Penn State
LionTech Rocket Labs

Critical Design Review

Presentation Overview

- Team Introductions
- Subscale Flight Results
- Vehicle Design
- Motor Selection and Future Testing
- Recovery System
- Rover Design
- Safety
- Budget
- 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

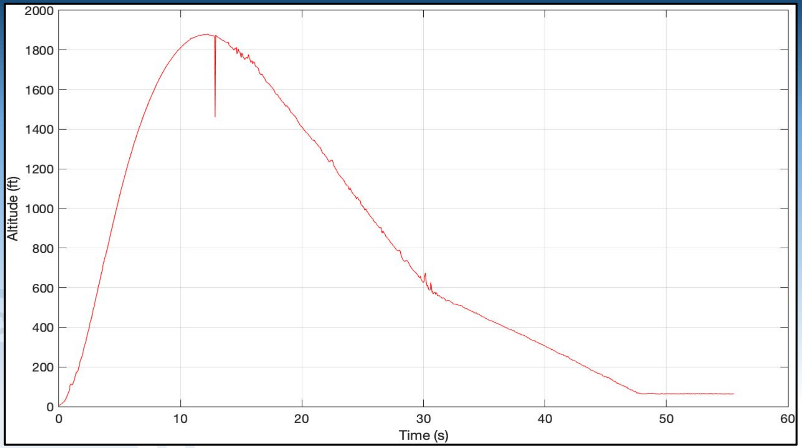
Payload Leads: Logan Baker, Jaimin Patel

Subscale Results

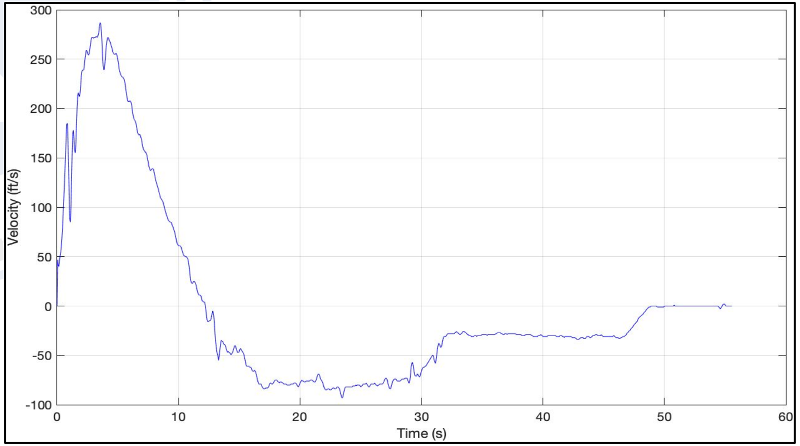
Launch day conditions:
Cloudless skies, 80℉, 5 mph cross winds

The launch vehicle reached an apogee of 1877 feet at 13.1 seconds into the flight.

The launch vehicle achieved a max velocity of 291 ft/s at 4.65 seconds into the flight.



Altitude vs Time of Subscale Flight

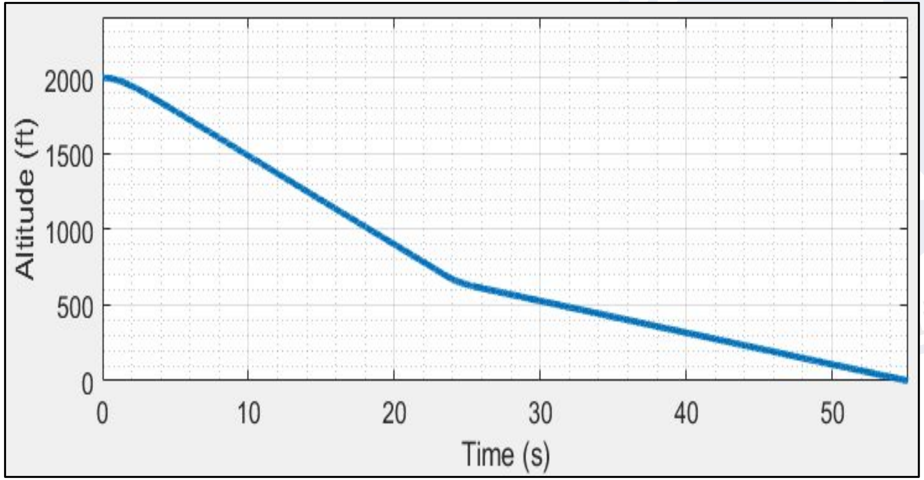


Velocity vs Time of Subscale Flight

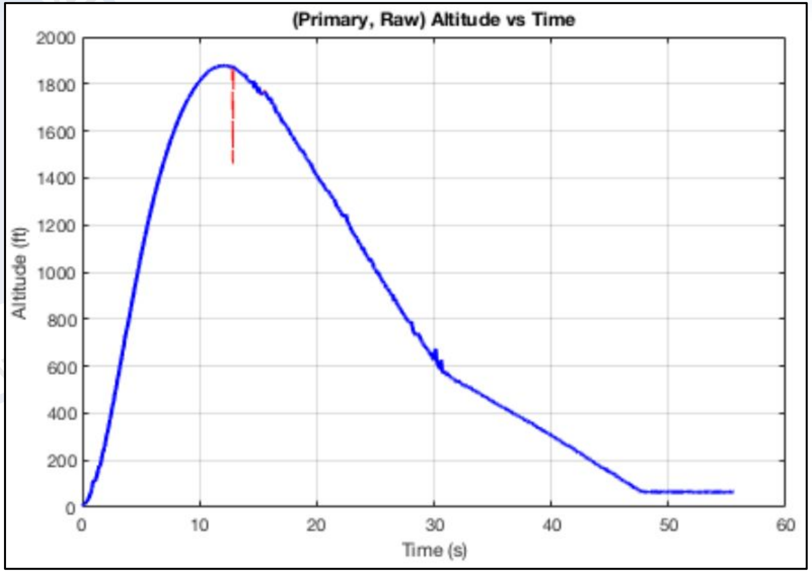
Subscale Results Continued

Successful parachute deployment

Descent time was 36s (Slightly faster than expected)



