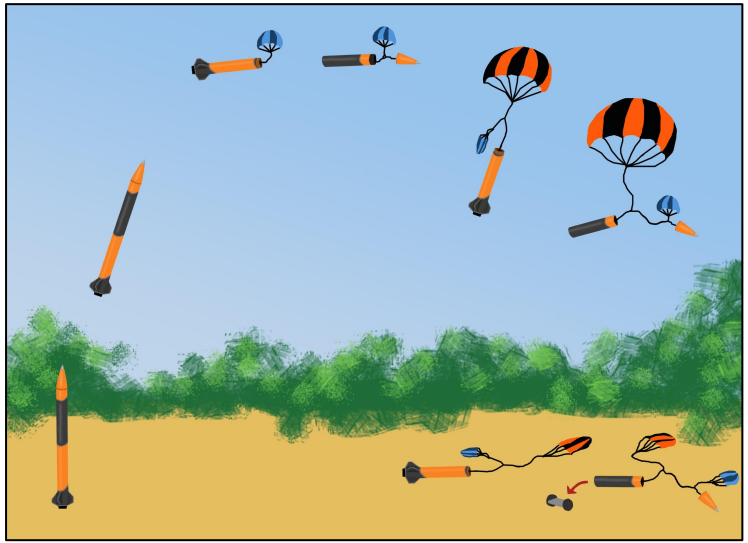
# Oregon State University


## Critical Design Review

01/15/2019

# Mission Overview

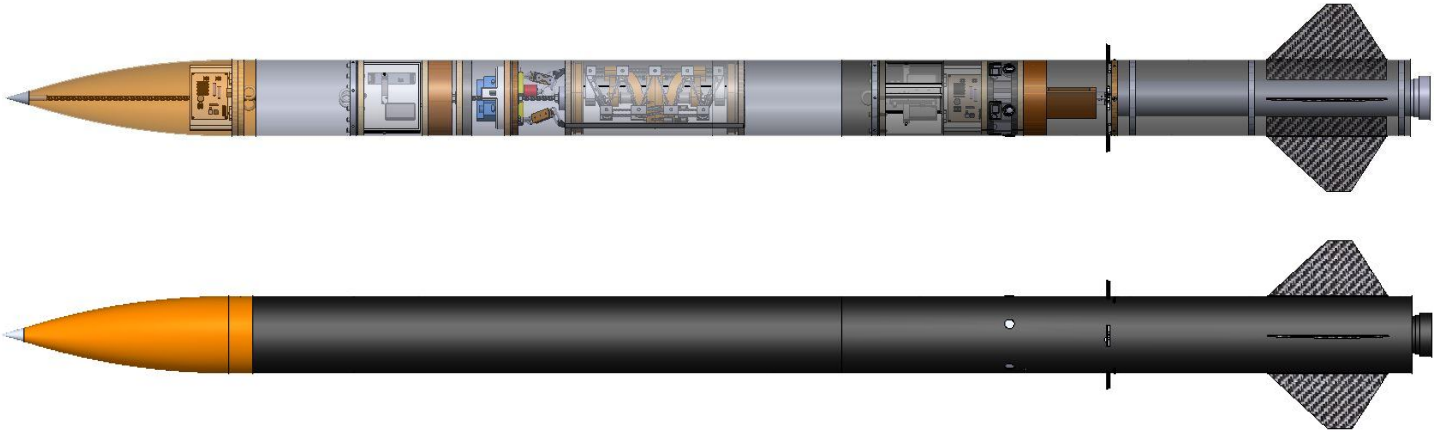
1. Launch
2. Motor burnout
3. Separation at apogee
4. Drogue parachutes deploy
5. Main parachutes deploy
6. Landing
7. Rover deployment
8. Soil collection
9. Scientific experiment



*Not to Scale*

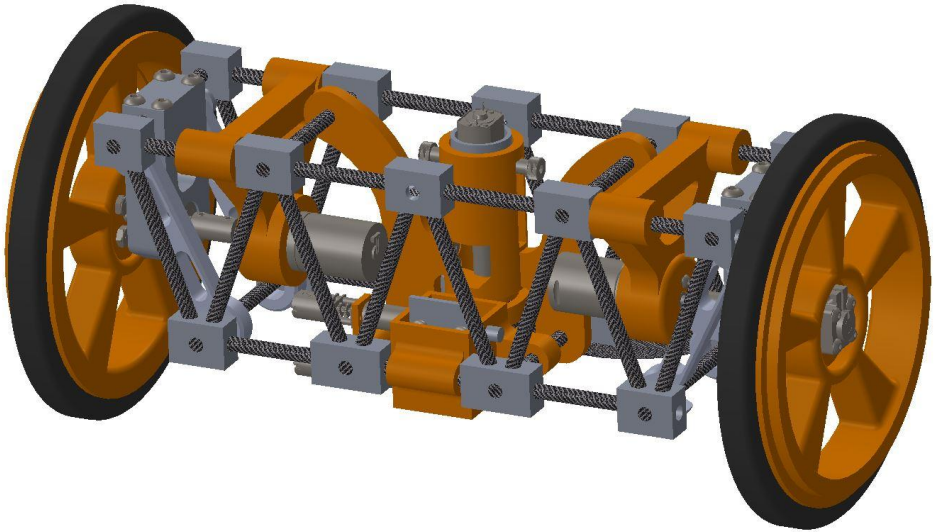
# Launch Vehicle Overview

- Total Length: 123.5 in.
- Total Weight: 48.9 lbf
- Airframe Inner Diameter: 6.25 in.

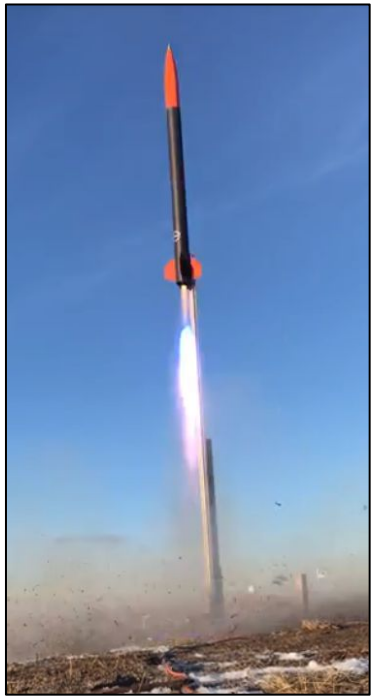


# Payload Overview

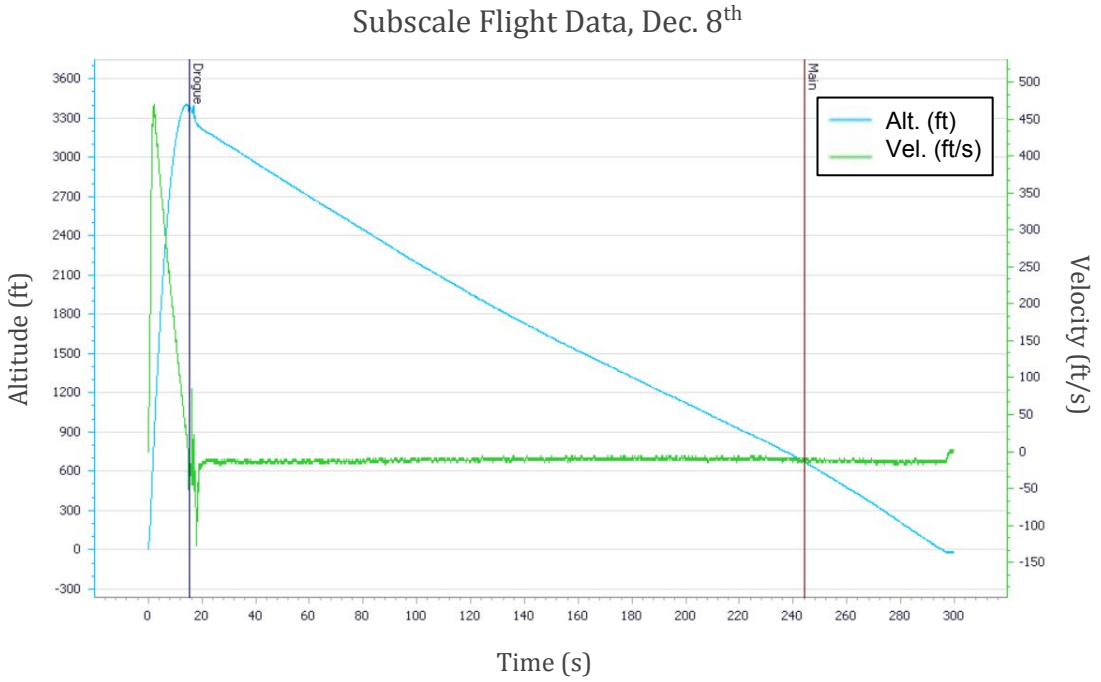
- Total Length: 13.95 in.
- Total Weight: 5.75 lbf



# Subscale Launches

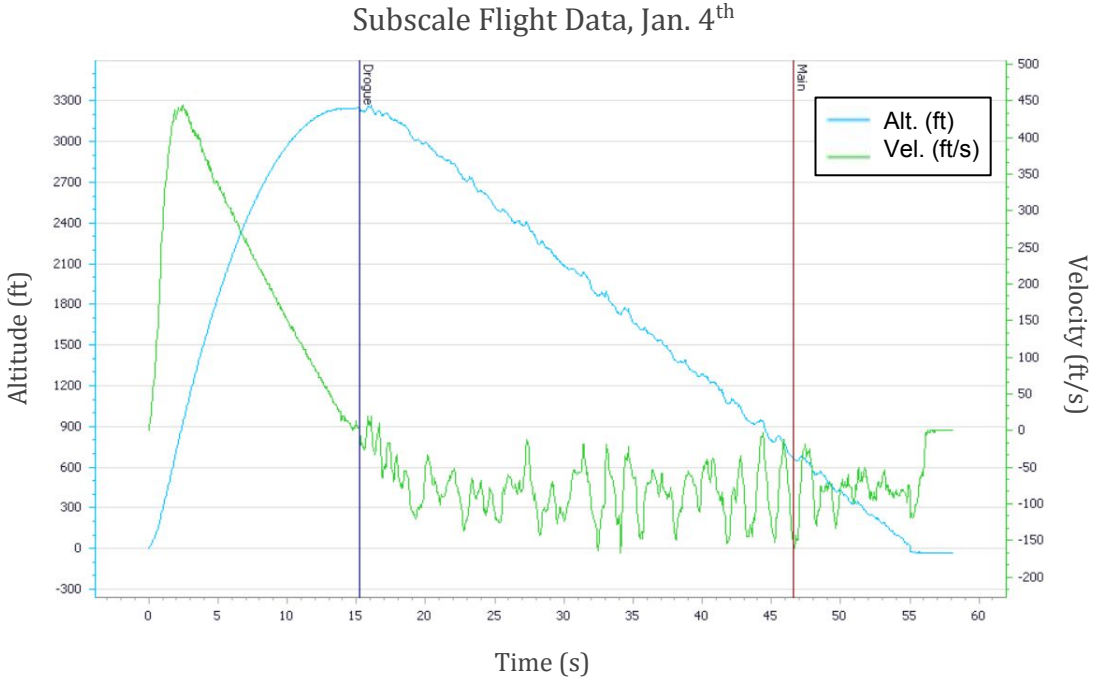


# Subscale Flight: December, 8th




| | |
|---|---|
| **Maximum Altitude** | 3402 ft |
| **Impact Velocity** | 13.0 ft/s |
| **Fore Impact Kinetic Energy** | 13.9 ft-lbf |
| **Aft Impact Kinetic Energy** | 30.1 ft-lbf |
| **Descent Time** | 281.3 s |

