Flight Readiness Review

Texas Tech University - Space Raiders

Our Team

- Faculty Advisor: Andrew Mosedale
- Adult Educator: Barre Wheatly
- Team Mentor: Bill Balash
- Team Leader: Davis Hall
- Safety Lead: Derrick Slatton
- Vehicle Lead: Edward Hieb
- Recovery Lead: Matthew Rowe
- Payload Lead: Jacob Hinojos

Launch Day Rocket and Payload Dimensions

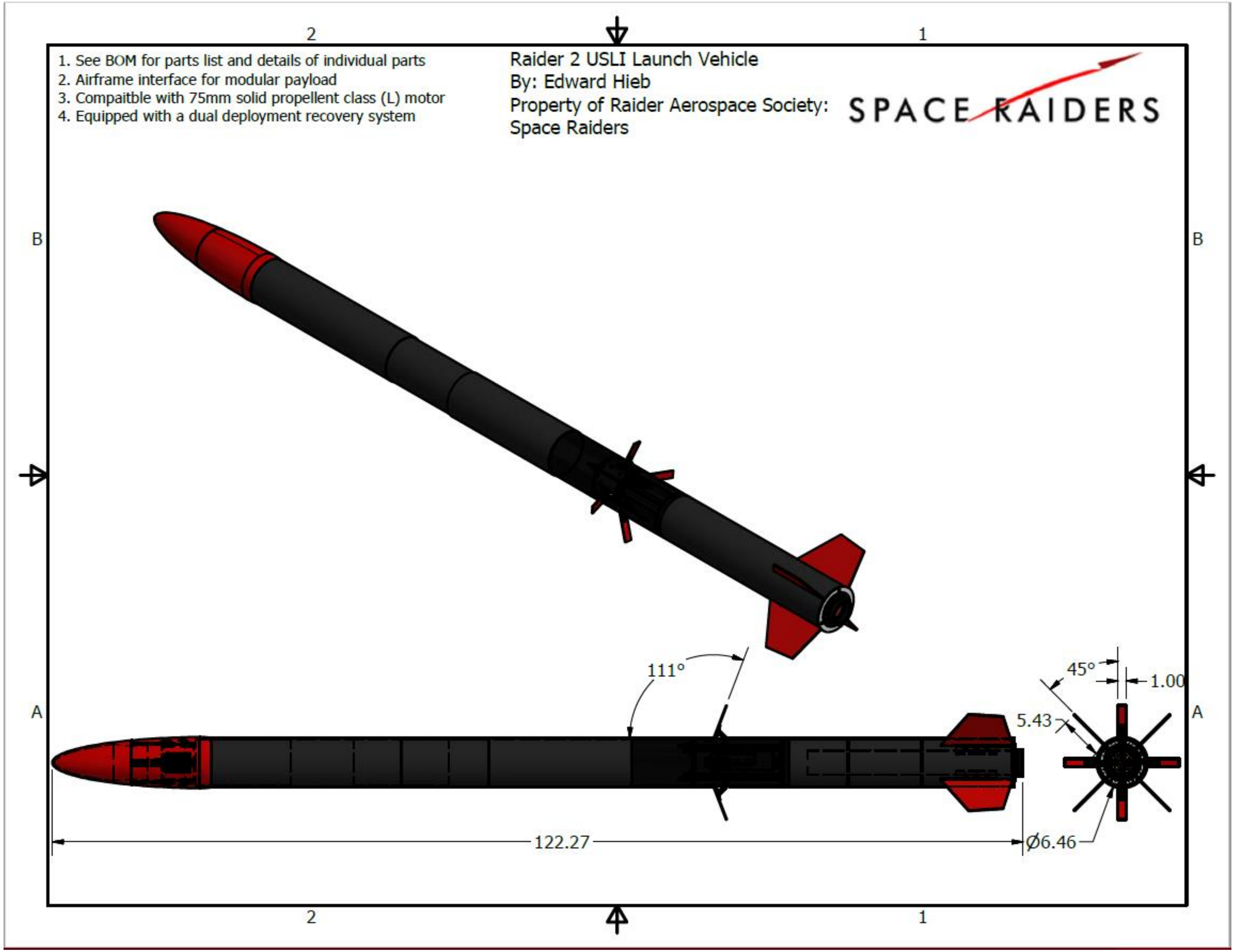
Rocket Dimensions

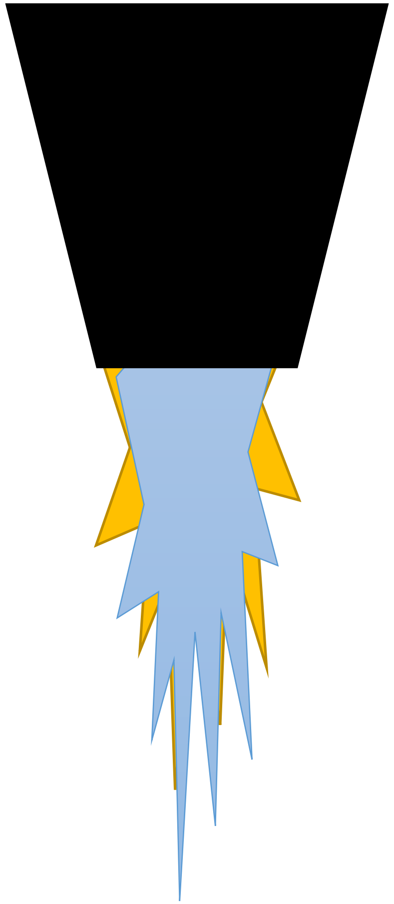
- Height: 10.37 ft
- Inner Diameter: 5.98 in
- Outer Diameter: 6.37-6.5 in
- Mass on Pad: 44.01 lbs
- Dead Mass: 36.93 lbs
- Mass Margin: 44 - 48 lbs

Rover Dimensions

- Length: 4.25 in
- Width: 2.9 in
- Height: 2.13 in
- Payload Section Length: 7.55 in
- Bearing Inner Diameter: 4.92 in
- Bearing Outer Diameter: 5.79 in

Vehicle Design





Launch Vehicle Weight Summary (Huntsville)

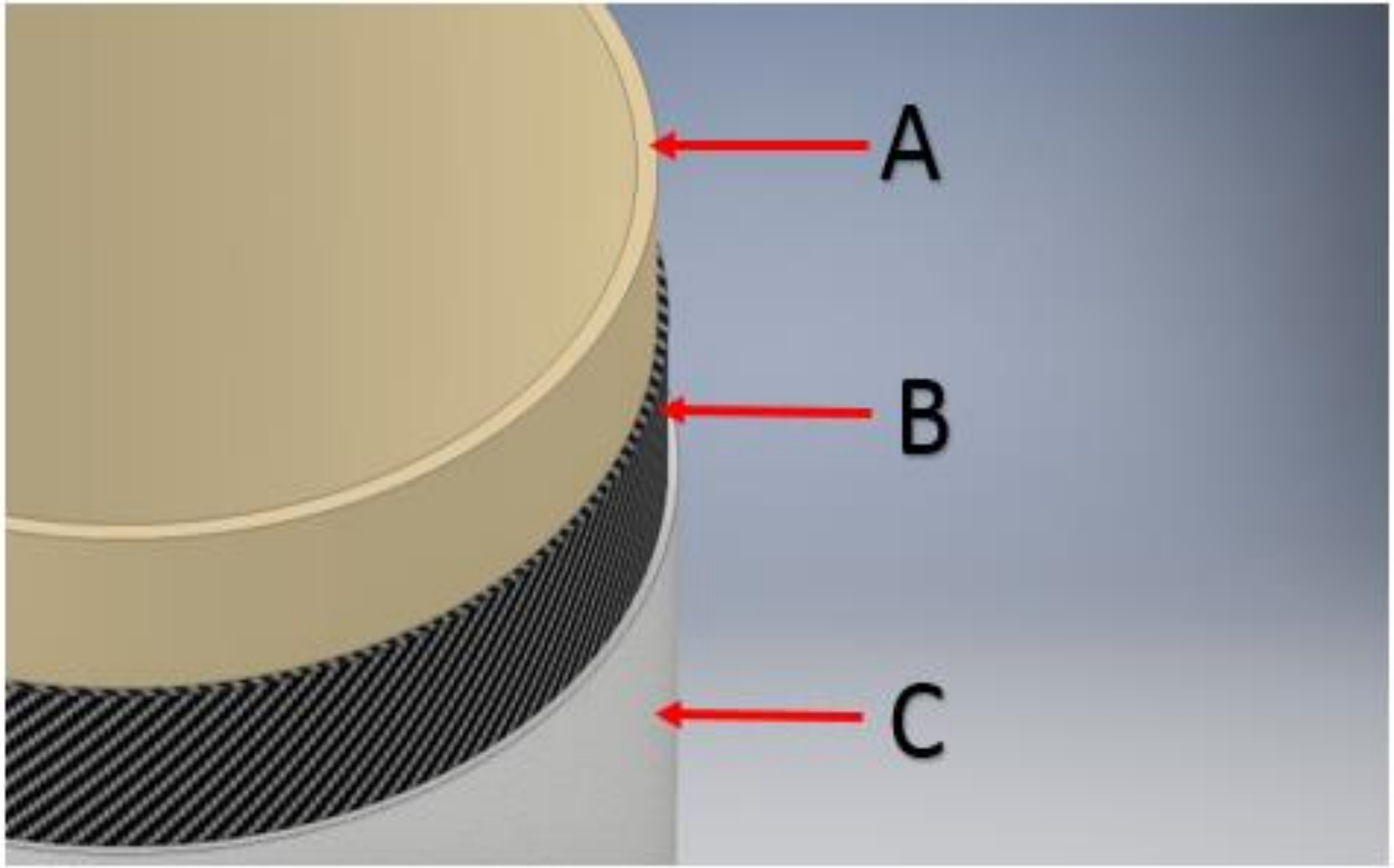
- Nose Cone Assembly Mass ……………………………………………………3.55 lbs
- Payload Section Mass ……………………………………………………………6.22 lbs
- E-Bay Section Mass …………………………………………………………….12.61 lbs
- Motor Grain and Casing Mass ……………………………………………..9.52 lbs
- Aft Section Mass ………………………………………………………………..14.55 lbs
- Ballast Weight (Huntsville)…………………………………………………..2.67 lbs
- Total Pad Weight (as launched)…………………………………………..46.68 lbs

