Plantation High School Team #2

2015 – 2016

Flight Readiness Review

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Contents

Team Summary

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Launch Vehicle Summary

- *Length:* 110”, *Diameter:* 5.5”
- *Mass:* 267.49 Oz (Without Motor), 342.57 Oz (With Motor).
- *Motor:* K1050 White Lightning.
- *Recovery:* One main (84”) and one drogue (24”) parachute.
- *Rail Size:* 96”, 10-10.

Milestone Review Flysheet

The team’s flysheet can be found on the “SLI Reports” section of the Aerospace website.

Payload Summary

Payload Title

Electromagnetic Interference (EMI) Detection

Experiment Summary

The payload will consist of an Arduino microprocessor with an antenna attached to its analog input, allowing the Arduino to detect electrical voltage in the air. Because EMI can disrupt electronics, it can affect the vehicle’s launch system, recovery system and payload. Ensuring that these systems are protected from EMI is essential to the successful completion of the SL project.

Changes

Vehicle

Actually measurement of the vehicle’s weight yielded an increase in mass, bringing the mass to about 267.5 oz. Analysis of data from the test flight showed an increase in the vehicle’s drag coefficient.

Payload

The team still plans on flying an EMF detector as its payload. However, the team is no longer in contact with Prestwick Academy. It plans to fly an additional payload developed by students at Bair Middle.

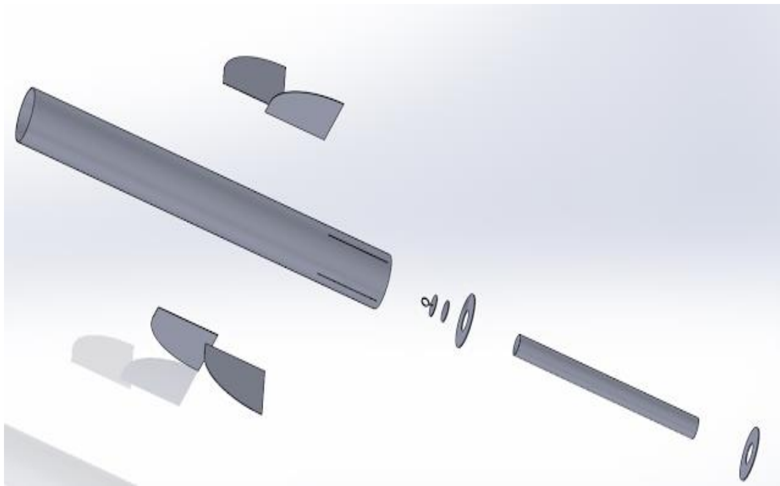
Project

No changes have been made to the project plan at this time.

Launch Vehicle

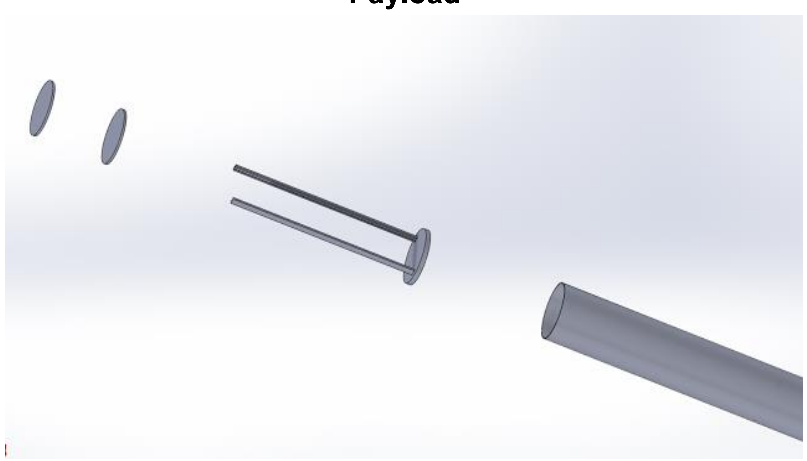
Structural Elements

Propulsion



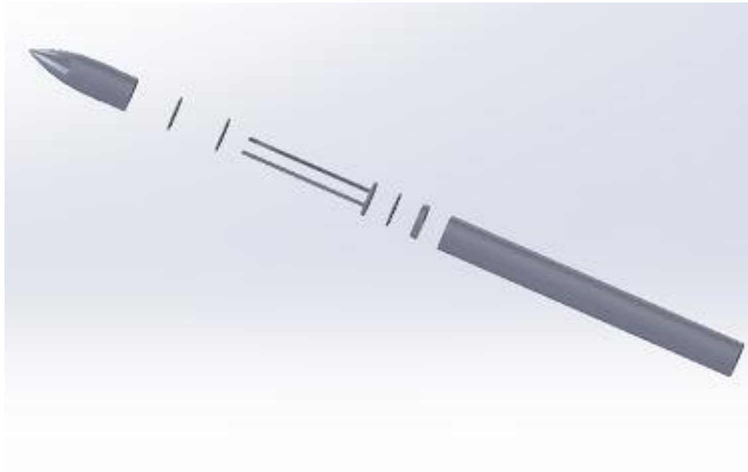
The propulsion system will consist of a 26” long, 54mm wide Blue Tube motor mount, a 1/8” G10 fiberglass centering ring and a ¼” thrust plate. The motor will be retained using a 54mm engine retainer.

Payload

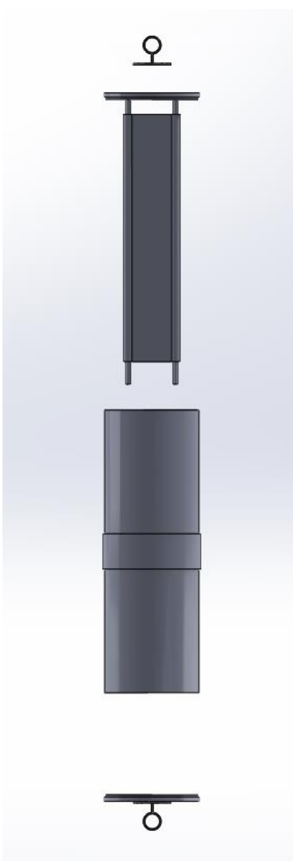


The payload system will consist of two t-rails connected to a 3D printed base with a battery pack. Two more plates will be 3D printed, each holding a payload. These plates will be slid onto the rails, and the entire fixture will be placed in the upper body tube.

Upper Airframe



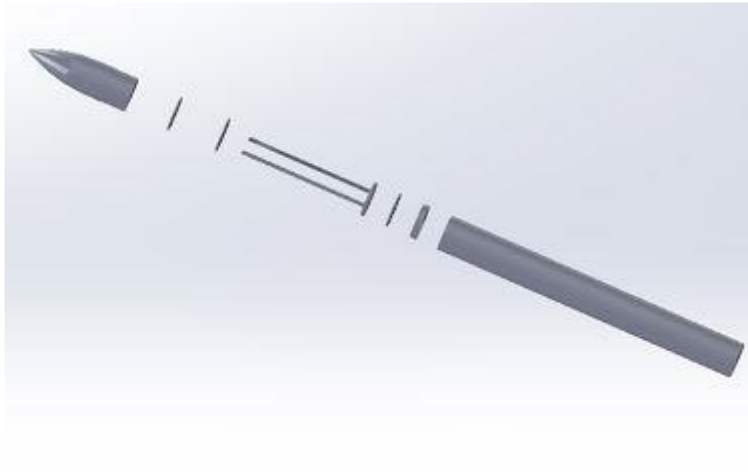
The upper airframe will be a 5.5” wide, 48” long Blue Tube body tube. The airframe will contain a 1/8” G10 fiberglass bulkhead, a 5.346” wide, 1” long coupler and the entire payload system, as well as the main parachute and upper 40’ of the recovery harness. A 13” ogive nosecone, with a shoulder of 4” will be attached to the body tube using 3 screws. A U-bolt will be attached to the bulkhead, allowing for integration with d-links in the recovery system.



Coupler

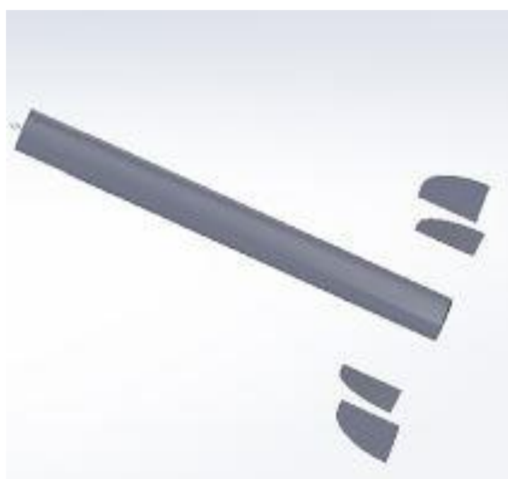
The coupler will be a 5.346” wide, 16” long Blue Tube. It will contain a laser cut wooden altimeter bay, holding two PerfectFlite Stratologger altimeters and a battery. The altimeter bay will be housed on two threaded rods, which will be bolted to two ¼” G10 fiberglass bulkheads, one on each side of the coupler. U-bolts will be attached to these bulkheads, allowing for integration with d-links in the recovery system. The coupler will also have a 2” Blue Tube band around its center, upon which a rotary switch, controlling the altimeters, will be mounted.

Upper Airframe



The upper airframe will be a 5.5” wide, 48” long Blue Tube body tube. The airframe will contain a 1/8” G10 fiberglass bulkhead, a 5.346” wide, 1” long coupler and the entire payload system, as well as the main parachute and upper 40’ of the recovery harness. A 13” ogive nosecone, with a shoulder of 4” will be attached to the body tube using 3 screws. A U-bolt will be attached to the bulkhead, allowing for integration with d-links in the recovery system.

Lower Airframe



The lower airframe will be a 5.5” wide, 46” long Blue Tube body tube. It will have a fin set, consisting of 4 fins in the shape of quarter ellipses, with root chords of 4” and semi spans of 8”. The lower airframe will also contain the entire propulsion system, drogue parachute, and lower 40’ of the recovery harness.

Recovery

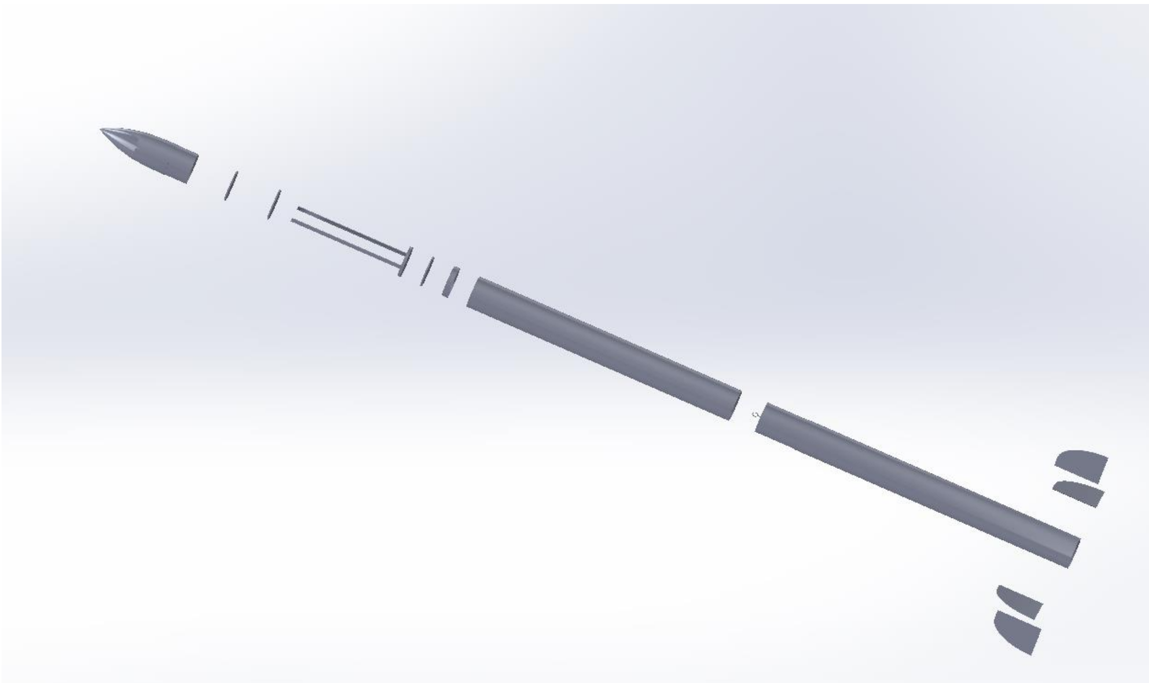
The recovery system will consist of an 84” main and 24” drogue parachute, an 80’, ½” tubular Kevlar shock cord, ejection charges and attachment hardware. Barrel swivels will be used to attach parachutes to the recovery harness. D-links will be placed on the ends of the recovery harness to attach it to U-bolts on the bulkheads and to the motor case. Ejection charges will be attached to terminals mounted on coupler bulkheads, which will be wired to the altimeters.

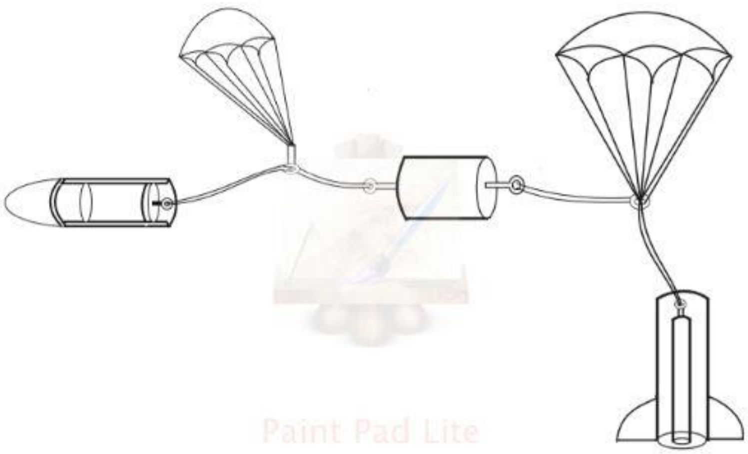
Electrical Elements

The electrical elements in the vehicle are the payload, GPS and altimeter bay. The GPS is a Garmin Astro Dog Collar, which will be attached to the payload integration system in the upper airframe. The payload will consist of an Arduino, SD card and antenna. The payload will be powered by 9V batteries at the base of the integration systems. The batteries will be retained in a battery pack on a 3D printed plate, resting above the bulkhead in the upper airframe. The batteries will be wired to the payload by charging the t-rails in the integration system. In the altimeter bay, the batteries are retained by zip tying them to the wooden bay. The altimeters are screwed onto the bay. The batteries are wired to rotary switches on the coupler band. These switches will then be wired to the altimeters, allowing them to be turned on and off. The altimeters will also be wired to terminals on the outside of the coupler bulkheads, allowing them to control the ejection charges. The entire altimeter bay will be retained on threaded rods in the coupler, between the two coupler bulkheads.

Drawings and Schematics

The following drawing show the assembly of the vehicle.





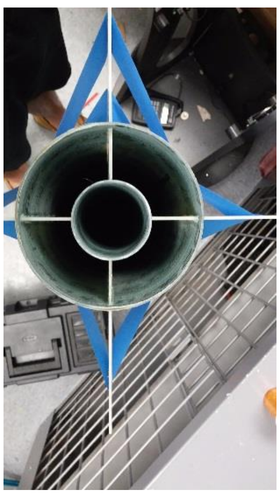


Figure 1: fins to motor mount glue joint.

Flight Reliability

The vehicle has undergone many stress and functionality tests. One test conducted was a stress test of fins once epoxide to motor mount. After fins are secured to motor mount through epoxy a small stress test is conducted to determine the strength of the glue joint (figure 1). After the vehicle passes the first stress test a fin fillet is done to ensure the fins are secure and will not flutter during flight.

The design file states that the maximum altitude of 5280ft will not be not be broken because projected height for the full scale flight is 5212ft. Launch vehicle is dry fitted to determine all components fit properly and that all mistakes are found before permanent gluing. All components such has coupler, upper body tube, lower body tube and payload bay are constructed based around given guidelines.

