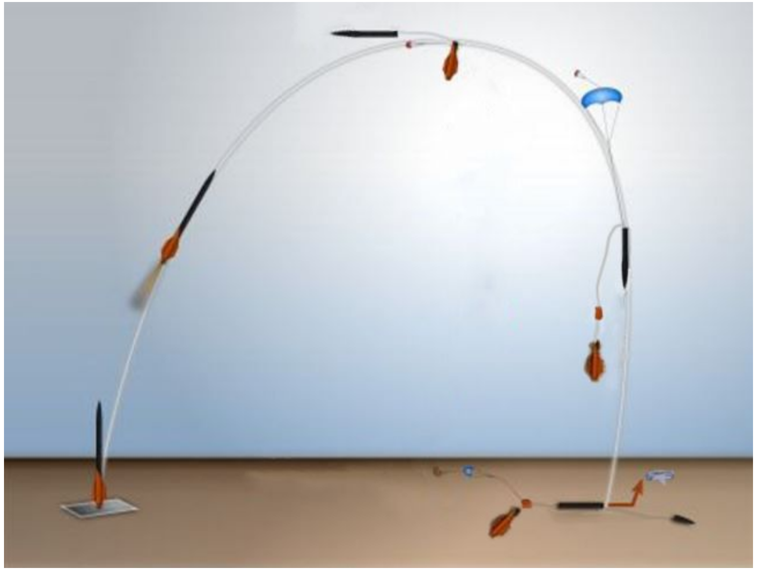
Oregon State University

Critical Design Review

01/27/2020

Mission Overview

1. Launch
2. Motor burnout
3. Separation at apogee
4. Drogue parachute deploy
5. Main parachute deploy
6. Landing
7. Rover deployment
8. Ice collection
9. Ice transportation



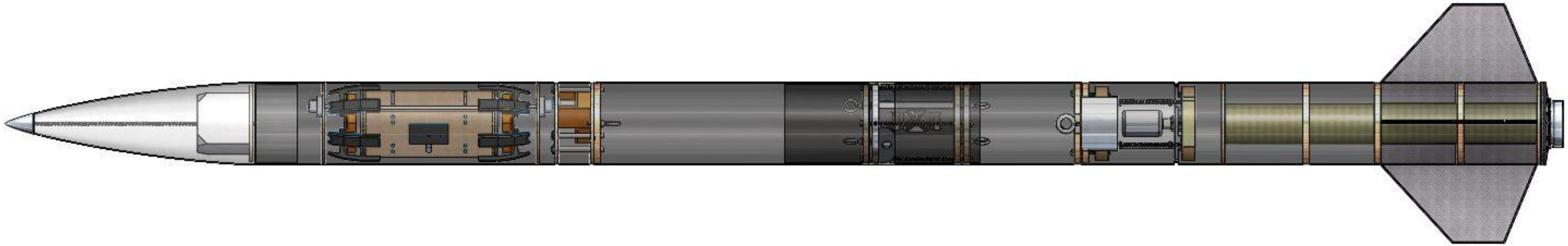
Launch Vehicle Overview

Length: 109 in.

Weight: 61 lbf

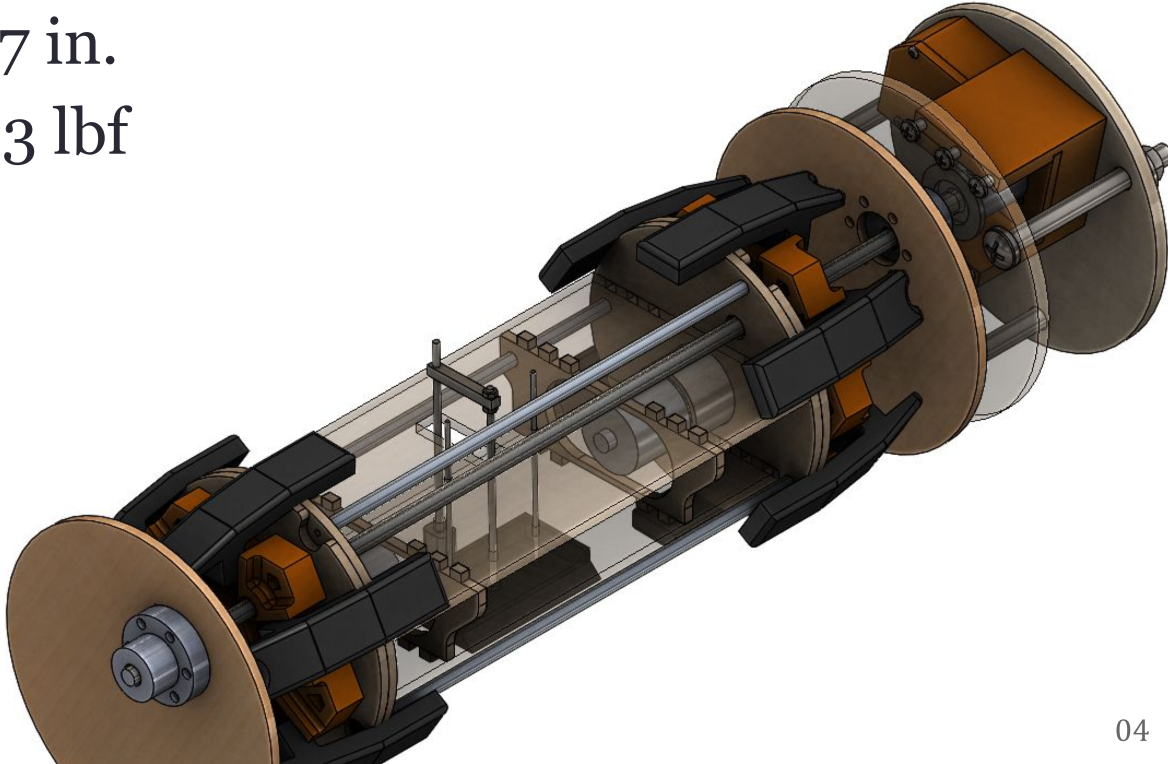
Inner Diameter: 6.25 in.

Rail: 1515



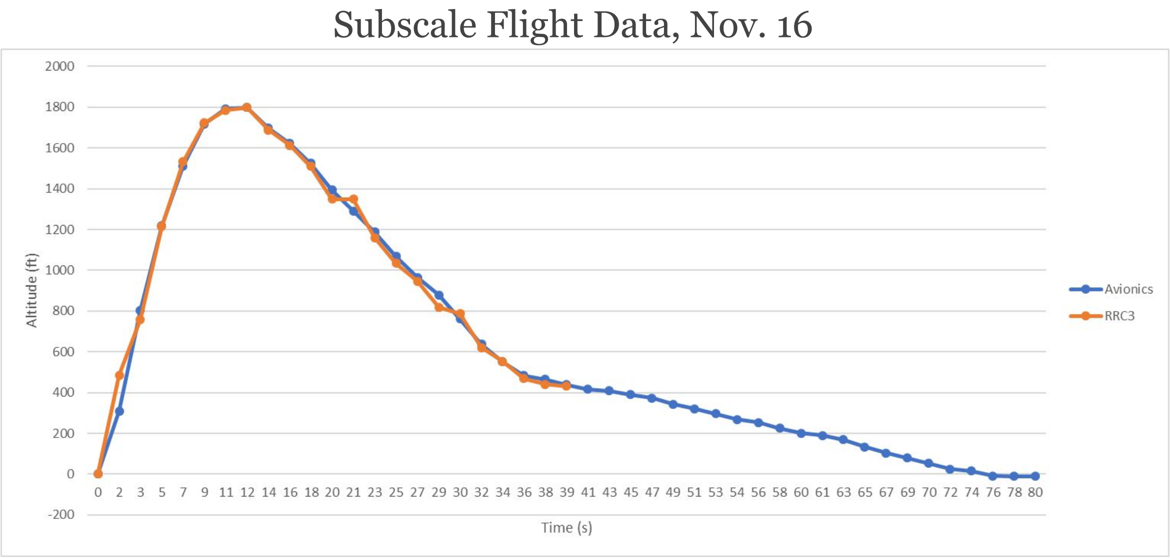
Payload Overview

- Total Length: 17 in.
- Total Weight: 13 lbf



Subscale Launch

Subscale Flight: November 16th

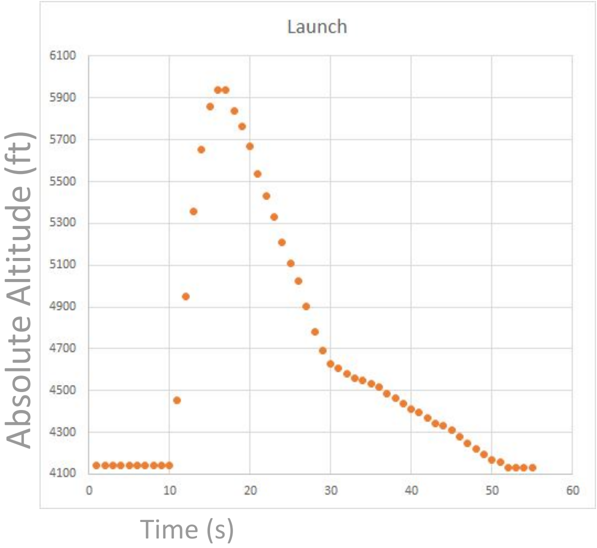


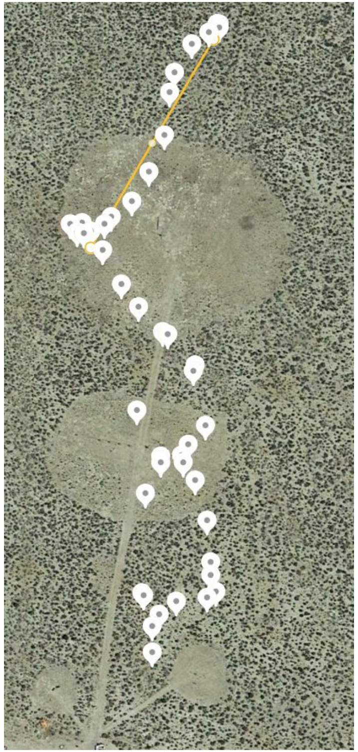
Maximum Altitude (ft)	1798
Impact Velocity (ft/s)	8.02
Impact Kinetic Energy (ft-lbf)	31.38
Descent Time (s)	62

