PHS
AEROSPACE
TECHNOLOGY & DESIGN

Critical Design Review

Plantation High School Team 1
NASA Student Launch 2015-2016

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1 Summary

Team Summary

School Name

- *Plantation High School*

Team Name

- *Plantation High School Team 1*

Address

- *69 Northwest 16th Street*
  Plantation FL, 33313

Team Mentor

- *Joseph Vallone*
  (NAR #835241 Level 2)

Launch Vehicle Summary

Total Length (in.)	**79**
Mass (w/o payload & motor) (lbs.)	7.7
Diameter (in.)	4
Motor	K695R
Rail Size	Length: 96” 1” x 1” Cross Section
Recovery	Dual Deployment Main: 500 ft. AGL Drogue: Apogee Harness length: 30 ft.

Milestone Review Flysheet

Posted on website as a separate document.

Payload Summary

Title: Live Telemetry GPS Mapping

Experiment Summary

Hypothesizing that telemetric data can be recorded, transmitted, and displayed in real time from a rocket during flight, the experiment will utilize various sensors to collect data and send it to a computer AGL via a wireless transmitter.

2 Changes Since Proposal

Launch Vehicle

- *Fiberglass nosecone size changed from 3 to 1 to 5 to 1*
    - *The supply company did not have the 3:1 Fiberglass nosecone*
- *Mass added to nosecone (approx.. 500g)*
    - *Increase stability and to ensure the launch vehicle does not achieve an altitude over 5280ft.*
- *Altimeter bay changed from 3D printed to bass wood*
    - *Ease of manufacture*

Payload

- *Adafruit 10-DOF IMU Breakout will be used instead of the Barometric Pressure Sensor Breakout – BMP180, Adafruit Ultimate GPS Breakout, and ADXL335 – 5V ready Triple-axis accelerometer*
    - *The Adafruit 10-DOF IMU Breakout is capable of carrying out all functions necessary for the experiment otherwise fulfilled by the Barometric Pressure Sensor Breakout, GPD Breakout, and the Triple-Axis accelerometer*

Project Plan

- *Parkway Middle Launch Day and Seminar date was moved until further notice*
    - *Lack of communication by the schools*

3 Vehicle Criteria

3.1 Design and Verification of Launch Vehicle

3.1.1 Mission Statement, Requirements, and Mission Success Criteria

Mission Statement

The mission of the Plantation High School Team 1 is to design, construct, and test-fly a solid propellant high- power rocket, which conforms, to the requirements and regulations mandated by the Statement of Work (SOW) provided by NASA. The launch vehicle is to be launched at Clegg Sod Farm in Huntsville, Alabama. The rocket must achieve a maximum altitude of one-mile (5280-ft.), carry an operating scientific payload, and recover safely, thereby satisfying all requirements mandated by the SOW, The team must also educationally engage the community as a part of the NASA SL project by conducting local outreach events.

Mission Success Criteria

The mission success criteria of the Plantation High School Team 1 are as follows:

- *All written documents are submitted to and approved by the NASA Review Panel.*
- *Design, construction, and test-flights of the launch vehicle are completed in compliance with the vehicle criteria and safety-requirements of the SOW, and are accomplished before launch week.*
- *The launch vehicle does not achieve an altitude greater than 5,280 ft. (1 mile) AGL.*
- *The launch vehicle successfully transports an operating scientific payload to apogee and during descent, while following payload and safety-requirements mentioned in the SOW.*
- *The launch vehicle safely recovers in compliance with the recovery and safety-requirements section of the SOW.*
- *The local community is engaged in educational activities relating to aerospace and engineering by the Plantation High School Team 1.*

Requirements

Requirement	*Feature to Satisfy Requirement*	*Requirement Verification*

	1.1 The vehicle shall deliver the science or engineering payload to an apogee altitude of 5,280 ft. AGL	*An on-board, altitude triggered ejection charge, a fitted motor, and an appropriate drag coefficient to ensure the launch vehicle with payload reaches, but does not exceed, target altitude.*	*An on-board barometric altimeter will be used to record the altitude reached. Simulations will also be carried out to ensure altitude is reached.*
	1.2 The vehicle shall carry one commercially available, barometric altimeter	*Two Perfectflite Stratologger SL100 altimeters*	*The launch vehicle will include two Perfectflite Stratologger SL100 altimeters mounted onto an altimeter bay*
	1.3 The launch vehicle shall be designed to be reusable and recoverable	*A recovery system will be implemented using a main and a drogue parachute*	*Simulations will be carried out to ensure the kinetic energy of the rocket at landing will be below a safe threshold, enabling the rocket to be flown again without repairs or modifications*
	1.4 The launch vehicle shall have a maximum of four independent sections	*The rocket will be constructed into two sections.*	*Upon ejection, the vehicle will only separate into two sections tethered together using Kevlar.*
	1.5 The launch vehicle shall be limited to a single stage	*The rocket will only use single stage motors.*	*The selection of the motors will satisfy the requirement and ensure only single stage motors will be utilized.*
	1.6 The launch vehicle shall be capable of being prepared for flight at the launch site within two hours	*A checklist w/ a scheduled, chronological set of events to keep the preparation of the launch vehicle in less than two hours.*	*A test run of the launch vehicle preparation will be performed prior to launch day to ensure launch vehicle preparations will take place within two 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 f any critical on-board component	*All electrical components of the launch vehicle will be provided with a power supply that will sustain the hour during launch-ready configuration and for the duration of the flight.*	*A full-scale launch will take place along with battery testing to ensure all on-board components are working properly after an hour long (min.) launch-ready configuration at the pad.*
	1.8 The launch vehicle shall be capable of being launched by a standard 12-volt direct current firing system	*Igniters used will be capable of lighting with a 12-volt direct current firing system.*	*Test ignitions of the igniters and motors will be performed.*

	1.9 The launch vehicle shall require no external circuitry or special ground support equipment to initiate launch	*The launch vehicle will contain all components necessary, within the airframe, for a successful launch.*	*Test flights will be conducted where the launch vehicle will initiate launch using only internal equipment and those provided by Range Services.*
	1.10 The launch vehicle shall use a commercially available solid motor propulsion system using APCP	*An AeroTech K695 will be used for the test and final flight.*	*Research prior to use of motors determined the AeroTech K695 is a commercially available, APCP utilizing motors.*
	1.11 (includes all 1.11 sub requirements) Pressure vessels on the vehicle shall be approved by the RSO	*The launch vehicle design does not include pressure vessels.*	*N/A*
	1.12 The total impulse provided by a middle and/or high school launch vehicle shall not exceed 2,560 Newton-seconds (K-class)	*Use of AeroTech K695 motor*	*The AeroTech K695 has a total impulse of 1496.47 Newtons/second, which does not exceed the limit.*
	1.13 All teams shall successfully launch and recover a subscale model of their rocket prior to CDR	*A subscale model of the rocket will be designed, constructed, and flown subsequent to the submission and approval of the proposal.*	*The team's Gantt chart will be followed accordingly. Simulations and measurements will be performed to ensure the subscale model is to scale and is capable of flying successfully.*
	1.14 All teams shall successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration	*The full-scale rocket will be constructed subsequent to the submission and approval of the CDR. The rocket will be flown on February 13th in Bunnell, FL. The same rocket will be used for the final flight in Huntsville, AL.*	*The rocket will remain unchanged from test launch to final launch.*
	1.14.1 The vehicle and recovery system shall have functioned as designed	*RockSim and test flights, subscale and full-scale.*	*Simulations and tests will be utilized to ensure the vehicle and recovery subsystem will/has function(ed) as designed.*
	1.14.2.1 If the payload is not flown, mass simulators shall be used to simulate the payload mass. The mass simulators shall be located in the same approximate location on the rocket as the missing payload mass.	*The test flight will use the payload that will be used in the final flight. If the payload is not used in the test flight, a mass simulator identical to the mass of the payload will be substituted for the payloads.*	*Simulated payload weights will be recorded, so that in the event of the payloads not being completed, correct mass objects may be substituted.*

	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.	*The payload will not have external surfaces.*	*N/A*
	1.14.3 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.	*The full-scale motor will be used for the full-scale test flight.*	*As the motor will not change, the test-flight data will produce accurate results in verifying the final flight in Huntsville, AL.*
	1.14.4 The vehicle shall be flown in its fully ballasted configuration during the full-scale test flight.	*RockSim, vehicle design*	*Vehicle will be constructed as designed.*
	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 changes will be made*	*Following the completion of the full-scale demonstration flight, the launch vehicle and all of its components will not be modified.*
	1.15 All vehicle prohibitions will be regarded concerning the design of the launch vehicle	*The prohibitions will not be included into the launch vehicle design in any aspect.*	*The vehicle prohibitions will be understood prior to the designing of the launch vehicle.*

3.1.2 Major Milestone Schedule

8/7/15	Request for Proposal
9/11/15	Proposal Due to NASA
10/2/15	Awarded Proposals Announced
10/7/15	Kickoff and PDR Q&A
10/23/15	Team web presence established
11/6/15 8AM CT	Preliminary Design Review due to NASA
11/9/15	PDR video teleconferences
11/30/16	Sub scale construction begins
12/4/15	CDR Q&A
1/15/16 8 AM CT	CDR Due to NASA
1/19/16	CDR Video Teleconference
1/20/16-2/5/16	Full-Scale Construction
2/3/16	FRR Q&A
2/8/16-2/12/16	Static Testing & Ejection Tests
2/13/16	Full Scale Flight, Bunnell, FL
3/14/16 8AM CT	Flight Readiness Review due to NASA
3/17/16-3/30/16	FRR Video Teleconferences
4/11/16	Team travels to Huntsville, AL
4/13/16	Launch Readiness Reviews (LRR)
4/14/16	LRR’s and safety briefing
4/15/16	Rocket Fair and Tours of MSFC
4/16/16	Launch Day
4/17/16	Backup Launch Day
4/29/16 8AM CT	Post-Launch Assessment Review (PLAR) due to NASA

3.1.3 Design at System Level

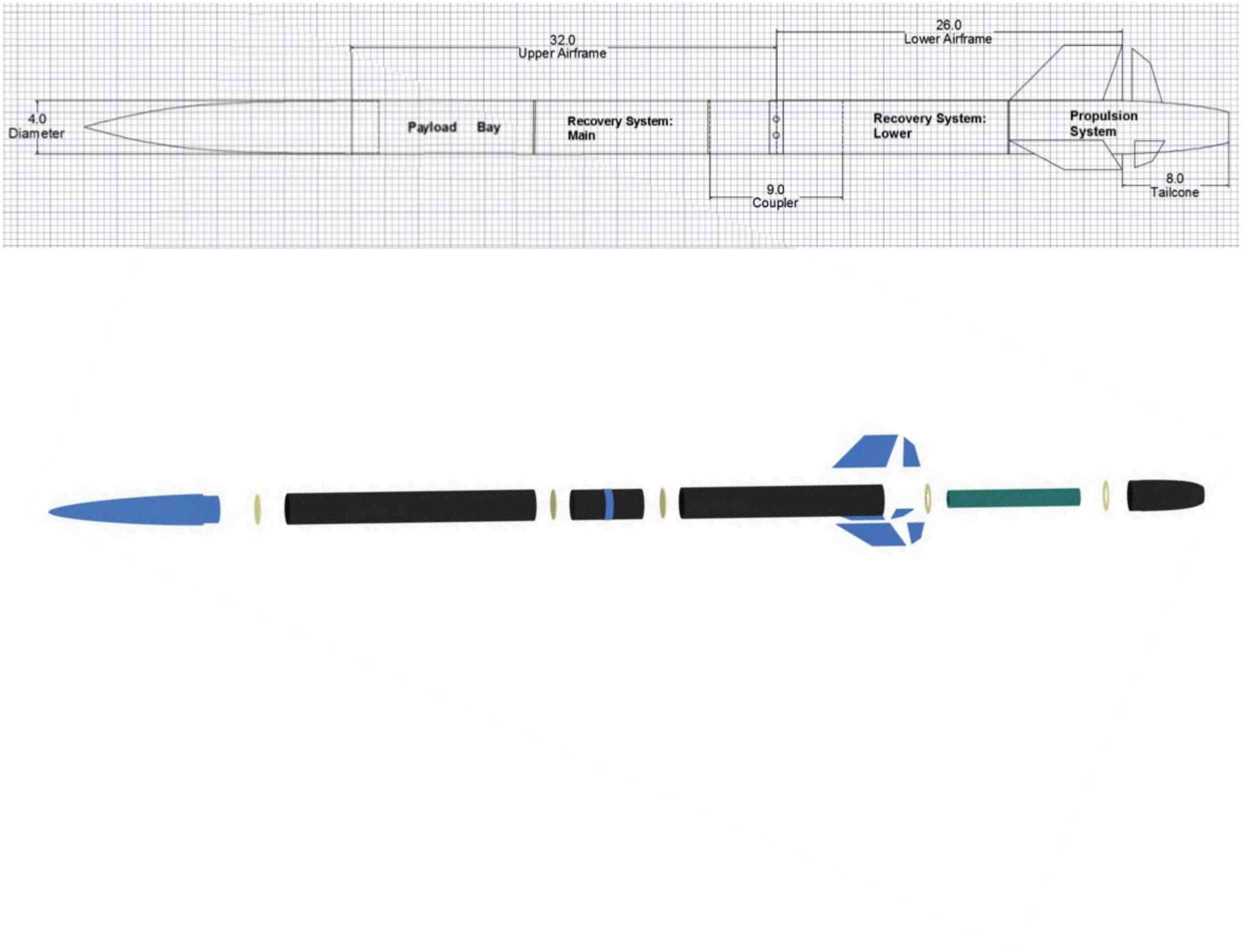
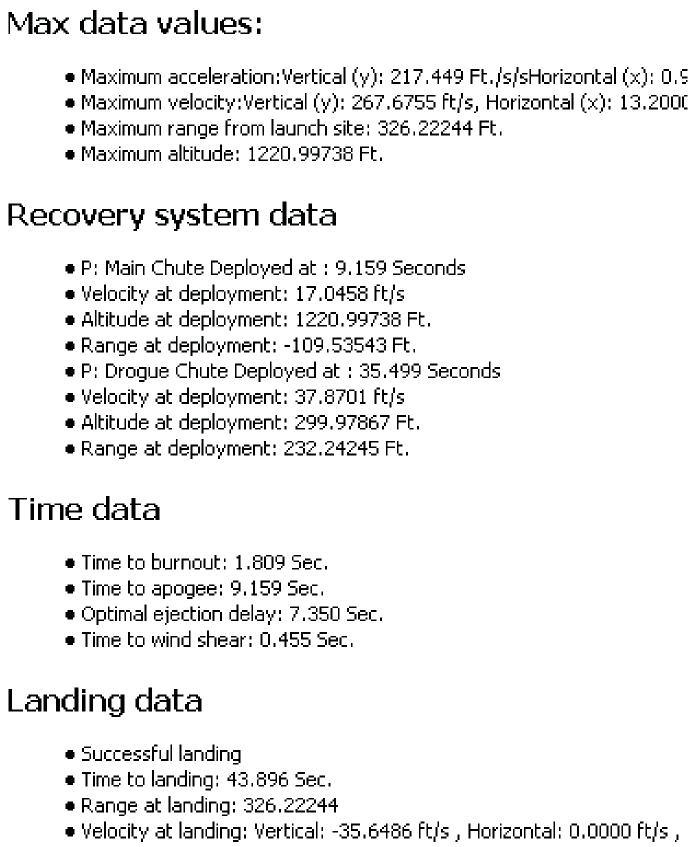


Figure 1 Final launch vehicle design

Final Analysis

Based on the simulations conducted through RockSim and the data retrieved from the subscale test launch, the capabilities of the systems and subsystems of the launch vehicle to perform as intended have been verified. Through comparisons of the subscale simulations and subscale test launch with the full-scale simulations, the design team has verified that the simulated coefficients of drag and static stability margin are reliable.

Subscale Model Results



Max data values:

- Maximum acceleration:Vertical (y): 217.449 Ft./s/sHorizontal (x): 0.9
- Maximum velocity:Vertical (y): 267.6755 ft/s, Horizontal (x): 13.2000
- Maximum range from launch site: 326.22244 Ft.
- Maximum altitude: 1220.99738 Ft.

Recovery system data

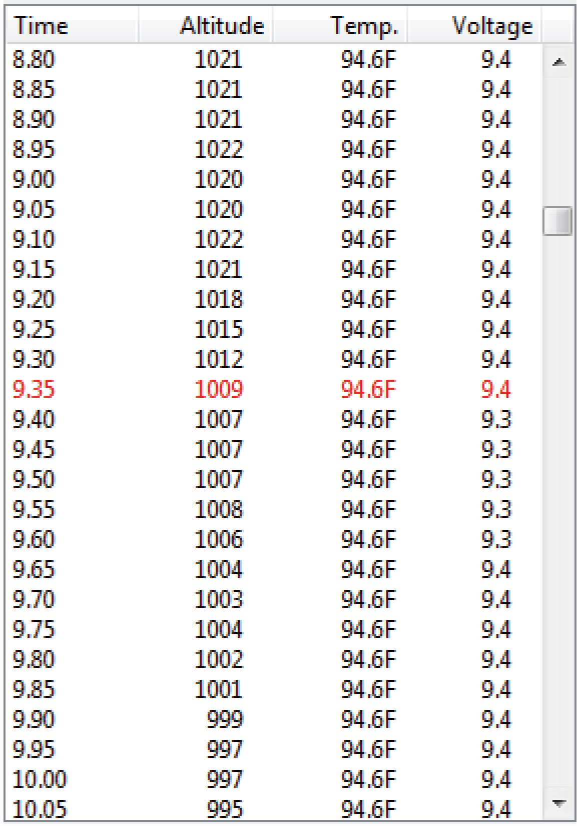
- P: Main Chute Deployed at : 9.159 Seconds
- Velocity at deployment: 17.0458 ft/s
- Altitude at deployment: 1220.99738 Ft.
- Range at deployment: -109.53543 Ft.
- P: Drogue Chute Deployed at : 35.499 Seconds
- Velocity at deployment: 37.8701 ft/s
- Altitude at deployment: 299.97867 Ft.
- Range at deployment: 232.24245 Ft.

Time data

- Time to burnout: 1.809 Sec.
- Time to apogee: 9.159 Sec.
- Optimal ejection delay: 7.350 Sec.
- Time to wind shear: 0.455 Sec.

Landing data

- Successful landing
- Time to landing: 43.896 Sec.
- Range at landing: 326.22244
- Velocity at landing: Vertical: -35.6486 ft/s , Horizontal: 0.0000 ft/s ,



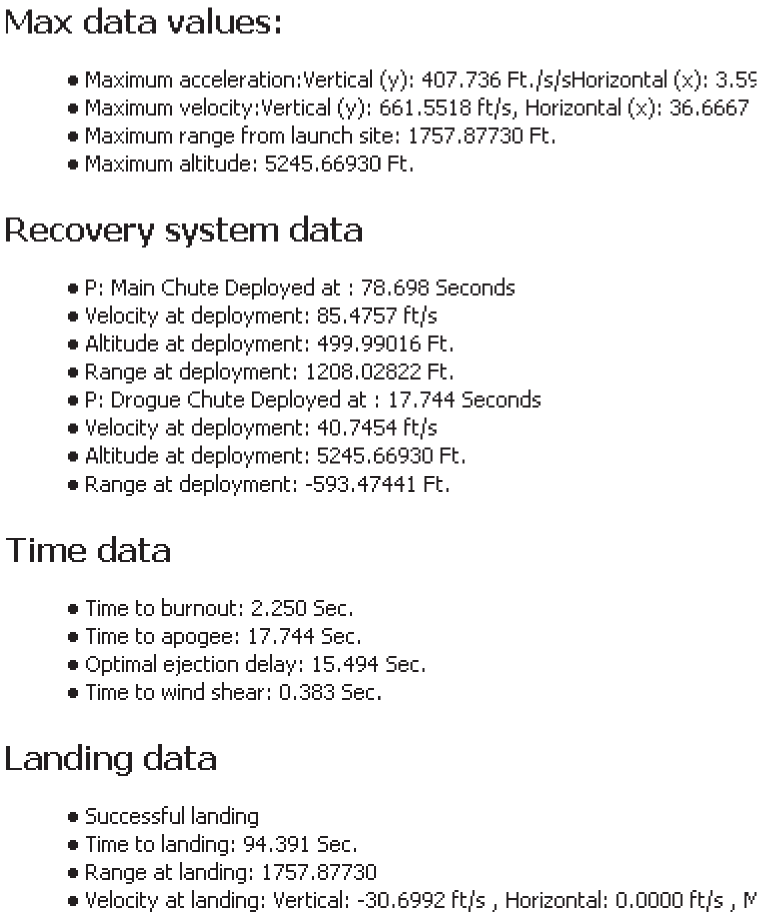
Time	Altitude	Temp.	Voltage
8.80	1021	94.6F	9.4
8.85	1021	94.6F	9.4
8.90	1021	94.6F	9.4
8.95	1022	94.6F	9.4
9.00	1020	94.6F	9.4
9.05	1020	94.6F	9.4
9.10	1022	94.6F	9.4
9.15	1021	94.6F	9.4
9.20	1018	94.6F	9.4
9.25	1015	94.6F	9.4
9.30	1012	94.6F	9.4
9.35	1009	94.6F	9.4
9.40	1007	94.6F	9.3
9.45	1007	94.6F	9.3
9.50	1007	94.6F	9.3
9.55	1008	94.6F	9.3
9.60	1006	94.6F	9.3
9.65	1004	94.6F	9.4
9.70	1003	94.6F	9.4
9.75	1004	94.6F	9.4
9.80	1002	94.6F	9.4
9.85	1001	94.6F	9.4
9.90	999	94.6F	9.4
9.95	997	94.6F	9.4
10.00	997	94.6F	9.4
10.05	995	94.6F	9.4

Figure 2 Subscale Test Launch Data*

*This image was retrieved from Perfectflite software available for download on their website

- Subscale Model Simulated Apogee: 1221 ft.
- Subscale Test Launch Apogee: 1022 ft.

Full-Scale Model Results


Max data values:

- Maximum acceleration:Vertical (y): 407.736 Ft./s/sHorizontal (x): 3.5
- Maximum velocity:Vertical (y): 661.5518 ft/s, Horizontal (x): 36.6667
- Maximum range from launch site: 1757.87730 Ft.
- Maximum altitude: 5245.66930 Ft.

Recovery system data

- P: Main Chute Deployed at : 78.698 Seconds
- Velocity at deployment: 85.4757 ft/s
- Altitude at deployment: 499.99016 Ft.
- Range at deployment: 1208.02822 Ft.
- P: Drogue Chute Deployed at : 17.744 Seconds
- Velocity at deployment: 40.7454 ft/s
- Altitude at deployment: 5245.66930 Ft.
- Range at deployment: -593.47441 Ft.