Test Data and Analysis

The payload was tested on ground by constructing components and calculating the amount of EMF detected by different electrical systems. To determine the amount of EMF given off by the systems an LED light and speaker are connected to the breadboard allowing for visual and auditory data to be collected[1]. The faster the LED blinks, and the higher the pitch of the speaker the more EMF the antenna is collecting. Tests were conducted by having a cell phone broadcast to another phone allowing for the EMF produced by the phone to be collected by the antenna[2]. This causes the LED to blink rapidly and have the speaker create a mid-range tone. Data was collected by connecting Arduino to the computer and reading the data directly from the antennae. Data is compiled and saved so that it can be compared to another electrical system[3]. When comparing the data to a different test such as computer EMF, where the antenna was placed near a 2 desktop computers and data shows a notable increase in EMF[4]. The following images show the payload configuration and differences in data near and away from EMF generating devices:

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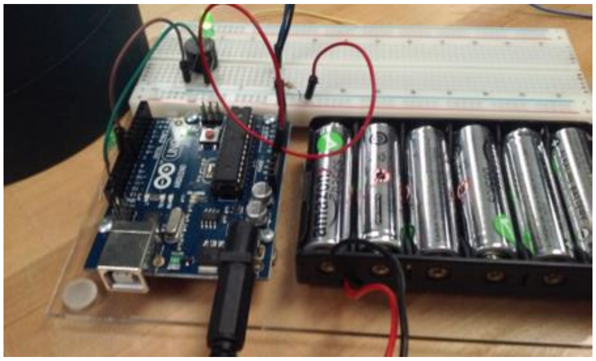


140	8
87	32
56	12
43	20
0	0
124	20
31	16
0	24
0	0
0	12
0	30
91	20
143	0
0	29
60	5
0	27

From ground ejection testing it can be concluded that drogue and main parachute can be deployed with 4 large shear pins securing upper and lower body tube. For drogue deployment an initial charge of 2.5 grams with a redundancy of 2.8 grams is needed to ensure proper drogue deployment. Main deploys at 500 ft. and needs a charge of 3 grams with a redundancy of 3.5 to allow all components to eject and descend launch vehicle.

Static testing of recovery system. Ejection charges are being tested with different black powder masses to determine the proper amount to separate rocket during decent.

Lower half drogue parachute deploying from ejection charge. 2.5 grams of black powder sufficed to blow out sheer pins and separate lower half.

Upper half main parachute deploying from ejection charge. 2.7 grams of black powder sufficed to blow out sheer pins and separate upper half.

Approach to Workmanship

Communication is vital to the construction of a functioning vehicle and its various systems and subsystems. Project managers will clearly allocate roles to individuals to ensure that every job is completed efficiently and correctly. Students will communicate these roles through messaging programs and by writing in their log book if it is not possible to meet face-to-face. Students will remain on schedule by following GANTT charts to complete construction on time. Safety will be the primary objective throughout construction, and the safety officer will ensure proper precautions are used. Communication and timeliness will also apply to the completion of written documents.

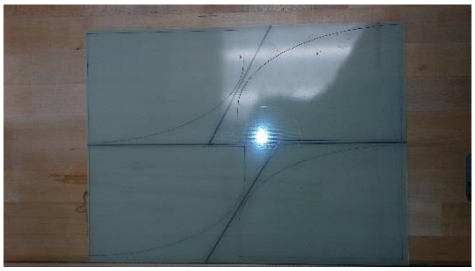


Figure 2: Crating tangent lines to the curved fins to make cutting and sanding easier with less tough angles to cut at. Fins can be worked on individually then combined later to be sanded to equal lengths.

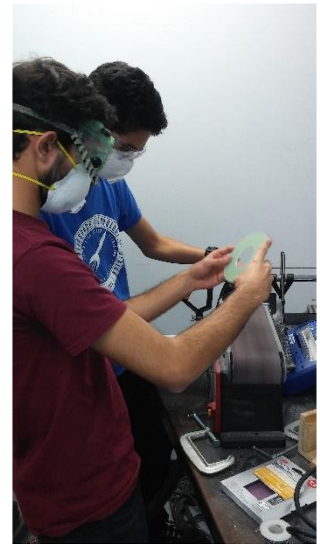


Figure 1: members sanding centering ring and referring to one another for confirmation on proper measurements.

The team's safety officer is always present to enforce the use of PPE's and documentation is always done to ensure each step is logged. Many jobs are done in pairs of two to mitigate the amount of error there can be. For example, one would do the measurements the other will check measurements and when both come to an agreement then construction takes place (Figure 1). Another way to minimize the amount of error is through the use of technical assistance (Figure 2).

Safety and Failure Analysis

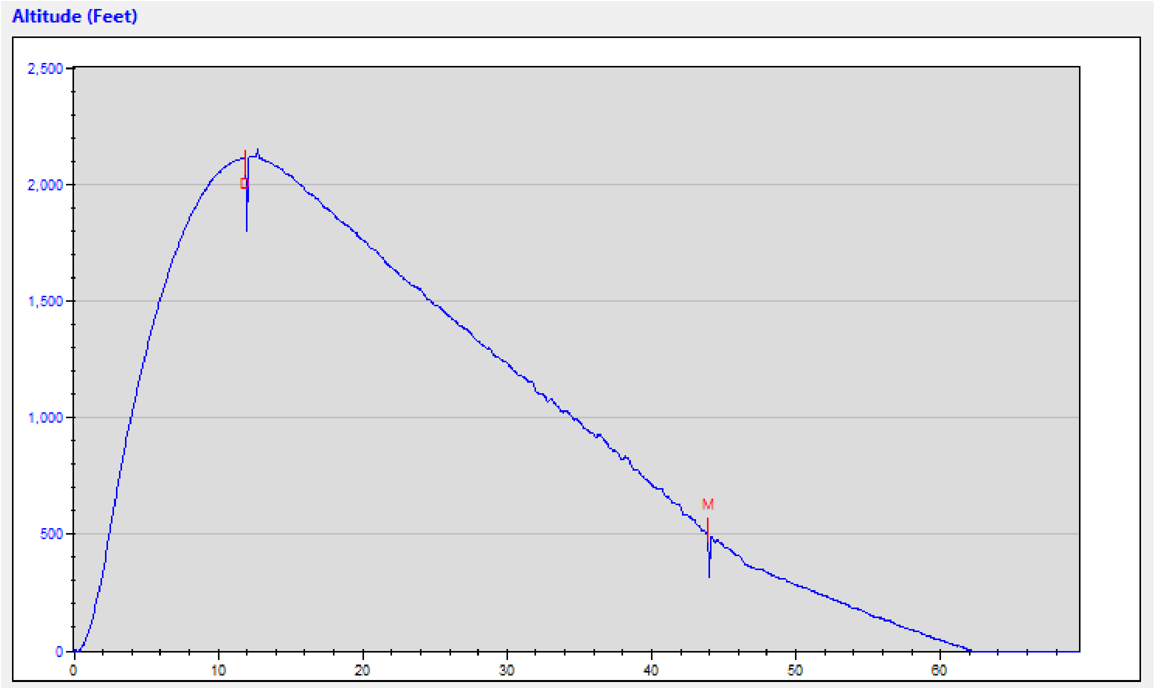
Possible Obstruction	Probability	Impact on Flight	Mitigation	Verification
Fins of the launch vehicle cannot withstand the forces of flight.	Low	Fins may be severely damaged or cause the launch vehicle to be unstable	The team will be sure to secure the fins to the launch vehicle and test all components before launch	The team will stress test the fins of the launch vehicle in order to ensure that the fins are secured tightly and will use programs such as Rocksim to ensure that the fins are able to withstand the required forces.
Motor mount is not securely attached.	Low	The motor may leave the launch vehicle or severely damage the launch vehicle. The launch vehicle may become highly unstable	The team will ensure that the motor mount is tightly secured and that it is able to withstand the required forces	The team will stress test the motor mount through pulling and tugging to ensure that there is no give. Through simulations, the team will ensure that the motor mount is able to withstand the required forces.
The launch vehicle is unable to successfully	Low	The launch vehicle is unable to successfully eject leading to a failed deployment of	The team will ensure that the amount of black powder placed inside of the launch vehicle is	The team will collect data from ejection charge tests to ensure that the amount of black powder used is sufficient enough to successfully decouple the

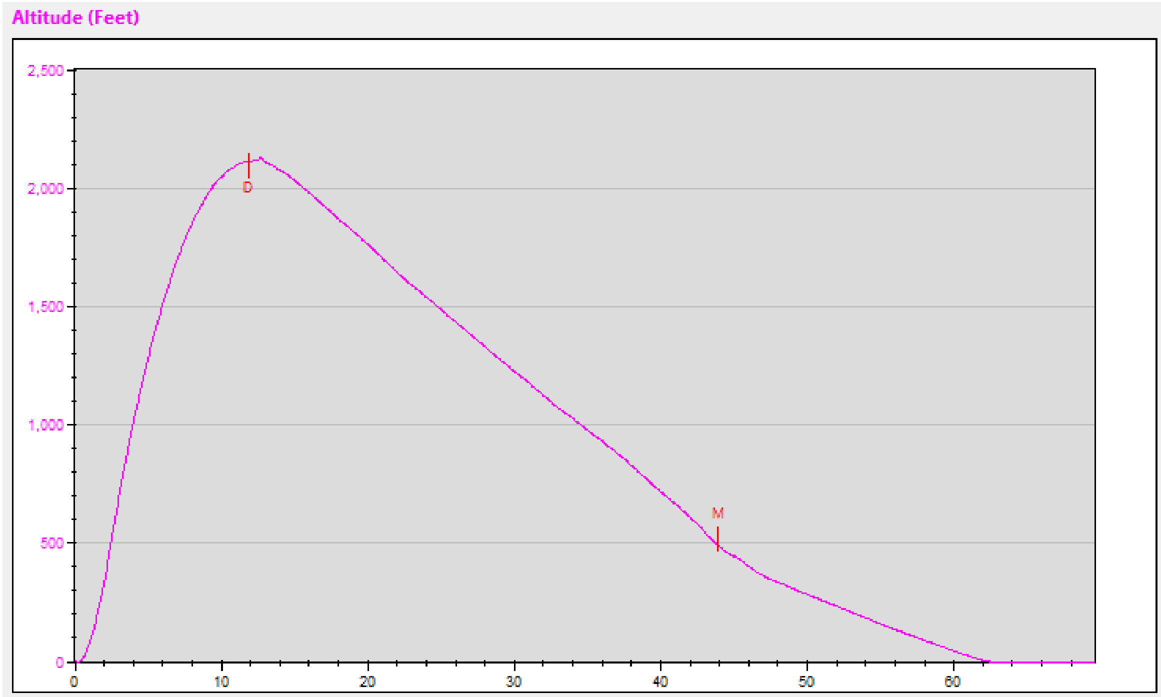
decouple during ejection		parachutes.	sufficient enough to successfully separate the rocket.	launch vehicle.
During ignition the launch vehicle does not leave the launch pad	Low	Launch is postponed	The team will wait at least 60 seconds before approaching the launch vehicle to ensure that it is safe	The team will inspect motors before launch to ensure that they are not damaged or old.

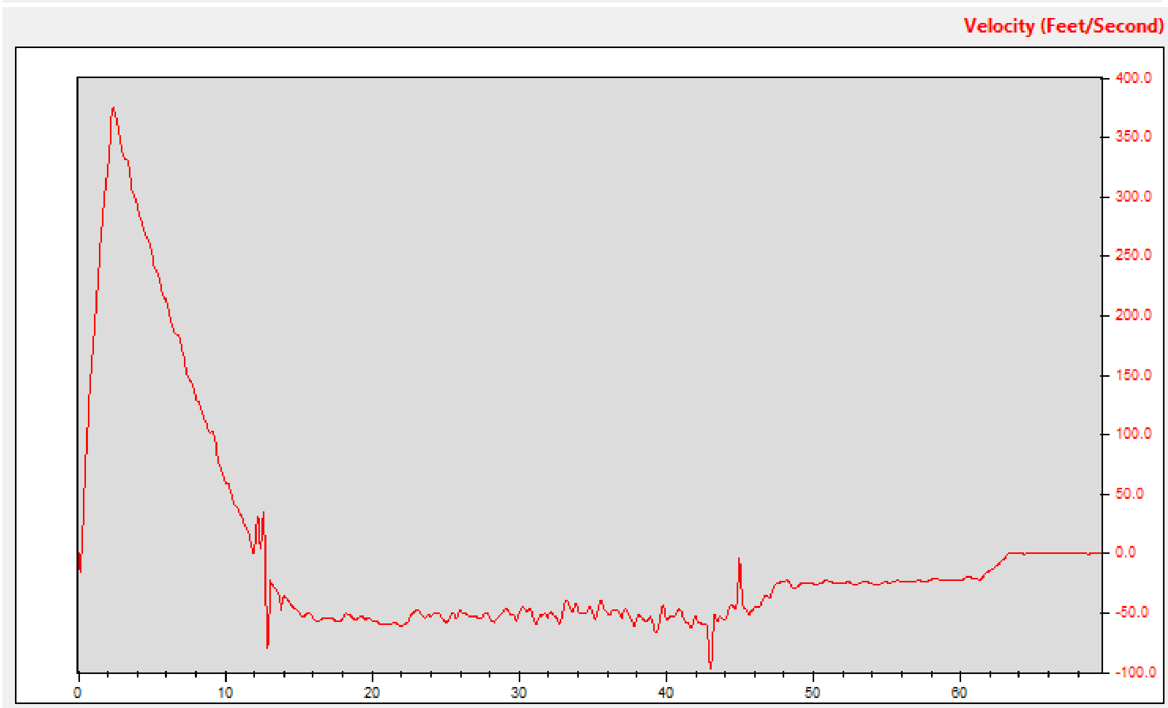
Test Results

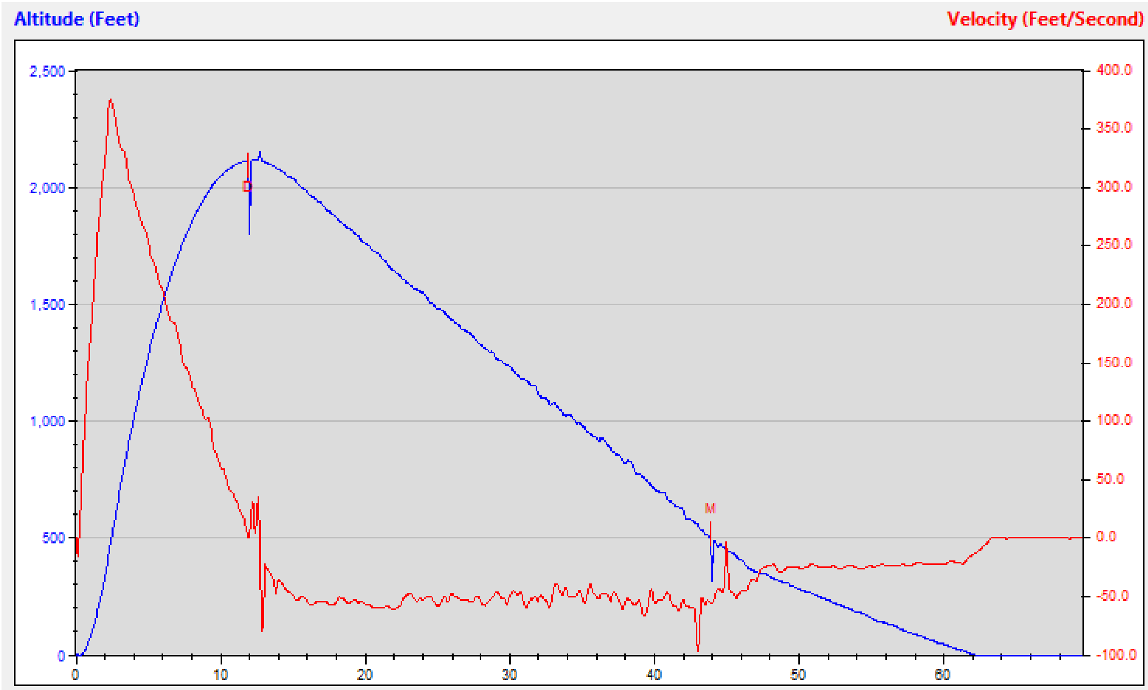
The full scale test launch expected altitude was 2350 ft. compared to actually test flight altitude of 2127 ft. The full scale test launch was smooth in all aspects of preparation to recovery landing. Before launch a procedure check list was created to ensure all aspects are done correctly and checked off to indicate that it has been completed and it's time to proceed to next step. On field changes were made from a 20ft Kevlar recovery harness for drogue parachute to a 40 ft. recovery harness. This change was needed because the drogue need more length so that it caught maximum amount of air upon decent of rocket to 500ft. Procedure list was followed strictly with parachutes being burrito folded 3 times to verify that the parachute will deploy properly during decent.

Ignition and flight was completely successful with no rocket weather coking, deployment of drogue at apogee, and deployment of main at 500ft. All ejection charges fired deploying recovery system with redundancy ensuring that all recovery components exited the launch vehicle. The following images show actual flight data, including raw altitude, smoothed altitude and velocity:




Altitude (Feet)
2,500
2,000
1,500
1,000
500
0
D
M
0
10
20
30
40
50
60


Velocity (Feet/Second)
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
-50.0
-100.0
0
10
20
30
40
50
60



Mass Statement

Upper Airframe

Part	Mass (oz.)
Body Tube	43.33
Nosecone	12.7
Payload	31.00
Bulkhead	3.62
GPS	5.15
Eyebolt	0.72
D-Link	1.53
Inside Coupler	1.30
Rail Button	0.05

Coupler

Part	Mass (oz.)
Coupler Tube	12.76
Coupler Band	1.40
Bulkhead (x2)	6.49
Eyebolt (x2)	0.72
D-Link (x2)	1.53
Threaded Rods	5.78
Altimeter (x2)	0.88
Altimeter Bay	5.23

Wiring	1.03
Nuts and Washers	1.98

Lower Airframe

Part	**Mass (oz.)**
Body Tube	40.44
Motor Mount	7.05
Centering Ring	2.80
Thrust Plate	4.40
Fin Set	16.54
Engine Retention	1.06
D-Link	1.53
Rail Button	0.05

Recovery

Part	**Mass (oz.)**
Main Parachute	17.28
Drogue Parachute	5.11
Main Recovery Harness	10.14
Drogue Recovery Harness	15.20

Totals

Section	**Mass (oz.)**
Upper Airframe	99.40
Coupler	47.39
Lower Airframe	73.87
Recovery	46.83
Total:	**267.49**

The basis of this mass statement is actual component and vehicle weights, measured during construction and prior to the test flight. The individual component weights in each section of the vehicle were summed and compared to the total weight of that section. The sections were then summed and compared to the total vehicle weight, to ensure that the mass of every component and section and of the entire assembled vehicle is entirely accurate.