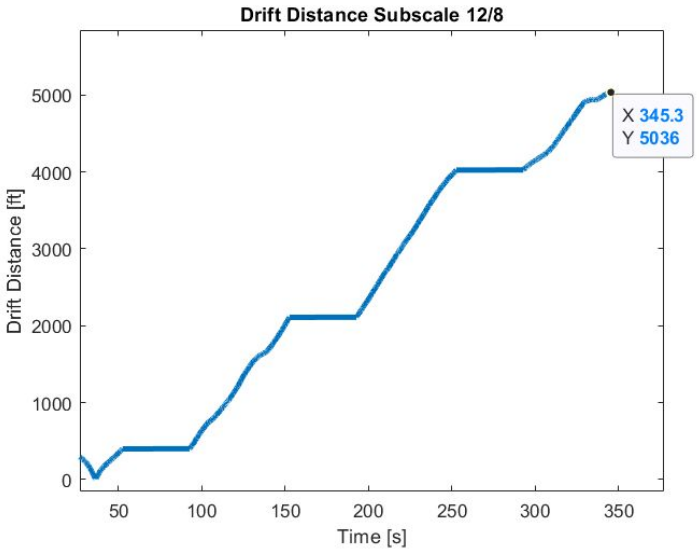
# Subscale Flight: January, 4th



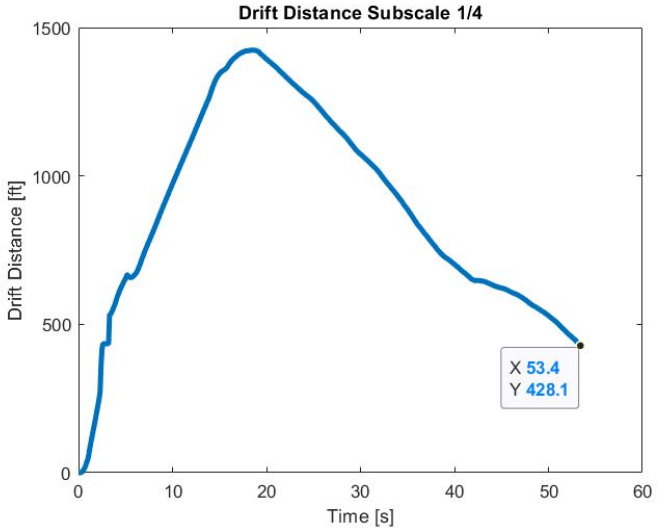

| | |
|---|---|
| **Maximum Altitude** | 3250 ft |
| **Impact Velocity** | 76.0 ft/s |
| **Fore Impact Kinetic Energy** | 475 ft-lbf |
| **Aft Impact Kinetic Energy** | 1031 ft-lbf |
| **Descent Time** | 40.1 s |

# Subscale Flight Data - Avionics

Subscale Dec. 8th - 5036 ft final drift




Subscale Jan. 4th - 428 ft final drift

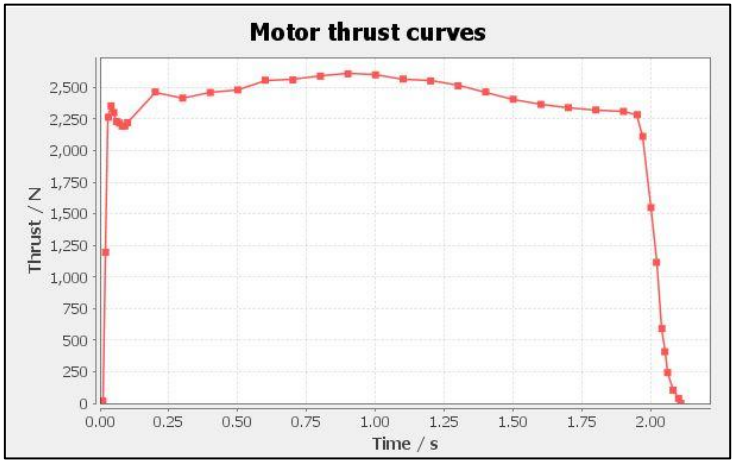


# Aerodynamics and Recovery

# Final Motor Choice

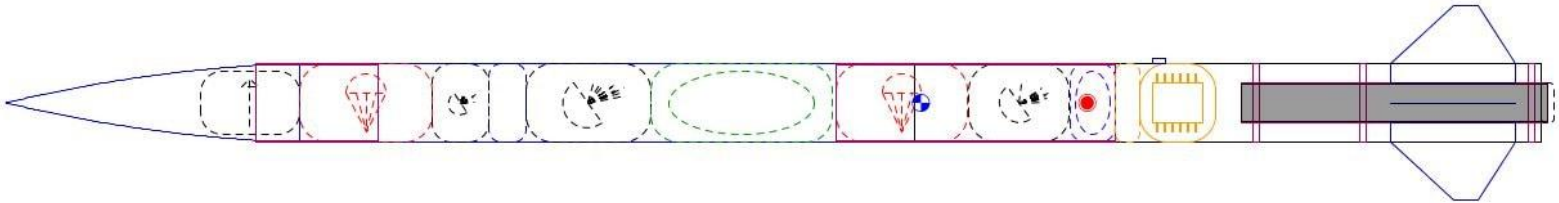
## Cesaroni L2375-WT

- Total Impulse: 4,905 N-s
- Avg. Thrust: 533.7 lbf
- Max Thrust: 586.3 lbf
- Rail Exit Velocity: 88.8 ft/s
- T/W: 12.0



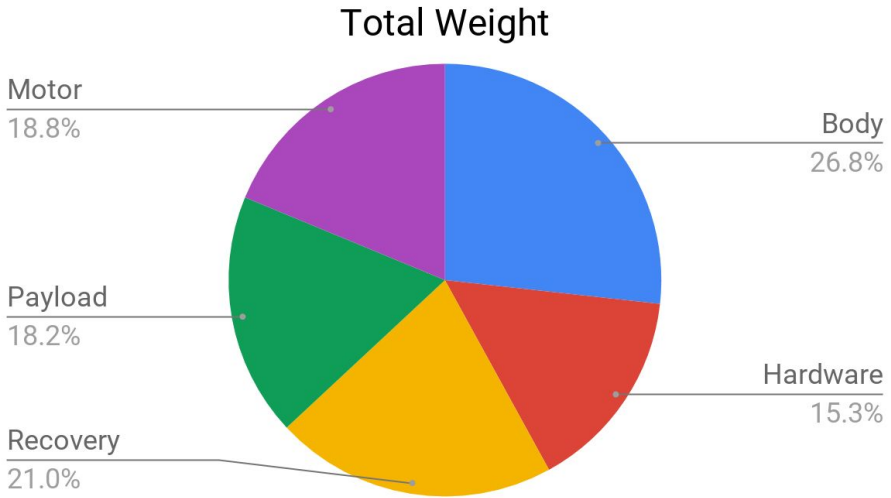
# Stability Margin

- Stability: 2.1 calibers
- Center of Gravity: 73.02 in.
- Center of Pressure: 86.29 in.



# Mass Statement

| Section | Weight (lbf) |
|---|---|
| Body | 13.08 |
| Hardware | 7.47 |
| Recovery | 10.29 |
| Payload | 8.89 |
| Motor | 9.17 |
| **Total** | **48.90** |



# Mass Margin

Apogee Altitude Mass Margin

| Weight Change | Projected Altitude |
|---|---|
| -5.80 lbf | 6,000 ft |
| 0 lbf | 5,296 ft |
| + 6.93 lbf | 4,500 ft |
| +17.15 lbf | 3,500 ft |

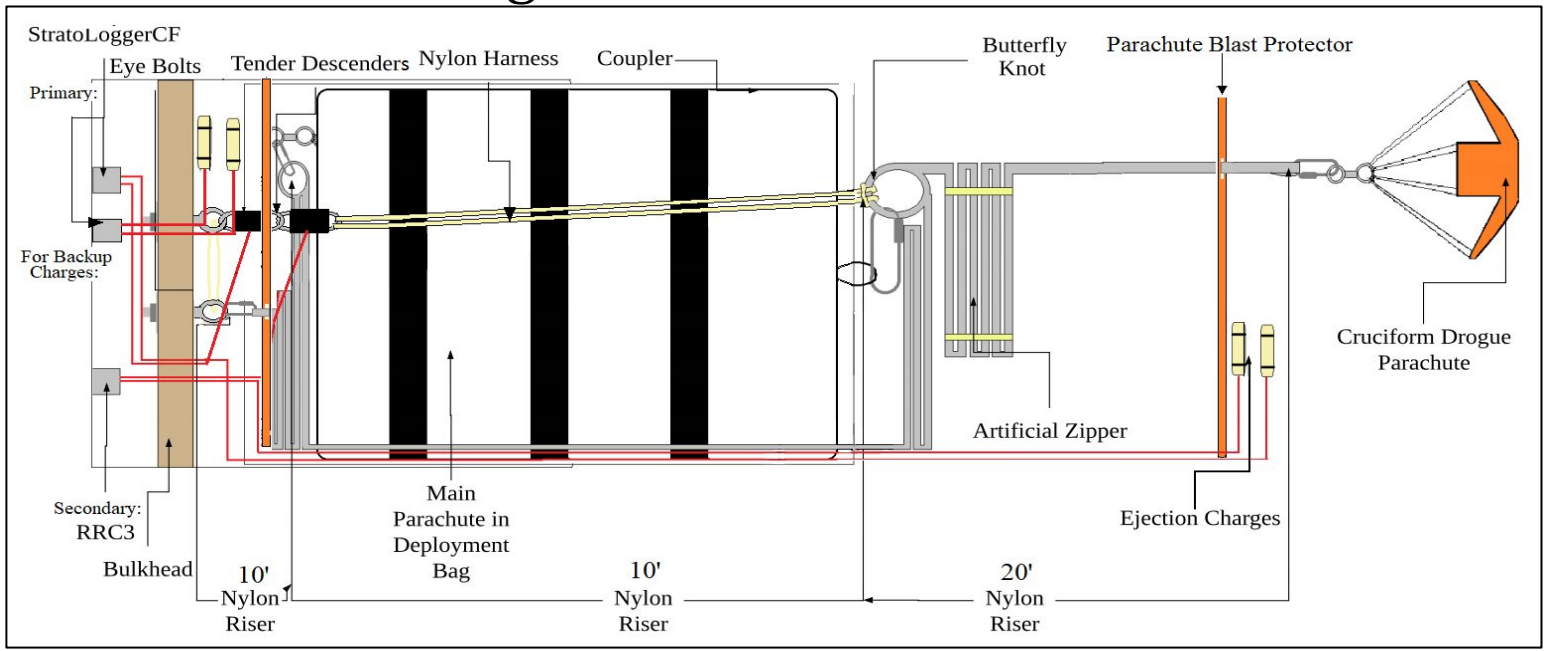
*Mass margin assumes weight change at current center of gravity