Time data

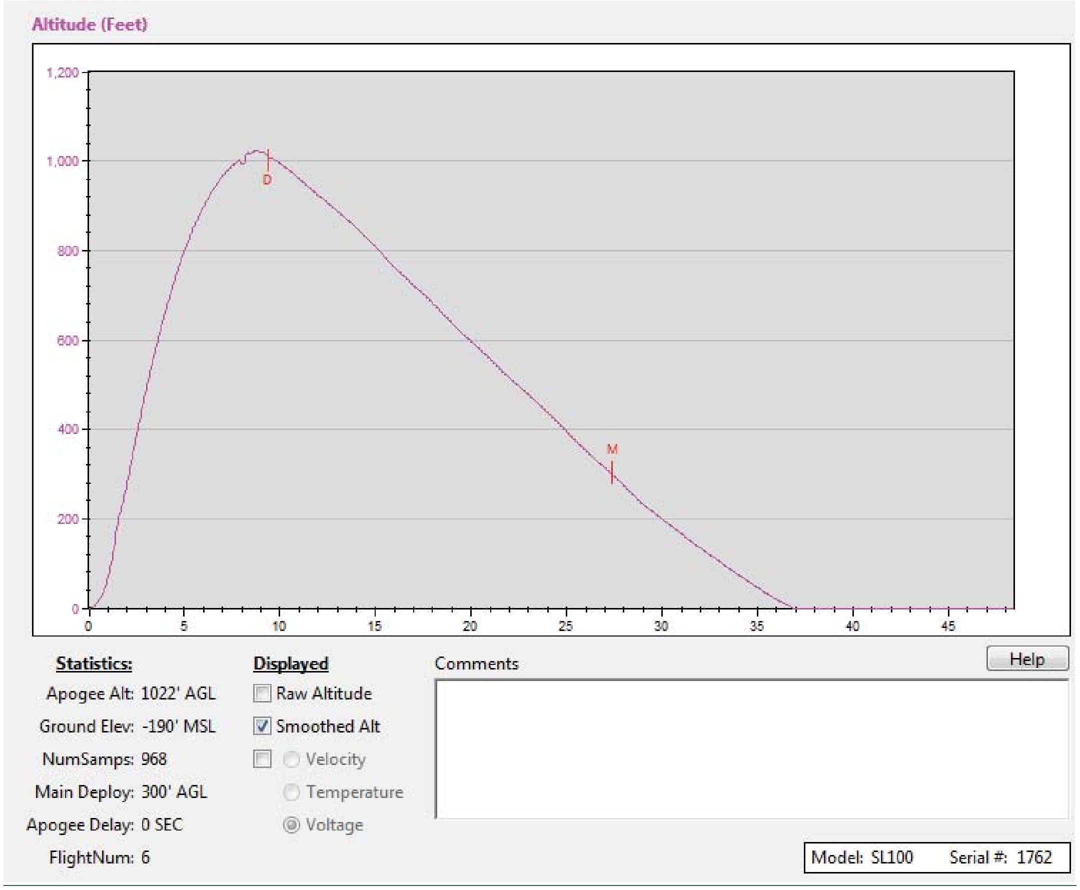
- Time to burnout: 2.250 Sec.
- Time to apogee: 17.744 Sec.
- Optimal ejection delay: 15.494 Sec.
- Time to wind shear: 0.383 Sec.

Landing data

- Successful landing
- Time to landing: 94.391 Sec.
- Range at landing: 1757.87730
- Velocity at landing: Vertical: -30.6992 ft/s , Horizontal: 0.0000 ft/s ,

Test Description and Results

- Plantation High School SL Team 1 Subscale Launch
- January 2, 2016; 11:00 AM
- Vista View Park; Davie, Florida
- Upon exit from the launch rail, the subscale launch vehicle weather-cocked for approximately 2 seconds before it achieved and maintained a straight and stable flight. It achieved an apogee of 1022 ft. before safely descending into a collection of short trees. After retrieving the launch vehicle, the team brought it back to the launch vehicle preparation area for assessment. The team concluded that no critical or impairing damage was done to the launch vehicle, and that all systems functioned as intended.



Statistics:

Apogee Alt: 1022' AGL
Ground Elev: -190' MSL
NumSamps: 968
Main Deploy: 300' AGL
Apogee Delay: 0 SEC
FlightNum: 6

Displayed

☐ Raw Altitude
☑ Smoothed Alt
☐ ○ Velocity
○ Temperature
● Voltage

Model: SL100 Serial #: 1762

Based on the performance of the subscale launch vehicle during the subscale test launch, the recovery system of the launch vehicle has been verified to perform as designed.

The recovery system of the subscale launch vehicle met the following requirements:

- Main chute ejection and deployment occurred at apogee
- Drogue chute ejection and deployment occurred at 300 ft. during descent

Final Motor Selection

- AeroTech K695R

Structural System: Airframe & Guidance

Functional Requirements

- *To provide the launch vehicle with a robust structural frame*
- *Effectively stabilize and guide the launch vehicle throughout its entire flight*

Market Availability/Ease of Construction

The intended concept may be achieved by being purchased or constructed - within the budget and skillset(s) possessed by the Plantation High School Team 1 - from a vendor or within the facilities available to the team.

System	Selected Concept	Characteristics	Subsystems
Airframe	• Blue Tube • Upper Airframe • Lower Airframe	• Upper length: 32 in. • Lower length: 26 in. • Diameter: 4 in.	• Nosecone • Upper • Lower • Bulkheads • Coupler/Altimeter Bay • Tailcone
Guidance	• Fins • Launch Rails (2x)	• Dual Trapezoidal Fin set • Carbon Fiber Fin set	• Fins • Launch Rails

Selection Rationale

Airframe

- *Size is adequate enough to provide room for other systems of the launch vehicle - including payload, recovery, and propulsion - as well as each subsystem of the systems*
- *Does not interfere with the mission objective of achieving a minimum apogee of one mile AGL as of the PDR*
- *BlueTube material used is capable of withstanding impact upon landing and works synergistically with the nose cone, coupler, and tailcone in providing the rest of the launch vehicle with a robust frame.*

Guidance

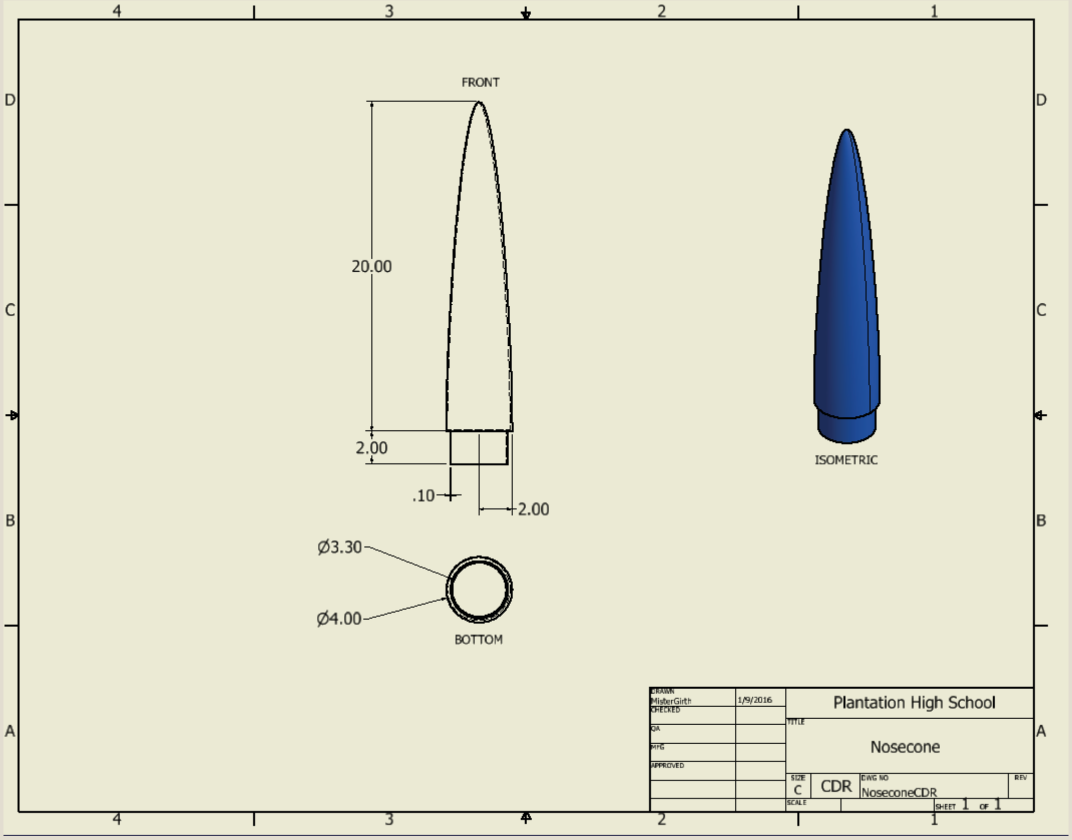
- *Allows the launch vehicle to achieve stability while exiting the launch rail, and maintain its stability throughout the duration of its flight*
- *All structural components of the guidance system are properly integrated with the launch vehicle, and are capable of remaining intact after impact upon landing*

Structural Subsystem: Airframe

Nosecone

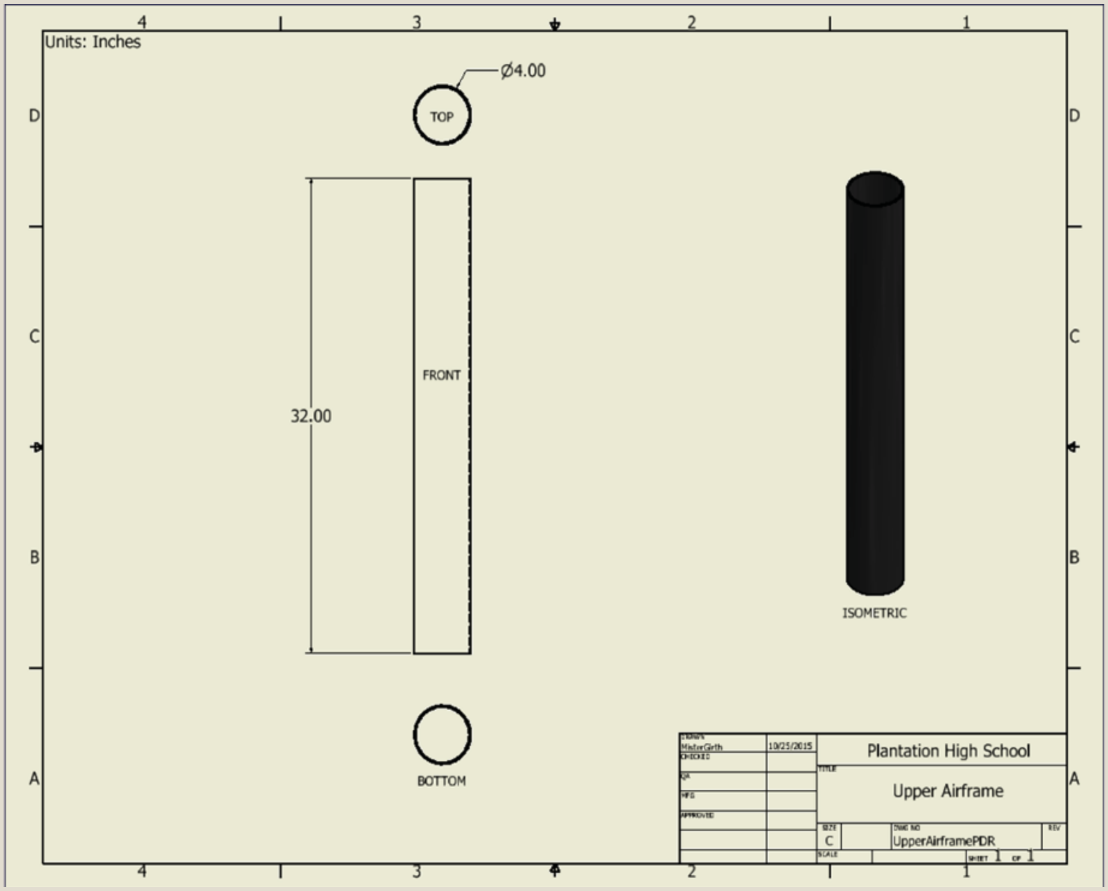
- *Ogive*
- *Fiberglass*
- *Length: 20 in.*
- *Diameter: 4 in.*
- *Shoulder Length: 2 in.*
- *Shoulder Diameter: 3.9 in.*

Decreases the amount of drag the launch vehicle faces during flight; improves stability of launch vehicle during flight



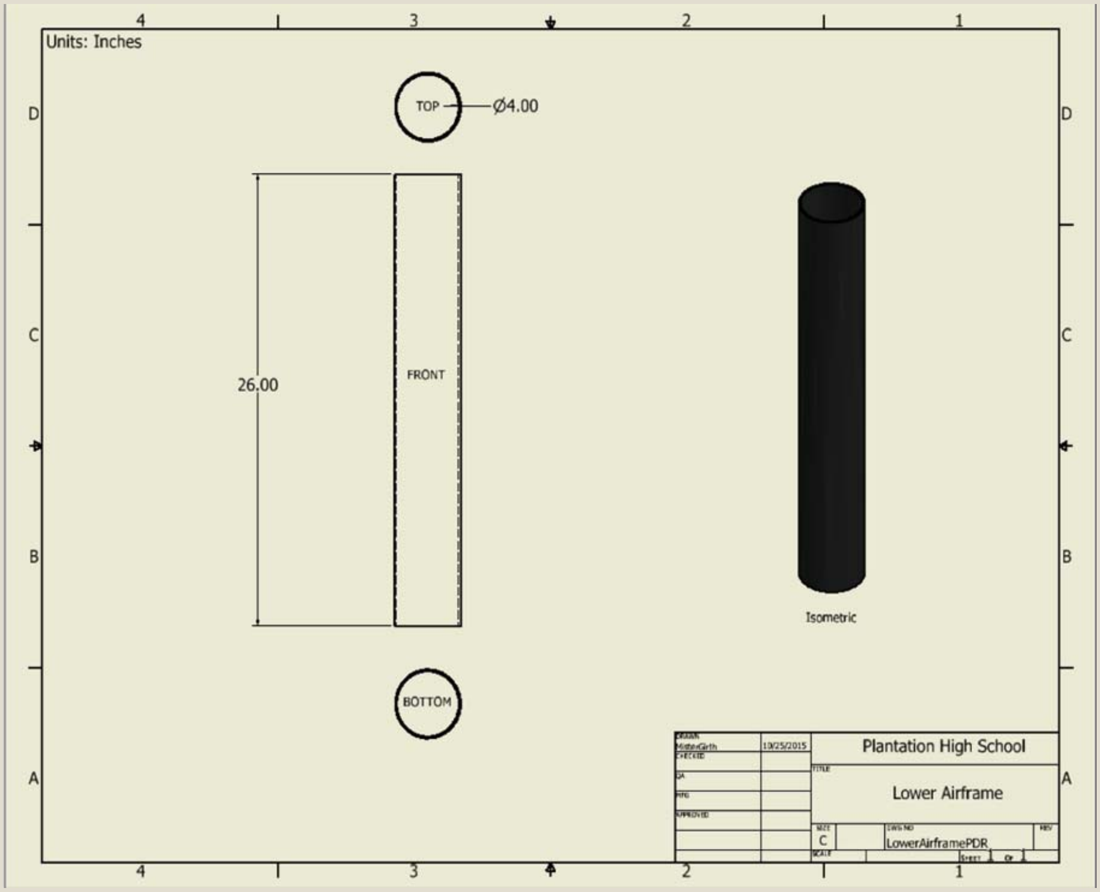
Upper Airframe

- *Blue Tube*
- *Length: 32 in.*
- *OD: 4 in.*
- *ID: 3.9 in.*
- *Houses*
    - *Payload system and subsystems*
    - *Recovery system; Main chute*



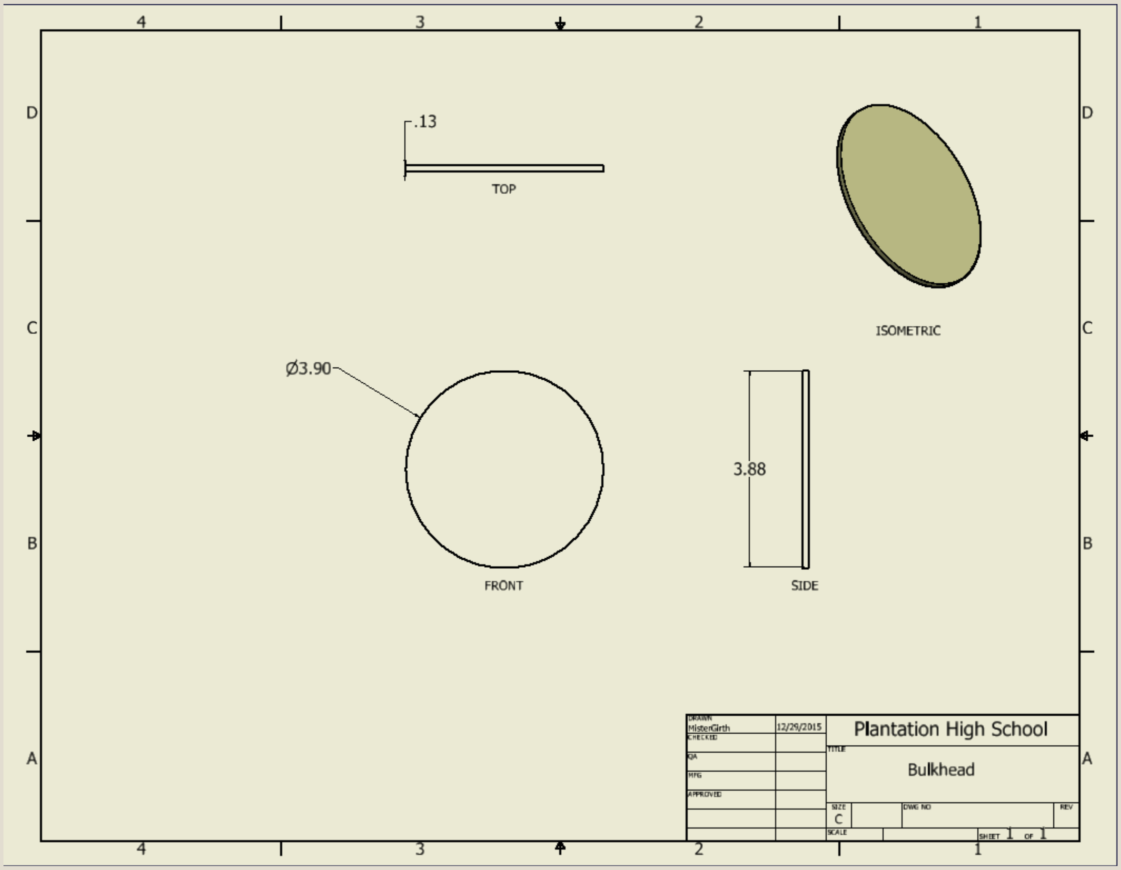
Lower Airframe

- *Blue Tube*
- *Length: 26 in.*
- *OD: 4 in.*
- *ID: 3.9 in.*
- *Houses*
    - *Propulsion system and subsystems*
    - *Recovery subsystem; Main Chute*
    - *Guidance Subsystem; fins*



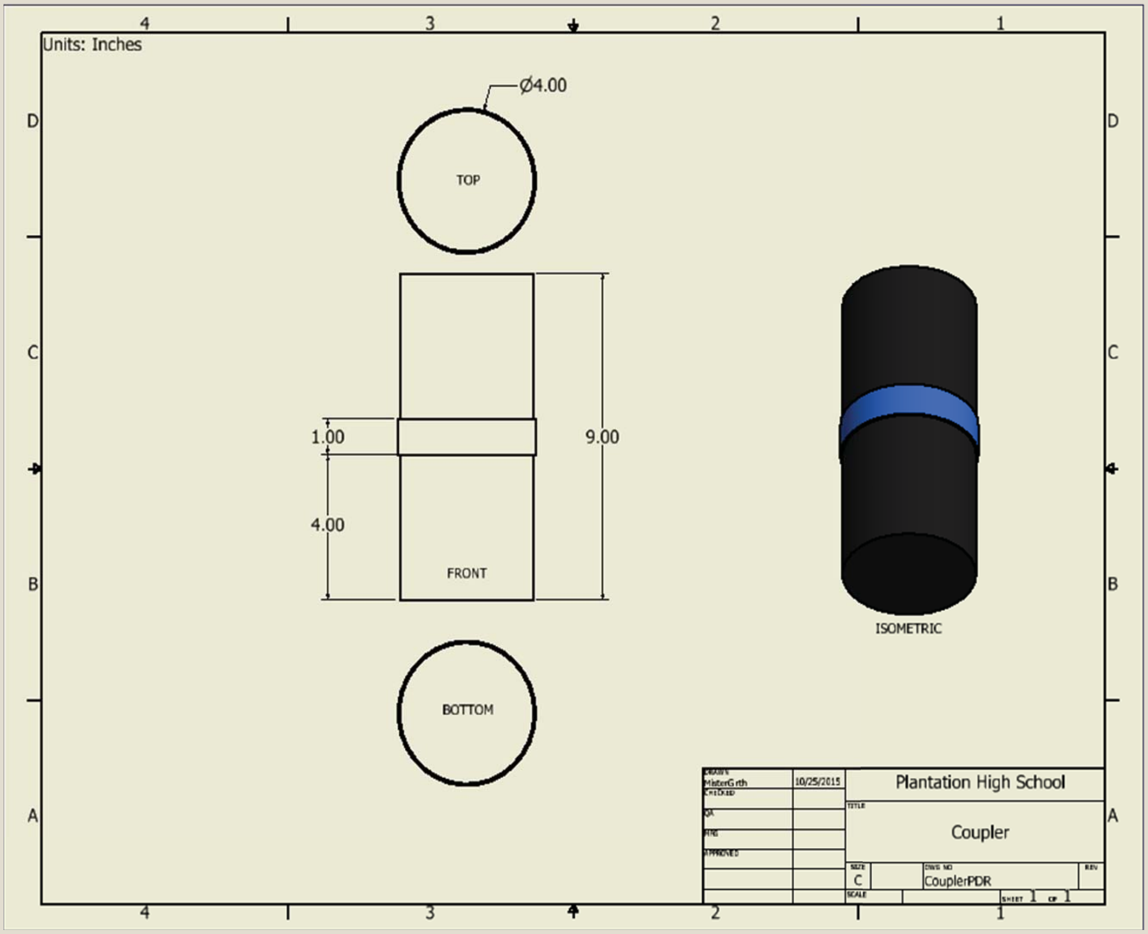
Bulkheads (3x)

- *G10 Fiberglass*
- *Diameter: 3.9 in.*
- *Thickness: 0.125 in.*
- *Designates:*
    - *Recovery subsystem; Altimeter Bay*
    - *Payload System*
    - *Recovery System*