Recovery

Structural Elements

The recovery harness is constructed from ½" tubular Kevlar, with a test strength of 7200 lbs., recommended by the manufacturer for vehicle's with diameters greater than 5". Parachutes are attached to the recovery harness using ½" d-links and barrel swivels. The main recovery harness is attached to bulkheads in the upper airframe and on the coupler. The drogue recovery harness is attached to the motor casing and a bulkhead on the coupler. Attachments are made using a d-link on the harness to an eyebolt. The eyebolts on the bulkheads are secured using two washers, a nut, and a lock nut. The eyebolt on the motor casing is pre-attached and secured. The bulkhead in the upper airframe is epoxied in, with a 1" long piece of coupler epoxied under it. The main coupler bulkhead is secured to two threaded rods using four washers, two wing nuts and two lock nuts. The drogue bulkhead is secured with four washers, two lock nuts and two nuts. The motor casing is secured into the motor mount, which is connected to the lower airframe by the centering ring and thrust plate. This staged recovery was successfully functionally tested during the test launch.

Electrical Elements

The electronic portion of the recovery system is an altimeter bay, composed of two PerfectFlite Stratologger altimeters, 9V batteries, switches and wiring. The altimeters are programmable to set off ejection charges at apogee or at a certain altitude. They are powered from the 9V batteries, which attach to rotary switches. The use of rotary switches ensures that the altimeters will not be powered off during flight. The altimeters are wired to terminals on the outside of the coupler bulkheads. Ejection charges are attached to these terminals as well, allowing the altimeters to set them off at the desired altitude. These electrical elements were successfully functionally tested during the test launch.

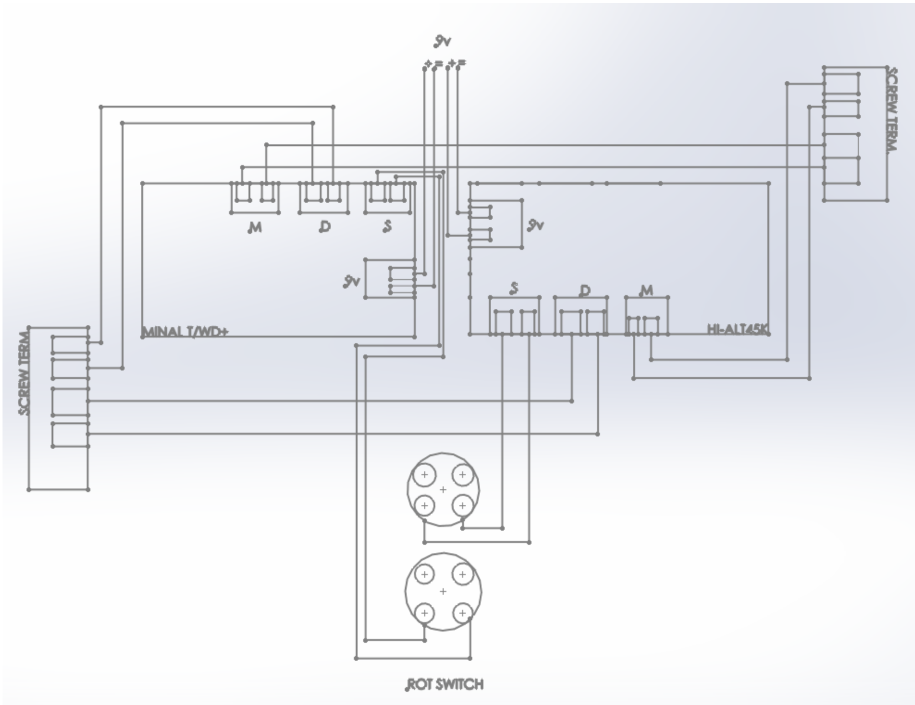
Redundancy

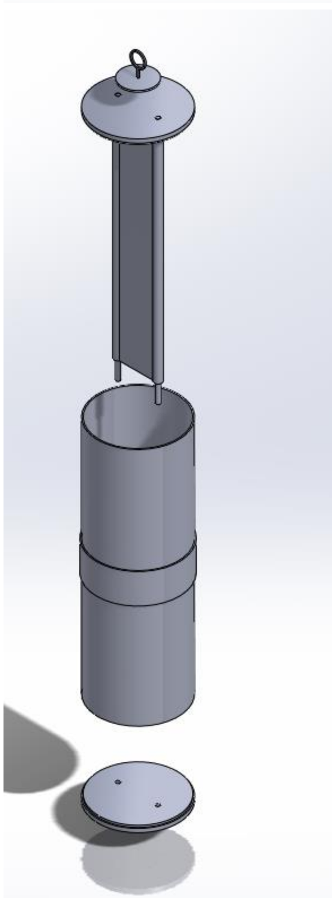
A redundant ejection charge is placed in each airframe, in case the initial charge fails to separate it from the coupler. Two altimeters are used in the recovery system, making it extremely unlikely that the charges fail to blow.

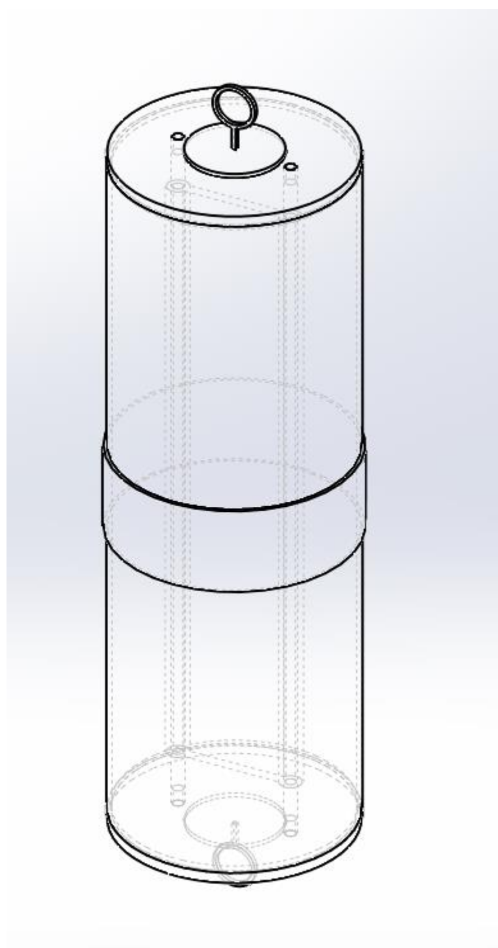
Sizes and Decent Rates

An 84" main and 24" drogue chute are being used in the vehicle. After the drogue parachute deploys, the vehicle is descending at about 92 f/s. After the main deploys, the vehicle descends at about 23.5 f/s.

Drawings and Schematics







Transmitters

A Garmin Astro Dog Tracker GPS is being flown with the vehicle. This GPS has a range of 9 miles and operates on the MURS 1 frequency band at 151,820 MHz. The GPS operates with less than 2 watts and no other transmitting devices are used.

Sensitivity to EMFs

The only onboard devices generating electromagnetic fields are the GPS and Arduinos in the payload. The EMFs generated by these devices are insignificant and unlikely to cause any damage to the recovery system. The test launch with the GPS, the only transmitter aboard the vehicle showed that it had no effect on the vehicle.

Suitability

Kinetic energy calculations show that the parachutes keep the kinetic energy of each tethered section of the vehicle to under 75 ft-lbs at landing. Test results show that the vehicle recovered safely, with no damage and that parachute size did not cause excessive drift. The attachment scheme, using barrel swivels, d-links and eyebolts is suitable because it ensures that the recovery system can withstand the high stresses placed upon, through the use of metal components. The use of d-links allows for the easy removal and attachment of the recovery system.

The vehicle's deployment process beings with the ignition of the ejection charge. This ignition breaks the shear pins securing the airframe to the coupler, causing separation. It then forces the parachute to eject and deploy. This process is suitable because it allows for the controlled deployment of parachutes at specific altitudes. Ground ejection tests prior to launch showed that all electronics were functional and that the ejection charge mass was suitable for the vehicle. The successful recovery of the vehicle during the test launch substantiated these results.

Safety and Failure Analysis

Failure	Failure Analysis	Solution
Shroud lines are tangled during ejection.	The parachute(s) will not deploy properly, leading to an unsuccessful recovery.	Shroud lines will be properly inserted into the rocket, and the recovery system will be tested before launch.
Recovery electronics fail.	The altimeters do not trigger the ejection charges at the proper heights and recovery would be unsuccessful.	The recovery system electronics will be tested before fight to ensure that everything is working properly.
Black powder charges fail to eject parachutes.	Shear pins remain unbroken and the vehicle is not slowed down enough for a safe landing.	Ground ejection tests will be run prior to launch to calculate the necessary amount of black powder.
Rocket lands in an inaccessible area.	The rocket/payload may be damaged, or unrecoverable, due to drift.	Weather conditions and electronics will be checked before flight and adjusted to.

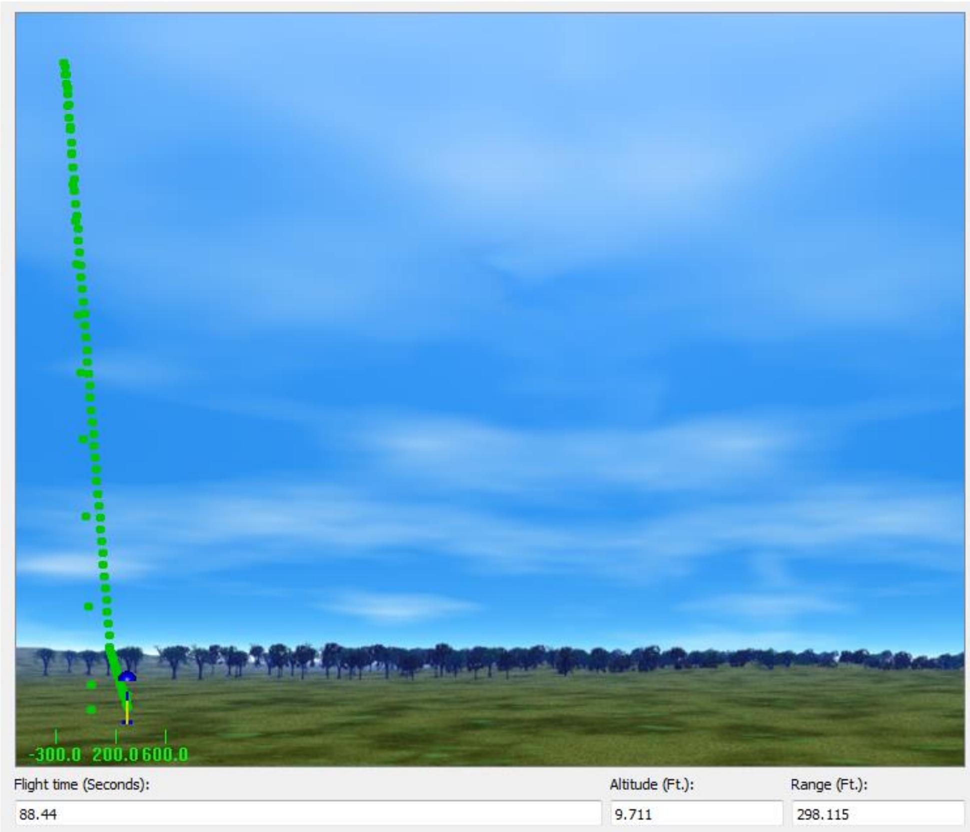
Mission Performance Criteria

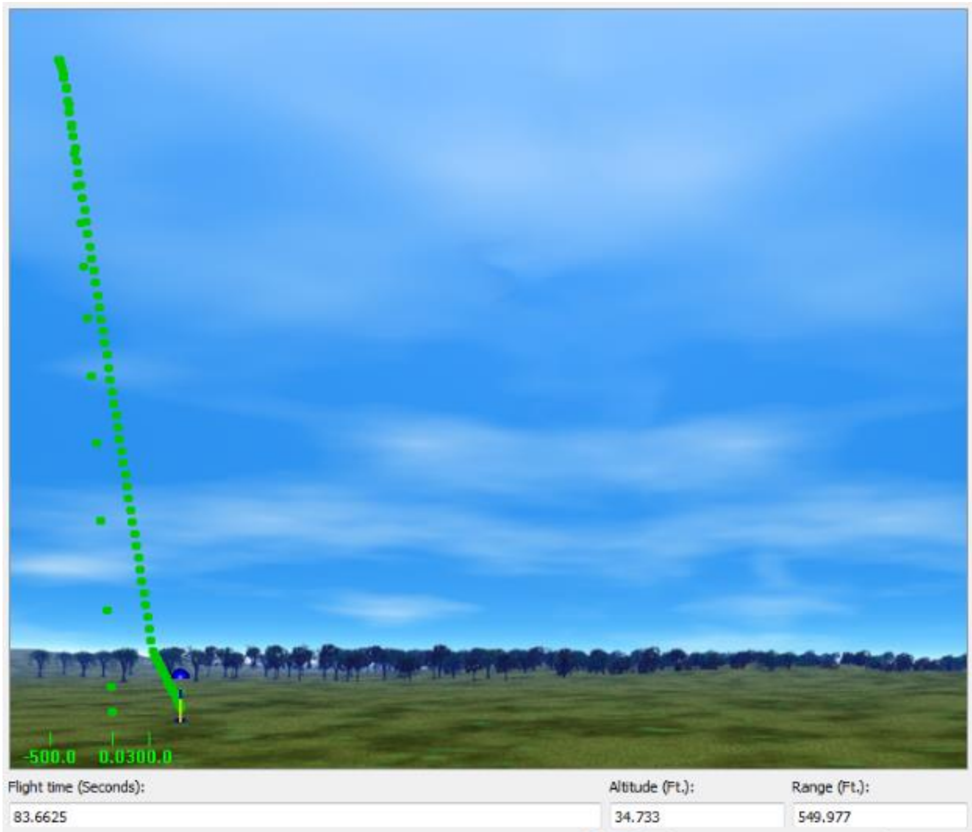
Criteria

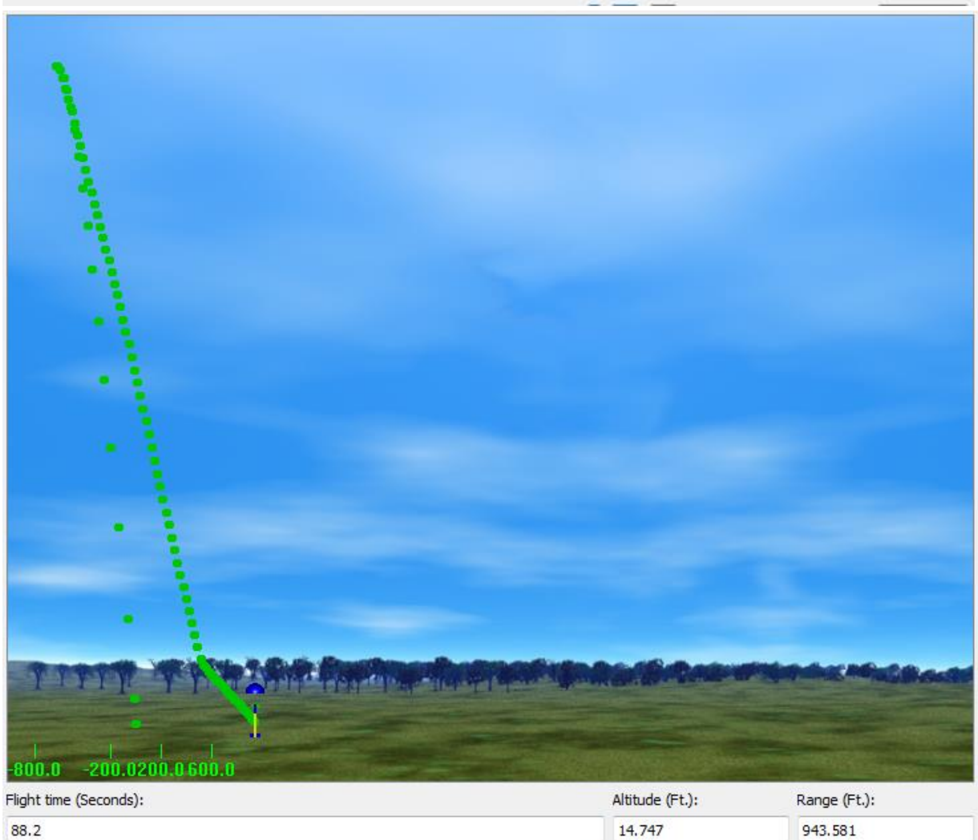
- The launch vehicle will not exceed an altitude of one mile.
- Each section of the launch vehicle will have a kinetic energy of less than 75 ft./lbs. at landing.
- The launch vehicle will carry out a straight, stable flight.
- The launch vehicle will be recovered in an undamaged and reusable state
- The drogue parachute will eject at apogee, and the main will eject at 500 ft.
- The payload will collect data on the voltage of residual electromagnetic energy in the atmosphere, and function with up to three other payloads.
- The payload will be recovered in an undamaged and reusable state.
- On board transmitting devices, such as the GPS will remain functional throughout the flight.

