Penn State
LionTech Rocket Labs

Flight Readiness Review

Presentation Overview

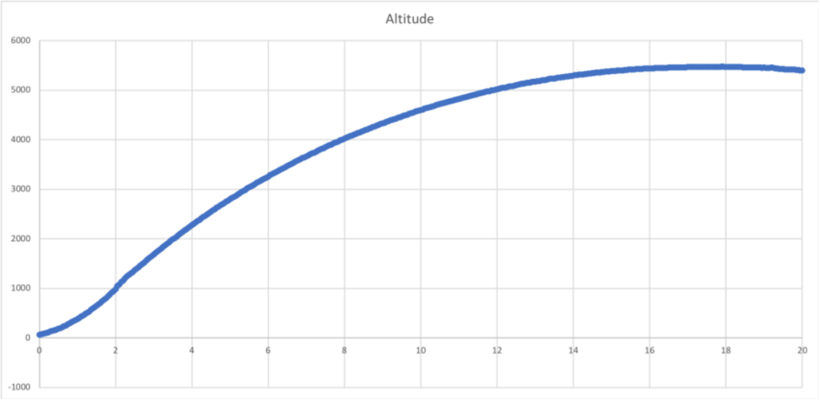
- Team Introductions
- Structures: Rocket Design
- Propulsion: Motor Selection and Future Testing
- A&R: Recovery System
- Payload: Rover Design
- Safety
- Budget
- Timeline
- Questions

Team Introduction

President:	Justin Hess
Vice President:	Torre Viola
Structures Leads:	Anthony Colosi
	Joshua Dubs
	Greg Schweiker
Propulsion Lead:	Matt Easler
A&R Leads:	Gretha Dos Santos
Payload Leads:	Lawrence Lee
	Jackson Sizer
	Joey Weston
Safety Officer:	Laura Reese
Treasurer:	Kristi Roth

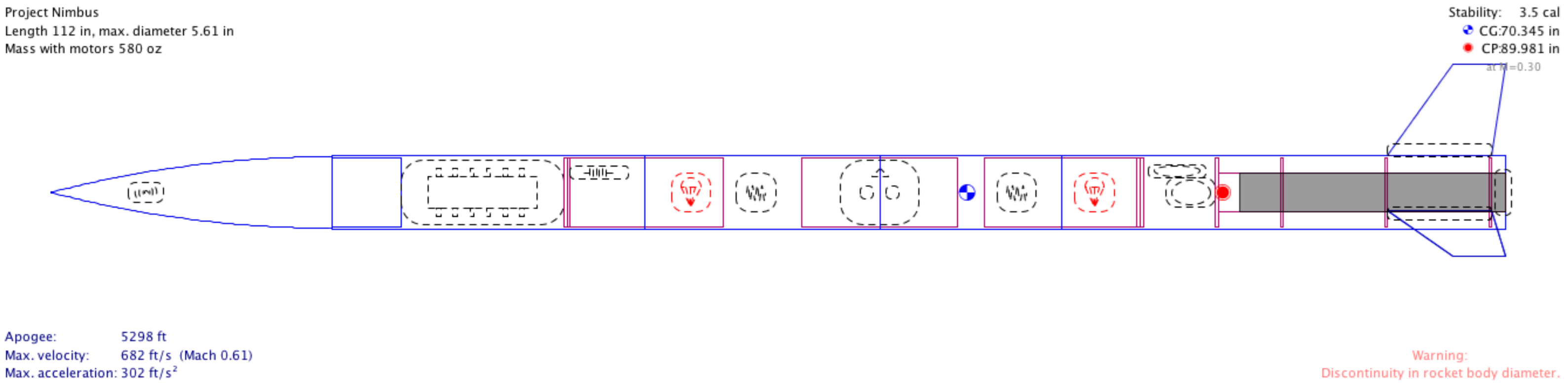
Fullscale Results

- The vehicle reached a 5472 ft apogee at 18.1 seconds into flight, matching our simulations with a 1% difference in apogee in and a 1.9% difference in time to apogee.



- Launch day procedures were very smooth and all subsystems performed nominally.

Vehicle Characteristics



- Length = 112 inches
- Total mass = 36.3 pounds
- Outer Diameter = 5.61 inches

MATLAB

- Stability: 3.74 calibers
- CG: 68.53 inches
- CP: 89.49 inches

OpenRocket

- Stability: 3.59 calibers
- CG: 69.86 inches
- CP: 89.98 inches

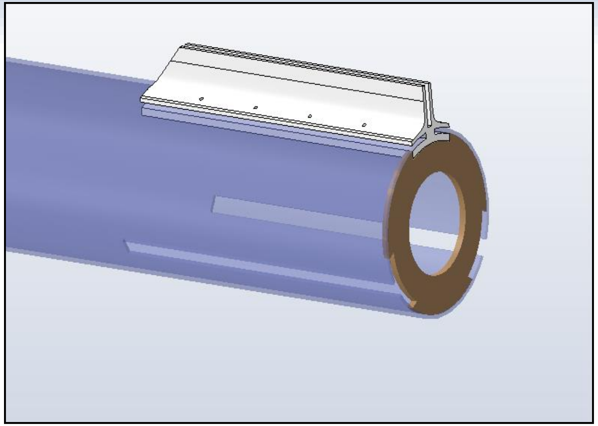
Component Masses

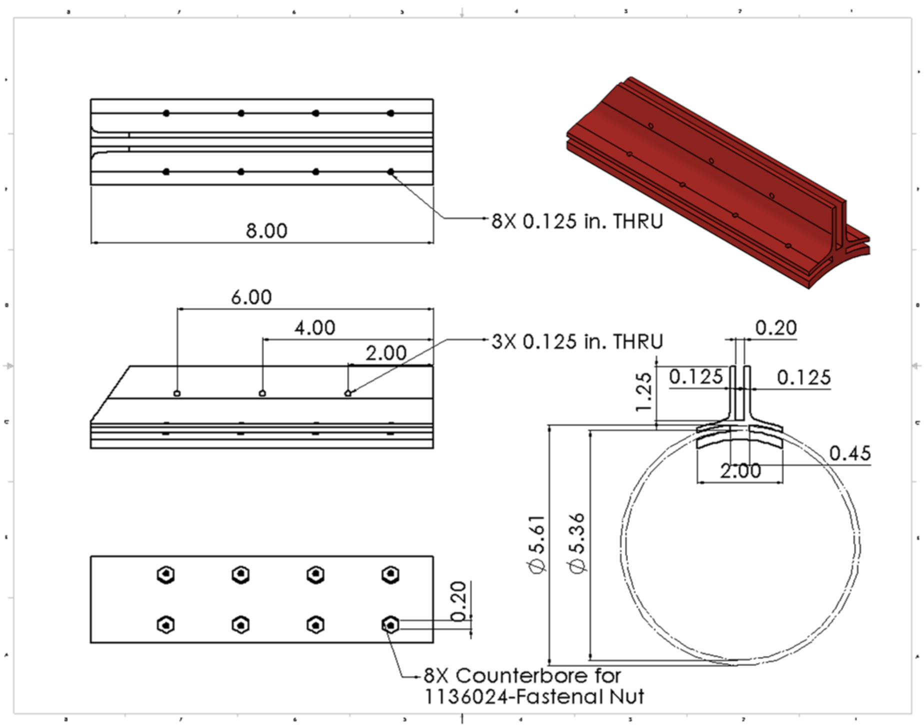
Component	Mass (oz)
Nose Cone	51.8
Payload Section	89.6
Payload-Main Coupler	17.4
Main Parachute Section	54.3
Main-Drogue Coupler	82.9
Drogue Parachute Section	37.4
Drogue-Booster Coupler	17.0
Booster Section	260.7