Predicted Altitude vs Time



Actual Altitude vs Time

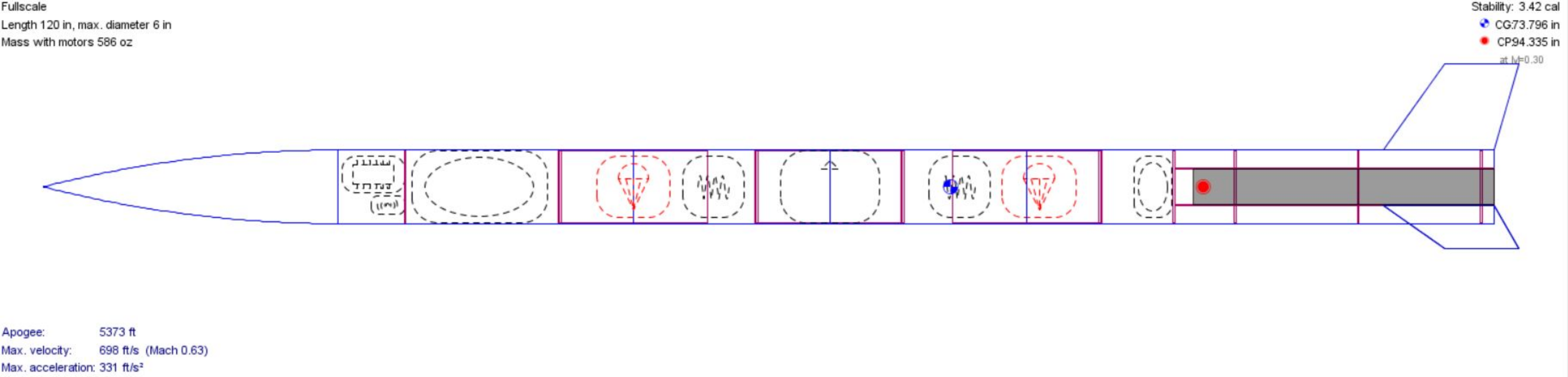
Subscale Flight Test Anomaly

Just after the rocket left the rail, it began to oscillate back and forth until around the time of motor burnout.

The team believes the cause of this anomaly was that the body tube sections were not flush against each other, leaving enough space for the rocket to bend when not supported.

This anomaly resulted in no injuries or property damage and special consideration will be taken during fullscale manufacturing to prevent this issue in the future.

Vehicle Characteristics



Length: 120 in.

Total Mass: 36.625 lbs

Outer Diameter: 6 in.

MATLAB Calculation

Stability: 3.38 calibers
CG: 73.28 in.
CP: 93.54 in.

Open Rocket Calculation

Stability: 3.42 calibers
CG: 73.796 in.
CP: 94.335 in.

Component Masses

Current masses for airframe body tubes are based on the supplier density given for the carbon fiber being used. This is multiplied by the estimated volume of carbon fiber material being used to find the masses of the body tubes.

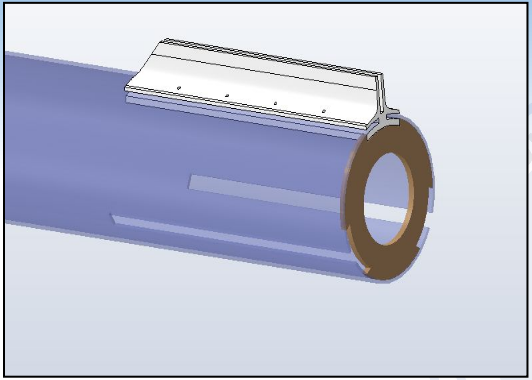
Testing will be done to ensure the density given is accurate to the supplier density.

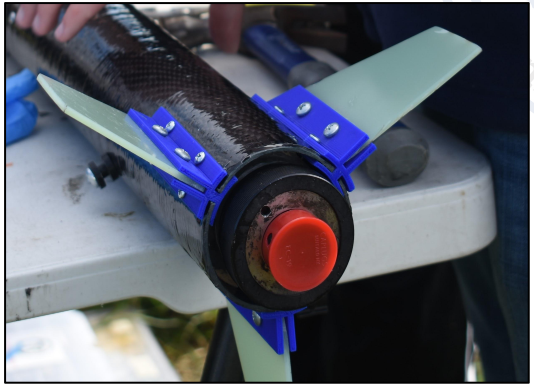
Component	Weight (oz)
Nose cone	84.6
Payload Section	74.3
Payload-Drogue Coupler	9.49
Drogue Section	18.6
AV Bay	87.4
Main Section	24.1
Main-Booster Coupler	13
Booster Section	99

