Oregon State University NASA USLI

11/15/2019

1) **Competition**

2) 2019 OSU USLI Team

3) OSU Rocket and Rover

4) Performance and Results

What is USLI?

NASA University Student Launch Initiative:

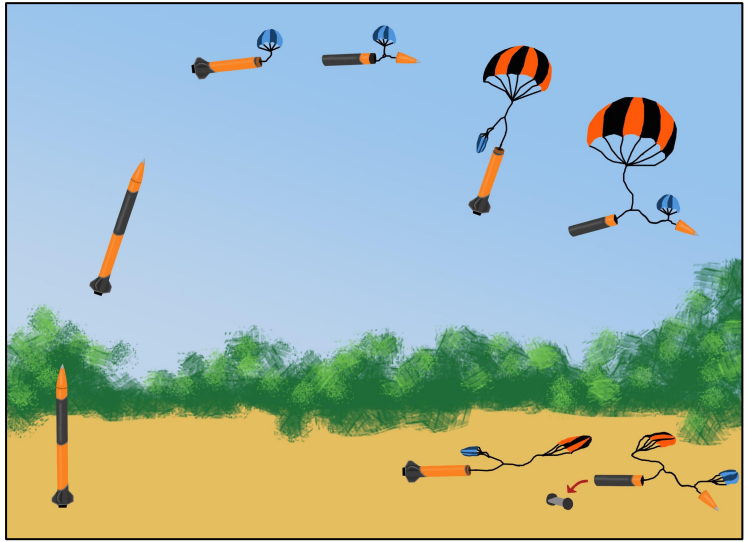
- 8 month competition
- 45 universities competed

2019 Competition

- Rocket had a target altitude of 4,500 ft.
- Carried a ground deployable rover payload

Mission Overview

1. Launch
2. Motor burnout
3. Separation at apogee
4. Drogue parachutes deploy
5. Main parachutes deploy
6. Landing
7. Rover deployment
8. Soil collection
9. Scientific experiment



Not to Scale

1) Competition

2) 2019 OSU USLI Team

3) OSU Rocket and Rover

4) Performance and Results

2019 OSU USLI Team

- 12 ME
- 2 ECE
- 3 CS
- 14 Volunteers

1) Competition

2) 2019 OSU USLI Team

3) OSU Rocket and Rover

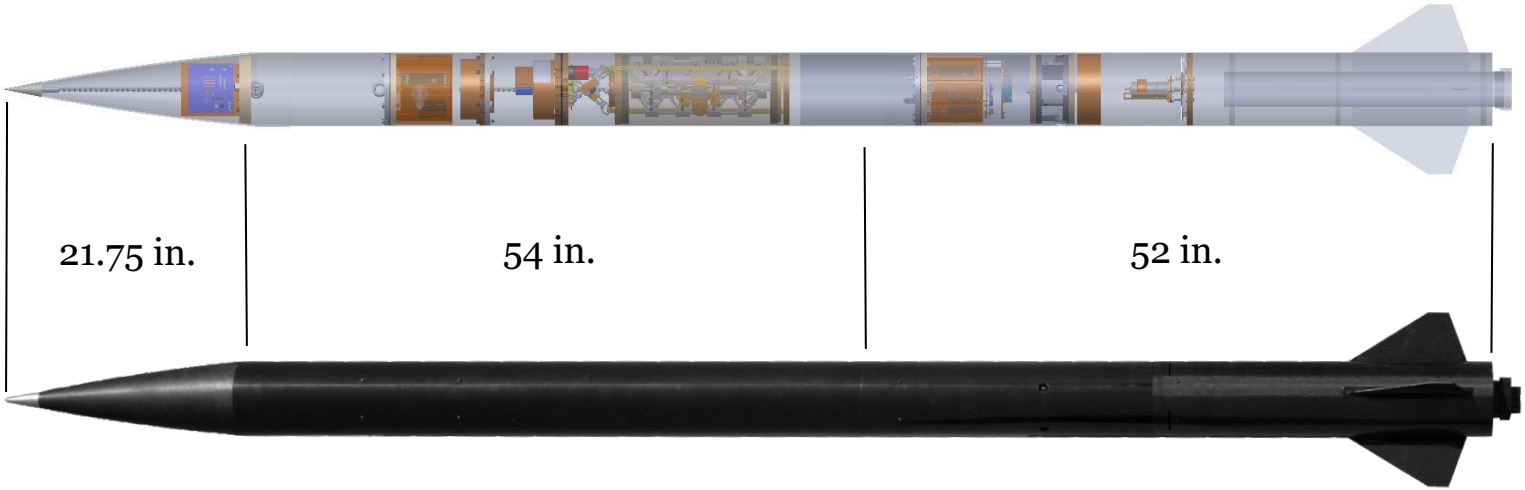
4) Performance and Results

Launch Vehicle Overview

- Total Length: 129.375 in.
- Total Weight: 56.9 lbf
- Airframe Inner Diameter: 6.25 in.

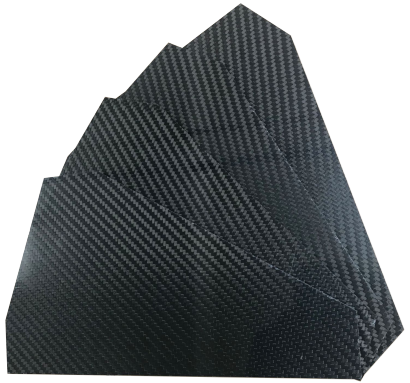
Launch Vehicle Design

Airframe



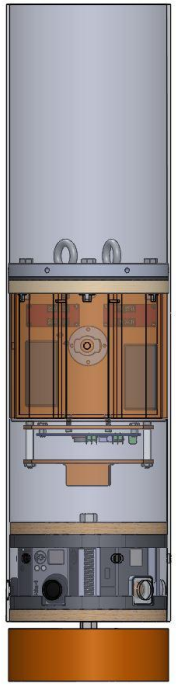
Aft Section

- Trapezoidal Fins
- 52 in. Body Tube
  - 24 Fiberglass (Fore)
  - 28 Carbon Fiber (Aft)
- Motor Retention
  - G12 Fiberglass Motor Tube
  - 3x Plywood Centering Rings
  - 6061 Aluminum Retainer



Canister and Coupler

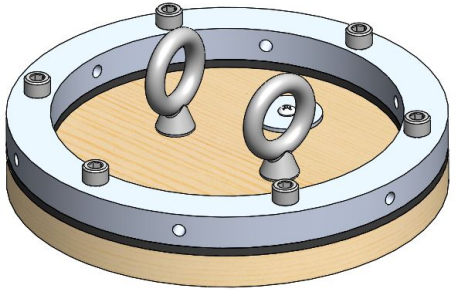
- G12 Fiberglass
- Coupler
  - 5 ⅛ in. within Nosecone
  - 6 ⅞ in. within Fore Body Tube
- Canister: 23.5 in. Long
  - 7 in. within Fore Body Tube
  - 16.5 in. within Aft Body Tube
- Contains:
  - Camera System
  - Aft Electronics Bay
  - Aft Parachutes



Pressure Seal

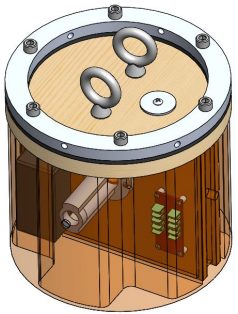
Cap on each electronic bay

- Six ¼-20 bolts compress a Santoprene rubber sheet
- Removable
- Minimizes needed charge size
- Radially mounted
- Provides a mounting point for parachutes



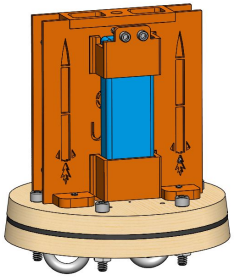
Fore Ejection Bay

- Located aft of fore parachutes
  - RF shielded
  - Pressure sealed
  - Fore parachute mounting point
- Specifications
  - Weight: 2.02 lbf
  - Length: 6 in.
  - Additively manufactured mount



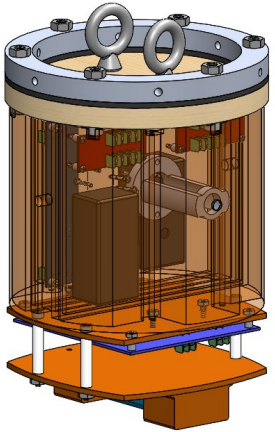
Fore Avionics Bay

- Located within the nosecone
  - RF transparent
  - Conserves space
  - Pressure sealed
- Specifications
  - Weight: 0.65 lbf
  - Length: 5in.
  - Additively manufactured mount