Launch Vehicle Air Frame

- 6in Blue Tube Body Tube
  - Rigid, single piece design for aft (DACS & motor) section
  - Cheaper and easier to modify
  - Light weight
- 6in Carbon & Kevlar Reinforced Phenolic Body Tube
  - Reinforced strength for separating sections
  - Better blast containment for separation charges
- 6in Blue Tube Coupler
  - Thinner wall thickness to maximize fuselage space
  - Light weight

Composite Phenolic Carbon Kevlar Tube

- Layer A: Phenolic
- Layer B: Carbon Fiber
- Layer C: Kevlar



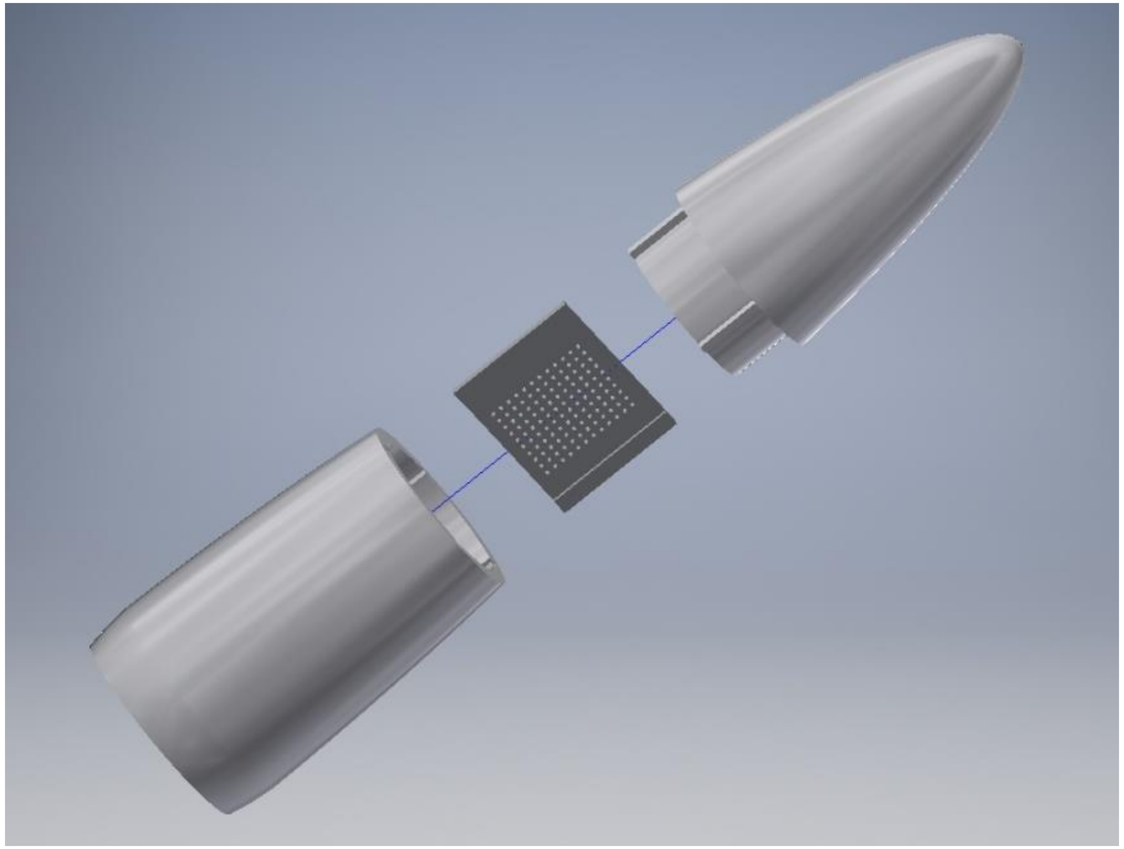
Bulkheads

- Multi-layer Plywood
  - Inexpensive and Lightweight
  - Easy to machine and mount
- Fiberglass Reinforced Plywood
  - Strong and lightweight
  - Easily machined
- G10 Fiberglass
  - Superior strength-weight ratio
  - Low space occupation due to 3/16th inch thickness
- Aluminum
  - High strength and weight
  - Complex and rigid mounting surface

Nose Cone

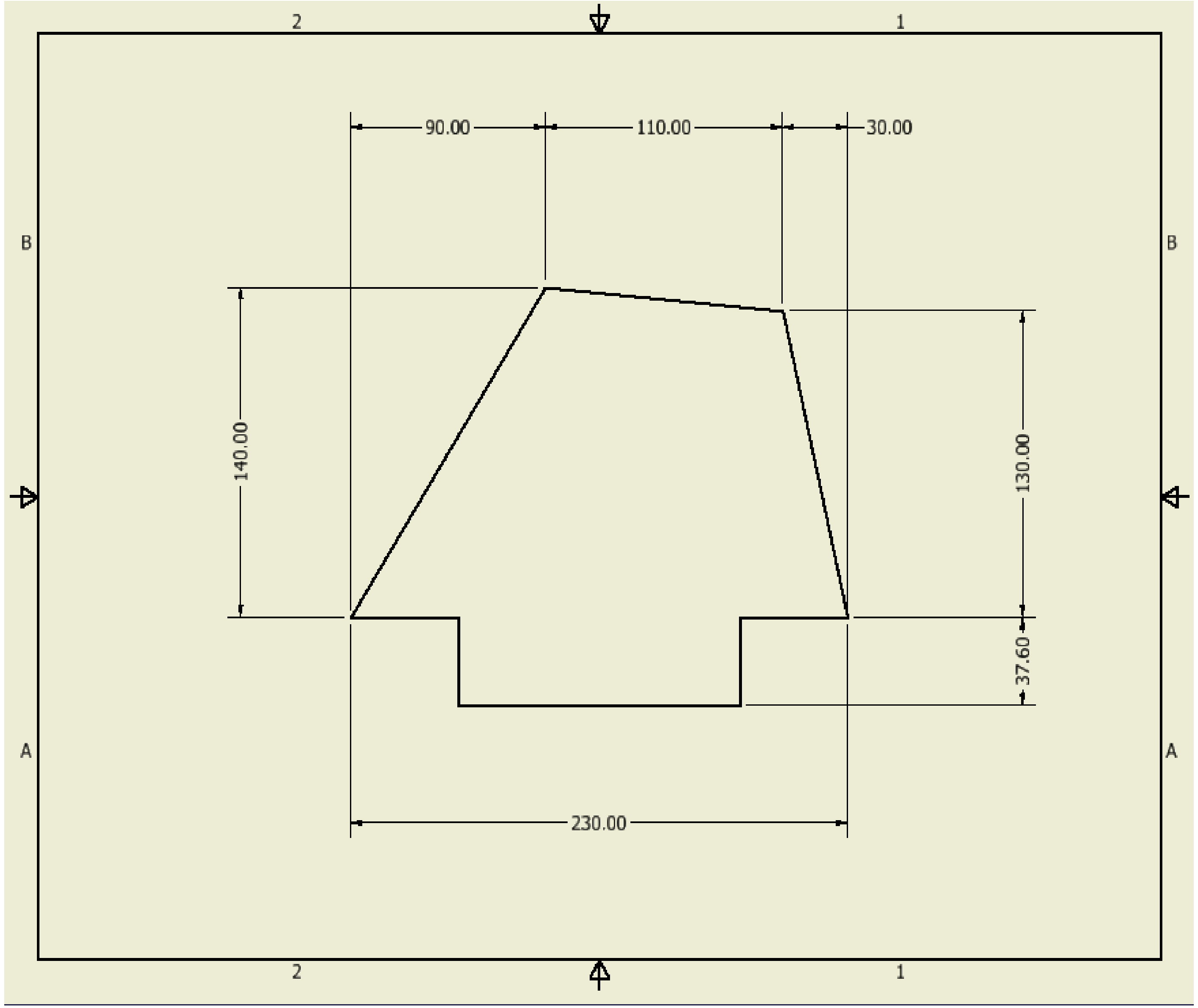
3D Printed Polycarbonate – Long Elliptical Shape

- High density print (60%)
- Part sled for mounting electronics
- Low drag due to geometry
- Affordable and customizable