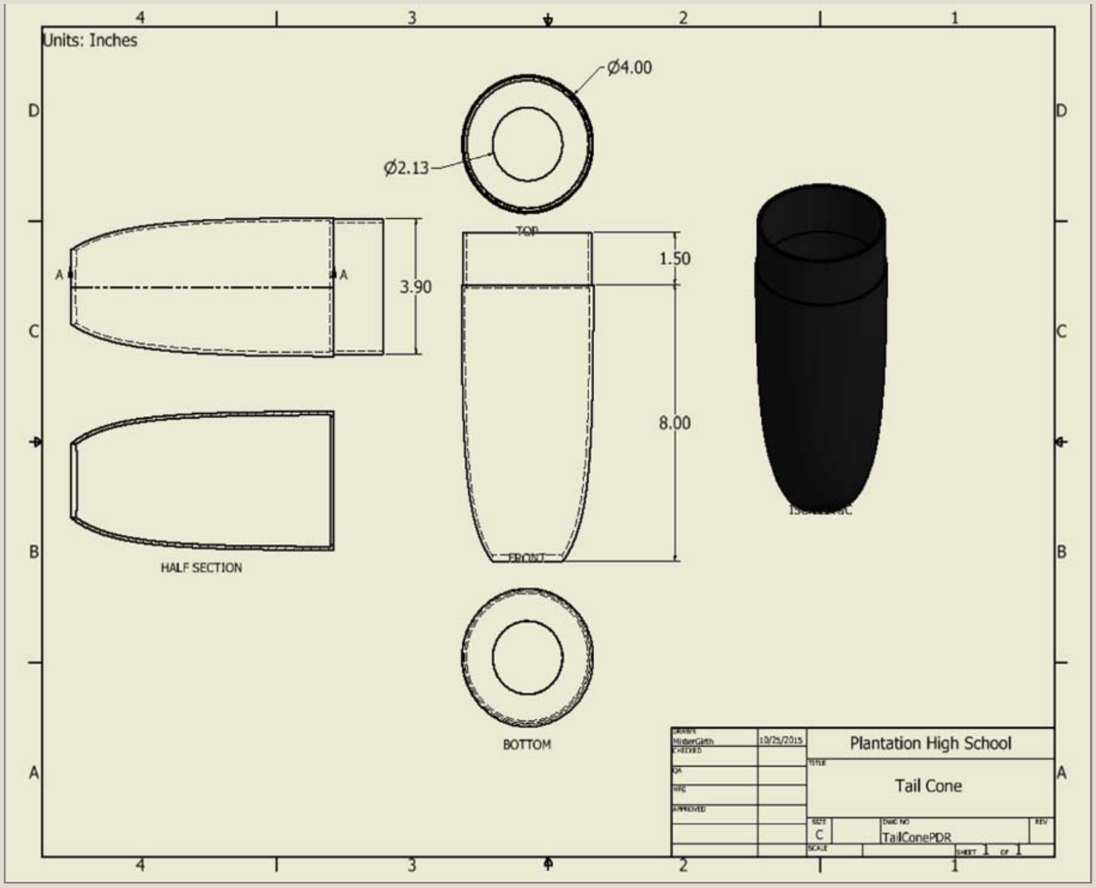
Coupler

- *BlueTube*
- *Length: 11 in.*
- *OD: 3.9 in.*
- *ID: 3.8 in.*
- *Houses:*
    - *Recovery subsystem; Altimeter Bay*
- *Serves as a conduit for the upper and lower airframes*



Tailcone

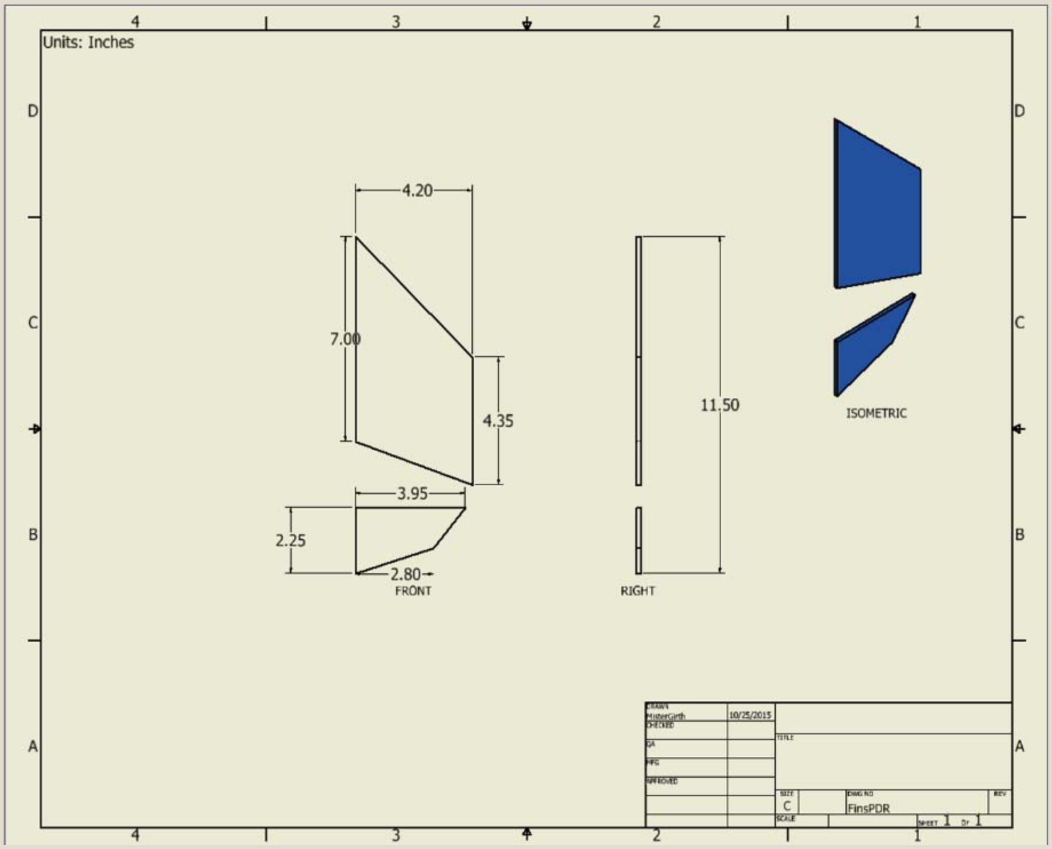
- *Polystyrene*
- *Ogive*
- *Length: 8 in.*
- *Front Diameter: 4 in.*
- *Rear Diameter: 2.2 in.*
- *Surrounds and protects the motor mount and motor while decreasing the drag of the launch vehicle.*



Structural Subsystems: Guidance

Fins

- *Carbon Fiber*
- *Trapezoidal; Dual Set*
- *Fin Count: 3*
- *Total Root Chord: 11.5 in.*
- *Height: 4.2 in.*
- *Thickness: 0.1 in.*
    - *Both the thickness of the G10 fiberglass and the proximity of the lower fin set to the upper fin set reduce the effects of fin flutter on the stability of the rocket.*
- *Adequately provides the launch vehicle with stability during flight.*



Launch Buttons (2x)

- *Steel Screws*
- *Guide the launch vehicle up the launch rail in order to provide a stable, vertical trajectory*

Payload System: Frame & Electronics

Functional Requirements

To record and transmit real-time telemetric data (altitude, air pressure, acceleration in all directions, and precise location (GPS)) to a receiver at ground level and the Plantation High School Aerospace Program's website.

Market Availability/Ease of Construction

The intended concept may be achieved by being purchased or constructed - within the budget and skillset(s) possessed by the Plantation High School SLI New Team - from a vendor or within the facilities available to the team.

System	Selected Concept	Subsystems/Components
Frame	• Universal Payload Frame	• Balsa Baseplates • Threaded Rods • Silicon Compression Tubes
Electronics	• Real-Time Telemetric Data Acquisition	• Barometric Pressure Sensor (BMP 180) • XBee Pro 900 • GPS Module • Triple-Axis Accelerometer • Sparkfun RedBoard

Selection Rationale

Frame

- *Design provides the payload electronics with durable and sturdy bases, which the electronics will be tethered to*
- *Sufficient space is provided for each electronic component with wiring throughout*
- *Capable of remaining intact after being subject to the amount of thrust generated by the K695R motor (695 N) and upon landing*

Electronics

- *Capable of successfully recording and transmitting real-time telemetric data (altitude, air pressure, acceleration in all directions, and precise location (GPS)) to a receiver at ground level and to the Plantation High School Aerospace Program's website.*
- *Easily integrated with the payload frame design*
- *Capable of functioning properly to achieve its objective*

Payload Subsystems: Frame

Balsa Baseplates

- *Provide the payload electronics with attachment surfaces.*
- *Supported by two threaded rods.*

Threaded Rods

- *¼ in. diameter*
- *Support the balsa baseplates within the payload bay.*
- *Fastened to a bulkhead separating the payload bay from the upper airframe recovery system with screws and washers.*

Silicon Compression Tubes

- *Located between each balsa baseplate to prevent them from oscillating during flight*

Recovery System: Altimeter Bay, Black Powder Ejection Charges, Chutes/Harness/Eyebolt

Functional Requirements

To guarantee that the launch vehicle recovers safely after the initial drogue chute is deployed at apogee and the main chute at 500 ft. AGL and to prevent any components of the launch vehicle from being damaged from impact upon landing.

Market Availability/Ease of Construction

The intended concept may be achieved by being purchased or constructed - within the budget and skillset(s) possessed by the Plantation High School Team 1 - from a vendor or within the facilities available to the team.

System	Subsystems
Altimeter Bay	• Altimeter Sled • Altimeters • 9v Batteries • Threaded Rods/Nuts & Washers • Bulkheads
Black Powder Ejection	• Black Powder Charges • E-matches
Chutes/Harnesses/Eyebolts	• Main Chute • Drogue Chute • Recovery Harness (Upper) • Recovery Harness (Lower) • Eyebolts and D-Links

Selection Rationale

Altimeter Bay

- *Robust altimeter sled*
    - *Provides a base for two Perfectflite Stratologger altimeters to remain tethered to as they perform their subsystem functions throughout flight*

    The subsystem functions are as follows:

    - *One altimeter sends impulses to two separate black powder ejection charges at different periods of flight; one at apogee and one at 500 ft. AGL during descent*
    - *A second altimeter sends impulses to two separate black powder ejection charges three seconds after each blast from the first altimeter*
    - *This is performed as a method to guarantee the deployment of both drogue and main chutes.*

Black Powder Ejection

- *Located in both upper and lower airframes*
- *Capable of separating the airframe component from the coupler as well as deploying each airframe's respective chute after being fired*

Parachutes, Harnesses, and Eyebolts

- *Drogue and main chutes*
    - *Must be capable of being tethered to a recovery harness within the launch vehicle*
    - *Must be properly deployable by black powder ejection charges at apogee and at 500 ft. AGL during descent*
- *Recovery harnesses*
    - *Attached to eyebolts and d-links on bulkheads located within both airframes and on each end of the coupler*
    - *Capable of withstanding the tension created by each black powder ejection charge*

Sketches

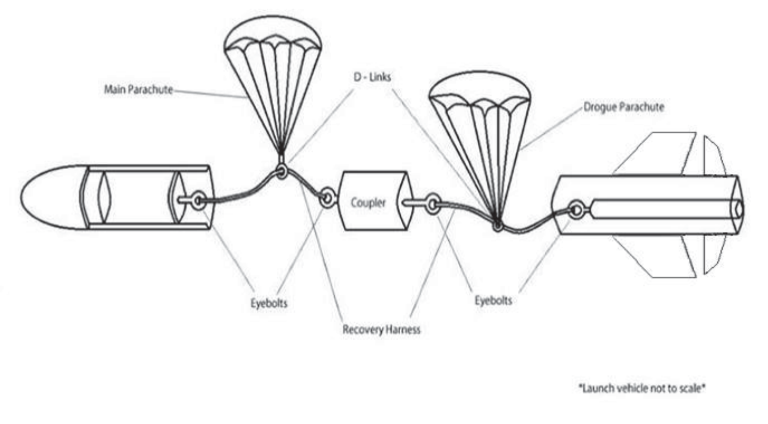


Figure 3 Sketch of recovery system in an exploded format.

Both main and drogue chutes are tethered to recovery harnesses of equal length and thickness. The main chute and its recovery harness are attached to a bulkhead in the upper airframe, while the drogue chute and its recovery harness are attached to a bulkhead in the lower airframe.

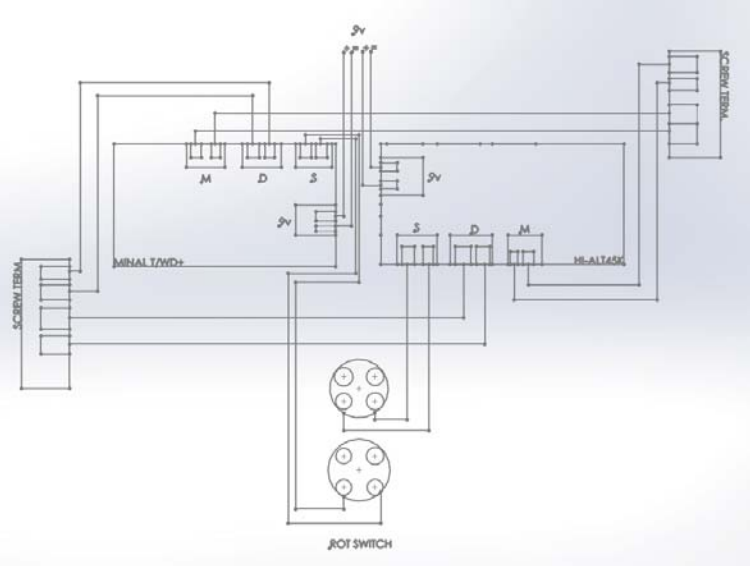


Figure 4 The recovery schematics

Within the altimeter bay are two Perfectflite SL100 altimeters. Both altimeters fire ejection charges at apogee and at 500 ft. AGL during descent to deploy the drogue and main chute. One altimeter fires three seconds after each charge as redundancy in order to guarantee the deployment of the drogue and main chutes.

Recovery Subsystems: Altimeter Bay

Altimeter Sled

- *Bass wood*
    - *Provides an attachment surface for the altimeters and 9v batteries*

Altimeters (2x)

- *Perfectflite Stratologger 100*
- *Tethered to the altimeter sled*
- *Measures the altitude of the launch vehicle at any given time;*
- *Sends an impulse to black powder ejection charges at apogee and at 500 ft. AGL to deploy drogue and main chutes*
- *Sends an impulse to black powder ejection charges after each initial blast at apogee and at 500 ft. AGL in order to guarantee the deployment of the drogue and main chutes*

9v Batteries (2x)

  - *Powers both altimeters*

Bulkheads (2x)

  - *G10 Fiberglass*
  - *Diameter: 3.9 in.*

  - *Thickness: 0.125 in.*
  - *Separates the altimeter bay from the upper and lower airframes. Threaded Rods/Nuts + Washers*
  - *¼ in.*
  - *Length: 11 in.*
  - *Steel*
  - *Fastened to each bulkhead of the altimeter bay*
  - *Supports the altimeter sled and secures it in place*

Recovery Subsystems: Black Powder Ejection

- *Black Powder Charges (4x)*
- *Main (2x):*
  - *2.5g*
- *Drogue (2x):*
  - *2g*
- *Used to deploy both drogue and main chutes at apogee and 500 ft. AGL respectively*
- *Fired from e-matches*
- *E-Matches (4x)*
- *Used to fire ejection charges to deploy drogue and main chutes at apogee and 500 ft. AGL respectively*

Recovery Subsystems: Chutes/Harnesses/Eyebolts

Drogue Chute

- *Giant Leap TAC-24*
- *Diameter: 24 in.*
- *Shroud Lines (x6):*
- *Location: Lower Airframe*
- *Deployment: Apogee*
- *Deployed to slow the launch vehicle before the main chute deploys at 500 ft. AGL*

Main Chute

- *Giant Leap TAC-60*
- *Diameter: 60 in.*
- *Shroud Lines (x6):*
- *Location: Upper Airframe*
- *Deployment: 500 ft. AGL during descent*
- *Deployed to slow the launch vehicle to an optimal descent velocity before landing*

Recovery Harness (Upper + Lower)

- *Tubular Kevlar*
- *Length: 30 ft.*
- *Thickness: 3/8 in.*
- *Main*
  - *Tethered to a bulkhead in the upper airframe and a bulkhead on one end of the coupler*
- *Drogue*
  - *Tethered to a bulkhead in the lower airframe and a bulkhead on one end of the coupler*
- *Used to connect the upper and lower airframes with the coupler*
- *Serves as harnesses for the drogue and main chutes*

Eyebolts and D-Links (4x)

- *Zinc-coated steel*
- *¼ in. Eyebolts*
- *¼ in. D-Links*
- *Three eyebolts are mounted on a bulkhead and one to the motor mount o Each eyebolt is accompanied by a d-link*
- *Serves to tether the recovery harnesses to the airframes*

Propulsion Systems: Frame & Motor

Functional Requirements

To provide the launch vehicle with sufficient thrust enabling it to exit the launch rails and to carry out a stable flight to the target apogee of 6,005 ft. AGL.

Market Availability/Ease of Construction

The intended concept may be achieved by being purchased or constructed - within the budget and skillset(s) possessed by the Plantation High School Team 1- from a vendor or within the facilities available to the team.

System	Subsystems
Frame	• Centering Rings • Motor Mount • Tail Cone
Motor	• AeroTech K695R • Motor Casing • Retention Cap

Section Rationale

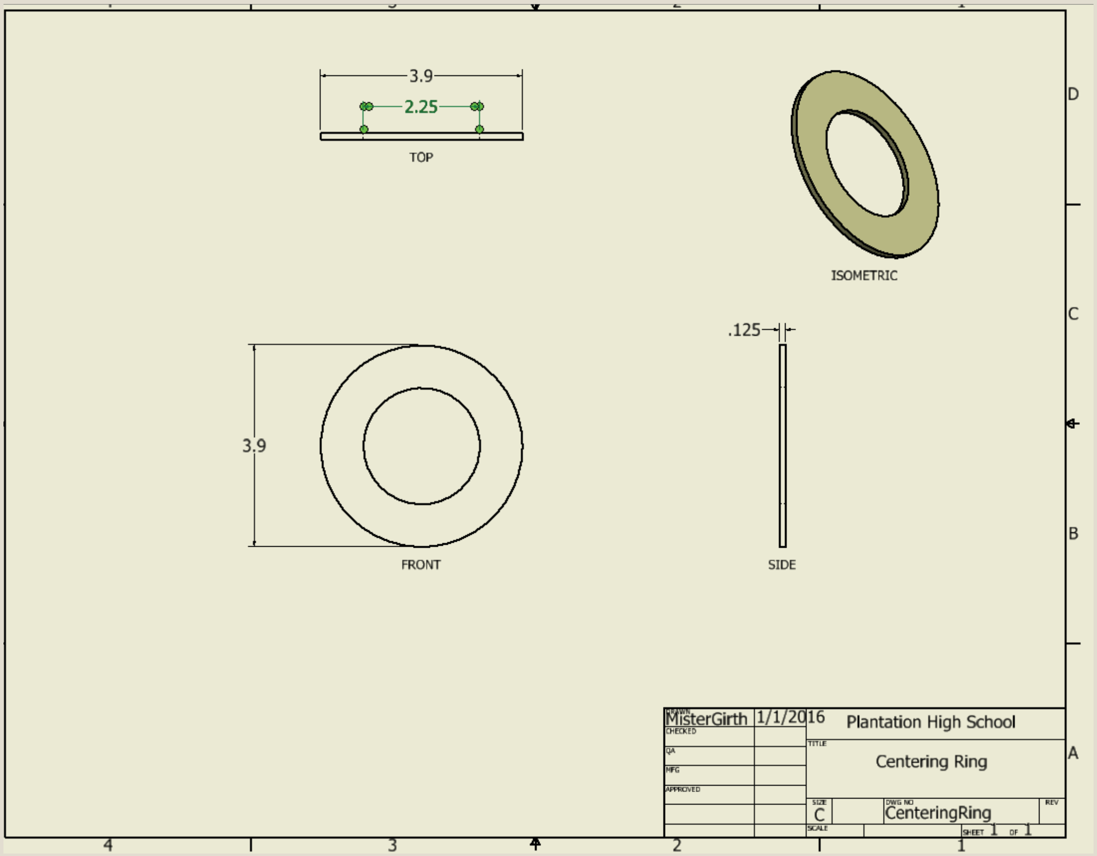
Frame

- *Motor mount*
    - *Firmly secures the selected motor within the lower airframe of the launch vehicle*
    - *Capable of withstanding heat generated by the motor as it expels propellant*
- *Centering rings*
    - *Robust*
    - *Can bolster the motor mount within the airframe without sustaining any damage*
- *Tail cone*
    - *Surrounds and protects the motor mount and motor*
    - *Decreases drag of the launch vehicle*

Propulsion Subsystems: Frame

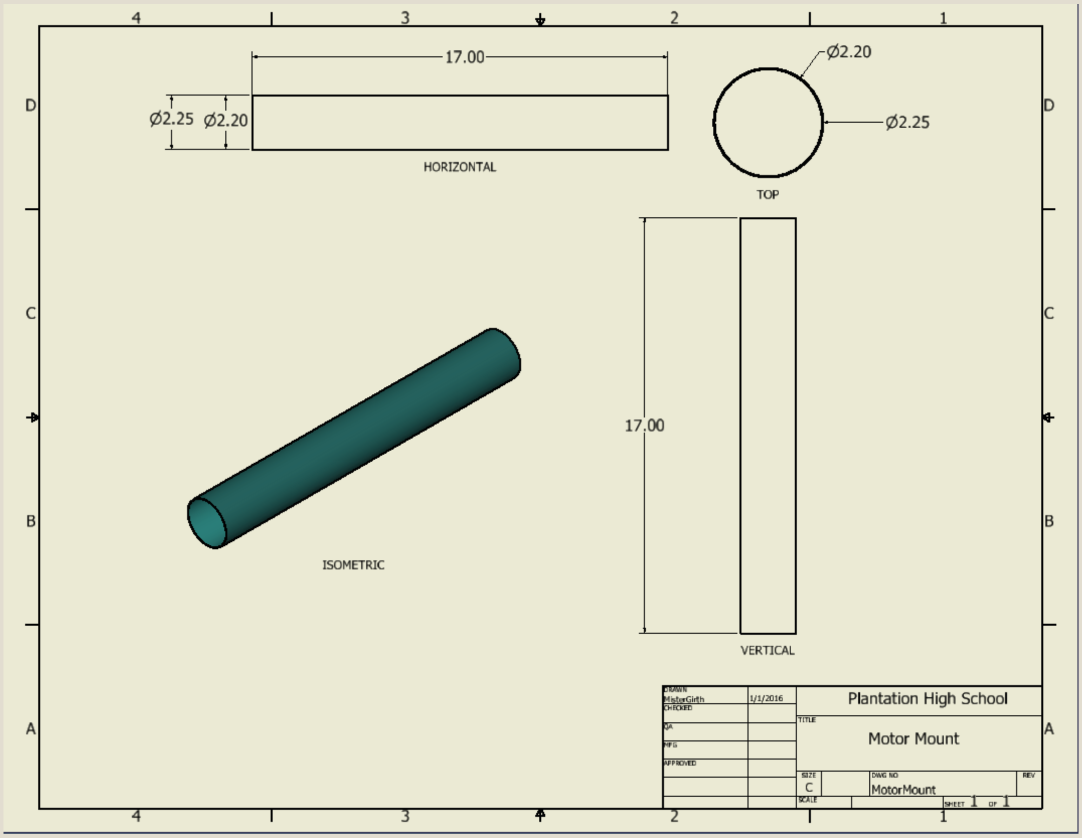
Centering Rings (2x)

- *G10 Fiberglass*
- *OD: 3.9 in.*
- *ID: 2.25 in.*
- *Thickness: 0.125 in.*
- *Bolster the motor mount within the airframe*



Motor Mount

- *Blue Tube*
- *Length: 17 in.*
- *OD: 2.25 in.*
- *ID: 2.2 in.*
- *Retains and secures the motor inside the lower airframe*



Tailcone

- *Polystyrene*
- *Ogive*
- *Length: 8 in.*
- *Front Diameter: 4 in.*
- *Rear Diameter: 2.2 in.*
- *Surrounds and protects the motor mount and motor while decreasing the drag of the launch vehicle*

Propulsion Subsystems: Motor

AeroTech K695

- *Reloadable*
- *Propellant Weight: 903 grams*
- *Average Thrust: 695 N*
- *Total Impulse: 1514 Ns*
- *Burn Time: 22 s*
- *Allows the launch vehicle to achieve a simulated apogee of 5245 ft.*

Motor Casing

- *Length: 16.8 in.*
- *Diameter: 2.1 in.*
- *Provides the frame for the motor.*
- *Tethered to the recovery harness in the lower airframe of the launch vehicle*