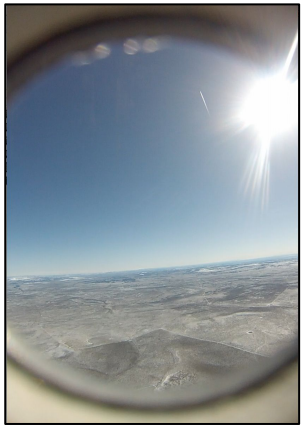
Aft Ejection and Avionics Bay

- Located aft of aft parachutes
  - RF shielded
  - Mounting point for aft parachutes
- Specifications
  - Weight: 2.33 lbf
  - Length: 8.5 in.
  - Additively manufactured mount



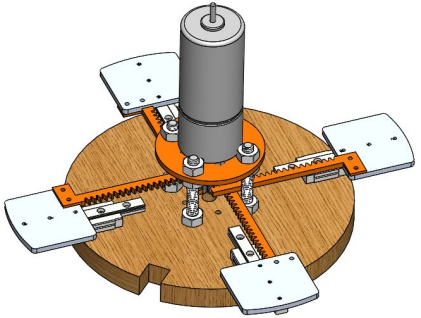
Camera System

- Five cameras consist of:
  - 2 GoPro HERO3s
  - 1 GoPro HERO5
  - 2 YI 4K Action Cameras
- Five recording combined into 360° video
- Lightweight and durable

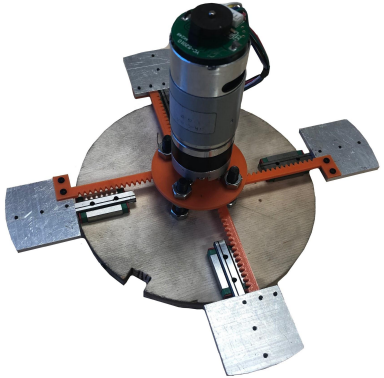


BEAVS

- Active System
  - Four blades extend through airframe
  - Driven off central gear
  - Control system utilizes ATU sensors

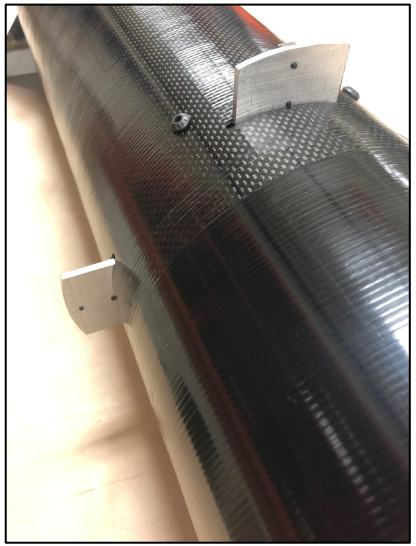


- Passive System
  - Coupled ballast bays in Fore and Aft
  - Adjust apogee altitude & maintain CG



BEAVS

- Active System
  - Electronic systems not present for full scale flight
  - Mechanical systems present in flight
- Passive System
  - First full scale flight - 0.0 lbf
  - Second full scale flight - 2.0 lbf



Ballast Bays

Wind Speed (mph)	Fore Ballast (lbf)	Aft Ballast (lbf)	Stability (calibers)	Apogee Altitude (ft)
0	0.14	1.03	2.10	**4500**
5	0.10	0.98	2.10	**4500**
10	0.06	0.93	2.10	**4500**
15	0.02	0.88	2.10	**4500**
20	0.00	0.71	2.11	**4500**

Radial Bolt Testing

- Passing Condition
  - Withstands 75 G
- Test Procedure
  - Instron - Compression test bulkheads and aluminum ring
- Status - Complete
  - Plywood bulkhead - failure
  - Plywood with aluminum ring - success
  - Aluminum ring - success

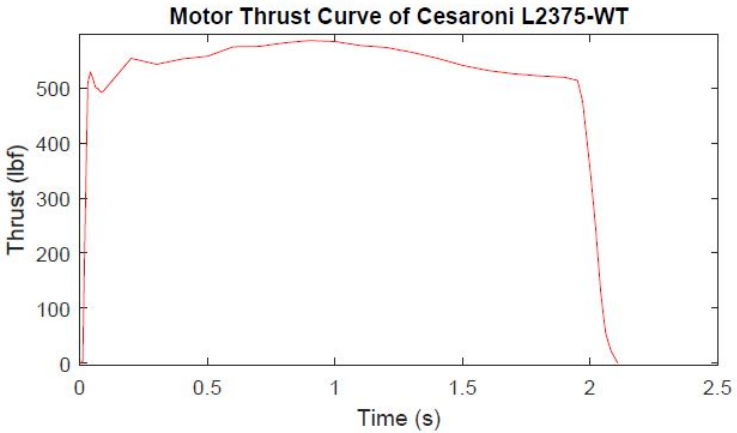
Airframe Structures Testing

- Passing Condition
  - Withstands 15 G
- Test Procedure
  - Instron - Compression test fiberglass airframe section with holes
- Status - Complete
  - Handled 46.5 G
  - Not tested to failure

Final Motor Choice

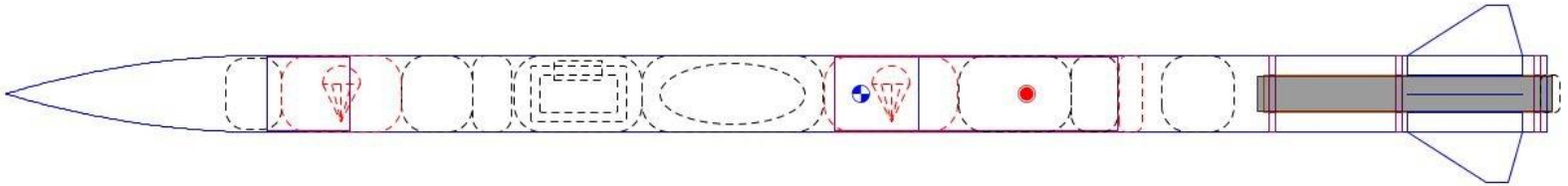
Cesaroni L2375-WT

- Total Impulse: 1,103 lbf-s
- Avg. Thrust: 534 lbf
- Max Thrust: 586 lbf
- Rail Exit Velocity: 83.4 ft/s
- T/W: 10.30



Stability Margin

- Stability: 2.14 calibers
- Center of Gravity: 71.0 in.
- Center of Pressure: 84.7 in.



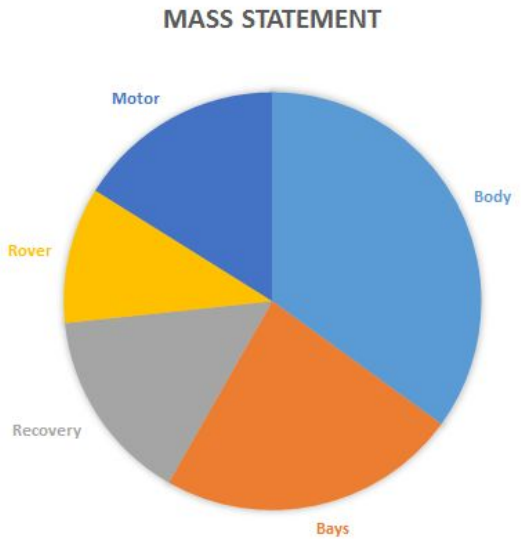
Predicted Altitude in Huntsville, AL

Wind Speed (mph)	OpenRocket Predicted Altitude (ft)
0	4,642
5	4,637
10	4,625
15	4,607
20	4,571

*Simulated with 0.0 lbf ballast

Mass Statement

Section	Weight (lbf)
Body	19.9
Bays	13.2
Recovery	8.56
Rover	6.01
Motor	9.17
Total	**56.9**

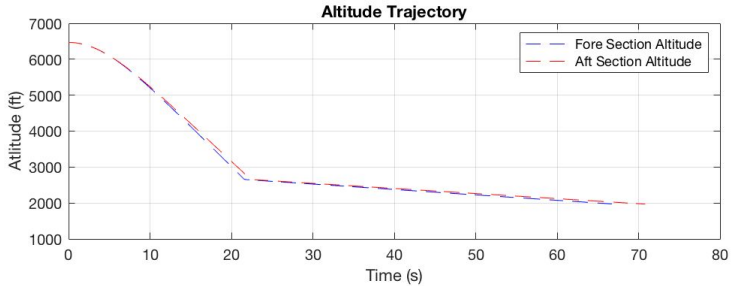


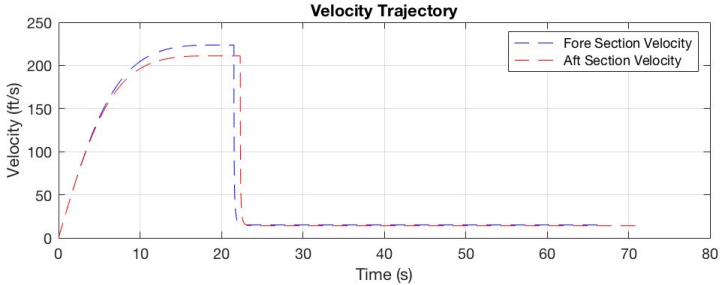
Recovery

- Toroidal Main Parachutes
  - Packed in deployment bag with Kevlar blanket
- Cruciform Drogue Parachutes
- Nylon 1 in. shock cord