Kinetic Energy Mass Margin

| | Current Weight | Available Weight Increase | Landing Kinetic Energy |
|---|---|---|---|
| **Fore** | 20.7 lbf | +4.3 lbf | 75 ft-lbf |
| **Aft** | 23.1 lbf | +0.8 lbf | 75 ft-lbf |

# Recovery Harness - Aft

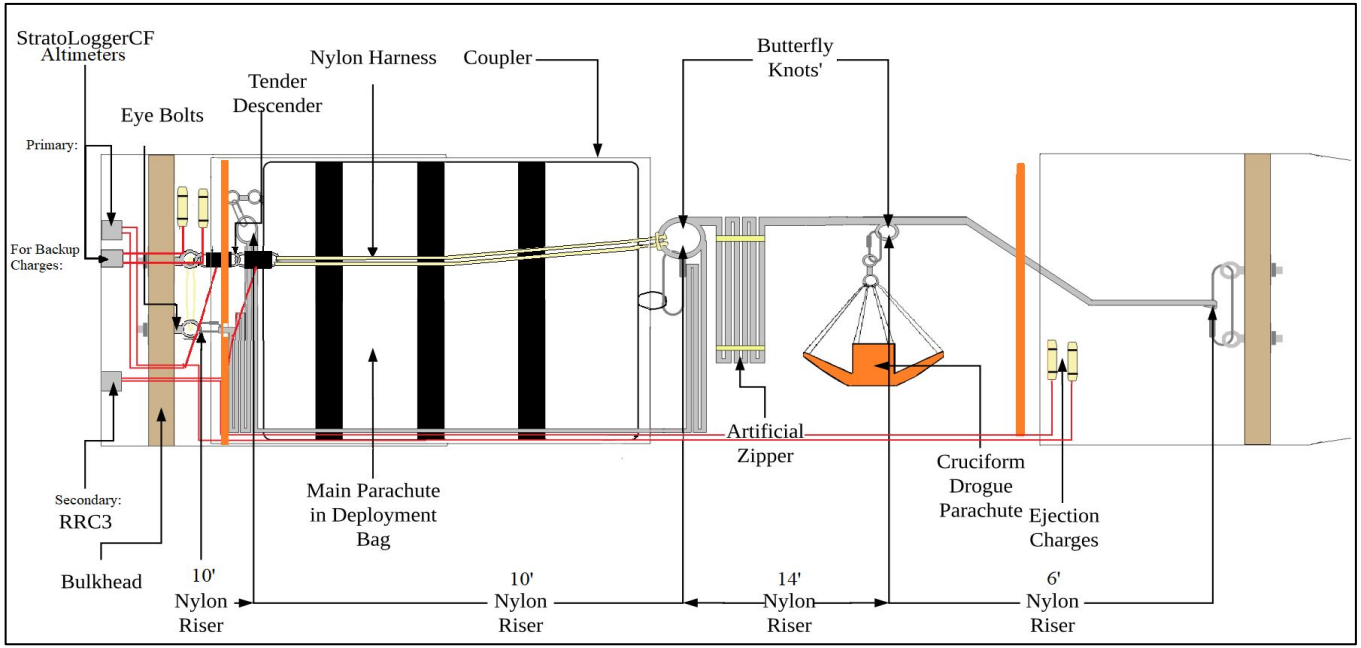
## Total Harness Length: 42 ft




*Not to Scale*

# Recovery Harness - Fore

## Total Harness Length: 42 ft

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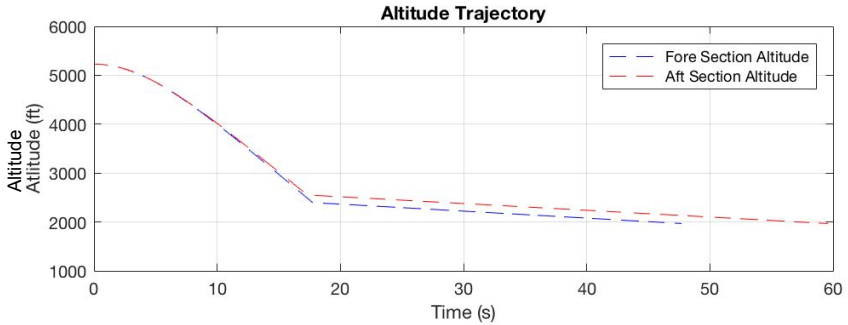
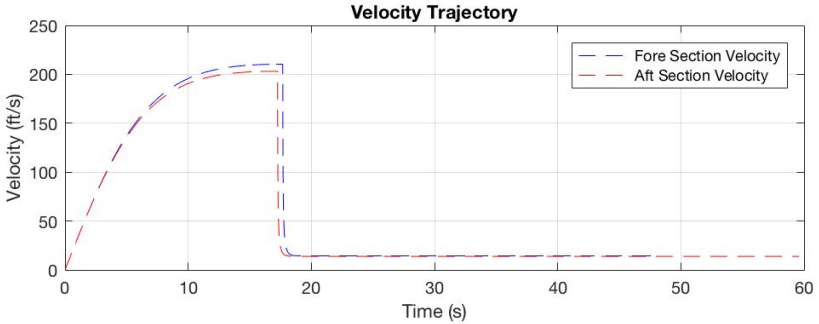
# Recovery - Parachute Information

- Main Parachutes
  - Toroidal parachutes used for their high coefficient of drag
- Drogue Parachutes
  - Cruciform parachutes used for lower spin and drift characteristics

# Recovery - Parachute Information

- MATLAB script that was used to determine:
  - Descent time
  - Landing kinetic energy
- Output used to determine:
  - 1.5 ft drogue for fore and aft
  - 8 ft parachute for the fore
  - 8 ft parachute for the aft



# Recovery - Kinetic Energies

| Measurement | Fore Section | Aft Section | Nosecone |
|---|---|---|---|
| Weight (lbf) | 18.51 | 23.081 | 2.2 |
| Velocity with Main and Drogue Deployed(ft/s) | 13.2 | 14.0 | 13.2 |
| Kinetic Energy with Main and Drogue Deployed (ft-lbf) | 50.2 | 69.8 | 7.0 |
| Velocity with Only Drogue Deployed (ft/s) | 111.0 | 112.0 | 111.0 |
| Kinetic Energy with Only Drogue Deployed (ft-lbf) | 3,480.6 | 4,499 | 421.2 |
| Velocity with no Parachutes Deployed (ft/s) | 115.0 | 116.0 | 115.0 |
| Kinetic Energy with no Parachutes Deployed (ft-lbf) | 3,804.2 | 4,826.5 | 452.2 |

# Recovery - Descent Times and Drift

| Wind Speed (mph) | 0 | 5 | 10 | 15 | 20 | Descent Time (s) |
|---|---|---|---|---|---|---|
| Drift of the Fore Section (ft) | 0 | 552 | 1,104 | 1,657 | 2,209 | 75.3 |
| Drift of the Aft Section (ft) | 0 | 526 | 1,052 | 1,576 | 2,104 | 71.7 |
| OpenRocket Simulation (ft) | 8 | 206 | 574 | 651 | 1,185 | 72.7 |

# Recovery - Packing

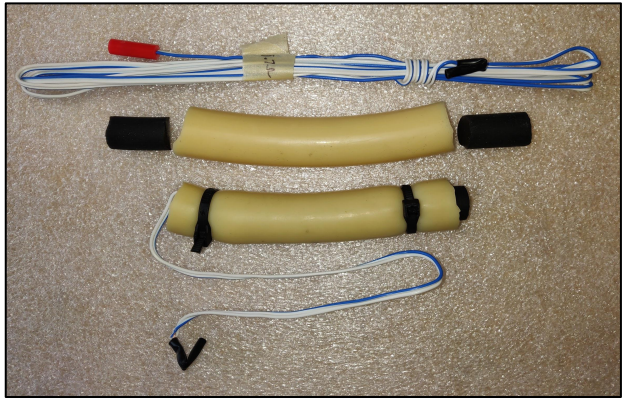
- Main parachutes
  - Packed into a 5.5 in. deployment bag
- Folding method recommended by OSRT advisors
- Blast protectors used near all ejection charges and Tender Descenders

# Recovery - Shock Cord

- Nylon 1 in. wide webbing shock cord
  - Kevlar protection near ejection charges
- One shock cord to attach the main and drogue
  - Total length: 42 ft (without knots)

# Ejection Charges

- Primary black powder charge
  - Separates the airframe at apogee
- Secondary charge
  - Ignited on a one second delay
- Charge Components
  - Black powder
  - Surgical tubing
  - Santoprene rubber plugs
  - E-match
  - Zip ties



# Demonstration: Separation Ejection

- Passing Condition
  - 5 consecutive tests fully separate launch vehicle
  - Expel drogue and retain main
- Test Procedure
  - Assemble launch vehicle
  - Secure airframe
  - Ignite charges
- Status - Incomplete
  - Successfully demonstrated on subscale
  - Full scale demonstration scheduled in January

# Avionics

- Avionics Telemetry Unit
  - 433 MHz TI CC1200 transceivers
  - Multi-sensor data logger: IMU, accelerometer, barometric pressure, temperature, altitude
- Code integration
  - TI CC1200 transceiver registry configuration and Tx/Rx
  - Data logger multi-sensor interaction with existing code base and with CC1200 code

