8/17**	**Mon 2/27/17**	
99		FRR Q & A	0%	1 day	Wed 2/8/17	Wed 2/8/17	
100		FRR Document	0%	12 days	Sat 2/11/17	Mon 2/27/17	
101		**Spring 2017**	**0%**	**15 days**	**Mon 3/6/17**	**Fri 3/24/17**	
102		FRR Submitted	0%	1 day	Mon 3/6/17	Mon 3/6/17	
103		FRR teleconference	0%	13 days	Wed 3/8/17	Fri 3/24/17	
104							
105		**LRR**	**0%**	**229 days?**	**Mon 7/11/16**	**Mon 4/10/17**	
106		**Spring 2017**	0%	1 day?	Mon 7/11/16	Mon 7/11/16	
107		LRR	0%	1 day	Tue 4/4/17	Tue 4/4/17	
108		Rocket Fair	0%	1 day	Thu 4/6/17	Thu 4/6/17	
109		Launch Day	0%	2 days?	Fri 4/7/17	Mon 4/10/17	108

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Project: v4 Student Launch 2017 Gant
Date: Mon 10/24/16

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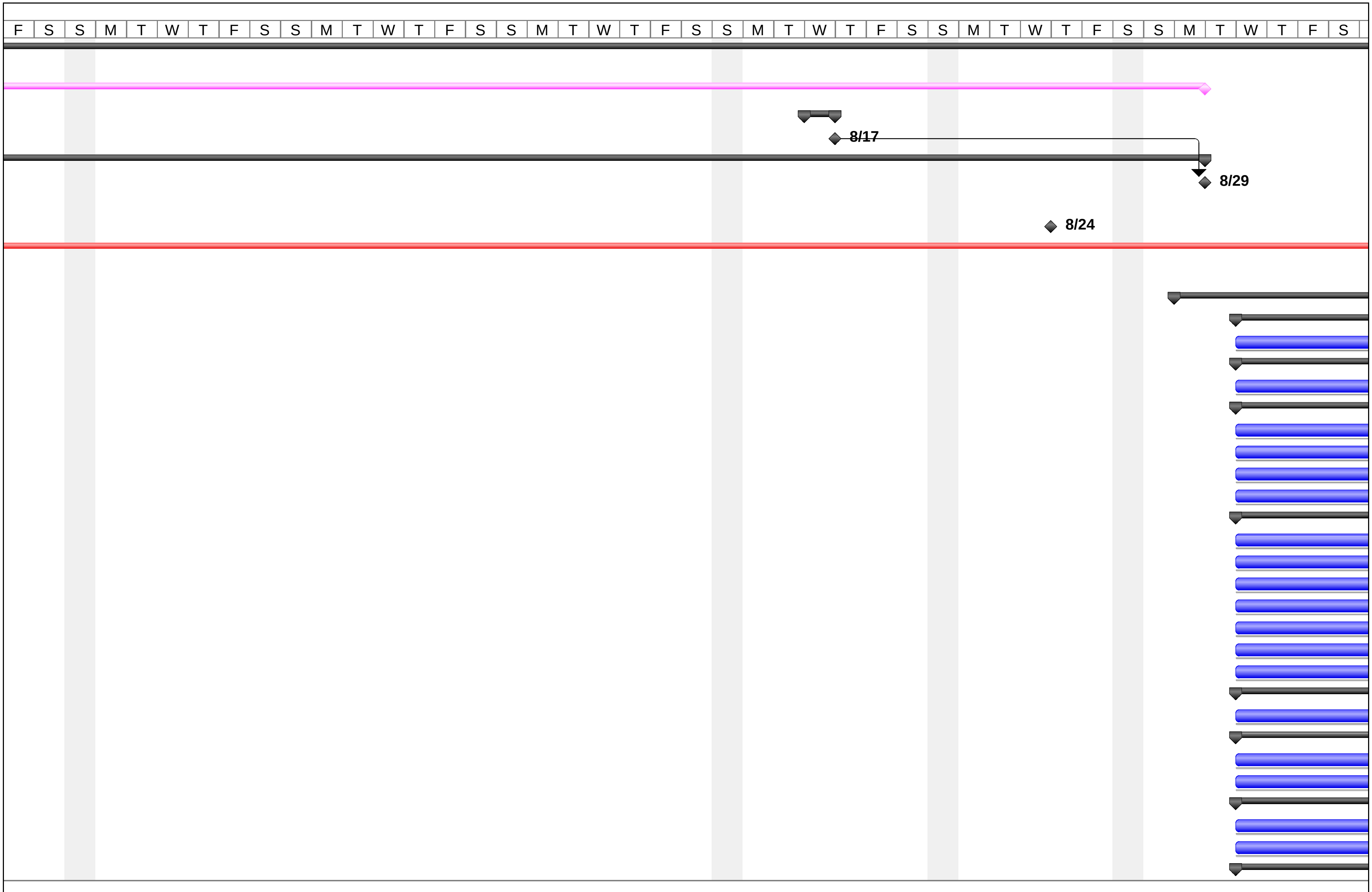
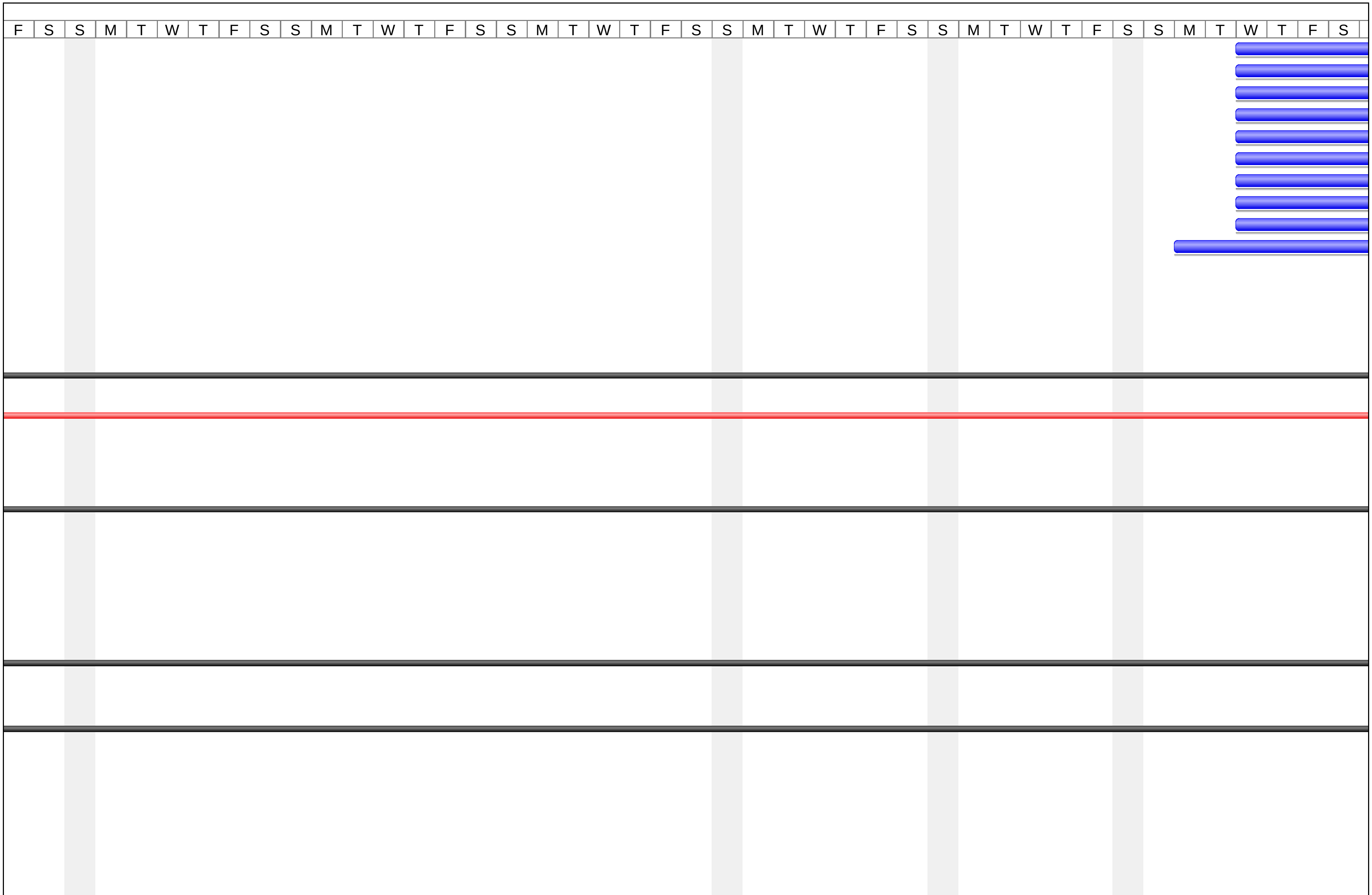