Airframe Construction

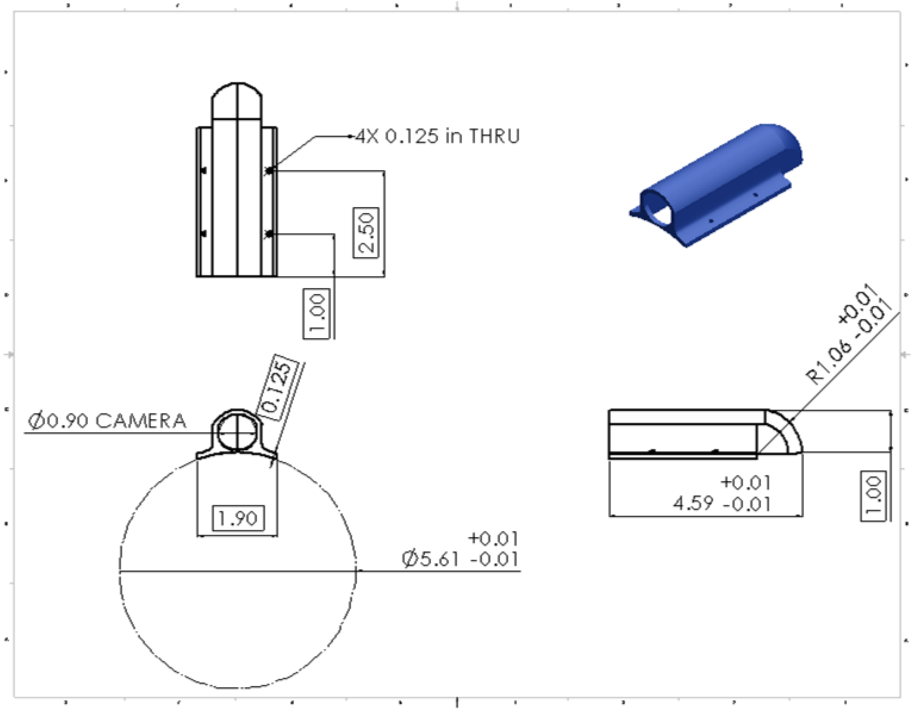
- Wrapped the body tube in two layers of carbon fiber weaving to ensure structural integrity
    - Verified during fullscale test flight.
- The carbon fiber weaving was coated with industrial epoxy and resin, hand wrapped around the blue tube, then wrapped with heat shrink tape.
- Heat shrinking tape was heated using a heat gun and hair dryer to shrink the tape tightly around the body tube which was left to cure for 48 hours.

Fin Bracket Design



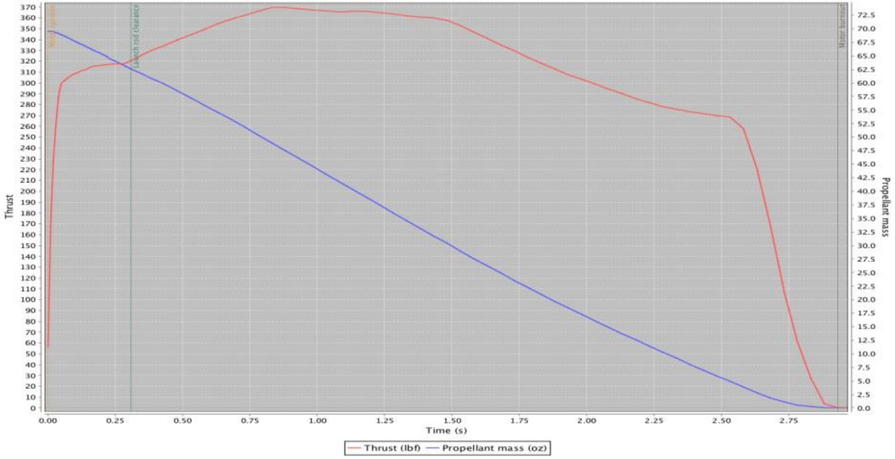


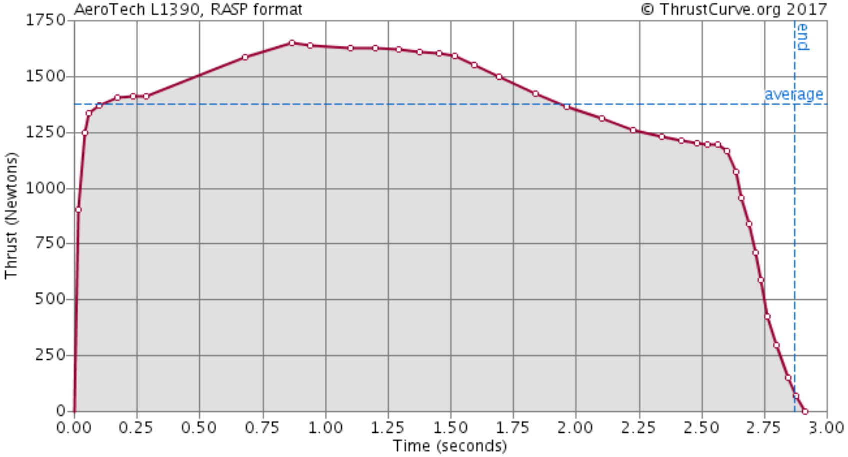
Camera Cover Design



Primary Motor Characteristics

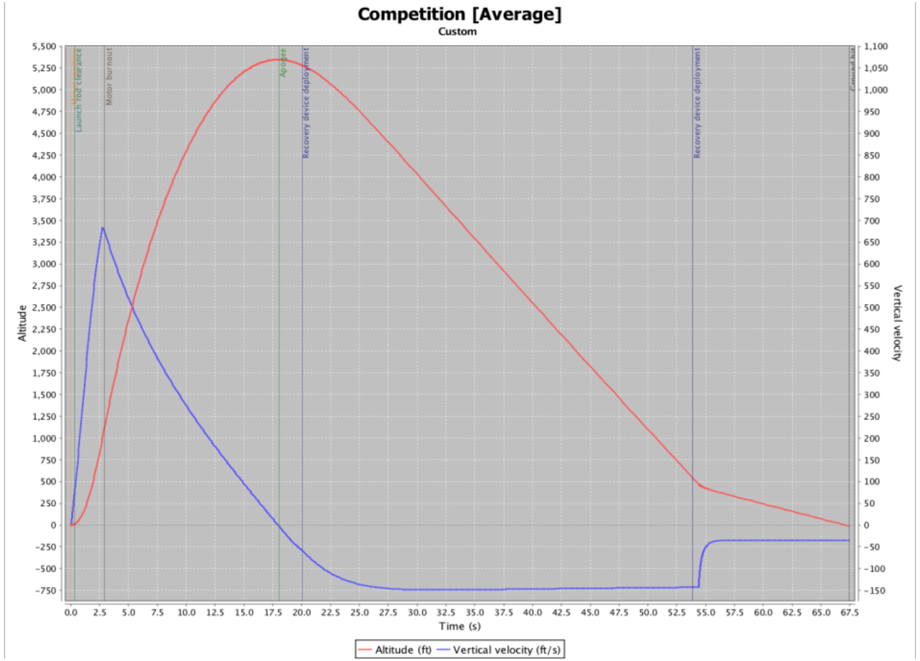
Motor	Apogee (ft)	Velocity off the Rail (fps)	Maximum Velocity (ft/s)	Thrust to Weight Ratio	Impulse (lbf*s)	Burn Time (s)	Mass (oz)
AeroTech L1390	5347	71.5	684	8.56	887	2.87	137