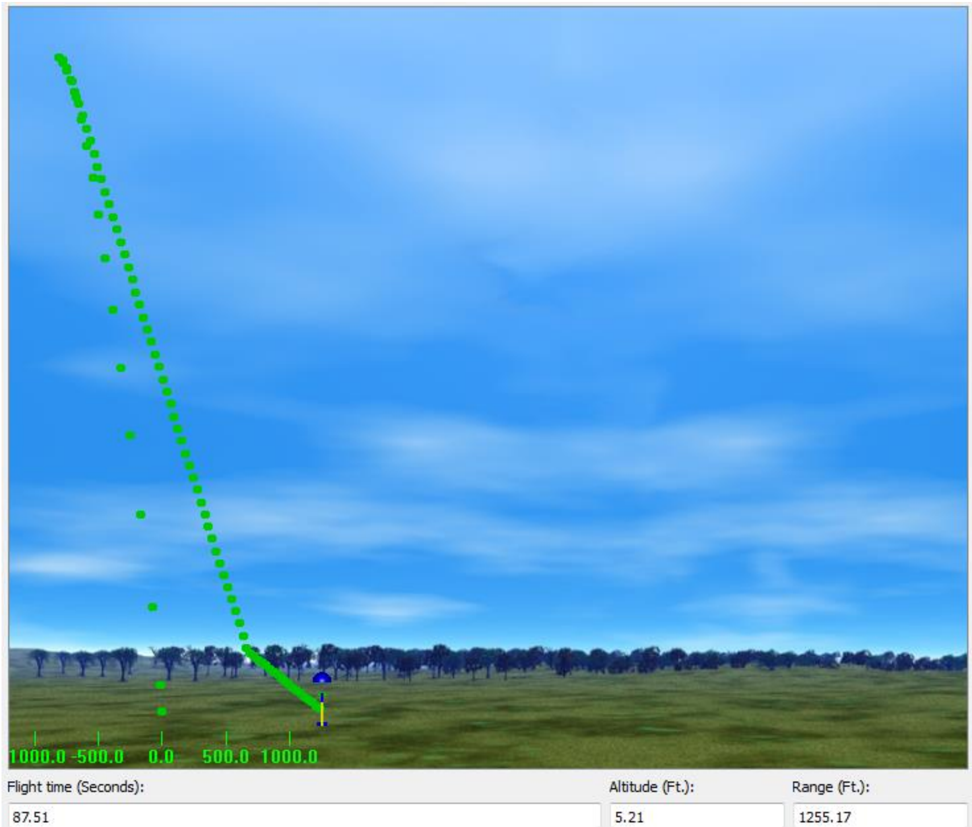
Flight Profiles

The following profiles show the vehicle's flight predictions in 5, 10, 15, and 20 mph wind.




-500.0 0.0300.0
Flight time (Seconds):
83.6625
Altitude (Ft.):
34.733
Range (Ft.):
549.977


-800.0 -200.0200.0600.0
Flight time (Seconds):
88.2
Altitude (Ft.):
14.747
Range (Ft.):
943.581



Altitude Predictions

The following are the results of six simulations conducted in Rocksim. Based on these, the vehicle as a predicted altitude of 5212 ft.

	Simulation	Results	Engines loaded	Max. altitude Feet	Max. velocity Feet / Sec	Max. acceleration Feet/sec/sec	Time to apogee	Velocity at deploym Feet / Sec	Altitude at deploym Feet
1	0		[K1050W-None]	5207.64	746.90	445.52	16.80	19.56	5207.65
2	1		[K1050W-None]	5207.91	746.90	444.97	16.80	19.36	5207.90
3	2		[K1050W-None]	5213.78	747.00	445.43	16.81	13.94	5213.78
4	3		[K1050W-None]	5217.22	747.06	445.43	16.82	9.40	5217.23
5	4		[K1050W-None]	5206.40	746.88	445.98	16.80	20.52	5206.41
6	5		[K1050W-None]	5213.65	747.00	444.92	16.81	14.10	5213.63

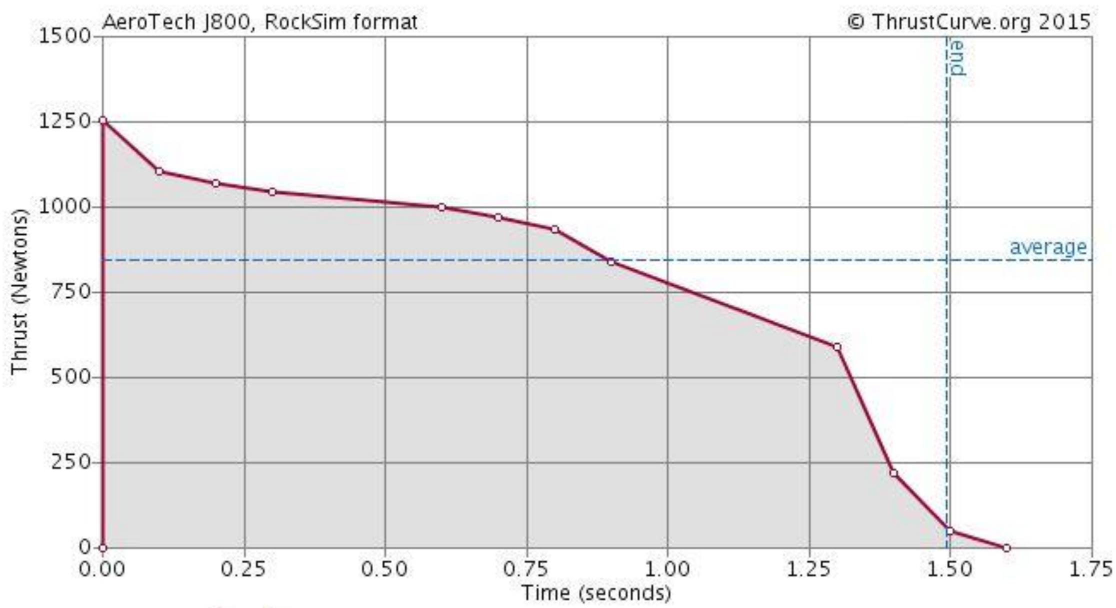
Component Weights

Component	Mass (oz.)
Upper Body Tube	43.33
Nosecone	12.7
Payload	31.00
Bulkhead	3.62
GPS	5.15
Eyebolt	0.72
D-Link	1.53
Inside Coupler	1.30

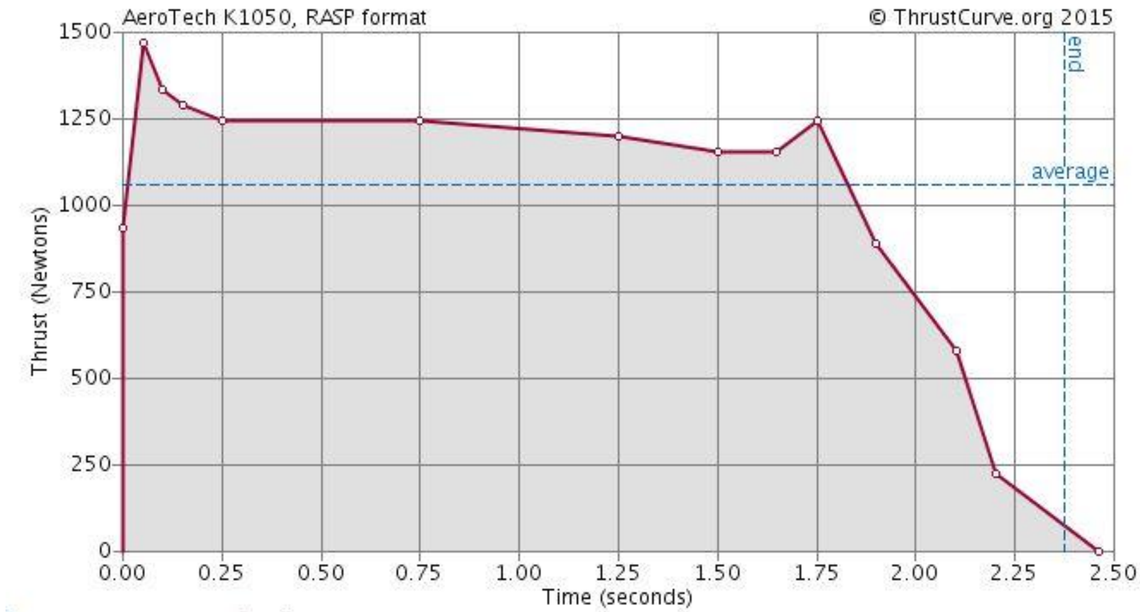
Rail Button	0.05
Coupler Tube	12.76
Coupler Band	1.40
Coupler Bulkhead	6.49
Threaded Rods	5.78
Altimeter	0.88
Altimeter Bay	5.23
Lower Body Tube	40.44
Motor Mount	7.05
Centering Ring	2.80
Thrust Plate	4.40
Fin Set	16.54
Engine Retention	1.06
D-Link	1.53
Main Parachute	17.28
Drogue Parachute	5.11
Main Recovery Harness	10.14
Drogue Recovery Harness	15.20

Thrust Curves

Full-Scale Test Launch



Full-Scale Launch

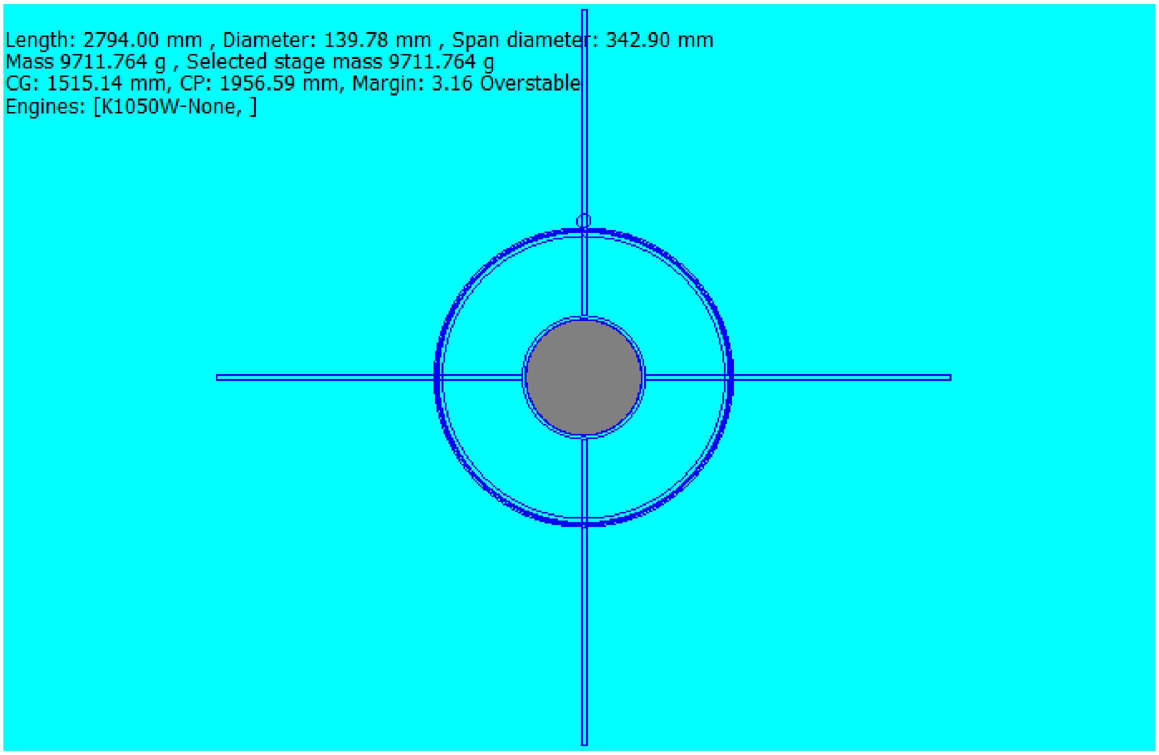


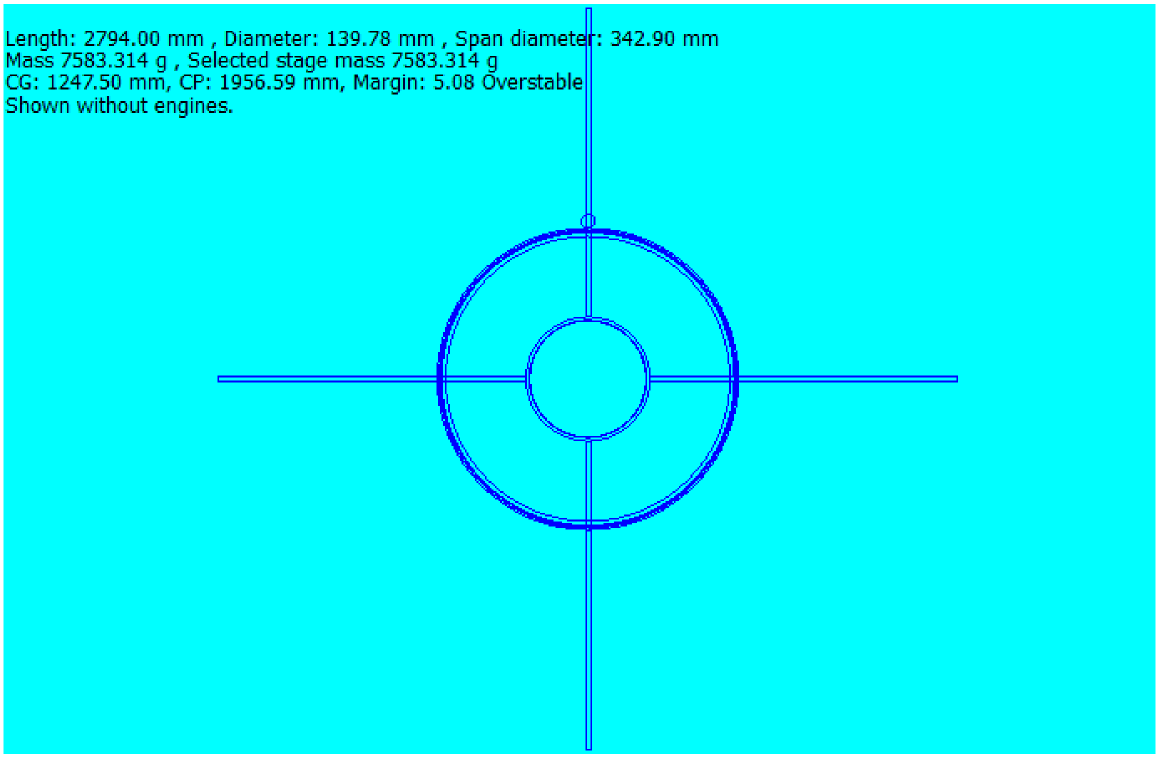
Thoroughness and Validity

Analysis of the full-scale test launch was completed using flight data from the vehicle's onboard electronics. Altitude data from the flight was compared to flight simulations to verify drag assessment. Measured center of gravity data was also included in new simulations. Simulations prior to launch estimated that the vehicle would reach an altitude of about 2300 feet. Actual launch data shows that the vehicle reached 2126 feet, meaning that the drag coefficient was higher than expected. This has caused the team to reduce vehicle mass in the payload. The team also expects that drag will decrease through painting and further sanding.