Retention Cap

- *Used to fasten the motor to its motor casing*

3.1.5 Approach to Workmanship

Requirement	***Feature to satisfy requirement***	***Approach to workmanship***	***Static or half scale tests of the feature to verify the quality of workmanship.***
The fins will not flutter during flight and will provide a stability margin adequate for flight.	*Fins will be epoxied through the wall of the lower body tube to the motor mount and will be cut from fiberglass, with a shape designed to provide a proper stability margin in flight.*	*Guides will mount the fins upright to avoid them setting crookedly. Adequate epoxy use will create a strong physical bond, preventing any fin flutter. Fins will be hand cut, then sanded to exact shape.*	*Fins will undergo a hand flex test to test it's physical bond to the rocket. Tracking of the stability of the rocket will help determine if the rocket fin design is stable and viable during the half scale flight.*
The body tubes will be robust enough to withstand the forces of high-powered flight and will be able to safely house the payload and other components.	*The body tubes will be cut from blue tube, a material found through experience to be sturdy enough for high-powered flight.*	*Body tubes will cut to shape using the hand saw. Rough edges will be sanded smooth and the ridged surface will be filled and sanded smooth.*	*Static pressure tests of the body tubes and use in the half scale flight will determine if the blue tube can handle high powered flight.*
The motor mount and centering rings that hold the motor mount will be strong enough to withstand the heat and force the motor	*The motor mount will be made of blue tube (refer to above section). The centering rings will be cut from fiberglass and epoxied*	*The centering rings will be cut using a drill press to maximize precision. The motor mount will be cut by hand saw. Rough edges of both components will be*	*The verification of the motor mounts ability to withstand the forces of the motor will only be able to be realistically tested in the half scale flight.*

will produce during flight.	*to the motor mount and lower body tube.*	*sanded smooth. All bonds of epoxy will use the proper amount of epoxy and have a strong physical bond.*	
The sleds of the altimeter bay and payload will be robust enough to withstand the forces of flight and protect the electrical components they hold.	*The sleds of the altimeter bay and payload will be made from PLA plastic.*	*The sleds will be 3-D printed to maximize precision in the creation of custom beds to house the electrical components of the altimeters and payload. The design will utilize a simple, structurally strong design to prevent shattering during flight.*	*Pressure tests of the sled designs on the ground will determine if the plastic is structurally sound enough to withstand the forces of flight.*
the tail cone will provide a amore streamline profile of the rocket and decrease drag during flight.	*The tail cone will be epoxied to the bottom of the lower body tubes, smoothing the normally sharp lower end of the rocket, reducing drag.*	*The tail cone will be epoxied and set onto the lower body tube and motor mount using a centering ring and epoxy. The epoxy will create a strong physical bond between the tail cone ad it's mount. The tail cone will be cut with the power saw from a fiberglass nose cone. the rough edges will be sanded smooth.*	*The information gathered in the simulations of the rocket will be tested in the half scale flight, to ensure the tail cone is reducing the drag of the rocket and helping it achieve target altitude.*
The nose cone will provide the proper stability to achieve the target altitude desired.	*The nose cone will match a simulated design that uses a nose cone shape and material that produces the proper drag needed to achieve target altitude.*	*The nose cone will be pre-manufactured plastic. The nose cone will be secured to the upper body tube through screws mounting through the upper body tube and shoulder of the nosecone. these holes will be drilled with the power drill.*	*Simulation data corroborated with half scale data will determine if the nose cone size and shape allows the rocket to reach target altitude.*
Recovery harness will be strong enough to withstand the forces of ejection and hold the three sections of the rocket together during descent.	*Recovery harness will be cut from 3/8 in tubular Kevlar; a material through experience to be more than strong enough to withstand the forces of ejection.*	*The Kevlar will be cut to length and attached to the separate sections of the rocket through D-links and eyebolts found on the motor case, bottom and top bulkheads of the altimeter bay, and bulkhead of the upper body tube.*	*Ground tests of ejection and information collected from the half scale flight, will determine if the Kevlar is strong enough to withstand ejection.*
The electrical systems of the altimeter bay and payload will function under the extreme conditions of high-powered flight.	*All components of the payload will be zip tied tightly to the their respective sleds. The altimeters used will be the Perfectflite sl100. the payload will utilize Arduino based electrical components. Both brands have been shown to withstand*	*All electrical components will be pre-manufactured, however any electrical connections made through soldering or breadboards, will be insulated to prevent shorting and will be tested for strong physical connection.*	*Use of elements of the electrical system of the rocket in the half scale will determine if the electrical components of the rocket can withstand and function in flight.*

	high-powered flight.		
The ejection charges, shear pins, and coupler will work together to allow for separation of the body sections at ejection, without causing damage to the recovery harness or the sections of the rocket.	*The shear pins will be of a size that will only break if a threshold of power from the ejection charges is reached. Once broken, the coupler will slide away from the body tubes and allow the recovery system to deploy.*	*The black powder ejection charges will be measured by the team mentor to a very specific size to ensure only the necessary amount of power is used for ejection. The holes for the shear pins will be drilled with a power drill. The coupler will be sanded smooth to prevent any snags upon ejection.*	*The team will conduct ground ejection tests to ensure the ejection system can function properly.*
All elements of the payload and rocket will come together to produce a flight that matches that of it's simulated flight. The target altitude will be reached and the descent rate and time will be as close to the simulation as possible.	*The rocket will be carefully massed and constructed. each component will be created to match as close as possible it's simulated counterpart.*	*All subsystems of the rocket will be meticulously constructed and put together. Where possible, machines will construct computer-generated designs of the rocket to maximize precision. Only the correct tools and materials will be used for each job.*	*Ground tests of the robustness of design of the rocket and cohesion of the rocket subsystems in conjunction with similar cohesion tests during the half scale flight, will ensure the rocket payload and design is viable for flight and can fly as simulated (reach target altitude, achieve target descent rate and time, etc.).*

3.1.6 Additional Component, Functional, & Static Testing

3.1.7 Status and Plans of Manufacturing & Assembly

Construction of the full-scale launch vehicle will take place subsequent to the CDR Teleconference. The following assembly process, as perfected by the subscale construction, will be used:

Body Tube Construction

1. *Mark BlueTube with measurements.*
2. *Cut lower body tube and upper body tube to length.*
3. *Fill BlueTube rivets with Rocketpoxy for the upper and lower body.*
4. *Rough sand body tubes.*
5. *Mark fin slots.*
6. *Dremel fin slots in lower body tube.*
7. *Re-cut fin slots with Dremel tool.*
8. *Epoxy bulkheads to rocket.*
9. *Drill holes for rail buttons.*
10. *Insert rail buttons.*
11. *Prime rocket.*
12. *Paint rocket.*

Coupler Construction

1. *Mark coupler and coupler band on BlueTube.*
2. *Cut coupler and coupler band to length.*
3. *Fill rivets in coupler band with Rocketpoxy*
4. *Sand down coupler band.*
5. *Epoxy coupler band to coupler tube.*
6. *Stencil bulkheads.*
7. *Cut bulkheads.*
8. *Epoxy bulkheads together.*
9. *Drill holes in bulkhead for wing nuts, wiring, terminals and eyebolts.*
10. *Attach eyebolts with washers to bulkheads.*
11. *Attach washers, threaded rods and nuts to bulkheads.*
12. *Screw in terminals to bulkheads with wiring.*
13. *Epoxy wiring from altimeter bay to bulkheads.*
14. *Insert altimeter bay*

Fin Construction

1. *Mark fin slots.*
2. *Stencil fins.*
3. *Cut fins with band saw.*
4. *Rough sand fins.*
5. *Epoxy fins to lower body tube and tailcone.*
6. *Epoxy fins to motor mount.*

Tailcone Construction

1. *Mark tailcone (polystyrene nose cone).*
2. *Cut tailcone to length.*
3. *Dry fit tailcone to lower body tube.*
4. *Dremel fin slots in tailcone with lower body tube.*
5. *Epoxy Tailcone to lower body tube.*
6. *Compress tailcone to lower body tube using rubber bands.*

Motor Mount Construction

1. *Mark BlueTube.*
2. *Cut motor mount to length.*
3. *Stencil centering rings.*
4. *Cut centering rings.*
5. *Epoxy centering rings to motor mount.*
6. *Drill hole for eyebolt in centering rings and attach eyebolt.*
7. *Attach D-links to eyebolt.*
8. *Epoxy motor mount to end of lower body tube and tailcone.*
9. *Re-cut fin slots with Dremel tool.*
10. *Sand fin slots inside and out.*

Recovery System

1. *Cut chute harness (Kevlar) to length*
2. *Tie chute harness to D-link of motor mount.*
3. *Pull chute harness through bulkhead of lower airframe.*
4. *Attach drogue and main parachute to chute harness.*

Altimeter Bay Construction

1. *Laser cut altimeter bay on basswood*
2. *Assemble parts to make altimeter bay*
3. *Insert threaded rods through the mounting holes*
4. *Add electrical components to the altimeter day and secure with zip-ties*
5. *Wire electronics*

Construct payload mass dummy

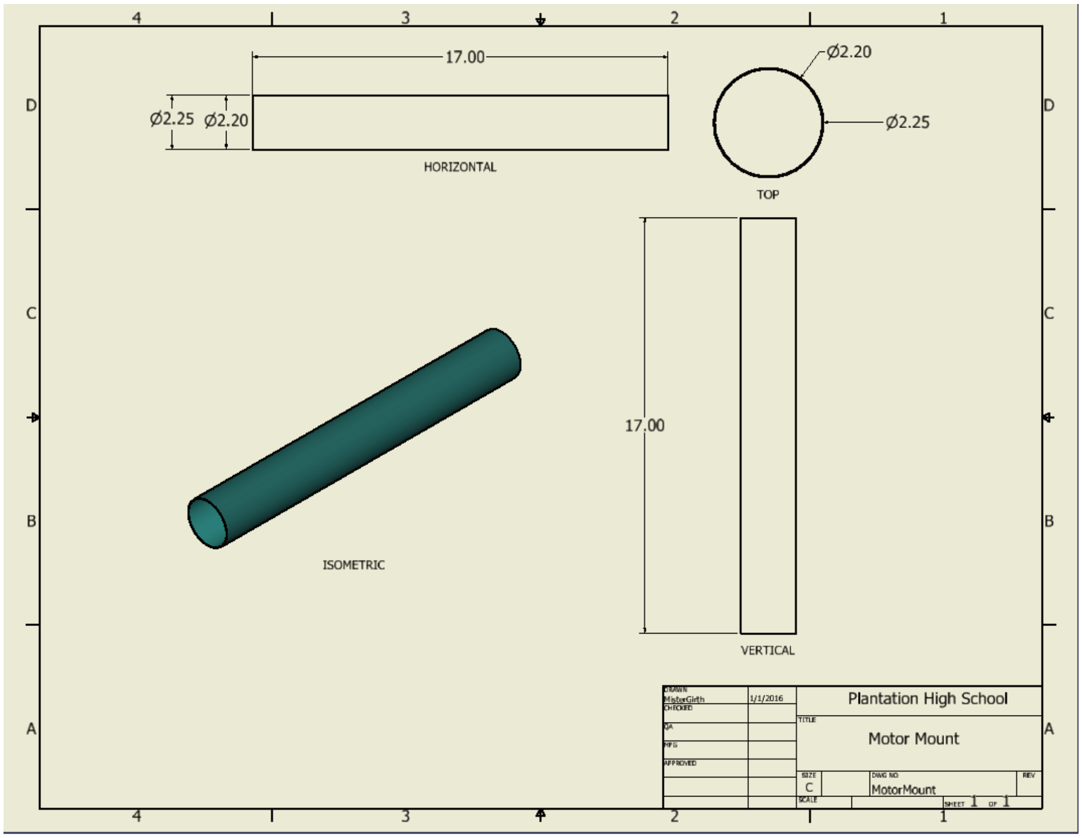
1. *Determine full-scale payload mass.*
2. *Scale full-scale mass down correct amount.*
3. *Find a piece of dummy material which is equal or greater in mass to desired amount*
4. *If the mass of the dummy is greater, calculate the density of the material and then derive the desired volume to subtract from the material.*
5. *Calculate the approximate weight and volume relative to the material of each component's scaled mass.*
6. *Mark off each component.*
7. *Cut components out of material.*
8. *Assemble dummy components in correct configuration and bind together with epoxy.*

3.1.8 Integrity of Design

Motor Mounting and Retention

Motor Mount

- *Blue Tube*
- *Length: 17 in.*
- *OD: 2.25 in.*
- *ID: 2.2 in.*
- *Retains and secures the motor inside the lower airframe*



AeroTech K695

- *Reloadable*
- *Propellant Weight: 903 grams*
- *Average Thrust: 695 N*
- *Total Impulse: 1514 Ns*
- *Burn Time: 22 s*
- *Allows the launch vehicle to achieve a simulated apogee of 5245 ft.*

Motor Casing

- *Length: 16.8 in.*
- *Diameter: 2.1 in.*
- *Provides the frame for the motor.*
- *Tethered to the recovery harness in the lower airframe of the launch vehicle*

Retention Cap

- *Used to fasten the motor to its motor casing*

Mass Statement

Total Launch Vehicle Mass:

- Without motor: 5361.7g/5.3kg
- With motor: 6867.7g/6.8kg

Structural System

Total Mass: 2706.6g/2.7 kg

Airframe

Component	*Mass (grams)*	*Basis*
Nosecone	*761.6*	*RockSim Analysis*
Nosecone Mass Object	*500 .0*	*RockSim Analysis*
Upper Airframe	*406.7*	*RockSim Analysis*
Lower Airframe	*330.4*	*RockSim Analysis*
Bulkhead (2x)	*46.0*	*RockSim Analysis*
Coupler	*142.0*	*RockSim Analysis*
Tailcone	*272.0*	*RockSim Analysis*

TOTAL:	2458.7	

Guidance

Component	Mass (grams)	Basis
Fin	81.3	RockSim Analysis
Launch Buttons (2x)	2.0	Measured within facility.
TOTAL:	247.9	

Recovery System

Total Mass: 1544.2/1.5 kg

Altimeter Bay

Component	Mass (grams)	Basis
Altimeter Sled	50.4	RockSim Analysis
Altimeter (2x)	20.0	RockSim Analysis
9v Batteries (2x)	60.0	RockSim Analysis
1/4 in. Threaded Rod (2x)	70.0	RockSim Analysis
¼ in. Lock Nuts and Washers (20x)	0.25	RockSim Analysis
Bulkhead (2x)	46.6	RockSim Analysis
TOTAL:	**448.2**	

Black Powder

Component	Mass (grams)	Basis
Black Powder Charge (Main; 2x)	2.5	Calculated using online black powder calculator
Black Powder Charge (Drogue; 2x)	2.0	Calculated using online black powder calculator
E-Match (4x)	1.5	Measured within facility
TOTAL:	**13.0**	

Chutes/Harnesses

Component	Mass (grams)	Basis
Main Chute	396.9	Giant Leap Online Store
Drogue Chute	153.1	Giant Leap Online Store
Recovery Harness (Upper)	134.0	Measured within facility
Recovery Harness (Lower)	134.0	Measured within facility
Eyebolt (3x)	35.0	Measured within facility
D-Link (4x)	40.0	Measured within facility
TOTAL:	**1083.0**	

Propulsion System

Total Mass: 2035g/2.0kg

Frame

Component	*Mass (grams)*	*Basis*
Centering Ring (2x)	*46.6*	*Simulated in RockSim*
Motor Mount	*146.2*	*Simulated in RockSim*
Tailcone	*272.1*	*Simulated in RockSim*
TOTAL:	***511.5***	

Motor

Component	*Mass (grams)*	*Basis*
Aerotech K695R	*903.0*	*Simulated in RockSim*
Motor Casing	*603.0*	*Simulated in RockSim*
Retention Cap	*17.5*	*Measured within facility*
TOTAL:	***1523.5***	

Basis of Mass Estimate

The values provided in the mass statement come from measurements conducted within the classroom and through RockSim software. Justification for determining component and vehicle mass from RockSim is based on the lack of planned construction materials within the facility.

Mass Margin

- *Current thrust-to-weight ratio: 13:1*
- *Mass margin before thrust-to-weight ratio is unacceptable (lower than 5:1): 18 kg*

3.1.9 Safety & Failure Analysis

The team safety officer will analyze the safety concerns to personnel during the project and potential failure modes of the project. Once assessed, the realistic hazards and failures will be organized into specific matrices to inform the team with. Once the team is aware of these hazards and failures, measures mapped out by the team safety officer to mitigate these hazards and failures will be executed by the team and verified by the team project manager.

3.2 Subscale Flight Results

3.2.1 Flight Data

Plantation High School SLI Team 1 Subscale Launch

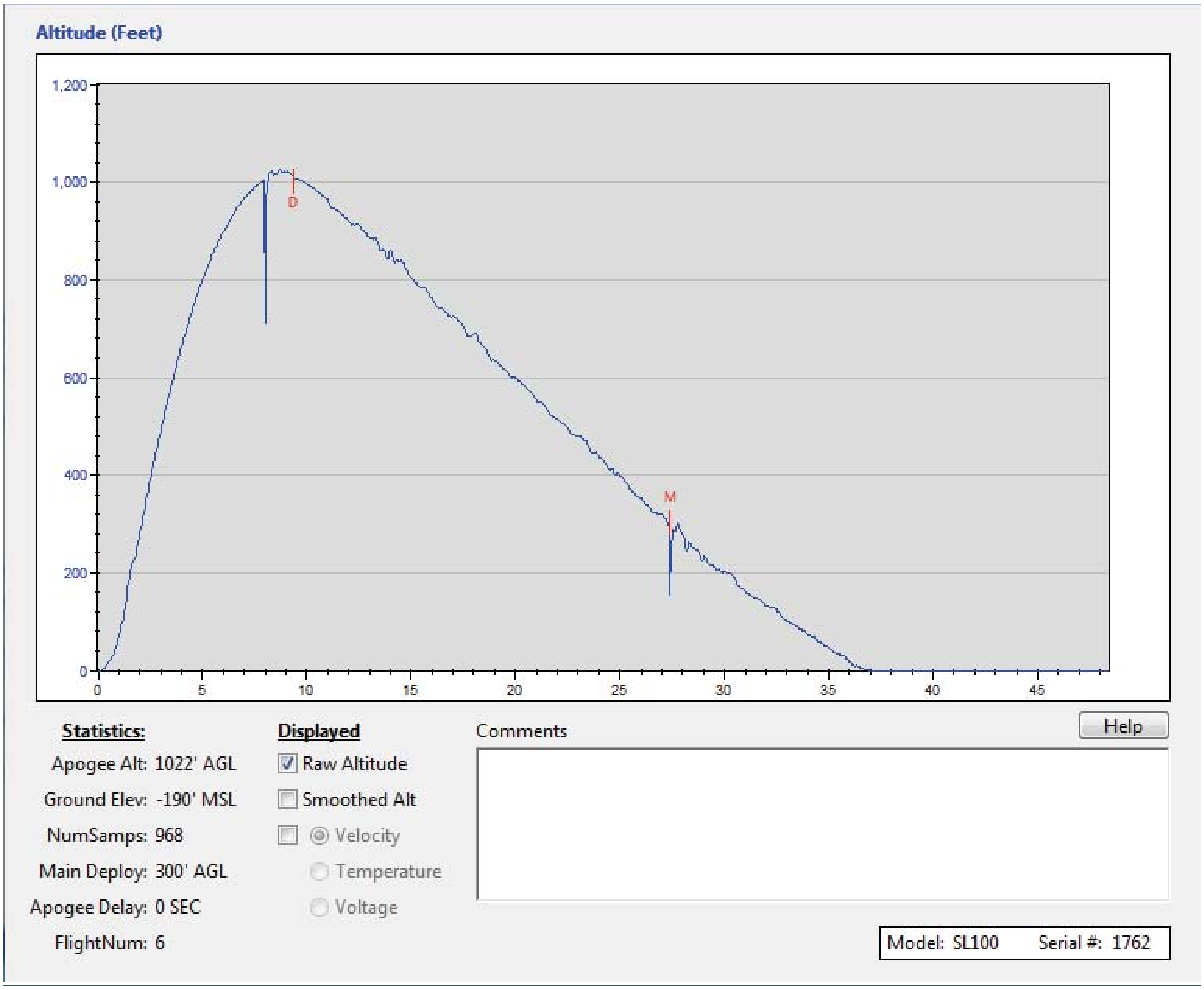
January 2, 2016; 11:00 AM

Vista View Park; Davie, Florida

- Upon exit from the launch rail, the subscale launch vehicle weather-cocked for approximately 2 seconds before it achieved and maintained a straight and stable flight. It achieved an apogee of 1022 ft. before safely descending into a collection of short trees. After retrieving the launch vehicle, the team brought it back to the launch vehicle preparation area for assessment. The team concluded that no critical or impairing damage was done to the launch vehicle, and the launch was considered a success.

Data	Flight Model*	Actual Flight Data
Apogee (ft.)	1221	1022
Time to landing (s.)	44	37

*Simulated using RockSim



Statistics:

Apogee Alt: 1022' AGL

Ground Elev: -190' MSL

NumSamps: 968

Main Deploy: 300' AGL

Apogee Delay: 0 SEC

FlightNum: 6

Displayed

☑ Raw Altitude

☐ Smoothed Alt

☐ ● Velocity

○ Temperature

○ Voltage

Comments

Model: SL100 Serial #: 1762

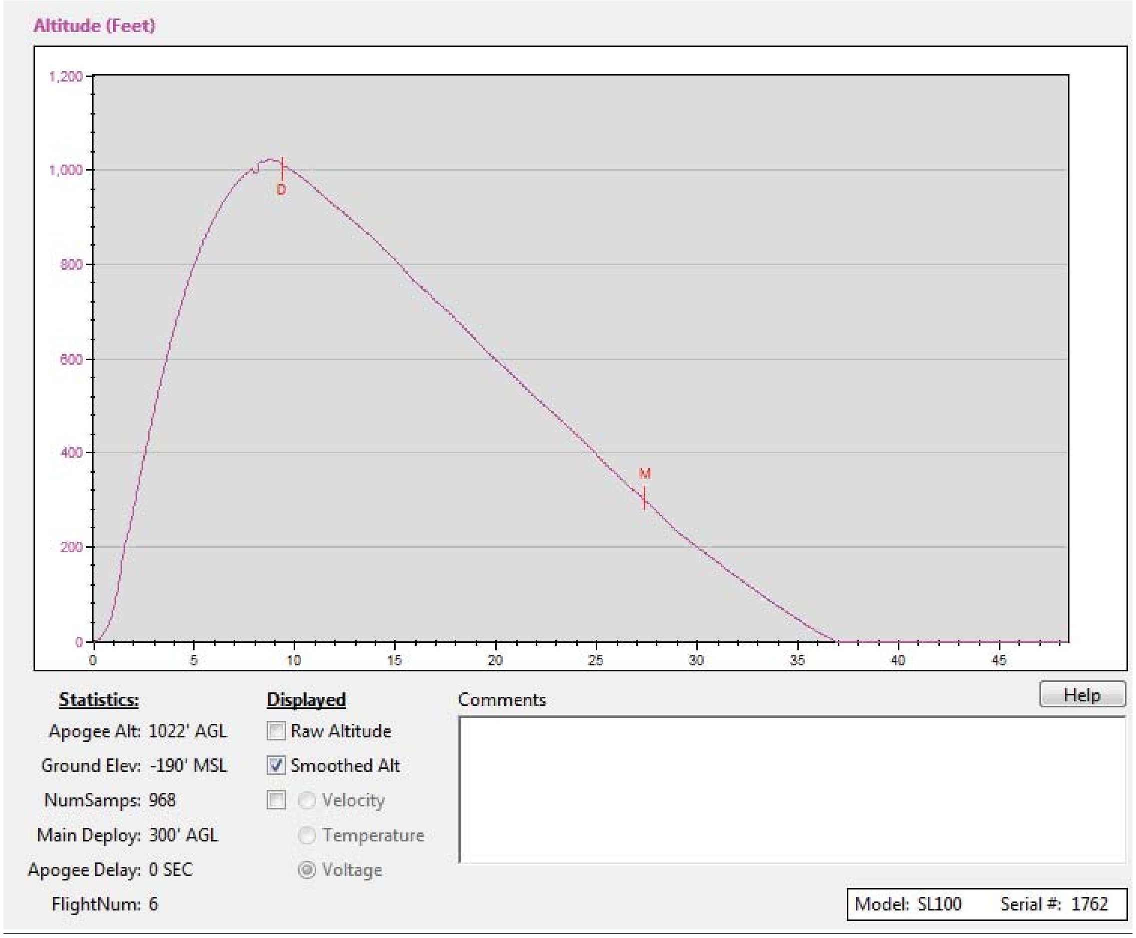
Figure 5 Raw Altitude Graph (subscale)

- Retrieved from the Perfectflite SL100 Altimeter using the Perfectflite DataCap program provided on the Perfectflite website.