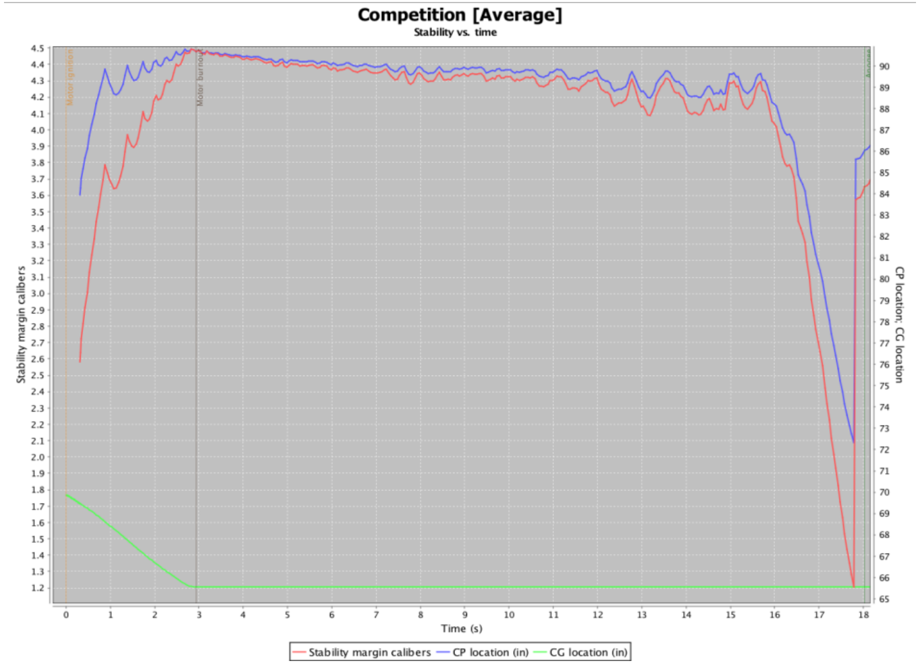


Primary Motor Flight Simulation

Altitude and Velocity vs Time



Stability, CG, and CP vs Time



Status of Requirements Verification

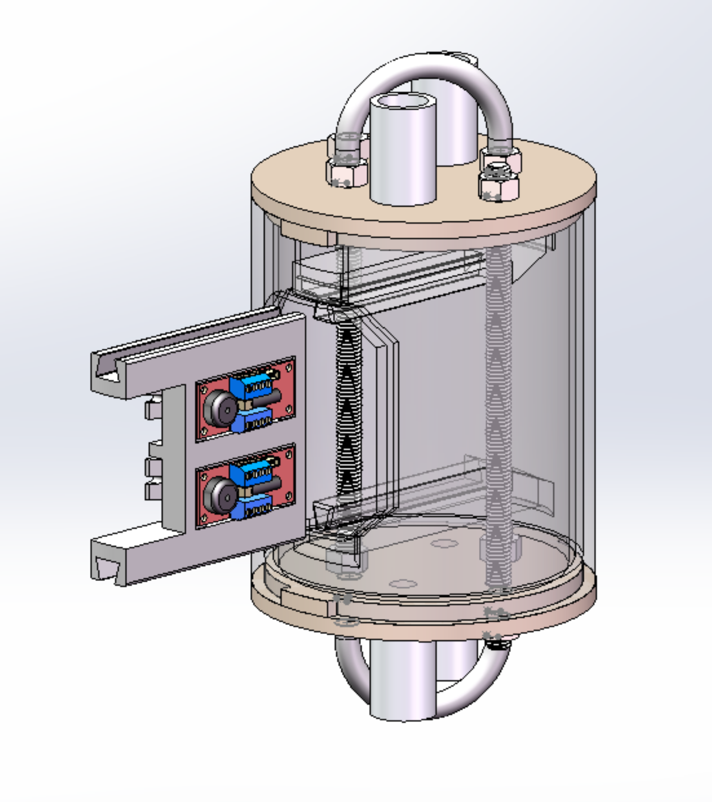
- The vehicle will deliver the payload to an apogee altitude of 5,280 feet above ground level.
    - Accurate OpenRocket simulations have been conducted, and a test launch was conducted to confirm the accuracy of the simulations.
- The launch vehicle will be designed to be recoverable and reusable.
    - Durable materials have been used
    - Modular design for localized repair
- The launch vehicle will have a maximum of four (4) independent sections.
    - The rocket was designed to consist of three (3) sections

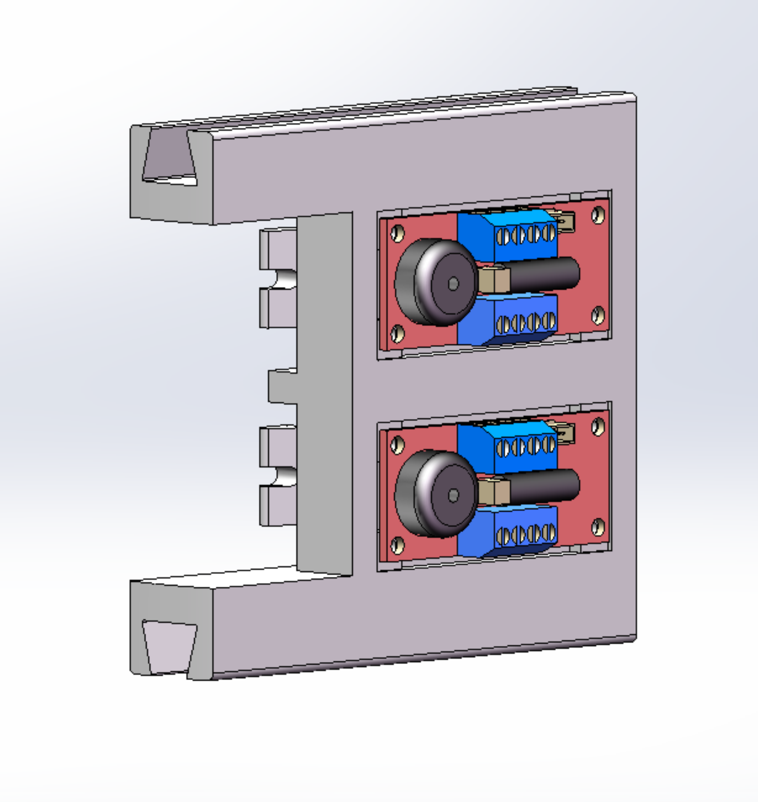
Status of Requirements Verification (cont)

- The launch vehicle will be capable of being prepared for flight at the launch site within 3 hours of the time the Federal Aviation Administration flight waiver opens.
  - Majority of construction done prior to launch day
  - Modular design for easy transport
  - Modular design to expedite assembly procedure

- The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit.
  - Payload located towards the front bringing CG forward
  - Large fins pull CP towards tail end