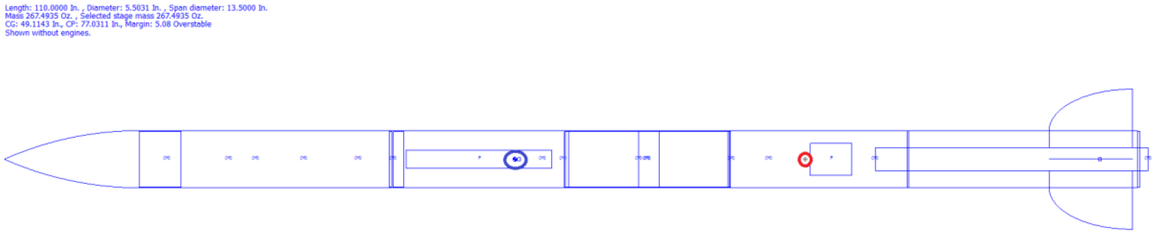
Stability

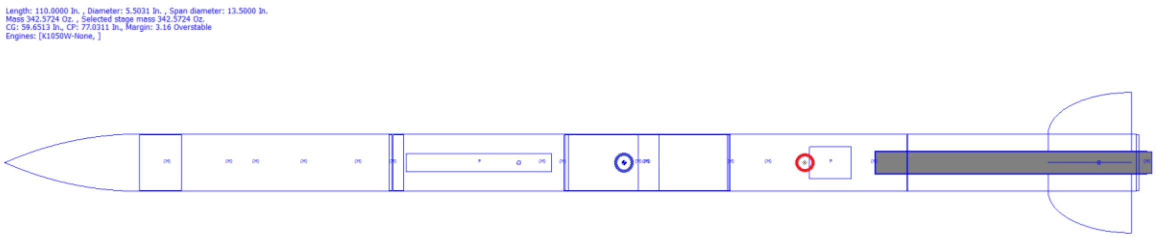
The following diagrams show static stability diagrams for the full-scale vehicle, with and without motor.





The following diagrams show the vehicle's Center of Gravity (CG) and Center of Pressure (CP) with and without motor. The CG and CP are marked by blue and red circles, respectively.





Kinetic Energy

Stage	Lower	Coupler	Upper
Rail-Exit	1030.5	296.5	793.5
Motor Burnout	61252.0	22856.0	61165.0
Drogue Deployment	4.8	1.8	4.8
Main Deployment	945.48	567.97	878.67
Landing	67.023	29.696	62.287

Kinetic energy increases rapidly during ascent. However, it is controlled during descent through the use of the recovery system, which ensures that the vehicle meets the requirements for safe recovery.

Drift

Wind Speed (MPH)	Predicted Drift (Ft)
0	117
5	298
10	550
15	944
20	1255

Vehicle Verification

Requirement	Feature to Satisfy Requirement	Verification	Results
1.1 The vehicle shall deliver the science or engineering payload to an apogee altitude of 5,280 feet above ground level (AGL).	The team will use data from Rocksim, subscale, and full-scale practice flights to predict the final rocket's flight, ensuring that it reaches a maximum altitude of 5,280 ft.	The team will use data from Rocksim to make any necessary changes to the rocket, which ensure that it reaches an altitude of 5,280 feet. The test launch will confirm its altitude.	Simulations predict an altitude of 5212 feet. The test launch produced an altitude of 2126 feet.
1.2 The vehicle shall carry one commercially available, barometric altimeter for recording the official altitude used in determining the altitude award winner.	The rocket will carry two PerfectFlite StratoLogger altimeters in its altimeter bay to measure altitude for scoring.	Connections, batteries, and altimeters will be checked and tested before flight to ensure altitude is measured correctly. The test launch will confirm functionality.	The altimeters successfully deployed recovery charges and recorded an altitude of 2126 feet.
1.3 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.	The launch vehicle will utilize a double-deploy parachute recovery system that will allow it to be safely recovered and flown again without needing repair.	A ground ejection test and subscale launch will be carried out to ensure the recovery system is functional for the full-scale flight. The test launch will confirm reusability.	Ejection tests were successful with 2.5 grams of black powder for drogue, and 2.7 grams for the main parachute. The vehicle was recovered undamaged after the test launch.
1.4 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.	The rocket will contain three independent sections: the upper body tube, coupler, and lower body tube.	The upper body tube, coupler, and lower body tube will be separated by bulkheads and attached by the recovery harness for recovery. Recovery harnesses will be stress tested before launch. The test launch will confirm functionality with three sections.	Stress tests before launch verified the strength of recovery harnesses. The test launch was successful using three independent vehicle sections.
1.5 The launch vehicle shall be limited to a single stage.	The rocket will be launched using one Aerotech K1050WL solid fuel motor designed to ignite only once during flight.	The rocket design will not contain more than one motor mount nor fit more than one motor. The test launch will confirm success with one motor.	The test launch was successful using one Aerotech J800 motor that ignited once during flight.

1.6 The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours, from the time the Federal Aviation Administration flight waiver opens.	The team will practice preparing the rocket to ensure that it can be assembled within the allotted time.	The team will allot time within the project plan for assembly practice.	The team was able to assemble the rocket on the day of the test launch within 2 hours.
1.7 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.	The rocket will not contain any parts that stop functioning after one hour on the launch pad.	The rocket will be left in flight configuration for a length of time, then checked for functionality. The test launch will confirm the ability to stay in configuration over a period of time.	The vehicle stayed in flight configuration on launch day and flew successfully.
1.8 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.	The rocket will be launched using a standard electric ignition system.	A 12 volt direct current will be used in ground tests, subscale launch, and the test launch to ensure electrical ignition functionality for launch day.	Ground ejection tests were successfully deployed using the 12 volt direct current. Subscale and test launches were also successful with a 12 volt direct current.
1.9 The launch vehicle shall require no external circuitry or special ground support equipment to initiate launch (other than what is provided by Range Services).	The rocket will only require an electric ignition system to initiate launch.	Subscale and test launches will be carried out without external circuitry to confirm functionality without it.	Subscale and test launches were successful using only a 12 volt direct current firing system without external circuitry.
1.10 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).	The rocket will fly on a K1050WT motor that is commercially available and approved.	Subscale and test launches will be flown using commercially available motors.	The subscale launch was successful with an Aerotech G80 motor. The test launch was successful with an Aerotech J800 motor.
1.10.1 Final motor choices must be made by the Critical Design Review (CDR).	The team will decide whether a different motor will be used by the CDR.	Various motors will be tested in RockSim to determine the optimal motor.	The final motor is the Aerotech K1050 White Lightning.

1.10.2 Any motor changes after CDR must be approved by the NASA Range Safety Officer (RSO), and will only be approved if the change is for the sole purpose of increasing the safety margin.	The team will only change the vehicle's motor plan after CDR if the previous motor poses a safety hazard; it must be approved by the RSO.	The test launch will confirm safety of the chosen motor.	The test launch was successful and safe, confirming the functionality of the motor choice.
1.11 Pressure vessels on the vehicle shall be approved by the RSO and shall meet NASA criteria.	The vehicle will not contain any pressure vessels.	The altimeter bay will contain air holes to prevent pressurization impairing readings.	The test launch was successful with no pressure vessels, and the altimeter was functional.
1.12. The total impulse provided by a Middle and/or High School launch vehicle shall not exceed 2,560 Newton-seconds (K-class).	The team will use a K-class K1050WL motor.	The K1050WL motor has a total impulse of 2,426 Newton-seconds. RockSim data will confirm an altitude with the motor.	RockSim predicts an altitude of 5212 feet with the K1050 WL.
1.13. All teams shall successfully launch and recover a subscale model of their rocket prior to CDR. The full-scale shall not be used as the subscale model.	The team will begin working on a subscale model after the PDR and will follow the project plan in order to construct and fly the model before the CDR.	The subscale model will accurately represent the performance of the full scale.	The subscale vehicle was launched successfully, and a separate full-scale vehicle has been constructed.
1.14. 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 following criteria must be met during the full scale demonstration flight:	After the CDR, the team will construct and fly the full-scale rocket. The team will fly the same rocket on launch day.	The test flight will confirm functionality of drogue and main chute deployment, tracking devices, and the success of the design.	The test flight was successful and recovered undamaged. The vehicle will be flown on launch day.
1.14.1. The vehicle and recovery system shall have functioned as designed.	All aspects of the launch vehicle and recovery system will be reviewed prior to, during, and after the flight to ensure that all systems function as designed.	A stress test will be performed on the recovery harness to confirm that it is secure, and D-links will be wrenched tight. The test launch will confirm the performance of the vehicle.	The test launch was successful and recovered as designed with the drogue deploying at apogee and the main at 500 feet. No damage was received.

1.14.2.1. If the payload is not flown, mass simulators shall be used to simulate the payload mass.	Either the payload or a dummy payload of the same size, mass, and weight as the true payload will be contained in the launch vehicle during flight.	The specific mass of the payload will be maintained in the rocket whether it is the payload itself or a dummy.	The test launch was performed with a dummy payload weighed to be the same mass as the true payload.
1.14.2.1.1. The mass simulators shall be located in the same approximate location on the rocket as the missing payload mass.	If a dummy payload is used, it will be placed in the same location as the payload in order to accurately simulate the payloads effect on the rocket's stability.	The dummy payload will be secured in the payload bay between the nose cone and upper bulkhead.	The test launch was successful using the dummy payload of equivalent weight to the true payload in the payload bay.
1.14.2.2. If the payload changes the external surfaces of the rocket or manages the total energy of the vehicle, those systems shall be active during the full-scale demonstration flight.	If an external payload or one that controls the rocket's flight is to be used, it will be flown during the full-scale test flight.	The full-scale test flight will not possess payload features altering external surfaces.	The test flight was successful without any payload features affecting external surfaces.
1.14.3. The full-scale motor does not have to be flown during the full-scale test flight. 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.	During the test flight, the team will use a motor providing a similar maximum velocity and maximum acceleration to the launch day motor.	The test flight will use a J800 motor which will simulate, as closely as possible, the maximum velocity and acceleration of the launch day motor.	The test flight used a J800 with a maximum velocity of 400 f/s, and a maximum acceleration of 424.5 f/s^2, similar to the K1050 that will be used on launch day.
1.14.4. The vehicle shall be flown in its fully ballasted configuration during the full-scale test flight.	The team will use the same amount of ballast during the full-scale test flight as it does on launch day.	The dummy payload, functioning as ballast, will be the same weight of the true payload.	The test launch was successful without ballast other than the dummy payload, the same mass as the payload on launch day.

1.14.5. 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).	No part of the rocket will be altered after the full-scale test flight unless authorized by the RSO.	The vehicle construction will be completed before the test launch. Fins and recovery harnesses will be stress tested, and ground ejection tests will ensure recovery functionality.	Vehicle construction was completed before the launch. Fins and recovery harnesses passed stress tests. The launch was successful, so no changes will need to be made.

Vehicle Safety and Environment

Failure Modes Analysis

Failure	**Cause**	**Effect**	**Mitigation**
Fins of the launch vehicle are unable to withstand the required forces	Improper construction of the launch vehicle's fins. Damage during transportation of the launch vehicle.	The launch vehicle will become unstable and fly in an unexpected projectory. The fins may fall off and pose as a hazard to spectators	Before launch the fins of the launch vehicle will be stress tested in order to ensure that there is no give. The team will be careful during transportation to ensure that the launch vehicle is not damaged.
The bulkhead of the launch vehicle is pushed out of the vehicle during ejection	Improper construction, stronger ejection forces than expected	Failure of the recovery system, launch vehicle debris falling from the sky	The bulkhead will be inspected before launch to ensure that it is sturdy.
Shear pins fail to break during the detonation of the ejection charges	A miscalculation in the amount of black powder leading to too little being utilized	The launch vehicle's recovery system would not deploy leading to possible damage to the launch vehicle and possible injury for spectators	The amount of black powder will be accurately weighed to ensure that designated amount from the ejection tests are used
The launch vehicle becomes unstable during flight	Faults in the launch vehicle's simulations. Improper construction of fins or other components	The launch vehicle may spiral out of control or veer off of expected trajectory	The launch vehicle will be inspected before launch to ensure that all components are secured
The motor of the launch vehicle malfunctions	Improper assembly of the motor, improper insertion of the ignitor	The motor may CATO which may lead to damage to the launch vehicle. The launch vehicle will remain on the	The motor will be assembled properly and the ignitor will be inserted properly. The launch vehicle will be inspected before launch on the pad

		launch pad if the ignitor is installed improperly	
The launch vehicle suffers from “fin flutter”	Improper construction, inaccurate simulations	The launch vehicle may become unstable and veer of course. The fins may sustain damage	The fins will be securely attached to the launch vehicle. The fins will be inspected before launch and stress tested.
During preparation for launch, the launch vehicle is not prepared properly	Improper allotment of jobs. Lack of knowledge of the launch vehicle’s components	The launch vehicle may malfunction during flight leading to a failed flight	The launch vehicle will be prepared properly and inspected before launch
Electronics for the recovery system fail	Improper wiring of electronics. Connections are broken during flight	The recovery system will fail to deploy during flight leading to a failed launch	Recovery electronics will be properly wired and will be inspected before launch
The recovery system fails to deploy	Failure of recovery electronics, Improper packaging of the parachute	The recovery system will fail to deploy during flight leading to a failed launch	Recovery electronics will be properly wired and will be inspected before launch
The launch vehicle’s battery fails during flight	The use of an older battery that was low on charge improper wiring of electronics	The recovery system will fail to deploy during flight leading to a failed launch	Recovery electronics will be properly wired and will be inspected before launch
Parachute shroud lines are tangled during deployment	Improper folding and packaging of the parachute	The recovery system will fail to deploy during flight leading to a failed launch	Recovery electronics will be properly wired and will be inspected before launch
The launch vehicle lands in an area that is inaccessible	A weather anomaly, inaccurate simulations	The team will be unable to retrieve the launch vehicle	The launch vehicle will not be launched in and area near nearby inaccessible areas
Organic material is caught ablaze during ignition of the motor	Dry vegetation being located underneath the launch vehicle during motor ignition	A serious fire may start causing harm to the launch vehicle and to the environment	Dry vegetation will be cleared from underneath the launch vehicle before ignition
Launch vehicle components fall during launch	Improper construction, loose parts being attached to the vehicle	Components may cause harm to the spectators below	The launch vehicle will be inspected and stress tested before launch to ensure that all components are safely secured
Launch vehicle is not assembled in the given	Improper allotment of jobs, lack of	The team will be unable to launch their vehicle	The team will practice preparing the launch vehicle

time	preparation		for launch before to ensure that everyone is aware of how it is assembled
During ignition of the motor, the launch vehicle remains on the launching pad	Improper installation of the ignitor. Improper assembly of the motor	The launch will be postponed and the ignitor will be wasted	The team will properly install the ignitor and assemble the motor properly

Significant Failures Discussion

Failure	**Likelihood**	**Consequences**
The recovery system fails to deploy during ejection	Low	The recovery system will fail to deploy during flight leading to a failed launch. Spectators will be at a risk for injury and the launch vehicle may be damaged during landing
During preparation for launch, the launch vehicle is not prepared properly	Low	The launch vehicle may malfunction during flight leading to a failed flight
Fins of the launch vehicle are unable to withstand the required forces	Low	The launch vehicle will become unstable and fly in an unexpected projectory. The fins may fall off and pose as a hazard to spectators. The launch vehicle may also be harmed
The main parachute catches ablaze during ejection due to improper folding of the fire blanket	Low	The parachute may be destroyed. The launch vehicle may land without a parachute posing a threat to spectators and possibly causing damage to the launch vehicle
Electronics for the recovery system fail	Low	The recovery system will fail to deploy during flight leading to a failed launch
The motor of the launch vehicle malfunctions	Low	The motor may CATO which may lead to damage to the launch vehicle. The launch vehicle will remain on the launch pad if the ignitor is installed improperly
Launch vehicle is not assembled in the given time	Low	The team will be unable to launch its vehicle.

Personnel Hazards

Hazards	Probability	Risk	Cause	Effect	Mitigations
Rocket debris land on spectators.	Improbable	Moderate Risk	Recovery system fails, or prematurely deploys.	Onlookers are at risk and may be severely injured.	Spectators will always be at the secure distance specified by the NAR safety distance table.
Motor ignition fails and rocket remains on the launch stand.	Improbable	Low Risk	Lack of continuity, or an old or damaged motor is used.	Rocket Launch is postponed.	The team will wait 60 seconds before investigating and the team will develop a flexible launching schedule.
Rocket lifts off and flies or drifts towards onlookers.	Improbable	Moderate Risk	Launch angle is not properly calculated for wind	The rocket veers off course and poses a threat to onlookers, possibly leading to severe injury.	Launch angle will be properly calibrated for the wind speed and direction.
Injury from machinery during construction	Remote	Low Risk	Improper use of machinery.	The user or other may be severely injured	Users of machinery will ensure that all safety guidelines are followed and that PPE's are worn at all times.
During ejection the shroud lines of the parachutes tangle.	Improbable	Moderate Risk	The wind, improper packaging of the parachute	The rocket's recovery system fails. The rocket may be severely damaged or onlookers may be injured.	Barrel swivels should be used to ensure tangle free lines
Recovery electronics fail during flight	Improbable	Moderate risk	Electrical connections are broken or not properly connected.	The rocket's recovery system fails. The rocket may be severely damaged or onlookers may be injured.	All electrical connections will be thoroughly checked and tested before launch.
Ejection charge fails to detonate.	Improbable	Moderate Risk	Rocket electronics fail during launch. The black powder charges either detonate too soon, too late or not at all.	Rocket will achieve elongated or shortened flight, or the parachute won't deploy, leading to a failed flight.	Black powder charges will be properly prepared.