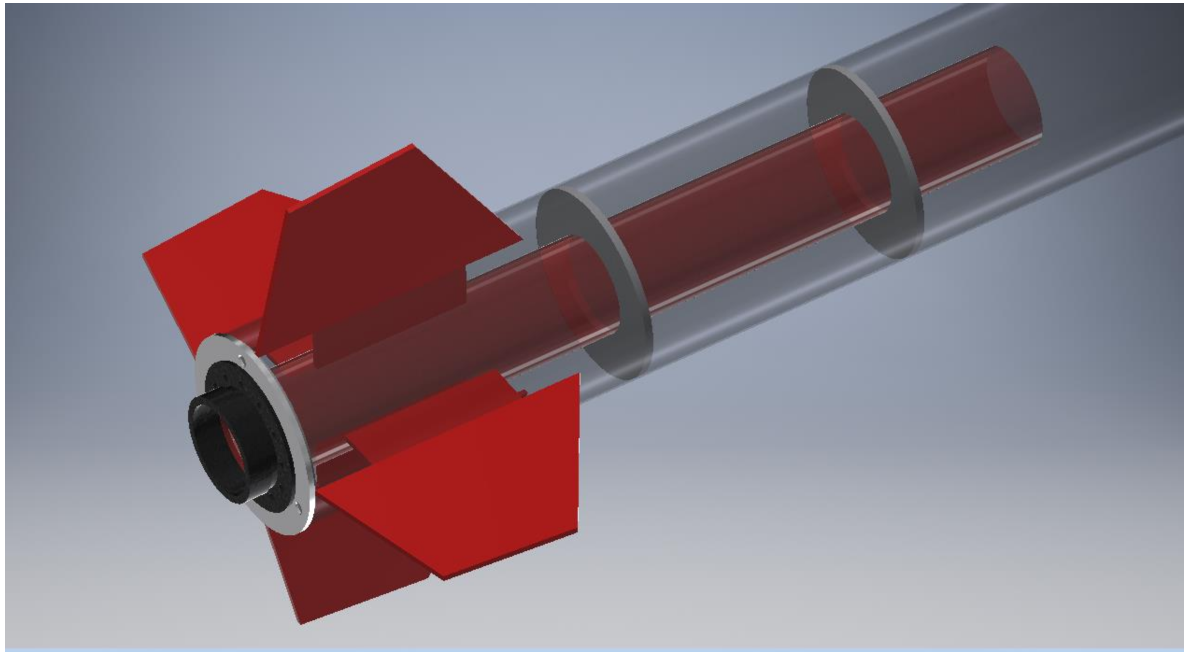
Final Fin Design
G10 Fiber Glass

- Heat resistant
- High tensile strength
- High strength-weight
- Reduces fin flutter
- Available in 3/16 inch
- Easily sanded using wet sanding technique



Internal Interfaces

- Couplers
  - Shear Pins & Screws
- Rover Housing
  - Bear/Coupler Interface
  - Rover/Guide Rail Interface
- Motor Mount
  - Thrust Plate
  - Centering Rings
- Nose Cone



Rail Button Selection
1515 Delrin Rail Buttons

- Commercially available
- Allows spacing for nose cone
- Delrin plastic is affordable

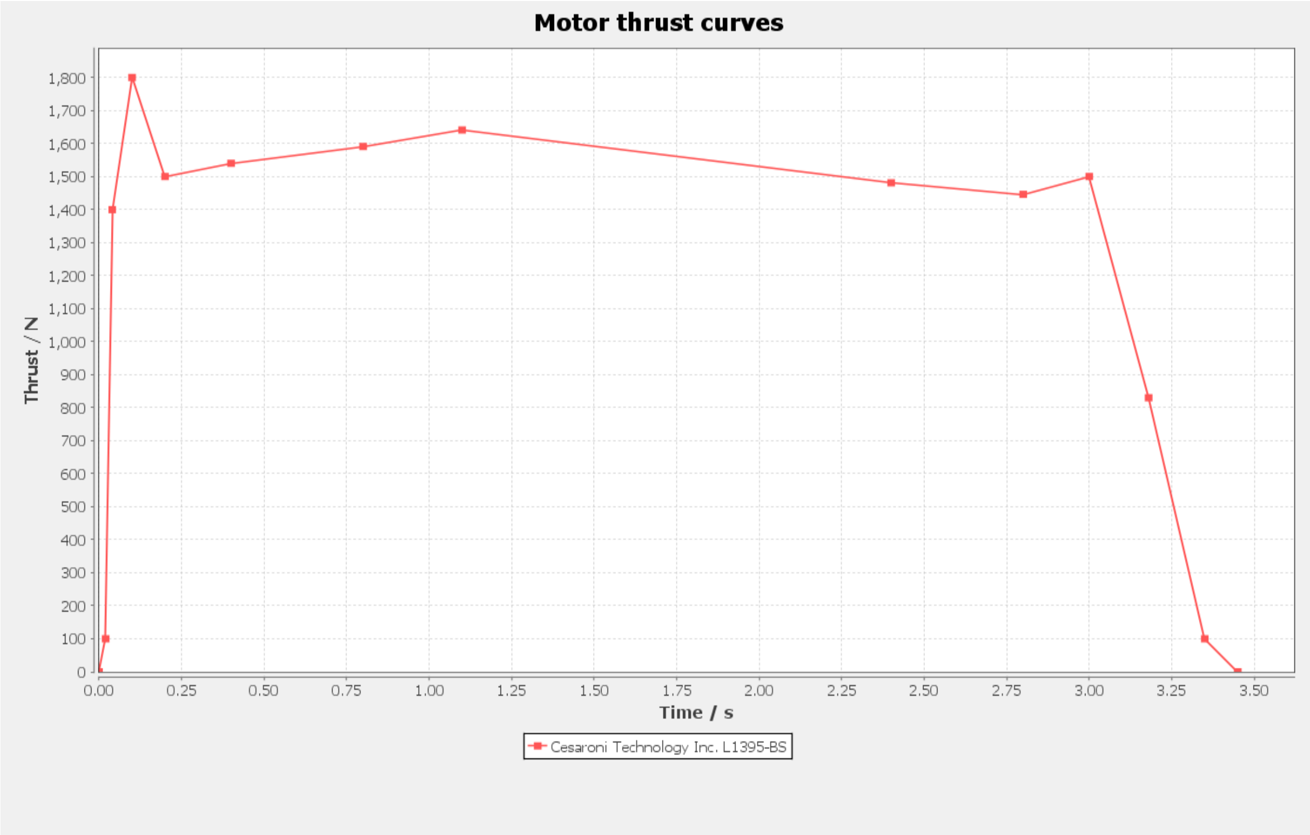
External Interfaces

- Launch Pad
  - 12 feet tall (Huntsville)
  - 10 feet tall (LS Test Flight)
- Guide Rails
  - 1515 Rails
  - 1515 Rail Buttons

Final Motor Selection

Cesaroni L1395 – BS (Blue Streak)

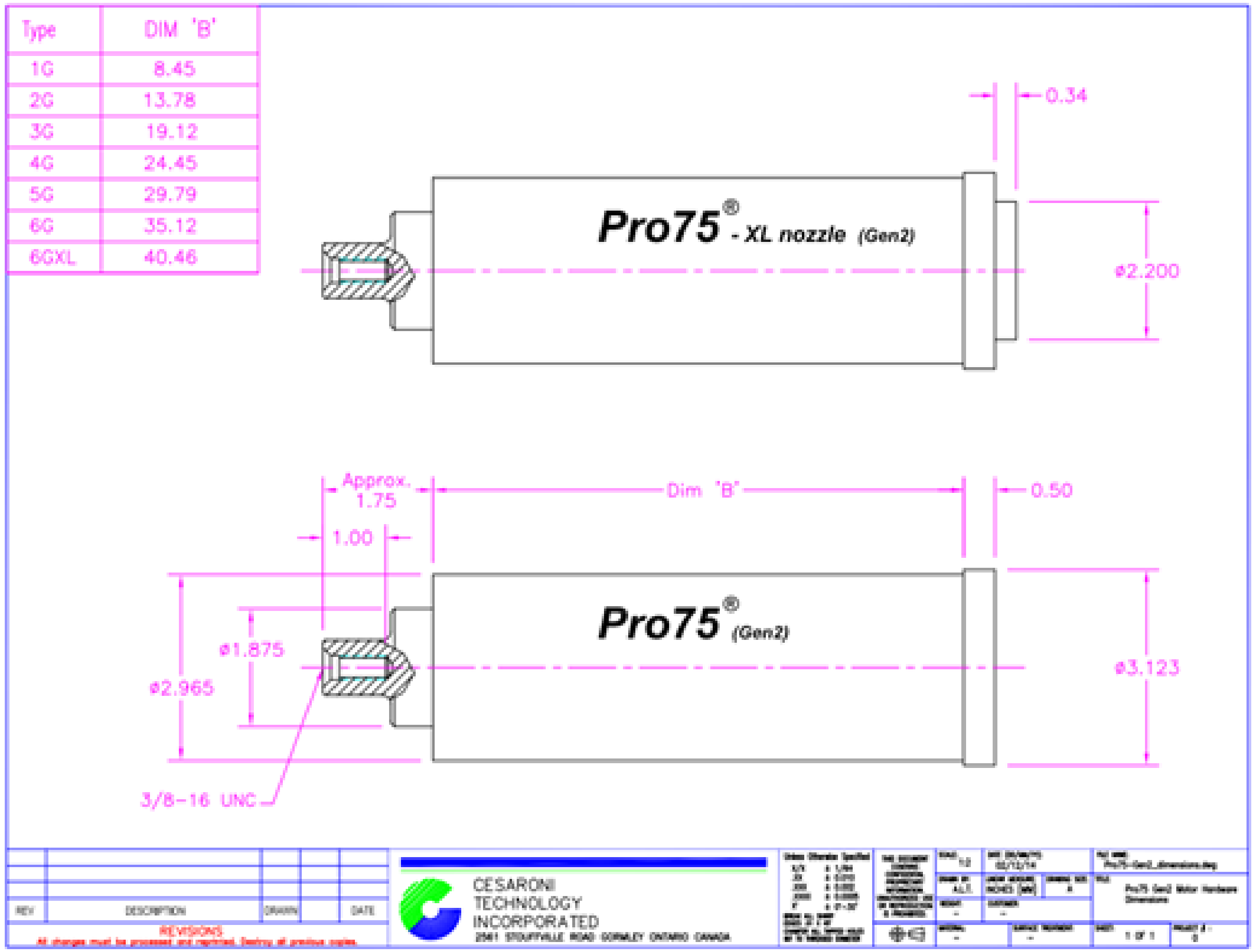
- 75mm, 4 Grain
- Average Thrust: 328.9 lbf
- Max Thrust: 404.7 lbf
- Total Impulse: 1100.4 lbf-s
- Burn Time: 3.45s
- Launch Mass: 9.5 lbm
- Dead Mass: 4.1 lbm