Avionics Bay

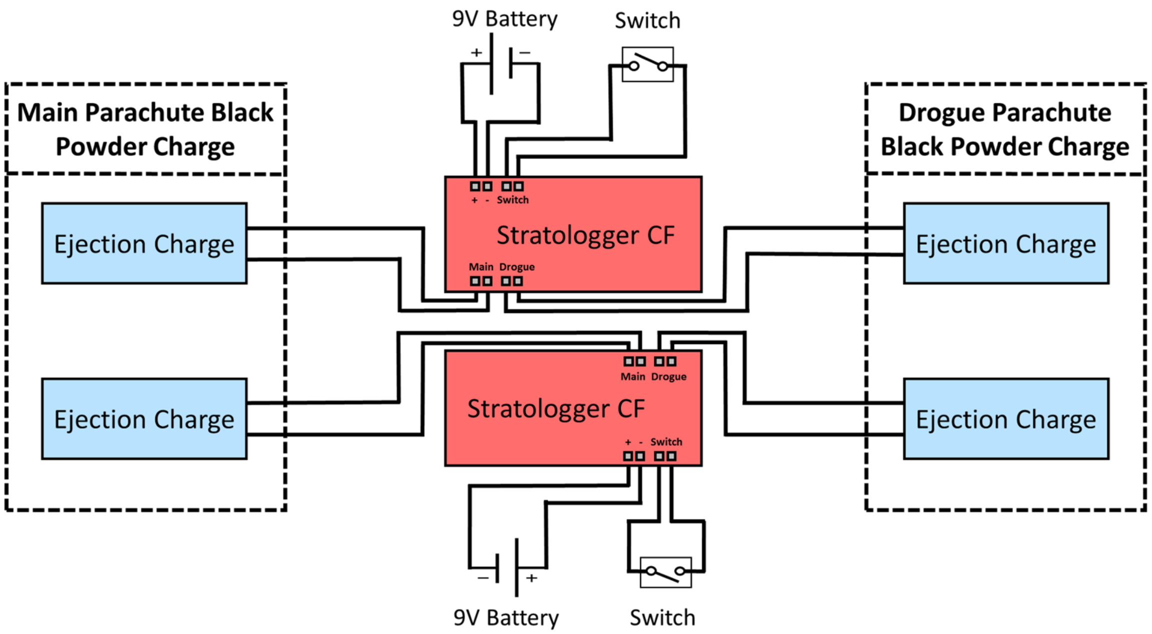




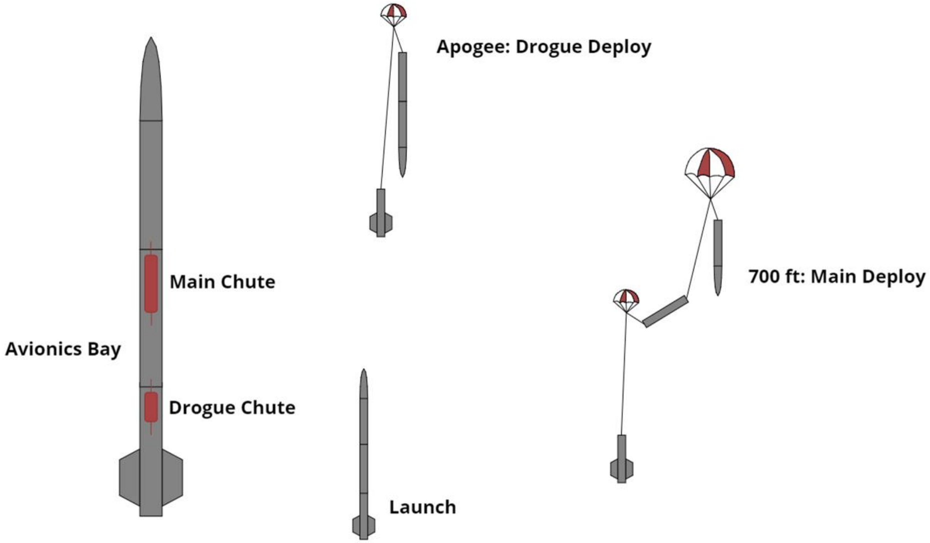
Avionics Bay Wiring Diagram

Features:

- Two independent sets of altimeters, batteries, ejection charges, switches
- Mechanical switch
- Ejection charges will be black powder
- Redundant charges have an addition gram of black powder
- FAA approved initiators will be used



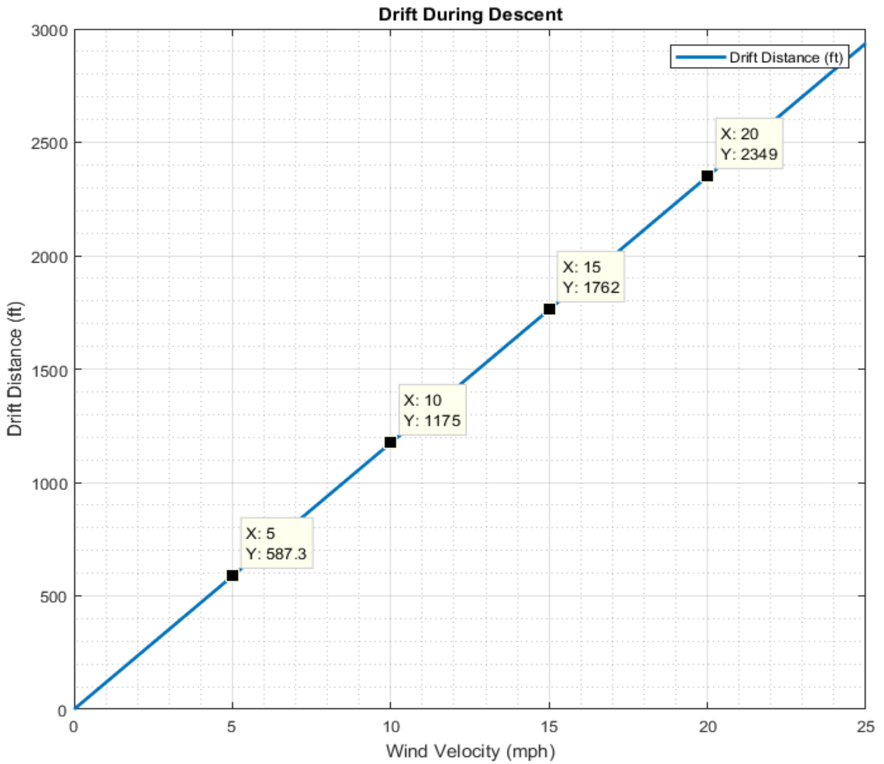
Parachute Sizes and Recovery Harness Lengths



Drogue Parachute	Main Parachute
12” Fruity Chutes Classical Elliptical and 30 ft Recovery Harness	84” Fruity Chutes Iris Ultra and 40 ft Recovery Harness

Estimated Drift

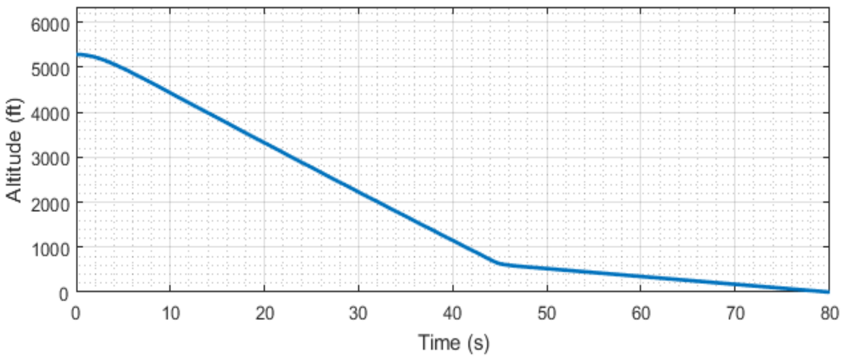
Wind Speed (mph)	Drift Distance (ft) $C_D = 2.2$
0	0
5	587.3
10	1175
15	1762
20	2349