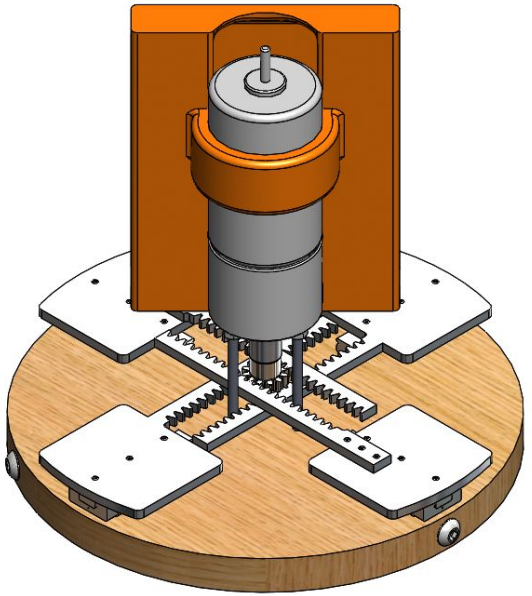
# Avionics Testing

- Battery Life
  - Success criteria: system remains fully powered ON and operational for 8 hours in standard configuration
- Transmission Continuity and Range
  - Success criteria: at least 1 packet arrives every 5 seconds for the duration of the test at a distance of at least 1 mile

# BEAVS

## Blade Extending Apogee Variance System

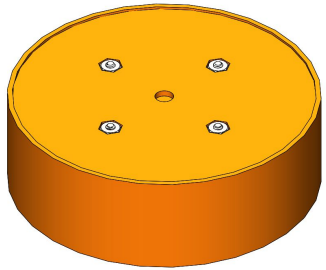
- Passive System
  - Coupled ballast bays
- Active System
  - Controls drag profile during flight
- Weight: 2.68 lbf



# BEAVS

## With passive system implemented:

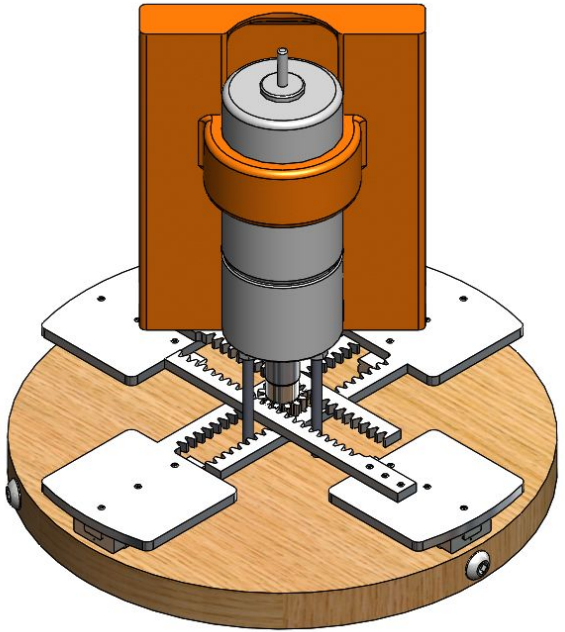
| Wind Speed (mph) | Aft Ballast (lbf) | Fore Ballast (lbf) | Stability (cal) | Apogee Altitude (ft) |
|---|---|---|---|---|
| 0 | 0.8 | 4.09 | 2.45 | 4726 |
| 5 | 0.8 | 4.09 | 2.45 | 4720 |
| 10 | 0.8 | 4.09 | 2.45 | 4706 |
| 15 | 0.8 | 4.09 | 2.45 | 4668 |
| 20 | 0.8 | 4.09 | 2.45 | 4628 |



*Simulations performed in OpenRocket

# BEAVS

- Electrical Components
  - Driven by DC motor
  - Rotary encoder for position
  - Avionics sensors
- Control Scheme
  - Varying Set Point



# Launch Vehicle Structures

# Body Tubes

## Fore

- Fiberglass
- Length: 49 in.
- Contains Payload

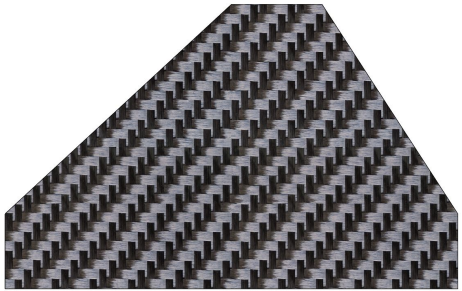
## Aft

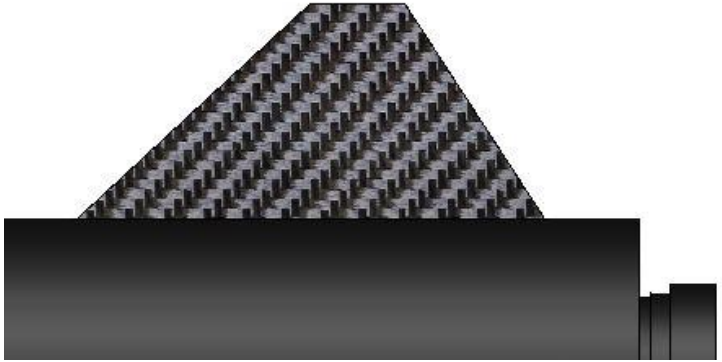
- Fiberglass and Carbon Fiber
- Length: 50 in.
- Holes for BEAVS and Cameras

# Fins

## Four Trapezoidal Clipped-Delta Fins

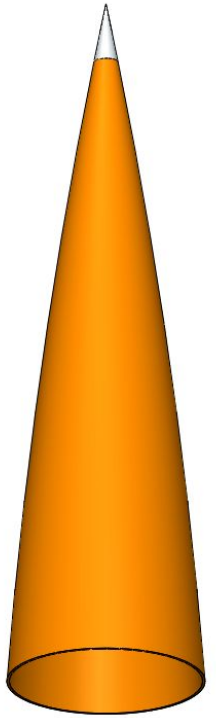
- 2 in. from Aft End
- Thickness: ⅛ in.
- Trailing edge swept forward





# Nosecone

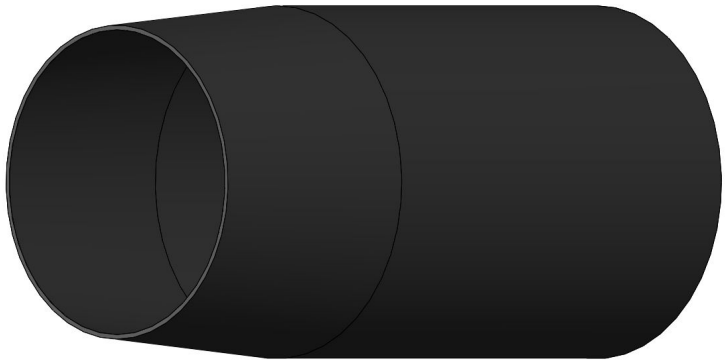
- Profile: 5:1 Ogive
  - Purchased at 7.5 in. diameter
  - Cut to 6.25 in. inner diameter
- Material:
  - G12 Filament Wound Fiberglass
  - Aluminum Tip
- Length: 23.5 in.



# Fore Coupler

## Manufactured by OSRT

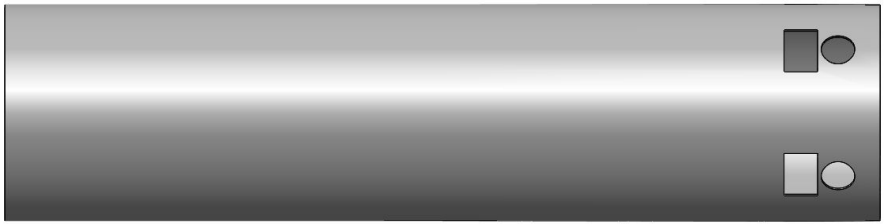
- Material: Fiberglass
- Length: 12 in.
- Tapered to fit in nosecone
- 1:1 body diameter to shoulder length ratio

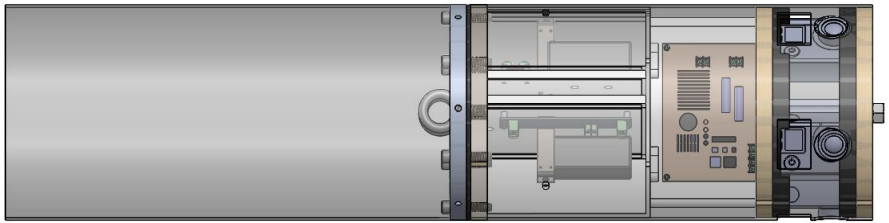


# Canister

## Manufactured by OSRT

- Material: Fiberglass
- Length: 22.25 in.
- Holes
  - Camera system
  - Arming port holes
  - Static port holes





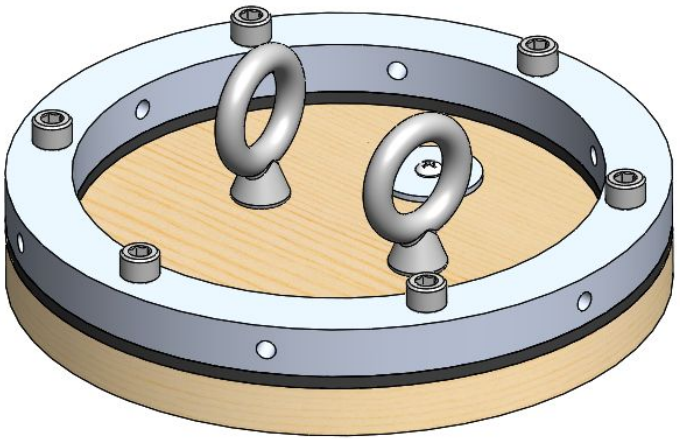
# Radial Bolt Testing

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

# Pressure Seal

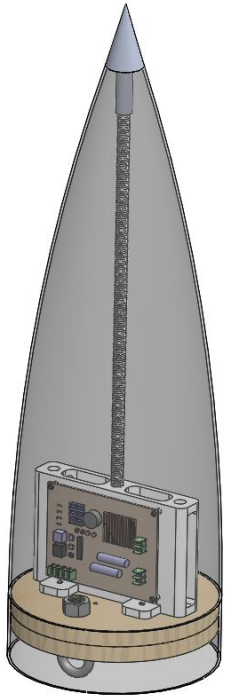
Caps each electronic bay

- Six ¼-20 bolts compress a santoprene rubber sheet
- Removable
- Minimizes needed charge size
- Radially mounted