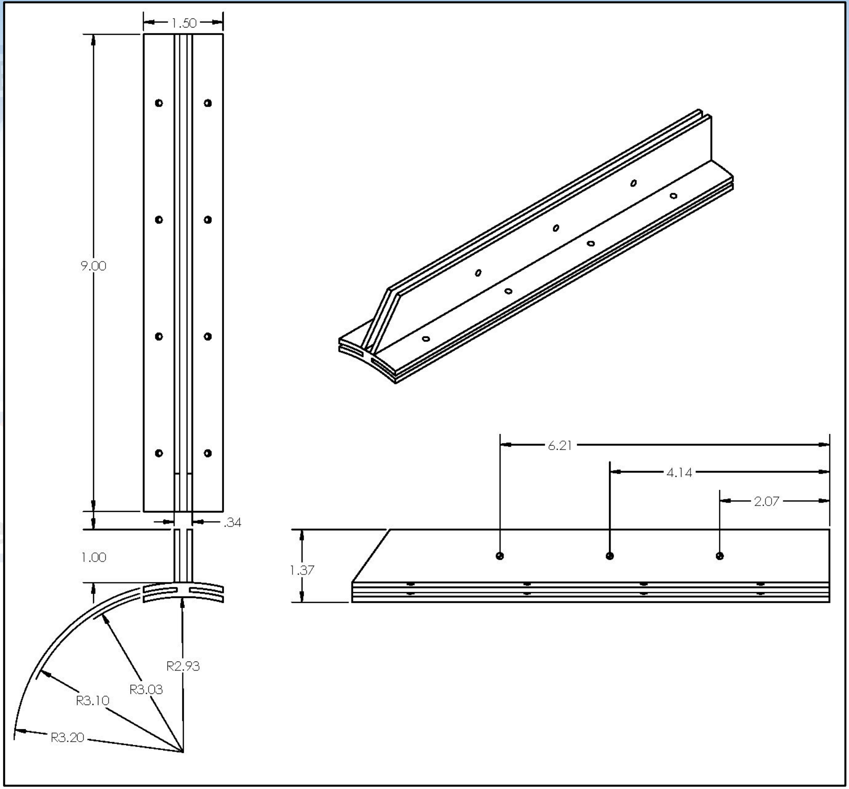
Airframe Selection

Attributes	Weight	Carbon Fiber (Shrink Tape) Score	Carbon Fiber (Shrink Tape) Weighted Score	Carbon Fiber (Vacuum Bagging) Score	Carbon Fiber (Vacuum Bagging) Weighted Score	Glass Fiber Score	Glass Fiber Weighted Score	Blue Tube Score	Blue Tube Weighted Score
Strength	0.15	3	0.45	5	0.75	4	0.60	1	0.15
Cost	0.10	3	0.30	1	0.10	2	0.20	5	0.50
Workability	0.10	2	0.20	1	0.60	3	0.30	5	0.50
Material Weight	0.15	3	0.45	3	0.45	1	0.15	4	0.60
Educational Value	0.25	5	1.25	5	1.25	2	0.50	1	0.25
Safety	0.25	2	0.50	3	0.75	1	0.50	5	1.25
Total	1.00		**2.95**		**3.40**		**2.35**		**3.25**
Rank			**3**		**1**		**4**		**2**

Fin Bracket Design



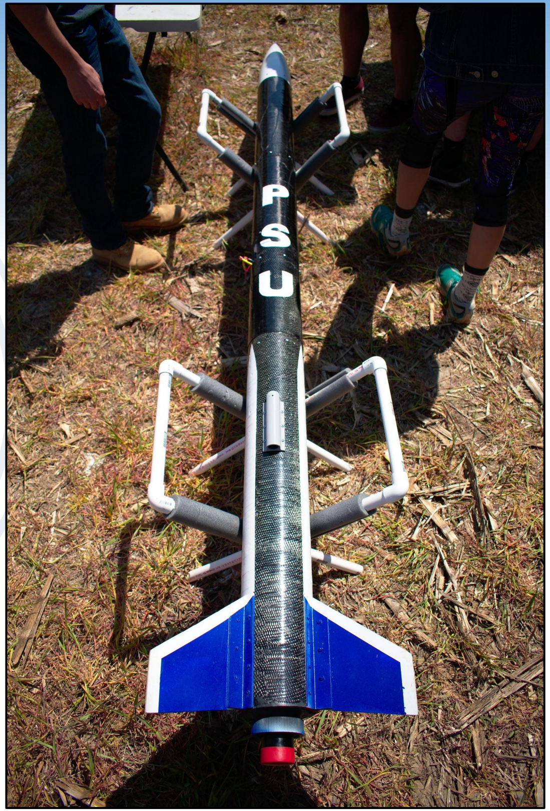




Vacuum Bagged Carbon Fiber

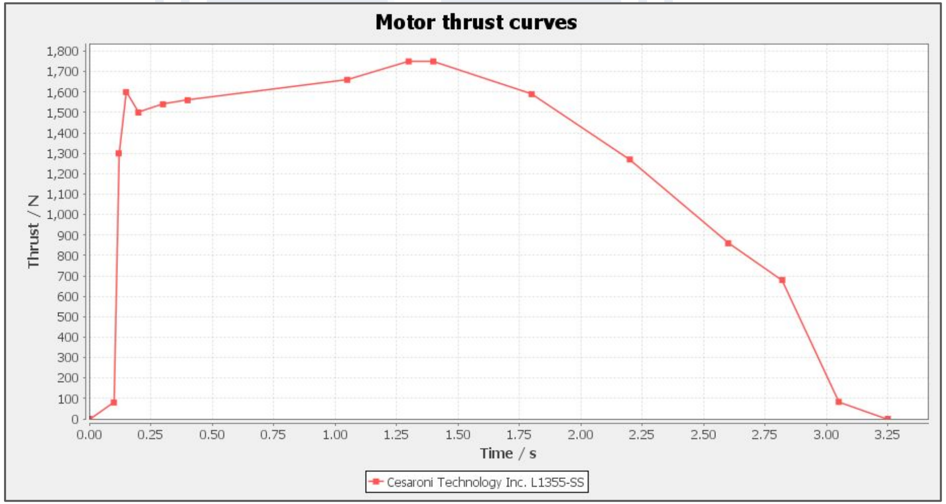
Carbon fiber with epoxy is wrapped around blue tube mandrel with packing tape and polyvinyl alcohol to ensure that the tube will not stick to the mandrel during the vacuum procedure.

The carbon fiber is covered with mold-release paper and a cloth to avoid sticking and to make sure the pump is safe during the vacuum process.