Motor Hardware

Cesaroni 75mm Casing

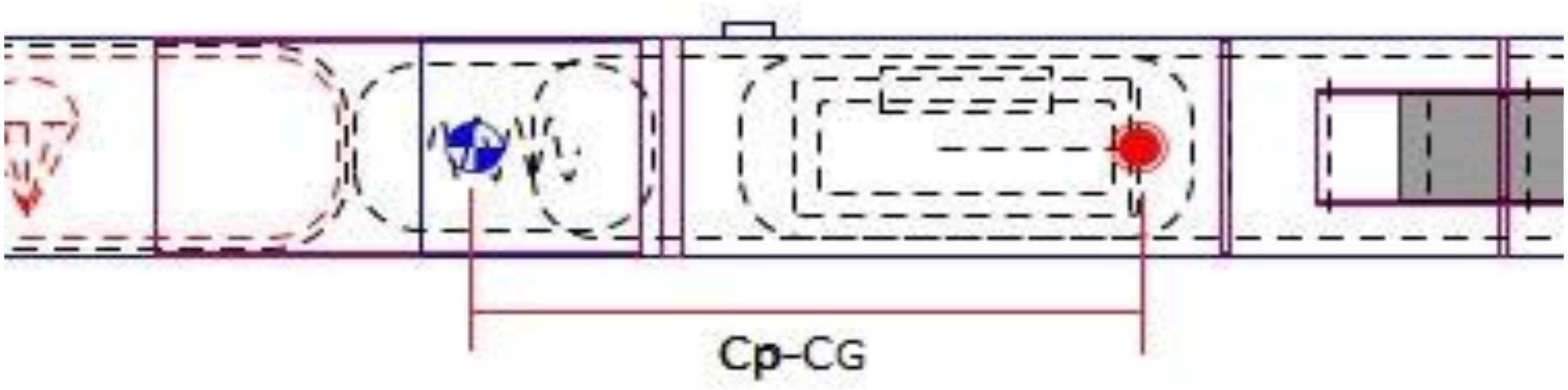
- Cesaroni manufactures casings for their motors therefore they are directly compatible with any of their motors
- CNC machined 6061 – T6 anodized aluminum



Stability Factor

$$Stability\ Factor = \frac{C_P - C_G}{d}$$

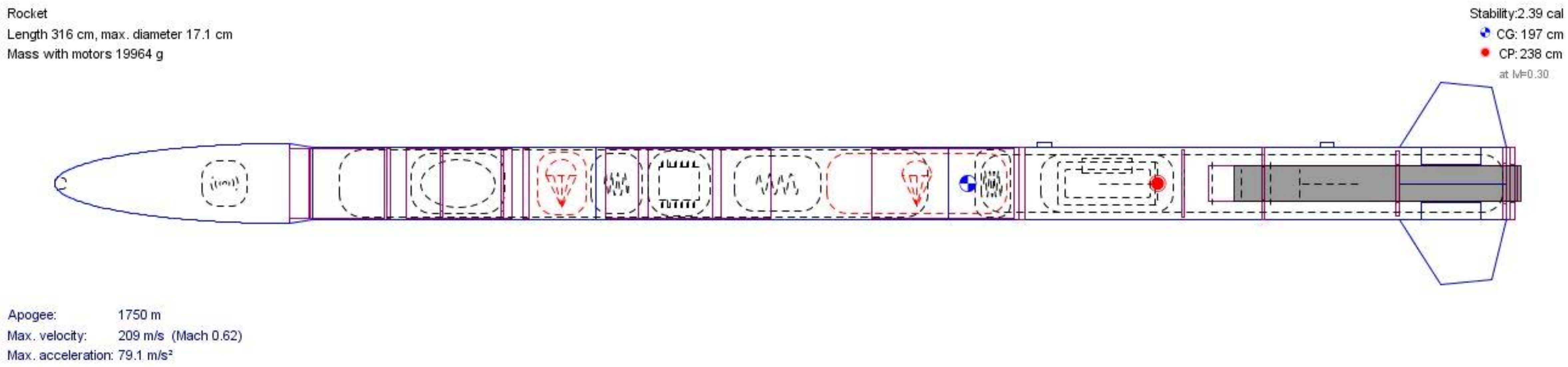
$$Stability\ Factor = \frac{238\ cm - 197\ cm}{15.24\ cm} = 2.69$$



Thrust to Weight Ratio

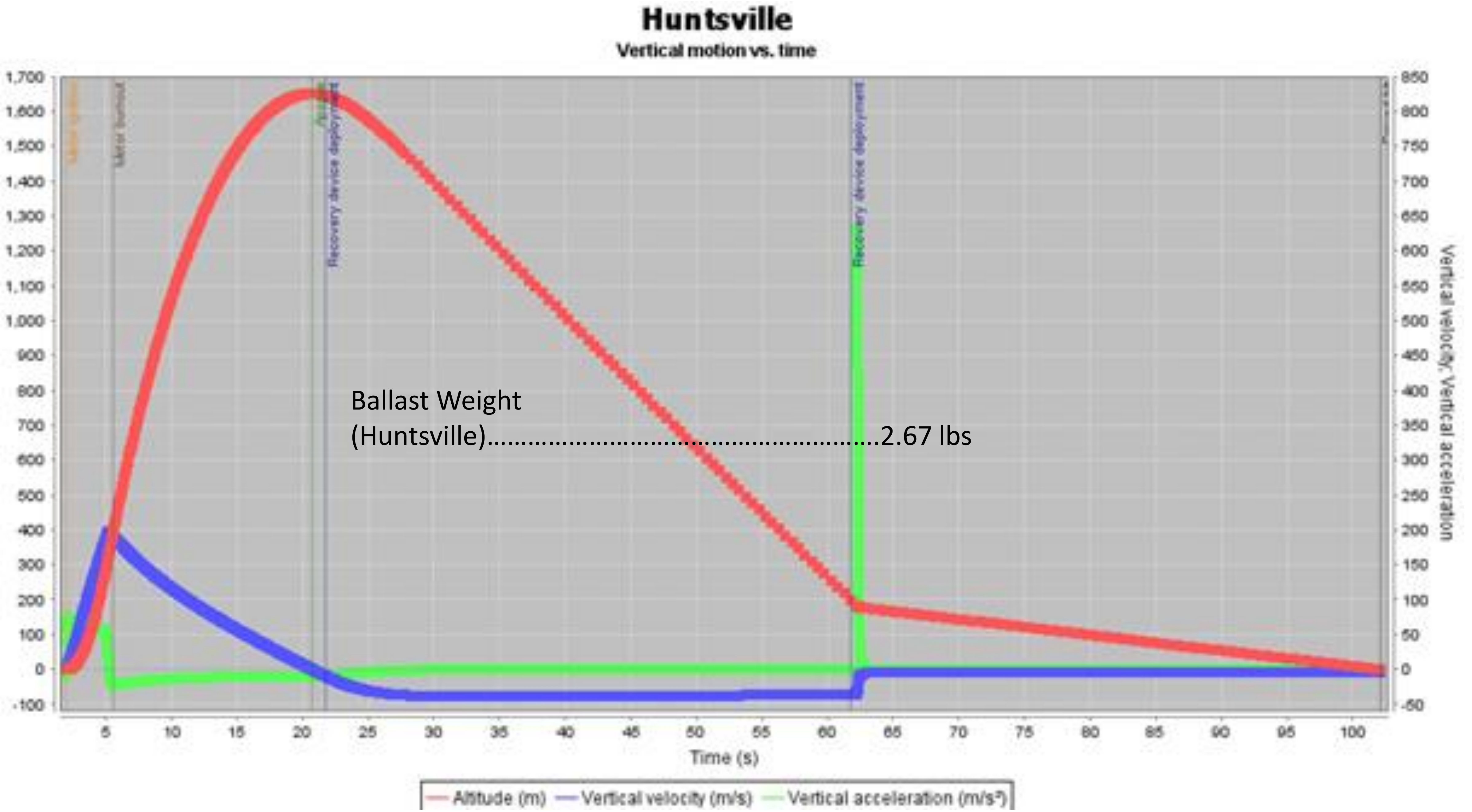
$$Thrust\ to\ weight\ ratio = \frac{Average\ Thrust}{Weight}$$

$$Thrust\ to\ Weight\ Ratio = \frac{1395\ N}{19.96\ kg * 9.81\ \frac{m}{s^2}} = 7.12$$