Subscale Flight Data - Avionics

Drift: 250 ft

Altitude: 1835 ft

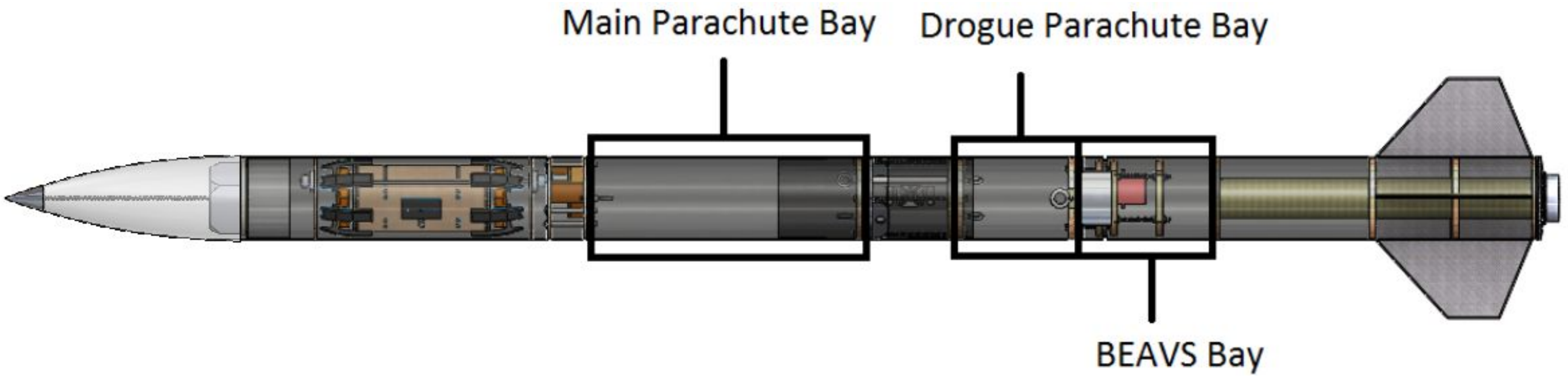




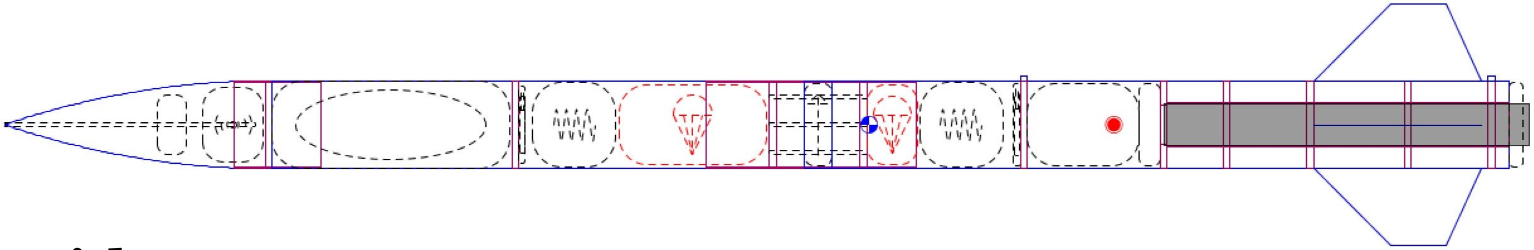
Aerodynamics and Recovery

Overview Slide

- Parachutes
- Recovery Hardware
- Deployment Energetics
- BEAVS 2.0



Stability Margin



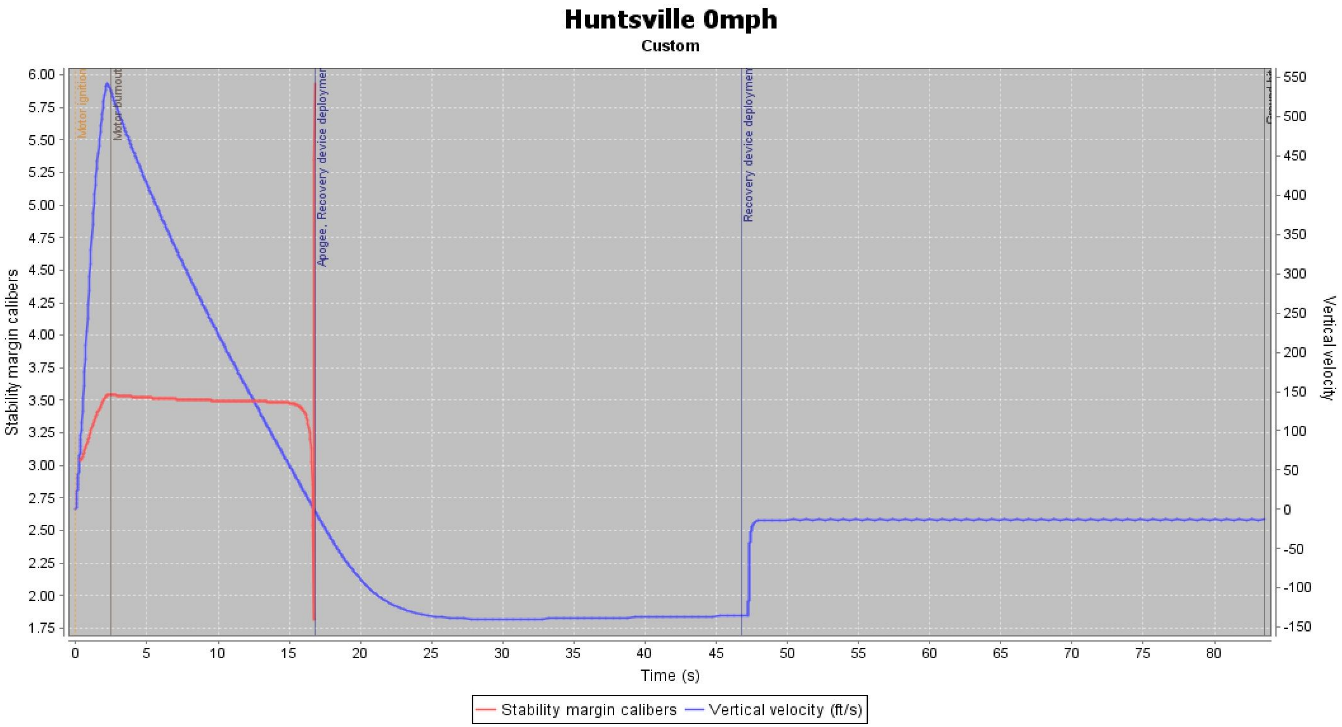
With Motor

C_P = 81.13 in C_G = 62.04 in **Stability:** 2.78 calibers

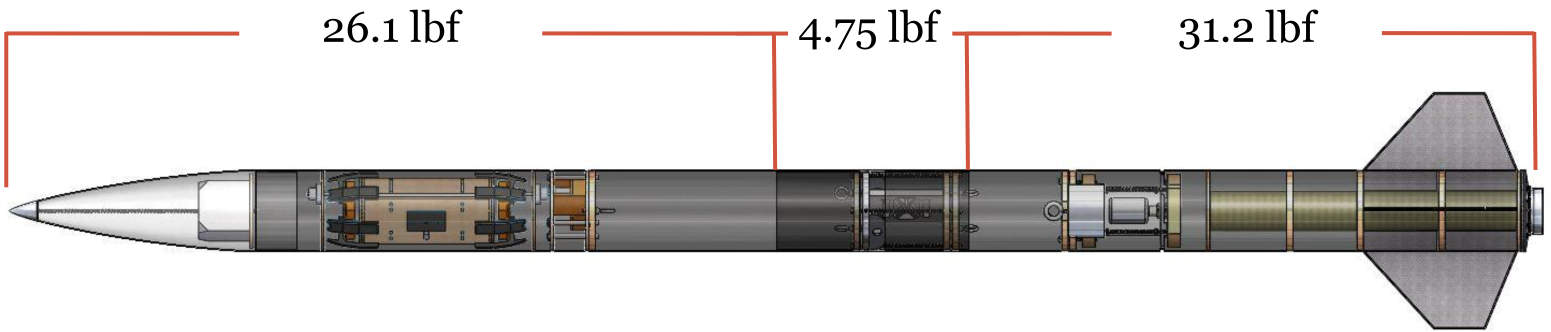
After Motor Burnout

C_P = 81.13 in C_G = 54.971 in **Stability:** 3.36 calibers

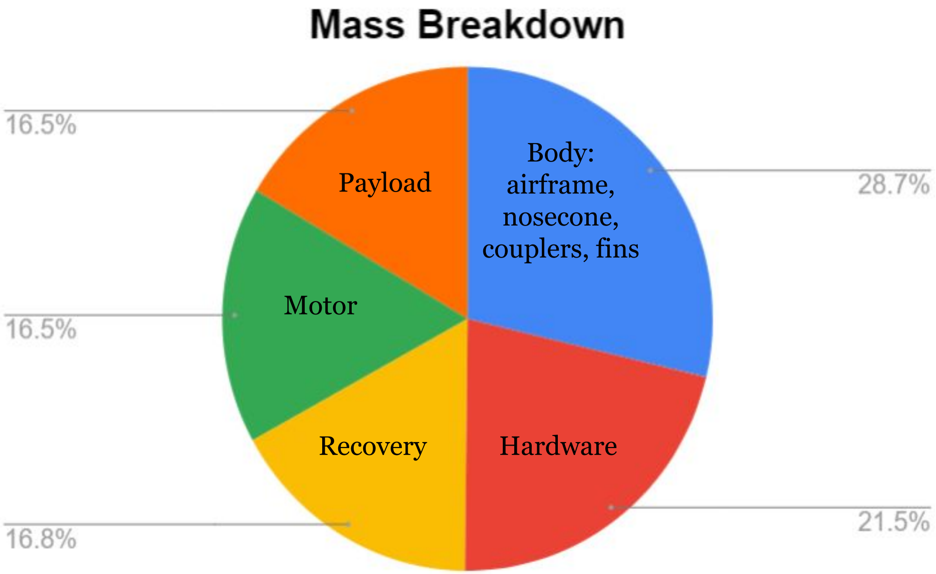
Stability During Flight



Mass Statement



Mass Statement



Mass Margin

Apogee Altitude Mass Margin

Weight Change	Projected Altitude
-9.9 lbf	5,500 ft
0 lbf	4,427 ft
+8.76 lbf	3,500 ft

*Mass margin assumes weight change at current center of gravity

Kinetic Energy Mass Margin

Section	Current Weight (lbf)	Available Weight Increase (lbf)	Landing Kinetic Energy (ft-lbf)
Fore	26.1	+ 10.3	75
Aft	31.2	+ 5.2	75
Coupler	4.75	+ 31.65	75

*Mass margin assumes weight change at current center of gravity

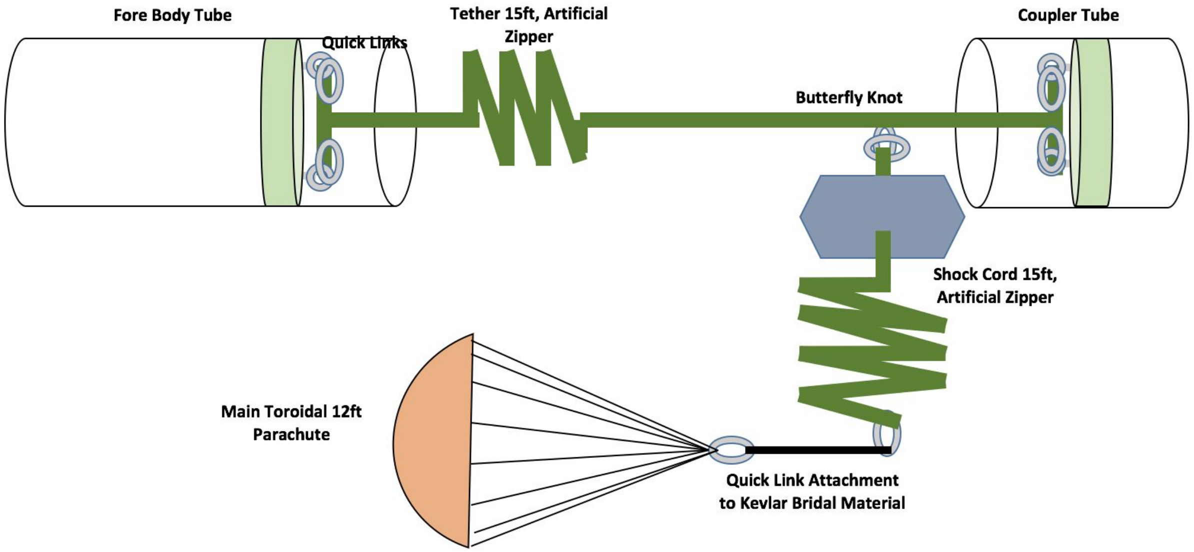
Kinetic Energy Analysis

Measurement	Fore section	Coupler	Aft section
Weight (lbf)	26.10	4.75	26.21
Landing Velocity (ft/s)	8.99	3.83	9.016
Landing Kinetic Energy (ft-lbf)	36.53	1.08	36.67

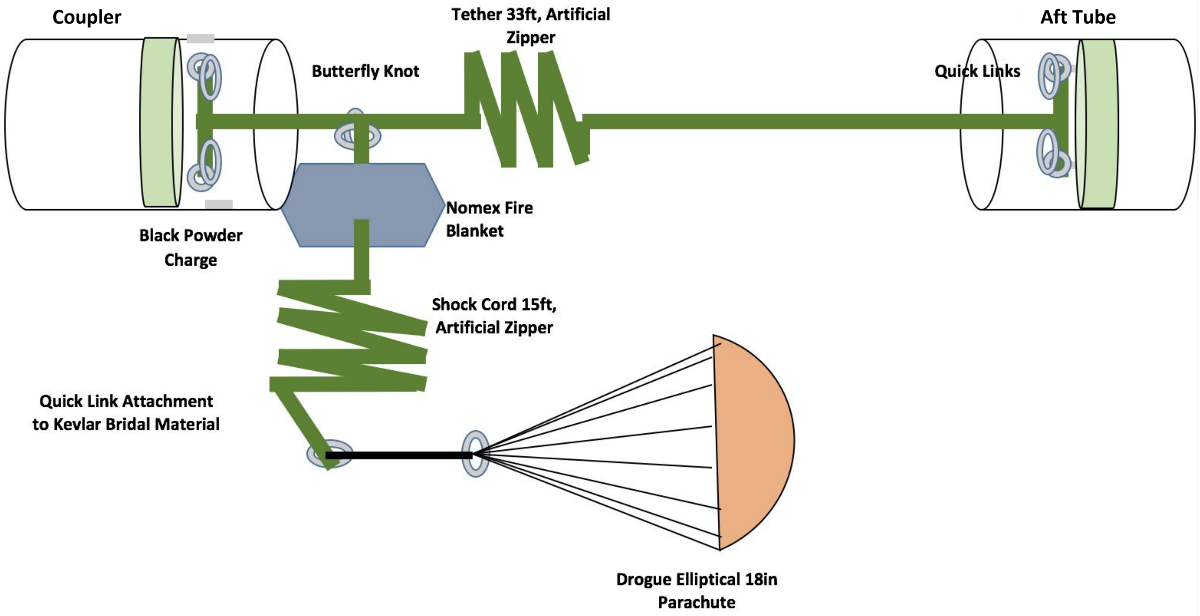
Descent Times and Drift

Wind Speed (mph)	0	5	10	15	20	Descent Times (s)
Matlab Drift (ft)	0	459	1100	1682	2103	**63.2**
OpenRocket Drift (ft)	7	260	505	744	950	**65**

