Penn State
LionTech Rocket Labs

Critical Design Review

Presentation Overview

- Team Introductions
- Vehicle Demonstration Flight Results
- Vehicle Design
- Recovery System Design
- Mission Performance Predictions
- Payload Design
- Payload Flight Results
- Safety
- Budget
- Outreach Results
- Timeline
- Questions

Team Introduction

Administrative:

President: Gregory Schweiker

Vice President: Kristi Roth

Safety Officer: Ben Akhtar

Interim Safety Officer: Matt Easler

Treasurer: Andrew Blount

PR / Outreach: Gooderham McCormick

Technical Team:

Flight Systems Lead: Matt Easler

Payload Systems Lead: Joseph Weston

Structure Leads: Arya Roesler, Sam Loeffler

Propulsion Lead: Wilson Chiang

A & R Leads: Spencer King, Kyle Batra

Payload Leads: Logan Baker, Jaimin Patel

Vehicle Demonstration Flight

Fullscale Launch Results

Launch day conditions: Cloudless skies, 30℉, 15 mph cross winds

The launch vehicle reached an apogee of 5361 feet at 17.5 seconds into the flight. This matched our simulations with a 2.5% difference in apogee in and a 1.4 difference in time to apogee.

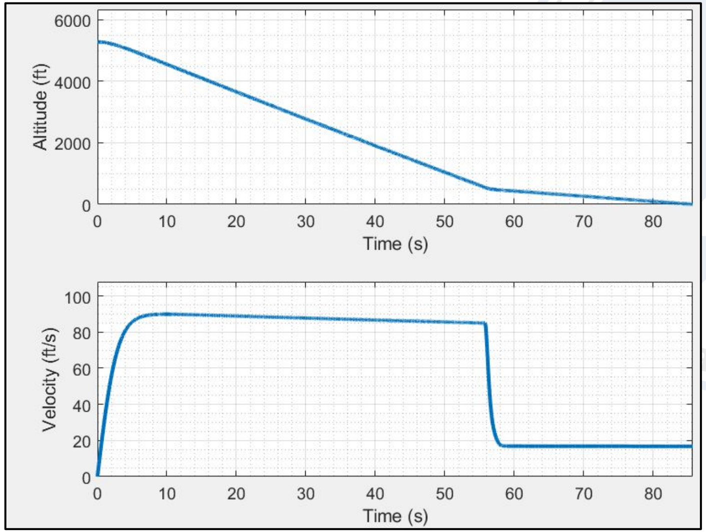
The flight vehicle performed as expected. Only minor cracks were observed on a single fin bracket after launch, all other components withstood the forces of the flight.

Fullscale Test Descent

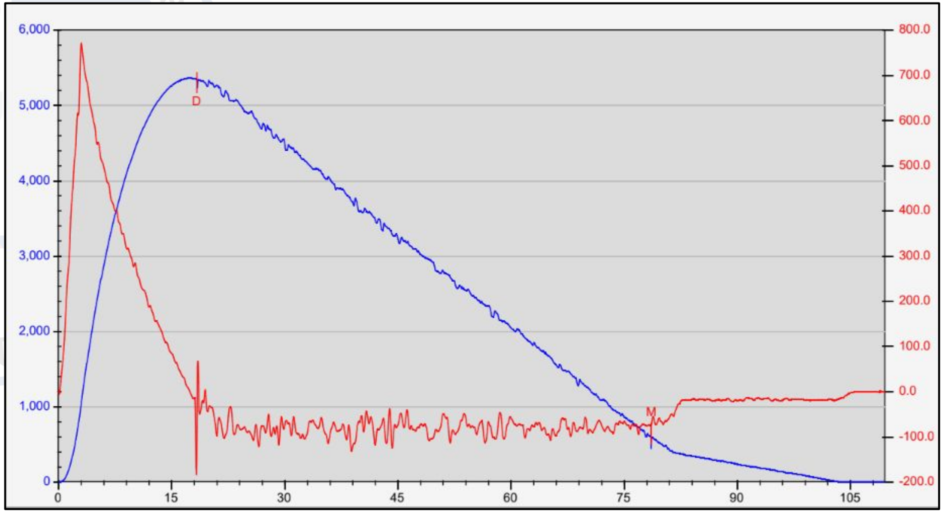
Drogue Descent was ~90 ft/s (~4 ft/s faster than predicted)

Main Descent was 19.5 ft/s (.7 ft/s faster than predicted)

Descent time was 84 s (3.3 s shorter than predicted)



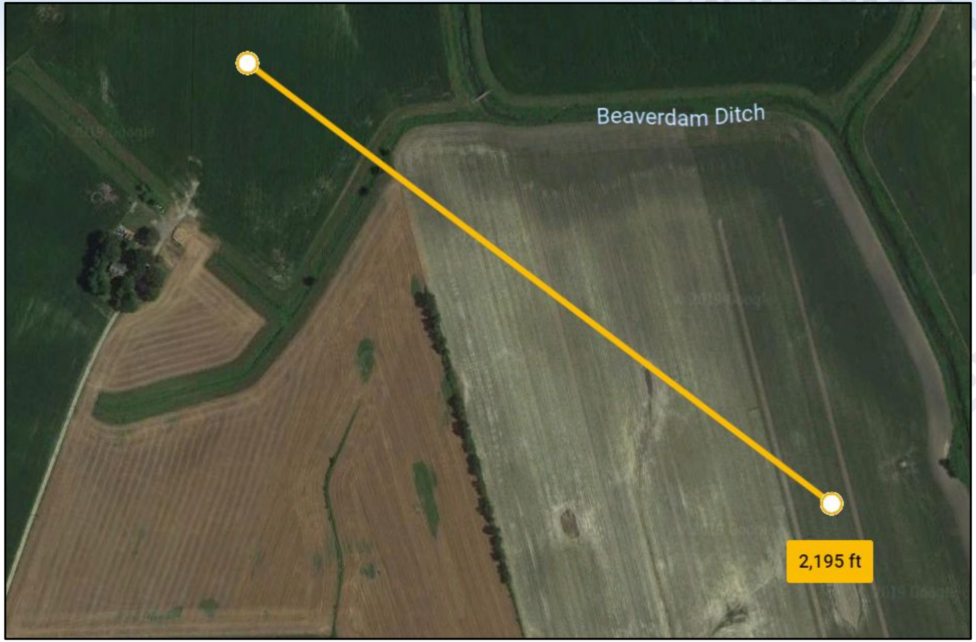
Predicted Velocity and Altitude



Actual Velocity and Altitude

Fullscale Test Drift

2195 ft drifted, 250ft further than expected for the 15 mph winds experienced



50 ft can be accounted by the higher flight

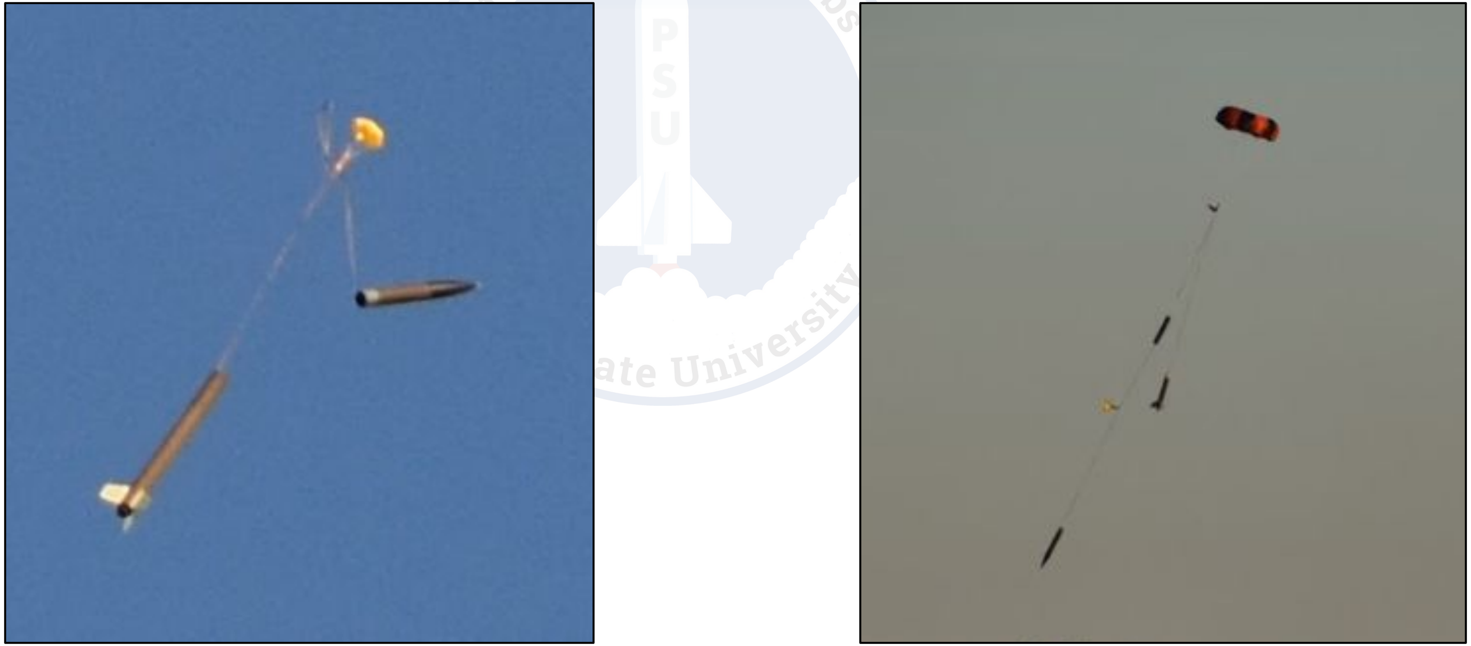
Other 200 ft accounted for by higher variance in tumbling and observing that the wind speed was faster at high altitudes