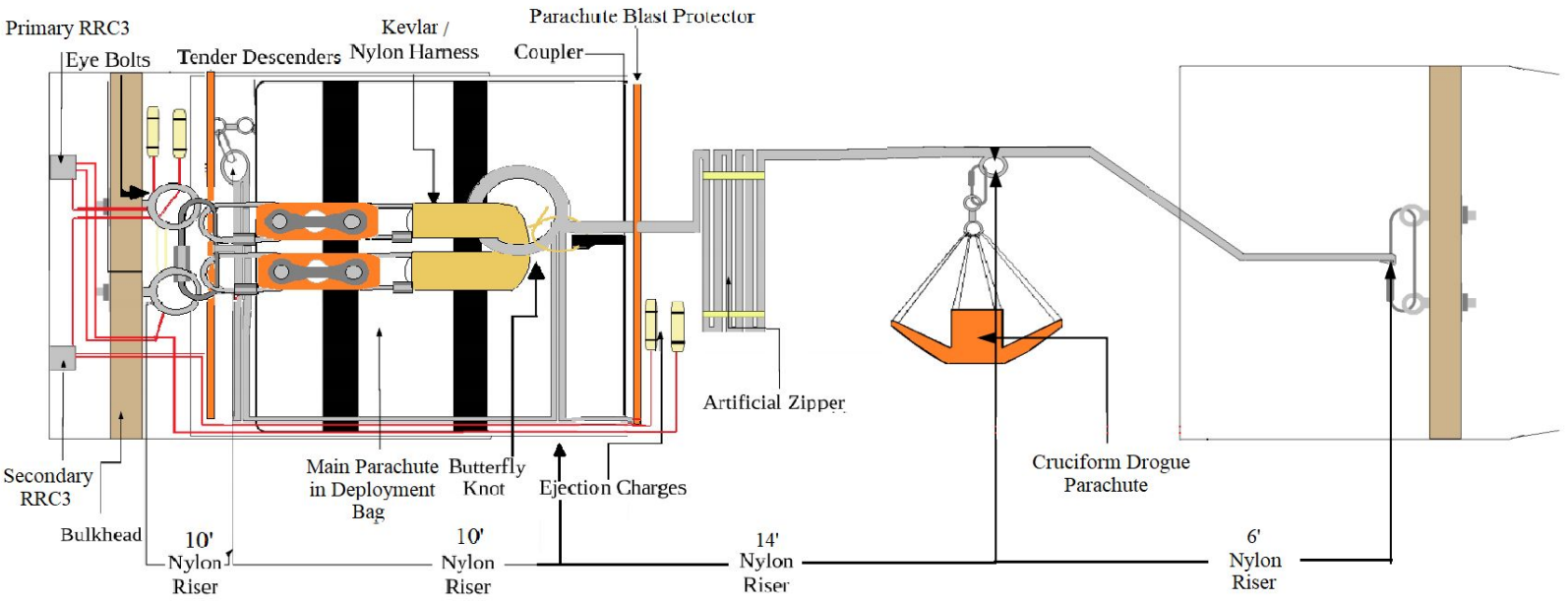
Recovery - Parachute Information

- MATLAB script determined:
  - Descent time
  - Landing kinetic energy
- Output determined:
  - 1.5 ft drogue parachutes
  - 8 ft main parachutes



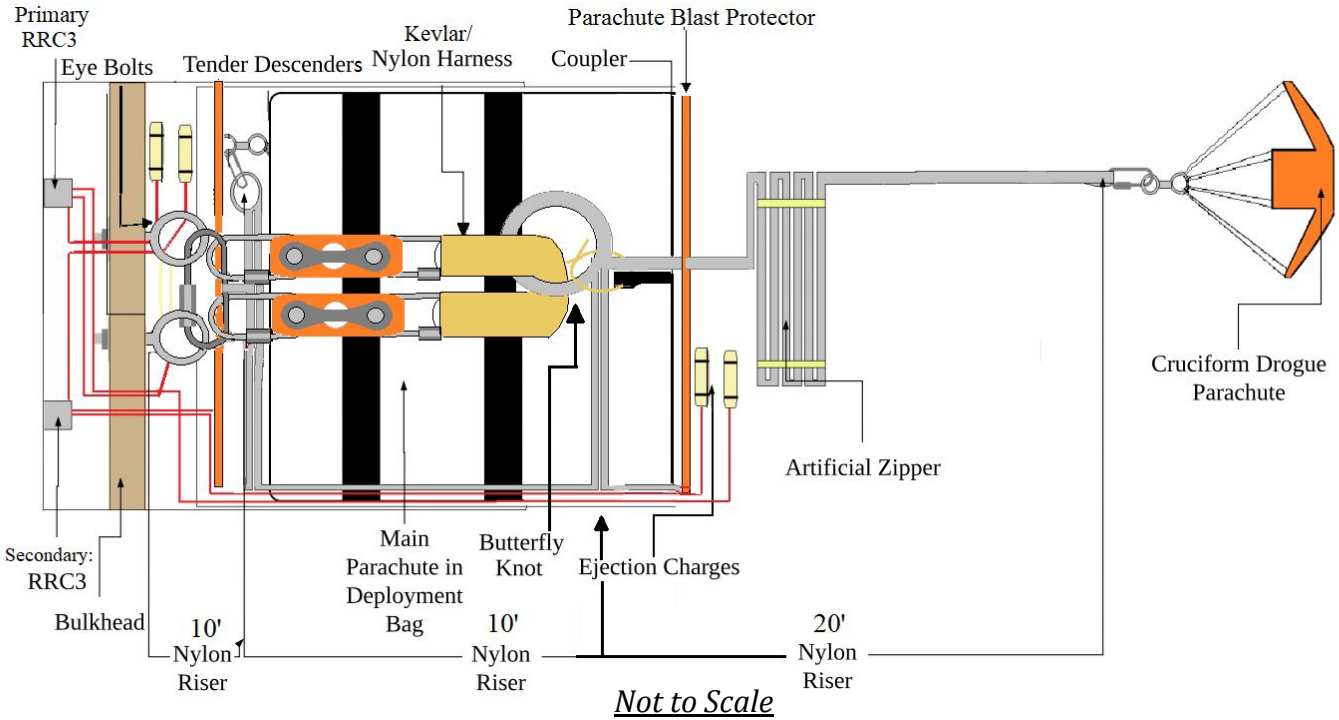


Recovery - Fore Layout



Not to Scale

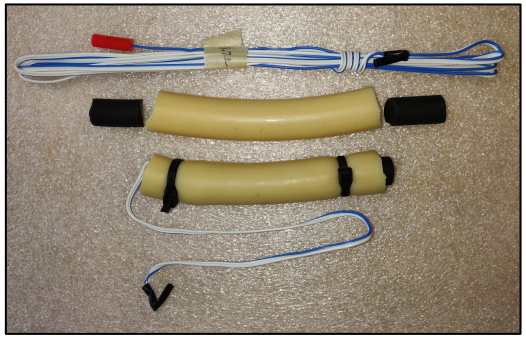
Recovery - Aft Layout



Recovery - Ejection Charge

- Fore Section
  - 4.0 g Primary
  - 6.0 g Backup
  - 4.0 g Deployment Bag Charges (x2)

- Aft Section
  - 5.5 g Primary
  - 8.0 g Backup
  - 4.0 g Deployment Bag Charges (x2)



Recovery - Velocity & Kinetic Energy

Weight (lbf)

Section	Nosecone	Fore	Aft
Weight	5.1	18.2	20.1

Velocity (ft/s)

Section	Tumbling	Drogue Only	Main & Drogue
Fore	115.0	111.0	**15.1**
Aft	116.0	112.0	**14.2**
Nosecone	115.0	111.0	**15.1**

Kinetic Energy (ft-lbf)

Section	Tumbling	Drogue Only	Main & Drogue
Fore	3,740.7	3,485.0	**64.2**
Aft	4,207.5	3,922.4	**62.7**
Nosecone	1,042.0	970.8	**17.9**

Recovery - Descent Times & Drift

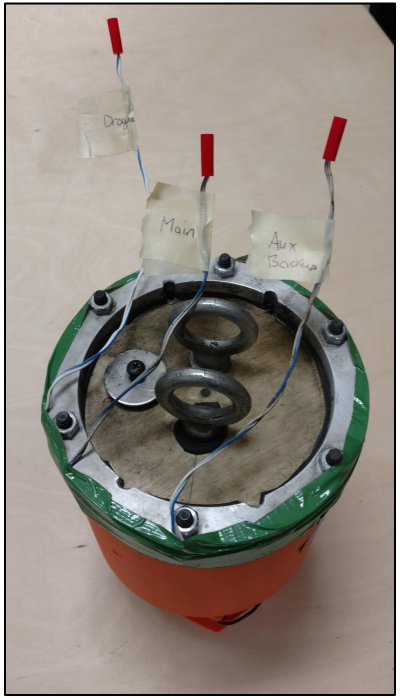
Wind Speed	0 mph	5 mph	10 mph	15 mph	20 mph	Descent Time (s)
Drift of Fore Section (ft)	0	492	984	1,476	1,967	67
Drift of Aft Section (ft)	0	519	1,039	1,558	2,077	71
OpenRocket Simulation	2	369	711	1,071	1,394	68