Altitude Predictions

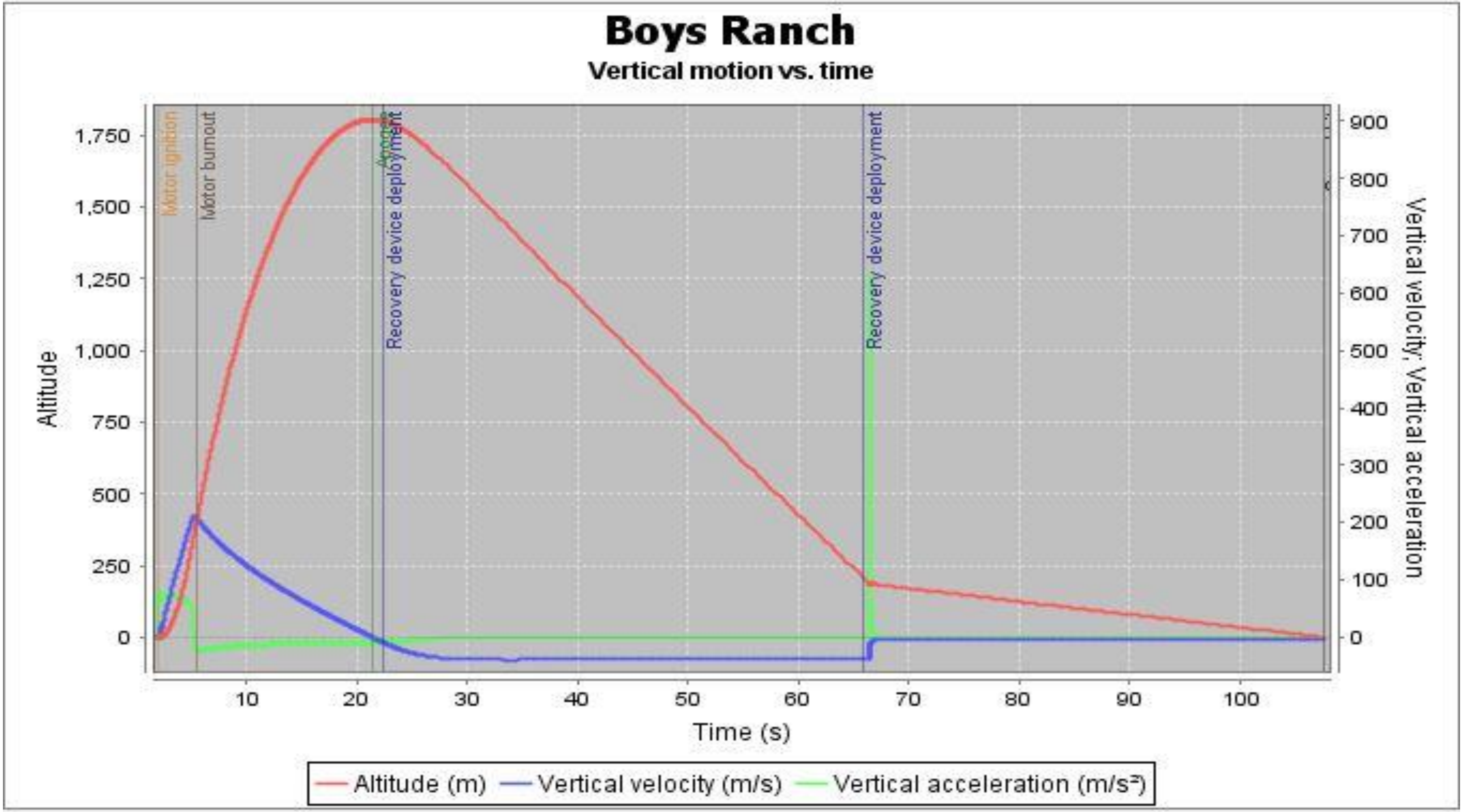
Wind Speed (mph)	Altitude (m)	Altitude (ft)
5	1654	5426
10	1644	5393
15	1632	5354
20	1626	5334



Ballast Weight
(Huntsville)…………………………………………………….2.67 lbs

Large Scale Flight

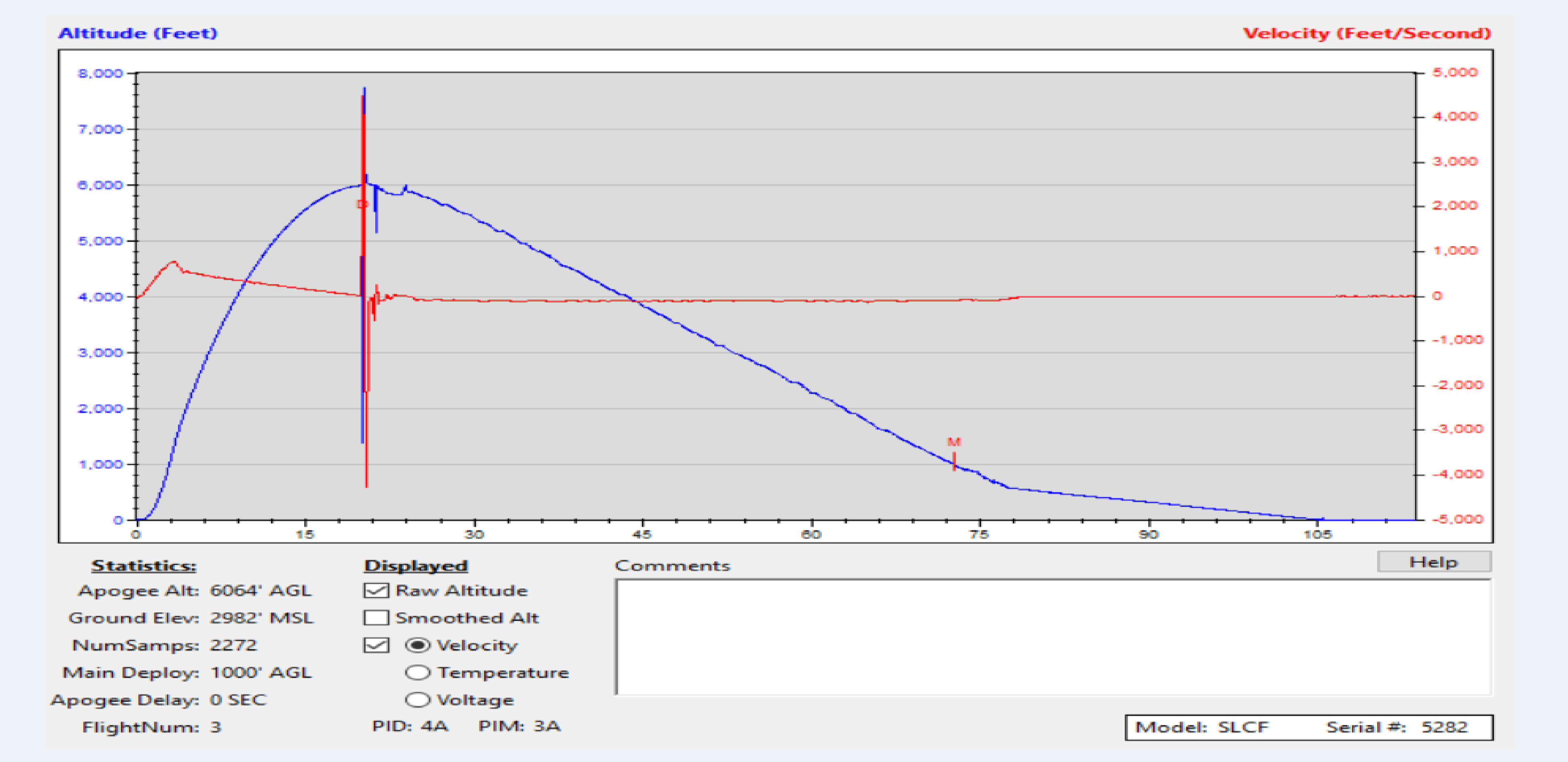
- We launched in Boys Ranch, TX (3/3/18)
- Weather conditions:
  - Wind Speed: 4mph
  - Sunny – Clear Skies
  - 40 Degrees F



Boys Ranch
Vertical motion vs. time
Motor ignition
Motor burnout
Apogee
Recovery device deployment
Recovery device deployment
Altitude
1,750
1,500
1,250
1,000
750
500
250
0
Vertical velocity; Vertical acceleration
900
800
700
600
500
400
300
200
100
0
10
20
30
40
50
60
70
80
90
100
Time (s)
Altitude (m)
Vertical velocity (m/s)
Vertical acceleration (m/s²)

Flight Results Data

- Apogee: 6064



Flight Failures and Solutions

- Payload bay shear pin failure
  - Resulted in destruction of ABS nosecone
  - Would have resulted in destruction of rover if it was present
- Solutions
  - Calculated new required shear pin size to withstand G forces of main deployment
  - Reprinting of nosecone with polycarbonate material instead of ABS

Large-Scale Test Flight Weight Summary (Boys Ranch)

- Nose Cone Assembly Mass ………………………………………………..3.55 lbs
- Payload Section Mass …………………………………………………….6.22 lbs
- E-Bay Section Mass ……………………………………………………….12.61 lbs
- Motor Grain and Casing Mass ………………………………………..9.52 lbs
- Aft Section Mass …………………………………………………………..14.55 lbs
- Total Pad Mass (as launched)………………………………………..44.01 lbs

Recovery

- Parachute sizes
- Recovery Harness Type
- Size
- Length
- Descent Rates

Parachute Sizes and Separation Charges

- Parachute Sizes
  - 4 foot pilot parachute
  - 2 foot drogue parachute
  - 16 foot main parachute

- Main Parachute charge sizes:
  - Main: 1.5g
  - Backup: 2.0g
- Drogue parachute charge sizes:
  - Main: 1.0g
  - Backup: 1.5g
- Nose cone separation charge sizes:
  - Main: 1.8g
  - Backup: 2.3g