- Data depicts the altitude of the subscale launch vehicle throughout its entire flight. The points on the graph marked 'D' and 'M' delineate the times at which the drogue and main chute ejection charges were fired.

- The downward spikes in altitude visible on the graph at approximately 9 seconds and 27 seconds were generated as a result of the activation of black powder ejection charges within the subscale launch vehicle. Since the blast from the ejection charges increases air pressure, the Perfectflite SL100 Altimeter momentarily read an altitude that was smaller than the actual altitude of the launch vehicle.

- Deployment of the drogue chute did not occur when the drogue black powder ejection charge was fired. The drogue chute was deployed by the ejection charge within the AeroTech G80 motor 7 seconds after the motor's ignition.



Statistics:

Apogee Alt: 1022' AGL

Ground Elev: -190' MSL

NumSamps: 968

Main Deploy: 300' AGL

Apogee Delay: 0 SEC

FlightNum: 6

Displayed

☐ Raw Altitude

☑ Smoothed Alt

☐ ○ Velocity

○ Temperature

● Voltage

Comments

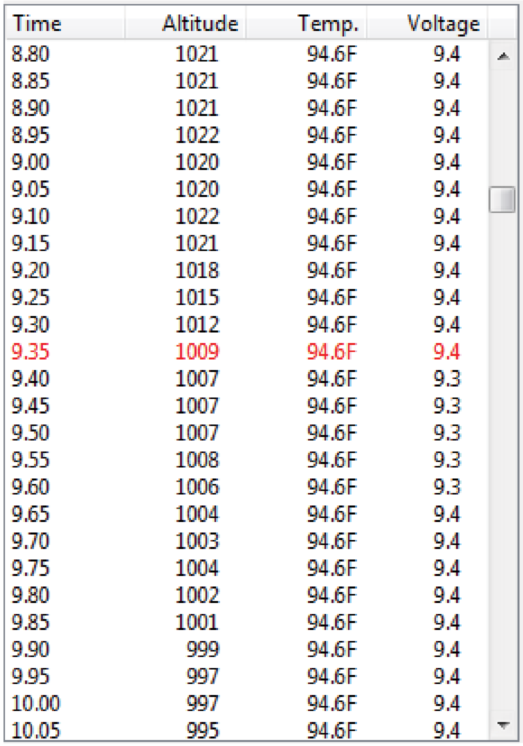
Model: SL100 Serial #: 1762

Figure 6 Smooth Altitude Graph (Subscale)

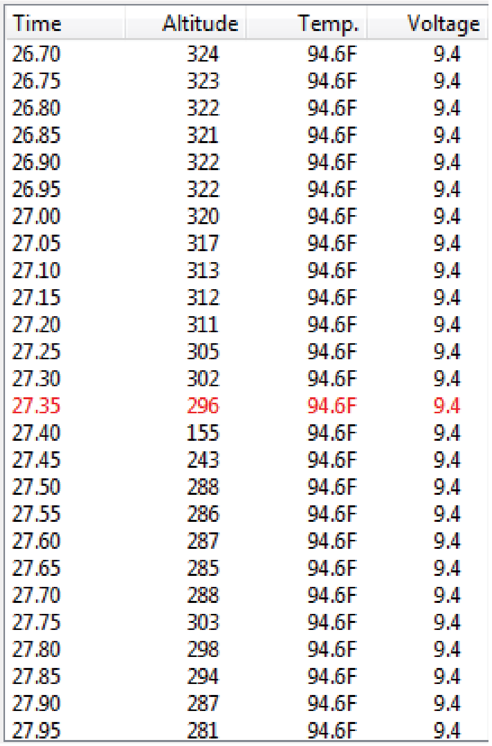
- This graph depicts the best-fit curve for the altitude data provided by the Perfectflite SL100 Altimeter.

- It does not depict the spikes in altitude due to ejection charges.

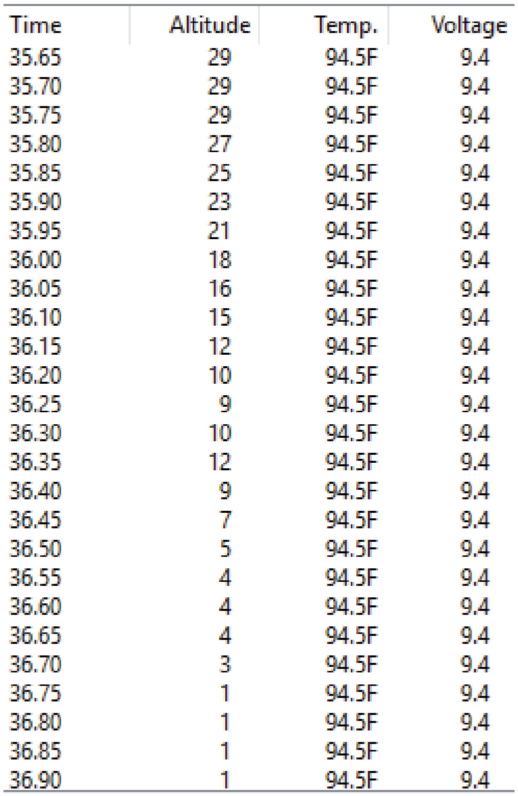
Raw Altimeter Data



Time	Altitude	Temp.	Voltage
8.80	1021	94.6F	9.4
8.85	1021	94.6F	9.4
8.90	1021	94.6F	9.4
8.95	1022	94.6F	9.4
9.00	1020	94.6F	9.4
9.05	1020	94.6F	9.4
9.10	1022	94.6F	9.4
9.15	1021	94.6F	9.4
9.20	1018	94.6F	9.4
9.25	1015	94.6F	9.4
9.30	1012	94.6F	9.4
9.35	1009	94.6F	9.4
9.40	1007	94.6F	9.3
9.45	1007	94.6F	9.3
9.50	1007	94.6F	9.3
9.55	1008	94.6F	9.3
9.60	1006	94.6F	9.3
9.65	1004	94.6F	9.4
9.70	1003	94.6F	9.4
9.75	1004	94.6F	9.4
9.80	1002	94.6F	9.4
9.85	1001	94.6F	9.4
9.90	999	94.6F	9.4
9.95	997	94.6F	9.4
10.00	997	94.6F	9.4
10.05	995	94.6F	9.4



Time	Altitude	Temp.	Voltage
26.70	324	94.6F	9.4
26.75	323	94.6F	9.4
26.80	322	94.6F	9.4
26.85	321	94.6F	9.4
26.90	322	94.6F	9.4
26.95	322	94.6F	9.4
27.00	320	94.6F	9.4
27.05	317	94.6F	9.4
27.10	313	94.6F	9.4
27.15	312	94.6F	9.4
27.20	311	94.6F	9.4
27.25	305	94.6F	9.4
27.30	302	94.6F	9.4
27.35	296	94.6F	9.4
27.40	155	94.6F	9.4
27.45	243	94.6F	9.4
27.50	288	94.6F	9.4
27.55	286	94.6F	9.4
27.60	287	94.6F	9.4
27.65	285	94.6F	9.4
27.70	288	94.6F	9.4
27.75	303	94.6F	9.4
27.80	298	94.6F	9.4
27.85	294	94.6F	9.4
27.90	287	94.6F	9.4
27.95	281	94.6F	9.4



Time	Altitude	Temp.	Voltage
35.65	29	94.5F	9.4
35.70	29	94.5F	9.4
35.75	29	94.5F	9.4
35.80	27	94.5F	9.4
35.85	25	94.5F	9.4
35.90	23	94.5F	9.4
35.95	21	94.5F	9.4
36.00	18	94.5F	9.4
36.05	16	94.5F	9.4
36.10	15	94.5F	9.4
36.15	12	94.5F	9.4
36.20	10	94.5F	9.4
36.25	9	94.5F	9.4
36.30	10	94.5F	9.4
36.35	12	94.5F	9.4
36.40	9	94.5F	9.4
36.45	7	94.5F	9.4
36.50	5	94.5F	9.4
36.55	4	94.5F	9.4
36.60	4	94.5F	9.4
36.65	4	94.5F	9.4
36.70	3	94.5F	9.4
36.75	1	94.5F	9.4
36.80	1	94.5F	9.4
36.85	1	94.5F	9.4
36.90	1	94.5F	9.4

- Apogee: 1022 ft.
- Drogue Ejection: 1009 ft.; 9.35 seconds
- Main Ejection: 296 ft.; 27.35 seconds
- Landing: 36.9 seconds
- Total Flight Time: approx. 37 seconds

3.2.2 Predicted Flight Model to Actual Flight Data Comparison

Based on simulations conducted through RockSim, the subscale launch vehicle was expected to achieve an apogee of approximately 1221 ft. and land after 44 seconds of flight time. Flight data retrieved from the on-board Perfectflite SL100 Altimeter instead measured the actual apogee to be 1022 ft. and determined that landing (impact AGL) occurred after approximately 37 seconds of flight time.

After comparing the simulated data to the data retrieved from the altimeter, the team concluded that the discrepancy between the simulated apogee and actual apogee occurred due to weather-cocking of the launch vehicle upon exit from the launch rail.

Weather Data

- *Temperature: 73°F*
- *Barometric Pressure: 30 In. Hg*
- *Wind Margin: 5-10 MPH*

Altitude: Percentage of Error

- *Percentage of Error = (Simulated Apogee – Actual Apogee) / Simulated Apogee*
- *= (1221 – 1021) / 1221*
- *= (199) / 1221*
- *= 16%*

3.2.3 Impact of Subscale Flight Data on Full-Scale Design

Due to the close accuracy of the subscale simulation to the data retrieved from the subscale launch and the fact that the discrepancy in apogee measurements retrieved from simulation and the Perfectflite SL100 Altimeter was caused by aggressive winds, the implications of the subscale launch, and the data retrieved from it, on the full-scale design are small. Analysis of the full-scale launch vehicle after data from the subscale launch was retrieved demonstrated that the static stability margin of the launch vehicle was not a minimum of 2 cal. A mass object of approximately 500 grams will be added in the nosecone to mitigate this issue.

3.3 Recovery Subsystem

3.3.1 Description of Parachute, Harnesses, Bulkheads, & Attachment Hardware

Recovery Subsystems: Altimeter Bay

Altimeter Sled

- *3D Printed/ABS plastic*
    - *Provides an attachment surface for the altimeters and 9v batteries*

Altimeters (2x)

- *Perfectflite Stratologger 100*
- *Tethered to the altimeter sled*
- *Measures the altitude of the launch vehicle at any given time;*
- *Sends an impulse to black powder ejection charges at apogee and at 500 ft. AGL to deploy drogue and main chutes*
- *Sends an impulse to black powder ejection charges after each initial blast at apogee and at 500 ft. AGL in order to guarantee the deployment of the drogue and main chutes*

9v Batters (2x)

- *Powers both altimeters*

Bulkheads (2x)

- *G10 Fiberglass*
- *Diameter: 3.9 in.*
- *Thickness: 0.125 in.*
- *Separates the altimeter bay from the upper and lower airframes.*

Threaded Rods/Nuts + Washers

- *¼ in.*
- *Length: 11 in.*
- *Steel*
- *Fastened to each bulkhead of the altimeter bay*
- *Supports the altimeter sled and secures it in place*

Recovery Subsystems: Black Powder Ejection

Black Powder Charges (4x)
- *Main (2x):*
    - *2.5g*
- *Drogue (2x):*
    - *2g*
- *Used to deploy both drogue and main chutes at apogee and 500 ft. AGL respectively*
- *Fired from e-matches*

E-Matches (4x)
- *Used to fire ejection charges to deploy drogue and main chutes at apogee and 500 ft. AGL respectively*

Recovery Subsystems: Chutes/Harnesses/Eyebolts

Drogue Chute

- *Giant Leap TAC-24*
- *Diameter: 24 in.*
- *Shroud Lines (x6):*
- *Location: Lower Airframe*
- *Deployment: Apogee*
- *Deployed to slow the launch vehicle before the main chute deploys at 500 ft. AGL*

Main Chute

- *Giant Leap TAC-60*
- *Diameter: 60 in.*
- *Shroud Lines (x6):*
- *Location: Upper Airframe*
- *Deployment: 500 ft. AGL during descent*
- *Deployed to slow the launch vehicle to an optimal descent velocity before landing*

Recovery Harness (Upper + Lower)

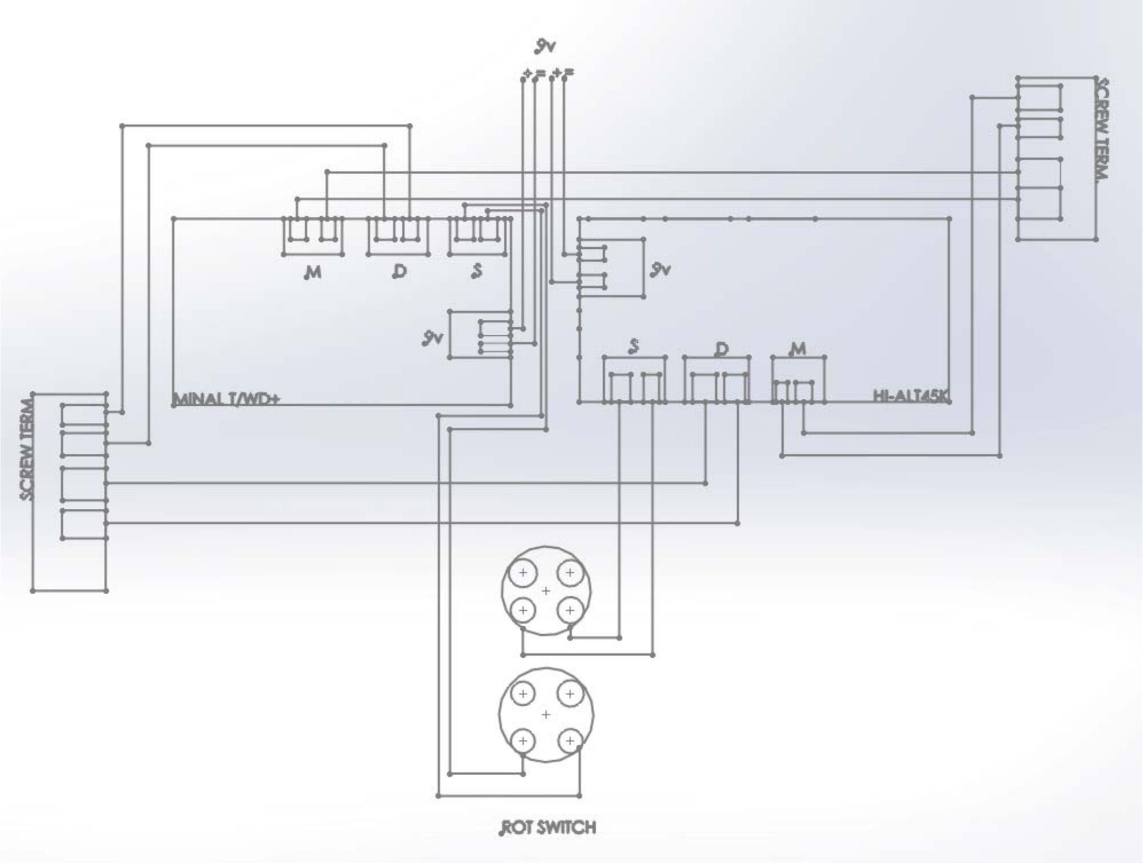
- *Tubular Kevlar*
- *Length: 30 ft.*
- *Thickness: 3/8 in.*
- *Main*
    - *Tethered to a bulkhead in the upper airframe and a bulkhead on one end of the coupler*
- *Drogue*
    - *Tethered to a bulkhead in the lower airframe and a bulkhead on one end of the coupler*
- *Used to connect the upper and lower airframes with the coupler*
- *Serves as harnesses for the drogue and main chutes*

Eyebolts and D-Links (4x)

- *Zinc-coated steel*
- *¼ in. Eyebolts*
- *¼ in. D-Links*
- *Three eyebolts are mounted on a bulkhead and one to the motor mount*
    - *Each eyebolt is accompanied by a d-link*
- *Serves to tether the recovery harnesses to the airframes*

3.3.2 Electrical Components & Recovery

Recovery Schematics (Altimeter Bay)



Within the altimeter bay are two Perfectflite SL100 altimeters. Both altimeters fire ejection charges; one altimeter fires a second charge after the other altimeter fires the first charge in order to guarantee the deployment of the drogue and main chutes. Both altimeters fire at apogee and 500 ft. AGL.

Procedure:

1. Both rotary switches are set to ON, and allow an electric current from the batteries to pass through and power the altimeter bay subsystem.

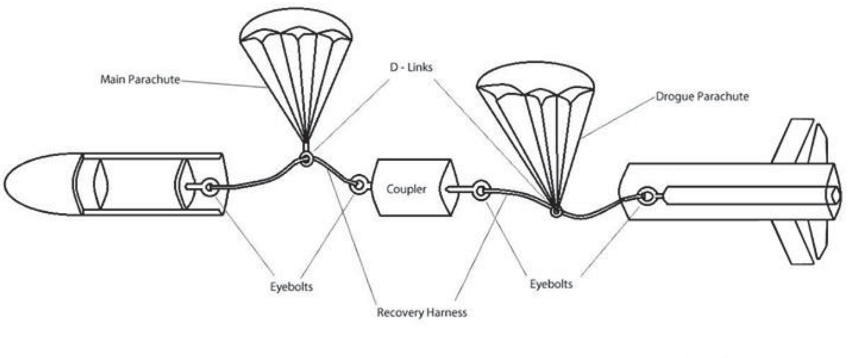
2. When the launch vehicle starts increasing its altitude, the altimeters begin reading and storing altitude information.

3. Once the altimeters recognize that the launch vehicle is descending and their recorded altitudes are decreasing, they send impulses to two e-matches, setting off the black powder ejection charges. One ejection charge fires a second after the other fires.

4. As the altimeters pass 500 ft. AGL during descent, they send impulses to two e-matches, setting off the black powder ejection charges. One ejection charge fires a second after the other fires.

5. Once the launch vehicle has been safely recovered, the rotary switches are set to OFF.

Recovery Schematics (Kinetic; Chutes/Harness/Hardware)



Launch vehicle not to scale

Figure 7 Recovery Schematics*

Both main and drogue chutes are tethered to recovery harnesses of equal length and thickness. The main chute and its recovery harness are attached to a bulkhead in the upper airframe, while the drogue chute and its recovery harness are attached to a bulkhead in the lower airframe.

***: Missing from the recovery schematics are d-links. D-links attach to the eyebolts and provide a medium for which the recovery harnesses may be attached to.**

3.3.3 Drawings & Diagrams

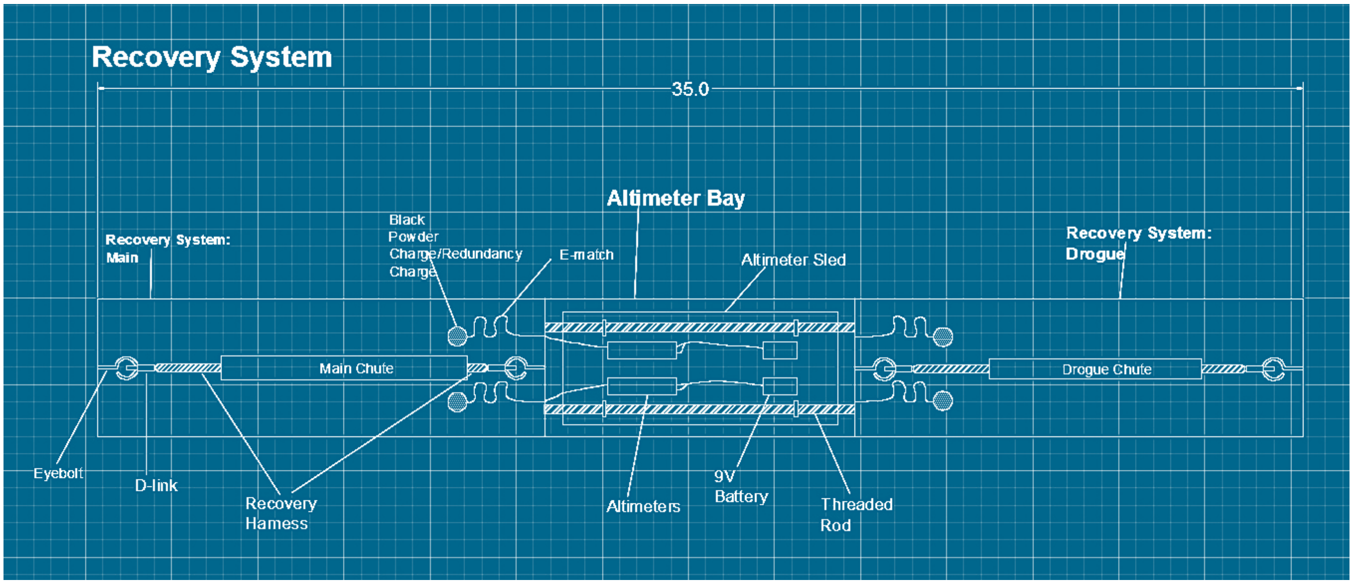


Figure 8 Recovery System 2D Schematic (Static)

3.3.4 Kinetic Energy at Significant Phases

Table 1 At main ejection

Section	Kinetic Energy (ft-lbs)	Mass (lbs.)	Velocity at Deployment (ft/s)
Upper Airframe + Nosecone	661	5.9	-85
Coupler	168	1.5	-85
Lower Airframe	336	3	-85

Table 2 Landing

Section	Kinetic Energy (ft-lbs)	Mass (lbs.)	Velocity at Deployment (ft/s)
Upper Airframe + Nosecone	57	5.6	-25
Coupler	14	1.5	-25
Lower Airframe	29	3	-25

3.3.5 Test Results

- Recovery subsystem performed as designed. The drogue parachute deployed upon reaching apogee via the altitude-controlled ejection charges. Upon reaching an altitude of 300 feet, the second set of ejection charges fired accordingly to deploy the main parachute.

- Ground ejection charge tests do not occur until after construction of the full-scale launch vehicle has been completed.
- Static tests of the recovery components will be conducted following the construction of the full-scale launch vehicle.

3.3.6 Safety & Failure Analysis

Despite having a nearly ideal recovery, one failure that the vehicle incurred was its location upon landing. (The vehicle landed in a tree above a swampy bog) Since the vehicle experienced moderate weather-cocking, the vehicle's drift distance was further than expected. The team has recognized that the failure is not one of the recovery subsystem but of the vehicle's design. The vehicle's recovery subsystem design was robust enough to keep the vehicle intact, despite having landed in a tree. Finally, the main parachute seemed to be slightly burned by the engine's exhaust. To mitigate the problem, the team will use fire protectant blankets instead of fire resistant wadding to wrap the parachutes in during the full-scale test launch.