Recovery Harness Main



Recovery Harness Drogue



Parachutes

Main

- 12 ft Toroidal Parachute
- C_d = 2.2

Drogue

- 18 in. Elliptical Parachute
- C_d = 1.5

* Both purchased from Fruity Chutes

Integration

Shock Cord

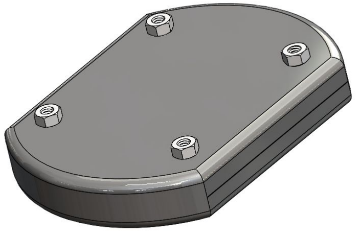
Fruity Chutes

- 1 in. Nylon webbing
- 3x 15 ft sections (tethers & main)
- 1x 33 ft section (drogue)

BEAVS 2.0

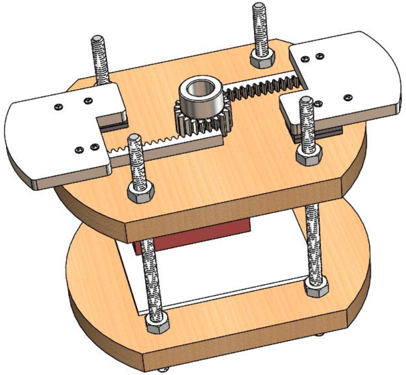
Passive System:

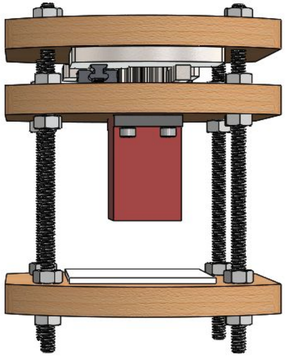
- Coupled ballast bays



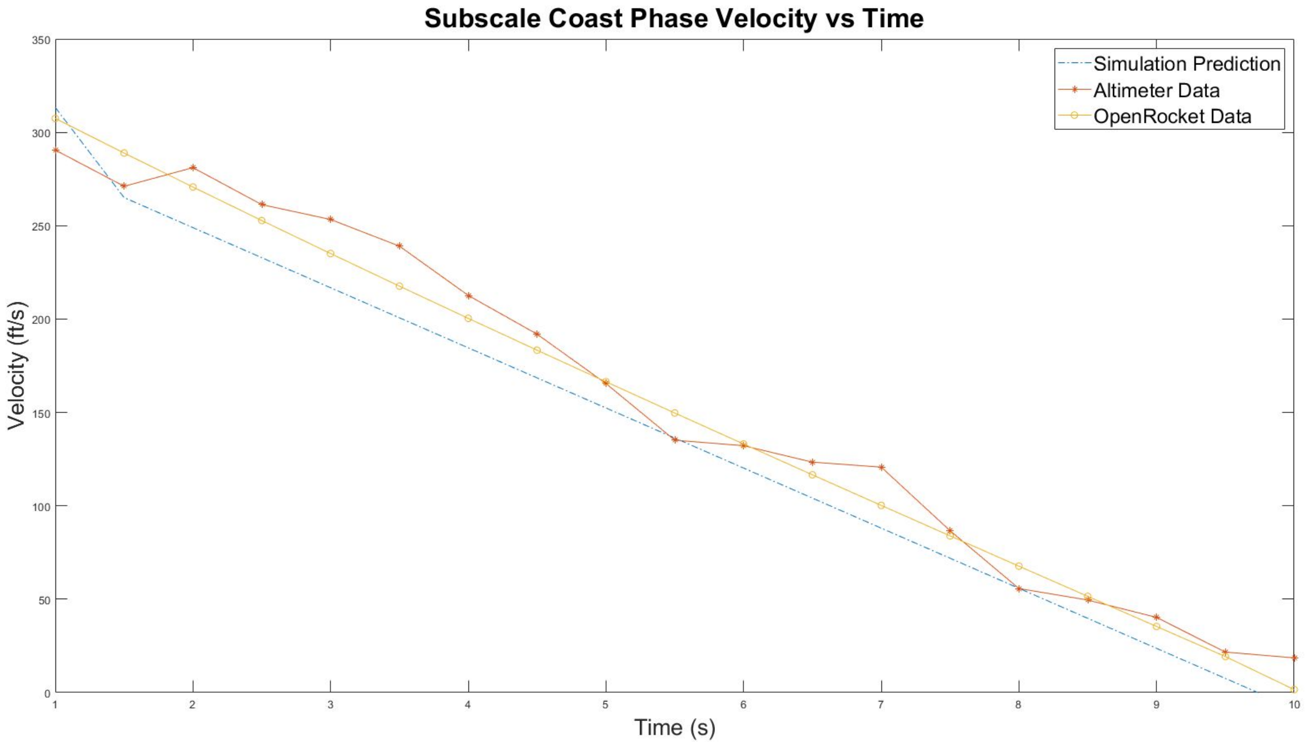
Active System:

- Dual blade rack & pinion
- Driven by servo
- Increases cross-sectional area by 16%

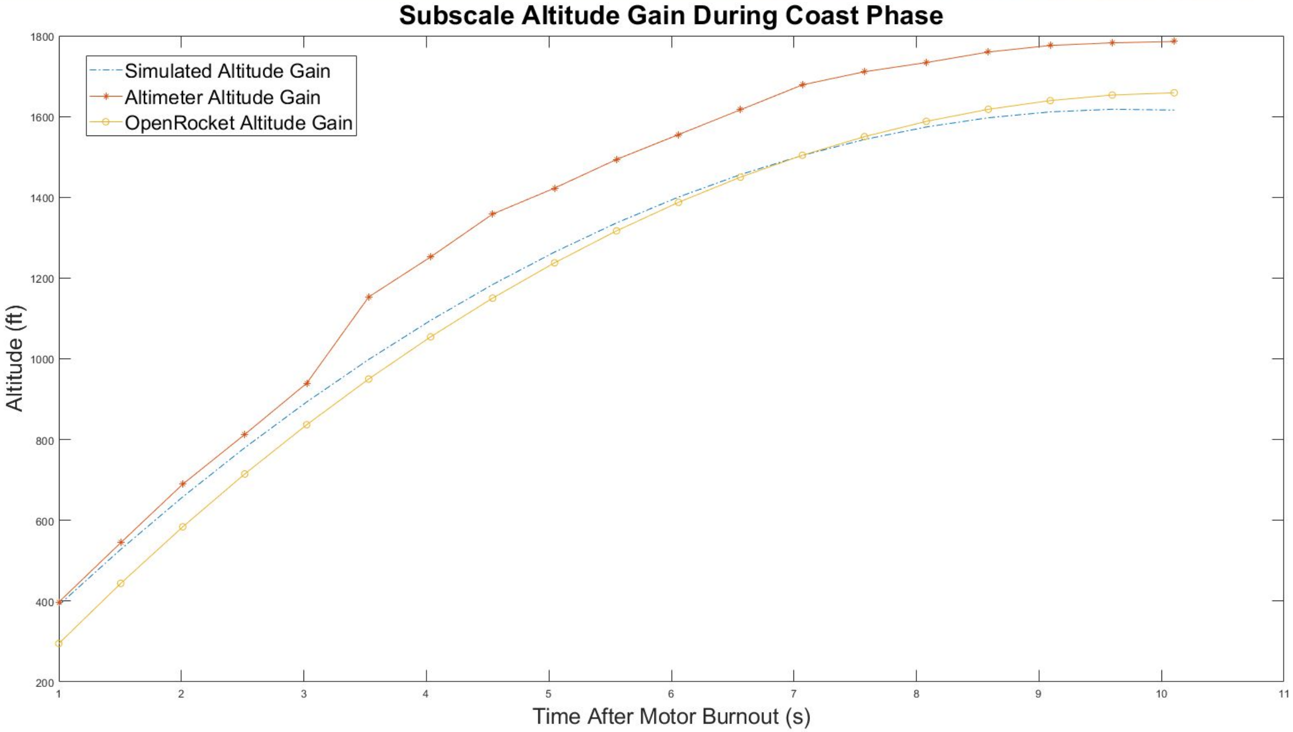




BEAVS 2.0 Altitude Prediction



BEAVS 2.0 Altitude Prediction



Black Powder Ejection Charges

CO_2 charges have been scrapped due to weight, length, and reliability concerns.

<u>Black Powder Sequence</u>

1. Primary drogue: ignites at apogee
2. Back-up drogue: ignites at one second past apogee
3. Primary main: ignites at 600 ft AGL
4. Back-up main: ignites at 500 ft AGL

Black Powder Ejection Charges

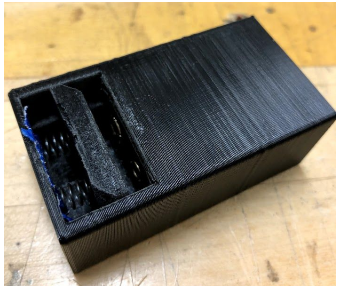
Materials

- Surgical Tubing
- Rubber Rod
- Cable Ties
- FFFFg Black Powder
- Firewire Initiator (E-match)
- Sharpie
- Quick Release Connector

Black Powder Ejection Charges

New Charge Sizes

Black Powder Charge	Size (g)
Main Parachute Primary Charge	4.8
Drogue Parachute Primary Charge	1.9
Main Parachute Back-up Charge	6.0
Drogue Parachute Back-up Charge	2.4



Ejection Testing

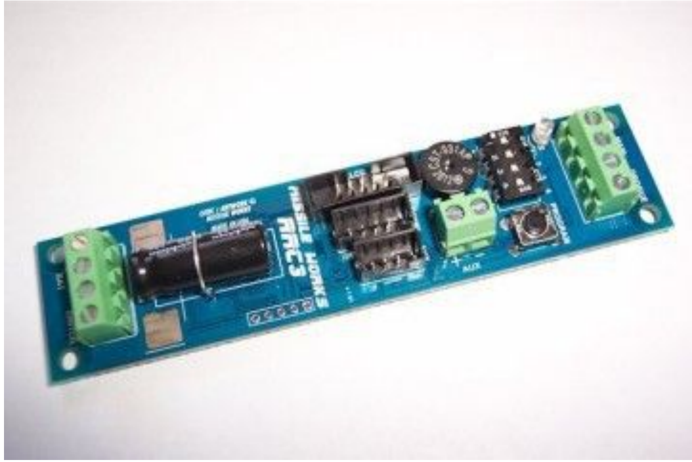
Designed and built a custom ejection test bed that can be adjusted to cater to different bay sizes.

Subscale Testing

- Main Deployment: Success with 2 g of black powder
- Drogue Deployment: Success with 2 g of black powder

Altimeters

- Missile Works RRC3 Sport Altimeters
    - User friendly
    - Easy to adjust without a computer
    - Easy to communicate with on a computer



Altimeter Testing

Fully Assembled 1:
Success

Fully Assembled 2:
Success

Without Airframe:
Success

Avionics and BEAVS 2.0 Electronics

Overview Slide

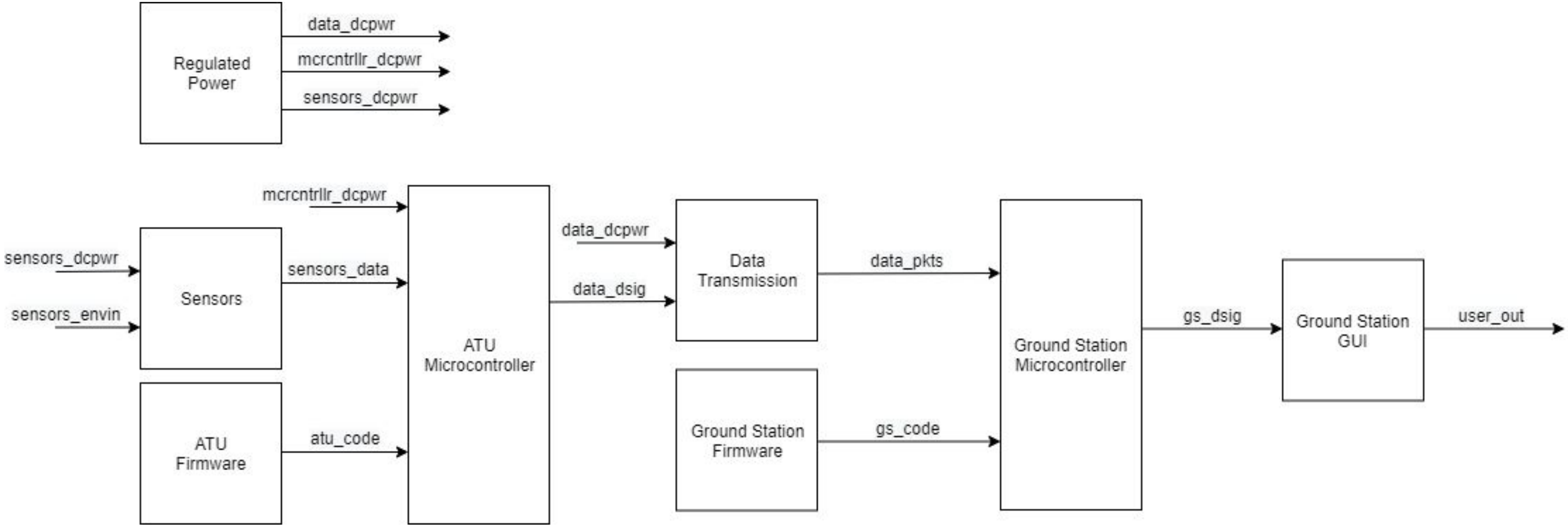
Avionics

- Give information to track the launch vehicle and provide data for analysis
  - GPS, Altitude, Acceleration