Environmental Concerns

Hazards	Probability	Risk	Cause	Effect	Mitigation
Rocket descends into a body of water.	Remote	Moderate	Wind speed is higher than expected.	All electrical, or non-waterproof sections of the rocket are damaged.	Rocket will not be launched at a station by a body of water.
Organic matter around the rocket ignites during ignition.	Remote	Low	Expulsion of hot matter dry ignites nearby vegetation.	A small fire may intensify and pose a threat to nearby onlookers.	Clear launch area of dry vegetation that may catch fire.
Rocket debris diffuse into the surrounding area.	Remote	Moderate	Recovery system fails, or prematurely deploys.	Rocket debris may pollute the environment, or harm spectators.	Only approved motors will be used and all rocket connections will be properly secured and double checked.
Electrical components of the rocket are damaged by precipitation.	Improbable	Low	Liquid seeps into the rocket while it is on the launch pad.	Electrical components such as the altimeter and ejection charge are damaged, or destroyed by the precipitation.	The rocket will be sealed using primer and paint.
The rocket is caught in a tree during descent and is damaged, or cannot be reached by the team.	Improbable	Moderate	The recovery system is deployed prematurely, or the winds are stronger than expected.	The rocket is harmed by the branches of the tree, or the rocket lands too high for the team to reach, thus ending the project.	Launches will be conducted in areas with few trees.
The fins of the launch vehicle are unable to withstand the forces of flight.	Low	Moderate	Improper construction, faults in launch vehicle design	The fins way detach from the rocket causing the launch vehicle to become unstable.	The fins will be securely attached to the launch vehicle and stress tested.
The recovery system is unable to deploy due to failed separation	Low	Moderate	An insufficient amount of black powder is used. Components of the rocket are caught on each other.	The launch vehicle lands without a recovery system, potentially causing severe damage to the launch vehicle.	A sufficient amount of black powder will be used to ensure that the launch vehicle will completely separate.
Shear pins fail to break causing the recovery system to not deploy.	Low	Moderate	An Insufficient amount of black powder is utilized	The launch vehicle will impact the ground at high speeds potentially causing severe damage to the launch vehicle.	A sufficient amount of black powder will be used to ensure a complete separation of the launch vehicle occurs.
Bulkhead is removed from the rocket during deployment of the recovery system	Low	Moderate	The bulkhead is not properly attached, improper construction	The launch vehicle will impact the ground at high speeds potentially causing severe damage to the launch vehicle.	The bulkhead will be stress tested and composed of the proper materials to ensure that it is able to withstand the forces of flight.
The launch vehicle descends too quickly and is damaged upon landing	Low	Moderate	Weather anomalies, faults in launch vehicle design	The launch vehicle will impact the ground at high speeds potentially causing severe damage to the launch vehicle.	Barrel swivels will be used to ensure that shroud lines do not tangle. Parachutes will be properly attached.

Payload Integration

Integration

Payload will be integrated in rocket with an aluminum two foot T-rail design that consists of 3D printed ABS plastic plates[1]. The plates' function is to provide structural T-rail support t[2]. 3D printed plates are used because of proven ABS plastic for its customizable thickness, strength, reliable years of past use, and ease of functionality by allowing strong adhesive connections with other ABS plastic glues. Plates will be printed to the exact inside diameter of rocket ensuring a secure fit for T-rails and maximum space for electronics to be mounted. Electronics will receive power from T-rails by having a base plate that holds four 9v batteries which are connected to T-rails allowing electricity to pass through them[3]. One T-rail will be positively charged while the other negatively giving electronics a proper circuit for energy to pass[4]. Payload will have detachable handle allowing for ease of extraction out of rocket for data collection and maintenance of plates. If a plate were to break or not function properly a design file will be kept at all times for a quick part swap with a newly printed plate. Garmin GPS tracker will be mounted on handle of payload so that rocket can be tracked wherever it drifts to.

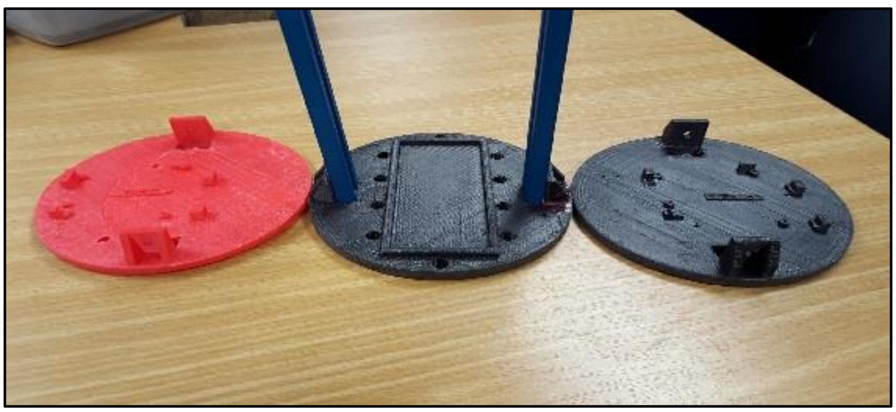


Figure 1: 3D printed baseplates.

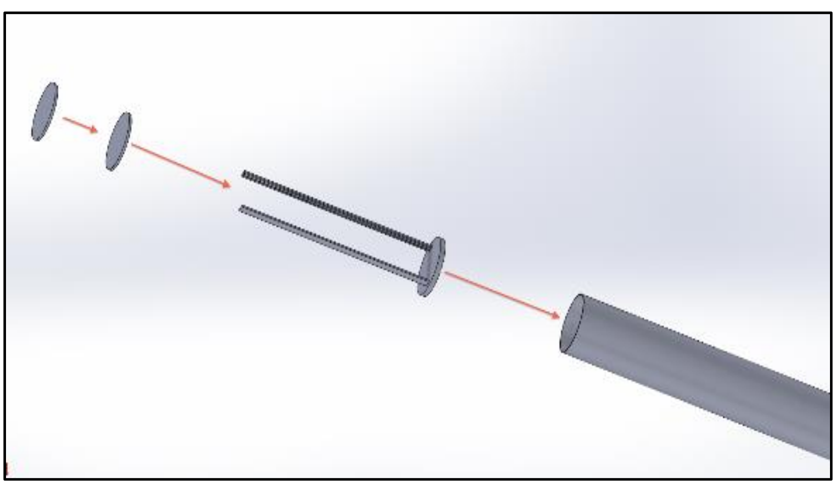
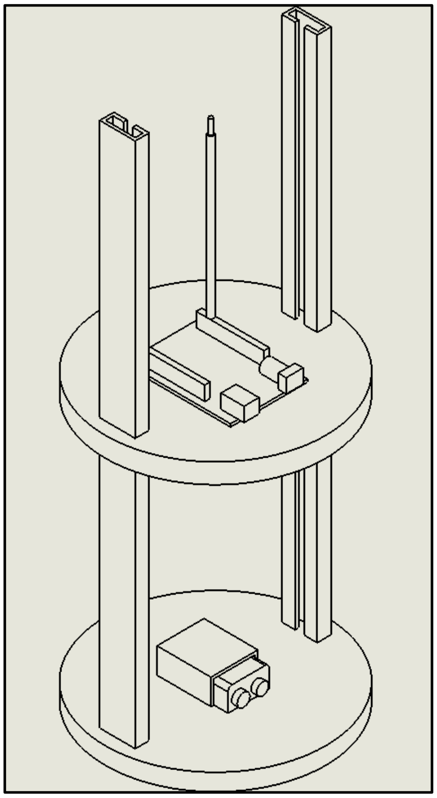


Figure 2: T-rail and plate integration.



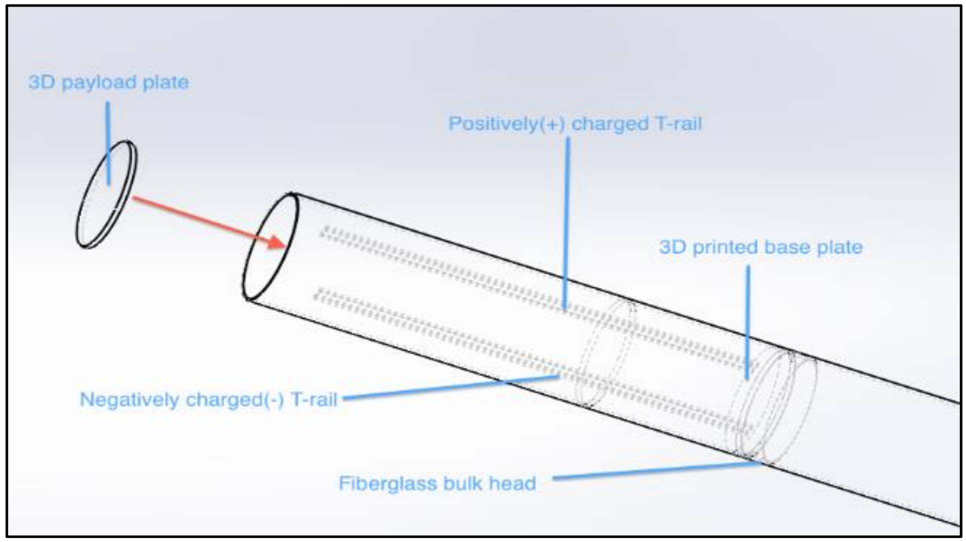


Figure 4: Positive and Negative T-rails.

Figure 3: Power supply.

Compatibility

The payload integration system is designed to be compatible with multiple payloads. Each payload will utilize a 3D printed base plate that fits into the body tube and onto the t-rails. The surface of these plates can be customized to suit any electronics necessary for a payload. The t-rails in turn will be attached to the base plate. This entire structure will fit inside of the upper airframe.

Integrity

The payload will be housed on a 3D printed plate, designed specifically for it. The payload plate will be circular, with a 5.346" diameter, allowing it to be housed in the upper airframe. The plate will then be attached to two t-rails. The whole structure will have a length of 24", allowing it to fit snugly between the nosecone and bulkhead.

Assembly Process

Figures 2 and 4 show the assembly process and the labeled components of the payload integration system. The t-rails will be screwed onto a base plate, containing a battery pack. The other payload plates will then be slid onto the rails and a 3D printed handle will be attached to the top of the rails. The entire structure will then be placed inside the upper airframe.

Payload Concept

Creativity and Originality

This experiment is creative because it collects data on a hazard that is often missed or discounted, but can still pose a danger to the success of the mission. The experiment will provide the team with the data necessary to analyze the extent of the risks posed by this hazard. It will also help the team determine how to mitigate this hazard in the future.

Significance

This experiment is significant because of the effects electromagnetic interference can have on the launch vehicle. Interference can affect any electronics on a launch vehicle, including altimeters and components of payloads such as microprocessors and sensors. In order to ensure that these electronics function properly, it is imperative that they be protected from interference. This payload will collect data on exactly how much interference acts upon them during flight. This will allow the team to assess the extent of possible effects on the launch vehicle's electronics, and the degree to which further protection may be needed.

Science Value

Objectives

The objective of the payload is to collect data on the amount of residual electromagnetic interference in the atmosphere, and use this data to determine the impact residual interference could have on the operation of the launch vehicle.

Mission Success Criteria

The payload will be considered successful if it meets the following requirements:

- Collects and logs data on electromagnetic interference
- Collects data that is significant and provides insight into the effect of residual interference on the flight.
- Integrates easily and securely into the launch vehicle, and functions in tandem with the vehicle's other systems.
- Functions along with up to three other payloads, designed by partner schools.

Logic, Approach, and Investigation

The experiment is conducted by altering the launch vehicle's altitude, and measuring the effect this has on the amount of residual electromagnetic interference in the atmosphere around the vehicle. This is investigated through the use of an Arduino Uno, which will read in data from an antenna.

Test and Variables

The test detects residual electromagnetic interference, using a solid core wire and Mega Ohm resistor. The measurement is done in volts. The experiment will measure the change in volts of interference due to altitude. Other variables, such as velocity may change as the experiment is being conducted. Environmental variables, such as temperature and humidity, will remain relatively

Relevance

The expected data will be relevant because it will show the voltage of residual electromagnetic interference in the atmosphere at different altitudes, up to a mile. This will allow the team to analyze the potential for hazardous effects from interference. This is relevant to the success and safety of the mission. Possible sources of error include the effects of the launch vehicle's acceleration, and interference from the vehicle's other electronics, which could be accidentally read as residual interference. Other than these sources, the payload will collect accurate data on electromagnetic interference.

Procedures

The experiment processes will be as follows:

- The antenna will detect the voltage of residual electromagnetic interference in the atmosphere.
- This voltage will travel into the Arduino through the resistor.
- The Arduino will save data to the SD card.
- This process will repeat for the duration of the flight.
- Post flight, the team will analyze the data from the SD card, and draw conclusions about how the interference changed in relation to the launch vehicle's altitude.

Payload Design

Structural Elements

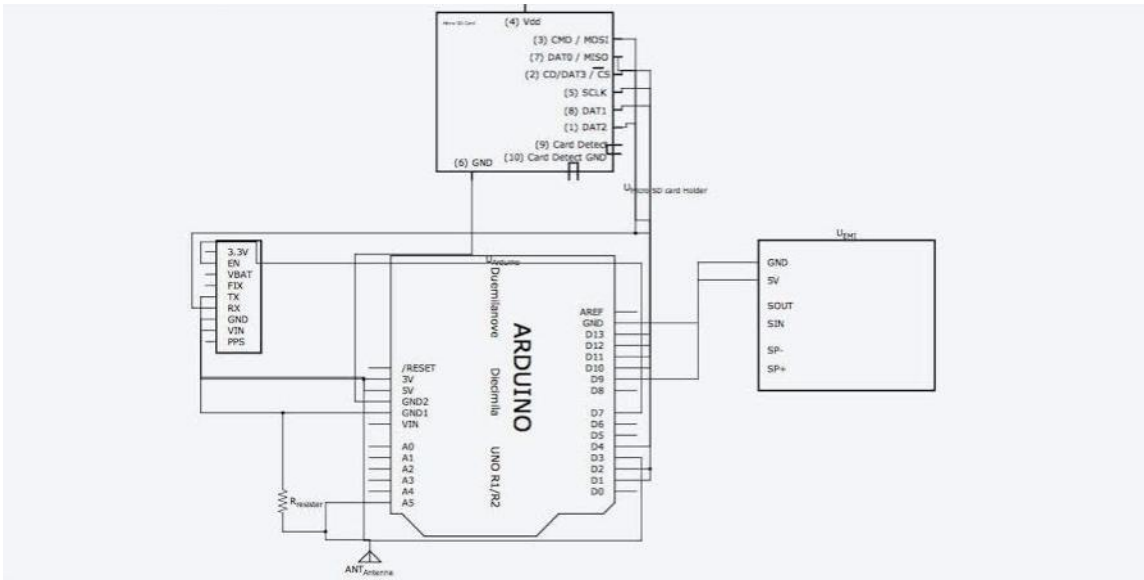
The payload will be housed in the vehicle's upper airframe, between a fiberglass bulkhead and the nosecone. It will be attached to a 3D printed base plate, which will then be screwed onto two t-rails. These structural elements ensure that the payload is secured during flight, making it reusable upon recovery.

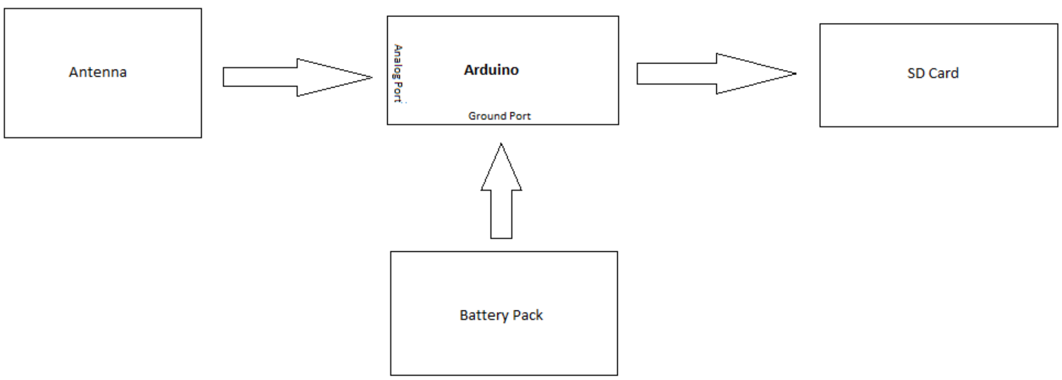
Electrical Elements

The payload itself will be made up of an Arduino UNO microprocessor, a resistor, an antenna and an SD card. The Arduino will run a program that will read voltage in from the antenna, and save it to the SD card. At the bottom of the payload integration system, a base plate will hold a battery pack, containing 4 9V batteries. These batteries will charge the t-rails, which will in turn provide power to the Arduino. These electrical elements ensure that the payload successfully collects data which can be later analyzed and reported by the team.