Looking into changing parachute to decrease C_D

Deployment Events

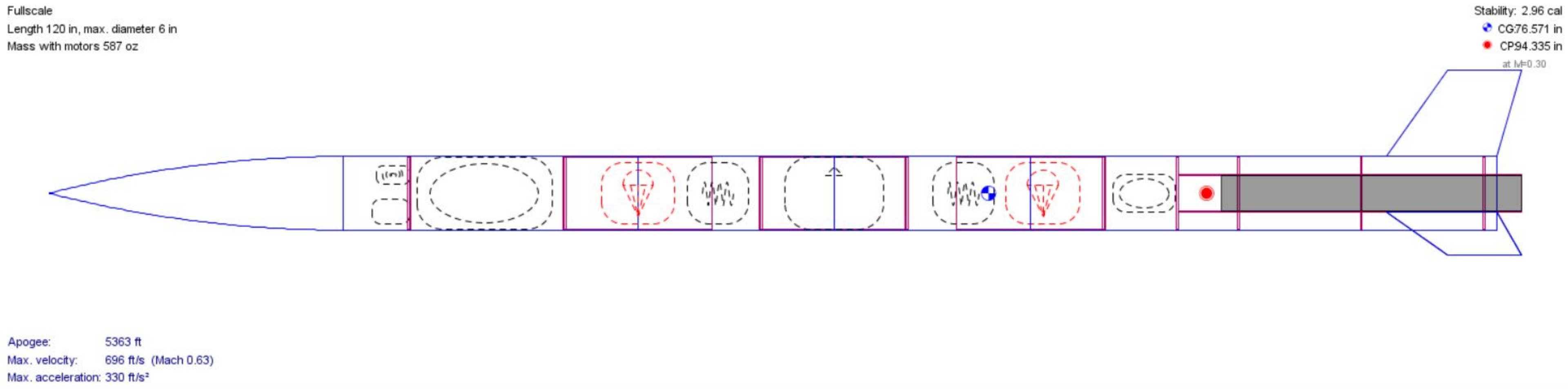
Altimeters reported separation charges fired at expected times

No tears, tangles, collisions, or excessive tumbling during descent



Vehicle Design

Vehicle Characteristics



Fullscale
Length 120 in, max. diameter 6 in
Mass with motors 587 oz

Stability: 2.96 cal
CG:76.571 in
CP:94.335 in
at M=0.30

Apogee:	5363 ft
Max. velocity:	696 ft/s (Mach 0.63)
Max. acceleration:	330 ft/s²

- Length = 120 inches
- Total mass = 36.7 pounds
- Outer Diameter = 6 inches

MATLAB

- Stability: 3.01 calibers
- CG: 76.40 inches
- CP: 94.46 inches

OpenRocket

- Stability: 2.96 calibers
- CG: 76.57 inches
- CP: 94.34 inches

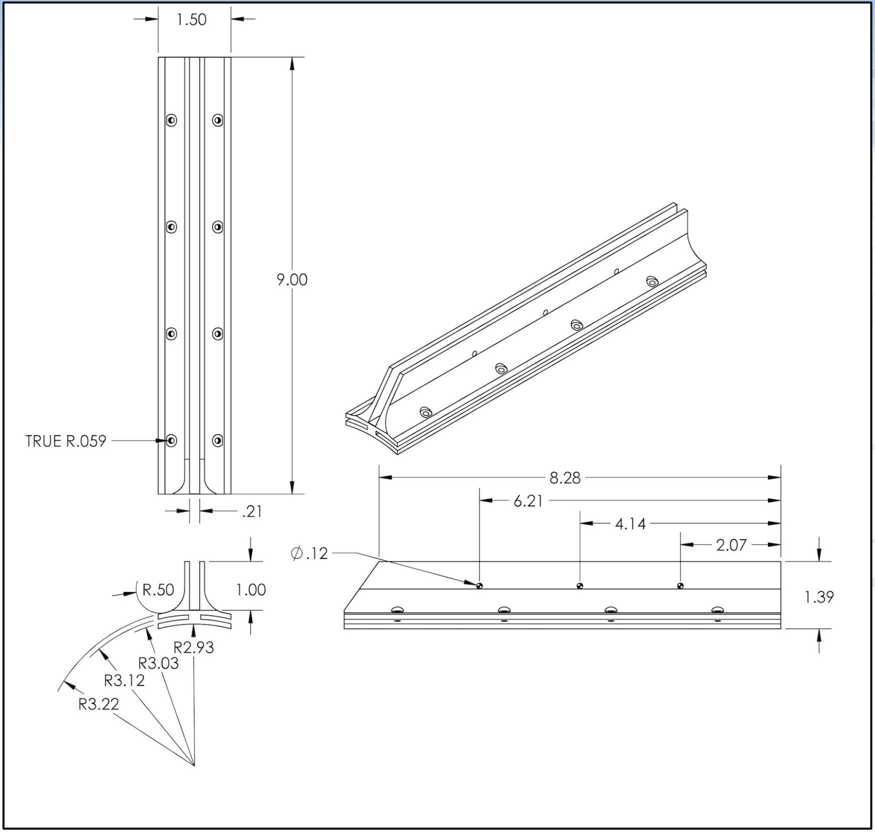
Component Masses

Component	Weight (oz)
Nose Cone	65.0
Payload Section	72.1
Payload-Main Coupler	9.5
Drogue Section	29.9
Drogue-Main Coupler	55.7
Main Section	43.2
Main-Booster Coupler	13.0
Booster Section (No Motor)	124.0

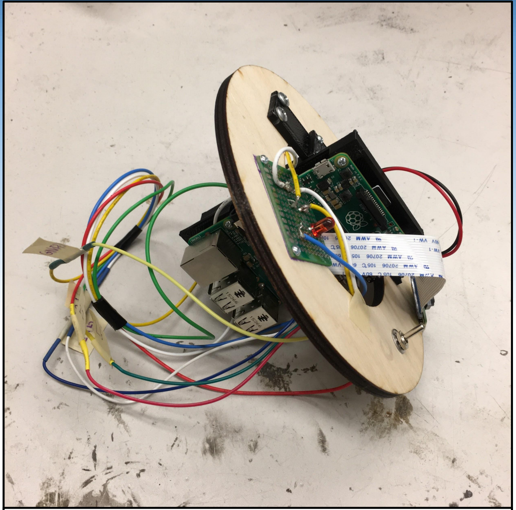
Airframe Construction

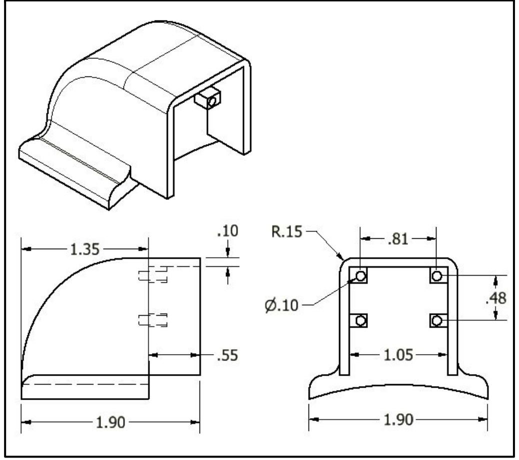
- Airframe body tubes constructed of 6 layers of carbon fiber ply to ensure structural stability.
- Carbon fiber coated with industrial grade epoxy, wrapped around a blue tube mandrel wrapped with packing tape, and vacuumed.
- Vacuum process pulls excess epoxy from carbon fiber. Vacuum is put on the tube for at least 24 hours to ensure a full cure of the epoxy.