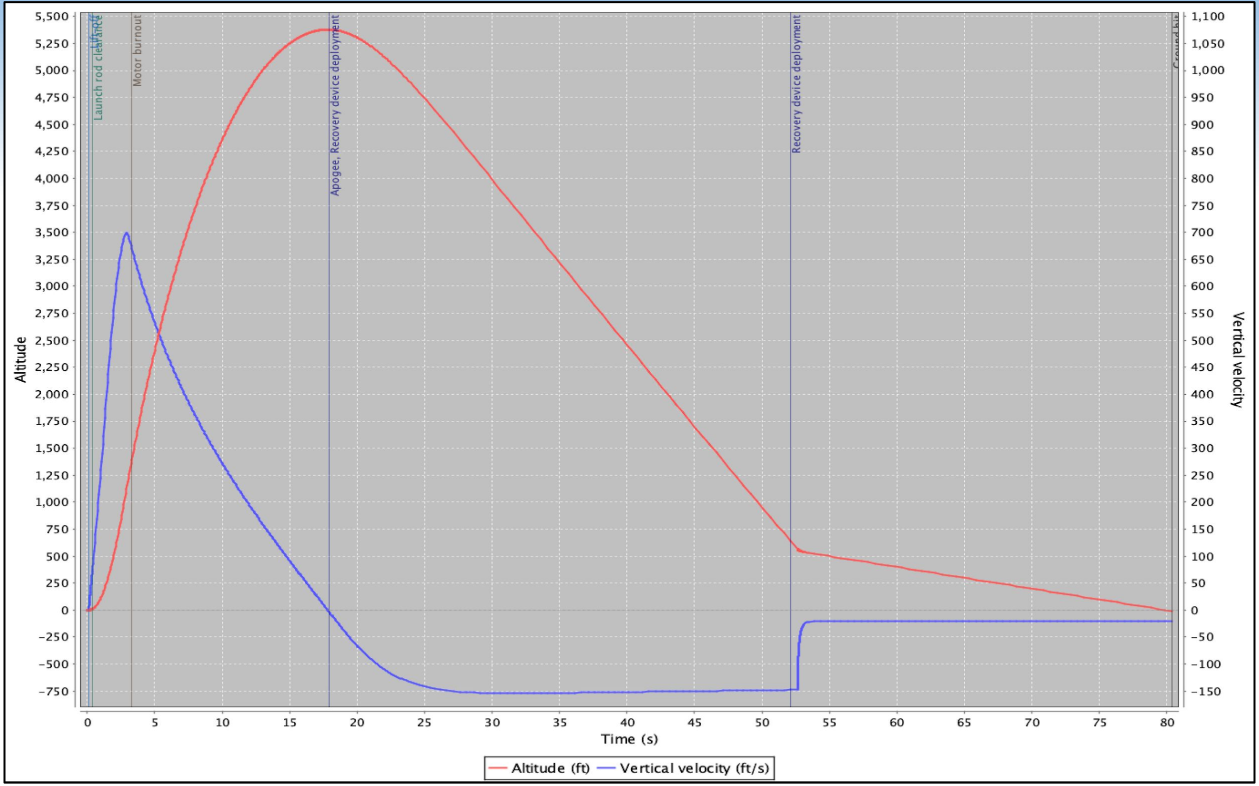


Primary Motor Characteristics

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 L1355	5379	75.7	699	7.77	905	2.95	175



Primary Motor Flight Simulation



Tensile Test of Vacuum Bagged Carbon Fiber

Will manufacture carbon fiber body tubes using vacuum bag technique

Testing tensile strength of a six layer wrap an seven layer wrap using a load cell in order to more accurately describe material properties of vacuum bagged carbon fiber

Structure 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
- The launch vehicle will be designed to be recoverable and reusable.
  - Vacuum bagged carbon fiber for maximum airframe strength
  - Modular design for localized repair
- The launch vehicle will have a maximum of four (4) independent sections.
  - Four sections were designed to house parachutes, motor, and payload

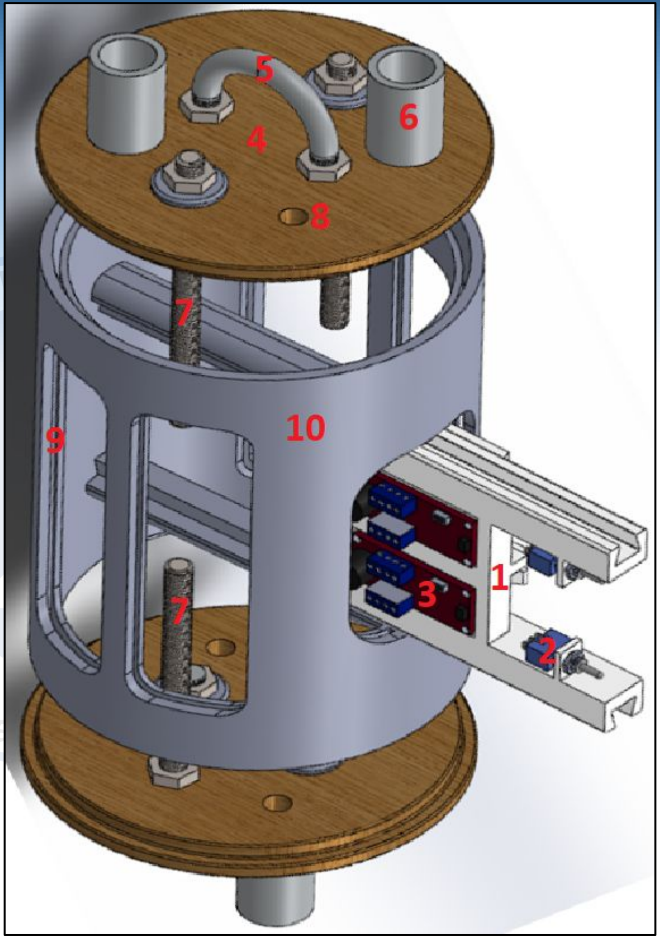
Structures Status of Requirements Verification

- 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.
  - Modular design for easy transport
  - Majority of construction 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 3.50 calibers at rail exit