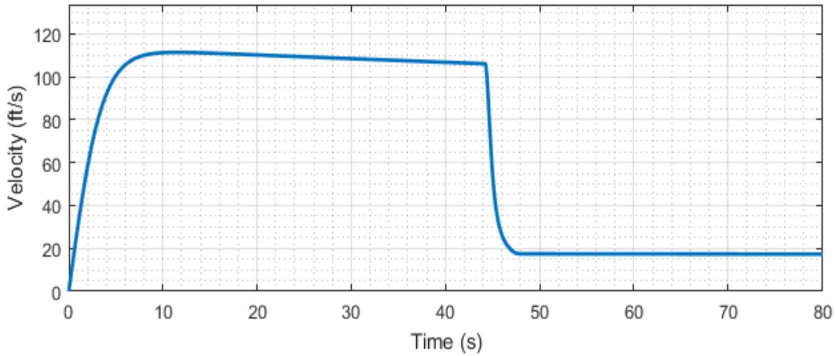


Kinetic Energy Throughout Descent

Section	Mass (oz)	KE at Main Deployment (ft-lb)	KE Right Before Landing (ft-lb)
Nose cone	163.2	1784	47.57
Avionics bay	90.6	987.6	26.40
Booster	209	2284	60.91

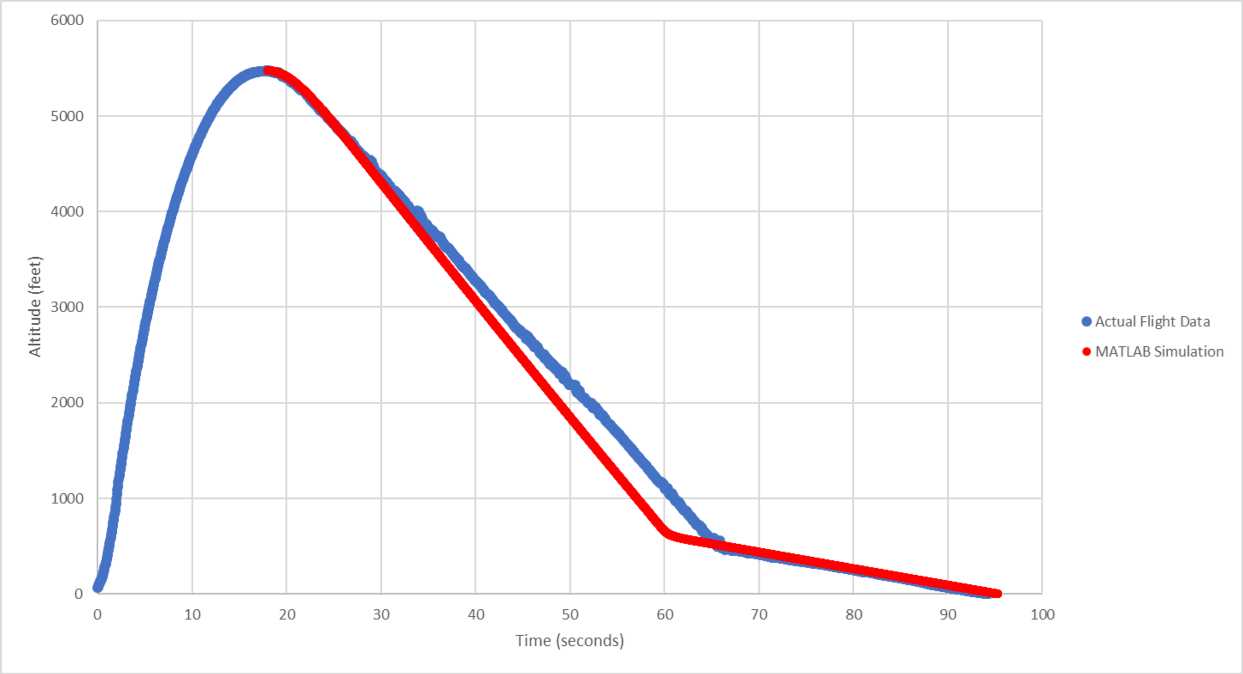
Section	Mass (oz)	Kinetic Energy (ft-lb) $C_D = 2.2$	Difference between MATLAB and Openrocket (%)
Nose cone	163.2	50.25	5.333
Avionics bay	90.6	27.89	5.342
Booster	209	64.30	5.272





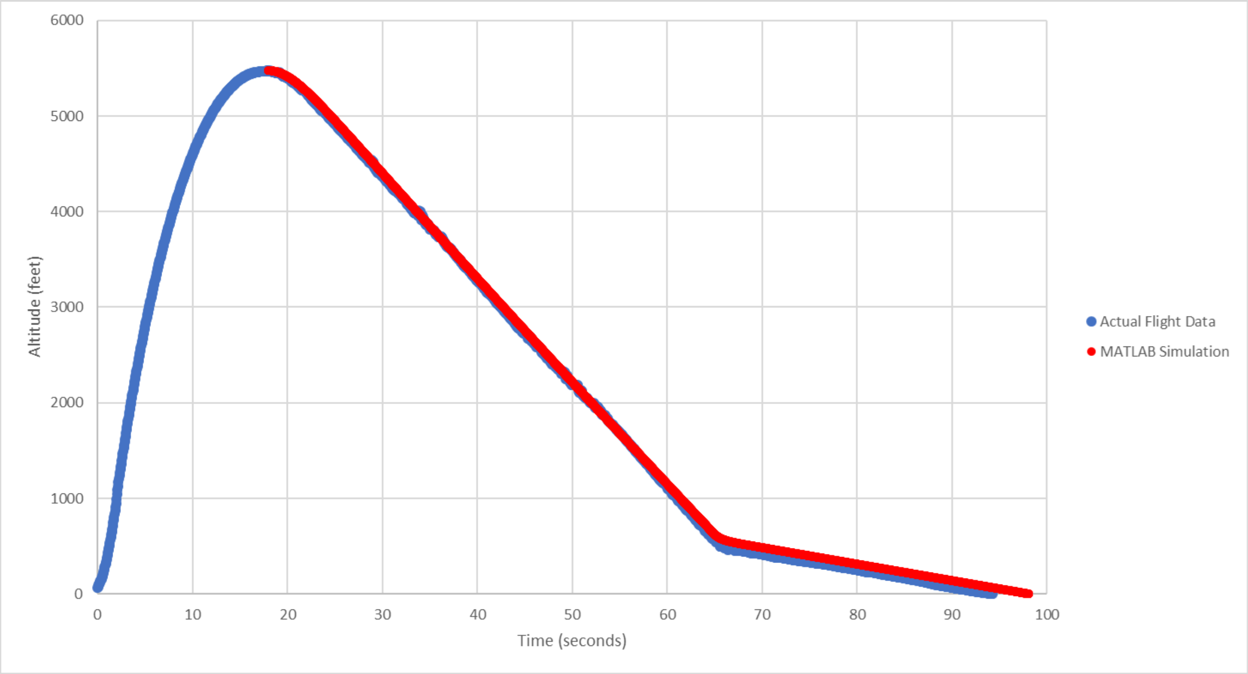
Full-scale Flight Results

- Moderately accurate initial flight prediction
- Inaccuracies due to miscalculating the drag of the body tube during descent



New Flight Model

- Corrected the drag of the body tube based on flight data
- Body tube drag is modeled to be equivalent to a 10.5” parachute with a Cd of 0.5