Project: v4 Student Launch 2017 Gant
Date: Mon 10/24/16

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	



Project: v4 Student Launch 2017 Gant
Date: Mon 10/24/16

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

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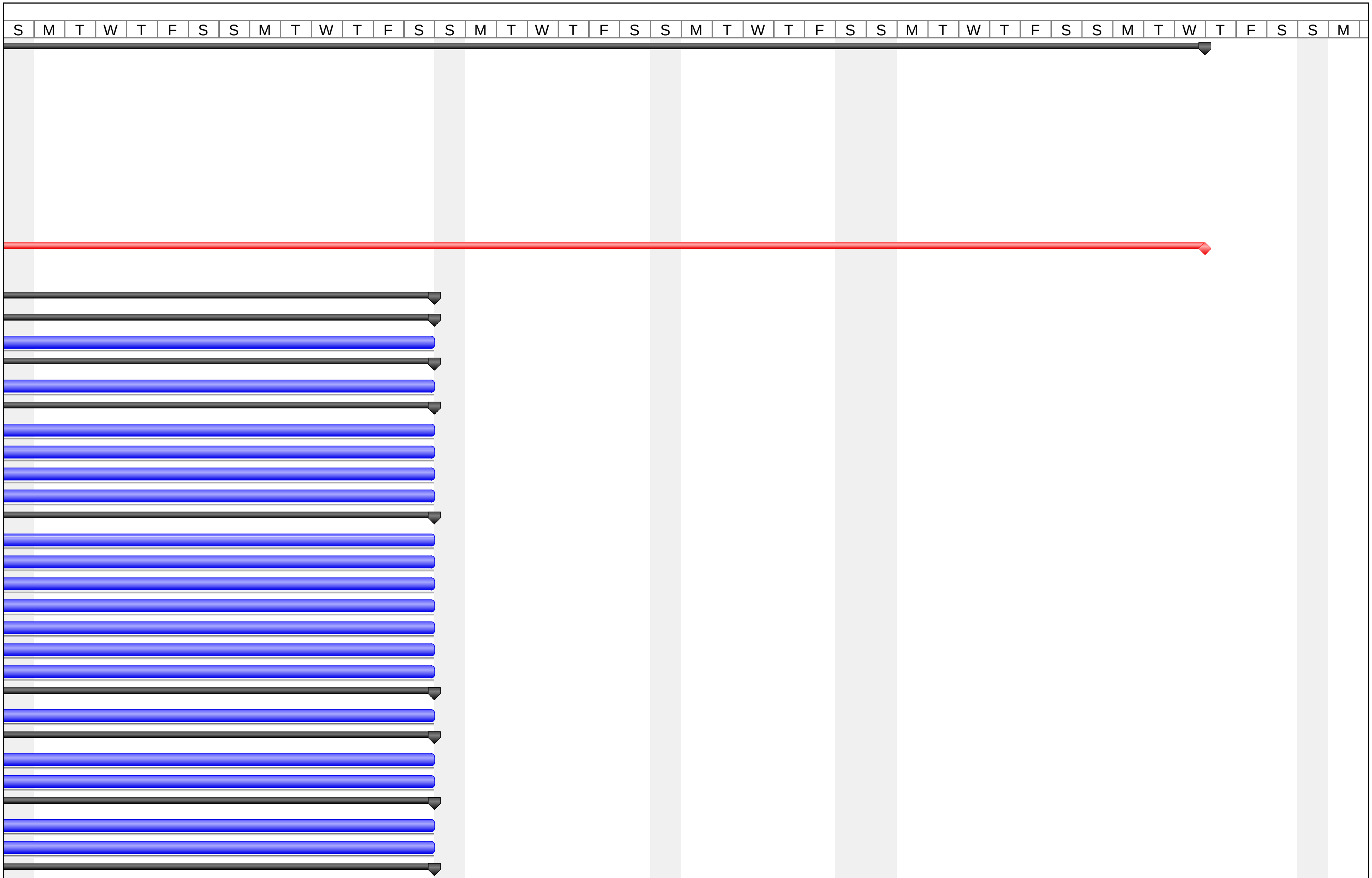
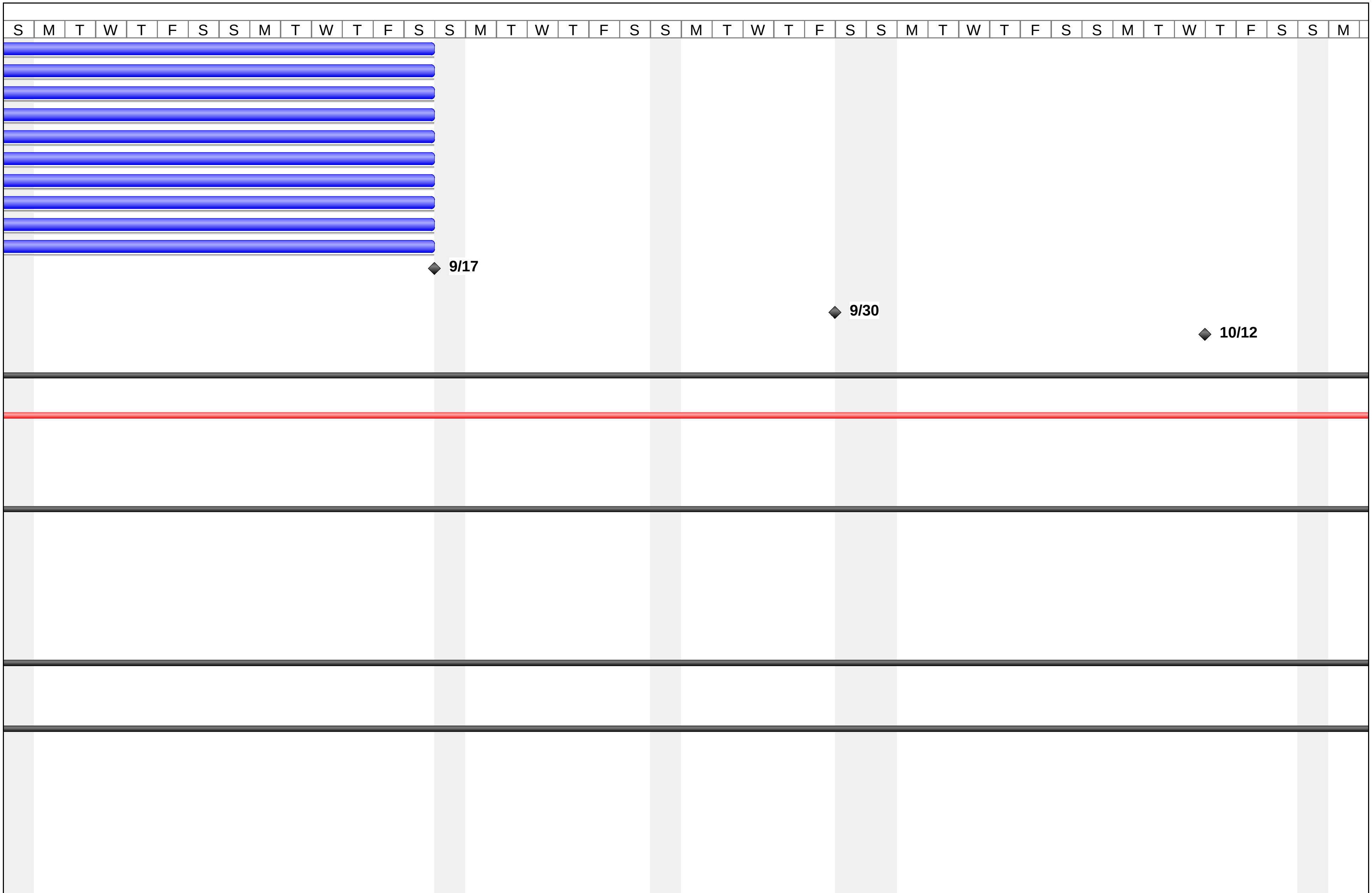
Project: v4 Student Launch 2017 Gant
Date: Mon 10/24/16