Recovery - Separation Demonstration

- Passing Condition
  - 5 consecutive tests fully separate launch vehicle
  - Expel drogue and retain main
  - Expel main
- Test Procedure
  - Assemble launch vehicle
  - Secure airframe
  - Ignite charges
- Status - Complete

Recovery - Pressure Demonstration

- Passing Condition
  - All three e-matches ignite in the correct order
- Test Procedure
  - Assemble altimeter sleds
  - Create a pressure seal inside bays
  - Pull air out with a vacuum
- Status - Complete
  - All three e-matches ignited
  - Timing was correct on auxiliary port



Avionics and Ground Station

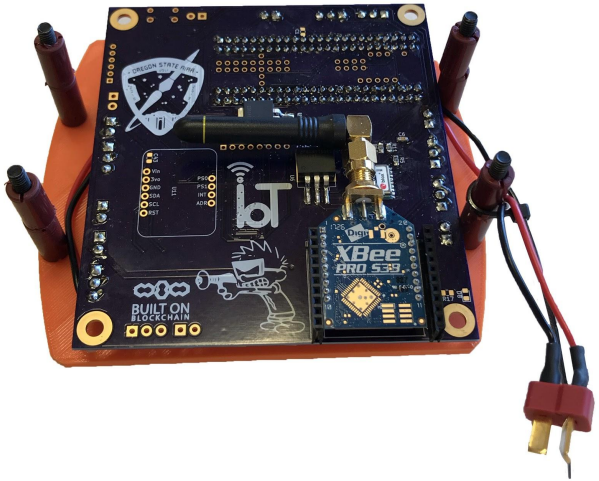
Avionics - Active Tracking

- Rocket-locating transmitters
  - Collects, logs, and transmits GPS data from GPS, GLONASS, and BeiDou satellite networks

- 900 MHz and 433 MHz RF transmission bands
  - Not working simultaneously, configurable via software
  - XBee Pro (900 MHz transceiver) runs at 250 mW
  - TI CC 1200 (433 MHz transceiver) runs at 40 mW

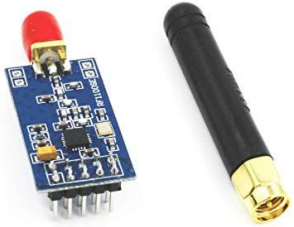
Avionics - Testing

- Battery Life Tests
  - Both configurations work under full power draw for 8+ hours
- Primary Band Test
  - Continuously transmitted past 2,500 ft reliably



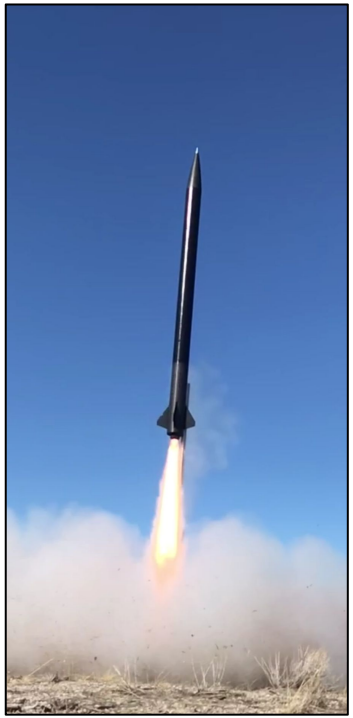
Interfaces with Ground Station

- Launch Vehicle Interface
  - 900 MHz and 433 MHz RF transmission of GPS coordinates from flight ATUs
  - 900 MHz transmission of PLEC trigger signal from ground station to PLEC
  - PC displays data over serial monitor
- Rover Interface
  - Ground station sends position coordinates to rover over 900 MHz band
  - Sends launch vehicle airframe locations and scientific base station