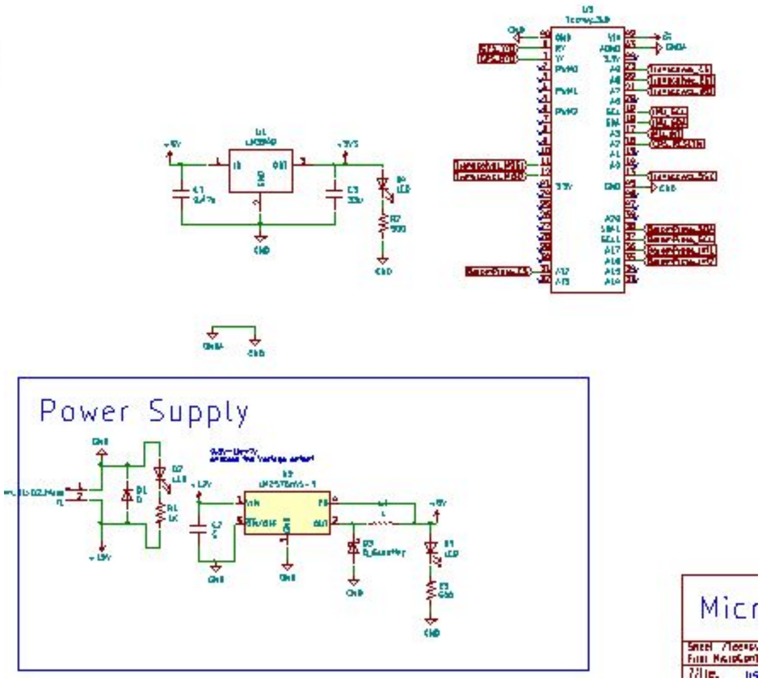
BEAVS

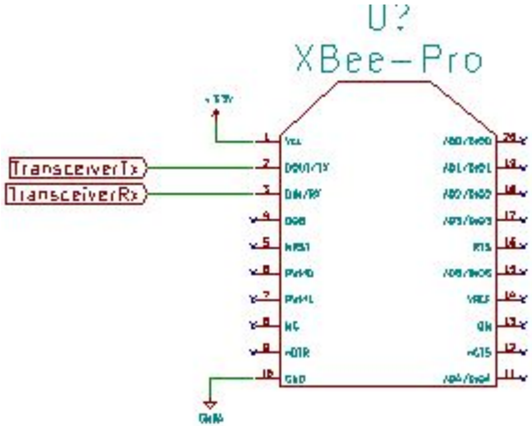
- Electronics to collect altitude and acceleration data and move fins using motors

Avionics

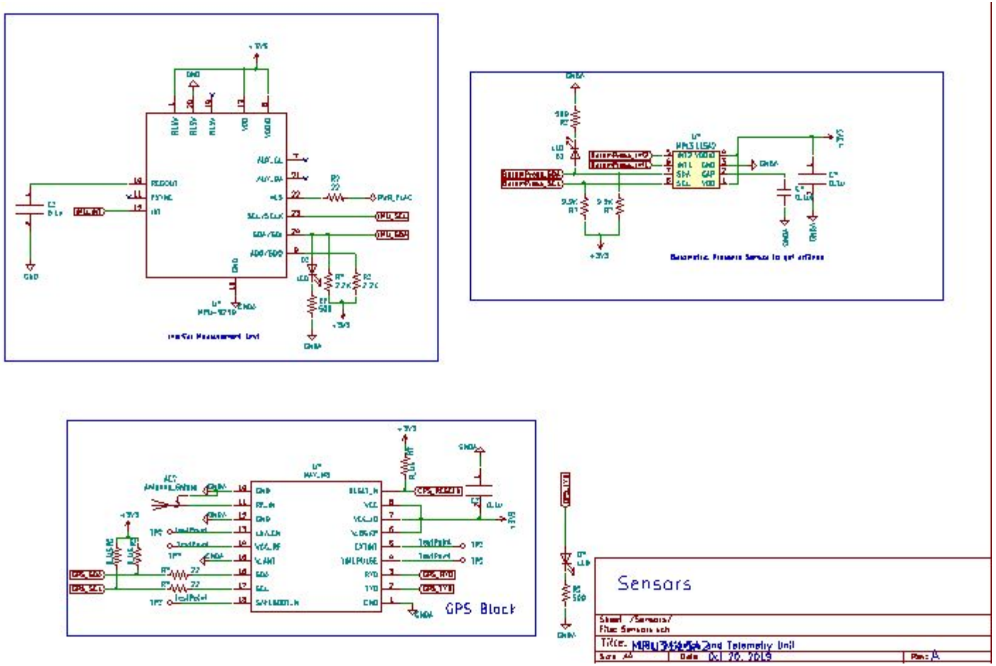

Regulated Power
data_dcpwr
mcrcntrllr_dcpwr
sensors_dcpwr
mcrcntrllr_dcpwr
sensors_dcpwr
sensors_envin
Sensors
sensors_data
ATU Firmware
atu_code
ATU Microcontroller
data_dcpwr
data_dsig
Data Transmission
data_pkts
Ground Station Firmware
gs_code
Ground Station Microcontroller
gs_dsig
Ground Station GUI
user_out

Avionics



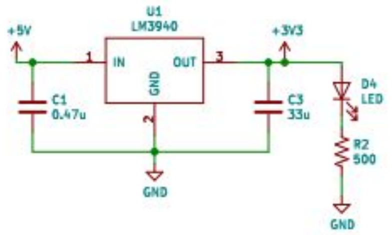


Avionics

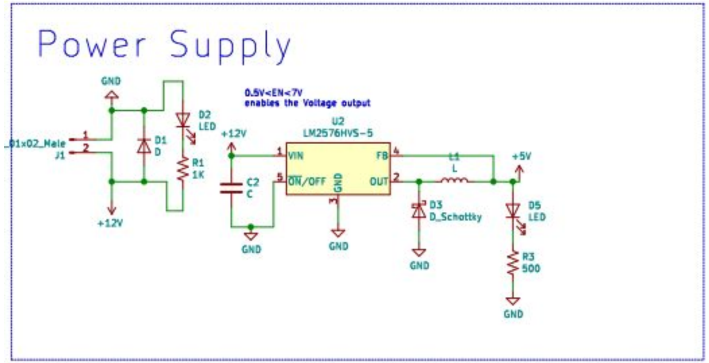


Avionics

- GPS
  - MAX-M8Q and SAM-M8Q were both tested
  - MAX-M8Q had better accuracy
  - SAM-M8Q had a lock faster
  - MAX-M8Q was chosen for accuracy

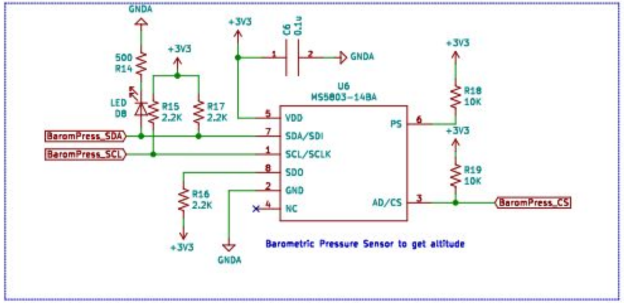


- Power Supply
  - Outputs 5 V
  - Supports necessary 400 mA

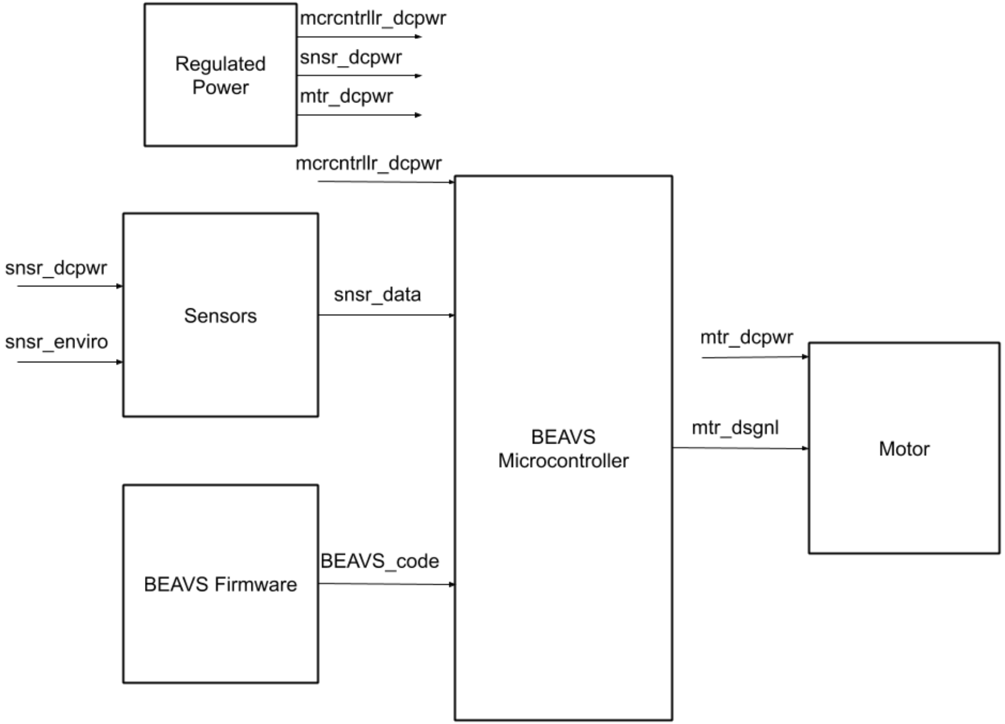


Avionics Testing

- Altitude
  - MPL3115a and MS5803 were tested
  - MPL3115a had more consistent high accuracy as compared in flight with altimeters
- Acceleration
  - ADXL377 was used for acceleration
  - Withstood launch forces



BEAVS 2.0 Electrical



BEAVS 2.0 Electrical Testing

Motor Testing

- Test with barometric pressure sensor
- Turned on as expected

Barometric Pressure

- Tested on local level with small changes
- Results matched with Avionics testing

Avionics and BEAVS 2.0 Software

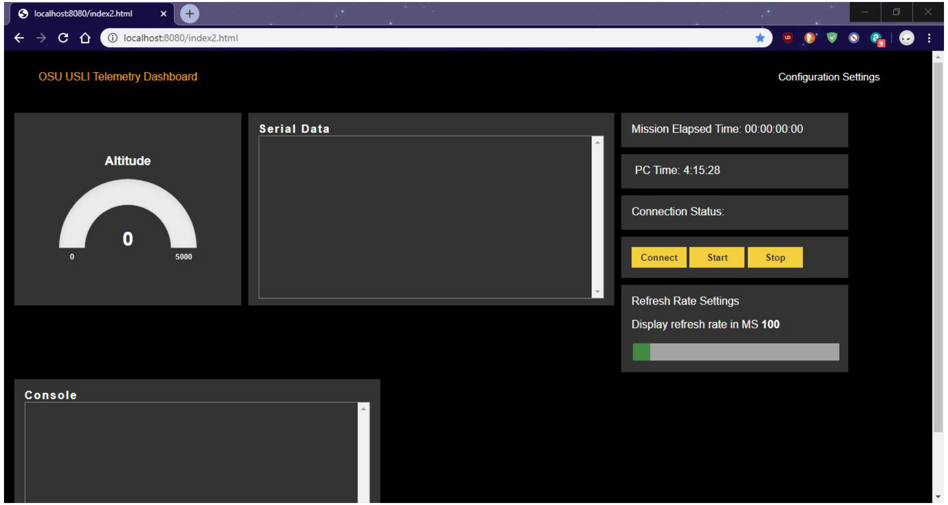
Overview Slide

- Avionics GUI
  - Contains all received information
  - Formats it in real time

- BEAVS
  - Algorithm to control motors
  - Reacts quickly

Avionics GUI

- Displays data
  - GPS and altitude
- Saves data
  - CSV file
- Configures serial settings



BEAVS 2.0

- Motor Control Activation
- Sensor Data Acquisition
- PID Control Scheme
- Kalman Filter