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 bay door

Avionics Ignition System

StratologgerCF Altimeter

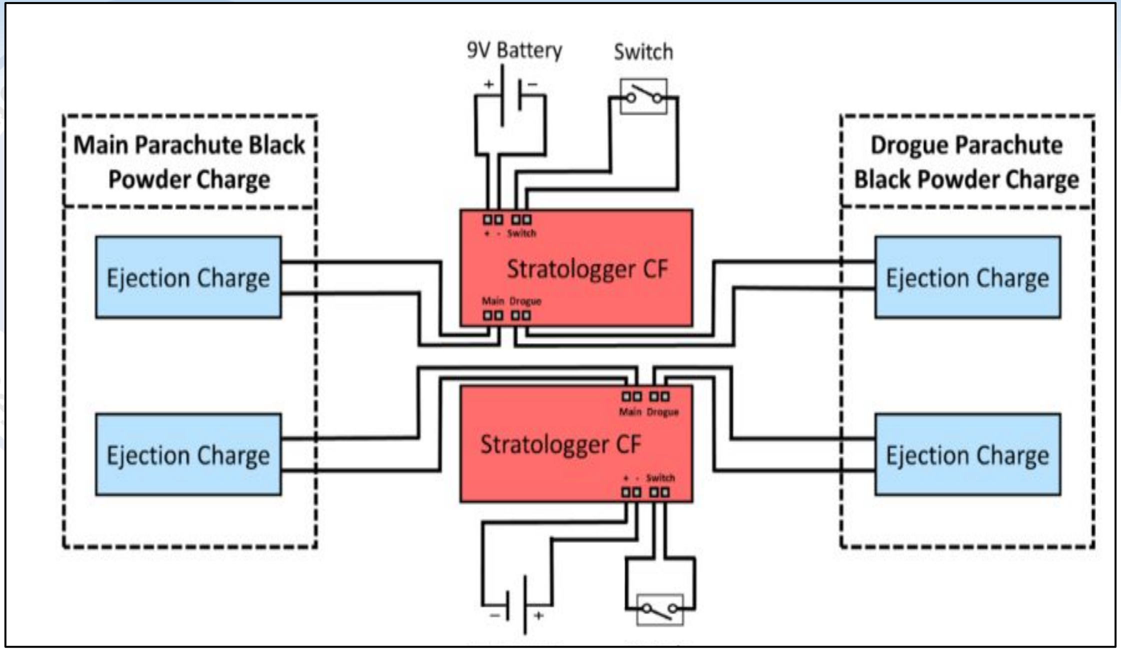
Toggle Switch

Duracell 9V Battery

18 Gauge Electrical Wire

FAA approved Initiators

Black Powder ejection charge



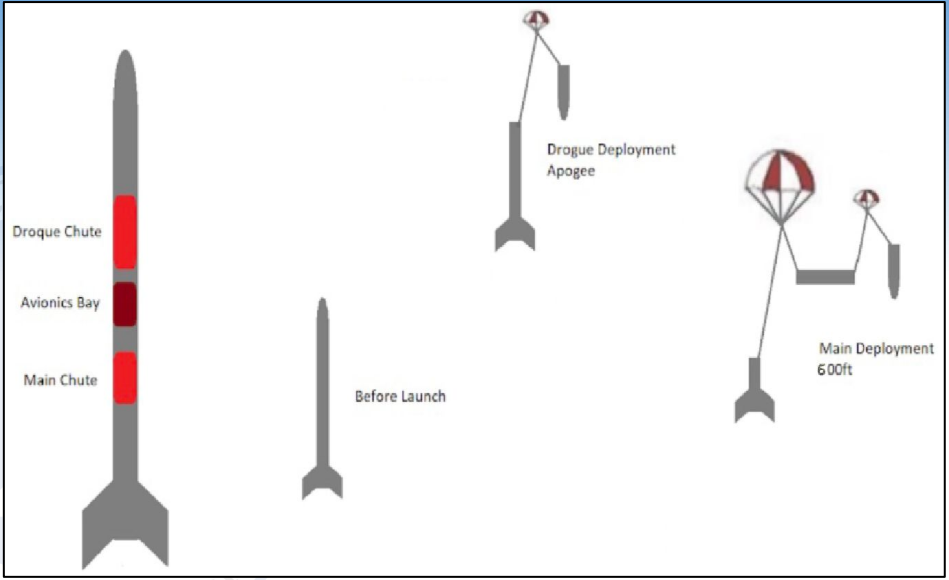
Recovery System

Primary deployment

- Drogue at apogee
- Main at 600ft ABG

Redundant deployment

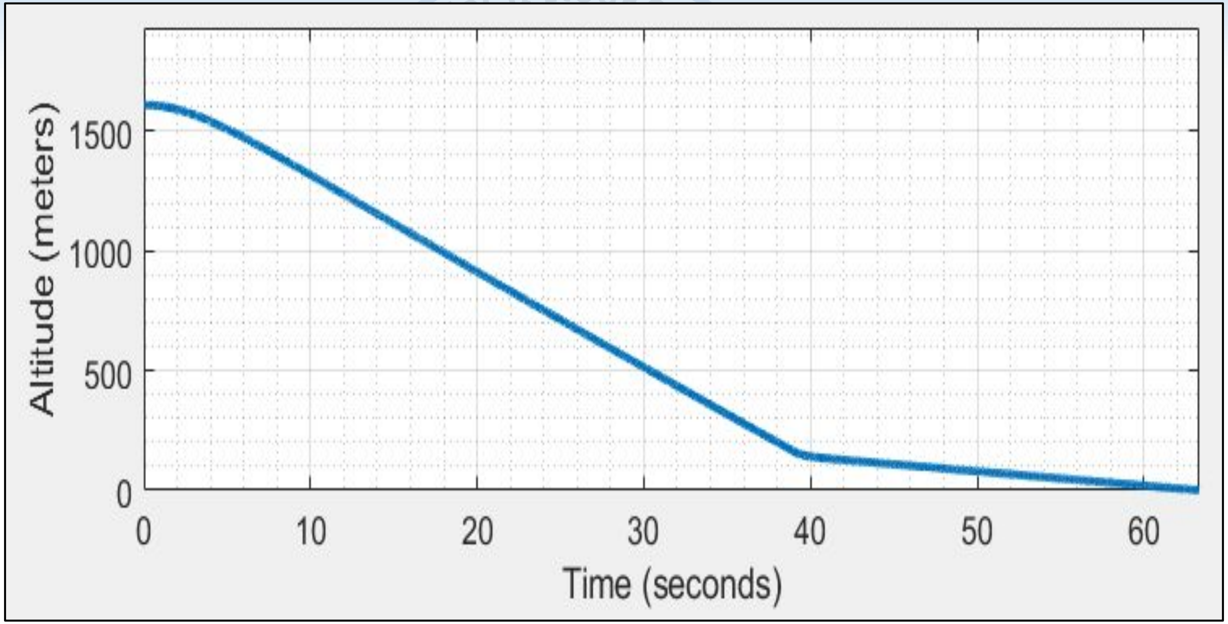
- Drogue at apogee +2s
- Main at 500ft ABG



Drogue	Main
12” Fruity Chutes Classical Ultra	84” Fruity Chutes Iris Ultra
26ft by 1/2in Kevlar shock cord	11ft by 1/2in Kevlar shock cord