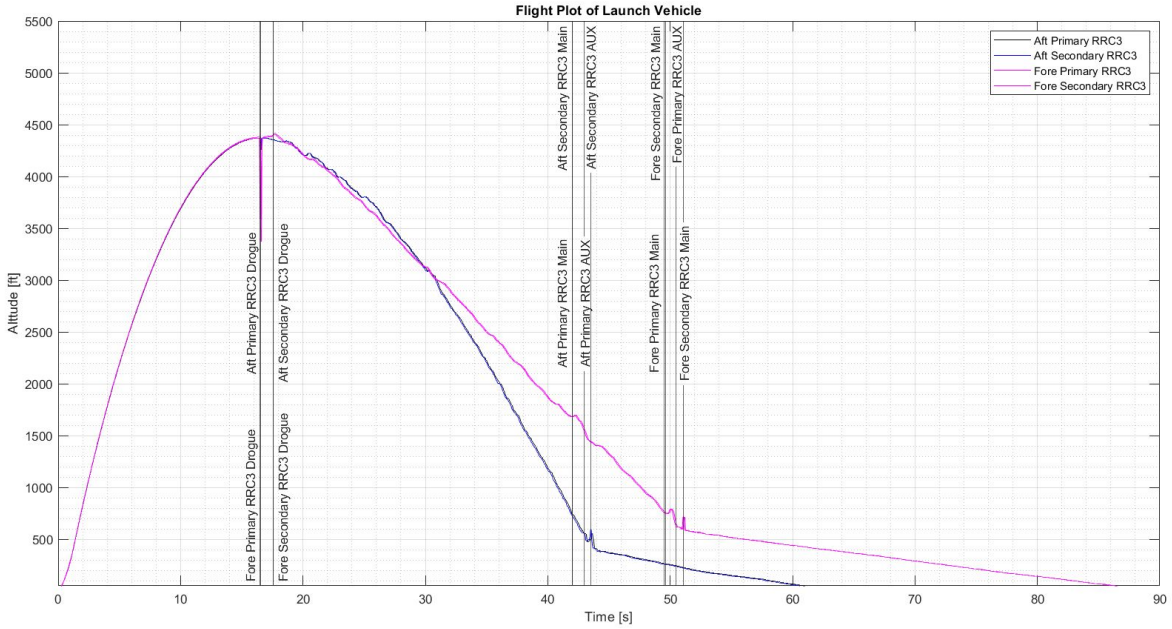
Vehicle Demonstration Flight

Test Launches



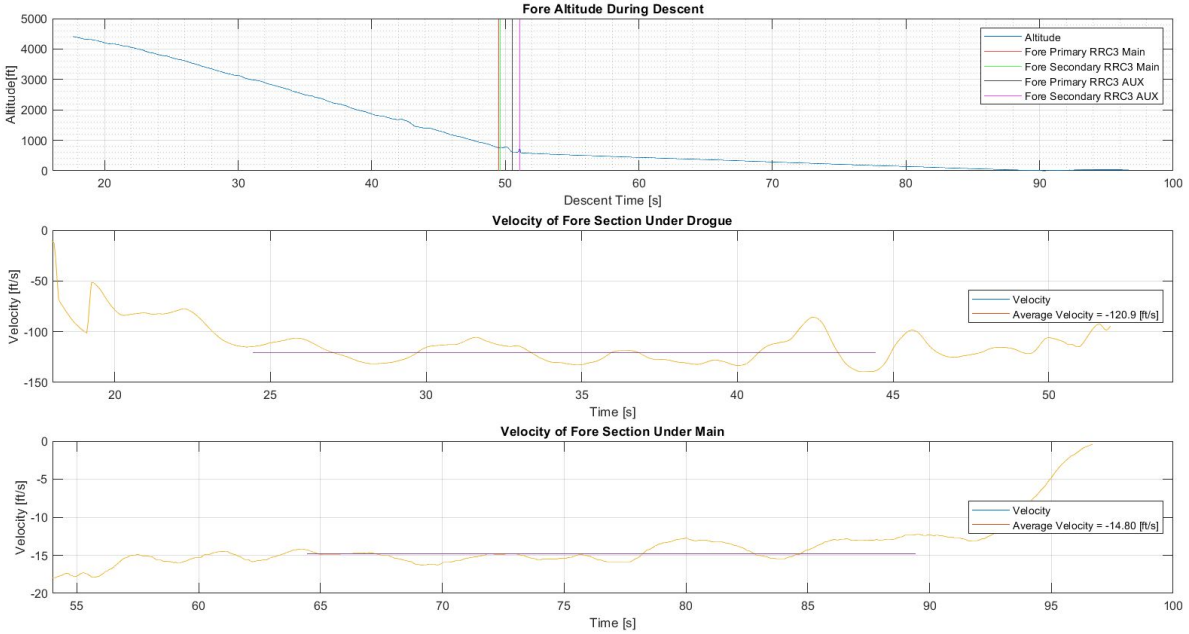
Launch Footage

Full Scale: Data Analysis



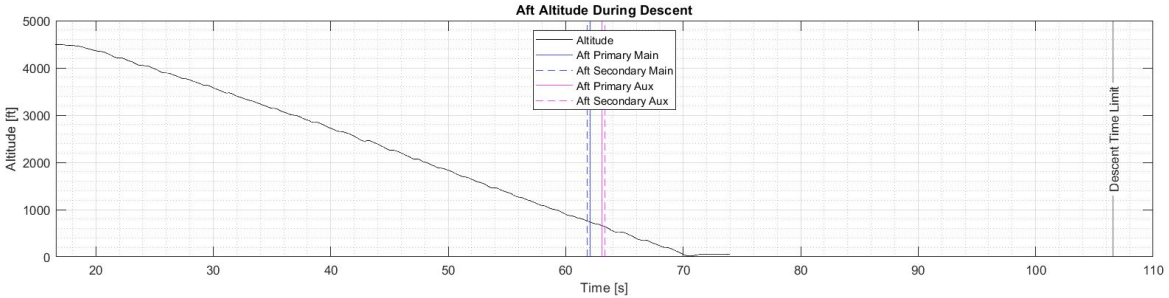
Maximum Altitude	4548 ft
Maximum Velocity	588 ft/s
Maximum Acceleration	621 ft/s^2

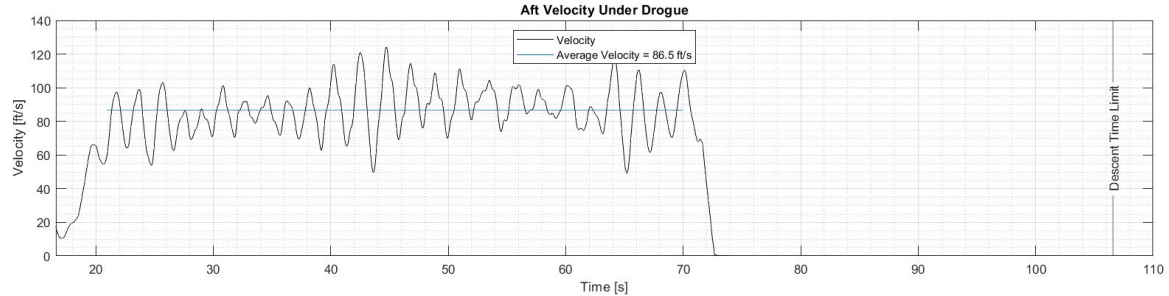
Full Scale: Fore Section Analysis



Maximum Altitude	4548 ft
Impact Velocity	11.7 ft/s
Fore Impact Kinetic Energy	38.5 ft-lbf
Nosecone Impact Kinetic Energy	10.7 ft-lbf
Descent Time	72.6 s

Full Scale: Aft Section Analysis

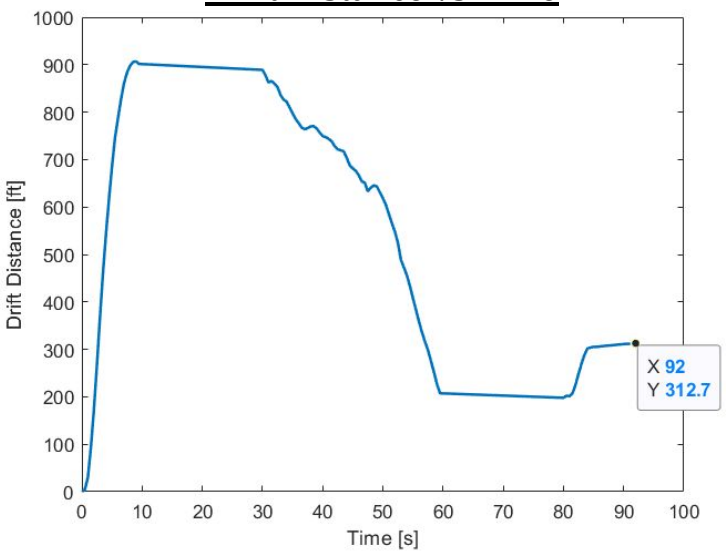




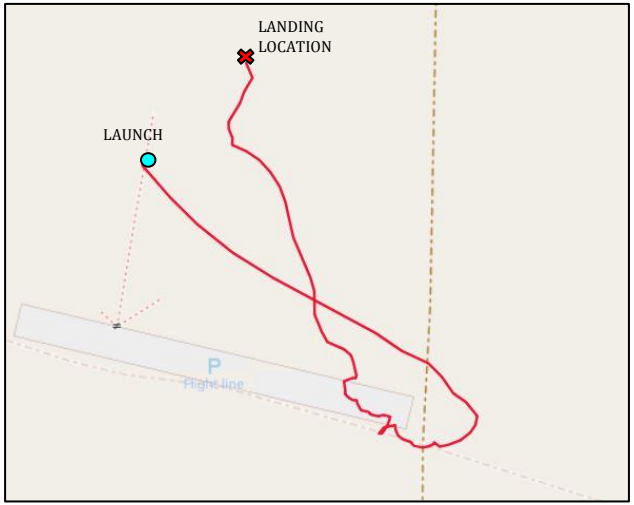
Maximum Altitude	5079 ft
Impact Velocity	11.5 ft/s
Aft Impact Kinetic Energy	65.9 ft-lbf
Descent Time	79.6 s

Full Scale: Drift Analysis

Drift Distance vs Time



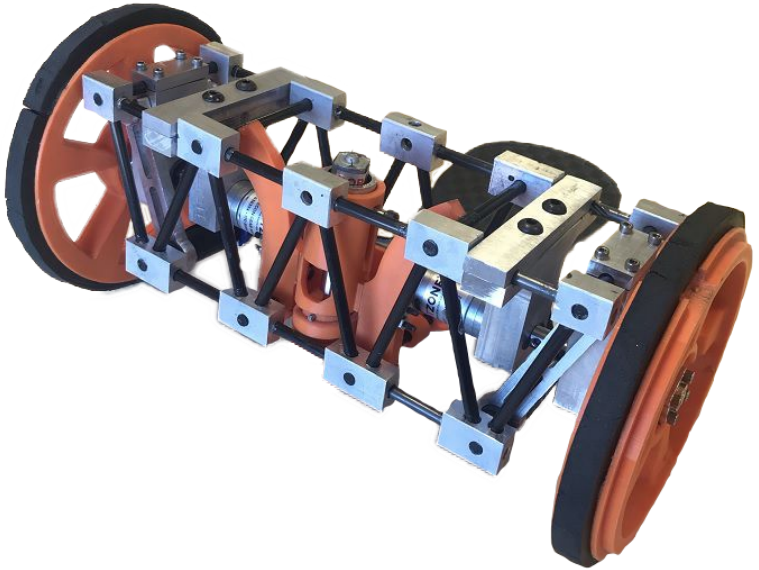
Overhead View of Drift Profile



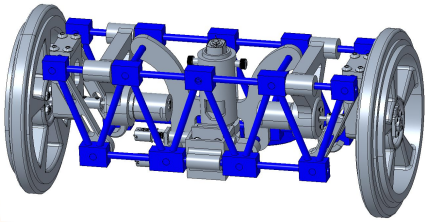
Payload Mechanical

Payload Overview

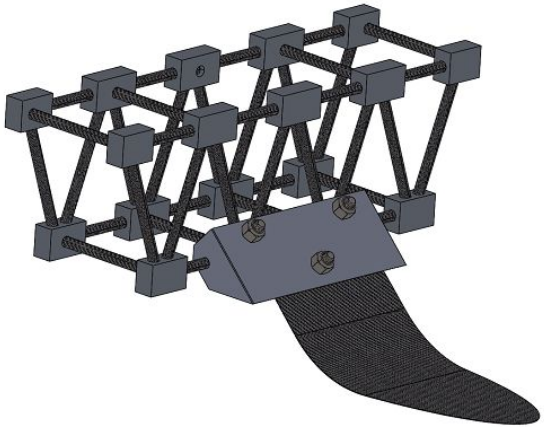
- Total Length: 13.95 in.
- Total Weight: 6.01 lbf