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	



Project: v4 Student Launch 2017 Gant
Date: Mon 10/24/16

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	



Project: v4 Student Launch 2017 Gant
Date: Mon 10/24/16

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

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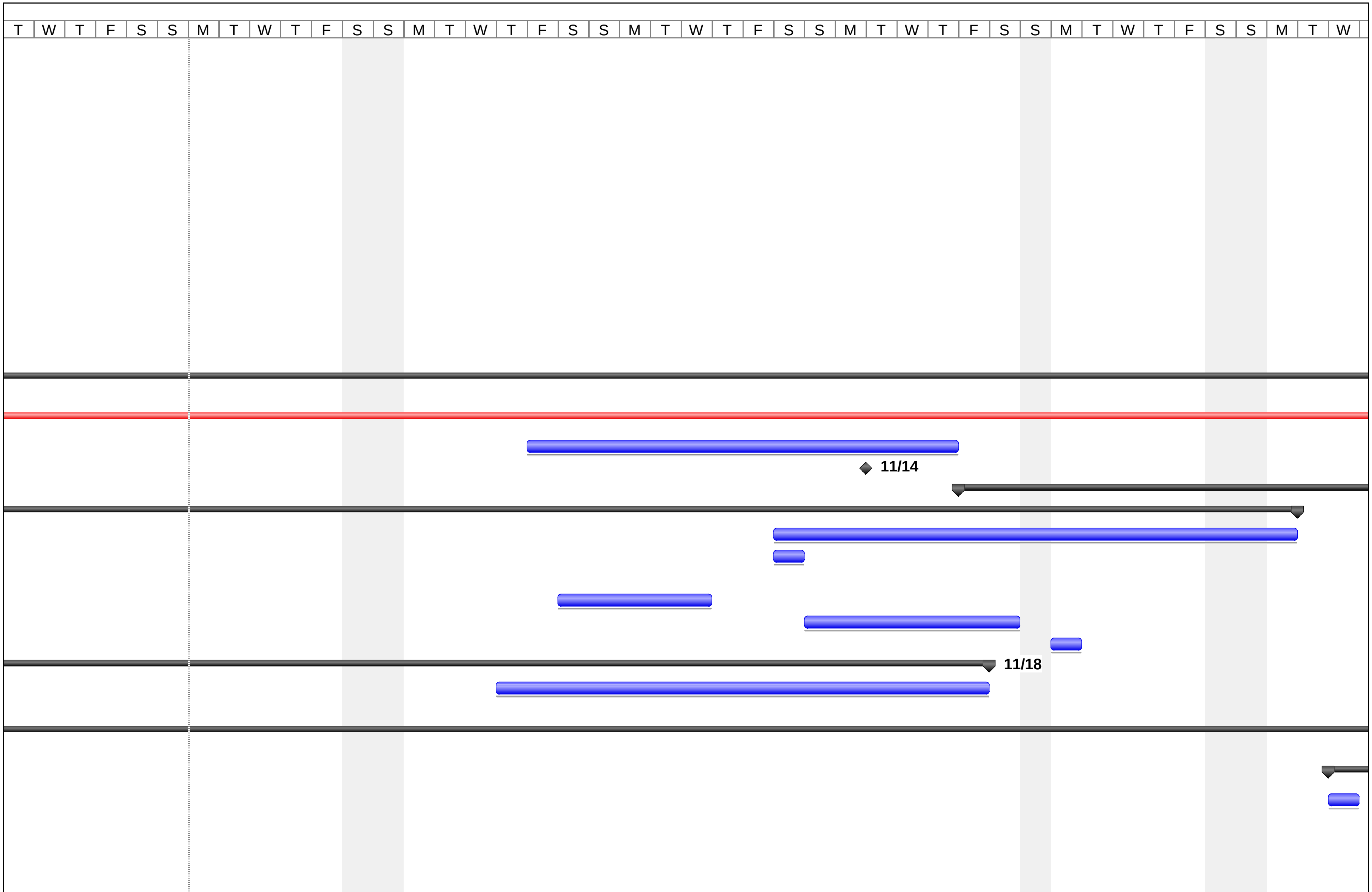
Project: v4 Student Launch 2017 Gant
Date: Mon 10/24/16

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W

Project: v4 Student Launch 2017 Gant
Date: Mon 10/24/16

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	



Project: v4 Student Launch 2017 Gant
Date: Mon 10/24/16

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

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Project: v4 Student Launch 2017 Gant
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Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