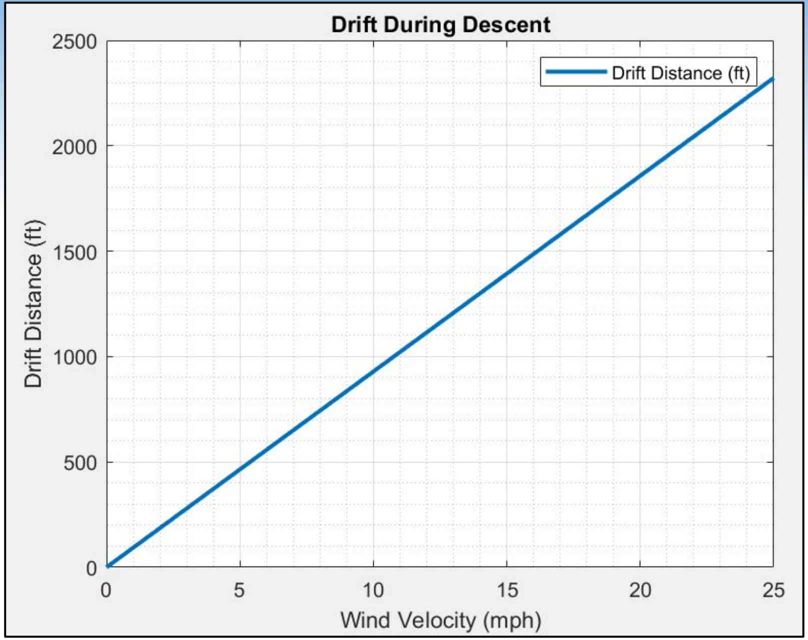
Descent Time

Descent time from apogee is 63.2s



Predicted Altitude versus Time of Fullscale Flight

Drift Distances



Wind velocity	5 mph	10 mph	15 mph	20 mph
Drift distance	464.44 ft	928.88 ft	1393.32 ft	1857.77 ft

Kinetic Energy

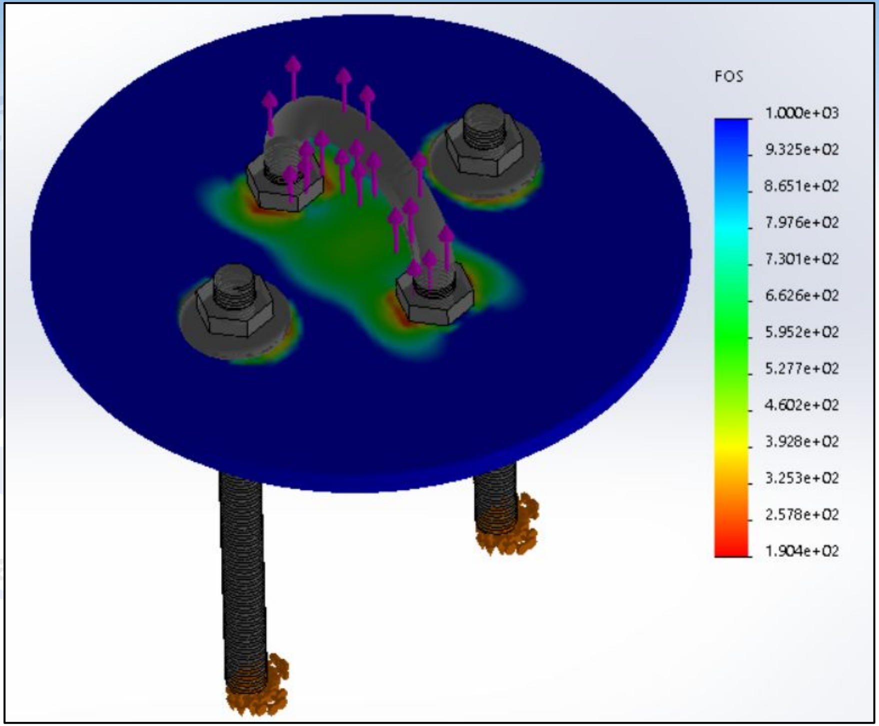
MATLAB landing velocity is 19.44 ft/s
OpenRocket landing velocity is 20.10 ft/s

Section	Mass	Kinetic Energy at landing (Matlab)	Kinetic Energy at landing (Openrocket)
Nose	168.4 oz	61.83 ft*lbs	66.09 ft*lbs
Avionics	123.3 oz	45.27 ft*lbs	48.39 ft*lbs
Booster	168.2 oz	61.76 ft*lbs	66.02 ft*lbs

Bulkhead testing

Optimizing U-Bolt and initiator hole locations on the avionics bay

Solidworks FEA simulation for strength optimization of the bulkhead plate



Separation Event

Calculated amount of shear pins the black powder ejection charge could break compared to the actual amount used.

	Full scale Drogue	Full scale Main	Full scale Drogue Redundant	Full scale 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 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.

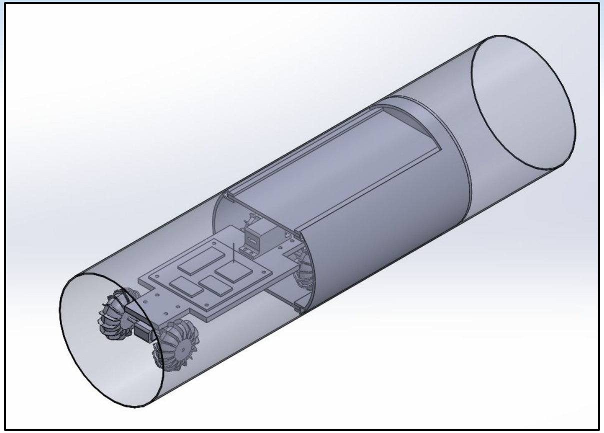
- The kinetic energy of each section has been calculated in Openrocket and verified with MATLAB

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 Openrocket and verified with MATLAB