Fin Bracket Design



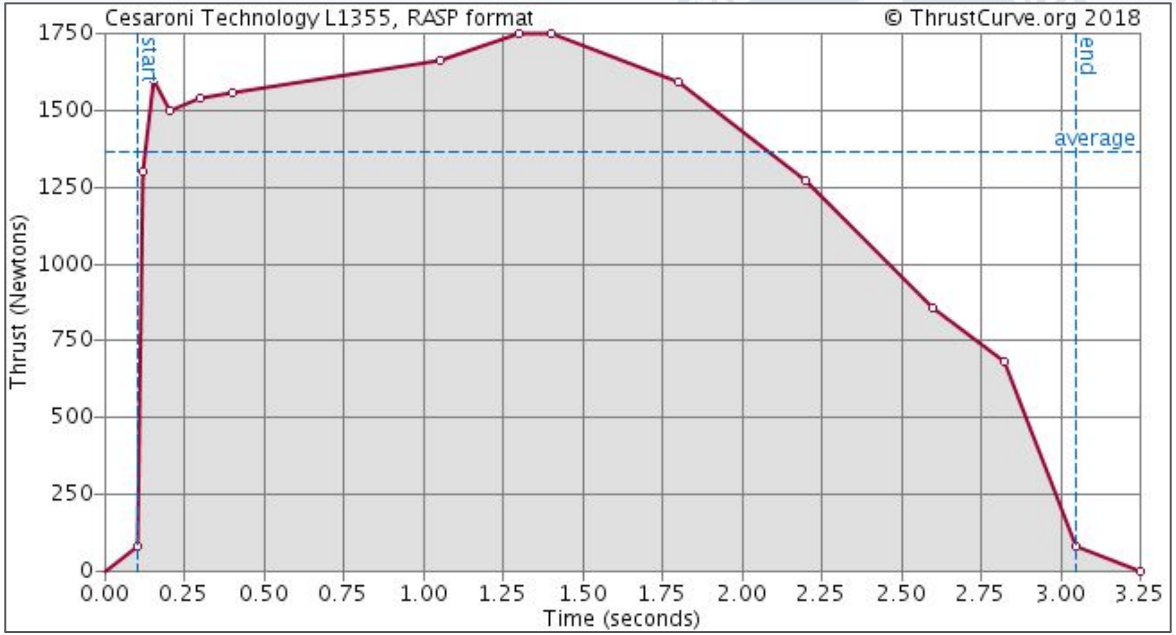
Camera System Design





Primary Motor Characteristics

Cesaroni L1355



- Total Impulse: **905 lbf*s**
- Burn Time: **2.95 s**
- Average Thrust: **306 lbf*s**
- Max Thrust: **393 lbf*s**
- TWR: **9.75**

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.
  - Apogee calculations are verified by the team’s MATLAB model.
  - Both models verified with fullscale flight test data.

- The launch vehicle will be designed to be recoverable and reusable.
  - Vacuum bagged carbon fiber for maximum airframe strength
  - Modular design for localized repair, already used for fin bracket replacement

- The launch vehicle will have a maximum of four (4) independent sections.
  - Four sections were built to house parachutes, motor, and payload

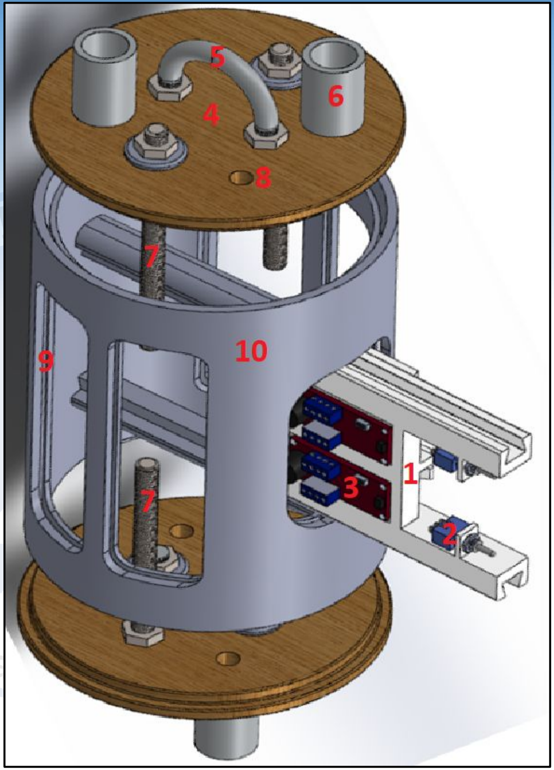
Status of Requirements Verification

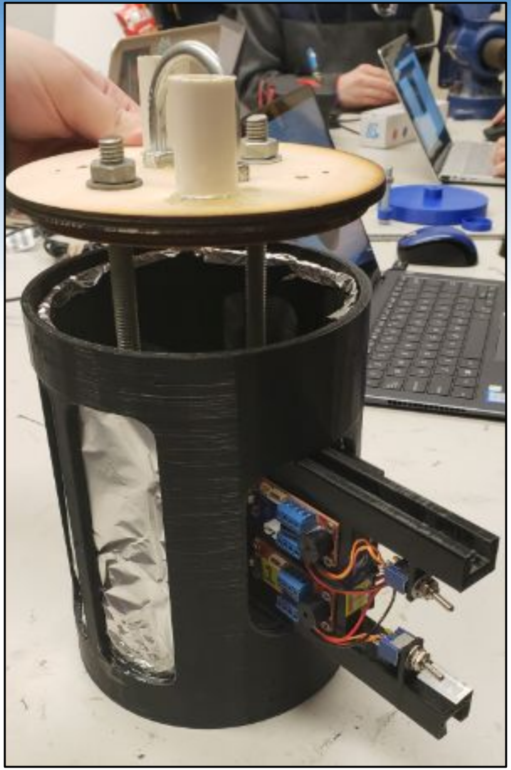
- The launch vehicle will be prepared for flight at the launch site within 3 hours of the time the Federal Aviation Administration flight waiver opens.
  - Demonstrated full vehicle construction in 2.5 hours at fullscale test flight
  - Majority of construction was done prior to launch day

- The launch vehicle will have a minimum static stability margin of 2.0 at the point of rail exit.
  - Payload located towards the front brings CG forward.
  - Large fins pull CP towards tail end.
  - Current static stability is 2.96 calibers at rail exit, model verified with fullscale test flight data and visual observation.

Avionics Bay

1. Avionics Board
2. Mechanical Switch
3. StratologgerCF Altimeter
4. Avionics Bulkhead
5. U-Bolt
6. Charger Well
7. Allthread Rod
8. Initiator wire pass through hole
9. Faraday Cage Channel
10. Avionics Bay