2017																																											
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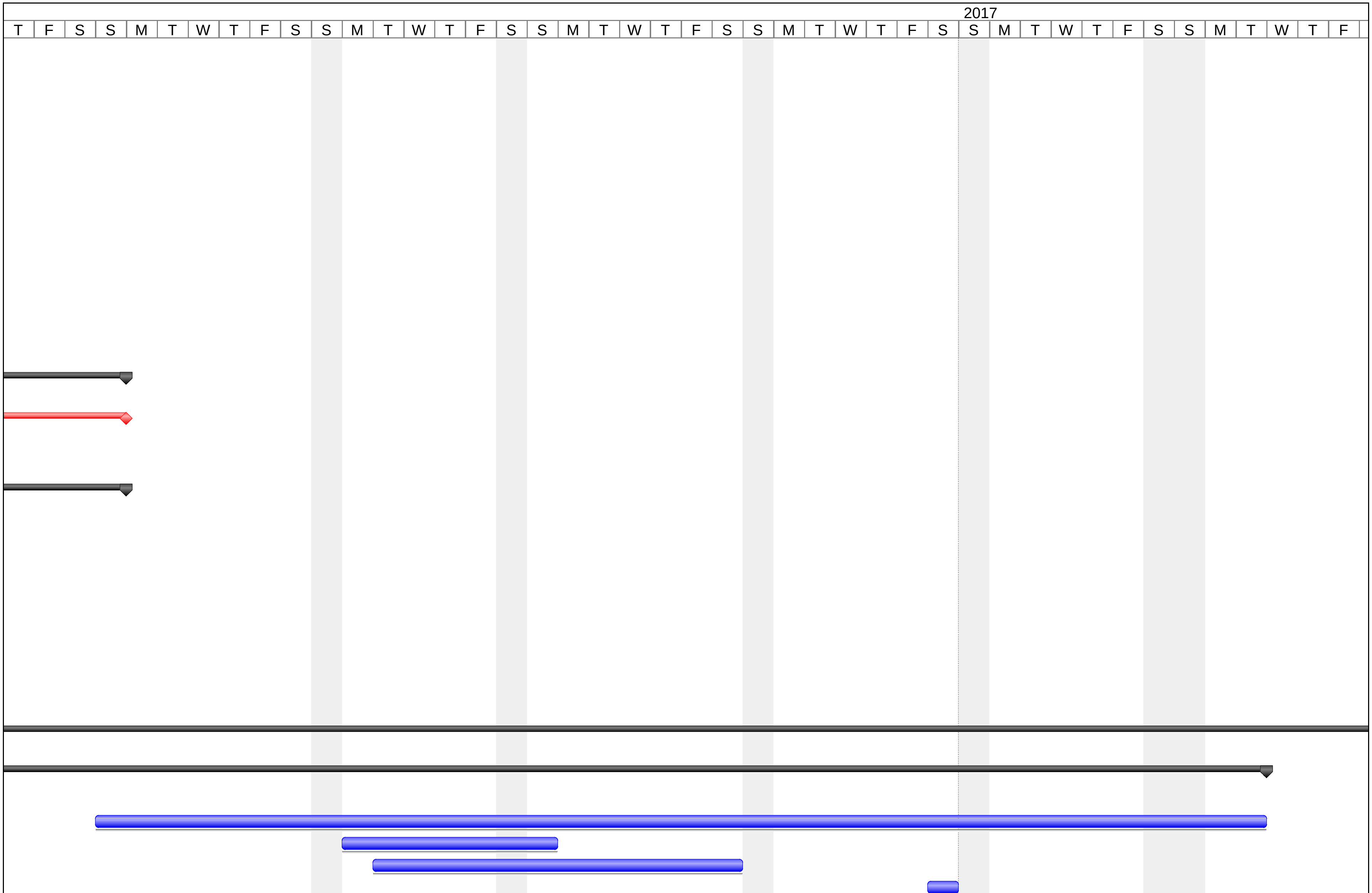
Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	



Project: v4 Student Launch 2017 Gant
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Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

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Project: v4 Student Launch 2017 Gant
Date: Mon 10/24/16

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

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Task		Milestone		External Tasks	
Split		Summary		External Milestone	
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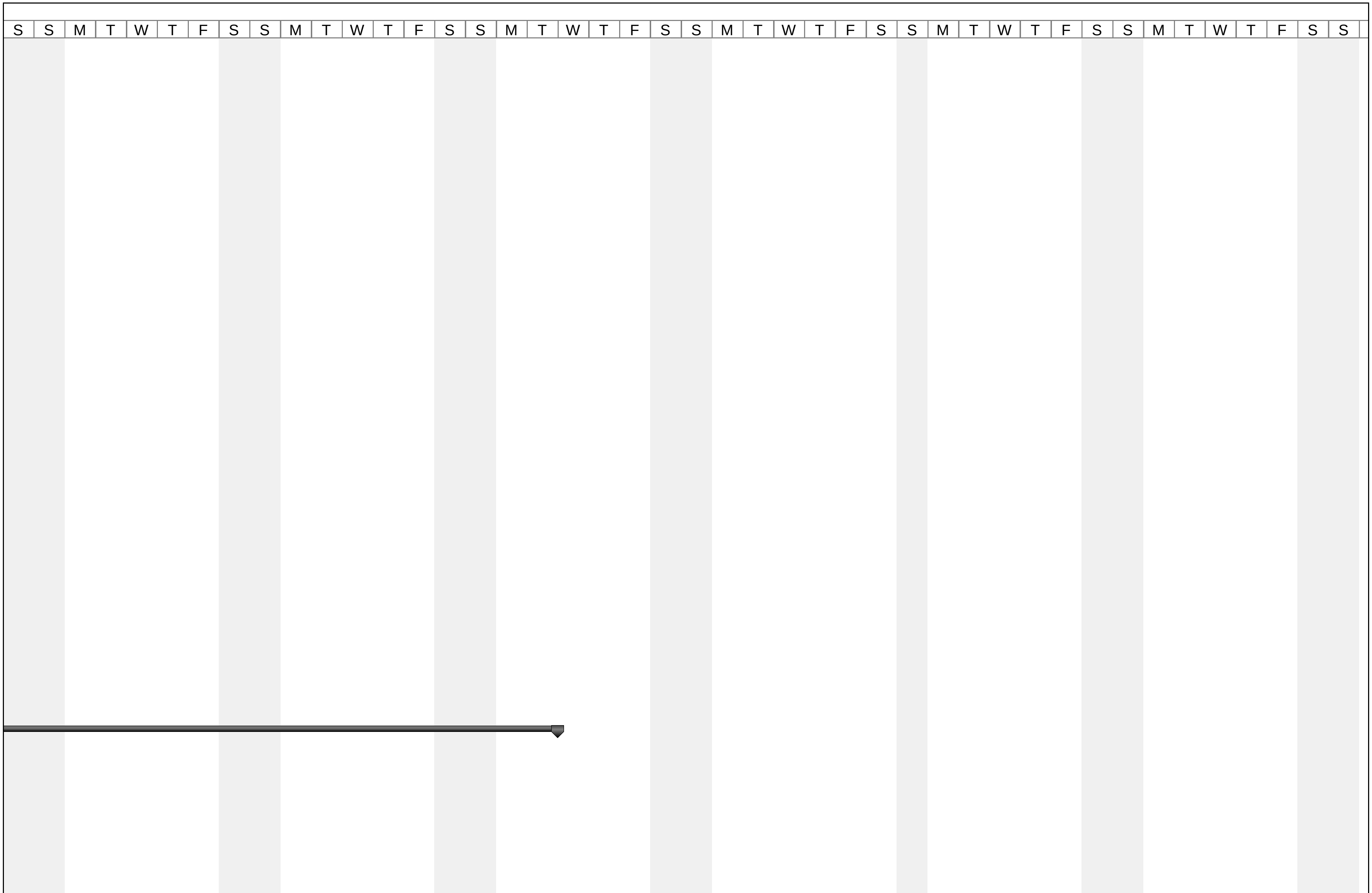