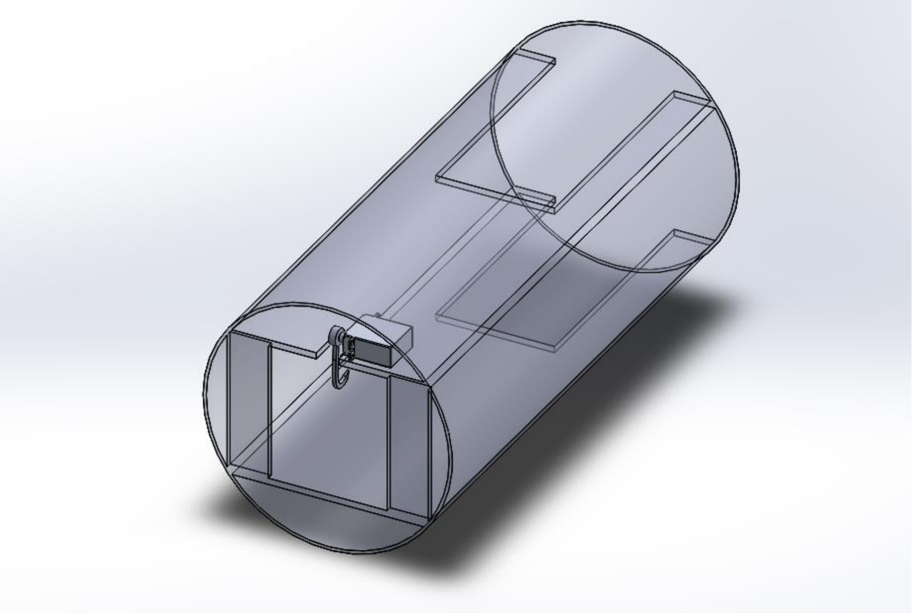
Payload Changes Since CDR

Rover:

- Design and dimensions of the rover body
- Solar panel deployment mechanism

Containment mechanism:

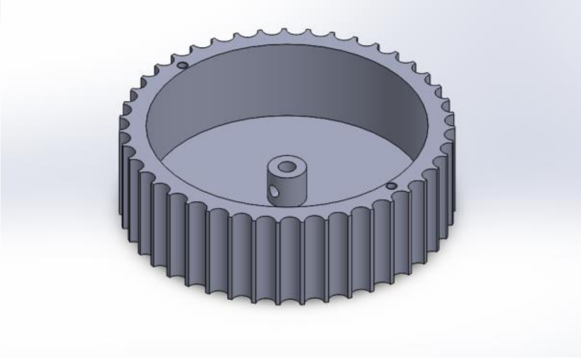
- Notches taken out of the shelf

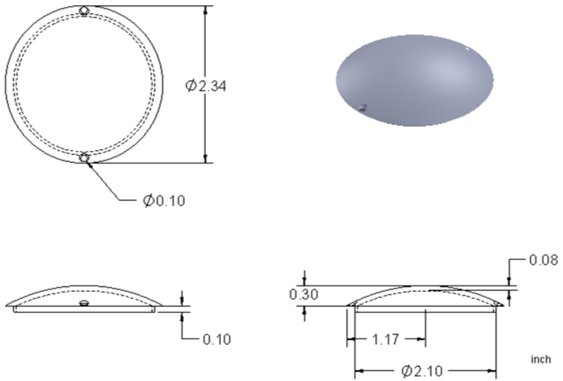


Unique Features of the Payload

Wheels:

- Constructed with PLA plastic
- Detachable hubcaps
- Grooves for additional climbing ability

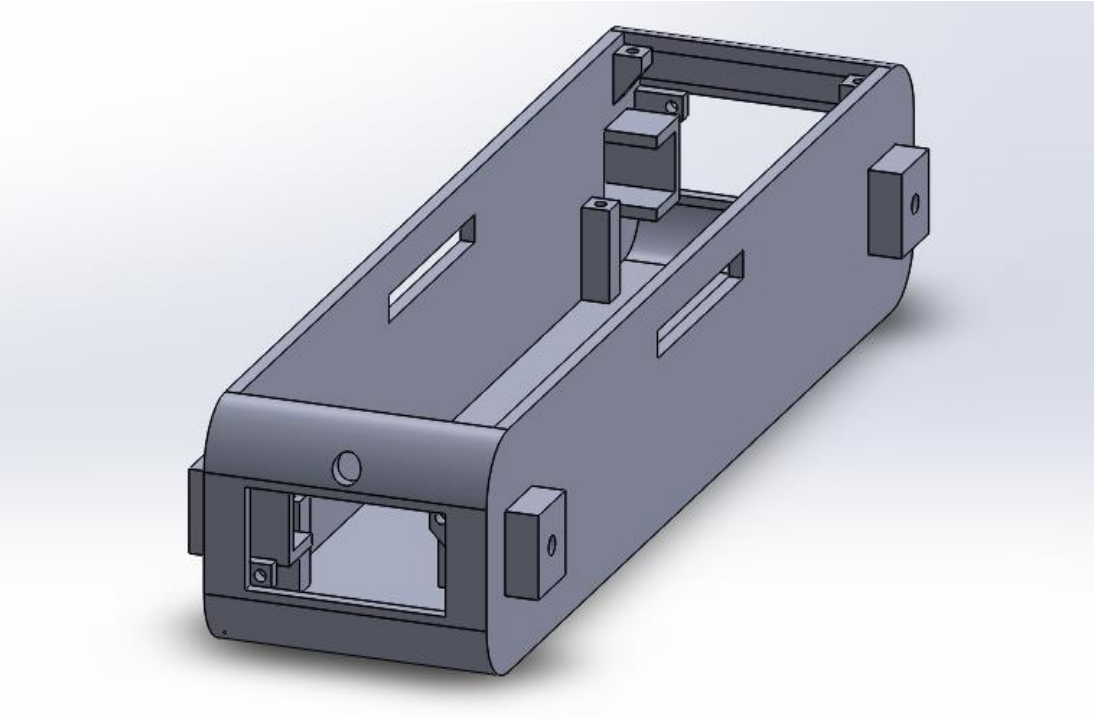




Unique Features of the Payload

Rover body:

- Constructed with PLA plastic
- Custom mounts for electronics
- Removable cover
- Slots for solar panels



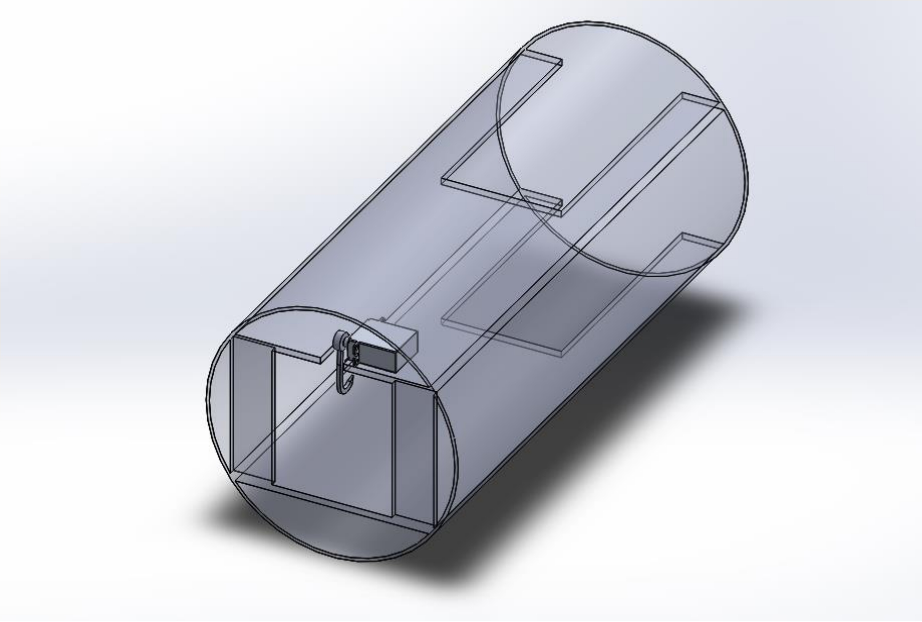
Unique Features of Payload

Containment Mechanism:

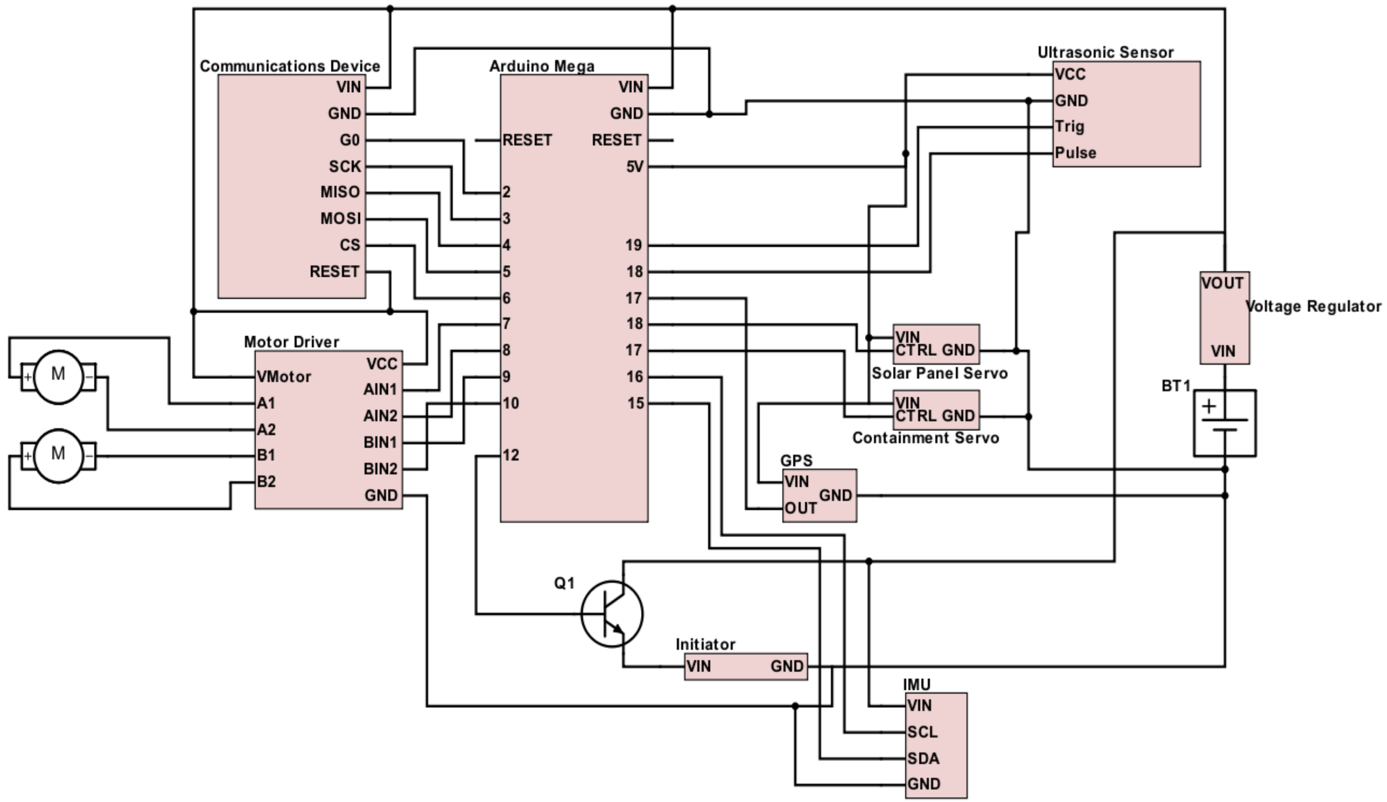
- Shelves to contain rover
- Rotating servo hook for containment

Deployment Mechanism

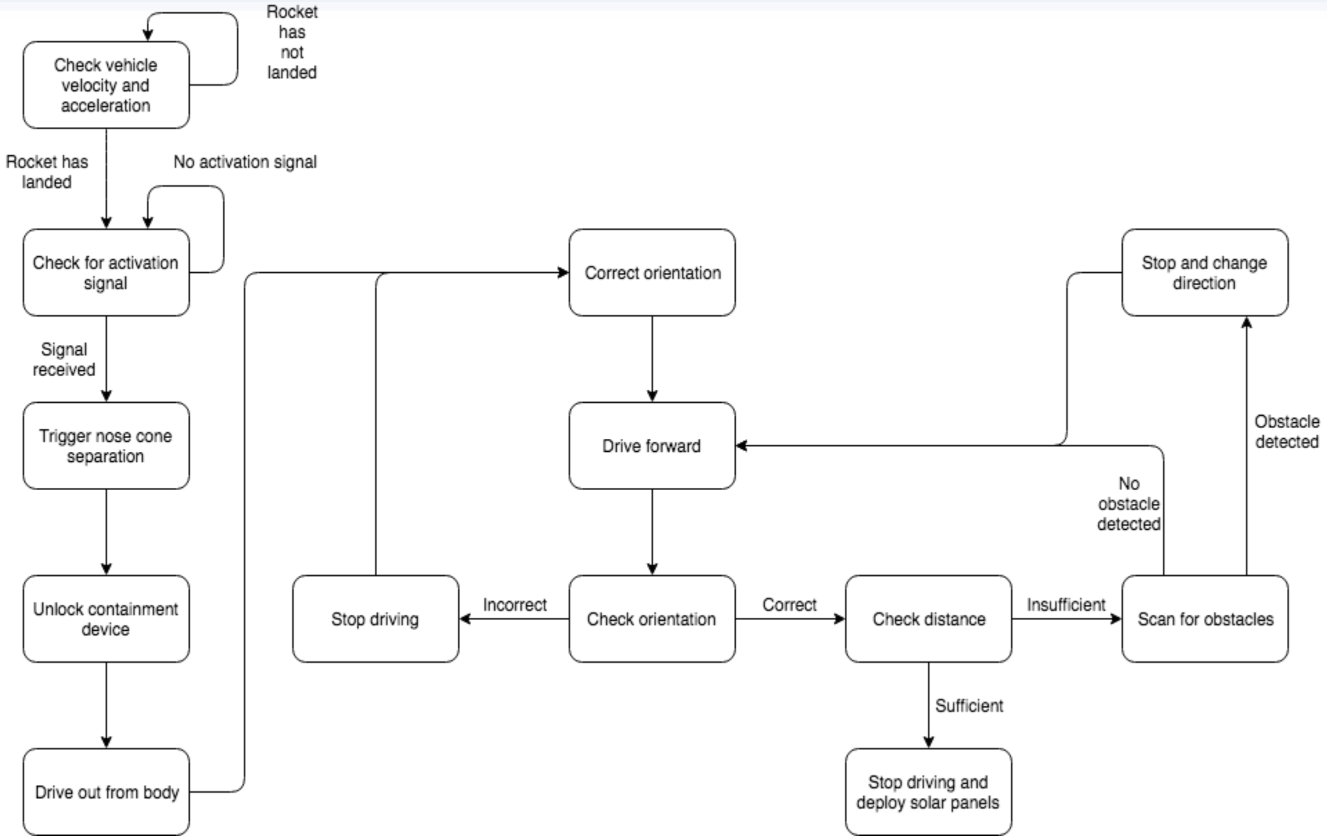
- CO_2 separation method
- Communication system