Avionics Board

StratologgerCF Altimeter

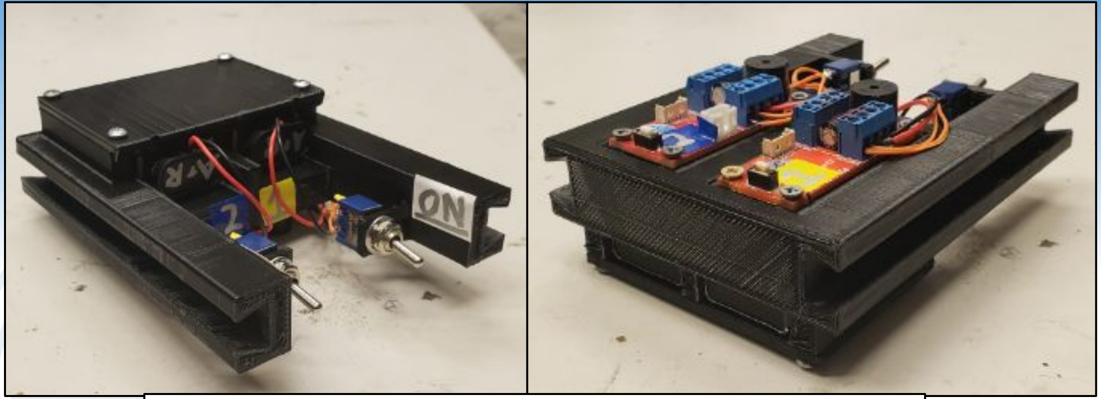
Toggle Switch

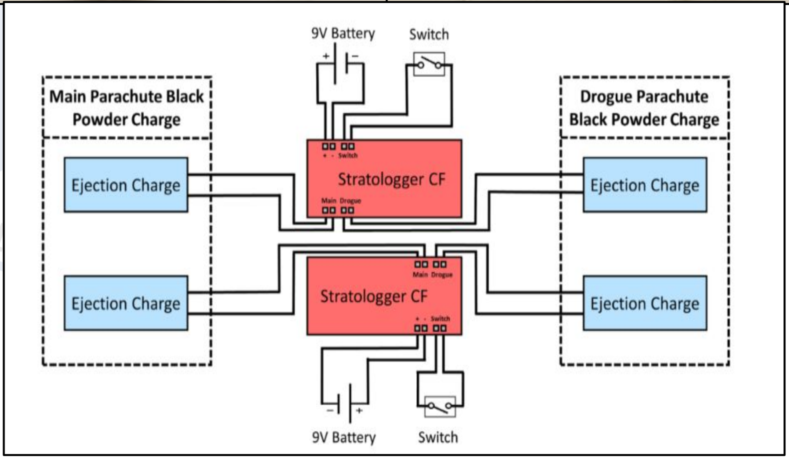
Duracell 9V Battery

18 Gauge Electrical Wire

3-D Printed with PLA

Components are screwed on





Separation System

Plywood Bulkheads
Connected by Steel all-threads

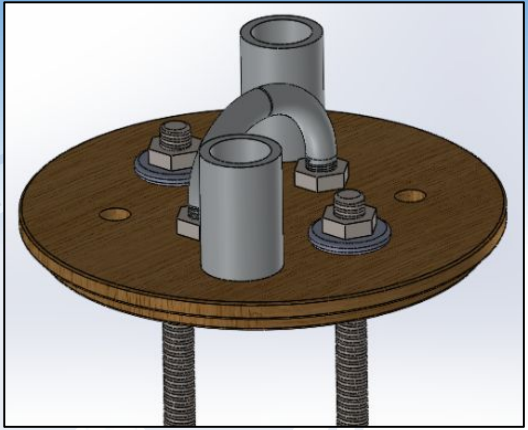
Initiator wire holes in bulkheads

PVC Chargewells

U-Bolt for Recovery Harness

Airtight Compartment for Black Powder gas expansion

Sections connected by 2-56 Shear Pins



	Drogue Primary	Main Primary	Drogue Redundant	Main Redundant
Calculated number of 2-56 shear pins	5	6	6	10
Factor of Safety	1.5	1.25	2	2
Actual number of 2-56 shear pins	3	5	3	5

Avionics Ignition System

StratologgerCF Altimeter

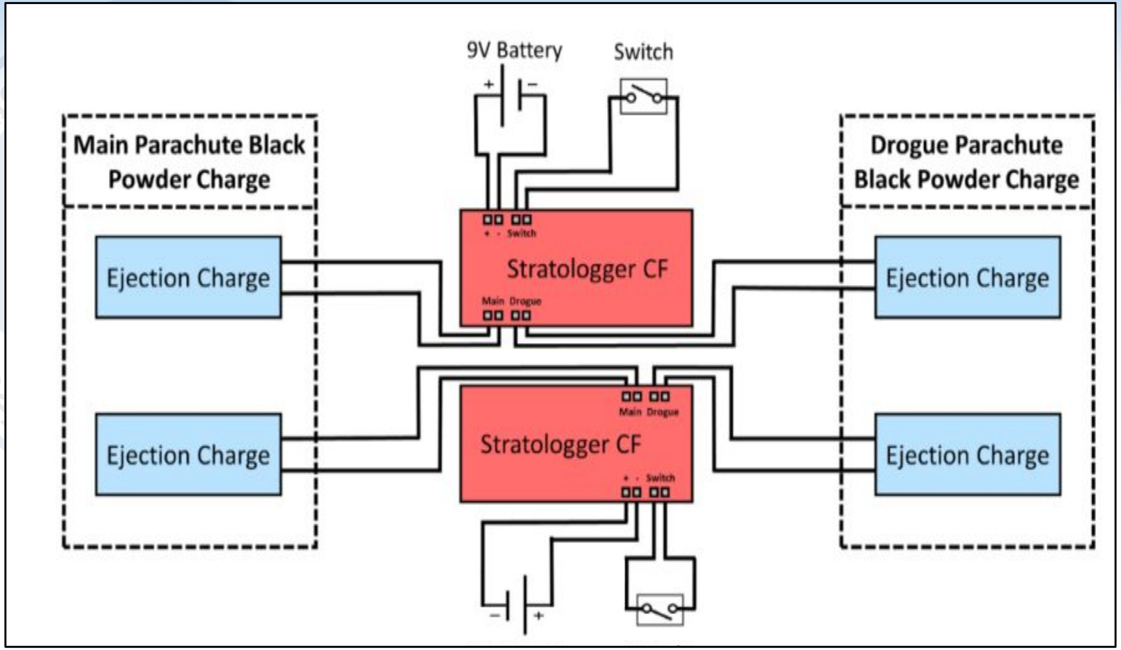
Toggle Switch

Duracell 9V Battery

18 Gauge Electrical Wire

FAA approved Initiators

Black Powder ejection charge



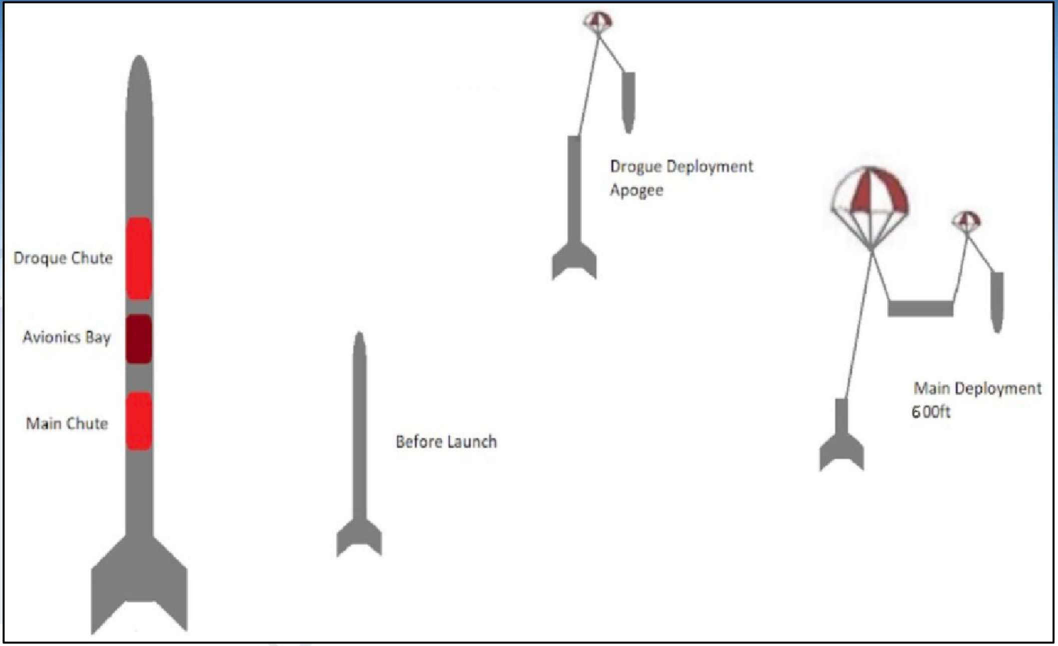
Recovery System

Primary deployment

- Drogue at apogee
- Main at 600ft ABG

Redundant deployment

- Drogue at apogee +2s
- Main at 500ft ABG



Drogue	Main
18” Fruity Chutes Classical Ultra	96” Fruity Chutes Iris Ultra
24ft by 1/2in Flat strap Kevlar shock cord	27ft by 1/2in Flat strap Kevlar shock cord

Avionics and Recovery Requirements Verification

Requirement 3.3: At landing, each independent section of the launch vehicle will have a maximum kinetic energy of 75 ft-lbf.