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

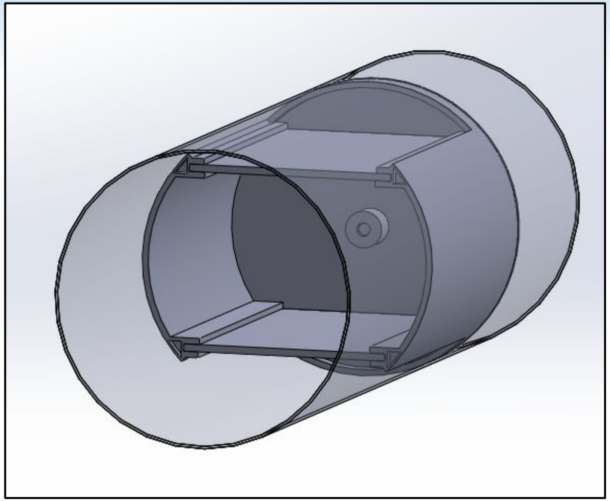


Rotating Payload Bay

- Rotates on a partially threaded hex bolt

- Removable shelves to easily test and integrate electronics

- Secondary bulkhead to mount containment electronics

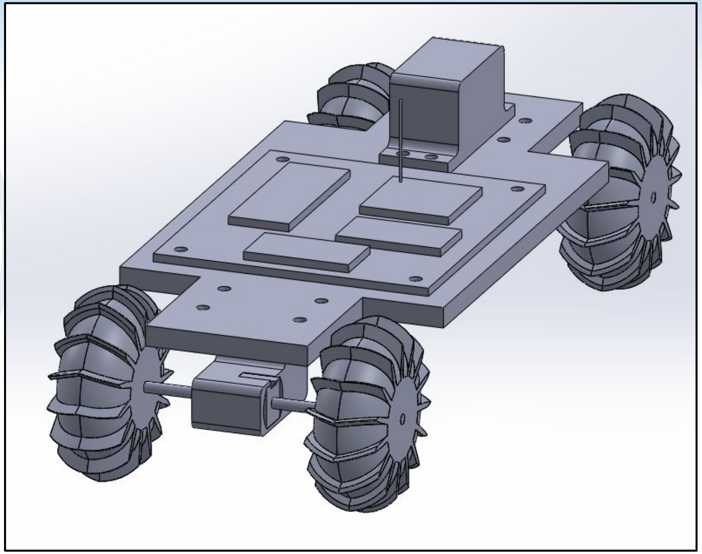


Rover Design

- Raised chassis with dual shaft motor mounts underneath

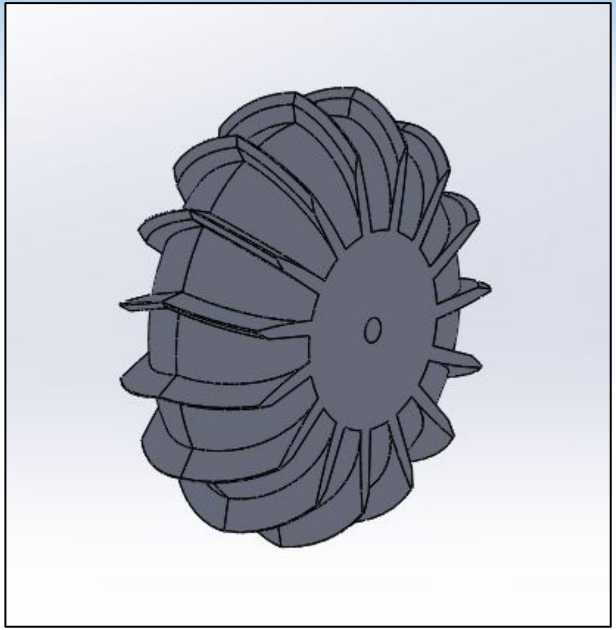
- Large area for electronic components including communications system, Arduino Nano, and 9V batteries

- 3D printed solenoid locking mechanism



Wheel Design

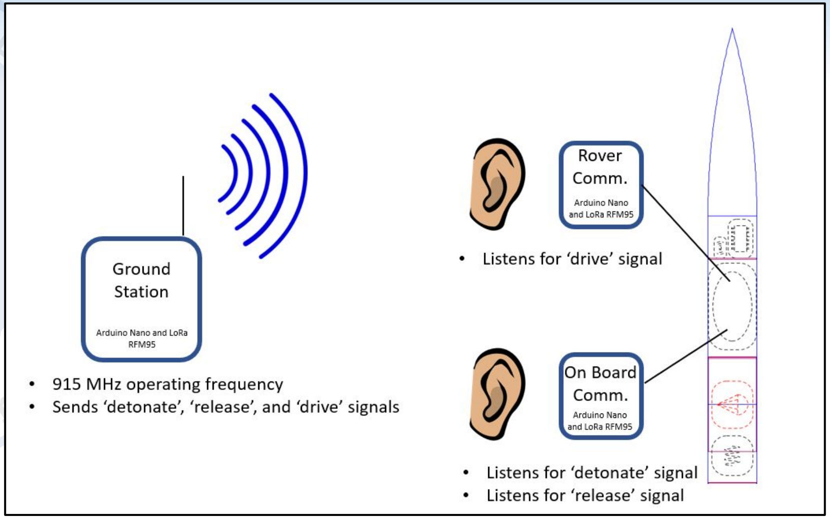
- Wide wheel design improve stability and grip on loose and uneven soil
- Angled treads to displace soil
- Optimized for increased traction with deep treads



Communications System

- LoRa RFM95 radio modules operating at 915 MHz, 10.3 mA RX current

- Ground station control software sends signals to 2 communication systems in the launch vehicle



Communications System Diagram

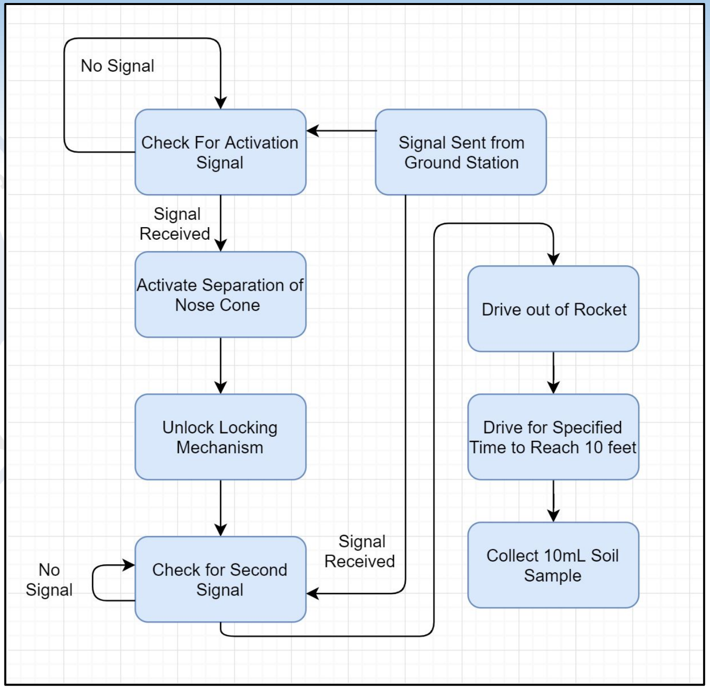
Separation and Containment Mechanisms

- Deployment is initiated by the ground station control software
- Uses an initiator to detonate a black powder charge to pressurize and separate the nose cone from the body tube
- Rover is contained during separation by a 24V solenoid locking mechanism