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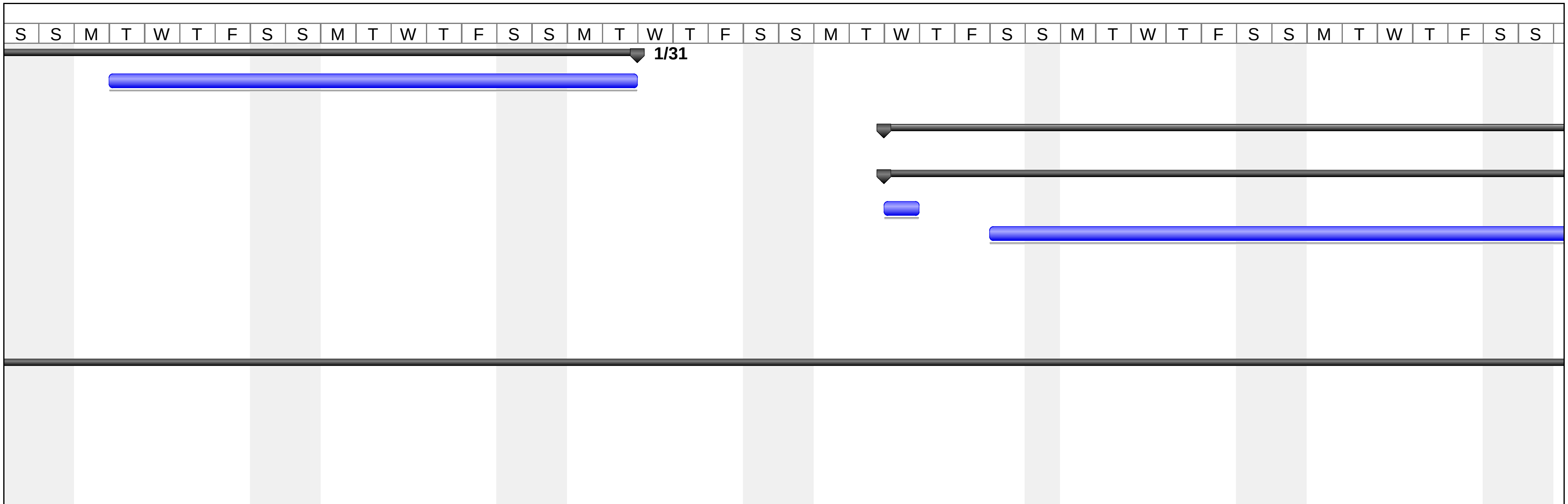
Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	



Project: v4 Student Launch 2017 Gant
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Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

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Project: v4 Student Launch 2017 Gant
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Deadline