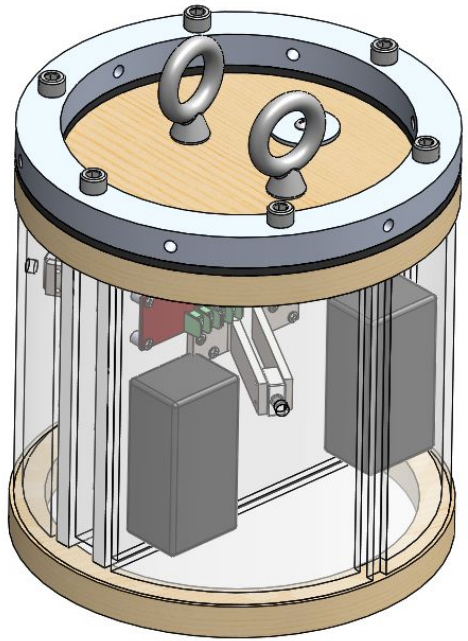
# Fore Avionics Bay

- Located within the nosecone
  - RF transparent
  - Conserves space
  - Pressure sealed
- Specifications
  - Weight: 0.65 lbf
  - Length: 4 in. wide x 5 in.
  - Additively manufactured mount



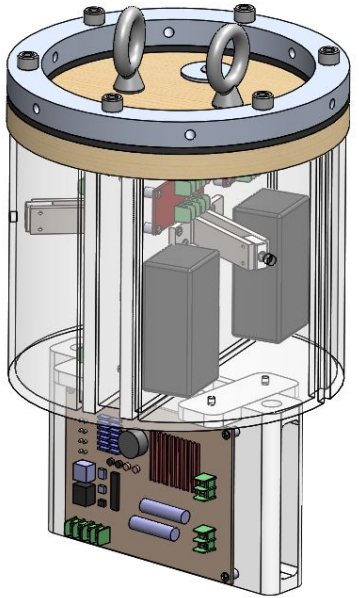
# Fore Ejection Bay

- Located fore of PEARS
  - RF shielded
  - Pressure sealed
  - Mounting point for fore parachutes
- Specifications
  - Weight: 1.72 lbf
  - Length: 4.5 in.
  - Additively manufactured mount



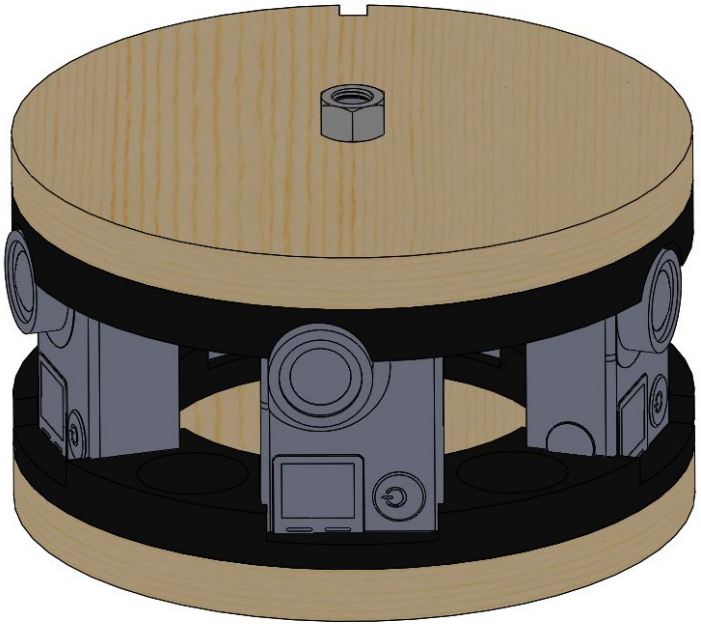
# Aft Ejection Bay

- Located aft of aft parachutes
  - RF shielded
  - Mounting point for aft parachutes
- Specifications
  - Weight: 2.33 lbf
  - Length: 8 in.
  - Additively manufactured mount



# 360 Camera System

- Five GoPro cameras
  - 360 degree panorama video
- Material:
  - ABS plastic
  - Plywood bulkheads

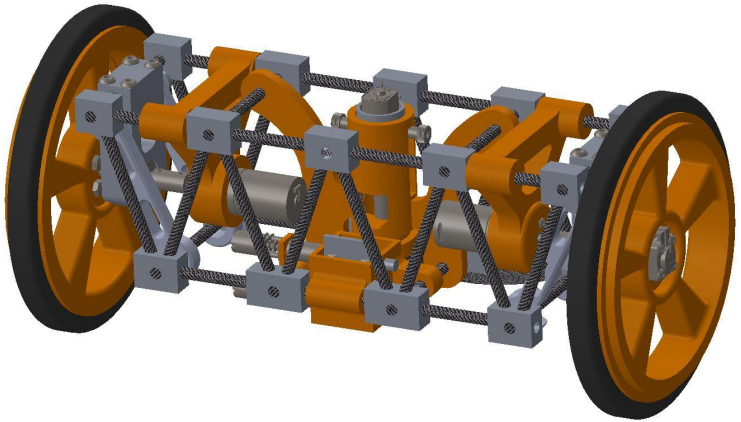


# Payload Mechanical

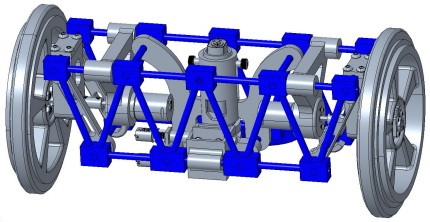
# Final Rover Design

Three Subsystems:

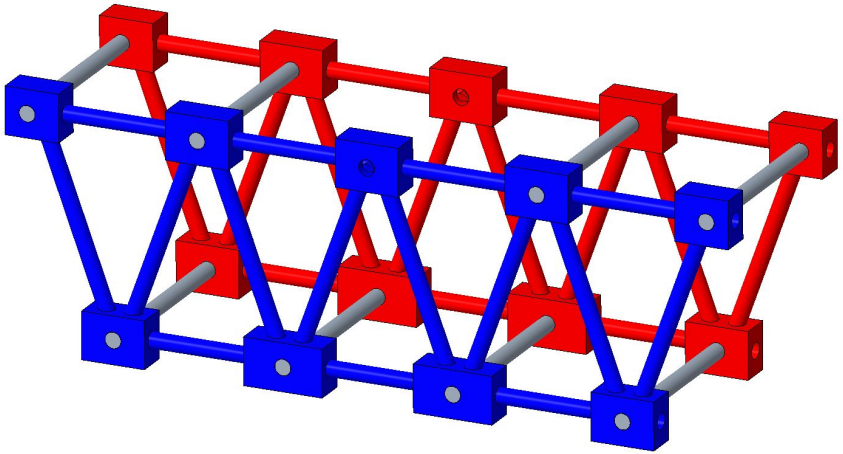
- Chassis
- Drivetrain
- SCAR (Soil Collection and Retention)



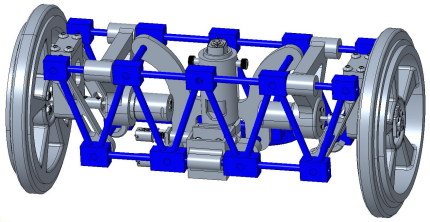
# Chassis



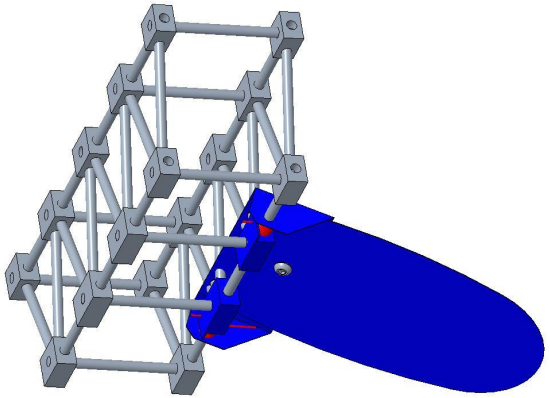
- Double Truss Design
  - Aluminum - Blocks
  - Carbon Fiber - Rods
  - Carbon Fiber - Tail
- Benefits
  - Strong
  - Lightweight

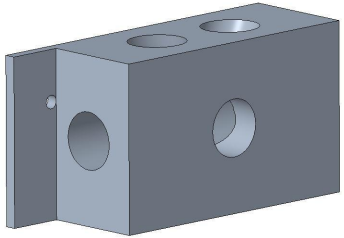


# Rover Stabilizing Tail

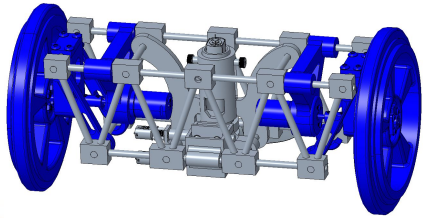


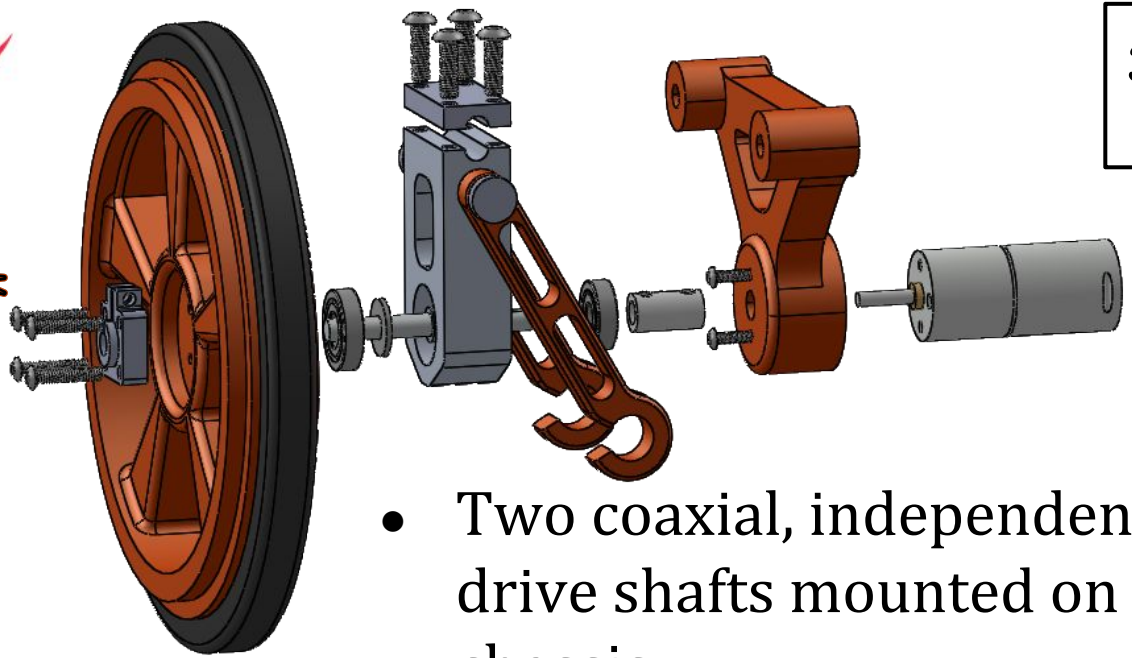
- Stabilizes the rover during movement
- Components
  - Stabilizing Blocks
  - Torsion Spring
  - Mounting Hardware
  - Carbon Fiber Tail