Recovery Testing

- Separation Charge Testing
  - Drogue, Main, Nose Cone
- Shock Cord Bundling

Landing Kinetic Energy

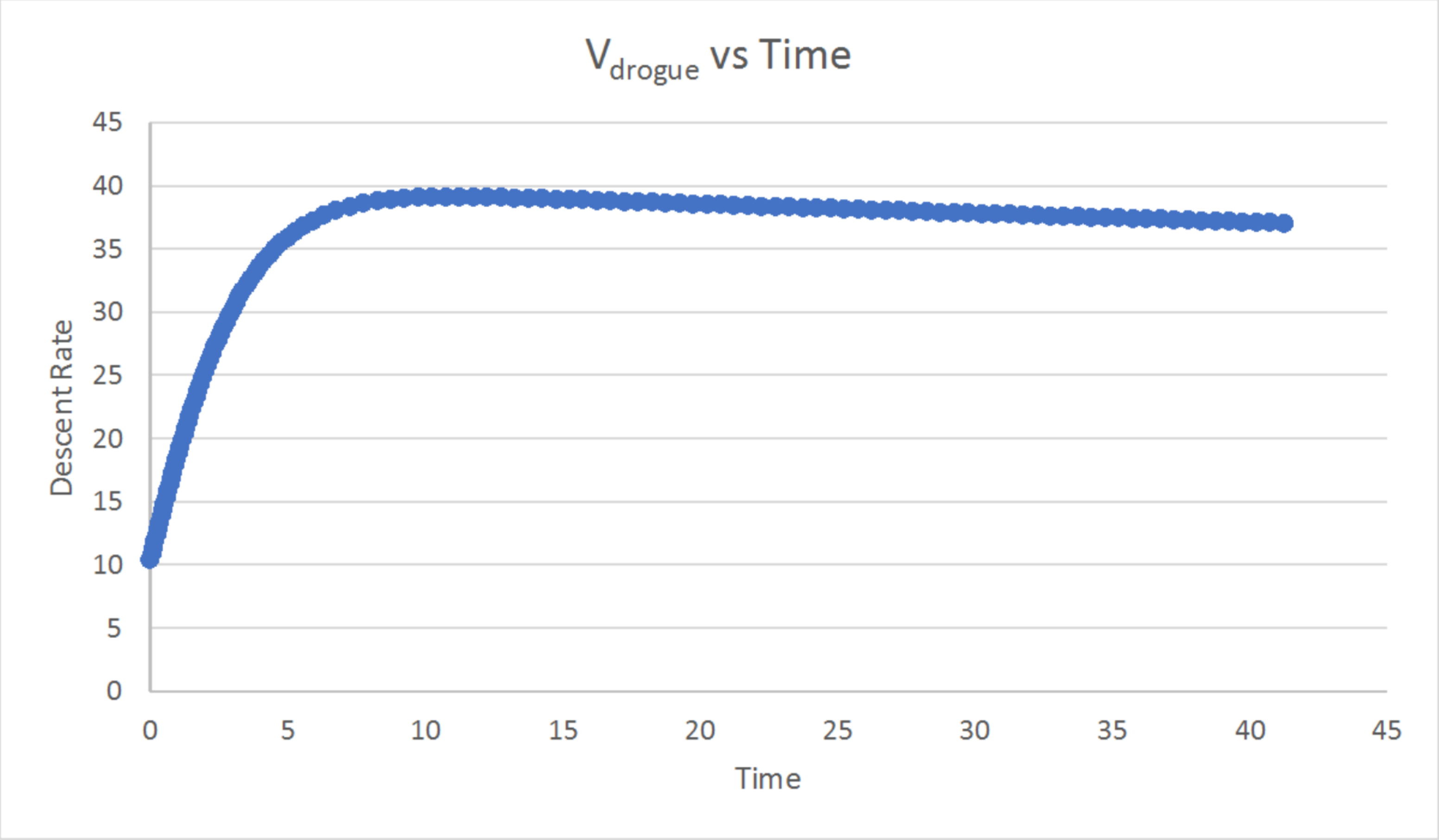
Kinetic Energy *FRR*			
Drogue Deployment			
	Section 1 (Forward)	Section 2 (Aft)	
Mass (g)	4451 g	13129 g	
Mass (lbm)	9.813 lb	28.944 lb	
Velocity (m/s)	38.082 m/s	38.082 m/s	
Velocity (ft/s)	124.941 ft/s	124.941 ft/s	
Kinetic Energy (J)	3227.506 J	9520.092 J	
Kinetic Energy (ft·lb)	2380.462 ft·lb	7021.660 ft·lb	
Main Deployment & Touchdown			
	Section 1 (Forward)	Section 2 (E-Bay)	Section 3 (Middle)
Mass (g)	4451 g	3752 g	8100 g
Mass (lbm)	9.813 lb	8.272 lb	17.857 lb
Velocity (m/s)	4.532 m/s	4.532 m/s	4.532 m/s
Velocity (ft/s)	14.869 ft/s	14.869 ft/s	14.869 ft/s
Kinetic Energy (J)	45.710 J	38.531 J	83.183 J
Kinetic Energy (ft·lb)	33.714 ft·lb	28.419 ft·lb	61.353 ft·lb

Drift Calculations

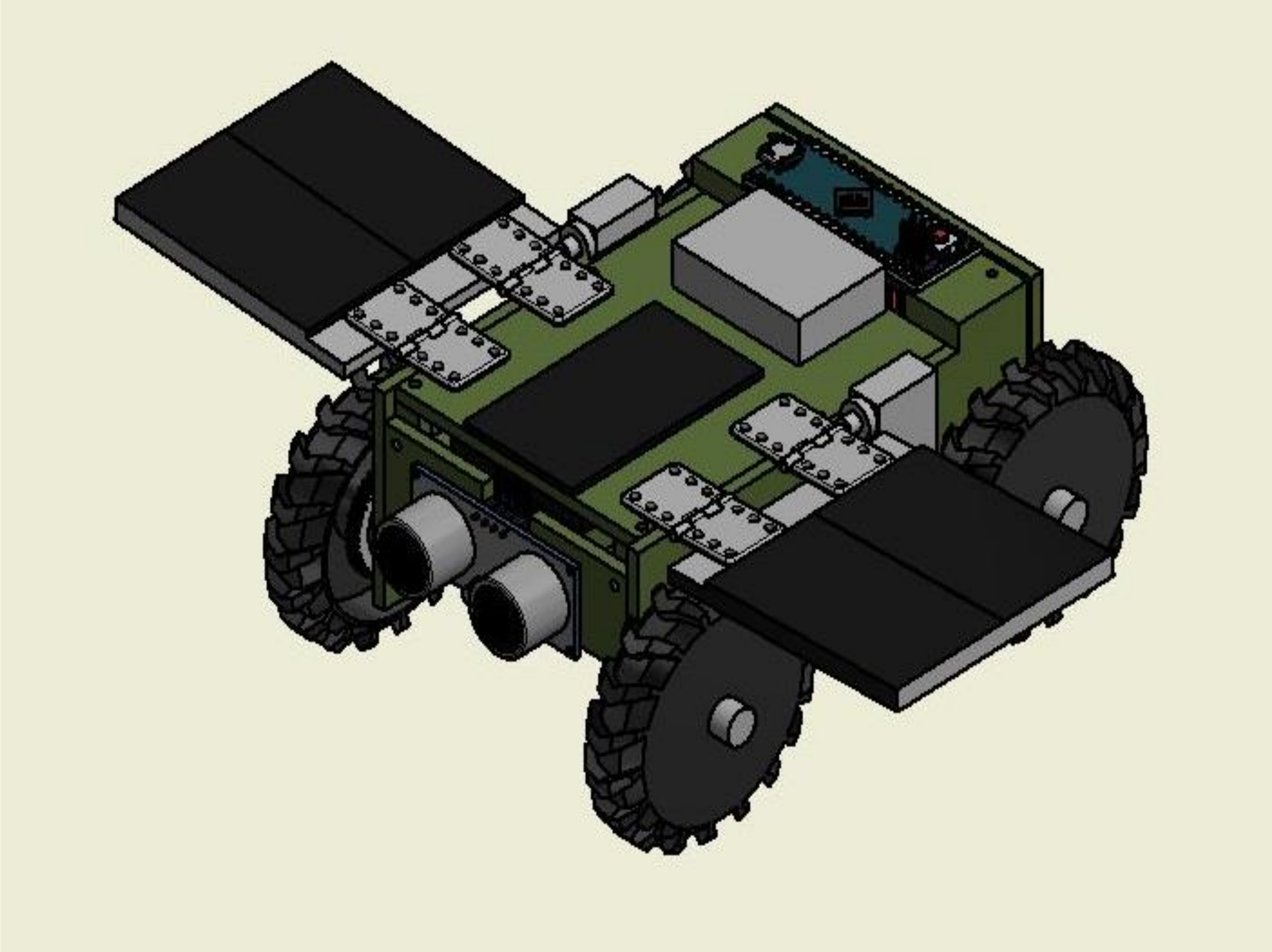
Nominal Drift (2 ft drogue and 16 ft main)					
Wind Speeds					
Wind Speed (mph)	0 mph	5 mph	10 mph	15 mph	20 mph
Wind Speed (ft/s)	0 ft/s	7.33333 ft/s	14.6667 ft/s	22 ft/s	29.3333 ft/s
Wind Speed (m/s)	0 ft/s	2.2352 m/s	4.4704 m/s	6.7056 m/s	8.9408 m/s
Drogue Drift					
Drift (ft)	0 ft	347.8360 ft	695.6719 ft	1043.5079 ft	1391.3438 ft
Drift (m)	0 m	106.0204 m	212.0408 m	318.0612 m	424.0816 m
Main Drift					
Drift (ft)	0 ft	207.8137 ft	415.6274 ft	623.4411 ft	831.2548 ft
Drift (m)	0 m	63.3416 m	126.6832 m	190.0248 m	253.3665 m
Total Drift (ft)	0 ft	555.6496 ft	1111.2992 ft	1666.9488 ft	2222.5988 ft
Total Drift (m)	0 m	169.3620 m	338.7240 m	508.086 m	677.4481 m

There was a 15% margin of error between simulated drift data and test drift data

Total Descent Rate (main and drogue combined)