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Project: v4 Student Launch 2017 Gant
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Task
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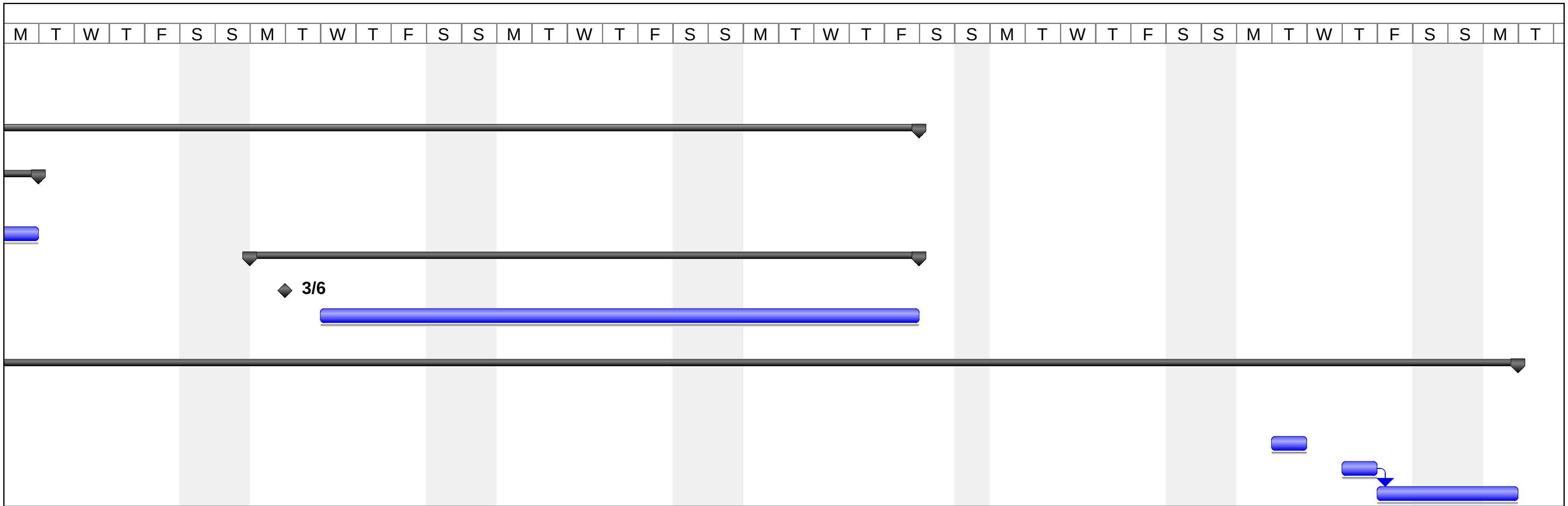

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

Project: v4 Student Launch 2017 Gant
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Appendix A: Statement of Work Cross Reference

No.	Requirement in SOW	FRR Section	Method of Validation
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).	**3.1.1.1**	
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.	**3.1.1.1**	
1.3	All recovery electronics shall be powered by commercially available batteries.	**3.1.4.1**	
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.	**7.2.2**	
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.	**4.1.1**	
1.6	The launch vehicle shall be limited to a single stage.		
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.		
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).		
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).		
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.		
1.15	The launch vehicle shall have a minimum static stability margin of 2.0 at the point of rail exit.		
1.16	The launch vehicle shall accelerate to a minimum velocity of 52 fps at rail exit		
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.		
1.18.2	The payload does not have to be flown during the full-scale test flight. The following requirements still apply:		
1.18.2.1	If the payload is not flown, mass simulators shall be used to simulate the payload mass.		
1.18.2.2	The mass simulators shall be located in the same approximate location on the rocket as the missing payload mass.		
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		
1.20	Vehicle Prohibitions		
1.20.1	The launch vehicle shall not utilize forward canards.		
1.20.2	The launch vehicle shall not utilize forward firing motors.		
1.20.3	The launch vehicle shall not utilize motors that expel titanium sponges (Sparky, Skidmark, MetalStorm, etc.)		
1.20.4	The launch vehicle shall not utilize hybrid motors.		
1.20.5	The launch vehicle shall not utilize a cluster of motors.		
1.20.6	The launch vehicle shall not utilize friction fitting for motors.		
1.20.7	. The launch vehicle shall not exceed Mach		

	1 at any point during flight.		
1.20.8	Vehicle ballast shall not exceed 10% of the total weight of the rocket.		
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.		
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.		
2.3	At landing, each independent sections of the launch vehicle shall have a maximum kinetic energy of 75 ft-lbf.		
2.4	The recovery system electrical circuits shall be completely independent of any payload electrical circuits.		
2.5	The recovery system shall contain redundant, commercially available altimeters. The term “altimeters” includes both simple altimeters and more sophisticated flight computers.		
2.6	Motor ejection is not a permissible form of primary or secondary deployment.		
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.		

2.8	Each altimeter shall have a dedicated power supply.		
2.9	Each arming switch shall be capable of being locked in the ON position for launch		
2.10	Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.		
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.		
2.11.1	Any rocket section, or payload component, which lands untethered to the launch vehicle, shall also carry an active electronic tracking device.		
2.11.2	. The electronic tracking device shall be fully functional during the official flight on launch day.		
2.12	The recovery system electronics shall not be adversely affected by any other on-board electronic devices during flight (from launch until landing).		
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.		
2.12.2	The recovery system electronics shall be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system electronics		
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.		

3.1	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.		
3.2	`Data from the science or engineering payload shall be collected, analyzed, and reported by the team following the scientific method.		
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.		
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	Each team must identify a student safety officer who shall be responsible for all items in section 4.3		

4.3	The role and responsibilities of each safety officer shall include, but not limited to:		
4.3.1	Monitor team activities with an emphasis on Safety during:		
4.3.1.1	Design of vehicle and launcher		
4.3.1.2	Construction of vehicle and launcher		
4.3.1.3`	Assembly of vehicle and launcher		
4.3.1.4	Ground testing of vehicle and launcher		
4.3.1.5	Sub-scale launch test(s)		
4.3.1.6	Full-scale launch test(s)		
4.3.1.7	Launch day		
4.3.1.8	Recovery activities		
4.3.1.9	Educational Engagement Activities		
4.3.2	Implement procedures developed by the team for construction, assembly, launch, and recovery activities		
4.3.3	Manage and maintain current revisions of the team's hazard analyses, failure modes analyses, procedures, and MSDS/chemical inventory data		
4.3.4	Assist in the writing and development of the team's hazard analyses, failure modes analyses, and procedures.		
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.		
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.		
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, educational engagement events, and risks and mitigations.		
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).		
5.4.3	No more than two adult educators.		
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.		