# Drivetrain

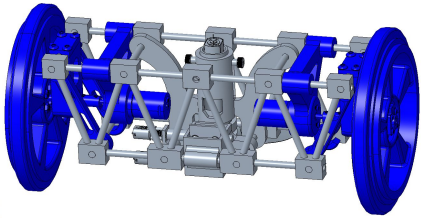




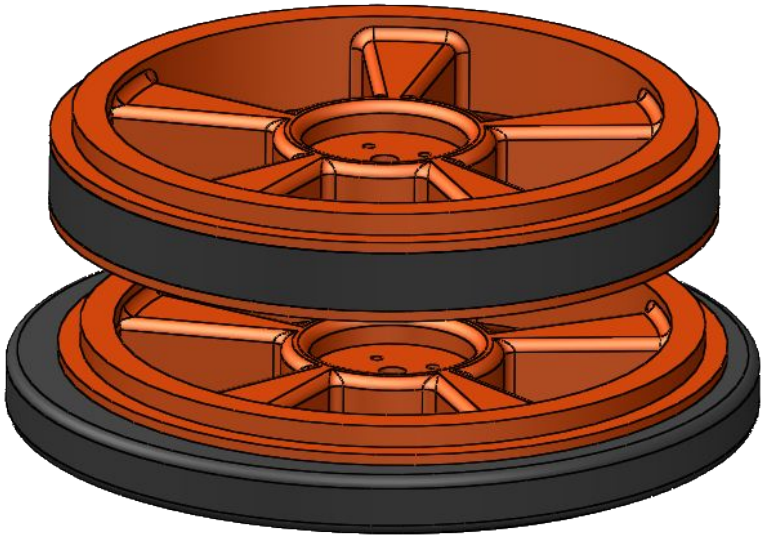
306 oz-in. of torque per DC motor

- Two coaxial, independently controlled drive shafts mounted on either end of chassis

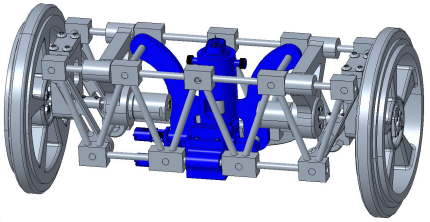
# Drivetrain



- DC motor torque output allows 30° slope climbing
- Urethane foam tire
  - Enables pressure seal for payload ejection
  - Expands for additional ground clearance

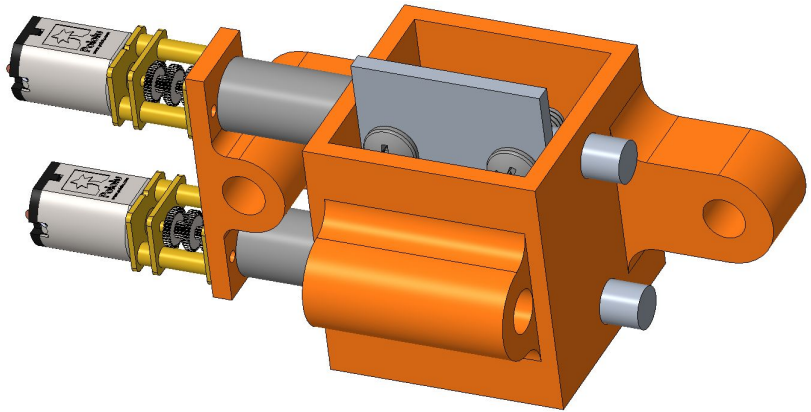


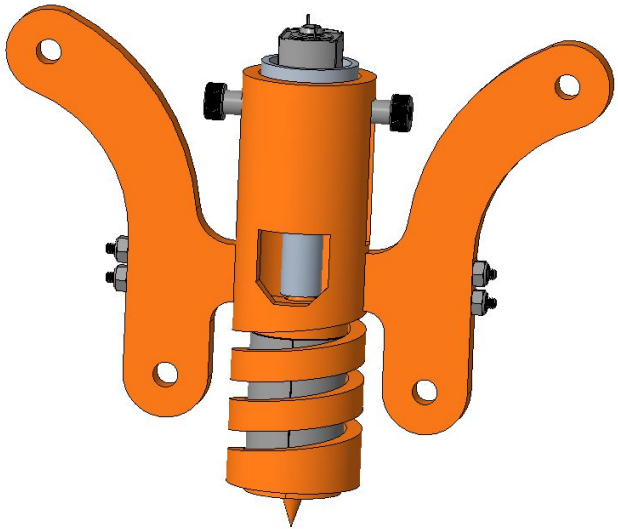
# SCAR



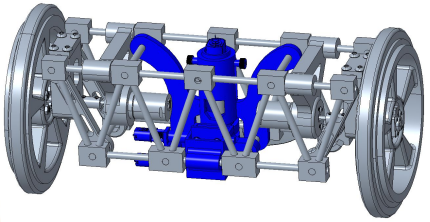
Consists of two systems:

- Soil Collection
- Soil Retention



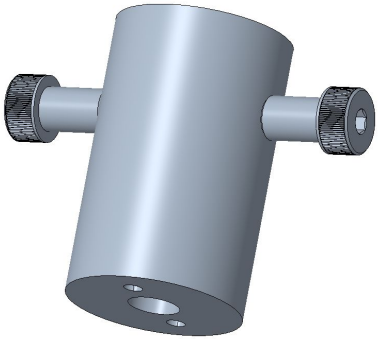


# SCAR - Soil Collection

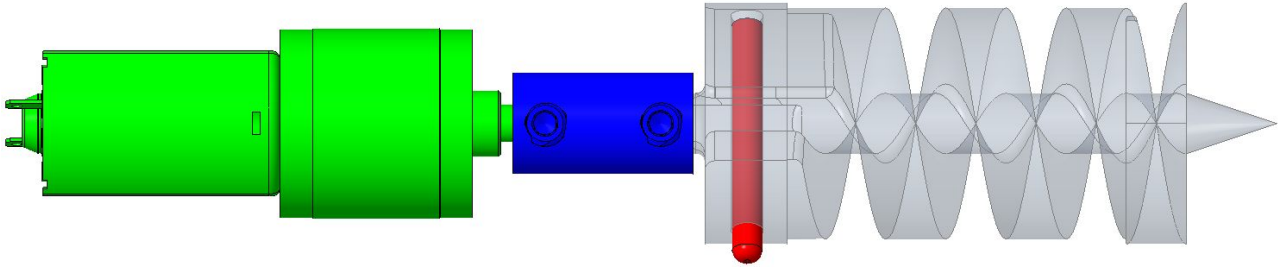


Collection Components:

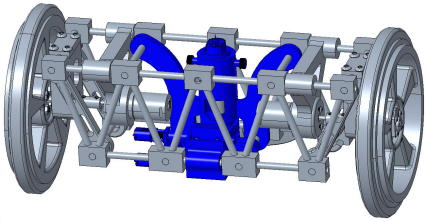
- Auger
- Auger Bar
- Coupler
- Motor
- Carbon Fiber Wrap (Not shown)



Motor Enclosure

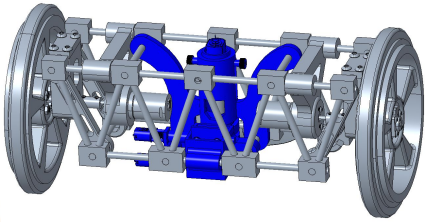


# SCAR - Soil Collection

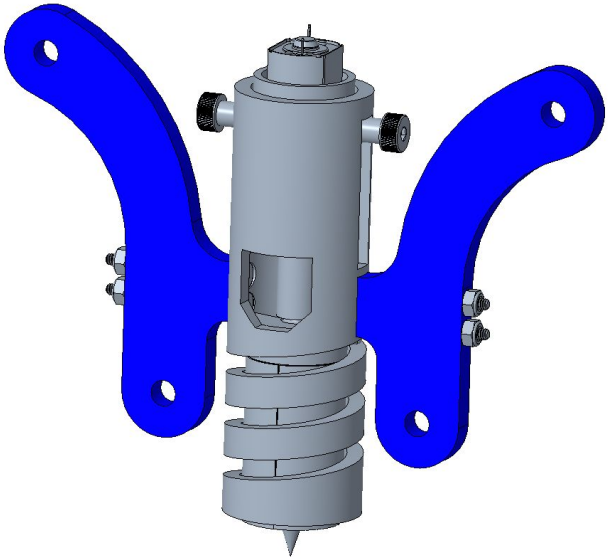


- Auger tube is used to extend/retract the auger from the rover
- Front slot is used to deposit soil into the Soil Retention container

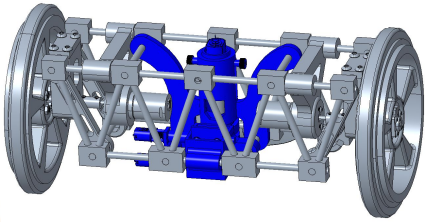
# SCAR - Soil Collection



- Mounting fixtures connect the Soil Collection system to the chassis.

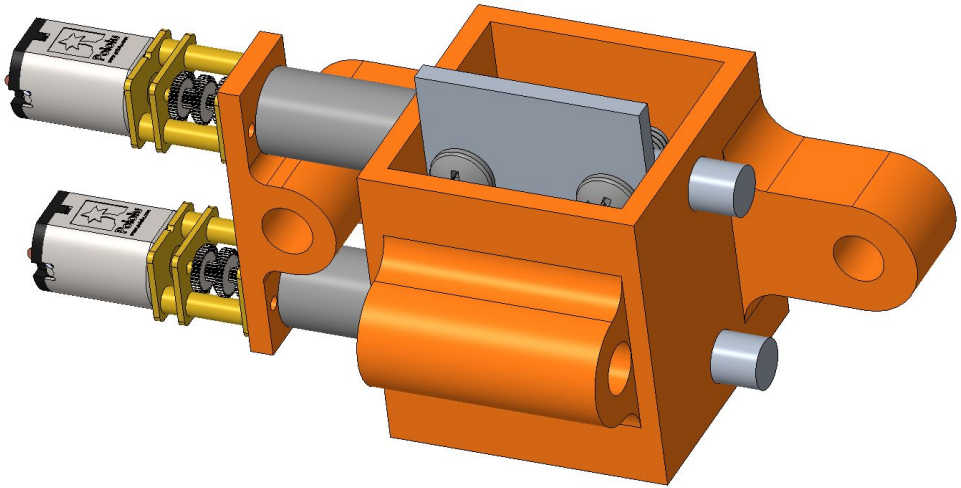


# SCAR - Soil Retention



## Retention Components:

- 2 Motors
- 2 Couplers
- 2 Shafts
- 2 Doors
- 1 Container
- 1 Motor Mount



# Test Plans: Payload Performance

## Field Transversal

- Success Criteria: Ability to travel over varied terrain such as wet grass and climb 30° inclines