Drawings and Schematics

Below is an electrical schematic and block diagram of the payload system.





Precision and Repeatability

The Arduino Uno has a clock speed of 16 MHz, allowing it to run its program quickly and collect data frequently. This allows for precise measurement, as the position of the launch vehicle will be constantly changing. The payload is reusable, and no parts of it, other than power supply after some time, will need replacing. This means that all measurements can be easily repeated. The payload will be secured in the upper body tube by the integration system. This system will be mounted to the bulkhead on one side, and protected by the nosecone on the other. This ensures that the payload will remain securely mounted in the upper body tube, which will be recovered safely through the use of parachutes in the recovery system. These systems will ensure that the payload is undamaged and recoverable.

Performance Predictions

The payload will begin operating while the vehicle is on the launch stand. It will continue to operate throughout the entire flight. Data will be collected during ascent, however due to the velocity of the vehicle, the data may not be collected fast enough to be useful. During descent, the vehicle is moving at a lower velocity, allowing the payload to collect more data. The team expects the payload to perform at all stages of flight, from lift-off, to motor burnout, to recovery, and will collect and analyze data from the whole flight.

Approach to Workmanship

Payload will be constructed with mentor supervision to ensure that all components and electrical systems are connected properly. Safety officer will be present in all phases of construction to ensure that all safety measure are taken during construction phase. All members will work together to complete full scale payload and have a specified role in the process.

Test and Verification

The payload has been ground tested by constructing an EMF detector on a breadboard, and moving it through the classroom, near computers, walkie-talkies and other electronics. Data was displayed through an LED, which shined brighter as the detector picked up more voltage and a speaker that beeped at higher frequencies as voltage increased. Raw data from the payload was also uploaded onto a laptop. Next, the team will construct the payload integration structure and integrate its payload onto a base plate. This payload, in its full integrated form will be ground tested prior to launch, to ensure that all payload requirements are met.

Payload Verification

Requirement	Feature to Satisfy Requirement	Verification	Results
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.	The team will design and construct a scientific payload to detect electromagnetic interference (EMI) during flight, and will follow any and all modifications or changes deemed necessary by the NASA Review Panel.	The Arduino payload will be ground tested before integration into the rocket; any changes to this payload deemed necessary will be made.	The payload was confirmed functional during its ground test.

3.2. Data from the science or engineering payload shall be collected, analyzed, and reported by the team following the scientific method.	The payload will collect data during flight onto an SD card, and the team will follow all parts of the scientific method in the analysis and reporting of this data.	The Arduino EMI detector will be ground tested prior to flight, ensuring that it is recording accurate data.	The payload successfully recorded data onto an SD card during its ground test.
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.	The rocket will not be using an unmanned aerial vehicle (UAV).	The payload ground test will confirm functionality without the need for a UAV.	The ground test was successful without a UAV, so the rocket will not use one.
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.	The payload will not have any elements that will be jettisoned, but the team would wait to receive authorization from the RSO to jettison.	The payload ground test will confirm functionality without the need for jettisoning elements.	The ground test was successful without jettisoning elements.
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.	The payload will be safely contained in the launch vehicle between the upper bulkhead and nose cone, allowing it to be recovered completely intact and immediately reused.	The test launch will use a dummy payload to confirm functionality of the payload bay and mitigation of damage.	The test launch was successful, and the payload bay was recovered undamaged.

Payload Safety and Environment

Failure Modes Analysis

Failure	Cause	Effect	Mitigation
The payload malfunctions and does not complete what it is required to	Improper wiring of the payload, improper programming	The payload does not complete the required task, the launch is pointless	The payload will be ground tested before launch to ensure its functionality, will be inspected before launch,

do			and packaged carefully inside of the vehicle
Payload is damaged from recovery	The recovery system fails, the payload is not properly protected from the forces of flight	The payload may not complete its required task, it may be impossible to pull the required data from the payload, the launch is pointless	The recovery system will be inspected before launch to ensure its functionality. The payload will be securely protected inside of the launch vehicle
The payload does not function as expected and does not collect any usable data	Improper testing of the payload to ensure that it would function inside of the launch vehicle	The payload does not complete the required task, the launch is pointless	The payload will be ground tested before launch to ensure its functionality, and will be inspected before launch
The payload is disconnected during flight	Improper packaging or wiring of the payload, The payload is not packed properly for launch	The payload does not complete the required task, the launch is pointless	Connections will be inspected and tested before launch to ensure functionality. The payload will be secured properly within the launch vehicle
The payload battery fails or dies during flight	The use of an older battery low on charge. Improper wiring of the battery to the payload	The payload does not complete the required task, the launch is pointless	The payload will use new batteries and connections will be tested for functionality
The payload protection is not constructed by the deadline	Improper planning, delays in the acquiring of materials	The team is unable to launch their vehicle due to the incompletion of the requirements	Components will be ordered ahead of time, a GANTT chart will be closely followed

Significant Failures Discussion

Failure	**Likelihood**	**Consequences**
The payload malfunctions and does not complete what it is required to do	Low	The payload does not complete the required task, the launch is pointless
The payload is disconnected during flight	Low	The payload does not complete the required task, the launch is pointless
The payload does not function as expected and does not	Low	The payload does not complete the required task, the launch is pointless

collect any usable data		
Payload is damaged from recovery	Low	The payload may not complete its required task, it may be impossible to pull the required data from the payload, the launch is pointless
The payload protection is not constructed by the deadline	Low	The team is unable to launch their vehicle due to the incompletion of the requirements

Personnel Hazards

Hazards	Probability	Risk	Cause	Effect	Mitigations
Electrocution from payload circuit.	Low	Moderate Risk	Payload is handled improperly or wired incorrectly.	Personnel receives a minor shock, electrical components of payload may be damaged.	The payload will be handled carefully and wires will be insulated properly. Wirings will be checked. Power source will be disconnected when handling payload components.
Payload malfunction produces heat or flame.	Improbable	Moderate Risk	Payload is wired incorrectly or allowed to short circuit.	Personnel inhales fumes or receives a burn from touching a hot component.	The payload will be handled and wired carefully. Wirings will be checked.

Environmental Concerns

Hazards	Probability	Risk	Cause	Effect	Mitigations
Electrostatic discharge damages payload electronics.	Remote	Moderate Risk	A large amount of electricity is exposed to the payload electronics.	Payload fails to function.	Rocket will not be flown in poor weather.
Precipitation damages payload electronics.	Improbable	Moderate Risk	Water seeps into the airframe.	Payload fails to function.	Rocket will not be flown in poor weather.

Launch Operations Procedures

Recovery Preparation

1. Fully unpack and lay out rocket
2. Pull D-Link that attaches to the motor casing out of the aft end of the rocket
3. Detach D-links for both parachutes
4. Z-fold Kevlar and tape (one layer thick of tape)
5. Place both Z-folded Kevlar bundles and Z-folded parachute inside the parachute protective blanket and burrito-wrap the blanket
6. Repeat for main parachute, except Kevlar is not included inside the parachute blanket
7. Unscrew altimeter bay

8. Replace batteries if necessary
9. Zip-tie batteries (3 zip-ties for each battery)
10. Test switches for each altimeter on the coupler
11. Reassemble the altimeter bay
12. Attach D-links from the parachutes back onto the coupler
13. Attach ejection charges to the 1st ports on either side of the altimeter bay
14. Re-Assemble the rocket with the ejection charges
15. Insert shear pins into the upper and lower parts of the coupler (use the dentistry tool to assist in keeping each hole in alignment)
16. Insert payload into rocket
17. Screw nose cone shut
18. Perform stress test on rocket components.
19. Re-assemble rocket

Motor Preparation

1. Mentor constructs motor with propellant and ejection charge
2. Attach D-Link from the main chute to eyebolt on motor
3. Screw on engine retention

Launch Setup

1. Place rocket on stand.
2. Arm altimeter bay (ensure everything is working properly)

Ignitor Installation

1. Unsheathe Igniter from its protective covering
2. Thread igniter through nozzle and into the motor
3. Ensure the igniter is all the way into the motor casing and in contact with the motor

Launch Procedure

1. Use something (e.g. Clamp, Rock) to mount the rocket slightly of the launch stand by placing it underneath the rocket (to ensure that the pressure does not build up and cause a catastrophic failure)
2. Countdown and launch.

Troubleshooting

1. If motor does not ignite, wait at least one minute before approaching the rocket
2. After waiting at least one minute, approach the rocket
3. Detach igniter from motor
4. If the igniter has already been spent, dispose it carefully
5. Bring rocket back to launch pad
6. Inspect the motor for any signs of deterioration
7. Re-load motor back into rocket after it has been repaired/diagnosed
8. Load the rocket with a new motor
9. Bring the rocket back to the launch pad
10. After hooking up the rocket to the launch rail, insert the igniter into the motor and ensure that it makes contact with the propellant.

Inspection

1. Ensure the rocket is safe to approach
2. Document the rocket immediately as it is found
3. Inspect entire rocket for any external damage that was possibly incurred during flight
4. Transport rocket to a sufficient inspection area
5. Begin disassembly process by unscrewing the nosecone
6. Remove payload and inspect for any damages
7. Analyze payload data via computer
8. Detach D-Links from the drogue and main parachutes on the altimeter bay
9. Unscrew Y-bolts to inspect and document altimeter system for any damage 1
10. Collect altimeter data
11. Remove E-match black powder charges from altimeter bay
12. Detach D-Link from upper airframe eyebolt and inspect main chute for damage
13. Detach D-Link from motor eyebolt and inspect drogue chute for damage
14. Unscrew engine retention and extract the motor from the lower airframe
15. Dispose the motor
16. Stress-test fins to ensure durability
17. Tug on eyebolts to verify the security of the bulkheads
18. Remove any excess shear pin material from upper and lower body tube
19. Address any problems with the rocket and their possible solutions

Safety and Quality Assurance

Risk Assessment

Recovery Preparation

Obstruction	Risk	Cause	Effect	Mitigation
The parachutes are improperly wrapped in the fire blanket	Low Risk	Improper handling, lack of knowledge	The parachutes may burn up once the ejection charges are blown	The team will ensure that the parachutes are properly wrapped within the fire blankets
The parachutes are improperly folded into the launch vehicle	Low Risk	Improper handling, lack of knowledge	The parachutes may tangle once deployed from the launch vehicle	The team will ensure that the parachutes are properly folded inside of the fire blankets within the launch vehicle
The parachutes are improperly attached to the launch vehicle	Low Risk	Improper handling, lack of knowledge	The parachutes may separate from the launch vehicle when the ejection charges are blown	The team will ensure that the parachutes are securely attached to the launch vehicle utilizing a Kevlar shock cord

Motor Preparation

Obstruction	Risk	Cause	Effect	Mitigation
The motor is improperly installed into the launch vehicle	Low Risk	Improper handling, lack of knowledge	The motor may malfunction, altering the launch. The motor may detonate harming the launch vehicle	The team will ensure that members are aware of how to properly insert a motor into the launch vehicle. The motor will be properly handled.

Setup on Launcher

Obstruction	Risk	Cause	Effect	Mitigation
The launch vehicle is improperly set up on the launch stand	Low Risk	Lack of knowledge, improper handling of components	The launch vehicle may fail to lift off from the launch stand or malfunction	The team will ensure that the launch vehicle is properly placed atop the launch stand

Igniter Installation

Obstruction	Risk	Cause	Effect	Mitigation
The igniter is installed improperly inside of the motor	Low Risk	Lack of knowledge, improper handling	The launch vehicle will remain on the launch pad, an igniter would be wasted, and the launch would be postponed	The team will ensure that they are aware of how to properly insert an igniter into the launch vehicle

Launch Procedure

Obstruction	Risk	Cause	Effect	Mitigation
The launch procedure is improperly followed	Low Risk	Improper management, lack of knowledge	Steps in launch vehicle assembly may be skipped leading to malfunctions occurring after lift off	The launch procedure will be closely followed while assembling the launch vehicle

Troubleshooting

Obstruction	Risk	Cause	Effect	Mitigation
The launch vehicle remain on the launch pad after the motor fires	Low Risk	Improper installation of the igniter, the use of an older motor	The launch vehicle will remain of the pad and the launch will be postponed	The team will ensure that the igniter is properly installed into the launch vehicle and that a new motor is utilized

Post-flight Inspection

Obstruction	Risk	Cause	Effect	Mitigation

The launch vehicle is tampered with during recovery before it can be properly documented	Low Risk	Improper management, lack of knowledge	The launch vehicle will be moved before being properly documented	The team will ensure that documentation occurs before the launch vehicle is tampered with.

Environmental Concerns

On February 13th the team launched the launch vehicle successfully with no issues. In order to avoid any issues or mistakes during preparation for the launch, the team strictly followed a launch checklist. All launch vehicle components were secured tightly to ensure that everything was in place and to decrease the chances of a component failing. All launch vehicle components deployed successfully during the launch with the drogue parachute deployment at apogee and the main parachute deployment at 500 ft. During flight, the launch vehicle was straight and stable with minimal weather cocking. The team was able to successfully recover the undamaged launch vehicle utilizing a GPS located in the upper body tube and record the data from both the main and drogue altimeters. Simulations showed that the launch vehicle would successfully land with a kinetic energy of less than 75 ft. /lbs. All NAR safety codes and regulations will be strictly followed and enforced to reduce the risk of injury for the team and spectators.

The team is aware of all possible obstructions that can occur in regards to the environment and aware of how these obstructions should be handled. All launch vehicle components will be tested before launch to ensure functionality and that there is no give. During launch vehicle assembly, the safety officer will repeat all concerns to ensure that all team members are aware of the risks. For example, all members will be aware of when the ejection charges are inserted inside of the launch vehicle and will be told not stand in front or behind the launch vehicle in case they fire. All connections will be checked in order to ensure that all components will be functional and that data can be successfully collected. All dry vegetation will be cleared from around the launch pad to ensure that a fire does not start when the motor fires.

Safety Officer

The team’s safety officer is Michael, who is responsible for maintain safety, quality and procedures checklist.

Project Plan

Budget

Launch Vehicle

Material	Length	Width	Height/ Thickness	Amount	Individual Price	Total Price
Kevlar Shock Cord	81 ft.	0.5 in	N/A	1	$3.75 per yard	$101.25
Everbilt screws	0.25 in	0.25 in	1.25 in	5	$0.20	$1.00
Blue Tube Airframe	5.5 in	5.5 in	48 in	2	$56.95	$113.90
Blue Tube Motor Mount	54 mm	54 mm	48 in	1	$23.95	$23.95
Blue Tube Coupler	5.33 in	5.33 in	16 in	1	$25.95	$25.95
Fiberglass Plate	12 in	12 in	0.25 in	1	$22.13	$22.13
Fiberglass Plate	12 in	24 in	0.25 in	1	$47.25	$47.25
D links	N/A	N/A	0.25 in	5	$1.35	$6.75
Shear Pins	N/A	N/A	N/A	1 (10 pack)	$8.60	$8.60
9 Volt Battery	26.5 mm	17.5 mm	48.5 mm	2 (2 pack)	$4.39	$8.78
PerfectFlite StratoLogger Altimeter CF	2.75 in	0.9 in	0.5 in	2	$58.80	$117.60
Wing nuts	N/A	N/A	N/A	4	$5.99	$5.99
Threaded rods	0.25 in	0.25 in	12 in	2	$6.70	$13.40
Main parachute	84 in	84 in	N/A	1	$74.95	$74.95
Drogue parachute	24 in	24 in	N/A	1	$10.95	$10.95
9 volt battery holders	N/A	N/A	N/A	2	$2.17	$4.34
Conical Plastic Nose Cone	5.38 in	5.38	17 in	1	$54.95	$54.95
Garmin Astro 220 (GPS)	N/A	N/A	N/A	1	$699.00	$699.00
Pratt Hobbies Micro Beacon	N/A	N/A	N/A	1	$12.00	$12.00
Great Plains 30-minute Epoxy	N/A	N/A	N/A	1	$11.79	$11.79
Black powder caps	N/A	N/A	N/A	1 (18 pack)	$5.81	$5.81
Eye Bolts	N/A	N/A	N/A	3	$1.64	$4.92

Subscale

Material	Length	Width	Height/ Thickness	Amount	Individual Price	Total Price
Kevlar Shock Cord	42 ft.	0.5 in	N/A	1	$3.75 per yard	$52.50
Everbilt screws	0.25 in	0.25 in	1.25 in	5	$0.20	$1.00
Blue Tube Airframe	2.56 in	2.56 inch	48 in	2	$26.95	$53.90
Blue Tube Motor Mount	29 mm	29 mm	48 in	1	$12.49	$12.49
Blue Tube Coupler	2.42 in	2.42 in	8 in	1	$9.25	$9.25
Fiberglass Plate	12 in	12 in	0.25 inch	1	$22.13	$22.13
Fiberglass Plate	12 in	24 in	0.25 inch	1	$47.25	$47.25
D links (Quick links)	N/A	N/A	0.25 inch	5	$1.35	$6.75
Shear Pins	N/A	N/A	N/A	1 (10 pack)	$8.60	$8.60
9 Volt Battery	26.5 mm	17.5 mm	48.5 mm	2 (2 pack)	$4.39	$8.78
PerfectFlite StratoLogger Altimeter CF	2.75 in	0.9 in	0.5 in	2	$58.80	$117.60
Wing nuts	N/A	N/A	N/A	1 (5 pack)	$5.99	$5.99
Threaded rods	0.25 in	0.25 in	12 in	2	$6.70	$13.40
Main parachute	24 in	24 in	N/A	1	$10.95	$10.95
Drogue parachute	15 in	15 in	N/A	1	$6.95	$6.95
9 volt battery holders	N/A	N/A	N/A	2	$2.17	$4.34
Black powder caps	N/A	N/A	N/A	1 (18 pack)	$5.81	$5.81
Eye Bolts	N/A	N/A	N/A	3	$1.64	$4.92
ABS filament (1 kg spool)	N/A	N/A	11.62 in	1	$19.99	$19.99