3.4 Mission Performance Predictions

3.4.1 Mission Performance Criteria

Below are all the mission performance criteria of the launch vehicle:

- *The launch vehicle can achieve its target apogee of 6005 ft. with a stable flight path.*
- *The launch vehicle can achieve its target apogee of 6005 ft. and its payload may successfully operate.*
    - *The payload is capable of recording and transmitting as many telemetric data samples per second as it can.*
- *The AeroTech K695R motor allows the launch vehicle to achieve its target apogee of 5245 ft. and provide the launch vehicle with an average upward thrust of 156 lbs. and total impulse of 340.4 lbf-s.*
- *The recovery system of the launch vehicle performs as intended:*
    - *Drogue chute deployment at apogee of 5245 ft.*
    - *Main chute deployment at 500 ft. AGL during descent*

The launch vehicle is capable of landing with both drogue and main chutes deployed, and all sections land with a kinetic energy of less than 75 ft-lbs individually.

3.4.2 Flight Profile Simulations

	Data value	Units
Time	0.4725	
Thrust	888.987	N
x-Thrust	-4.39159	N
y-Thrust	888.978	N
Acceleration	433.192	Feet/sec/sec
x-Acceleration	-2.15	Feet/sec/sec
y-Acceleration	433.187	Feet/sec/sec
Acceleration Total	401.039	Feet/sec/sec
x-Acceleration Total	-2.15	Feet/sec/sec
y-Acceleration Total	401.033	Feet/sec/sec
Velocity	154.426	Feet / Sec
x-Velocity	-0.065	Feet / Sec
y-Velocity	154.426	Feet / Sec
Mach number	0.138051	
Altitude	32.375	Feet
Range	0.011	Feet
Cd	0.428461	

Figure 9 At launch stand

	Data value	Units
Time	25.9875	
Thrust	0	N
x-Thrust	0	N
y-Thrust	0	N
Acceleration	32.033	Feet/sec/sec
x-Acceleration	0	Feet/sec/sec
y-Acceleration	32.033	Feet/sec/sec
Acceleration Total	0.221	Feet/sec/sec
x-Acceleration Total	0.193	Feet/sec/sec
y-Acceleration Total	-0.107	Feet/sec/sec
Velocity	86.877	Feet / Sec
x-Velocity	27.991	Feet / Sec
y-Velocity	-82.244	Feet / Sec
Mach number	0.0788922	
Altitude	4660.54	Feet
Range	-370.025	Feet
Cd	0.75	

Figure 10 After drogue chute ejection

	Data value	Units
Time	91.7662	
Thrust	0	N
x-Thrust	0	N
y-Thrust	0	N
Acceleration	29.698	Feet/sec/sec
x-Acceleration	0	Feet/sec/sec
y-Acceleration	29.698	Feet/sec/sec
Acceleration Total	2.463	Feet/sec/sec
x-Acceleration Total	0.193	Feet/sec/sec
y-Acceleration Total	-2.455	Feet/sec/sec
Velocity	42.387	Feet / Sec
x-Velocity	34.027	Feet / Sec
y-Velocity	-25.275	Feet / Sec
Mach number	0.0379225	
Altitude	269.043	Feet
Range	1880.59	Feet
Cd	0.75	

Figure 11 After main chute ejection

	Data value	Units
Time	99.8662	
Thrust	0	N
x-Thrust	0	N
y-Thrust	0	N
Acceleration	31.749	Feet/sec/sec
x-Acceleration	0	Feet/sec/sec
y-Acceleration	31.749	Feet/sec/sec
Acceleration Total	0.449	Feet/sec/sec
x-Acceleration Total	0.193	Feet/sec/sec
y-Acceleration Total	-0.405	Feet/sec/sec
Velocity	34.967	Feet / Sec
x-Velocity	0	Feet / Sec
y-Velocity	-34.967	Feet / Sec
Mach number	0.0312572	
Altitude	12.559	Feet
Range	2141.41	Feet
Cd	0.75	

Figure 12 At landing

3.4.3 Altitude Predictions

Max data values:

- Maximum acceleration:Vertical (y): 407.735 Ft./s/sHorizontal (x): 3.593 Ft./s/sMagnitude: 407.735 Ft./s/s
- Maximum velocity:Vertical (y): 661.5528 ft/s, Horizontal (x): 36.6667 ft/s, Magnitude: 664.3035 ft/s
- Maximum range from launch site: 1757.87859 Ft.
- Maximum altitude: 5245.65310 Ft.

3.4.4 Weights

Refer to mass statement section of vehicle design criteria.

3.4.5 Motor Thrust Curve

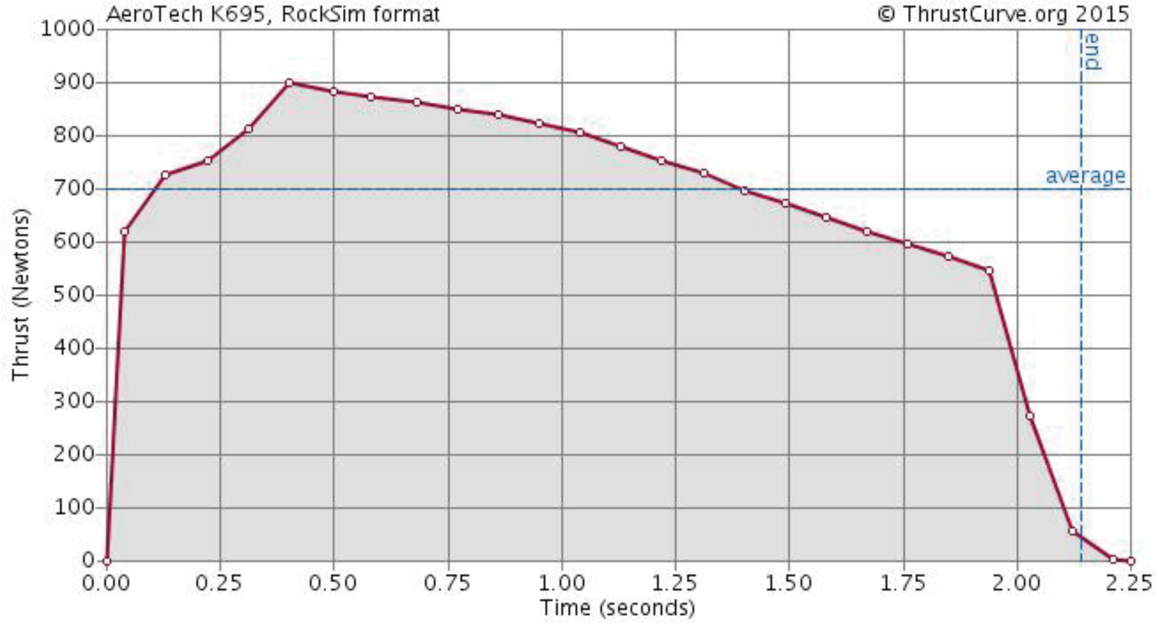
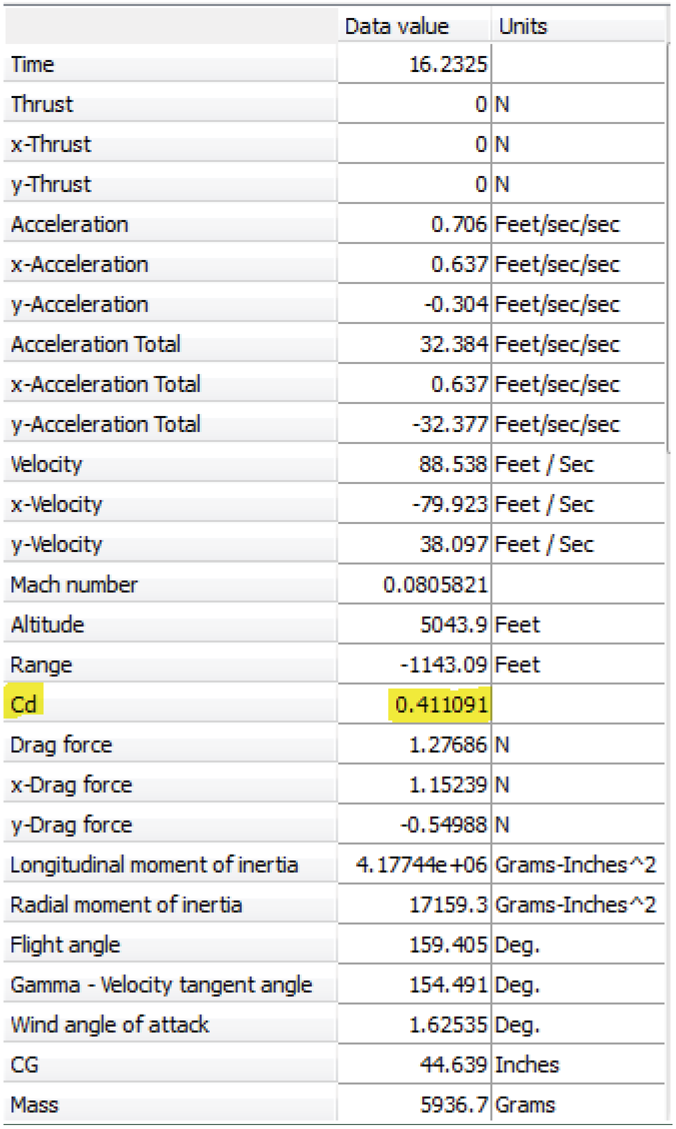


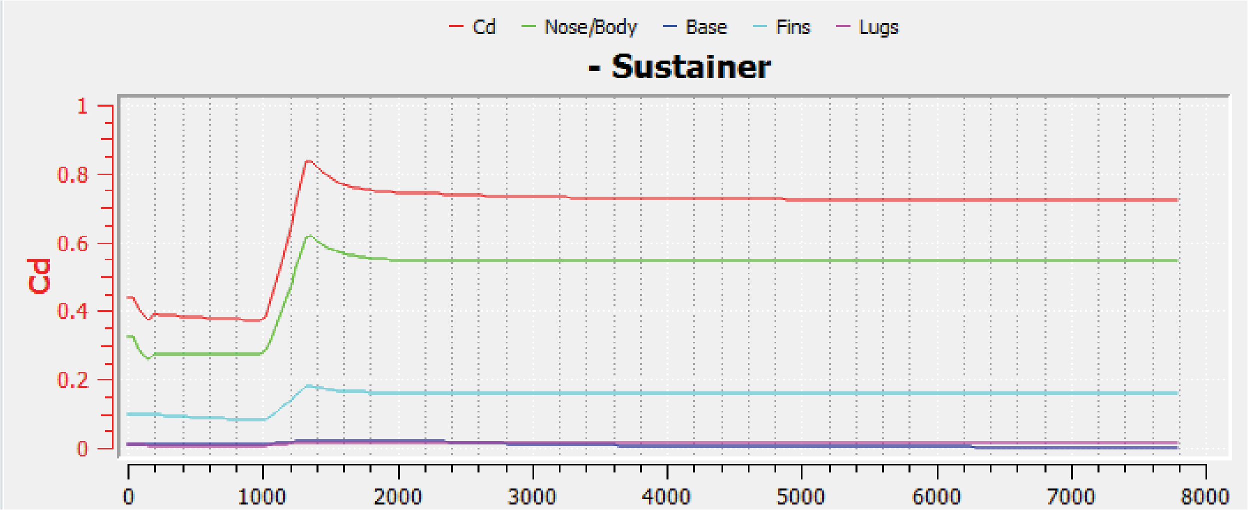
Figure 13 Thrust curve of AeroTech K695 motor from ThrustCurve.org

3.4.6 Validity of Analysis, Drag Assessment, and Scale Modeling Results



	Data value	Units
Time	16.2325	
Thrust	0	N
x-Thrust	0	N
y-Thrust	0	N
Acceleration	0.706	Feet/sec/sec
x-Acceleration	0.637	Feet/sec/sec
y-Acceleration	-0.304	Feet/sec/sec
Acceleration Total	32.384	Feet/sec/sec
x-Acceleration Total	0.637	Feet/sec/sec
y-Acceleration Total	-32.377	Feet/sec/sec
Velocity	88.538	Feet / Sec
x-Velocity	-79.923	Feet / Sec
y-Velocity	38.097	Feet / Sec
Mach number	0.0805821	
Altitude	5043.9	Feet
Range	-1143.09	Feet
Cd	0.411091	
Drag force	1.27686	N
x-Drag force	1.15239	N
y-Drag force	-0.54988	N
Longitudinal moment of inertia	4.17744e+06	Grams-Inches^2
Radial moment of inertia	17159.3	Grams-Inches^2
Flight angle	159.405	Deg.
Gamma - Velocity tangent angle	154.491	Deg.
Wind angle of attack	1.62535	Deg.
CG	44.639	Inches
Mass	5936.7	Grams

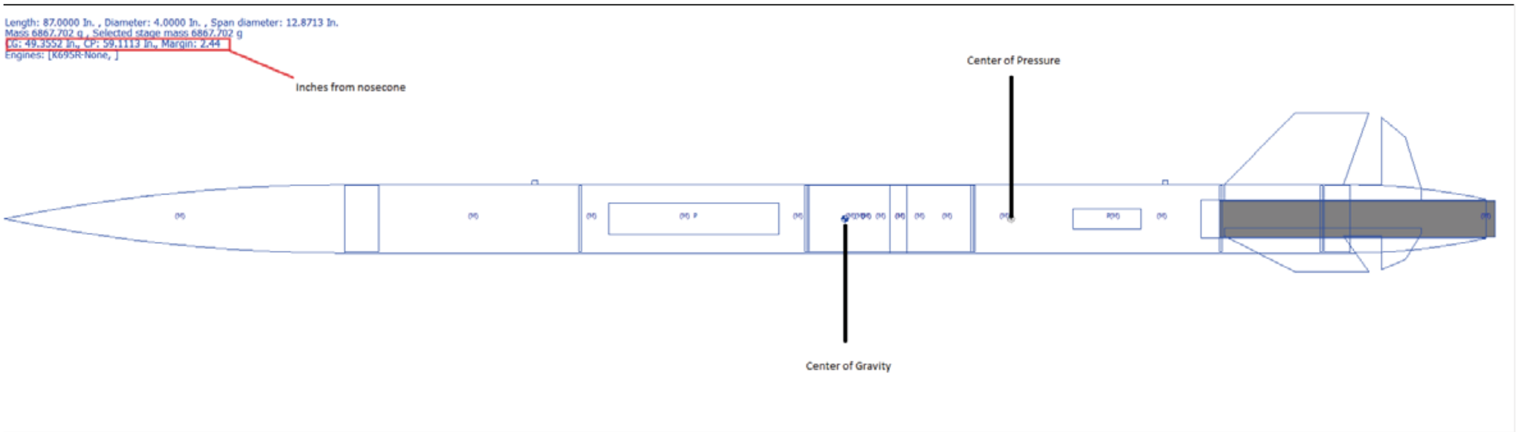
Figure 14 Drag data from Rocksim



- *Average coefficient of drag: 0.41*

- *The coefficient of drag of the launch vehicle was determined through the process of Altitude-Back-Tracking:*
    - *By factoring in all constants that affect the apogee of the launch vehicle into simulations, the coefficient of drag of the launch vehicle was adjusted until the simulated apogee matched the apogee achieved by the launch vehicle during the subscale test launch.*

3.4.7 Stability Margin and Actual CP & CG Relationship and Locations



Length: 87.0000 In. , Diameter: 4.0000 In. , Span diameter: 12.8713 In.
Mass 6867.702 g , Selected stage mass 6867.702 g
CG: 49.3552 In., CP: 59.1113 In., Margin: 2.44
Engines: [K695R-None,]

- Stability Margin: 2.44
- Center of Gravity (CG): 49 in. from tip of nosecone
- Center of Pressure (CP): 59 in. from tip of nosecone

3.5 Payload Integration

Integration Plan

- *All the equipment will be mounted on a sled that is then put between 2 rails, which are used to keep the sled in place and upright.*
- *There is a 1” clearance on the top and bottom of the payload bay to separate it from the rest of the rocket.*
- *These rails will have a specially designed cap screwed on top to keep the sled from moving during flight.*
- *The main components sled in the payload bay will be 9” x 3” x 0.5”.*
- *The rails from the base will be 1.5” x 0.5” x 9.5”, with a 0.25” indentation on the side at 0.5” from each side.*
- *The power supply bay is placed beneath the main electrical area in its own section.*
- *The power supply bay will be 2.5” x 4”.*

Compatibility of elements

- *There needs to be two holes situated a modest distance from each other on the payload bay area to allow airflow for the barometric pressure sensor.*

Simplicity of Integration Procedure

- *The main payload electronics sled is placed in a pre-made frame whose dimensions are stated above.*
- *The pre-made frame has been designed in such a way as to allow it to slide into the payload bay area.*
- *While in the payload bay the payload frame is secured with bulkheads both above and below it.*

Payload Changes from Subscale

- *There were no changes resulting from the half scale.*

3.6 Launch Concerns and Operation Procedures

1. *Unpack vehicle from transportation (trailer)*
2. *Carry vehicle to assessment table.*
3. *Separate body tubes from coupler.*
4. *Separate nose cone from upper body tube by removing its corresponding the screws.*
5. *Detach altimeter bay from inside of the coupler by removing the nuts on the bottom side of the coupler.*
6. *Assess all electrical circuitry including the solution on each end of the altimeter bay to ensure an airtight bay.*
7. *Insert battery into its proper position.*
8. *Zip-tie all 3 portions of the battery to the bay (2 horizontal ties and 1 vertical tie).*
9. *Supply power to the altimeter bay by plugging in the battery.*
10. *Test altimeter for sufficient power and reliability by plugging the altimeter into a computer.*
11. *Re-assemble altimeter into bay.*
12. *Re-assemble altimeter bay into coupler*
13. *Remove recovery subsystem.*
14. *Preform stress test on recovery system including parachutes, shock cords, and shroud lines.*
15. *Preform parachute drag test by holding the parachute by its end and free floating it through the air.*

16. *Re-assemble the recovery system back into the airframe.*
17. *Begin to test the ejection charges by loading the specified black power amount into the bay.*
18. *Use the help of an advisor to ignite the charge safely.*
19. *Re-assemble the recovery and ejection system back into the airframe.*
20. *Stress test fin malleability, nose cone strength, rail button reliability, and any other vehicle part that is necessary by applying pressure.*
21. *Re-assemble nose cone onto the upper body tube by re-applying the screws.*
22. *Retrieve the motor.*
23. *Unscrew motor cap and insert motor into the launch vehicle.*
24. *Once approved by the RSO, take launch vehicle to the launch pad.*
25. *Detach launch rail in order to easily access the rail.*
26. *Slide the vehicle onto the rail by lining the rail buttons up with the slot on the launch rail.*
27. *Apply power to the payload and altimeter bays by turning the screw located on the coupler.*
28. *Carefully monitor the altimeter beeps to ensure the main and drogue parachutes deploy at their specified altitudes.*
29. *Once the altimeter finishes its parachute deployment altitudes, listen for the constant chirping of the altimeter to ensure the altimeter is fully functional.*
30. *Open motor casing by unscrewing the cap.*
31. *Insert prepared igniter into the motor.*
32. *Tape igniter to motor casing using electrical tape in a z-fold fashion.*
33. *Re-screw the cap onto the motor casing.*
34. *Attach electrical input device to both igniter ends.*
35. *Test electrical continuity between the igniter and the electrical input device by using a continuity-testing device.*
36. *Listen to the altimeter and payload bay once more to check for sufficient power.*
37. *Clear the area of the launch vehicle.*
38. *Assign roles to record time, video, and surveillance on the vehicle before the launch. (Multiple persons per role is recommended)*
39. *Once approved by the RSO, start a countdown from 5 to 1*
40. *At 1 on the countdown, launch the vehicle by giving electrical power to the igniter.*
41. *Carefully observe the vehicle for any faults in the flight.*
42. *Once touchdown is achieved, wait 60 seconds before approaching the vehicle.*
43. *Deactivate altimeter and payload bay by unscrewing the screw located on the coupler.*
44. *Assemble vehicle into the original state prior to the launch*
45. *Carry vehicle back to the assessment table.*
46. *Assess any damage to the rocket*
47. *Disassemble the altimeter and payload bay.*
48. *Individually plug the altimeter and each payload into a computer to securely retrieve the data.*

49. *Assess data.*
50. *Reassemble the altimeter and payload bays back into the vehicle.*
51. *Dispose of used motor casing.*
52. *Assess overall flight.*
53. **If launch fails, wait 60 seconds before approaching launch pad**

3.7 Safety and Environment (Vehicle and Payload)

3.7.1 Failure Modes

Failure mode	**Mitigation**	**Verification**
The rocket and payload fail to be completed on time.	*The team will follow a GANTT chart (that allots for extra time in the case of externalities outside the team's control delaying some parts of the timeline) to ensure that the project is completed before deadlines.*	*The team project manager will pay close attention to deadlines and reorganize the distribution of labor or call for necessary changes to design to ensure the GANTT chart is followed.*
During transportation or construction, the rocket is damaged and cannot fly.	*The rocket will only be transported in thick padding to prevent damage. The rocket will never be left near tools or materials that could damage it in the lab.*	*The construction head will keep careful watch over the rocket in the lab. The range safety officer will keep careful watch over the rocket during transportation and at the launch site.*
On the launch stand, the rocket motor fails to ignite.	*To prevent the absorption of moisture by the motor, it will remain in an airtight plastic bag within the flammable materials carrying case.*	*The team mentor will ensure the motor is stored and handled correctly.*
As the rocket begins it's ascent, the rocket weathercocks heavily and flies off course.	*The rocket will be designed with a stability margin that minimizes the affects of weathercocking. The Rocket will never be flown in winds above 20 mph.*	*the design team will ensure an optimal stability margin is achieved. The range officer will check weather conditions and delay or cancel a launch if conditions are inadequate for launch*
At apogee the body tubes fail to separate from the coupler.	*The design team will use simulations to determine what shear pin thickness and black powder size will allow the body tubes to separate properly.*	*Static tests will ensure the simulated black powder and shear pin sizes are adequate to separate the body tubes*
The force from the ignition of the motor shakes loose some parts of the payload or breaks off pieces of the rocket.	*The rocket and payload will be made of materials robust enough to withstand the forces of flight.*	*Ground tests mimicking the forces experienced during flight will verify the rocket and payload are robust enough.*
The body tubes separate, but the parachute or drogue fails to	*To prevent the tangling of shroud lines or a fail in the folding of the*	*Ground tests of ejection will ensure the parachute and*

unfurl at ejection.	parachutes to unfurl, the parachutes and shroud lines will be folded using a z-fold technique, to avoid tangling.	drogue can properly open at ejection using t.he z-fold.
The electrical systems of the altimeters or payload short.	The construction and payload team will double check all wirings and insulate any exposed wiring that could short.	Ground tests of the payload and altimeters will ensure that all wiring connections are strong.
Failure of team workmanship/cohesion.	Team members will share labor and cross check work to share collective knowledge and get work done efficiently and correctly.	Project managers will instigate the team communication and ensure work is correctly distributed.