## Soil Collection

- Success Criteria: Ability to drill and collect a variety of soil compositions

## Object Avoidance

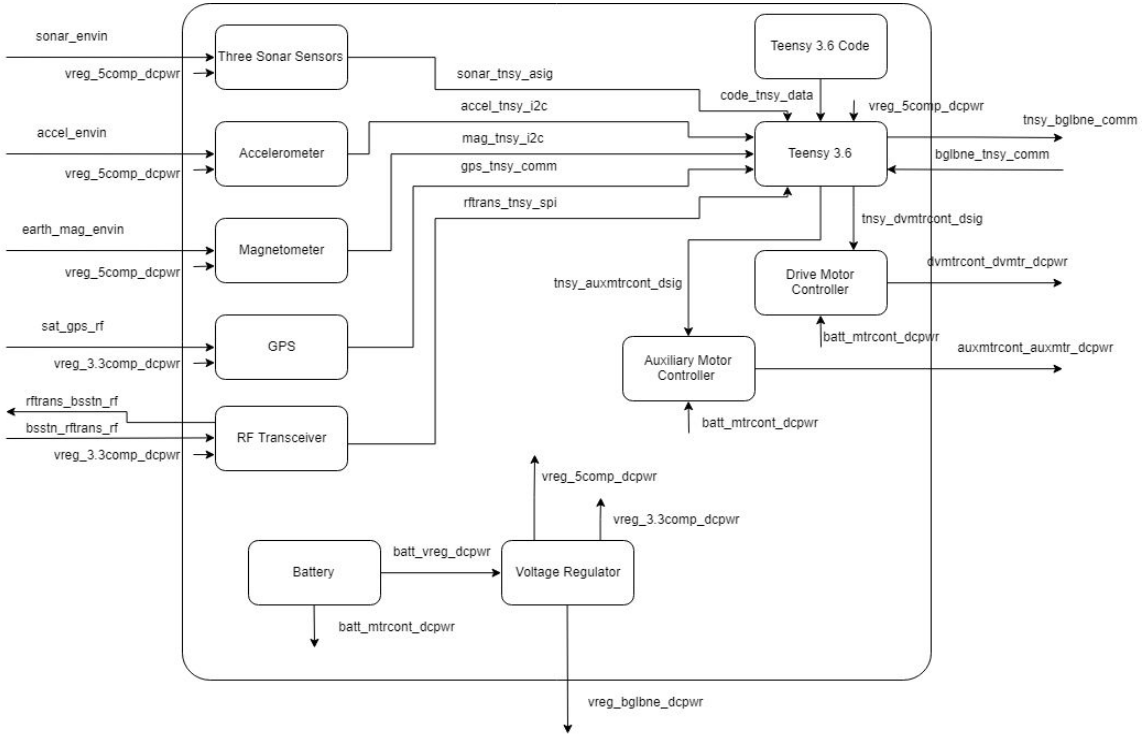
- Success Criteria: Ability to detect and avoid objects large enough to hinder rover movement

## Soil Retention

- Success Criteria: Ability to transfer soil to retention container and seal with a variety of soil compositions

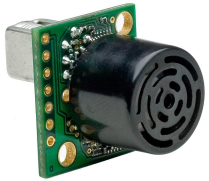
# Payload Electrical

# Top Level Diagram



# Navigation

- Sonar
  - Obstacle and Collision Avoidance



- Global Positioning System (GPS)
  - Confirm distance from Launch Vehicle


- Computer Vision (CV)
  - Launch Vehicle identification
  - Scientific base station docking

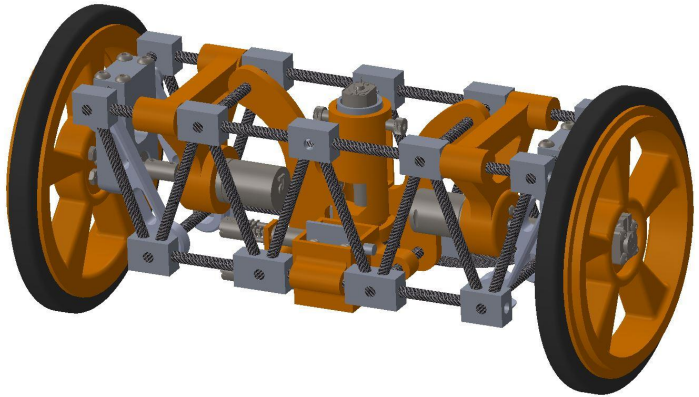
# Soil Collection Components

- Accelerometer
  - Measure orientation of the rover
- Auger Motor Controller
  - Bidirectional motor controller to insert and retract auger
- Container Door Motor Controller
  - Top is open during auger operation
  - Bottom opens upon docking at the base station

# Payload Software

# Payload Functions

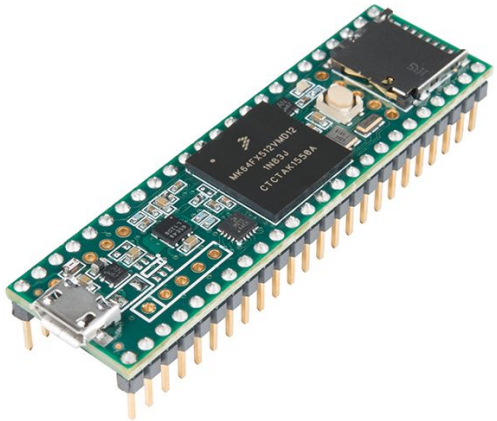
1. Move specified distance away from launch vehicle
2. Collect soil sample in sealed container
3. Transport sample to scientific base station
4. Repeat collection in set number of different locations



# Payload Teensy 3.6

## Phase 1 - Move away from launch vehicle body

- Object avoidance
- Move on to phase 2 after GPS check and Gyro check



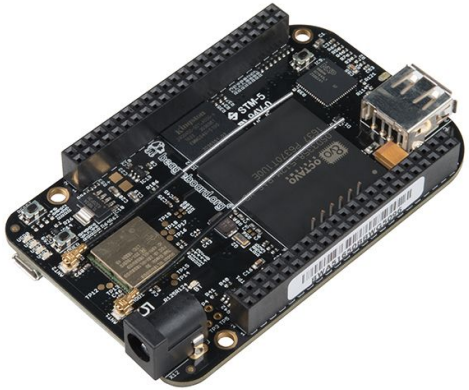
# Payload Teensy 3.6

## Phase 2 - Collect and deliver set number of samples

- Receive base station coordinates via RF
- Navigate to base station
- Deposit sample
- Find new sample location and log coordinates
- Repeat a set number of times

# Payload Beaglebone Routines

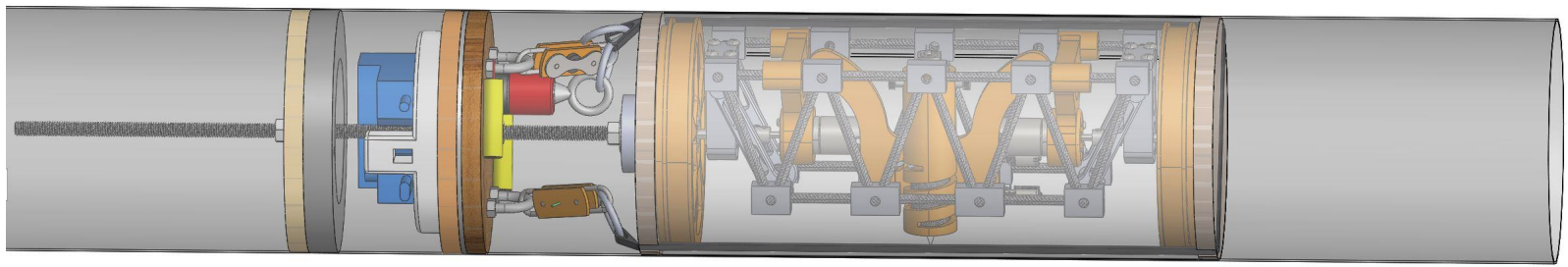
- Launch Vehicle Detection
  - Send signal for Teensy to face away from launch vehicle
- Object Detection
  - Send signal for Teensy to move right or left of an object
- Docking Process
  - Send a series of commands to dock Teensy



# Payload Ejection and Retention

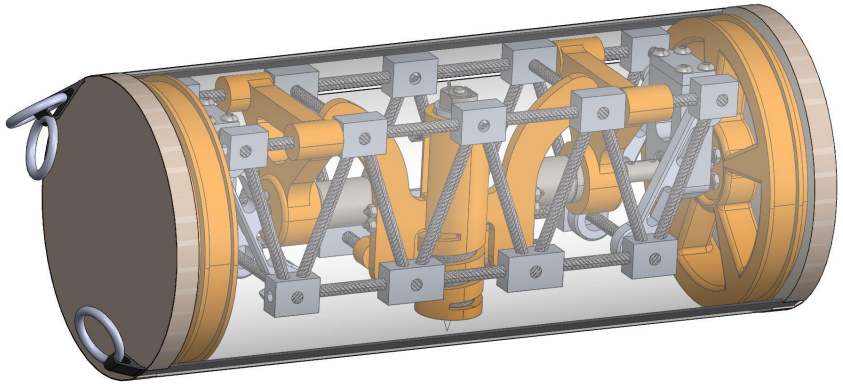
# PEARS

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



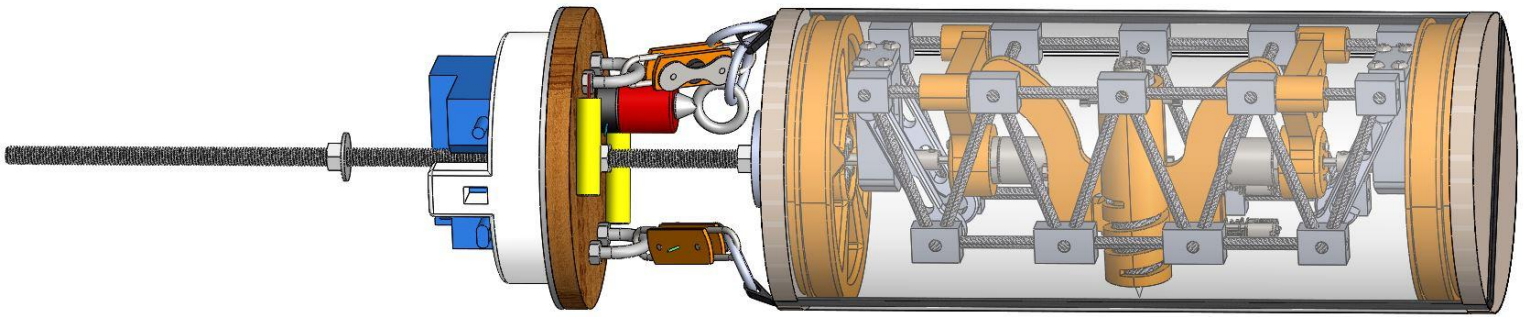
# Payload Wrap Assembly

- Fiberglass wrap encloses rover and bulkheads
- Plywood spacers on either end
- Kevlar harness retains plywood to rover and attaches to retention devices