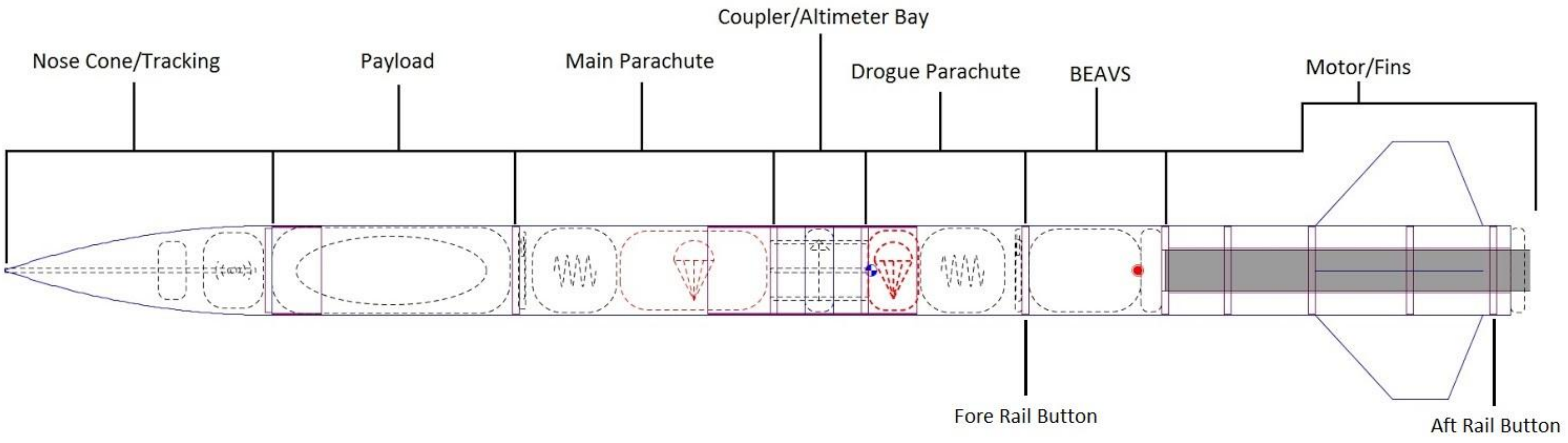
Constraints

The software is subject to several constraints throughout development:

- The software will abide to memory constraints of physical hardware
- The software must be able to handle fast operations as it will be working with real-time data
- It must handle error correction quickly

Launch Vehicle Structures and Propulsion

Launch Vehicle Layout

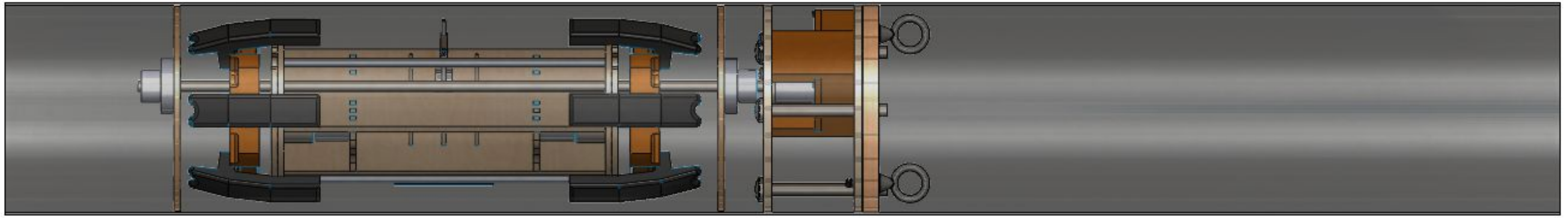


Body Tubes

- The airframe body tubes will be manufactured by Innovative Composite Engineering
- The Aft tube will be entirely carbon fiber
- The Fore section will be entirely fiberglass
- Fin slots cut in house by structures team, using custom fixtures

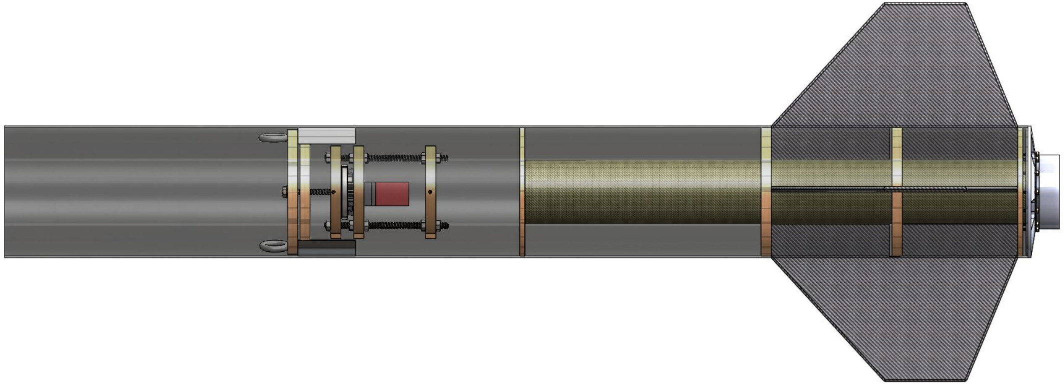
Fore Section

- Simple in over all design
- Houses payload and main parachute
- Very important to protect payload



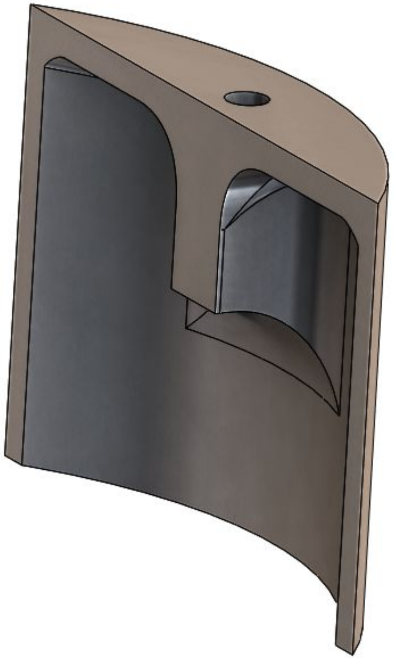
Aft Section

- Intricate construction
- Houses drogue parachute, motor bay, and BEAVS
- Thrust plate to transfer thrust forces directly to airframe
- Commercial motor retainer
- Through-wall fin construction to increase rigidity for both fins and motor mounting



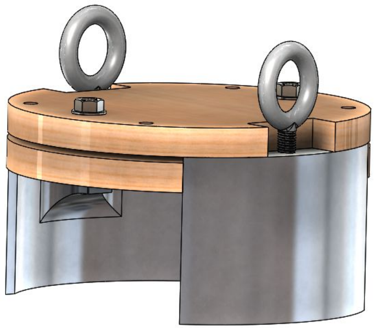
Aft Parachute Mounts

- Special consideration for the aft parachute mounts as BEAVS needs to still be accessible through the bulkhead
- Allows strong airframe-to-coupler bond
- Threaded parachute mounting points
- Two mount design simplifies manufacturing



Pressure Sealing Bulkheads

- Sealing off parachute bays for recovery deployment
- Using plywood bulkheads and rings to compress gaskets when bolts are tightened
- Located in the coupler, and the Aft section parachute bay



Nose Cone Avionics Bay

- Houses tracking for entire launch vehicle
- Has altimeter independent of recovery electronics
- Single through threaded rod for mounting
- 3D-printed mounts for electronics

Nose Cone

<u>Overview</u>

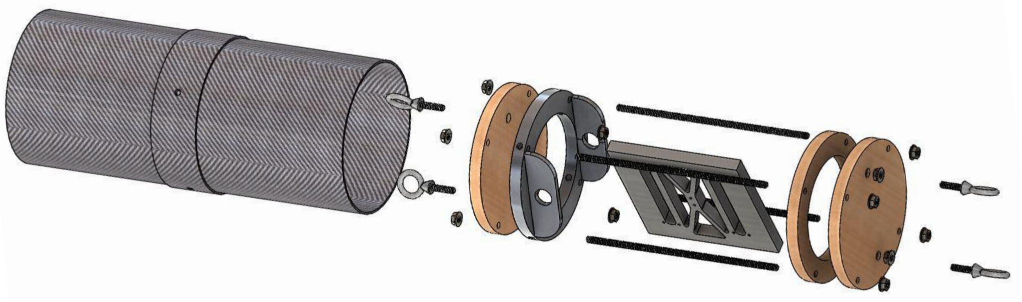
- Ogive nose cone roughly 3.5:1 ratio
- Deployed on the ground by rover deployment system
- Held in place by 4-inch coupler and shear pins
- Manufacturing and availability constraints

<u>Manufacturing</u>

- Modifying commercial 7.5 -inch nose cone
- Fiberglass construction
- Using custom fixture to modify

Coupler

- Houses deployment altimeters, mounting for parachutes and black powder ejection charges
- Removable altimeter bay
- 2-inch switch-band to enable external altimeter bay access
- Altimeter bay held in place by external fasteners
- Extends 6.5 inches into airframe

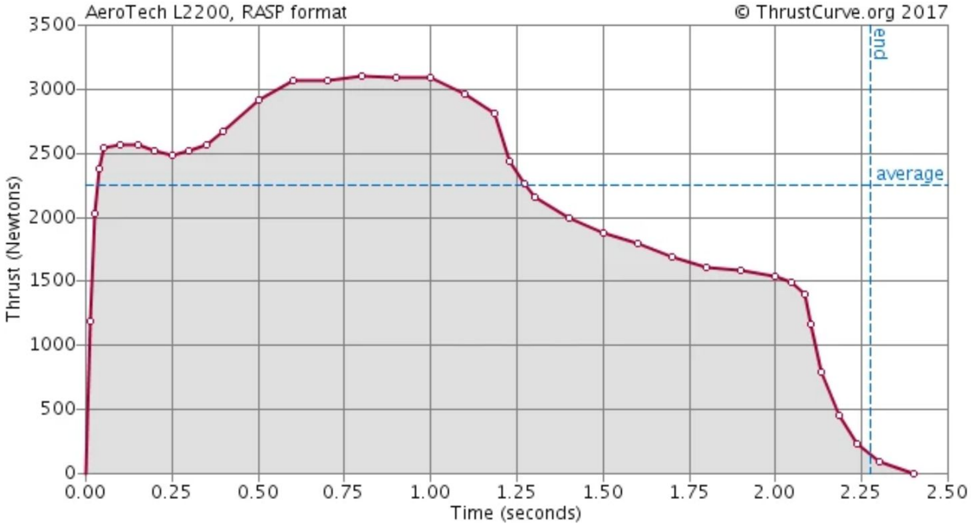


Fins

- Composite sandwich
- Core of G10 Fiberglass
- Layers of carbon fiber on either side
- Alternating orientations of 0, 45, and 90 degrees

Final Motor Choice

- Motor selection as of CDR - AeroTech L2200G
- Estimated apogee: 4427 ft
- Burn Time: 2.32 seconds
- Average Thrust: 494.6 lb-s
- Total Impulse: 1147 lb-s
- Diameter: 2.95 in.
- Thrust to weight: 11.4:1
- Rail exit velocity: 81.8 ft/s



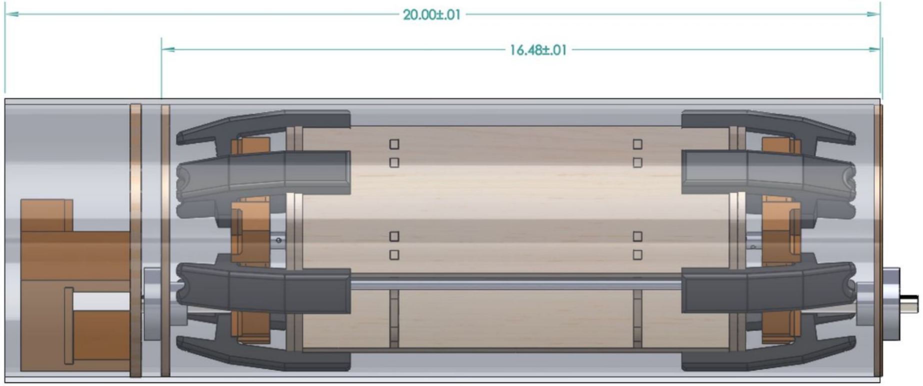
Structural/Pressure Testing

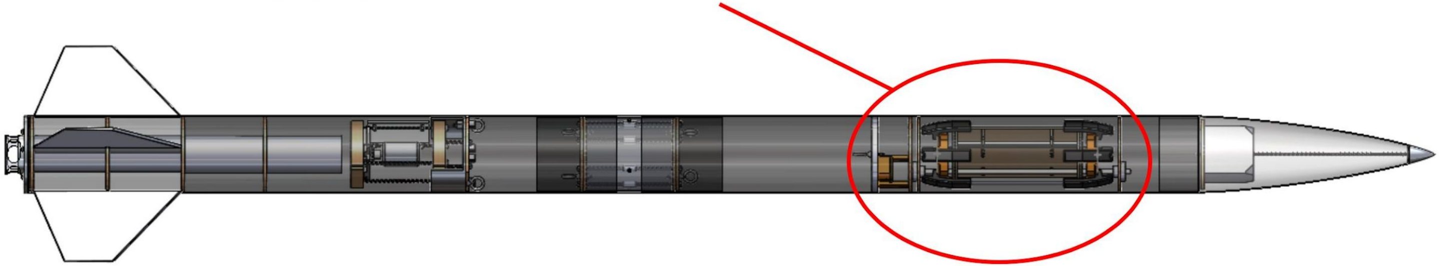
- Testing will be conducted on all pressure sealing bulkheads
  - Ensure sealing capabilities for deployment
  - Not Complete - Waiting on airframe materials