3.7.2 Personnel Hazards and Data

Personnel Hazard	**Mitigation**	**Verification**
Irritation of skin should it come into contact with epoxy or other adhesives.	When working with epoxy or other adhesives, personnel will wear latex gloves and use brushes and application sticks to apply the adhesive.	Personnel will run through a checklist prior to any job requiring the use of adhesives that will instruct them to use the proper PPE's when handling adhesives.
Irritation of the skin, eyes or throat due to dust and microfiber particles that are produced during the handling of carbon fiber.	When handling soft carbon fiber, personnel will be required to wear gloves and face masks and will avoid all skin contact with the fiber.	Personnel will run through a checklist prior to any job requiring the use of carbon fiber that will instruct them to use the proper PPE's when handling carbon fiber.
Irritation of the eyes or lungs from fumes or particulate given off from jobs involving spray paint, epoxy, the cutting of hardened carbon fiber, the cutting of fiber glass, etc.	When involved with jobs that will result in the production of dangerous fumes or airborne particulate, personnel will work under a fume hood and wear facemasks and goggles.	Personnel will run through a checklist prior to any job involving the production of dangerous fumes or particulate that will instruct them to use the proper PPE's when handling these jobs.
Personnel injury in the form of a cut from use of a static blade such as a razor or	Personnel will always cut away from themselves and others. Blades will be kept sharp to avoid blade catching. Personnel will not cut with gloves on to	Personnel will run through a checklist prior to any job requiring the use of static blades that will instruct them to

hand saw.	*maximize precision and control.*	*use the proper procedure and handling of static blades.*
Personnel injury in the form of a cut from the use of a "moving" blade such as a power saw or dremel.	*Personnel will cut slowly and carefully. Personnel will never place body parts in the path of the blade.*	*Prior to using a "moving" blade, personnel will run through a checklist to the remind them of proper behavior associated with the handling of these tools.*
Injury of a personnel's eyes due to particulate entering the eyes during the cutting or grinding of a material such as fiber glass or carbon fiber.	*When cutting or grinding any material with a blade, personnel will wear goggles.*	*before beginning any job involving the cutting or grinding of a material, personnel will run through a checklist reminding them to use goggles.*
Injury of personnel in the form of burns due to the ignition of a motor, ejection charge or igniter.	*Open flames, sparks and all electronic devices will not be allowed within 25 feet of the motor on launch day and all flammable materials will be kept in the flammable storage unit (in the lab), or ammo cases and the metal, flameproof carrying case for launches).*	*All personnel will take a safety test after being drilled the safety regulations associated with flammable materials to ensure they are aware of the proper handling of such materials.*

3.7.3 Environmental Concerns

Environmental effects on the rocket:

Prior to launch environmental factors such as moisture present in the air or moisture in the form of precipitation can harm the electrical systems of the rocket. To avoid this, the rocket will never fly if it is raining out. Factors such as exceptionally high winds could result in the rocket drifting off course during recovery, landing in a body of water, into a power line, or into a tree or other tall body. If winds ever exceed 20 mph, then the rocket will not fly. Upon recovery hard surfaces such as rock or asphalt could damage the rocket's frame or payload. To prevent damage to any components of the rocket or payload, a TAC 24 inch drogue and TAC 60 main parachute will be utilized on the full scale. Additionally, all sections of the rocket and payload will be constructed with materials found to be robust enough to withstand the forces of impact upon recovery.

The rocket's effects on the environment:

As the rocket motor ignites, exhaust from the burn can set fire to dry or dead vegetation below the rocket. To avoid the spread of fire, all flammable materials will be removed from directly below the launch stand. In the case of an unforeseen mishap, a piece or pieces of the rocket could fall from the rocket and pose a threat to local wildlife. To prevent any spreading of the pieces of the rocket, the three sections will be tethered together with a recovery harness. Also, any pieces that break off from the rocket as it hits the ground or object, should the parachute fail to open, will be removed.

4 Payload Criteria

4.1 Testing and Design of Payload Equipment

4.1.1 Design at System Level

Selection Rationale

- *Sparkfun Redboard*
    - *Improved functionality and lower price from the Arduino Uno R3*
- *XBee Pro 900*
    - *Optimal choice for wireless communication on the Arduino platform due to immense documentation and technical capability*
- *Barometric Pressure Sensor Breakout – BMP180*
    - *Performance*
        - *BMP180's superior range is optimal for the payload experiment*
    - *Price & Ease of Sourcing*
        - *By sourcing many of our parts from the same supplier, small discrepancies in price are made up for through shipping*
- *ADXL335 – 5V ready triple-axis accelerometer*
    - *Chosen to meet the internal requirement of having separate outputs for the x, y, and z coordinates*
    - *Meets instrument margin of error requirements for the experiment*
- *Adafruit Ultimate GPS Breakout*
    - *Has a range and accuracy optimal for the experiment, which allows for its use anywhere and the expectation of optimal performance*

Custom made payload bay

- *Custom manufacture of the payload frame was chosen to fix several technical issues experienced in the past with former designs.*
- *Tapered rail design*
    - *To avoid structural problems in the past which were due to wobbling caused by the oscillations of the rocket in flight. By tapering up to the top of the rails this design feature should allow for much greater structural stability during flight.*
- *Single vertical sled design*
    - *Improves modularity as well as to fix aforementioned structural problems (wobble). This design feature allows us to change component sleds easily, which gives the option to easily change experiments, which contributes to reusability.*
- *Cap design feature*
    - *Included to minimize wobble and to ensure that the main components sled is properly secured in between our rails. This helps minimize the risk of disconnection between*

    - *components on the main components sled*
- *Separate power supply bay*
    - *Attached to the main components bay separately to improve modularity and reusability. By being able to interchange power supply modules it theoretically gives the ability to extend battery life infinitely.*

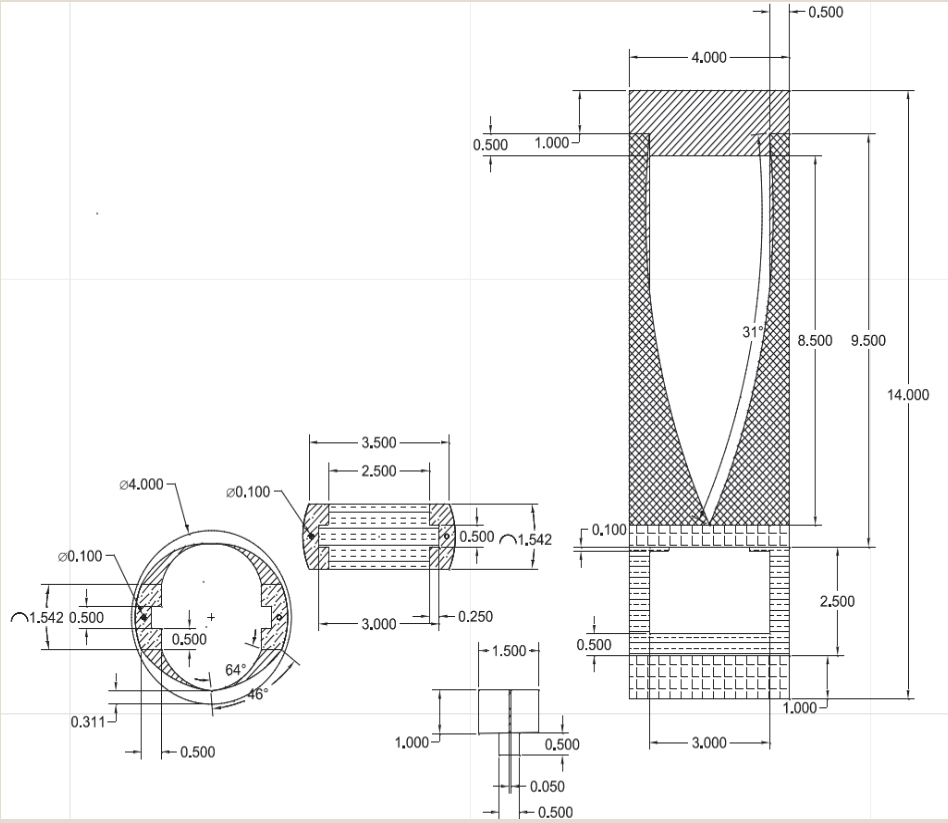
These changes have several benefits apart from fixing previous structural problems.

These include:

- *Lower weight in part because of the fully 3d-printed design.*
- *Increased modularity and reusability.*

Drawings and specifications

- *The main components sled in the payload bay will be 9” x 3” x 0.5”.*
- *The rails from the base will be 1.5” x 0.5” x 9.5”, with a 0.25” indentation on the side at 0.5” from each side.*
- *The power supply bay is placed beneath the main electrical area in its own section.*
- *The power supply bay will be 2.5” x 3.9”*



Analysis Results

- *Analysis of tests results will be done after planned testing is performed.*

Tests Results

- *Tests will be performed immediately upon construction, before the FRR.*

4.1.2 System-Level Functional Requirements

The sensor package included meets all the requirements outlined in the PDR as follows:

- *Barometric Pressure Sensor is used to collect pressure data, the data is then sent to the flight computer.*
- *GPS module is used to give exact position of rocket at any given point. This data is sent to through flight computer.*
- *Triple Axis Accelerometer is used to measure the G's of the rocket in the x, y, and z planes. This data is sent to through flight computer.*
- *The temperature data will be used to analyze the changes in temperature as the rocket ascends. This data is sent to through flight computer.*
- *The orientation data will be used to record how much the rocket changes angle during flight. This data is sent to through flight computer.*
- *The compass heading data will be used to record the rockets roll during flight.*
- *Sparkfun RedBoard to process all the data that the sensors produce, acting as a flight computer.*
- *XBee Pro 900 transmits data coming from flight computer to a corresponding XBee pro 900 on ground. at a minimum latency of 500 ms.*
- *The data received from flight computer is transmitted to a website which dynamically represents the data in real-time.*

4.1.3 Approach to Workmanship

- *Construction and programming of the scientific payload will be approached in a professional and meticulous manner*
- *All design and manufacturing problems are being tackled on a case-by-case basis and are quickly resolved as they are found*
- *Safety procedures and guidelines will be followed*

4.1.4 Component, Functional, and Static Testing

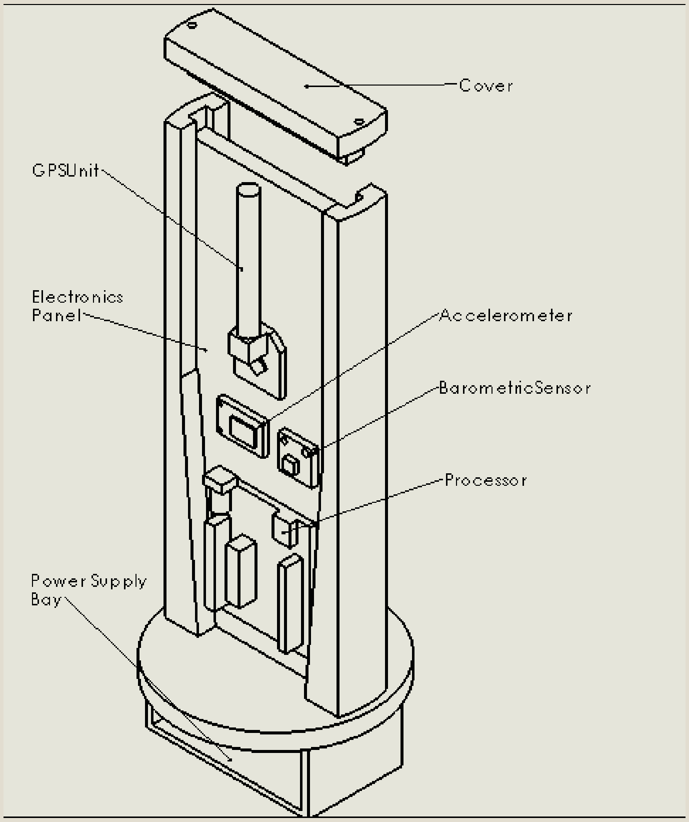
- *To verify the payloads measurement and long range transmitting capabilities we will have a variety of tests. These include:*
    - *A range test in which the payload module is taken a specific distance away from the transmitter to test latency and accuracy as distance increases.*
    - *A accuracy test in which we use the payload to measure values for each sensor when the values are already known, the deviation from the correct values will be the calibration error.*
- *All tests will be performed before the FRR.*

4.1.4 Status and Plans of Manufacturing and Assembly

- *Manufacturing has been delayed due to design flaws and missed deadlines.*
- *The entire payload frame is planned to be 3D printed with ABS plastic.*
    - *To meet all design requirements this form of manufacturing was needed.*

4.1.5 Integration Plan

Payload Bay



- *All the equipment will be mounted on a sled, between two 3D printed rails*

  - *Used to keep the sled in place and upright*
- *1” clearance on the top and bottom of the payload bay to separate it from the rest of the rocket*
- *Rails will have a 3.5” x 1.5” x 1.5” cap screwed on top to keep the sled from moving during flight*
- *The main components area of the payload bay will be 9” x 3” x 0.5”*
- *The rails will be 1.5” x 0.5” x 9”, with a 0.25” indentation on the side at 0.5” from each side*
- *The power supply bay is placed beneath the main electrical area in its own section*
- *The power supply bay will be 2.5” x 4”*

4.1.6 Precision of Instrumentation & Repeatability of Measurement

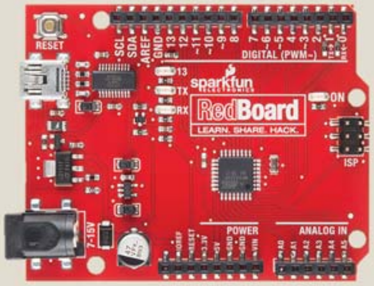
Instrument	Range	Precision Measurement
BMP180(Barometer)	300 to 1100 hPa	0.02 hPa
BMP180(Temperature)	-40 to 85 °C	0.17m
Adafruit Ultimate GPS Breakout (746)	Anywhere in satellite range	Less than 3m
LSM303(Accelerometer)	N/A	+/- 3 G
LSM303(Compass)	±1.3 to ±8.1 gauss	N/A
L3GD20H(Gyroscope)	N/A	±250, ±500, or ±2000 degree-per-second scale
XBee Pro 900 RPSMA (WRL-09099)	Up to 6 mi	N/A

4.1.7 Payload Electronics

Electrical Components

Arduino Flight Computer[*]

Sparkfun RedBoad



- *Used to process the data transmitted from the sensors*
- *Technical specs*
    - *14 Digital I/O Pins (6 PWM outputs)*
    - *6 Analog Inputs*
    - *32k Flash Memory*
    - *16MHz Clock Speed*

Barometric Pressure Sensor[*]

Barometric Pressure Sensor Breakout – BMP180

- *Sensor to collect and send pressure data to the flight computer*
- *Technical Specs*
    - *Range of 300 to 1100 hPa*
    - *Accuracy down to 0.02 hPa in advanced resolution mode*

Wireless Communication Device[*]

XBee Pro 900 RPSMA

- *Used to transmit data from flight computer to a corresponding XBee Pro 900 AGL at a minimum latency of 500 ms (milliseconds)*
- *Data received from flight computer is transmitted to a website which dynamically represents the data in real-time*
- *Connected to the flight computer through an XBee Shield*
- *Technical specs*
    - *Fast 156 Kbps RF data rate*
    - *Up to 6 miles (10 km) RF LOS with high gain antennas*

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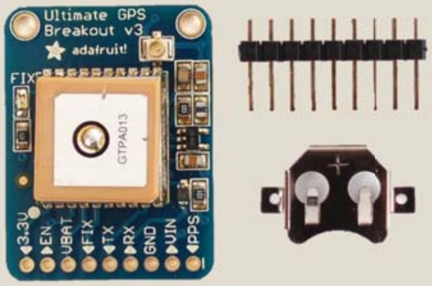
[*] Image courtesy of Sparkfun
[*] Image courtesy of Sparkfun
[*] Images courtesy of Sparkfun

GPS Module*

Adafruit Ultimate GPS Breakout



- *Used to give exact position of rocket at any given point*
- *Technical Specs*
    - *Satellites: 22 tracking, 66 searching*
    - *Position Accuracy: < 3 meters (all GPS technology has about 3m accuracy)*
    - *Velocity Accuracy: 0.1 meters/s*
    - *Warm/cold start: 34 seconds*
    - *Maximum Velocity: 515m/s*
    - *Jammer detection and reduction*

Triple Axis Accelerometer

ADXL335 - 5V ready triple-axis accelerometer

- *Used to measure the G's of the rocket in the x, y, and z planes*
- *Technical Specs*
    - *+/- 3Gs margin of error on measurements*

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[*] Image courtesy of Adafruit

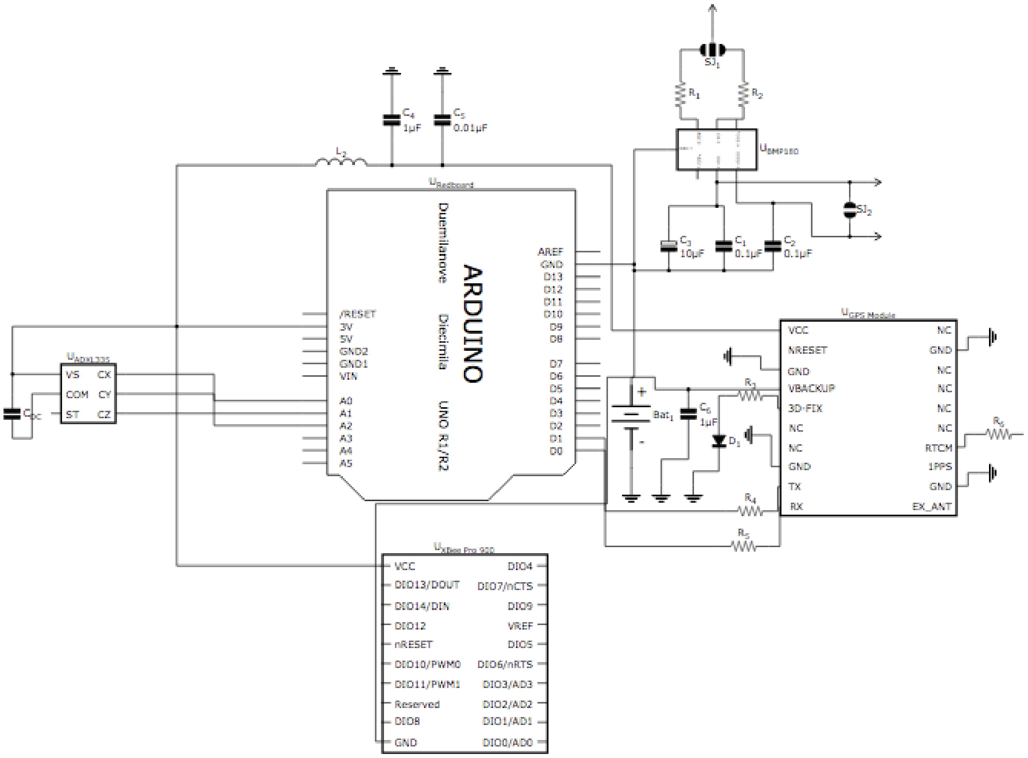

Figure 15 Electrical schematics of payload system (PBC)[*]

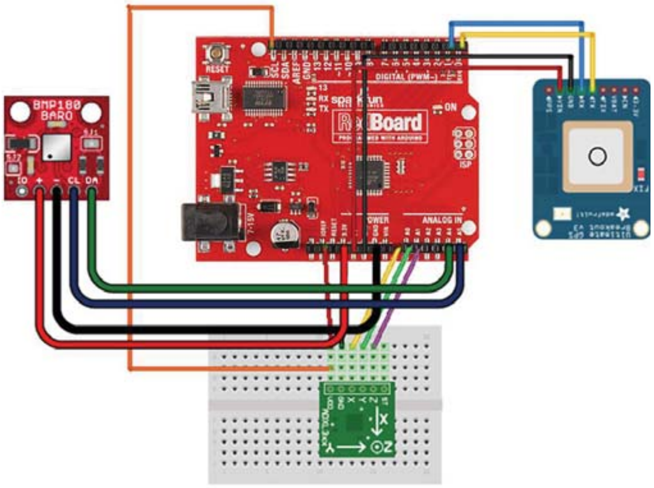

Figure 16 Electrical schematics of payload system

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[*] XBee Pro 900 is connected to the flight computer through the XBee Shield, which will be placed directly into the flight computer

6.2 Payload Concept Features and Definition

Creativity and Originality

The payload exhibits creativity and originality in several ways outlined by the following:

- *Many of the components are designed and manufactured specifically for this project.*
- *The payload makes liberal use of relatively cheap methods of manufacturing, incorporating 3D printed ABS plastic in many components.*

Uniqueness or Significance

- *Provides a platform for relatively cheap and simple manufacture, integration, and use of complex wireless telemetric systems.*
- *The liberal use of 3D printing and 3D printed materials (ABS plastic), makes this project very unique as opposed to a more conventional approach of wood or metal.*

Suitable Level of Challenge

- *The design, construction, and use of this payload provides a suitable challenge to the team due to the following:*
  - *Teaches operation of wireless transmitting and receiving equipment.*
  - *Teaches engineering design and problem analysis.*
  - *Teaches how to work in a feature driven way.*
  - *Teaches how to work in a limited timeframe and with a budget.*
  - *Teaches electrical engineering skills as well as mechanical engineering skills.*

6.3 Science Value

Hypothesis

- *Telemetric data can be recorded, transmitted, and displayed in real time from a rocket, which is in motion.*

Payload Objectives

- *To record and transmit real-time telemetric data (altitude, air pressure, acceleration in all directions, temperature, orientation, compass heading, and precise location (GPS)) to a computer on the ground.*
- *To send the data collected to a website which displays it also in real-time.*

Payload Success Criteria

- *Record and transmit real-time telemetric data (altitude, air pressure, acceleration in all directions, temperature, orientation, compass heading and precise location (GPS)).*
- *Data collected is sent to the website which displays it also in real-time.*

Test and Measurement Variables

Tests

- *Atmospheric pressure tests with a barometric pressure sensor.*
- *Location tests with a GPS module.*
- *Altitude and rocket motion tests with a triple-axis accelerometer.*
- *Temperature tests with a thermometer.*
- *Orientation test using gyroscope.*
- *Compass heading tests using compass.*

Controls

- *Atmospheric pressure at launch site (Barometric pressure sensor).*
- *Original position of rocket as recorded by the accelerometer and GPS modules.*

- *Original orientation as recorded by the gyroscope.*
- *Temperature at launch site (Thermometer).*
- *Original compass heading as recorded by compass.*

Variables

- *Atmospheric pressure as rocket ascends.*
- *Position in space relative to original recorded position.*
- *Orientation as rocket oscillates.*
- *Temperature as rocket ascends.*
- *Compass heading as rocket rolls.*

Relevance of data

- *The atmospheric pressure data will be used to analyze the changes in atmospheric pressure as the rocket ascends.*
- *The GPS data is used to tell where the rocket is at any given moment.*
- *The accelerometer data is used to tell the orientation of the rocket at any given time.*
- *The temperature data will be used to analyze the changes in temperature as the rocket ascends.*
- *The orientation data will be used to record how much the rocket changes angle during flight.*
- *The compass heading data will be used to record the rockets roll during flight.*

Experiment

- *Logic*
  - *As the rocket ascends the data recorded from the instruments should change accordingly. The changes should follow a predictable curve.*
- *Approach*
  - *This experiment will be approached by acquiring sensors that can record the data required.*
- *Method of Investigation*
  - *On the launch pad all the instruments are calibrated and zeroed to launch pad conditions.*
  - *As the rocket ascends data from the barometric pressure sensor (BMP180), triple axis accelerometer (LSM303), thermometer (BMP180), gyroscope (L3GD20H), compass (LSM303), and GPS module is sent to the central flight computer.*
  - *The flight computer takes this data and sends it through an XBee Pro 900 RPSMA to a corresponding XBee on the ground.*
  - *The data received from the flight computer is then streamed in real-time to a pre-made website which displays the telemetry data.*

Preliminary Process Procedures

- *At the launch pad all the instruments are turned on to calibrate and take their control measurements.*
- *These measurements are the conditions that exist on the launch pad to allow for an accurate measurement each time.*