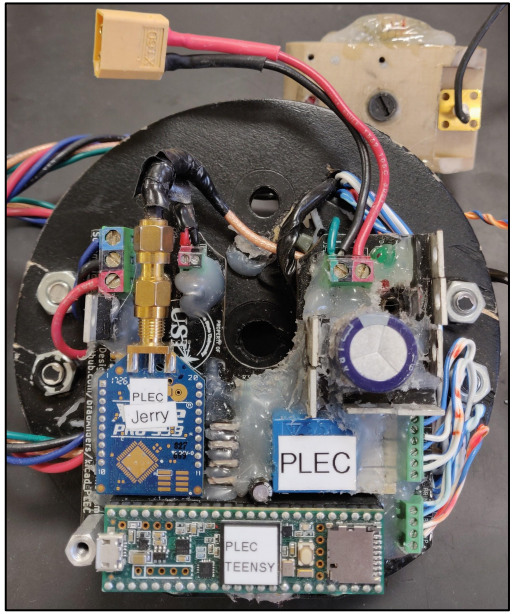
# Ejection and Retention

- Wrap is retained to removable retention assembly
  - L2 Tender Descender x2
  - ARRD
- Black powder ejection charges
- PLEC shown in blue



# Payload Ejection Controller (PLEC)

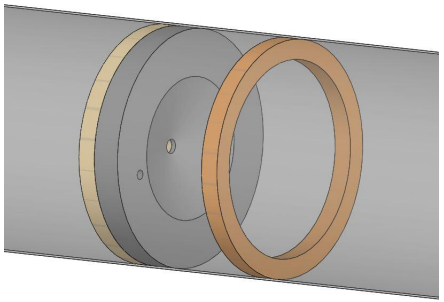
- Controls retention devices and ejection charges
  - Only allows ejection charges to be ignited once all retention device e-matches are set off
- Armed with a single-pole double-throw switch
  - Shunts the system for safety while integrating



# Fore Hard Point

Fixed series of bulkheads in fore airframe

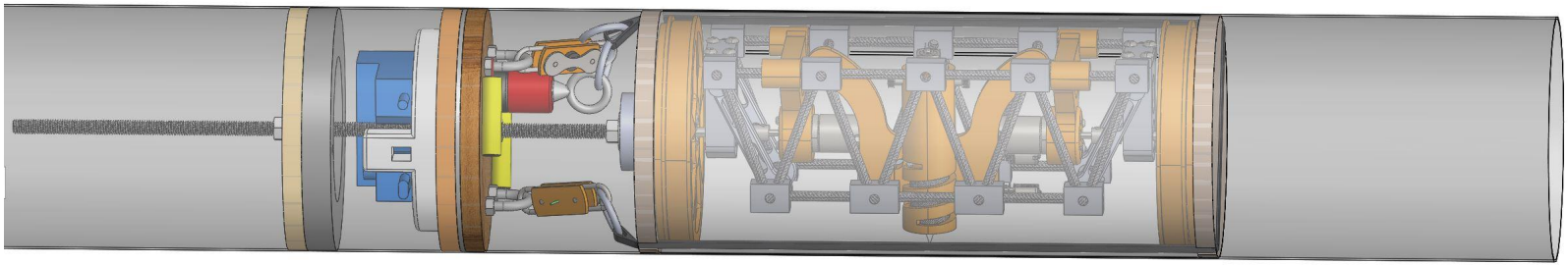
- Pass through bulkhead
  - Creates pressure seal with PEARS
- Funnel eases integration of PEARS threaded rod
- Bulkhead with ⅜ in. hole for secure retention



# Full Integration

Integration into fore airframe

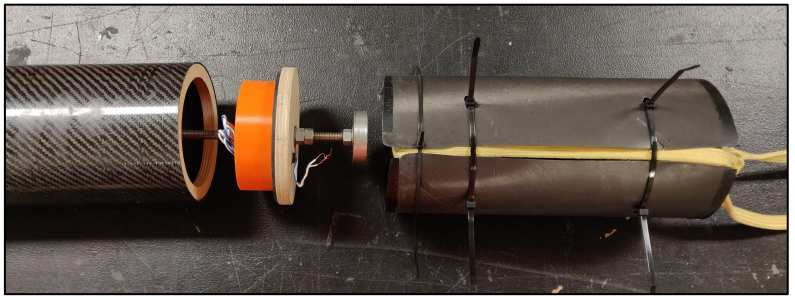
- Pressure seal between PEARS and FHP
- Fore ejection bay mounted on threaded rod
- PLEC armed from exterior once fully integrated



# Test Plans: Payload Ejection

- Passing Condition
  - Rover clears airframe
  - Rover separates from PEARS wrap
- Test Procedure
  - Assemble and integrate PEARS
  - Secure airframe
  - Activate charges

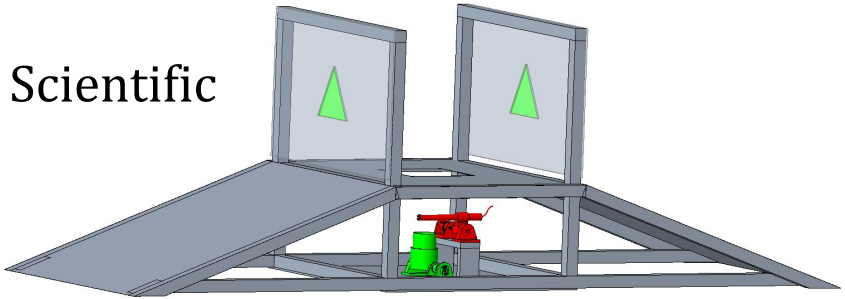
- Status - Incomplete
  - Tested on 5.2 in. airframe
  - Scheduled full scale test in January



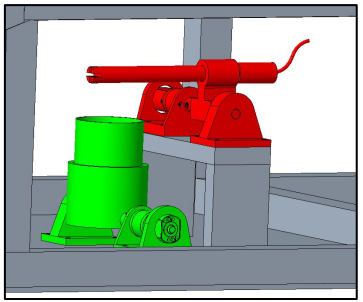
# Scientific Base Station

# Scientific Experiment Design

- Mock Experiment:
  - X-Ray Fluorescence on Scientific Base Station

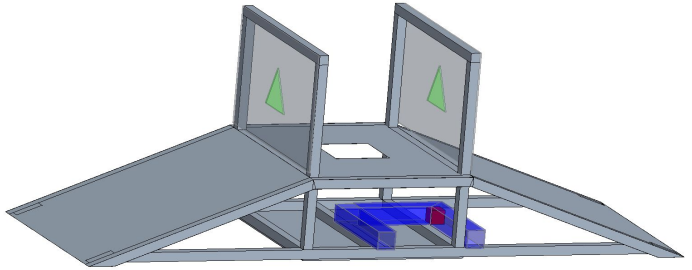


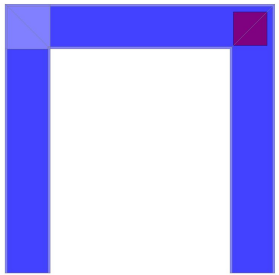
- Actual Experiment:
  - Mapping pH of numerous soil samples collected



# X-Ray Fluorescence

- X-Ray Emission:
  - Strontium-90 radioactive isotope emits beta particles
  - Beta particles hit the lead block, emitting x-rays
  - X-rays collide with soil sample, emitting a quantized x-ray
  - Detected x-ray wavelengths are specific to soil content

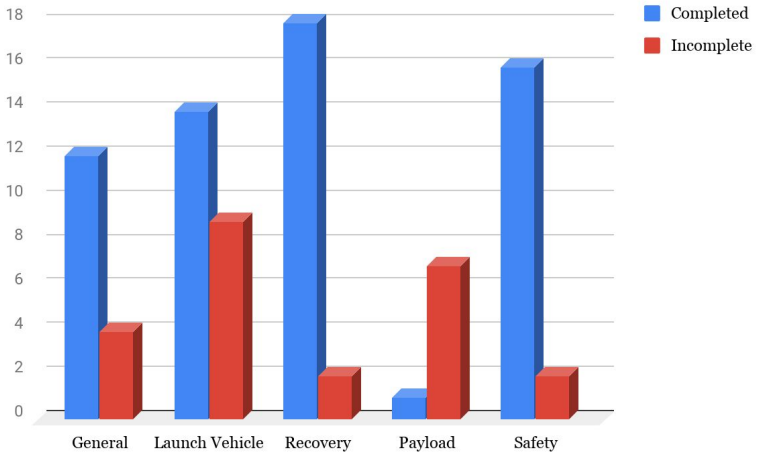




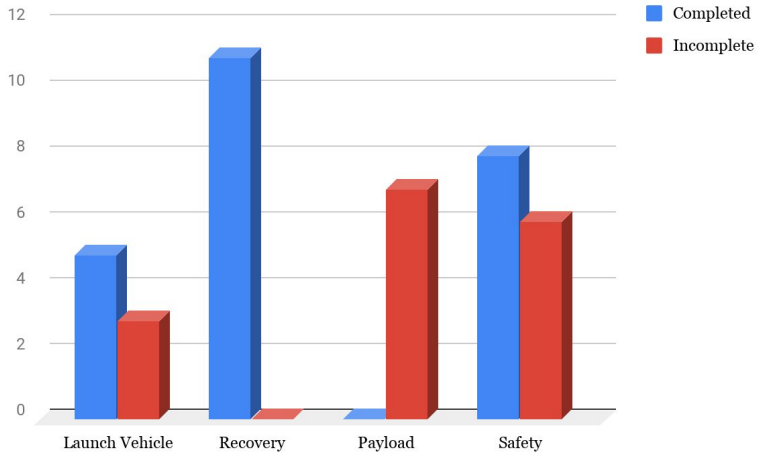
# Testing and Requirement Verification

# Requirement Verifications

## Status of NASA Requirement Verifications




## Status of Team Derived Requirement Verifications




*Status as of 01/11/2019

# STEM Engagement

# Event Pictures


# Completed Events

- Yamhill-Carlton High School (27)
- Discovery Days (950)
- Veneta Elementary School (350)
- OSU Women's Basketball Game (150)
- OSU Honors College Colloquium (12)
- Evergreen Air & Space Museum (150)
- Westview High School (96)

Total: 1,735

# *Questions?*