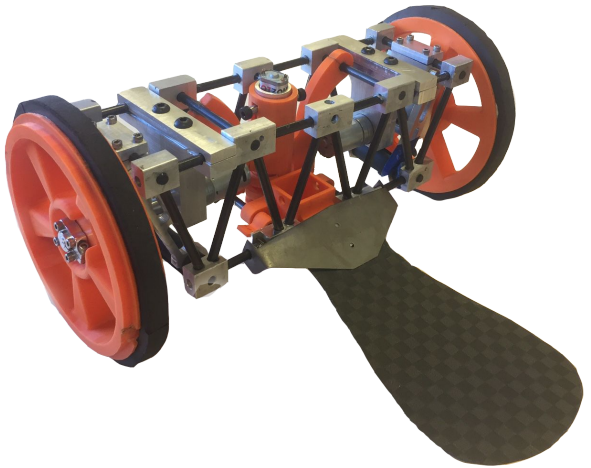


Chassis

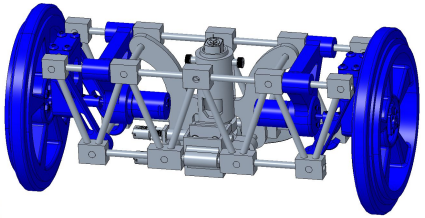


- Connection Blocks - Aluminum
- Rods - Carbon Fiber
- Tail - Three Ply Carbon Fiber

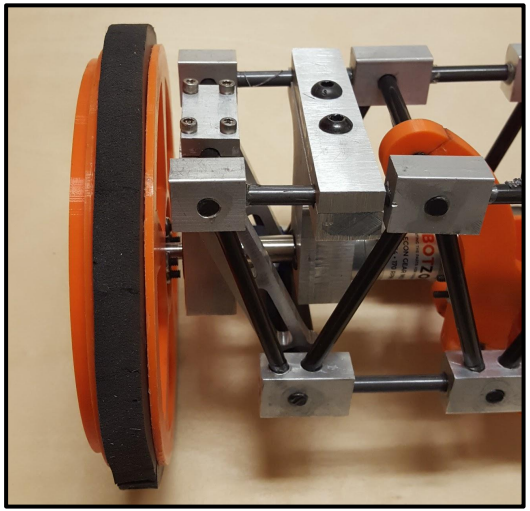




Drivetrain

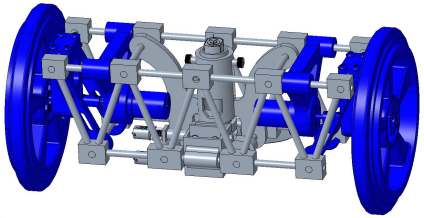


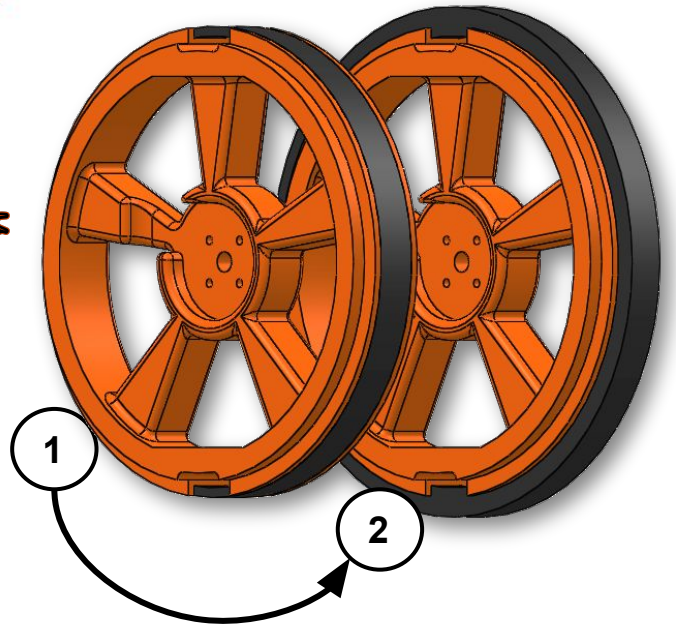
Brushed DC motors sized to climb 30° slopes



- Two independently-controlled motor/wheel assemblies mounted within rover chassis

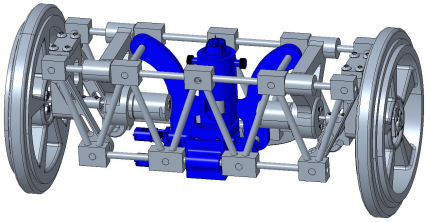
Drivetrain



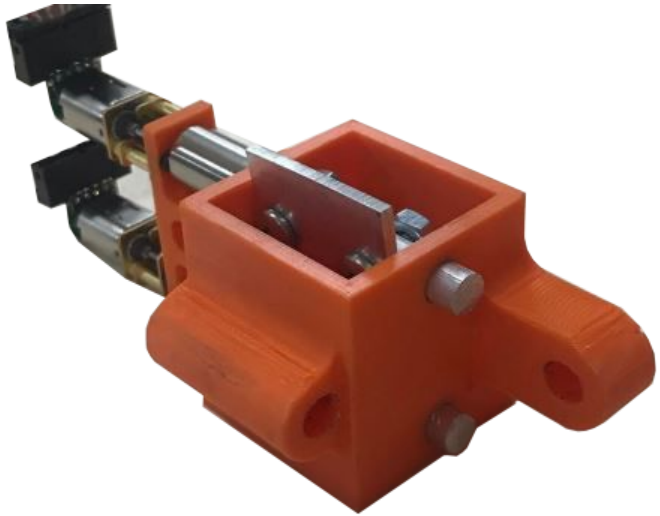


- 6.00 in. diameter PLA wheels
  - Urethane foam tire
- Compressed tires (1) exert force on airframe interior
- Tires quickly expand upon ejection (2)
  - Increases ground clearance by 0.50 in.

SCAR

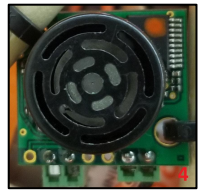


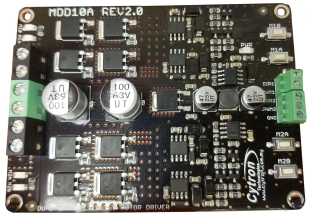
- Soil Collection
  - Auger fed into soil
- Soil Retention
  - Two independent doors



Navigation

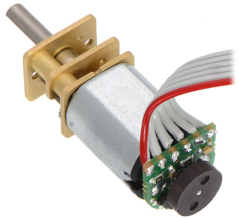
1. Drive Motor Controller - Bidirectional PWM
2. Magnetometer - Heading as angle from North in 1 degree increments
3. GPS - Multi sample implementation with accuracy of 30 ft in any direction
4. Sonar - Directional detection of obstacles





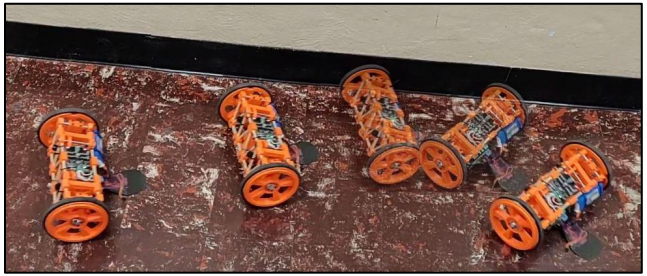
Collection and Retention

1. Auger and Retention Motor Controllers
2. Motor Encoders
3. Accelerometer - Levelness sensing
4. Transceiver - Receives coordinates of the airframe and scientific base station
5. Teensy 3.6 Microcontroller



Mobility Testing

Rover Orientation

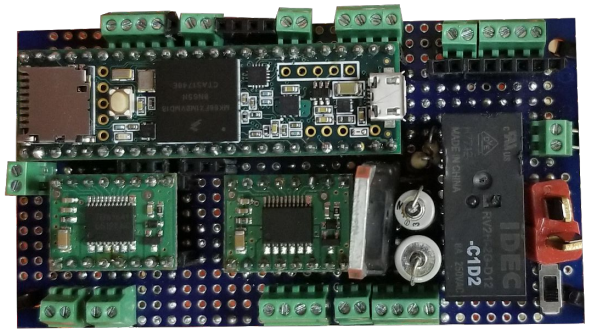


Object Avoidance

30° Slope Climb

Rover Printed Circuit Board

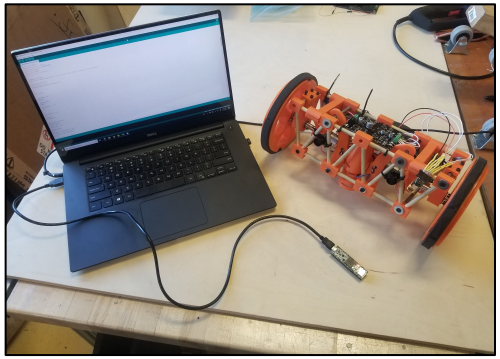
- Protoboard functionality testing - complete
- Final PCB - incomplete
- Protoboard Shield PCB - incomplete