- Testing of altimeter bay strength
  - Ensure connection between Fore and Aft
  - Verify stress analysis
  - Not Complete - Waiting on airframe materials

Payload

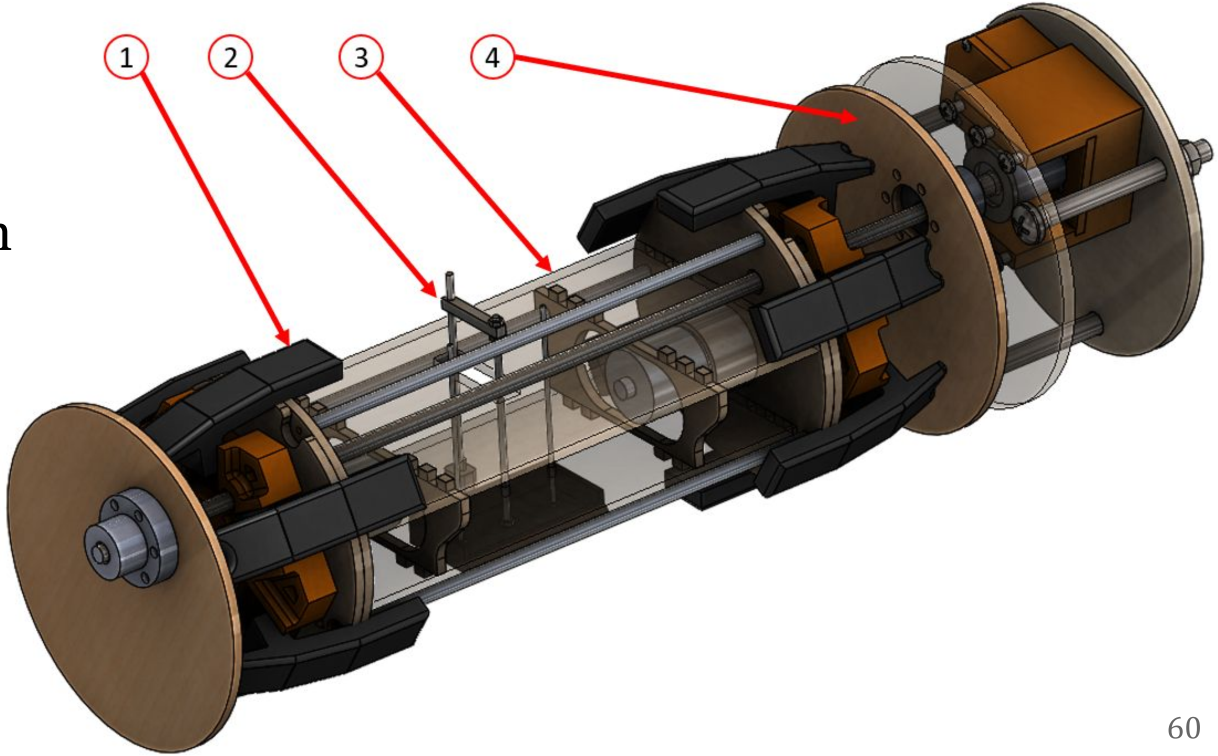
Overview Slide





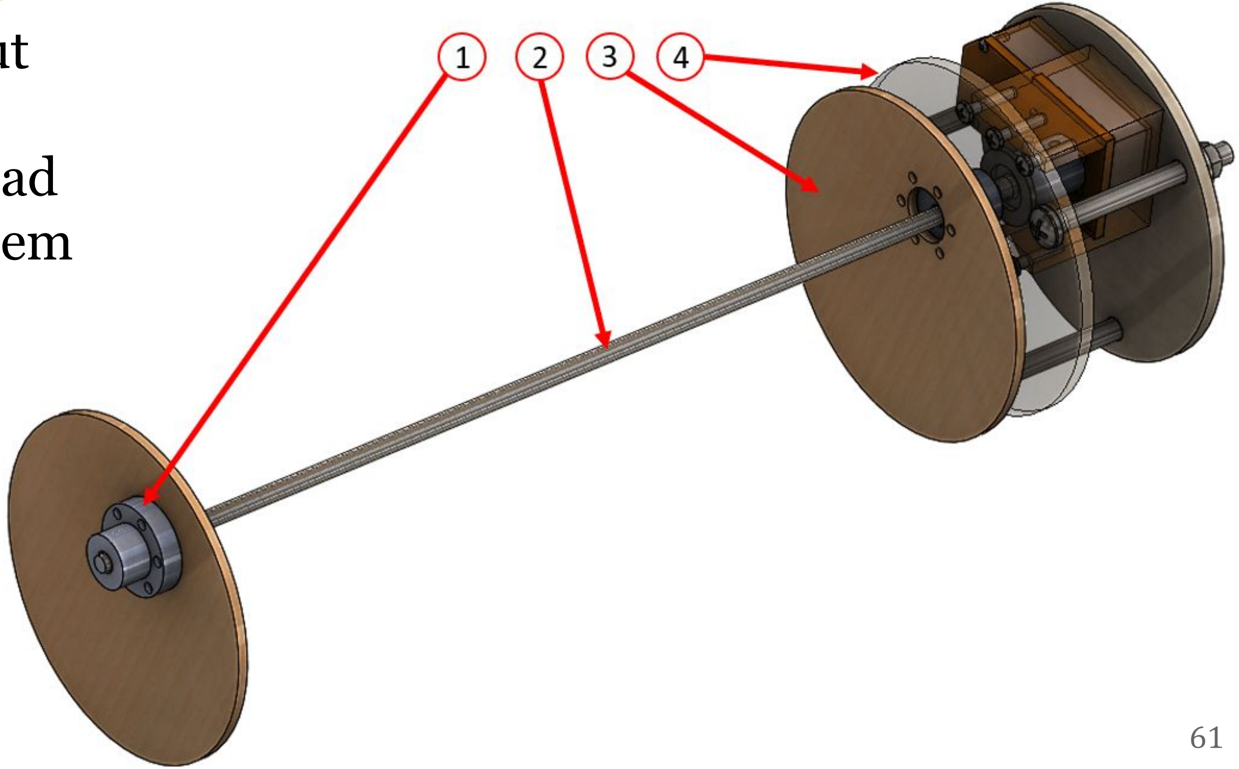
Final Payload Design

1. Drivetrain
2. Collection
3. Structure
4. Ejection System



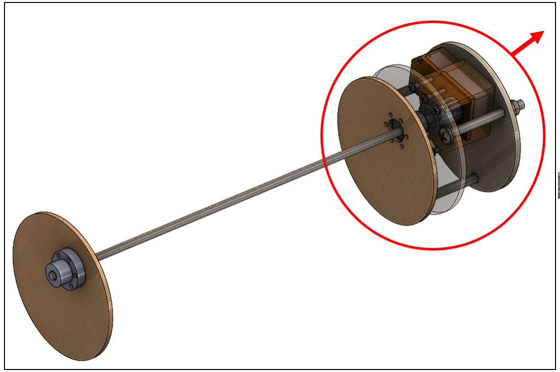
Ejection System

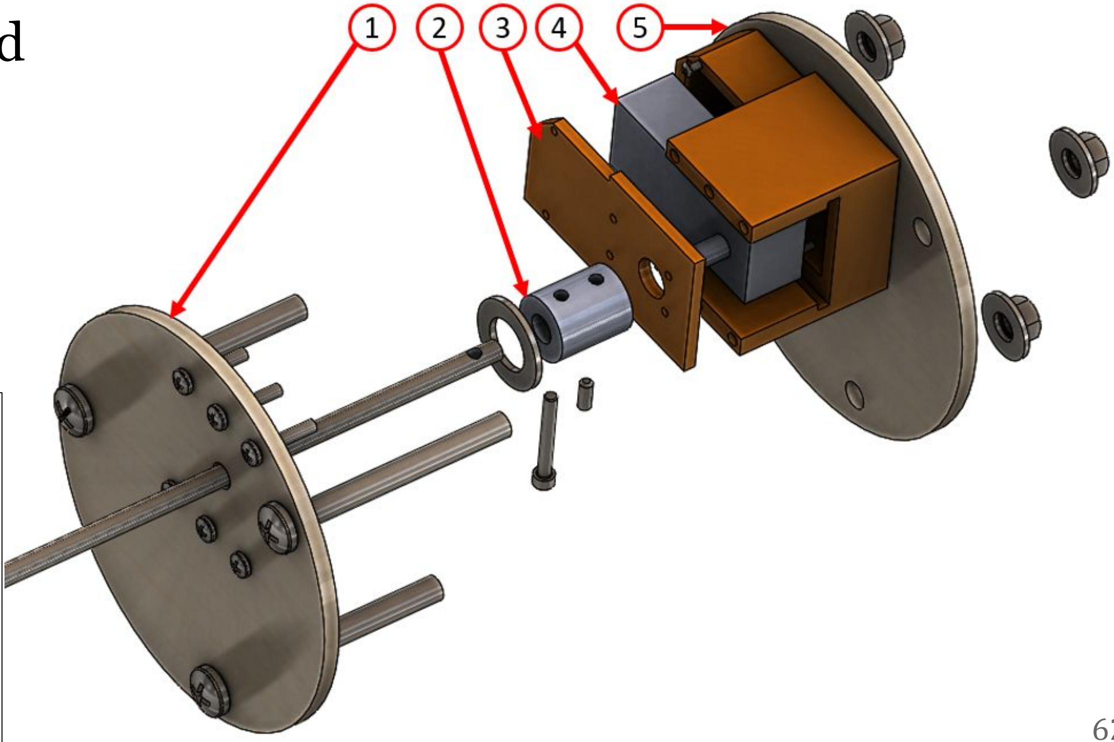
1. Lead Screw Nut
2. Lead Screw
3. Mobile Bulkhead
4. Retention System



Retention System

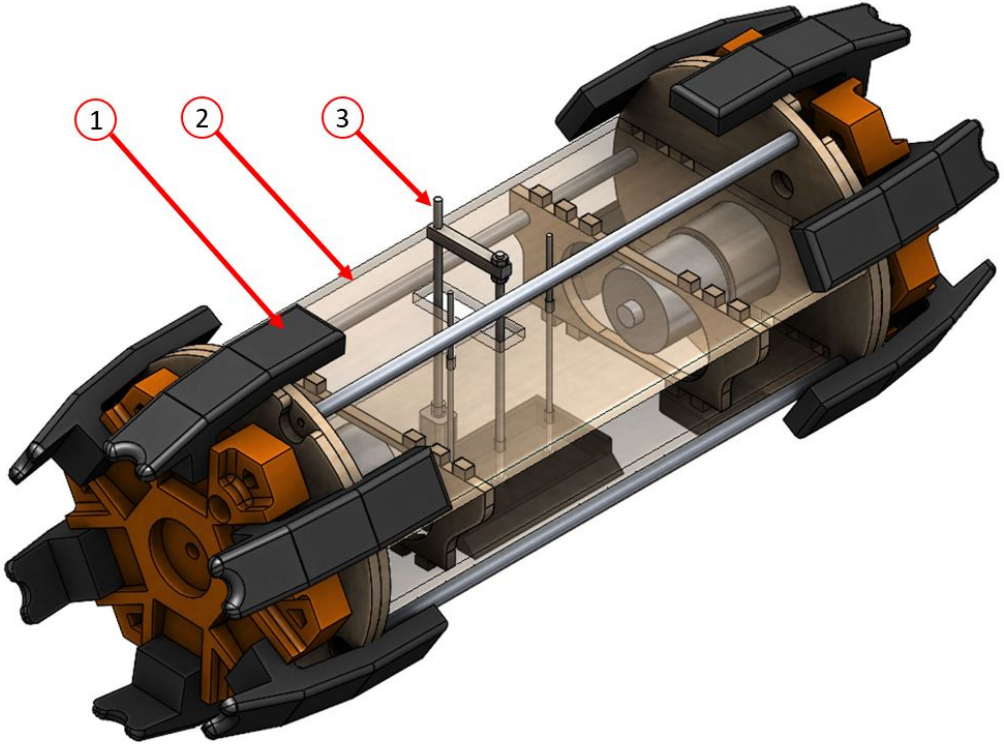
1. Retaining Bulkhead
2. Coupler
3. Motor Retainer
4. Worm Gear Motor
5. Bulkhead (Fore Section)