5 Project Plan

5.1 Budget

5.1.1 Launch Vehicle Expenses

Item	Quantity	Place of Purchase	Total Price
Fiberglass Nosecone	1	Rocketry Warehouse	$22.00
Polysteyrene Nosecone (Tailcone)	1	Madcow Rocketry	$21.95
Carbon Fiber Fins	1	Sollar Composites	$44.50
Eyebolts	6	Lowes/Home Depot	$13.62
Centering Rings	2	ARR	$4.98
Lock Nuts	20	Lowes/Home Depot	$2.40
Washer	20	Lowes/Home Depot	$2.20
BlueTube Airframe	2	ARR	$77.90
BlueTube Coupler	2	ARR	$21.90
Carbon Fiber Plate	1	Rockwest Companies	$78.99
Fiberglass Sheet (138 in.^{2})	3	Grainger	$40.41
9v Batteries (4 pack)	1	Amazon	$8.00
Threaded Rod	2	Lowes/Home Depot	$1.96
TOTAL EXPENSE			**$340.81**

5.1.2 Recovery Expenses

Item	Quantity	Place of Purchase	Total Price
Tubular Kevlar (3/8 in.)	80 ft.	Rocketry Warehouse	$63.20
Perfectiflite Altimeter	2	Perfectflite	$98.92
Nylon Parachute 24”	1	Giant Leap Rocketry	$30.68
Nylon Parachute 70”	1	Giant Leap Rocketry	$126.78
TOTAL EXPENSE			**$319.58**

5.1.3 Payload Expenses

Item	Quantity	Place of Purchase	Total Price
XBee Pro 900 RPSMA (WRL-09099)	2	Sparkfun	$109.90
Sparkfun Redboard	1	Sparkfun	$19.95
Adafruit Ultimate GPS Breakout (746)	1	Adafruit	$35.95
ADXL335 - 5V ready triple-	1	Sparkfun	$14.95

axis accelerometer			
Barometric Pressure Sensor (BMP180)	1	Sparkfun	$9.95
XBee Explorer Dongle	1	Sparkfun	$24.95
Sparkfun XBee Shield	1	Sparkfun	$14.95
Break Away Headers	2	Sparkfun	$3.00
Breadboard Self-adhesive (white)	1	Sparkfun	$4.95
Jumper Wires Standard 7" M/M Pack of 30	1	Sparkfun	$4.95
Adafruit 10- DOF IMU Breakout	1	Adafruit	$29.95
CR122 12mm Diameter – 3v Lithium coin cell battery	1	Adafruit	$0.95
TOTAL EXPENSE			**$274.40**

5.1.4 Motor Expenses

Item	Quantity	Place of Purchase	Total Price
AeroTeach K695R	3	Sirius Rocketry	$96.04
AeroTech G77R	2	Apogee Rockets	$42.78
TOTAL EXPENSE			**$138.82**

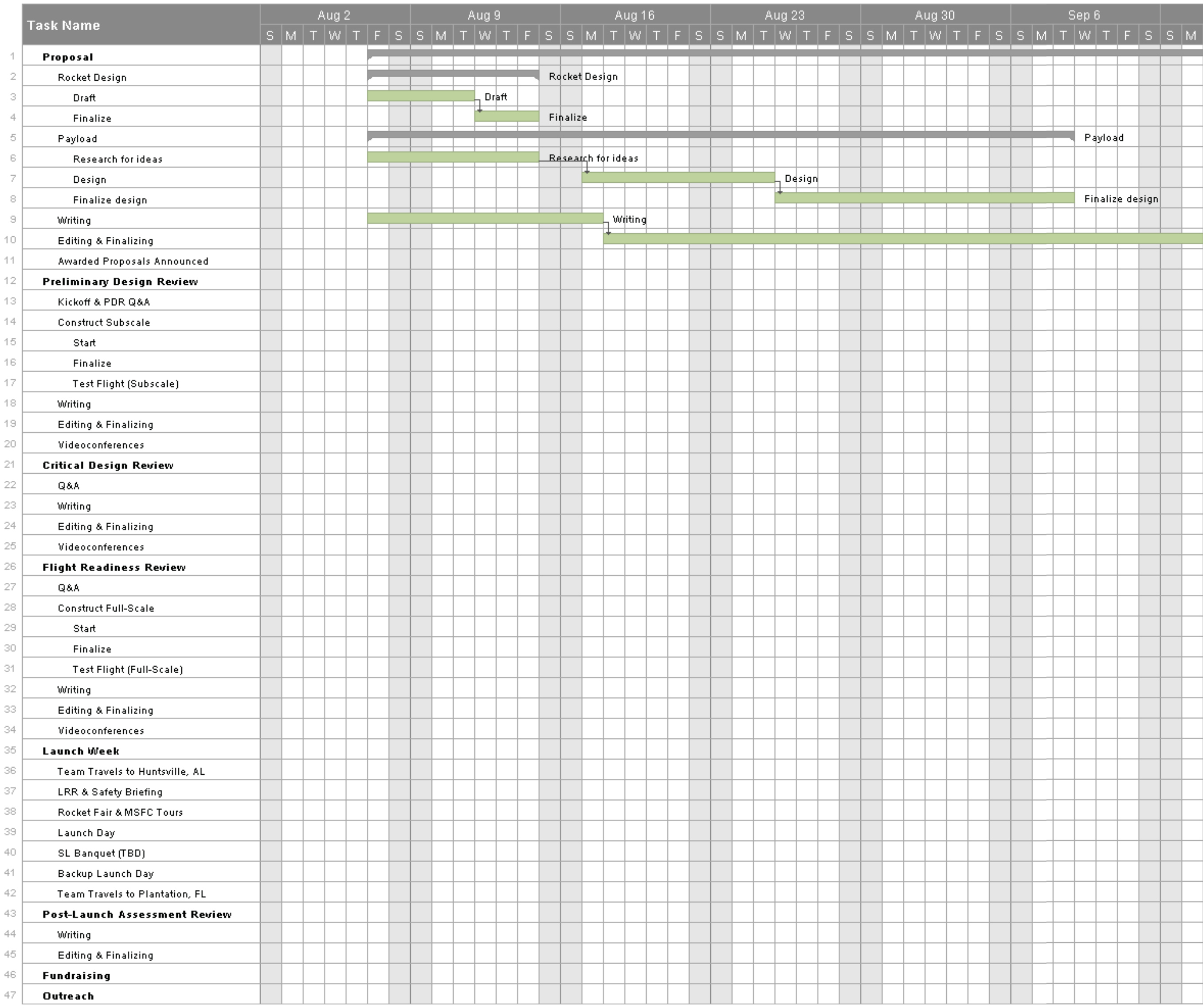
5.1.5 Trip Expenses

Item	Quantity	Price per Unit	Time Spent	Total Price
Rental Vans	2	$76.02 per day	7 days	$1,064.38
Gas (Vans)	N/A	$237.13 per van	7 days	$474.26
Gas (Pick-Up Truck)	N/A	$279.65	7 days	$279.65
Hotel Rooms	3	$126.00	6 nights	$2,268.00
TOTAL EXPENSE				**$4,087.89**

5.1.6 Combined Total Expenses

Item	Quantity
Launch Vehicle Expenses	$340.81
Recovery Expenses	$319.58
Payload Expenses	$274.40
Motor Expenses	$138.82
Trip Expenses	$4,087.89
GRAND TOTAL	**$5161.50**

5.2 Timeline



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1	**Proposal**
2	Rocket Design
3	Draft
4	Finalize
5	Payload
6	Research for ideas
7	Design
8	Finalize design
9	Writing
10	Editing & Finalizing
11	Awarded Proposals Announced
12	**Preliminary Design Review**
13	Kickoff & PDR Q&A
14	Construct Subscale
15	Start
16	Finalize
17	Test Flight (Subscale)
18	Writing
19	Editing & Finalizing
20	Videoconferences
21	**Critical Design Review**
22	Q&A
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25	Videoconferences
26	**Flight Readiness Review**
27	Q&A
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32	Writing
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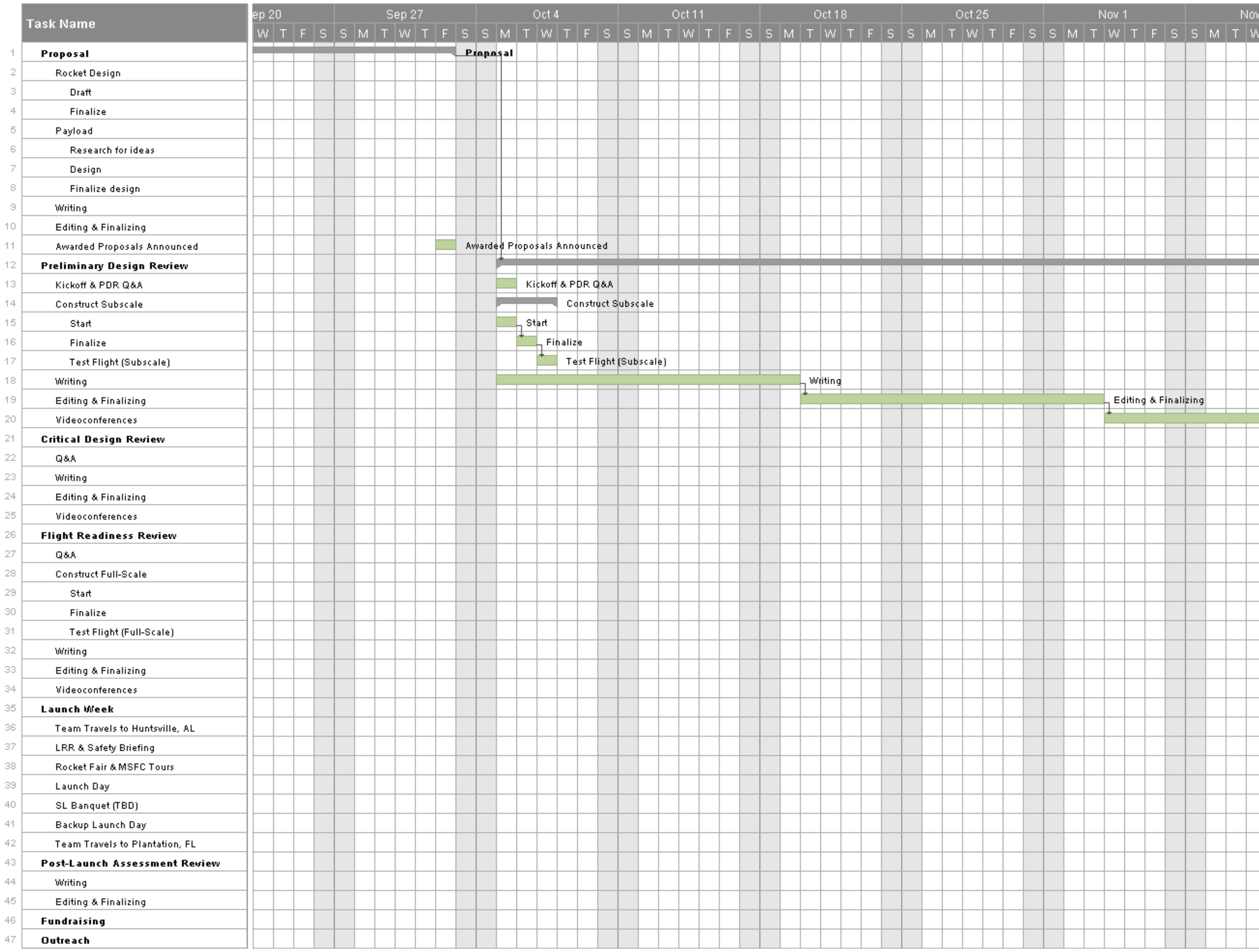
34	Videoconferences
35	**Launch Week**
36	Team Travels to Huntsville, AL
37	LRR & Safety Briefing
38	Rocket Fair & MSFC Tours
39	Launch Day
40	SL Banquet (TBD)
41	Backup Launch Day
42	Team Travels to Plantation, FL
43	**Post-Launch Assessment Review**
44	Writing
45	Editing & Finalizing
46	**Fundraising**
47	**Outreach**



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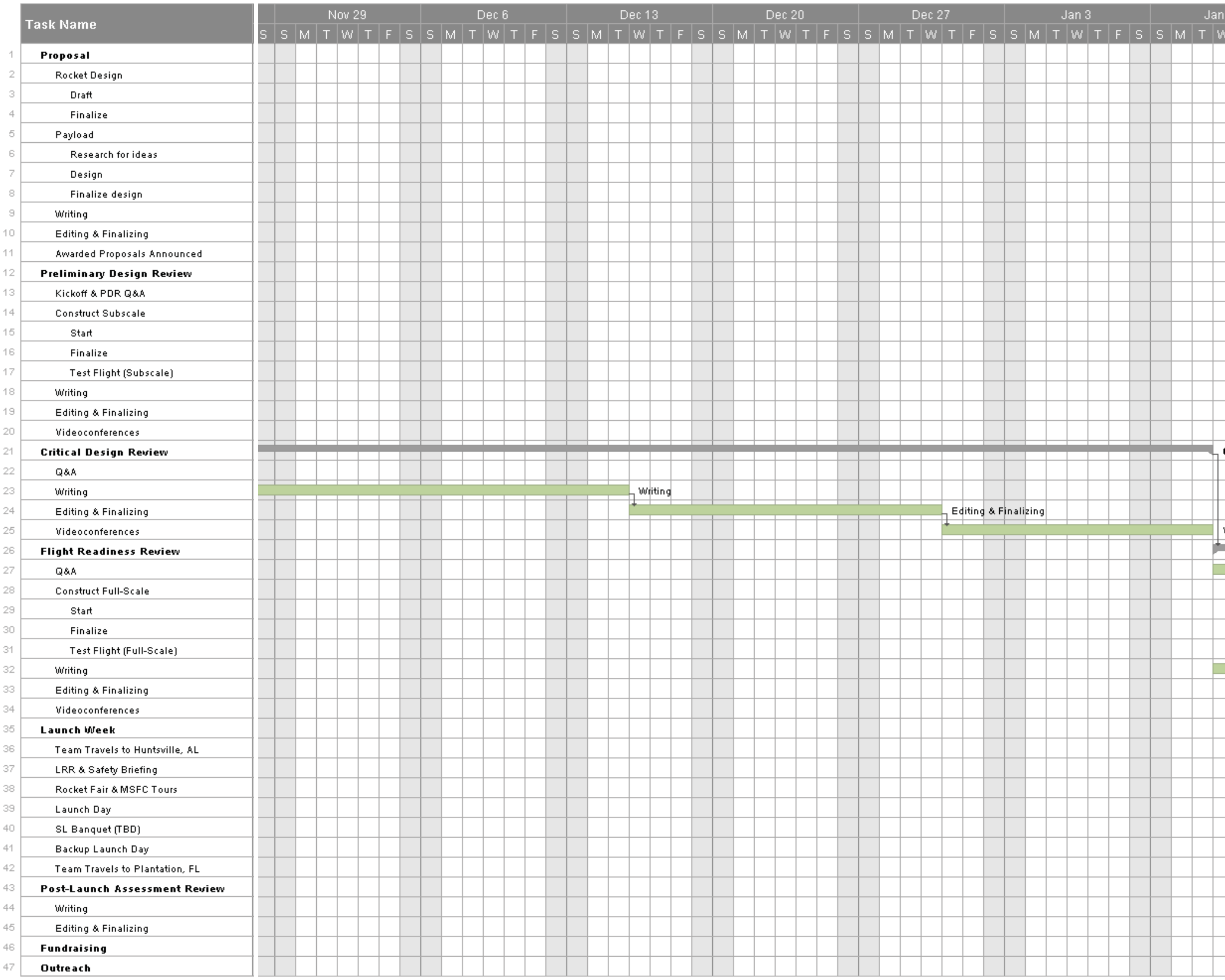
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Dec 6
Dec 13
Dec 20
Dec 27
Jan 3
Jan
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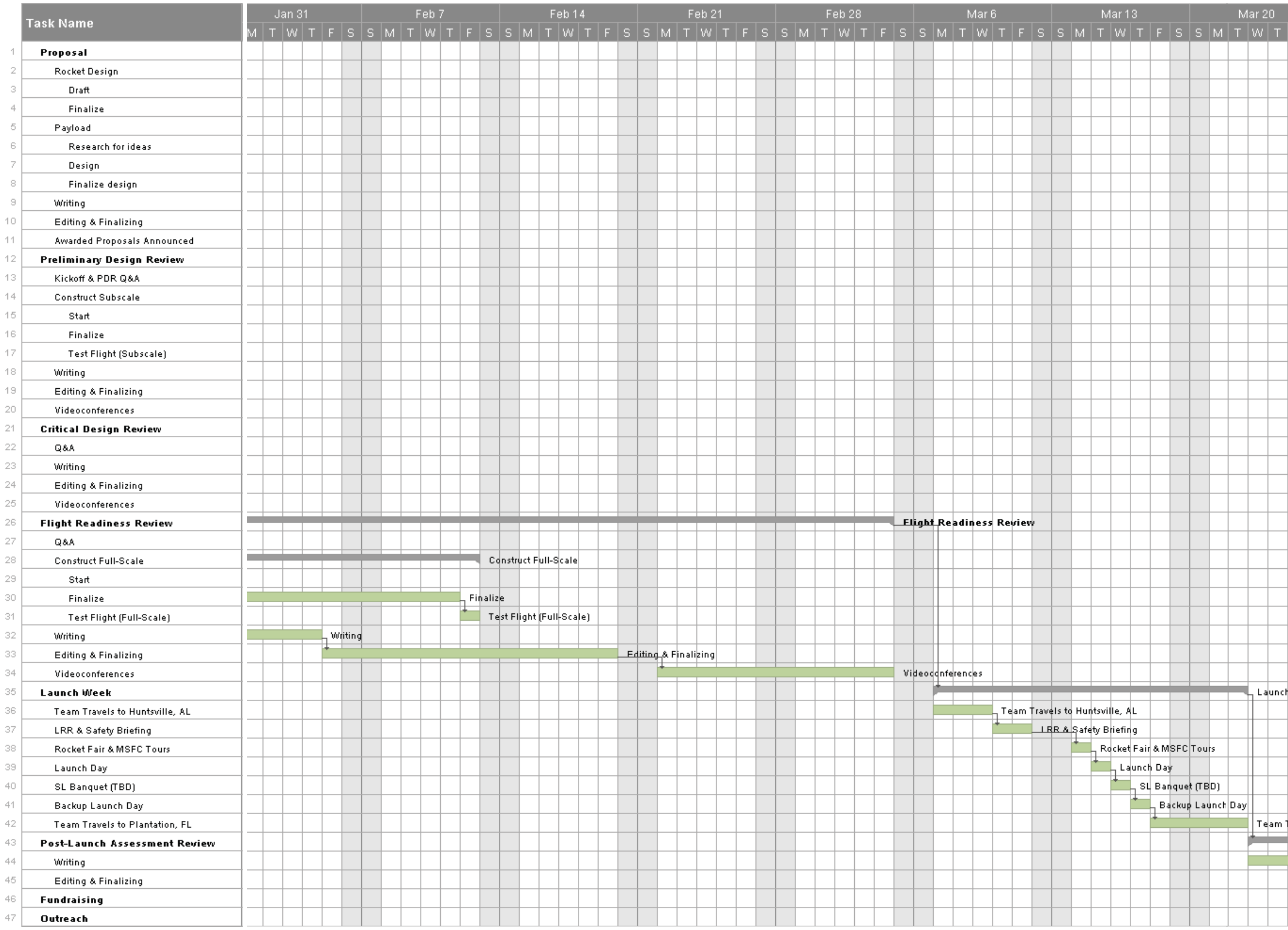

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5.3 Funding Plan

Junk Food Sales

- *Throughout the SLI 2015-2016 Season, the Plantation High SLI Teams will be selling junk food and beverages to students after school, through the aerospace program*
- *Sales have begun and are very successful in producing an income to help fundraise for the project*
- *All profit is being divided between the two Plantation High SLI teams*

School Fair

- *The aerospace program will participate in the Plantation High Annual School Fair. This event allows everyone who wishes to attend to visit the school and partake in activities set up by student organizations and outside sponsors*
- *At the event, both SLI teams from Plantation High School will cooperate to set up an activity booth*
- *Activities planned for the event include, but are not limited to: UFO rocket construction, spin art, customizable dog-tags, and junk food sales*

Additional fundraising ideas are currently being researched.

5.4 Educational Engagement Plan

With proper planning and communication with our partners, several events have been planned out which will easily engage at least 200 students. These outreach opportunities will enlighten the students on allowing them to comprehend what engineers do and how they think. The following events will take course over the eight months leading up to the launch week in Huntsville, Alabama.

5.4.1 Open Lab Nights at Plantation High

Time: Every Thursday the month of February, starting February 4th at 5pm

Location: Plantation High School cafeteria

Audience: Elementary students

- *Activity: Building small Estes rockets with the guidance of the Plantation High SL team members*

Audience: 5th Grade students

- *Activity: Building TARC style rockets and working with computer programs such as OpenRocket to design rockets.*

Once the sessions have been completed, a launch day will be set up at our local PAL field where the students get to come out and fly their rockets. The students will be provided kits and all supplies necessary.

On the 14th of November, the team will be visiting Plantation Middle School to set up a booth and activities for the students

5.4.2 Women in Engineering Empowerment Seminar

Time: Span of 4 months, once per month from 3PM-5PM

Location: Plantation High School Aerospace classroom

Audience: Girls who are interested in the Engineering/STEM fields

Activity:

- *A representative from the Women in Engineering Society will speak to the students on what makes a female engineer, how to get involved in the STEM fields, and the pros & cons associated with being a woman in engineering*
- *The girls will also participate in a project with the team and the society member*

This event is currently in the planning process; therefore, details will be disclosed upon finalization.

5.4.3 Boy Scout Rocket Construction Night

A local boy scout group will be constructing Estes rockets. The PHS SLI Teams and mentor will supply the scouts with all supplies and kits necessary along with out guidance during construction. During construction, the team mentor will give a step-by-step demonstration on how to properly build an Estes rocket, along with helpful tips and hints.

- *Time: After December*
- *Location: American Heritage School*
- *Audience: Boy Scouts*

5.4.4 Parkway Launch Day and Seminar

A presentation will be given in which the PHS SLI Team 1 will introduce the students to our Aerospace Program and perform a model rocket safety review.

- *Time: TBD*
- *Location: Parkway Middle School*
- *Audience: 8th grade STEM space science class*

Joint Rocket Launch

- *Time: TBD*
- *Location: Vista View Park*

6 Conclusion

The Plantation High School SL Team #1 is comprised of nine students, and is mentored by Ken Green and Joe Vallone. Currently, the team has developed and simulated a launch-vehicle design using RockSim software and has tested this design through a subscale model flight. Ian is the designated safety officer, who will ensure and guarantee the safety of the team and civilians throughout the life cycle of the launch vehicle (construction, static/ground-testing, launching, etc.). The team is prepared to engage in further development and construction of the proposed launch vehicle once approval from NASA has been obtained to proceed with the construction of the full-scale launch vehicle and the GPS Mapping Live Telemetry payload. The team is a part of a program that has participated in the NASA SLI project for the past ten years. Therefore, the team is aware of all requirements and actions needed to carry out the project as planned. The team will continue selling junk food after school in order to raise funds for the project. Leading up to the SLI trip, outreach events, such as those involving the Women in Engineering Society, will be continuously planned to engage as many students as possible. By doing so, the team will not only be teaching young children about our program, but also spreading the word of it as well. Plantation High School's Aerospace program has grown vastly over the course of the years and has become something to be proud taking part of.