- The kinetic energy of each section has been calculated in MATLAB and verified with Openrocket

Requirement 3.9: Recovery area will be limited to a 2,500 ft. radius from the launch pads.

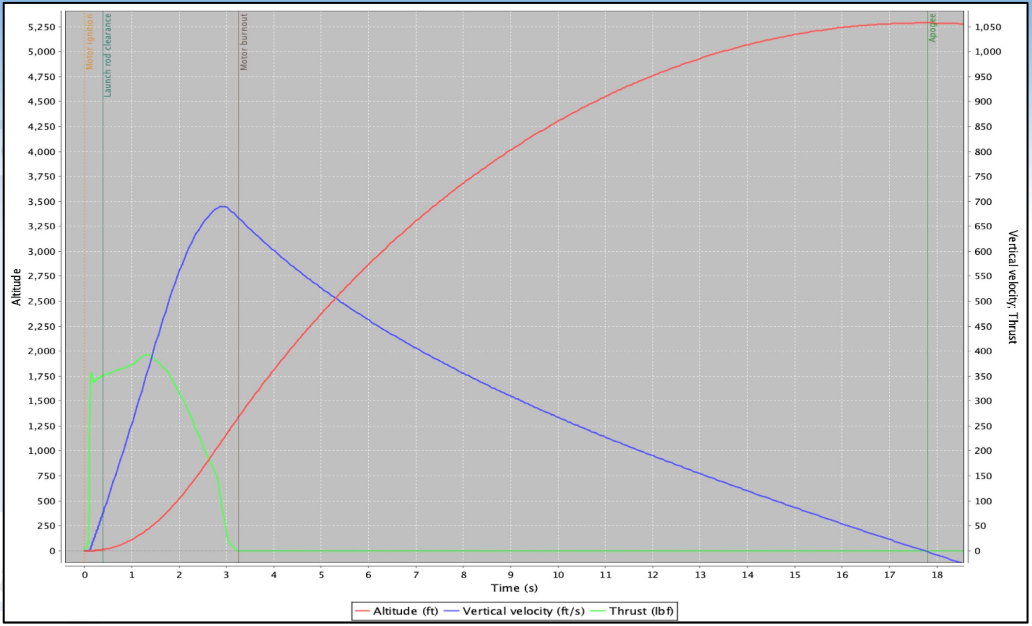
- The drift distances at 5, 10, 15, and 20 mph cross winds has been calculated in MATLAB and verified with Openrocket

Team Requirements: All Team derived requirements were successfully met in the flight test launch vehicle.

Mission Performance Predictions

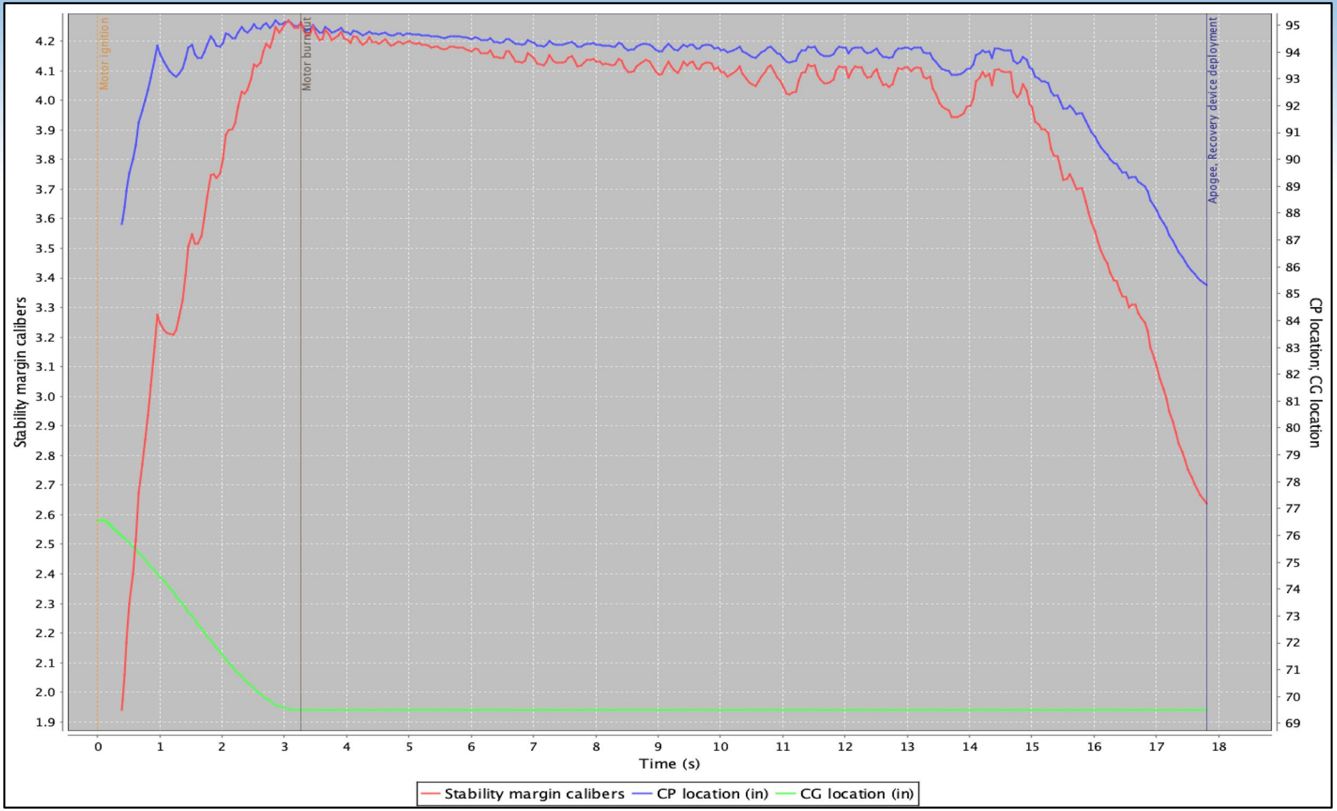
Primary Motor Flight Simulation

- Apogee: **5,289 ft**
- Max Velocity: **698 ft/s**
- Rail Exit Velocity: **75.5 ft/s**
- Stability: **2.96 calibers**



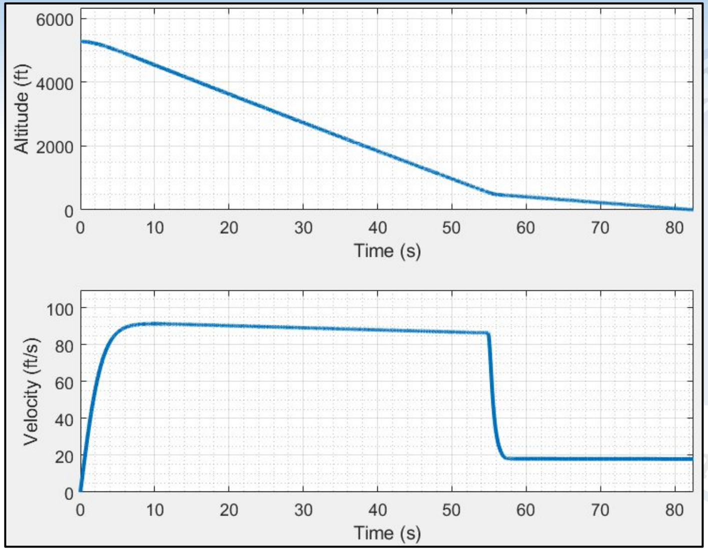
Wind velocity	5 mph	10 mph	15 mph	20 mph
Apogee	5,298 ft	5,255 ft	5,177 ft	5,135 ft