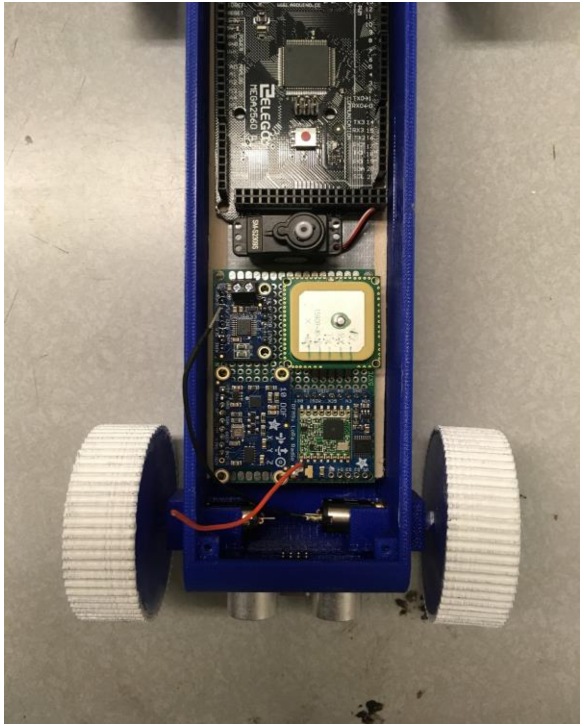
Electronic Components

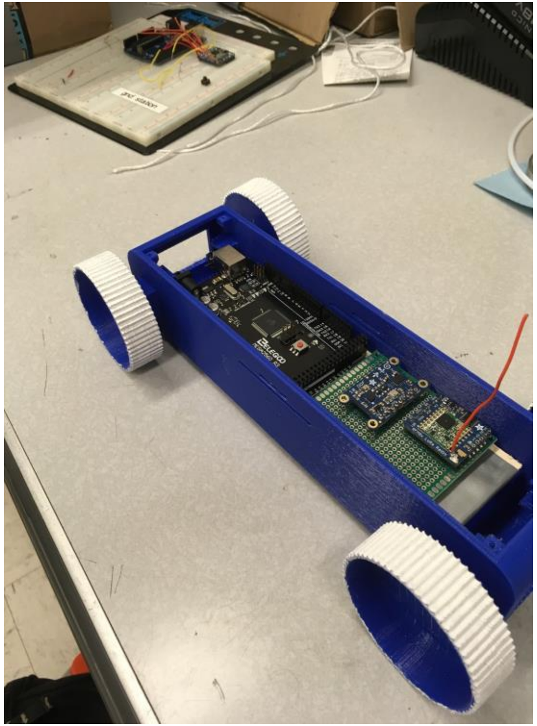


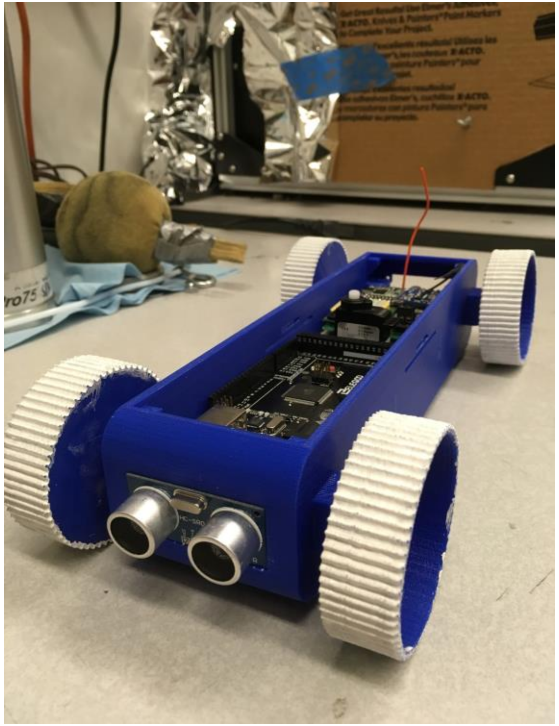
Software Design



Payload Construction







Why Payload Differs from Earlier Models

Solar Panel Design: More functional and more feasible

Shelf Modifications: Allows rover to exit body

Wheel Modifications: Better climbing ability, maximizing width of the rover

Dimension Modifications: Ease of assembly and maximizing other dimensions

Assembly And Launch Procedures

- Safe handling procedures
  - Initiators
  - Black Powder
- Redundancy in case of failure
  - Master copy of code
- Testing
  - Verifiable steps
  - Hardware and software
- Verifiability
  - Sign-off sheet

Testing

- Communication System
  - .75 miles with minimal packet loss
  - Because of communication system design, minimal packet loss is acceptable
- CO_2 Ejection
  - Insufficient pressure on first test
  - Increased pressure
- Impact Testing performed on Carbon Fiber Wrapped Blue Tube

Safety Overview

- Hazardous materials identified and hazard mitigation plans developed for each material
- Major personal and environmental hazards were identified, mitigation plans were put into place, and verifications were established
- Major failure modes were identified, mitigation plans were put into place, and verifications were established
- All members going to Alabama have taken safety training

Changes Since CDR: Likelihood and Severity Definitions

- In order to better quantify likelihood and severity values for the personnel risk, environmental hazards, and failure modes, different likelihood and severity definitions were established for each set of risk (personnel risks, environmental hazards and failure modes)
- This allowed the likelihood of each risk to be more clearly defined
- The new likelihood definitions take into account the effect of the mitigations in reducing the risk

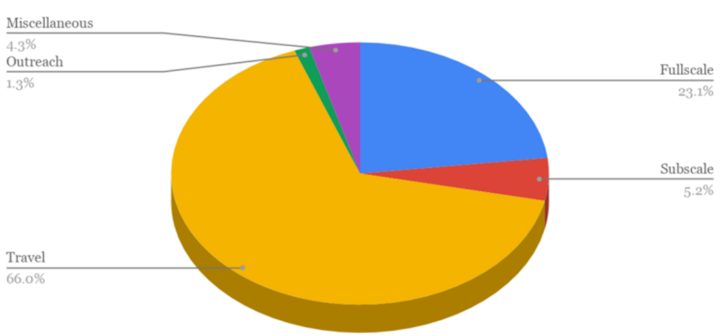
Failure Modes and Mitigations

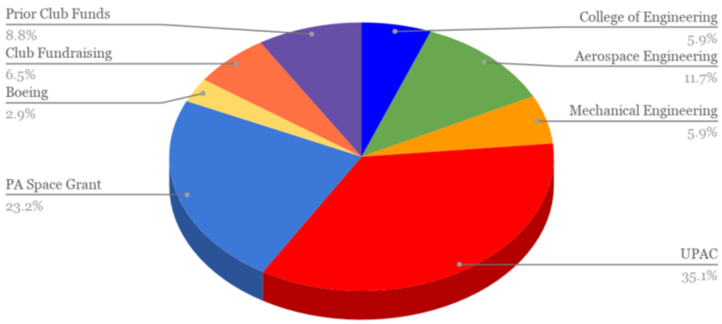
- Failure Modes and Effects Analysis tables were updated after fullscale launch in order to reflect lessons learned from the launch, and identify additional mitigations necessary to resolve the coupler zippering issue
- Verifications were fully established by each subsystem, many of which were based on the launch day procedure set developed by the team

Mission Overview – Budget

Expected Outflow

Budget	Total Cost
Fullscale	$2,662.80
Subscale	$604.37
Travel	$7,612.56
Outreach	$150.00
Miscellaneous	$500.49
Total	**$11,530.22**





Expected Inflow

Donor	Requested Amount
College of Engineering	$1,000.00
Penn State Aerospace Engineering	$2,000.00
Penn State Mechanical Engineering	$1,000.00
UPAC	$6,000.00
PA Space Grant	$3,965.62
The Boeing Company	$500.00
Club Fundraising	$1,105.00
Prior Club Funds	$1,502.59
Total	**$17,073.21**