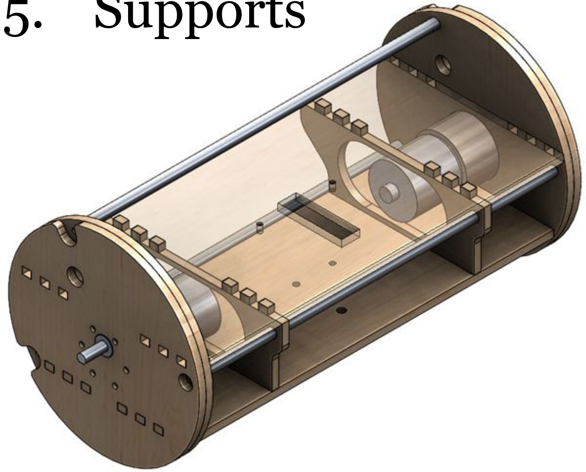
Rover Design

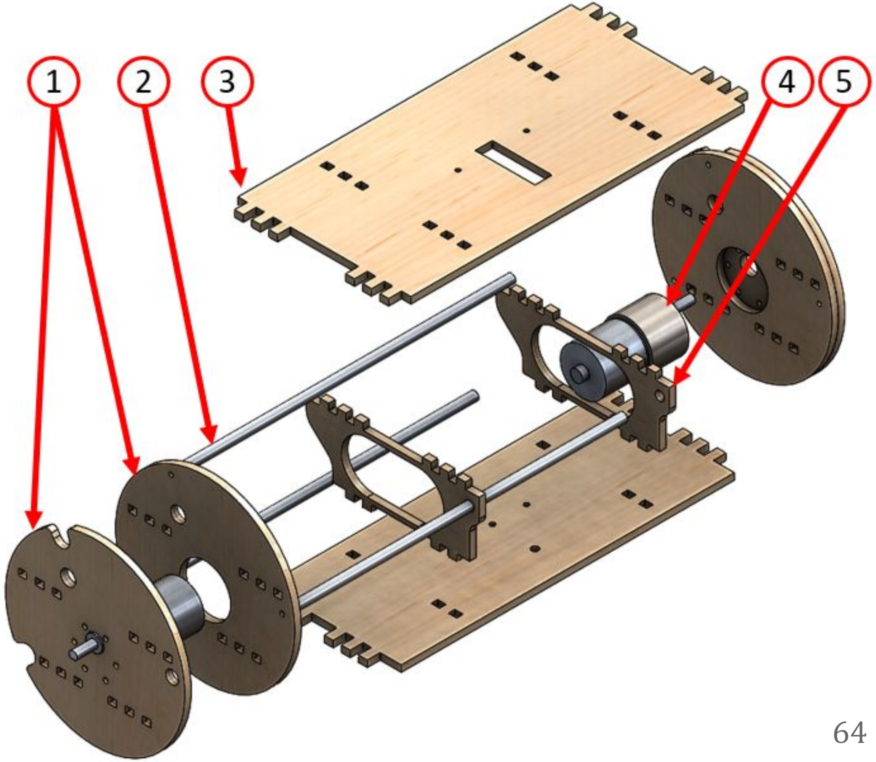
1. Drivetrain
2. Chassis
3. Collection



Chassis Design

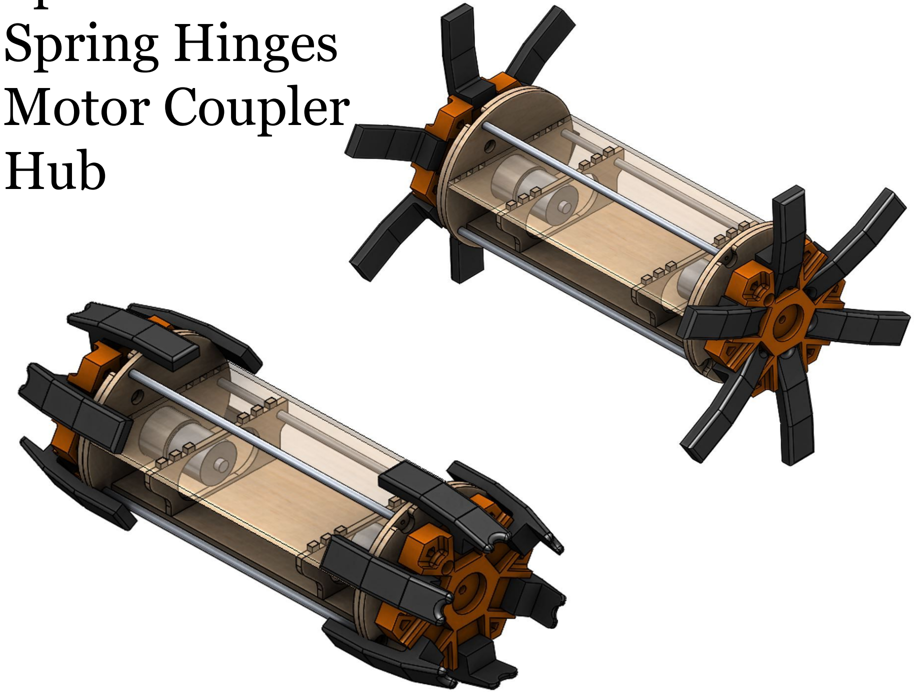
1. Retaining Disks
2. Aluminum Supports
3. Mounting Surface
4. Motor
5. Supports

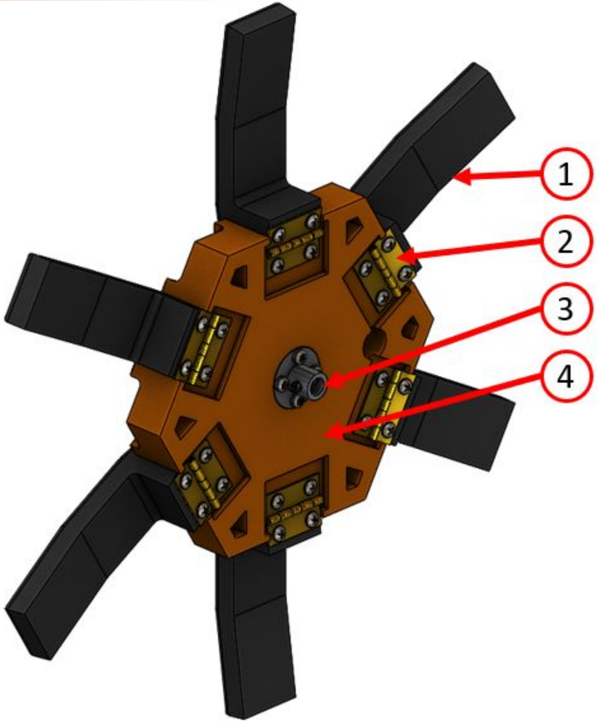




Drivetrain

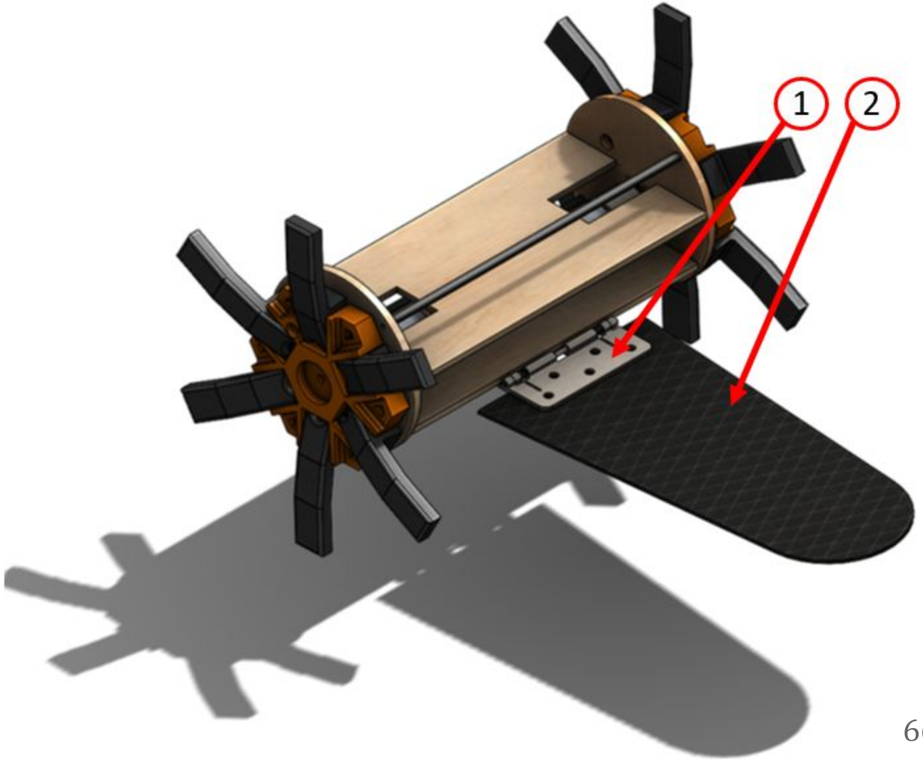
1. Spokes
2. Spring Hinges
3. Motor Coupler
4. Hub





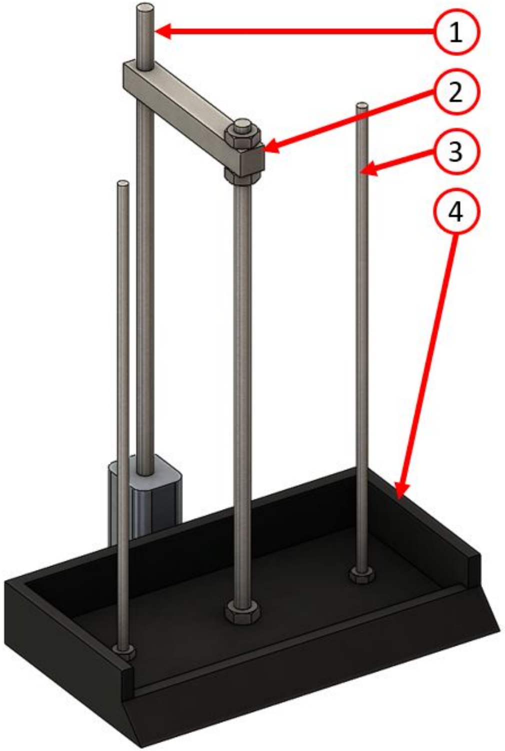
Rover Stabilizing Tail

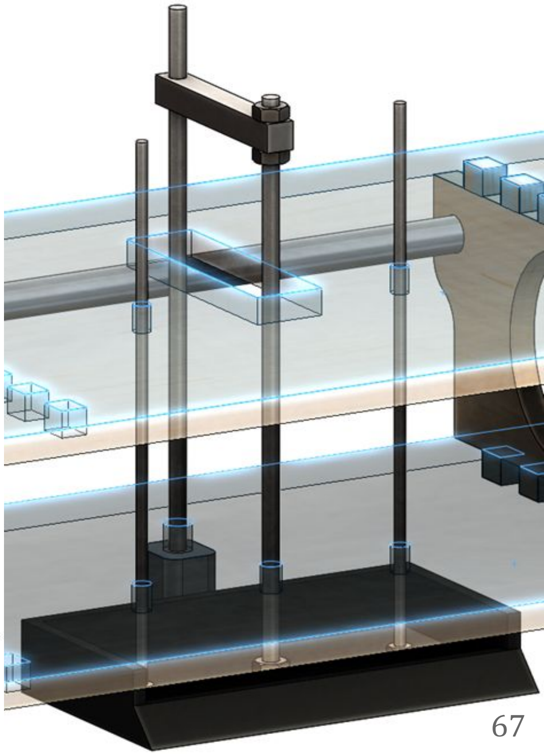
1. Spring Hinge
2. Carbon Fiber Tail



Collection System

1. 6V Lead Screw Motor
2. Lead Screw Bracket
3. Sliding Rod
4. Scoop





Testing Plans

Test/System	Number/Type	Status	Results
Payload Testing	CES Chassis Material Analysis	Complete	Successful
	Chassis FEA	Complete	Successful
	Chassis Prototyping	Complete	Successful
	Wheel Prototyping	Complete	Successful
	Collection Prototype Testing	Complete	Successful
	Drop Testing	In Progress	N/A
	Drive Testing	In Progress	N/A
	Battery Life Testing	In Progress	N/A
	Ejection System Testing	In Progress	N/A
	Retention Strength Testing	In Progress	N/A
	Retention Robustness Testing	In Progress	N/A