Rocket Flight Stability in Static Margin Diagram

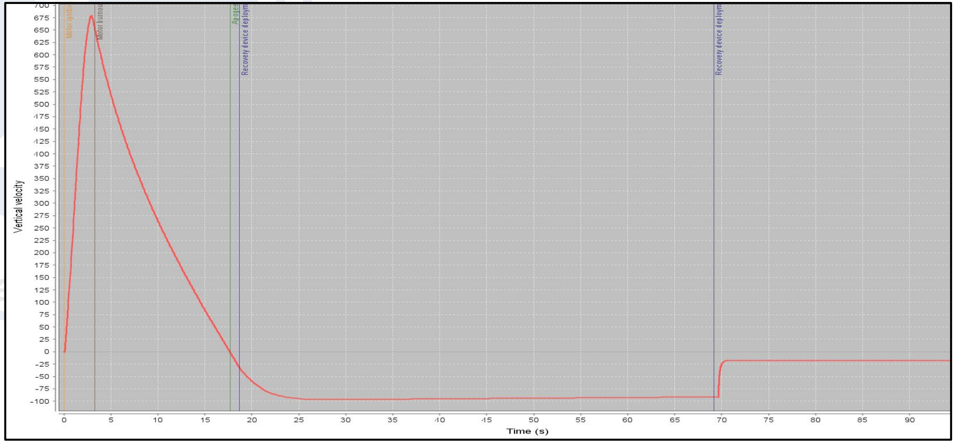


Predicted Descent

	MATLAB	OpenRocket
Drogue Descent	87 ft/s	86s
Main Descent	18.0 ft/s	17.8 ft/s
Time	83.6 s	88.2 s

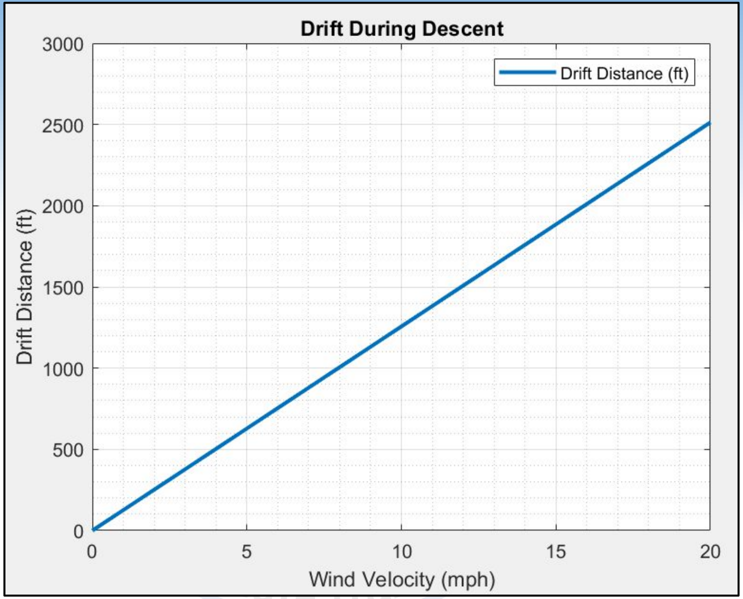


MATLAB Model



OpenRocket Model

Predicted Drift



Wind velocity	5 mph	10 mph	15 mph	20 mph
Drift distance	605.35 ft	1210.7 ft	1816.05 ft	2421.4 ft

Predicted Kinetic Energy

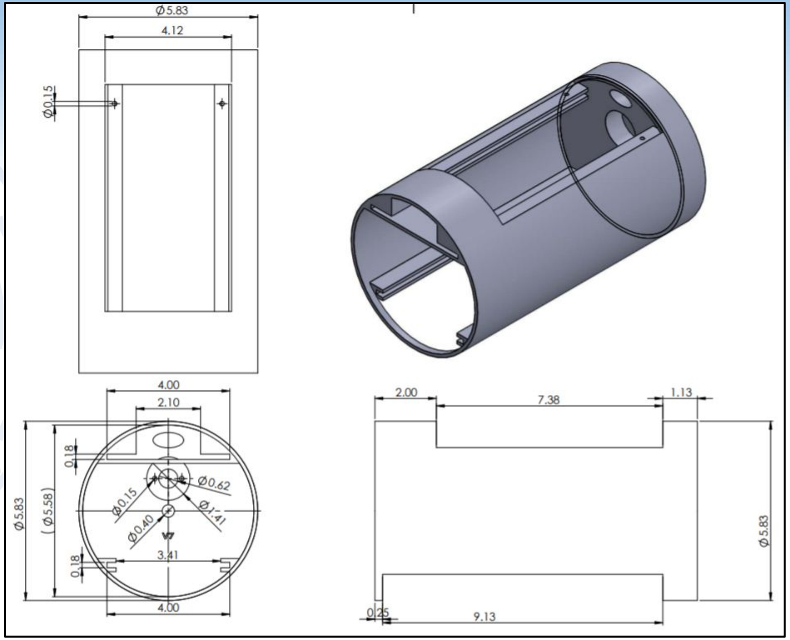
MATLAB landing velocity is 18.02 ft/s
OpenRocket landing velocity is 17.80 ft/s

Section	Mass	Kinetic Energy at landing (MATLAB)	Kinetic Energy at landing (OpenRocket)
Nose	160.5 oz	50.59 ft*lbs	49.42 ft*lbs
Avionics	123.3 oz	38.86 ft*lbs	37.95 ft*lbs
Booster	184.2 oz	58.06 ft*lbs	56.71 ft*lbs

Payload Design and Flight Results

Payload Design and Dimensions

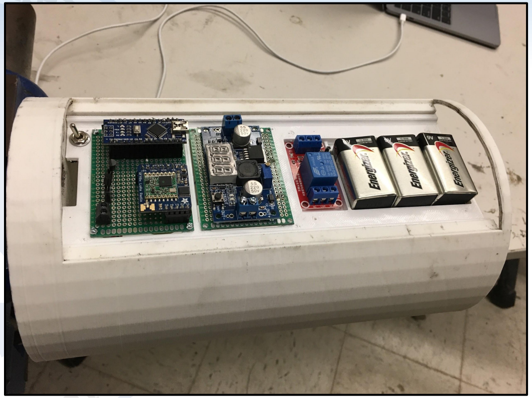
- Payload body tube section
    - 11 x 5.97 inches
- Payload rotating bay
    - 10.5 inches long
    - Additional 0.375 inches for secondary bulkhead
    - Internal space: 9.25 x 3.05 inches
- Rover, fully assembled
    - 9.10 inches long
    - 2.95 inches tall



Rotating Payload Bay Dimensions

Key Design Features

- Rotating payload bay
    - For correct orientation upon landing
- 3D Printed electronics board
    - To hold all deployment and retention electronics
- External switch access via door



Rotating payload bay with electronics board

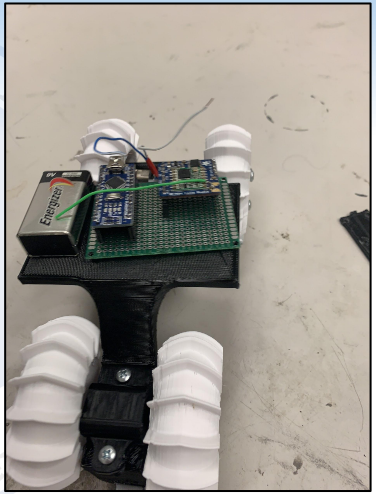
Payload Door

Key Design Features

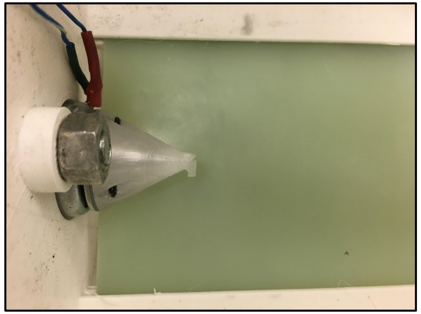
- 3D Printed Rover

- Solenoid Locking Mechanism
    - For rover retention during flight

- Ground Station Communications System
    - For communicating with the deployment, retention, and rover electronics.