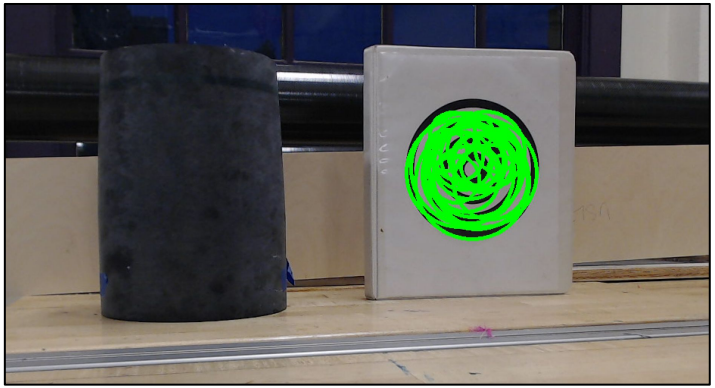
Payload Software

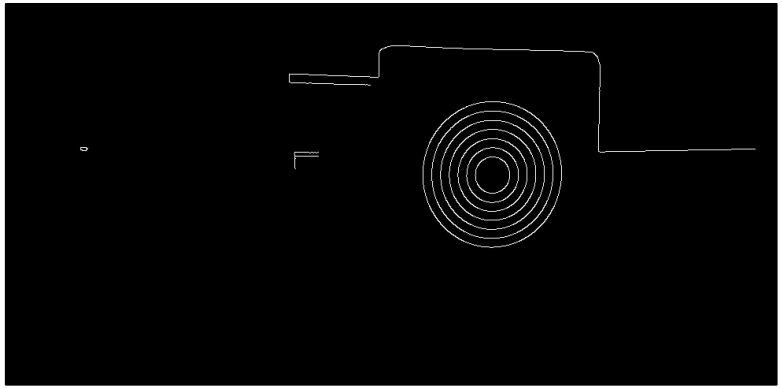
Rover Software

1. Reliably move away from launch vehicle
2. Soil collected and sealed
3. Receive GPS data and sample count via RF
4. Travel to the coordinates given
5. Dock and deposit soil sample into a collection chamber for analysis
6. Exit the base station to retrieve additional soil samples until sample count is reached



Beaglebone CV Testing

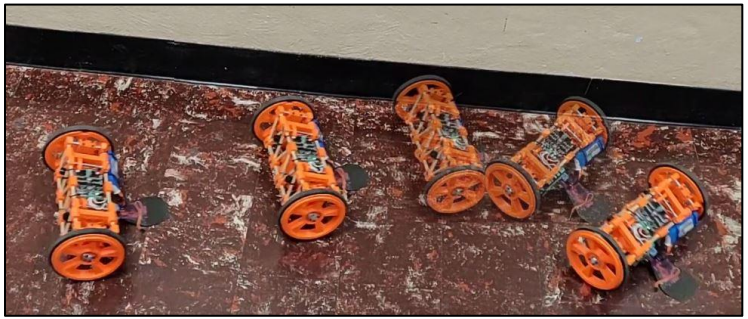




- Successful circle detection with no false positives
- Minimal extra lines drawn by Canny threshold

Rover Navigation Testing

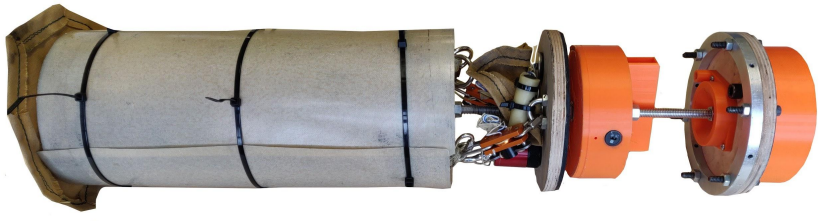
- Object avoidance - Complete
  - Allow rover to navigate with obstructions
- Radio Frequency Communication - Incomplete
  - Send GPS coordinates to the rover at varying distances
- Docking - Incomplete
  - Allow rover to climb base station and deposit soil

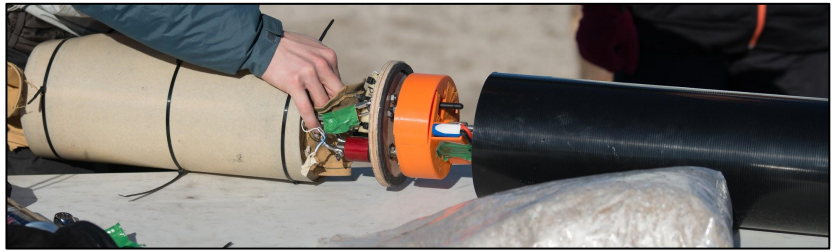


Payload Ejection and Retention

Payload Ejection and Retention

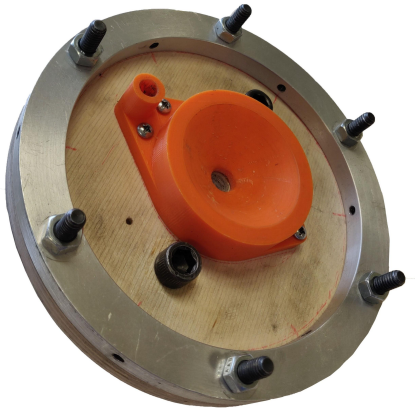
- Consists of 3 systems
  - Payload Wrap Assembly
  - Removable Retention Assembly
  - Payload Ejection Controller (PLEC)
- Integrates into airframe to the Fore Hard Point (FHP)

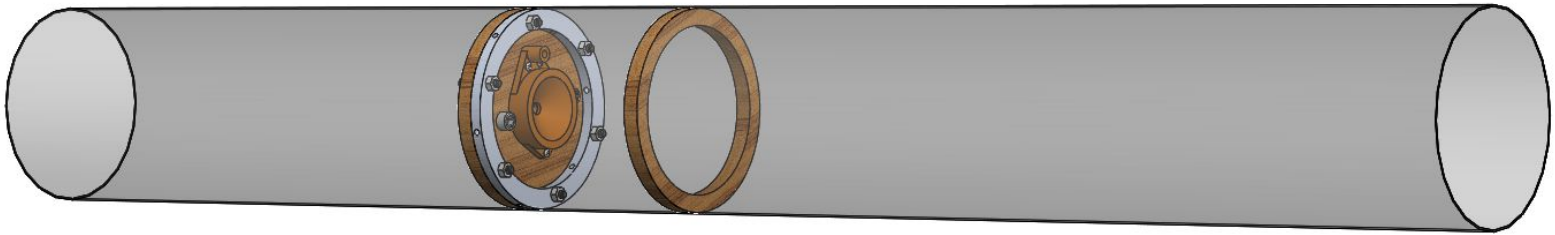




Fore Hard Point

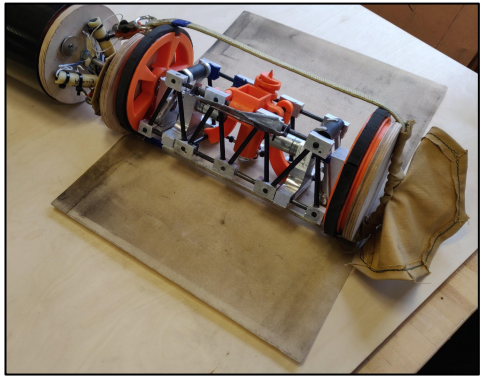
- Removable radial bolted assembly
  - Funnel for integration
  - Bulkheads for PEARS retention
  - Removable for safety procedures in event of failed payload ejection
- Pass through bulkhead
  - Epoxied in airframe to create pressure seal

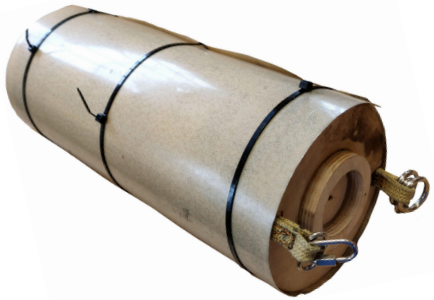


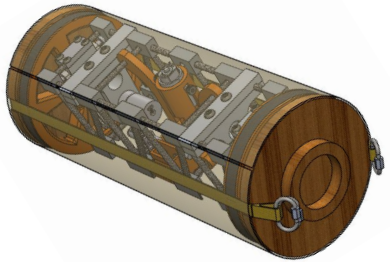


Payload Wrap Assembly

- Fiberglass wrap
- Plywood bulkheads for ejection protection
- Kevlar harness retains rover and attaches to retention devices on removable assembly

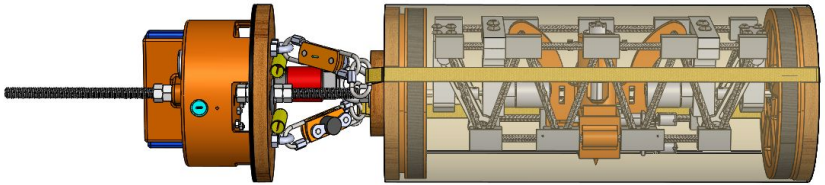


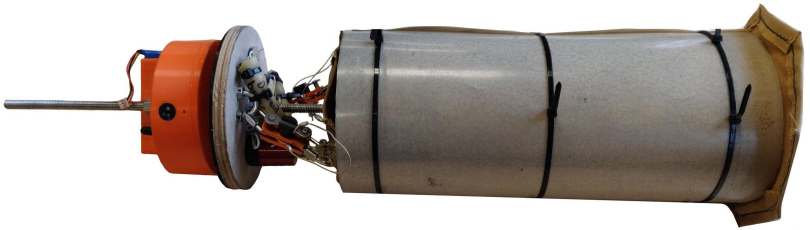




Ejection and Retention

- Wrap retained to removable assembly
  - Two L2 Tender Descenders and ARRD
- Ejected with black powder charges
  - Primary: 1.2 g
  - Backup: 2.0 g