Payload Electronics

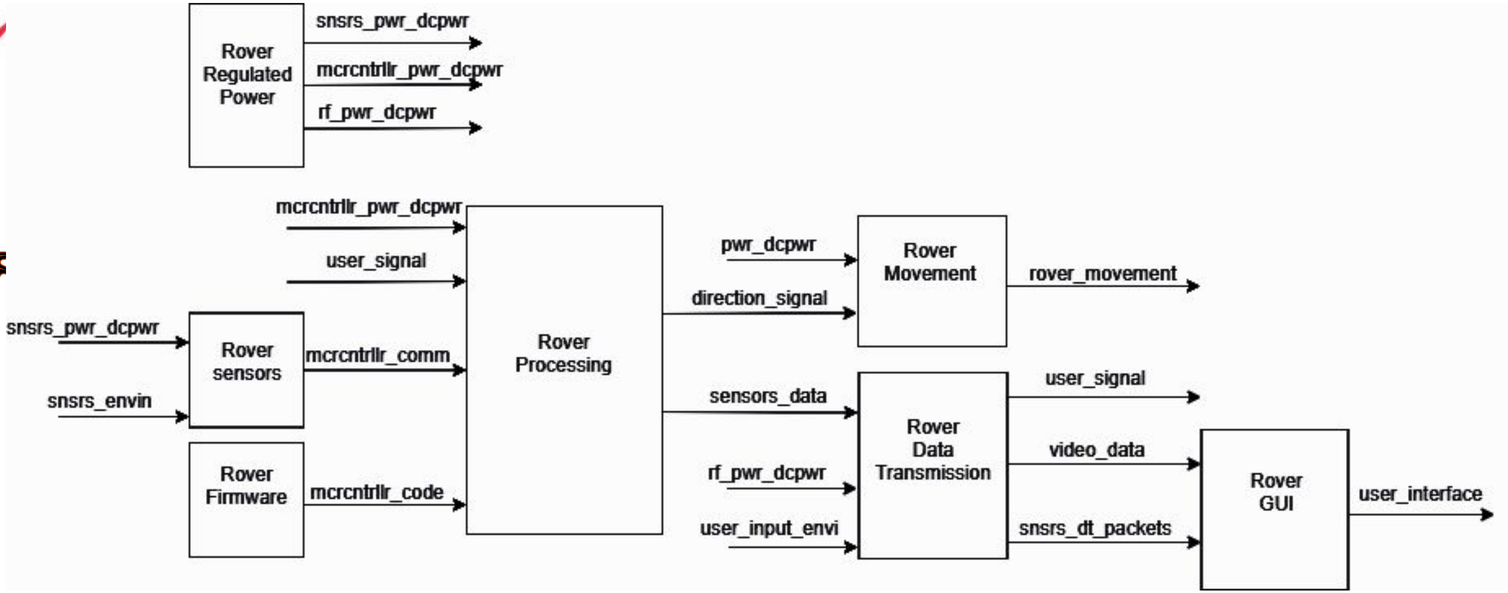
Overview Slide

Controls Testing

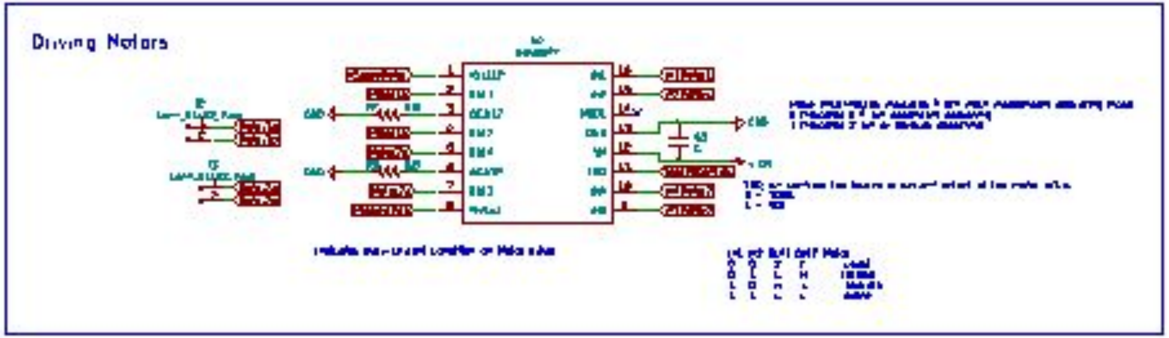
- Test bed was constructed for motors
- Successful activation of motors

GPS testing as mentioned in Avionics

Top Level Diagram



Movement



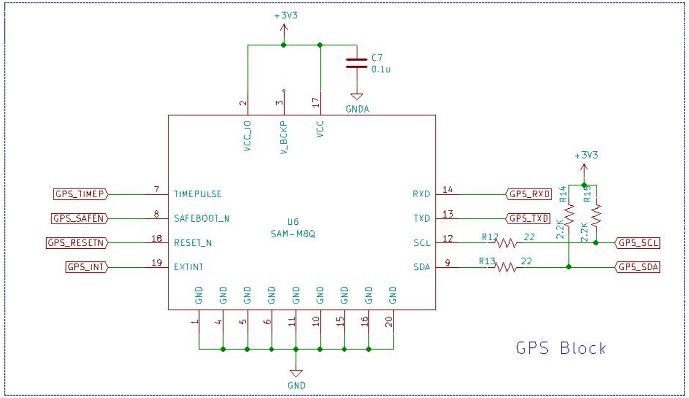
Remote Control

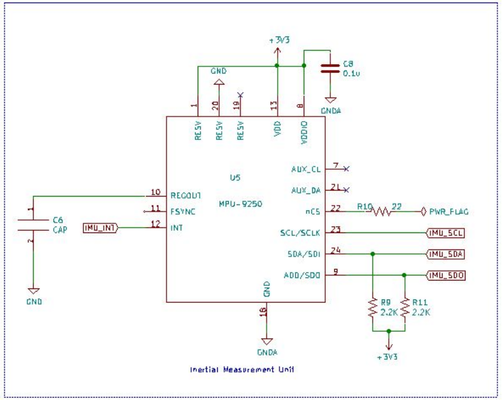
- Controls the movement of rover
- Controlled by a team member

Movement

- 2 motors
- Controlled from a dual H-bridge

Navigation





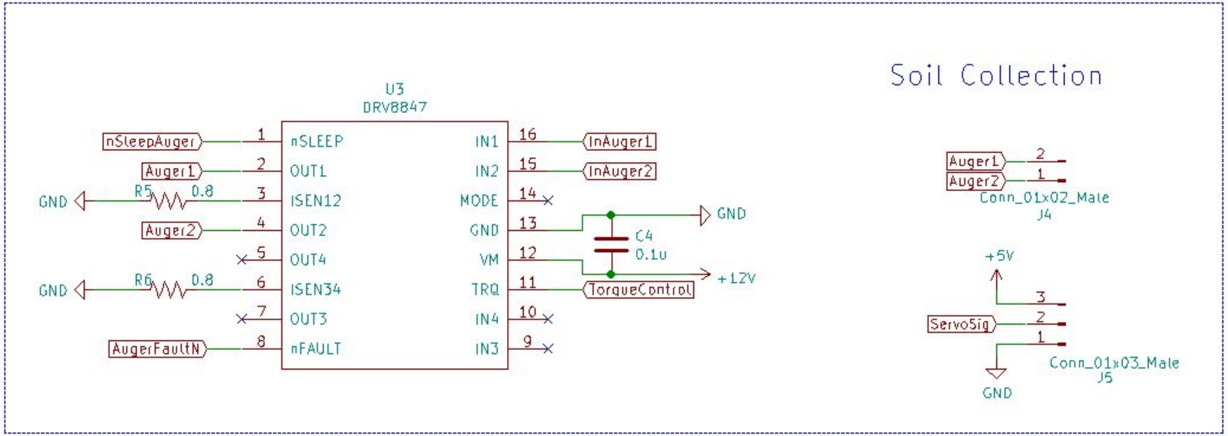
GPS

- Provide information to driver
- Help locate rover

Accelerometer

- Provide information to driver

Ice Collection Components



- 6V motor
- Triggered by a remote
- Single H-bridge

Payload Software

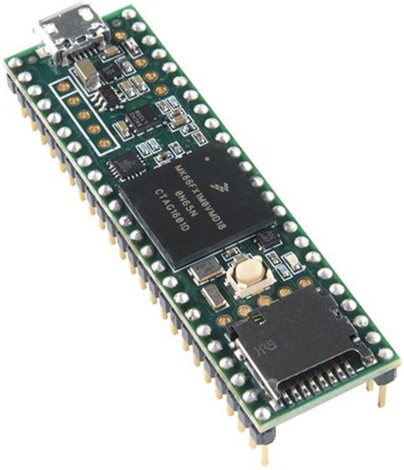
Overview Slide

Payload GUI is written in C#. The GUI will display GPS and position data that it receives via serial port, along with the coordinates of collections sites. The GUI also displays a video stream from the rover.

Payload Control System is written in Arduino programming language using Firmata and Processing to allow the Xbox One controller to remotely control the movements of the rover.

Payload Teensy 3.6

- Will be written in C
- Controls motors based on user input
- Collects data from sensors
- Quick response from stimuli



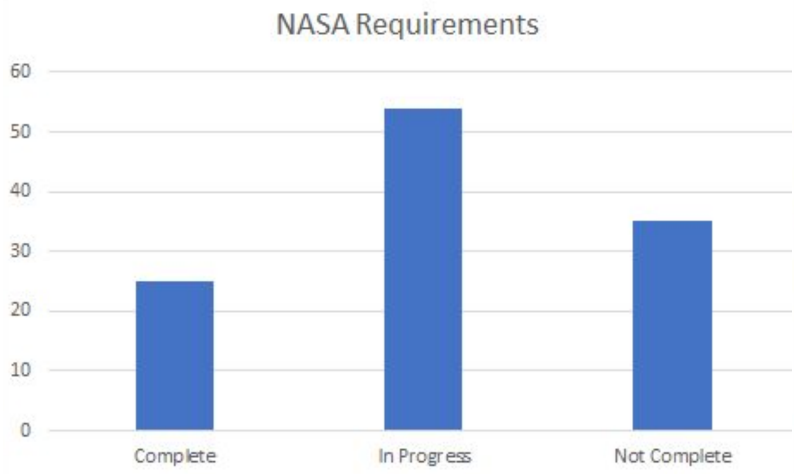
Constraints

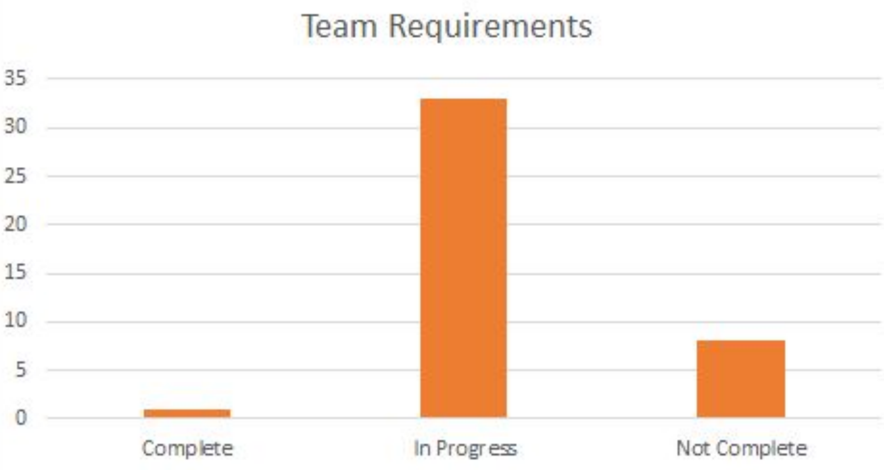
The software is subject to several constraints throughout development:

- The software will abide to memory constraints of physical hardware
- The software must be able to handle fast operations as it will be working with real-time data
- It must handle error correction quickly
- It must relay data over a network

Testing and Requirement Verification

Requirement Verifications





STEM Engagement

Overview Slide

- OSRT has had multiple displays about the team since PDR
- There have also been multiple events where the team has completed an entire lesson plan.
  - Baking soda and vinegar rockets with Franklin K-8 School
  - Direct current motors with Saint Thomas More Catholic School
  - Building paper bridges with Lake Oswego Junior High

Event Picture

Completed Events

- 2 football tables
- 1 basketball table
- Franklin K-8 School
- Saint Thomas More Catholic School
- Presentation at Monte Vista High School in California
- Lake Oswego Junior High
- Evergreen Air & Space Museum
- Crescent Valley High School
- Students reached: 1,560

Safety

Overview Slide

“The danger which is least expected soonest comes to us."

– Voltaire

- Equipment
- People take responsibility
- Prevention is the best strategy

Equipment

- Go-Bag
  - Contains gloves, face shields, and other protective gear
  - First aid kit with an emphasis on burns
  - Equipment to disarm black powder
- New equipment so everyone can be protected
  - Face shields
  - Gloves
  - Burn bucket

People are Responsible

- Designated Safety Officer
  - Wears orange vest
  - Must be entirely focused on safety
  - Has “Go-Bag”
- Everyone should be on watch
  - Checklists include safety watch items

Prevention

- Checklists
  - Assembly order is optimized so dangerous materials are less likely to impact launch vehicle and operators
  - Motor and ignition system is installed last
- Attendance to integration
  - If an individual does not attend they cannot assemble the rocket
  - Ensures all individuals are familiar with proper safety procedures

Questions?