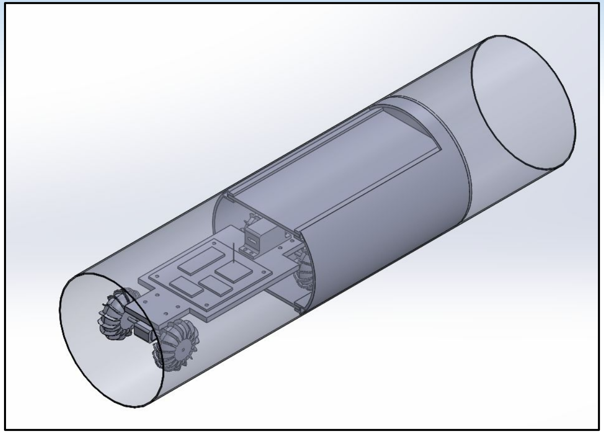
Autonomous rover



Solenoid locking mechanism

Payload Design

- Rotating payload bay to ensure correct orientation upon landing
- An autonomous rover that will recover a 10 mL soil sample
- Rotary solenoid containment mechanism to hold the rover in place during flight



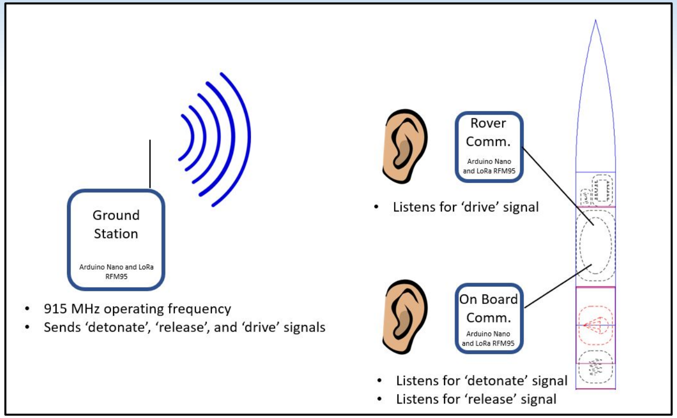
Payload Integration

- Rotating payload bay
    - Flush with the inside of the payload section
- External access door
    - Carbon fiber door flush with the carbon fiber body tube
- Nose cone deployment
    - Integration between structures and payload subsystems for shear pins and ensuring pressurization

Interfaces with Ground System

- Communications system with 3 LoRa RFM9x radio modules
  - 100 mw power
  - 915 MHz fixed operating frequency

- 3 unique signals sent from ground station to launch vehicle electronics and rover electronics



- 915 MHz operating frequency
- Sends 'detonate', 'release', and 'drive' signals

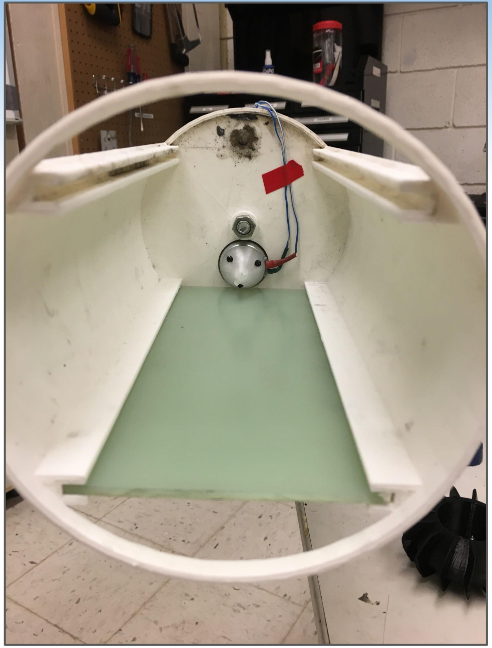
- Listens for 'drive' signal

- Listens for 'detonate' signal
- Listens for 'release' signal

Communication system

Payload Demonstration Flight Results

- Successful demonstration of the solenoid retention mechanism
- Correct orientation upon landing for the rotating payload bay



Solenoid locking mechanism front view

Test Plans and Procedures

- Initiator circuit
- Rotating payload bay
- Retention mechanism
- Communications system
- Nose cone separation
- Motor testing

Ground testing for nose cone deployment

Payload Requirements Verification

Requirement 4.3.2: The rover will be retained within the vehicle utilizing a fail-safe active retention system. The retention system will be robust enough to retain the rover if atypical flight forces are experienced.

- Retainment mechanism has been fully design and tested on vehicle demonstration flights

Requirement 4.3.3: At landing, and under the supervision of the Remote Deployment Officer, the team will remotely activate a trigger to deploy the rover from the rocket.

- Communications system has been designed to fully meet this requirement and will be tested prior to competition launch

Safety, Budget, Outreach, and Project Plan

Safety: Overview

- Hazardous materials identified and hazard mitigation plans developed for each material
- Major personal and environmental hazards were identified and mitigation plans are fully developed
- Major failure modes were identified and mitigation plans are fully developed
- All members take safety training course modules offered by EHS

Hazardous Materials

- New hazardous material: carbon fiber wrapping

Material	Hazards	Mitigations
Carbon fiber wrapping	Airborne fibers can cause severe respiratory irritation. Electrically conductive airborne fibers can cause short circuits in electrical systems.	Limit airborne fiber production during machining operations. Wear a dust mask when machining carbon fiber wrapping.
FibreGlast 2060 60 minute epoxy cure	Causes serious eye damage. Toxic if swallowed or inhaled. Can cause skin and respiratory tract irritation. Chronic exposure can result in harm to the liver, kidneys, eyes, skin or lungs.	Always wear gloves when applying the epoxy and epoxy cure.
FibreGlast 2000 epoxy resin	Skin and eye irritation	Wear gloves while handling.

Failure Modes and Mitigation

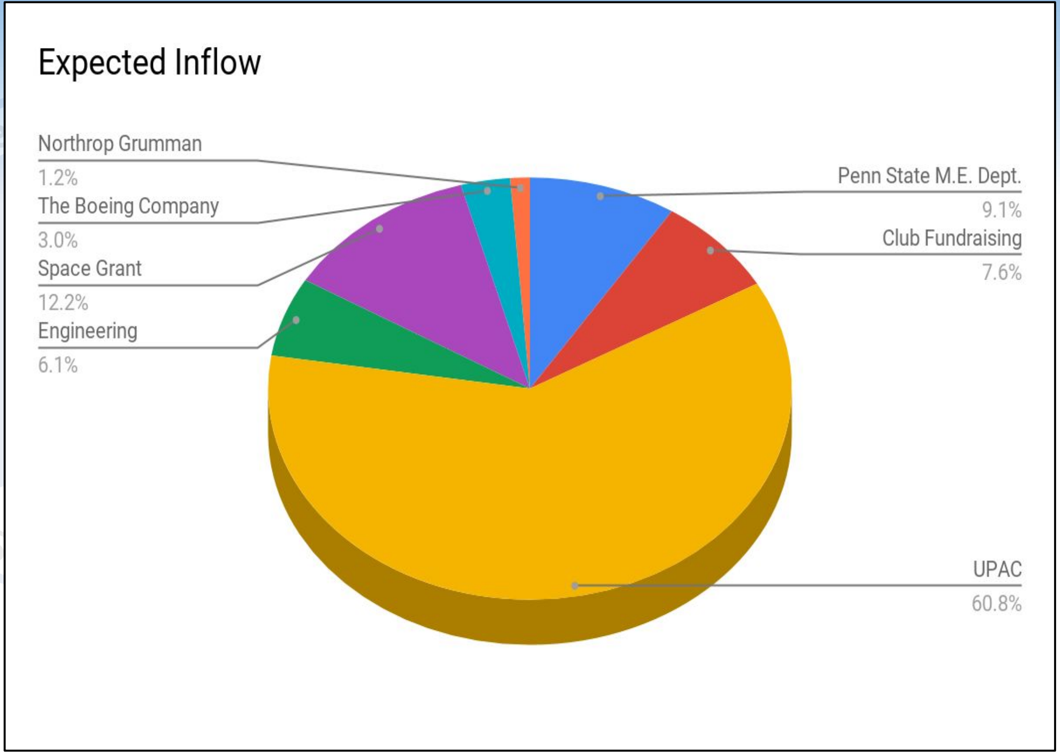
- Motor is not retained
  - Motor does not undergo controlled descent with the rest of the rocket
  - Use of active motor retention with three epoxied centering rings
  - Verified by vehicle Demonstration Flight
- Bulkhead separation from the body tube
  - Insufficient epoxy strength results in premature separation of the rocket, potentially followed by ballistic descent
  - Visual inspection and preflight check
  - FEA on bulkheads to optimize initiator wire holes placement that minimize stress concentrations
  - Verified by vehicle Demonstration Flight

Failure Modes and Mitigation

- Premature activation of payload nose cone deployment
  - Control software triggers premature detonation of black powder
  - Nose cone of the rocket separates prematurely
  - Perform thorough rigorous testing on the control software to prevent premature triggering
  - Isolate deployment software and wiring from all other systems to prevent accidental premature detonation
  - Verified by vehicle Demonstration Flight
- Ejection charges failing to go off or failing to separate the rocket
  - Would cause ballistic descent
  - Use fresh batteries for each launch and check altimeter continuity before each launch
  - Calculate the amount of explosive power necessary to separate the rocket
  - Calculations verified by vehicle Demonstration Flight