Electronics Design

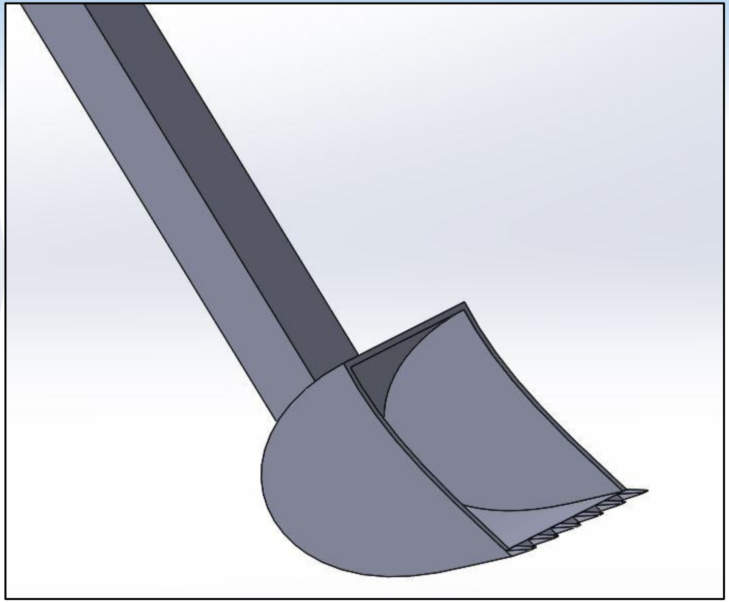
- Arduino Nano used for ground station, rover, and deployment mechanisms

- Using Arduino and transistors to act as switches for powering solenoid, initiator, and DC motors



Soil Sample Recovery

- Mechanical bucket attached to the bottom side of the rover
- The bucket will swing down to collect a soil sample underneath of the rover
- The bucket will return to the rover where it will be securely fasten into a designated space on the bottom



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 had been fully design and will be tested prior to 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

Payload Test Plans and Procedures

Demonstration tests will be conducted for the following prior to fullscale test flight:

- Retention Mechanism
- Communications Testing
- Ejection Mechanism
- Rover Maneuvering

Safety: Overview

- Hazardous materials identified and hazard mitigation plans developed for each material
- Major personal and environmental hazards were identified and preliminary mitigation plans were developed
- Major failure modes were identified and preliminary mitigation plans were 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

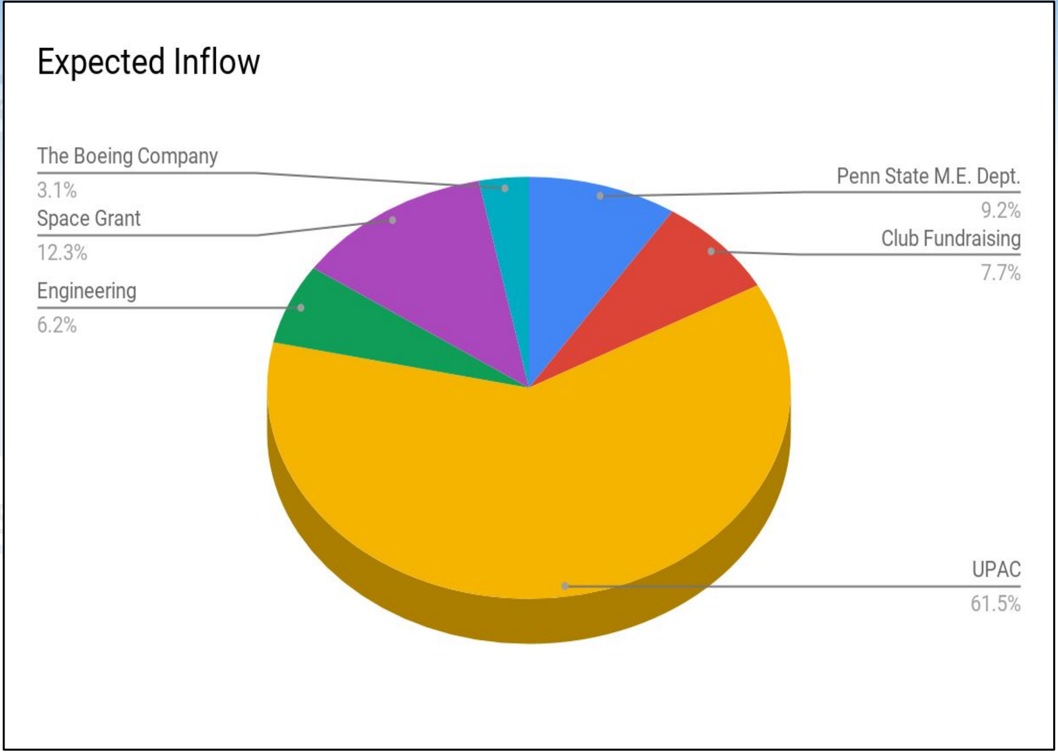
- Motor is not retained
  - Motor does not undergo controlled descent with the rest of the rocket
  - Use of active motor retention with three epoxied centering rings
  - Verified by previous year competition and test flights
- Bulkhead separation from the body tube
  - Insufficient epoxy strength results 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

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
- 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

Budget - Inflow

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**



Budget - Outflow

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
Total	**$18,250.00**