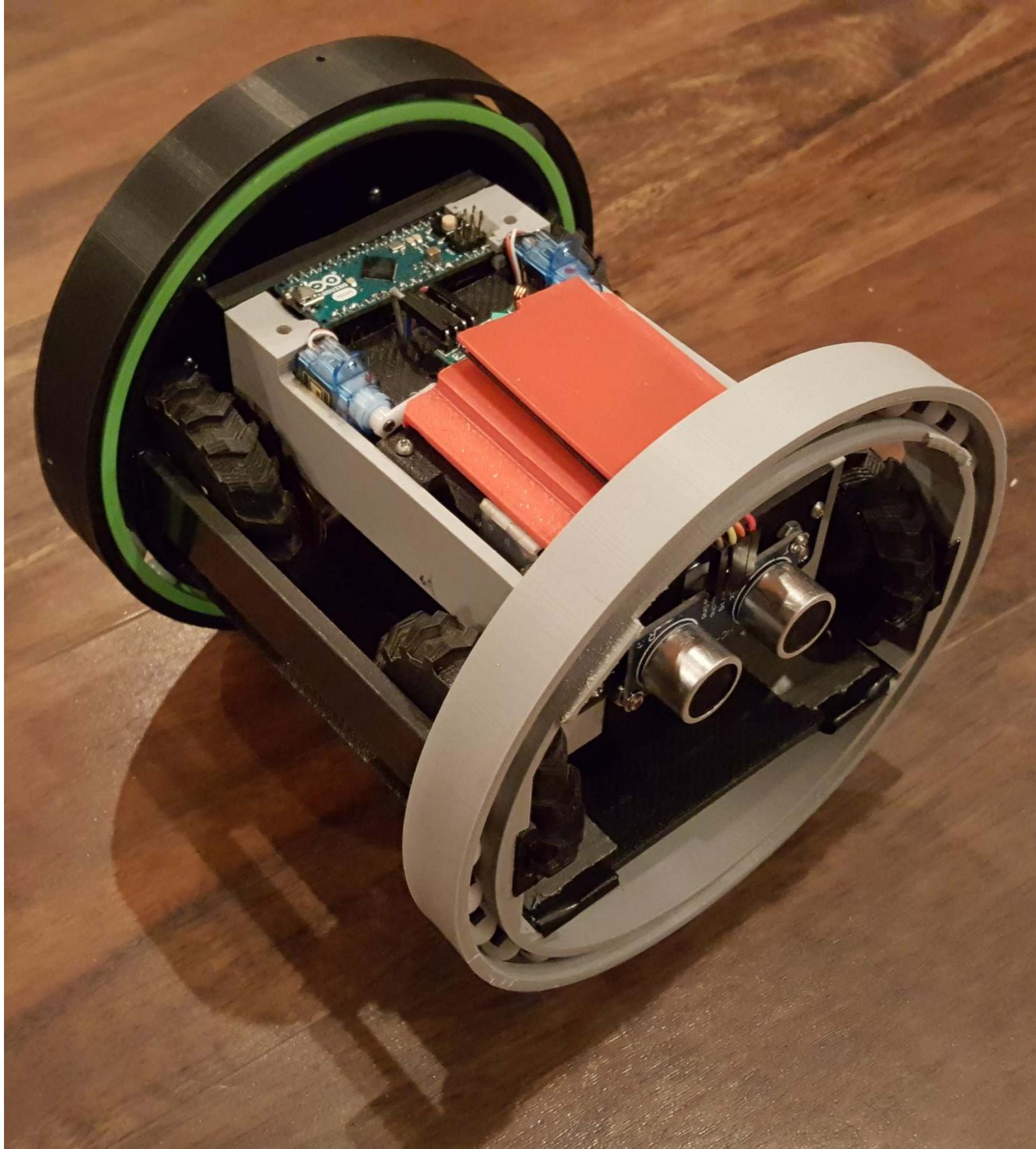


Payload



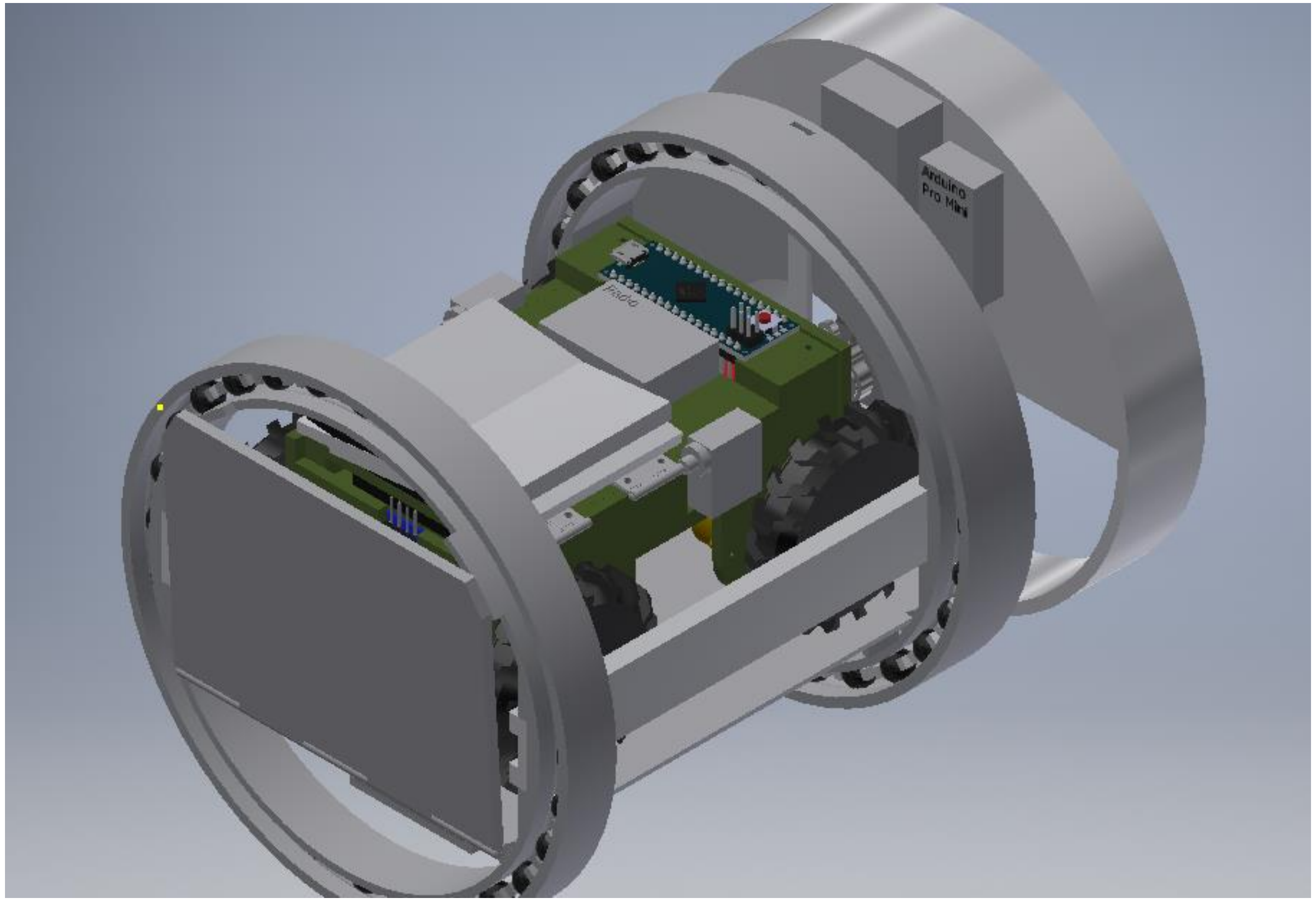
Payload Summary

- Rover Weight: 1lb, 0.2oz
- Payload Assembly Weight: 3.5lbs
- Rover Length: 5.87in
- Rover Width: 4.3in
- Rover Hight: 2.5in
- Wheel Diameter: 2.25in
- Bearing Housing ID: 4.92 in
- Bearing Housing OD: 5.79 in



Rover Design

- Rover Chassis
- Rover Housing
- Bayonet Fitting
- In Wheel drive train
- Ultrasonic Steering
- Hinged Solar Deployment



Payload Integration

- Mounted within a coupler tube
- Self-Orienting Housing
- Supporting wheel rail system
- Payload section of air frame composite upgrade