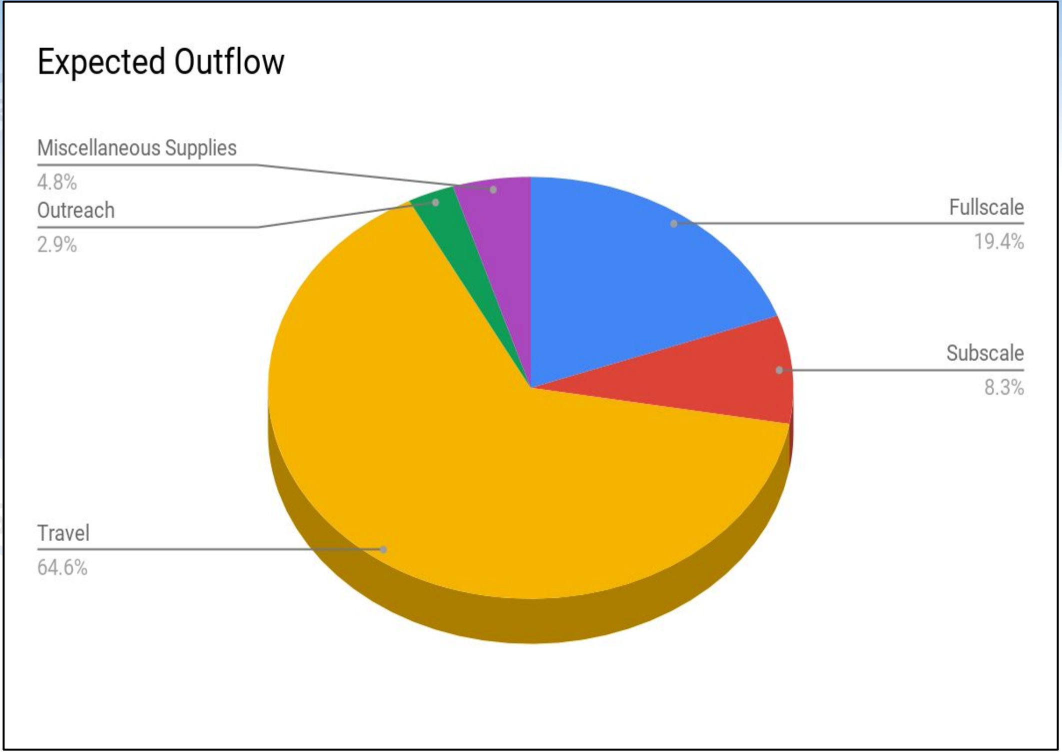
Budget - Inflow

Donor	Requested Amount
Penn State Aerospace Engineering Department	$2,000.00
Penn State Mechanical Engineering Department	$1,500.00
Club Fundraising	$1,250.00
University Park Allocations Committee	$10,000.00
Engineering Undergraduate Council	$1,000.00
Pennsylvania Space Grant Consortium	$2,000.00
The Boeing Company	$500.00
Northrop Grumman	$200.00
Total	**$18,450.00**



Budget - Outflow

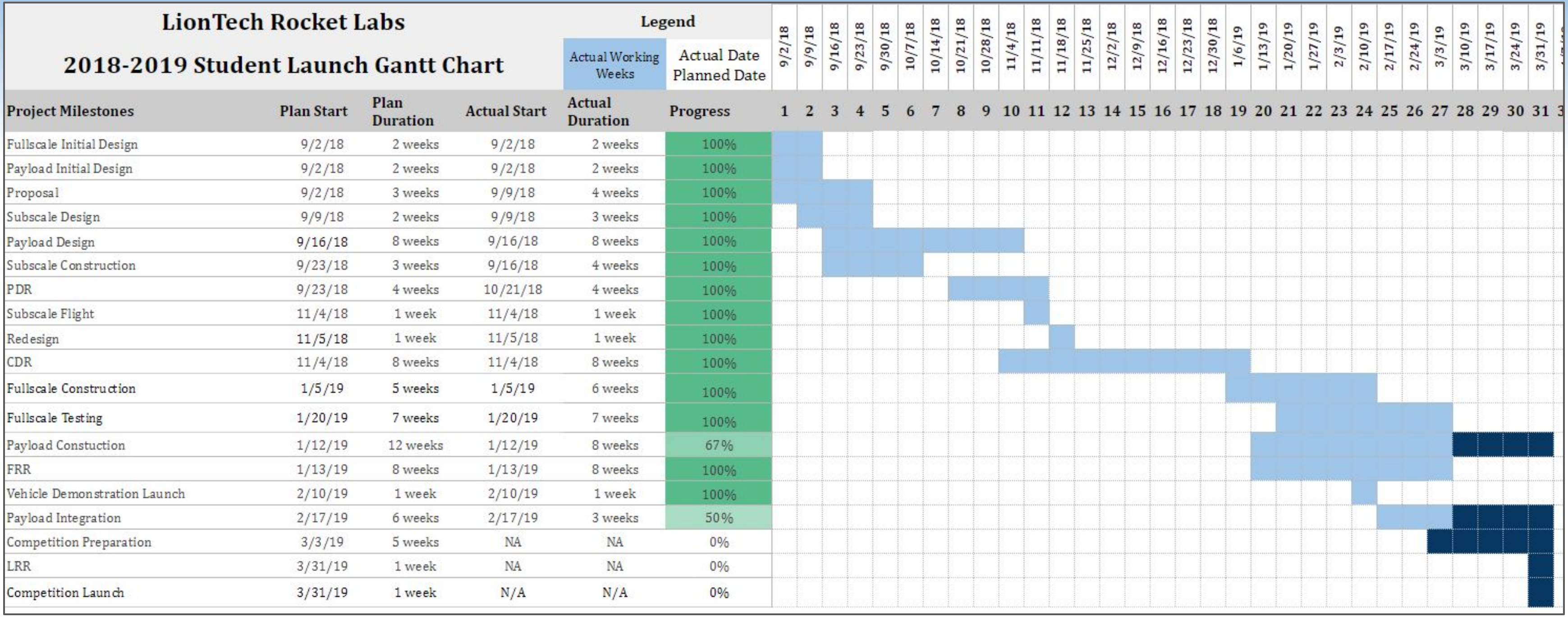
Budget	Total Cost
Fullscale	$2,031.85
Subscale	$867.69
Travel	$6,750.00
Outreach	$300.00
Miscellaneous Supplies and Equipment	$500.00
Total	**$10,449.54**



Outreach Results

665 students of varying ages were reached through STEM focused outreach events across 6 different events

Project Plan



LionTech Rocket Labs

2018-2019 Student Launch Gantt Chart

Legend

Actual Working Weeks

Actual Date Planned Date

Project Milestones	Plan Start	Plan Duration	Actual Start	Actual Duration	Progress
Fullscale Initial Design	9/2/18	2 weeks	9/2/18	2 weeks	100%
Payload Initial Design	9/2/18	2 weeks	9/2/18	2 weeks	100%
Proposal	9/2/18	3 weeks	9/9/18	4 weeks	100%
Subscale Design	9/9/18	2 weeks	9/9/18	3 weeks	100%
Payload Design	9/16/18	8 weeks	9/16/18	8 weeks	100%
Subscale Construction	9/23/18	3 weeks	9/16/18	4 weeks	100%
PDR	9/23/18	4 weeks	10/21/18	4 weeks	100%
Subscale Flight	11/4/18	1 week	11/4/18	1 week	100%
Redesign	11/5/18	1 week	11/5/18	1 week	100%
CDR	11/4/18	8 weeks	11/4/18	8 weeks	100%
Fullscale Construction	1/5/19	5 weeks	1/5/19	6 weeks	100%
Fullscale Testing	1/20/19	7 weeks	1/20/19	7 weeks	100%
Payload Constuction	1/12/19	12 weeks	1/12/19	8 weeks	67%
FRR	1/13/19	8 weeks	1/13/19	8 weeks	100%
Vehicle Demonstration Launch	2/10/19	1 week	2/10/19	1 week	100%
Payload Integration	2/17/19	6 weeks	2/17/19	3 weeks	50%
Competition Preparation	3/3/19	5 weeks	NA	NA	0%
LRR	3/31/19	1 week	NA	NA	0%
Competition Launch	3/31/19	1 week	N/A	N/A	0%