Payload

Material	Amount	Cost Per Unit	Total
Arduino Kit	1	$24.51	$24.51
Micro SD Card	1	$9.99	$9.99
9 volt battery	1 (2 pack)	$4.39	$4.39
Mega OHM Resistor	1	$0.49	$0.49
Solid Core Wire	1	$2.50	$2.50
9 Volt Battery Holder	2	$2.17	$4.34
Red and Black Jumpers	1 (70 pack)	$4.99	$4.99

Motor

Motor	Cost Per Unit	Amount	Total
Aerotech G80	$19.89	3	$59.67
Aerotech J800	$92.99	2	$185.98
Aerotech K1050WL	$148.74	1	$148.74

Travel

Item	Cost	Time	Total
Van rental	$693.37 per week	7 days	$693.37
Fuel for van	$242.50	7 days	$242.50
4 Georgia hotel rooms	$272	2 days	$544.00
4 Huntsville hotel rooms	$316	6 days	$1,896.00

Outreach

Item	Amount	Total Cost
Estes Bull Pup™ 12D	12 (Bulk pack)	$83.99
Estes Wizard™ Rocket Kit	12 (Bulk pack)	$45.01
A8-3 motors	24 (Bulk pack)	$43.19
B6-6 motors	24 (Bulk pack)	$43.79
BT60 Couplers	20	$13.00
BT60 18 inch Body Tubes	4 (Packs of six)	$51.64
Nose Cones	20	$157.00

18mm Motor Mounts	20	$118.00
Attiny85	10	$14.50
CR2025 battery case	10	$56.10
CR2025 Battery	10	$5.25
Assorted LED pack	1 (pack of 300)	$8.50
Breadboard	10	$10.30
Protoboard	2 (pack of 5)	$5.98
40 Ohm Resistor	10	$0.78

Totals

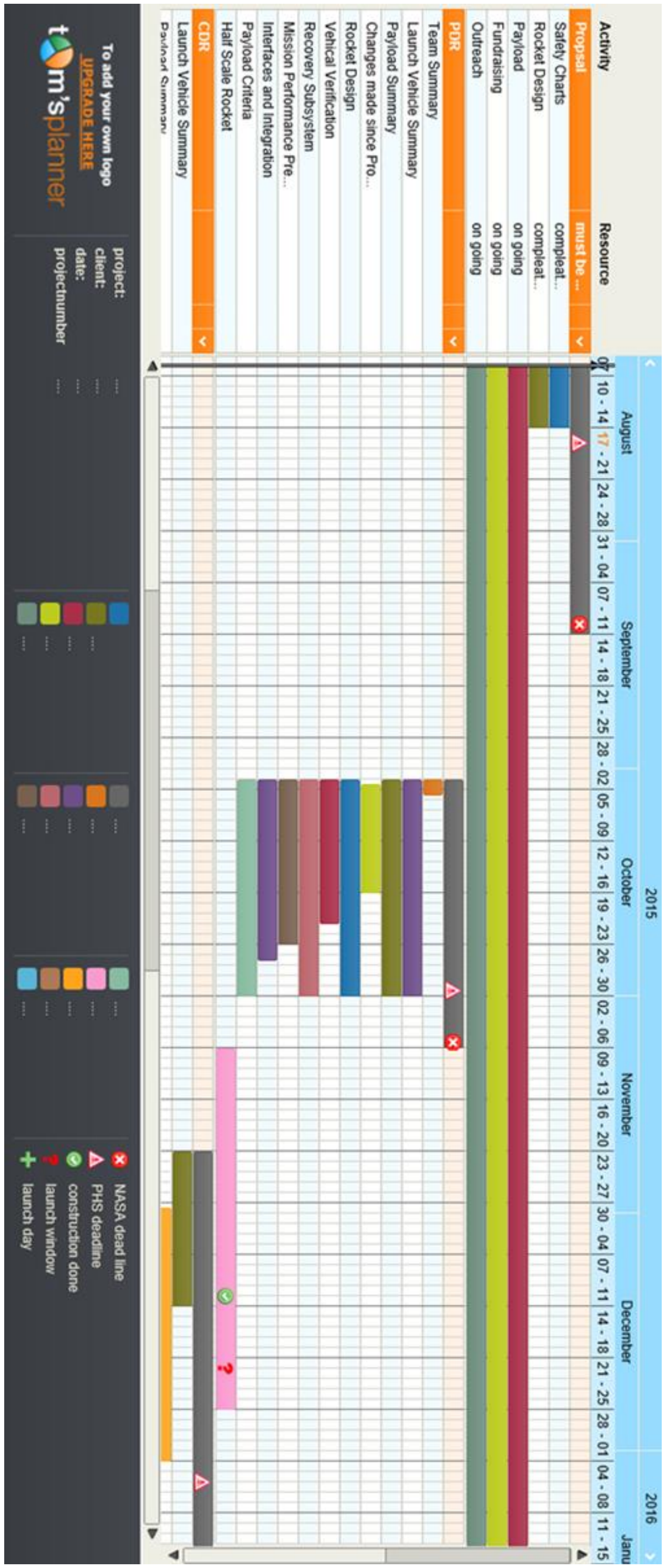
Section	Cost
Launch Vehicle	$1406.29
Payload	$51.21
Subscale	$427.21
Motor	$394.29
Travel	$3375.87
Outreach	$657.03
Total:	**$6311.90**

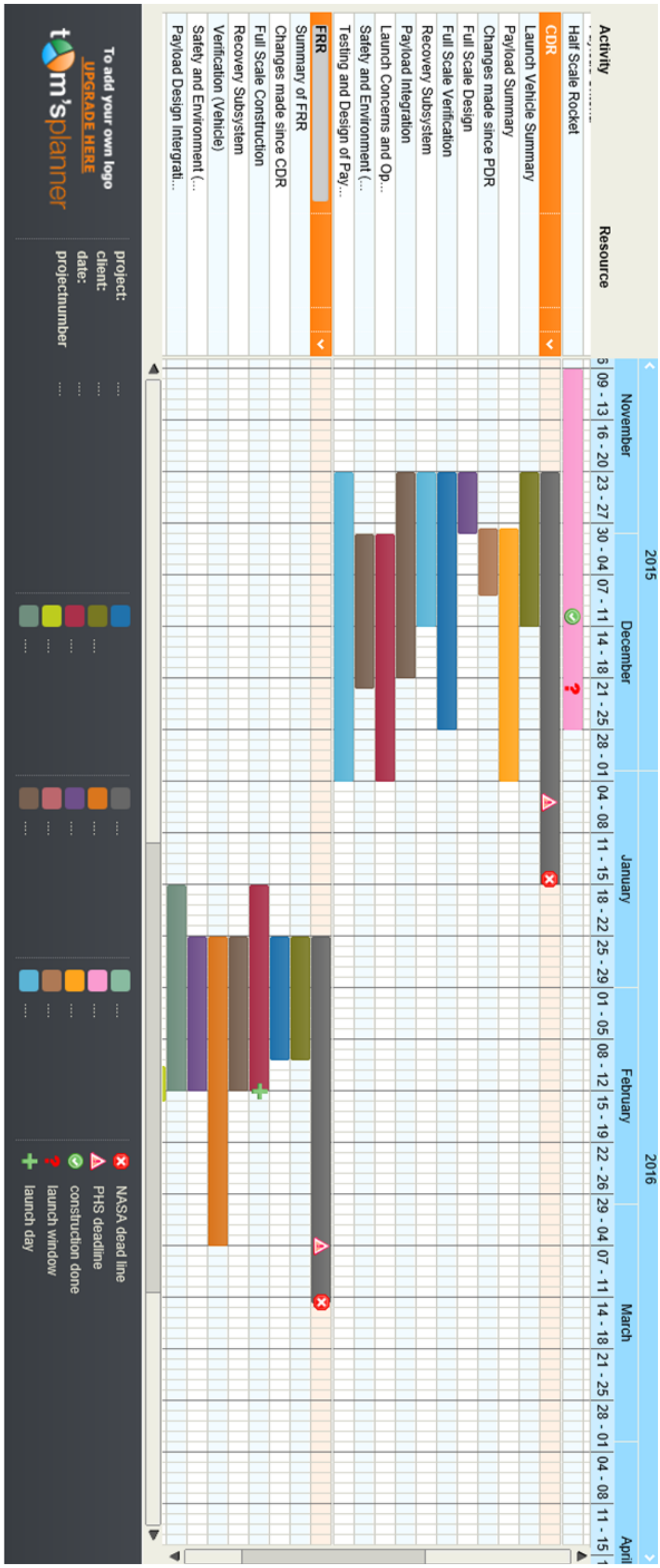
Funding

Fundraising activities will be conducted throughout the school year.

- Afternoon junk food sales of chips, candy, other snacks, sodas and Frappuccino's.
- Sponsors: ask for funding for projects from local businesses and community partners.
- Grants: the mentor and team will apply for STEM grants.
- The team will create a *Find It, Fund It* page to raise money through donations.
- The team will conduct a night launch of small rockets, charging for entrance and food.

GANTT Charts




Activity
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Half Scale Rocket
CDR
Launch Vehicle Summary
Payload Summary
Changes made since PDR
Full Scale Design
Full Scale Verification
Recovery Subsystem
Payload Integration
Launch Concerns and Op...
Safety and Environment (...
Testing and Design of Pay...
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Summary of FRR
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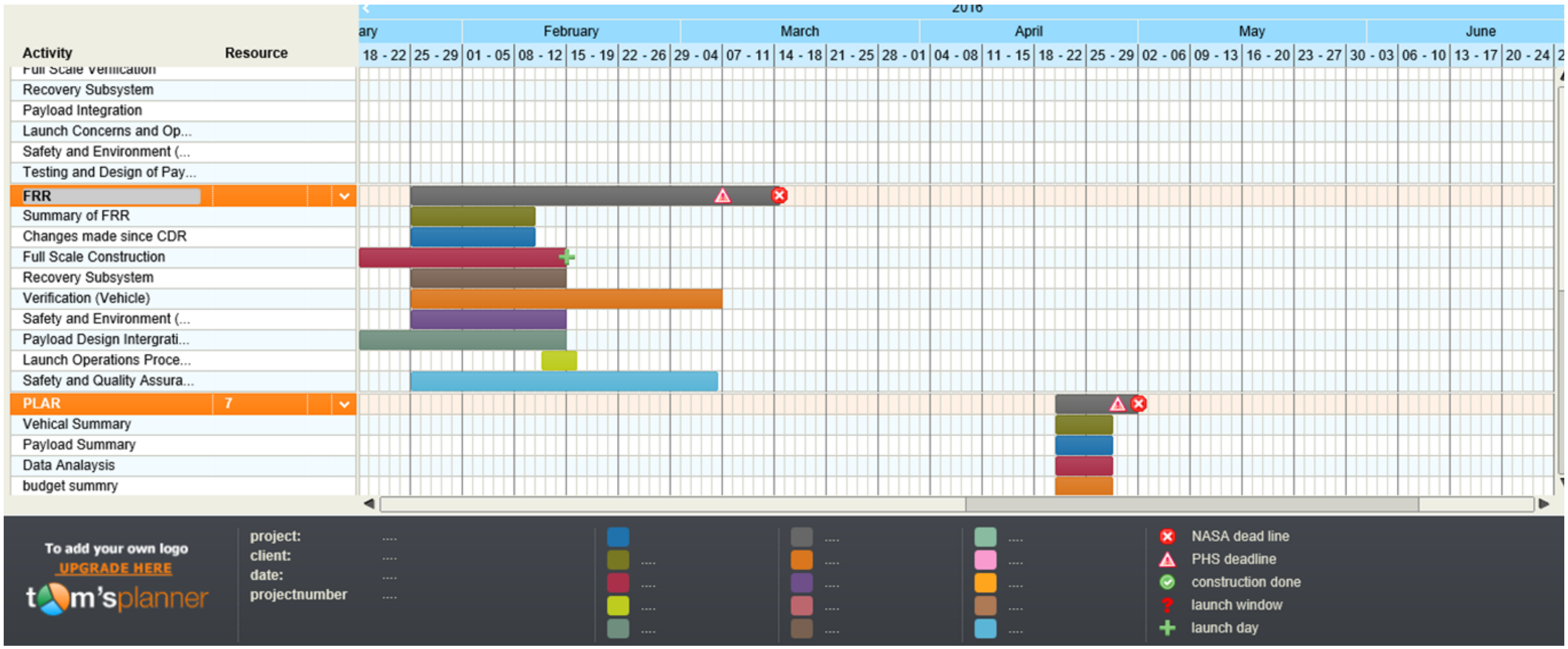

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To add your own logo
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NASA dead line
PHS deadline
construction done
launch window
launch day

Critical Path

After the completion of the FRR, the team must finalize plans to travel to Huntsville. Delays to this may cause affect the team's final launch.

During these activities, the team must also conduct fundraising and outreach events. Delays to outreach events may affect the development of payloads. After the final launch, the team must complete the PLAR. This may be affected by delays to the acquisition of data from the payloads and altimeters.

Educational Engagement

Student engagement in extracurricular activities is a large part of the education system of Broward County. Regardless of age, grade, or race, SL Team 2 seeks to introduce new people to the Aerospace Program and STEM activities every year.

Planned Events

The Student Launch team will be working with Bair Middle and Peters Elementary.

- **Night Launch/ Carnival:** Before the SL trip to Alabama, SL Team 2 plans on hosting a carnival type event where younger students from local schools will be familiarized with the rocket building and flying process. Students that participated in Open Lab Nights and other outreach events will be able to launch their completed rockets at the Night Launch. The attendees can participate in small carnival games and have the chance of winning prizes. All proceeds go towards Team 2 to help with funding and trip payments.
- **Open Lab Nights**: Plantation High's aerospace room will be open from 6PM - 8PM every Wednesday starting February 10th, 2016 for elementary (2nd-4th grade) school visits. The students will be engaging in engineering activities, alternating each week between constructing ESTES model rockets and working on STEM "mini-projects." The activities will be broken up and grouped between grade levels, and students will participate in events that consist of:
    - The 2nd and 3rd graders will learn the process of rocket construction through building ESTES rockets. They will learn how to attach fins onto the body tube, glue motor clip onto motor mount, attack shock cords to nose cones, and the rest of rocket building. After each students is allowed to construct their own rockets, they will be able to launch their rockets at the Night Launch that SL Team 2 plan on hosting.
    - The 4th and 5th graders will work on more complex rocket designing. The team members will discuss ideas for a rocket build. The team members will then sketch their ideas on paper, and will make decisions with the guidance of Plantation students. After the elementary students have a finalized plan, their rocket plans will be translated into OpenRocket. From here students are able to manipulate the rocket dimensions and learn how to simulate flights. Once finished on OpenRocket, the students will build their rockets. Using their computer designs, they will use provided supplies to match the designs to their best ability. When rocket construction is over, the students have a chance to fly their rockets at the Night Launch and get data from the flights.
- **Other school visits:** The team plan on visiting the affiliated schools and will:
    - Demonstrate the program's drones
    - Present information about the SL project and the team's rocket
    - Launch small rockets

- **Payload design:** The affiliated schools will have the opportunity to design a payload to be built and flown by the SL team. The requirements for this payload will include:
    - A maximum length of 8 inches
    - A maximum weight of 1 kilogram
    - The payload must also be a scientific experiment that will collect data to be analyzed and reported on.
- **Bair Middle School Outreach:** Plantation's SL Team 2 plan on engaging with Bair Middle School in order for the students to participate on STEM-oriented activities. SL Team 2 will exhibit current and past SL rockets to the middle school students and let them learn the rocket building process. The students will get a chance to learn how to code through coding the payload for the SL Team (EMF Detector).

Plantation High School Aerospace Program trailer and rocket display at the Sunrise Back to School Roundup hosted by the City of Sunrise.

Conclusion

Plantation High School Team 2 has successfully constructed and test flown a full-scale launch vehicle. This vehicle has a measured diameter of 5.5”, a length of 110” and mass of approximately 267 ounces. The team feels confident in the testing and verification of its vehicle, and its ability to complete the remaining mission requirements, including a successful flight on launch day in Huntsville.