Rover Electronics

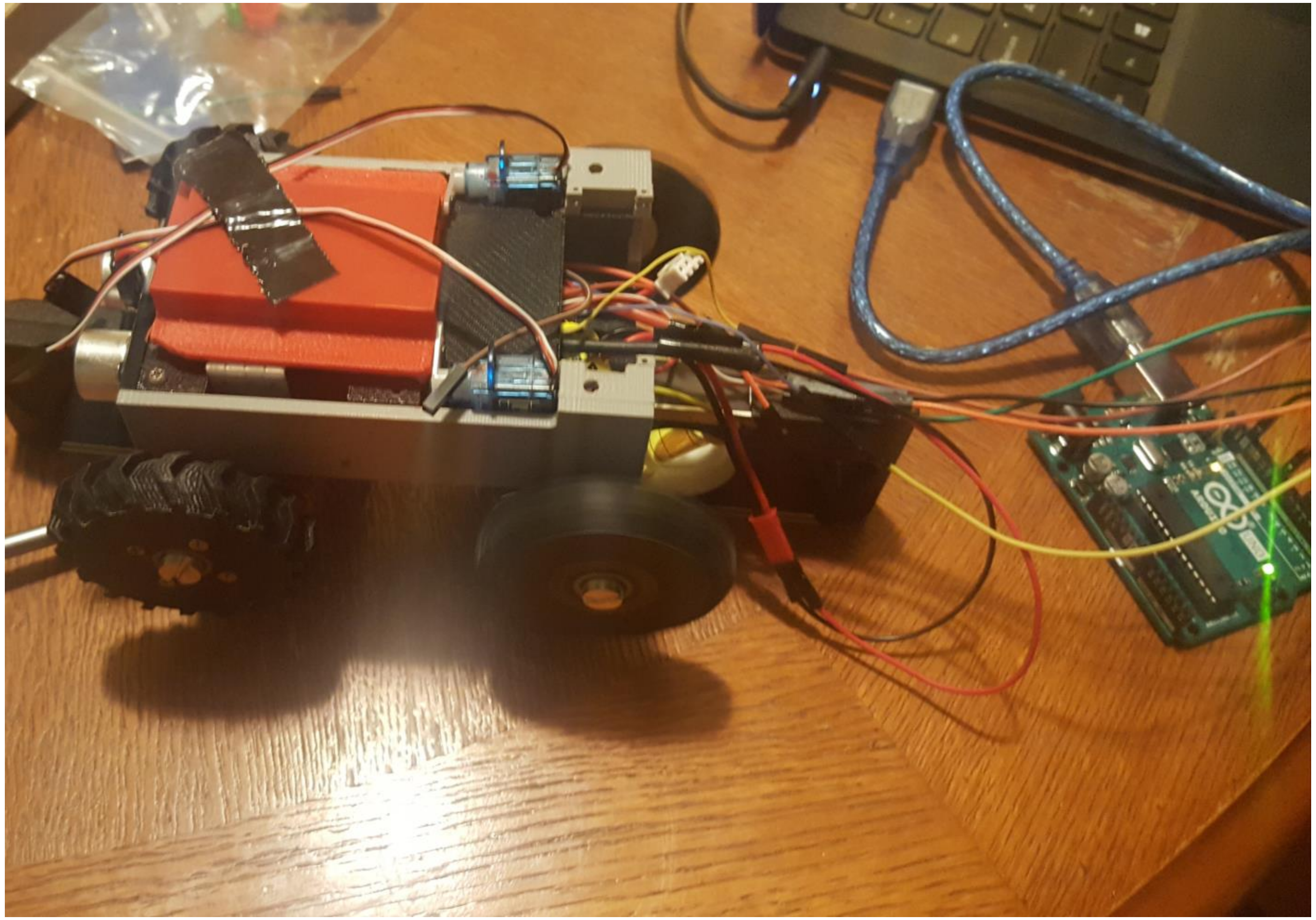
Travel Electronics

Microcontroller: Arduino Micro

- Small and light microcontroller that will carry out tasks and experiments

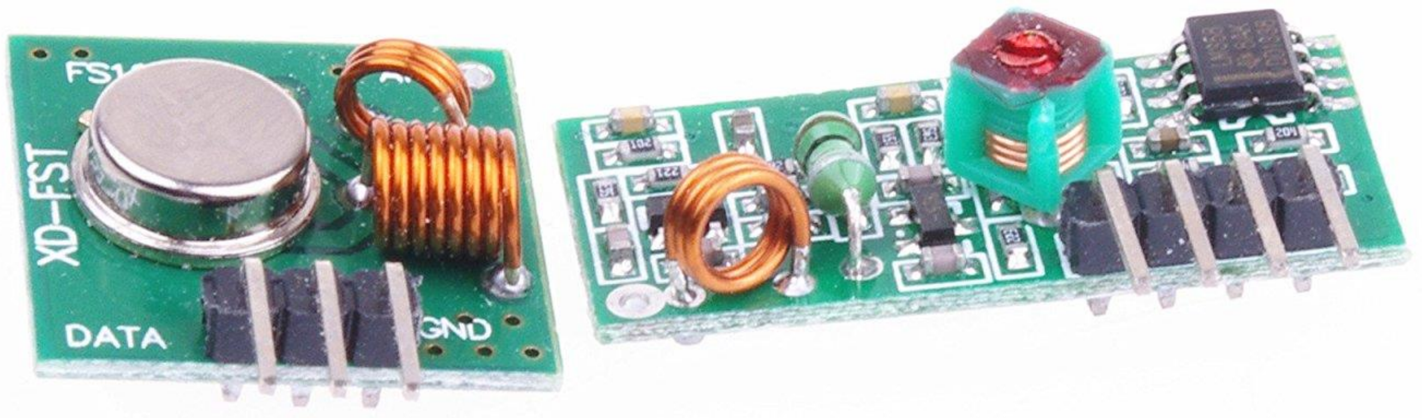
Ultrasonic Sensor:

- Used for obstacle avoidance



Changes Since CDR

- Motor mount
- Transmitter/receiver
- Bayonet locking pin
- Back servo mount



Payload Testing

- Motor power
- Gear meshing
- Rover egress
- Bearing load test

Requirements Verification

Vehicle & Recovery

- Apogee of 5280 ft
- Altimeters
- Exit Rail Velocity of 52 fps
- Rocket has max of 4 sections
- Main and Drogue Chute
- Nose Cone Ejection
- Parachute Entanglement

Payload & Safety

- Correct Rover Deployment
- Remote Activation of Rover
- Rover must travel 5 ft
- Rover Will Deploy Solar Panels
- Safe Launch Set Up
- Emergency Safety Equipment
- Behavior and Conduct

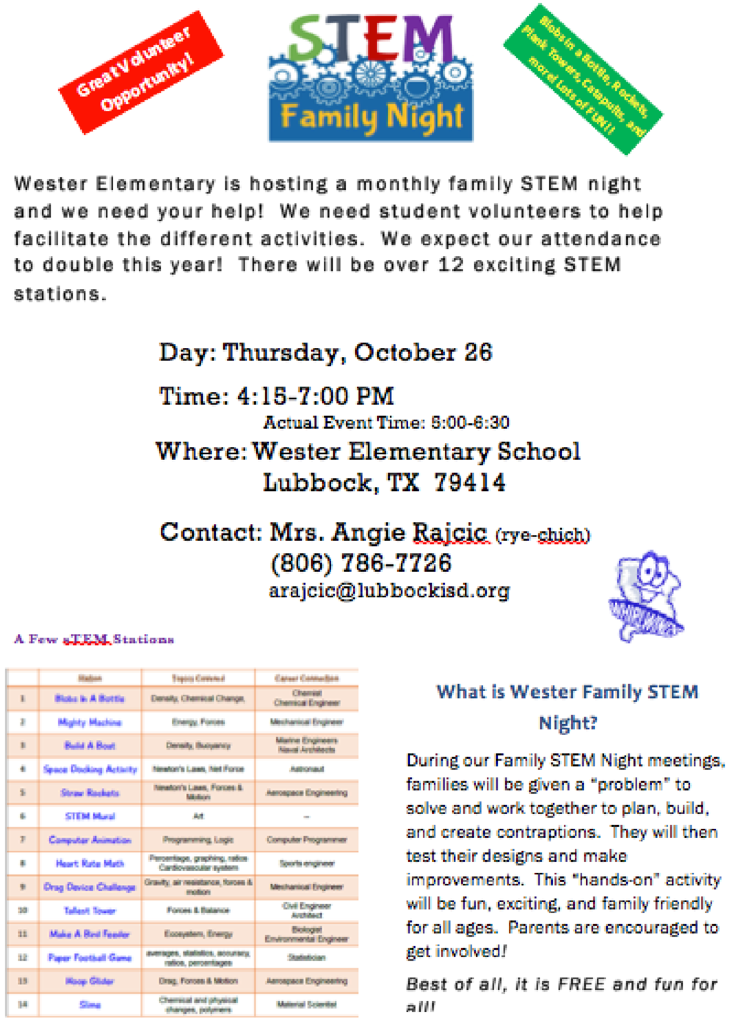
Safety Improvements

- Failure Mode Assessment Chart
- Hazards Recognition
- Environmental Concerns
- MSDS Data Sheets

Item	Identification	Description	Failure Modes	Cause of Failure	Effect On The	Safeguard and	Risk, 1-10
5	Eyebolt	Creates connection between the bulkhead and shock cord	• Eye bolts threaded end could get severed from bulkhead and lose the parachute or vehicle section upon deployment	• Vibrations during flight • Loose Fitting with bulkhead	• Failure to recover undamaged vehicle sections	• Inspect for yielding and proper welds	8
7	Nose Cone	Creates efficient drag coefficient and secures Payload experiment equipment	• Failure to deploy and separate • Nose Cone Damage	•Complication with the shear pins installed • Adjacent section premature deployment would cause unpredicted damage	• Failure to detach will prevent successful deployment of the rover • Damage to nosecone would affect the nosecone performance or payload continuity.	• In the event the nosecone is separated from the vehicle recovery system, a backup parachute has been installed • Larger shear pins installed and will be	9

Outreach

- Satisfied Outreach Requirement



	Station	Topics Covered	Career Connection
1	Blobs In A Bottle	Density, Chemical Change,	Chemist Chemical Engineer
2	Mighty Machine	Energy, Forces	Mechanical Engineer
3	Build A Boat	Density, Buoyancy	Marine Engineers Naval Architects
4	Space Docking Activity	Newton's Laws, Net Force	Astronaut
5	Straw Rockets	Newton's Laws, Forces & Motion	Aerospace Engineering
6	STEM Mural	Art	–
7	Computer Animation	Programming, Logic	Computer Programmer
8	Heart Rate Math	Percentage, graphing, ratios Cardiovascular system	Sports engineer
9	Drag Device Challenge	Gravity, air resistance, forces & motion	Mechanical Engineer
10	Tallest Tower	Forces & Balance	Civil Engineer Architect
11	Make A Bird Feeder	Ecosystem, Energy	Biologist Environmental Engineer
12	Paper Football Game	averages, statistics, accuracy, ratios, percentages	Statistician
13	Hoop Glider	Drag, Forces & Motion	Aerospace Engineering
14	Slime	Chemical and physical changes, polymers	Material Scientist