Appendix B: Partners in Industry

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

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

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

Mike Stoop (Fiberglassing, Programming, Design)
Mike Stoop is currently the CTO of PriceDoc, Inc, a healthcare related web services company. Mike has been in the software industry for 30 years and an avid rocketeer for 40 years. Mike achieved his level 3 certification in 2002 and has participated in many individual and team 'M" class and above rocket projects. He has launched K and larger engines with electronic dual deploy many more than 15 times. Mike is also the owner of Madcow Rocketry, a mid/high power rocket kit manufacturer.

Drew , SpaceX (Fiberglassing, Programming, Design)

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

Appendix 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:

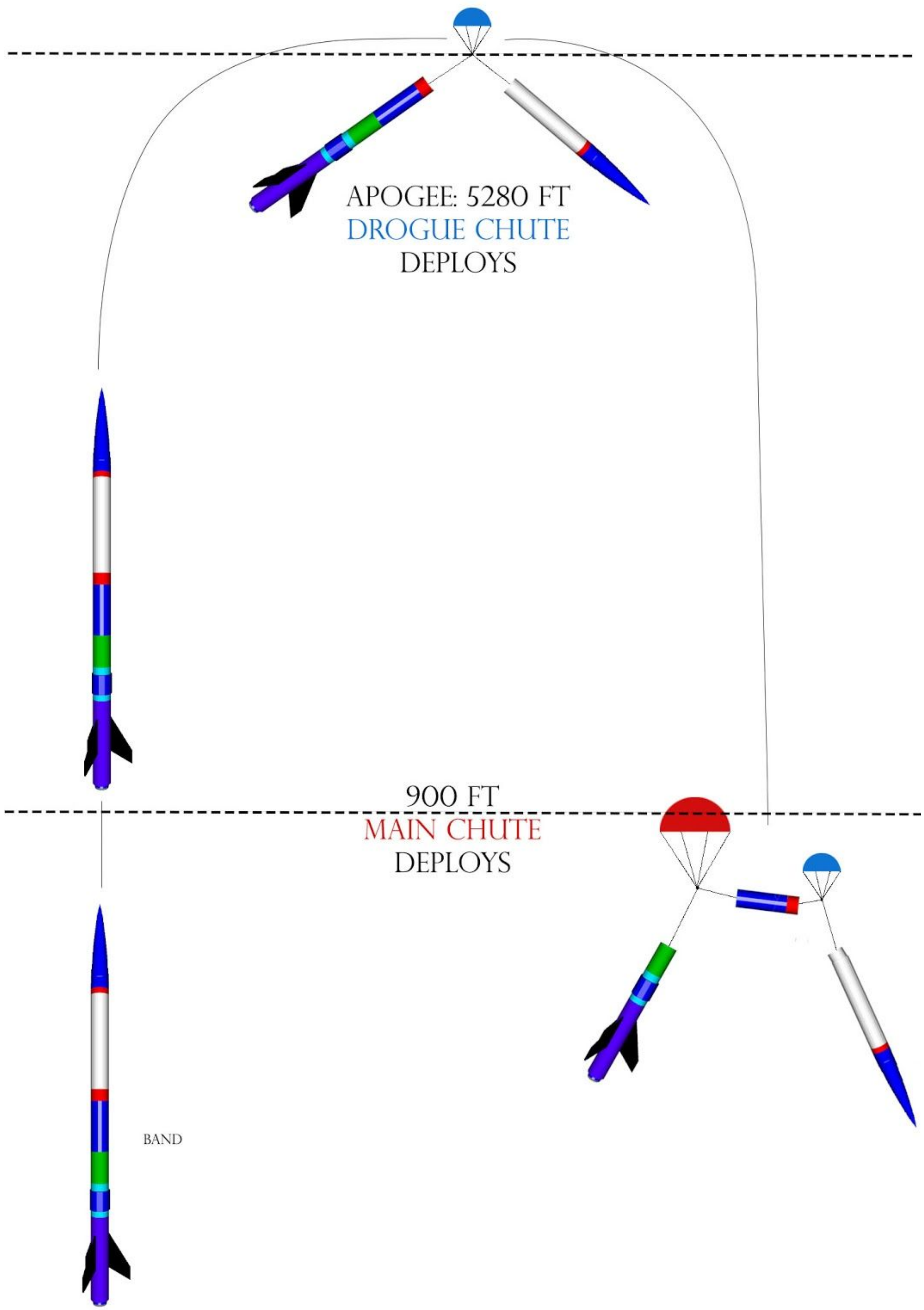
- Keep work area orderly and clean; neatly arrange all equipment and material. Put all tools and materials back where they belong.
- Always think through an entire task before starting it, and never rush a process or take chances.
- If you are unsure about safety operation or process, ask for assistance 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



Appendix F: Material Safety Data Sheet (MSDS)

MSDS Outline

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

Fiberglass

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

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

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

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

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

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

Black Powder 4F

Hazardous Components

Material or Component	%	CAS no.	TLV	PEL

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

Physical Data

Boiling Point: N/A
Vapor Pressure: N/A
Vapor Density: N/A
Solubility in Water: Good
Specific Gravity: 1.70 - 1.82 (mercury method) and 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:** NH4ClO4	**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.