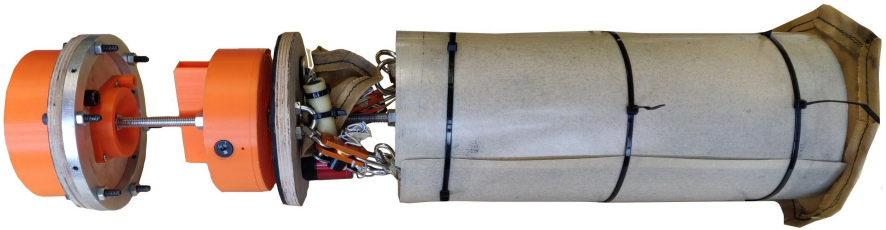


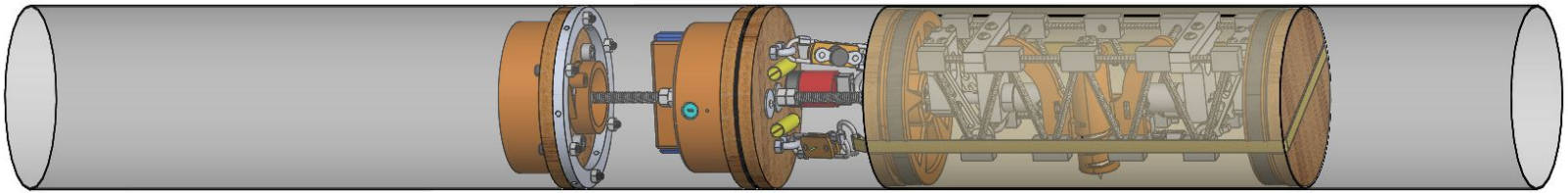
Payload Ejection Controller

- Controls retention devices and ejection charges
  - Sequential e-match ignition tested
- Mounted on removable assembly
- Contained within RF shielded case
- Armed with DPST switch

Integration in Fore Airframe

- Pressure seal between PEARS bulkhead and FHP
- Fore ballast bay mounted on threaded rod fore of FHP
- PLEC armed from exterior once on the launch rail





PEARS Testing

- Successful ground testing of ejection sequence
- Successful retention and deployment during test flights

PEARS Testing

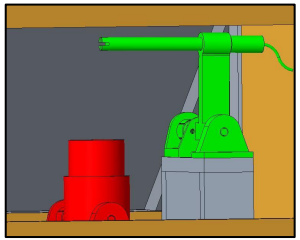
Payload Demonstration Flight

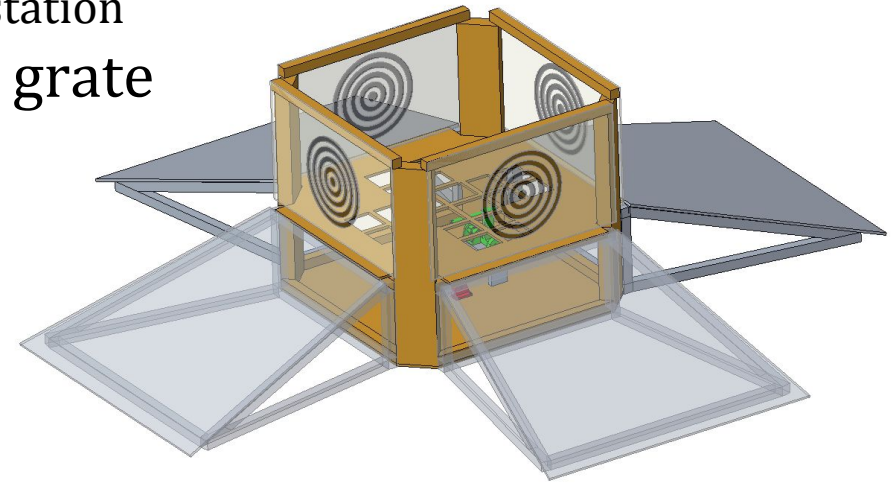
- Scheduled for March 16th in Brothers, OR
  - Will be flown with Cesaroni L25375-WT
- Flight will also act as Vehicle Demonstration Re-Flight
  - Max ballast configuration

Scientific Base Station

Scientific Experiment

- Modular Experiment Design
  - Mapping of pH samples
- Rover navigates up ramps
  - CV sees circles on ground station
- Rover deposits soil into grate





1) Competition

2) 2019 OSU USLI Team

3) OSU Rocket and Rover

4) Performance and Results

Competition Launch

Payload Deployment

Payload Mission

STEM Engagement Event Pictures

STEM Engagement Events

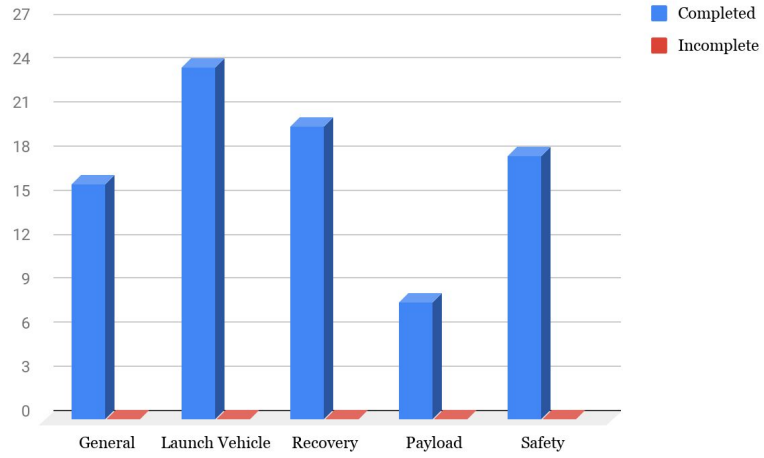
Date	Event	Engagement Number
Oct. 26	Yamhill-Carlton Rocketry	27
Oct. 31	Discovery Days	950
Nov. 9	Veneta Elementary	350
Nov. 14	OSU Women's Basketball	150
Nov. 27	OSU Honors Colloquium	12
Dec. 15	Evergreen Air & Space	150
Dec. 19	Westview High School	96

Date	Event	Engagement Number
Jan. 18	Lenox Elementary	520
Jan. 19	Cub Scout Lock-In	250
Jan. 26	Western University	100
Jan. 26	Reaching for the STARS	500
Feb. 19	Franklin Elementary	28
Feb. 28	Philomath Middle School	229

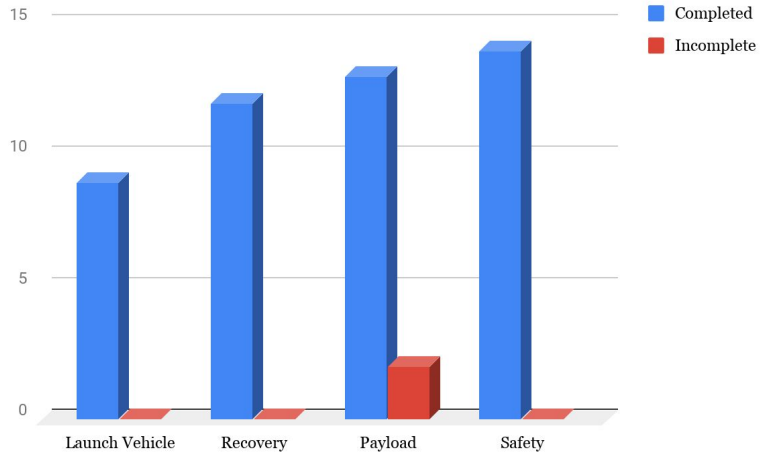
Total: 3,362

Summary of Requirements

NASA Requirement Verifications



Team Derived Requirement Verifications



2018-2019 Competition Results

Team Achievements:

- Completed 5 rocket launches
- Rover successfully deployed
- Taught 4,820 K-12 students

Scoring:

- 4th Overall out of 45 Teams
  - 1st in Launch Vehicle Award
  - 3rd in Project Review Award
  - 3rd in Altitude Performance
  - 3rd in Rocket Fair Display

Acknowledgments

- Oregon Space Grant Consortium
  - Catherine Lanier
  - Jack Higginbotham
  - Shirley Campbell
- Oregon State College of Engineering
  - Dr. Squires
- Oregon Rocketry
  - John Lyngdal, Joe Bevier, Alan Hammond
- Industry Sponsors

Questions?