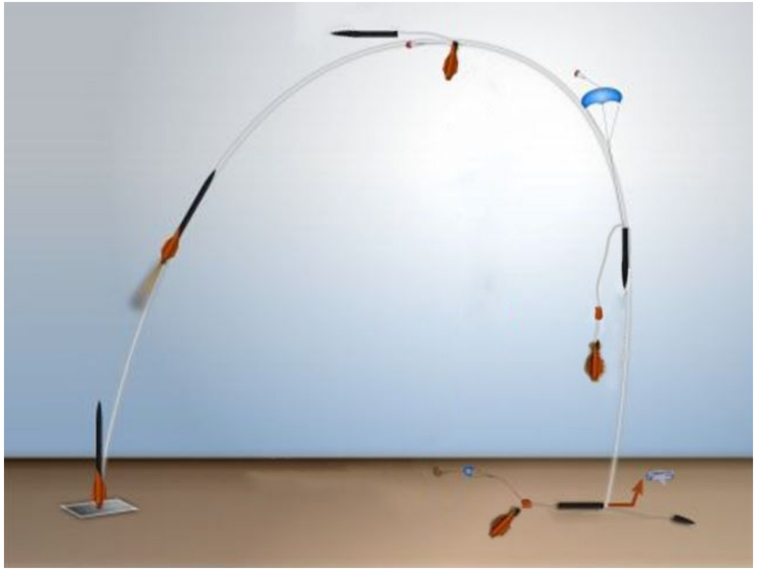
Oregon State University

Flight Readiness Review

03/10/2020

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: 119 in.

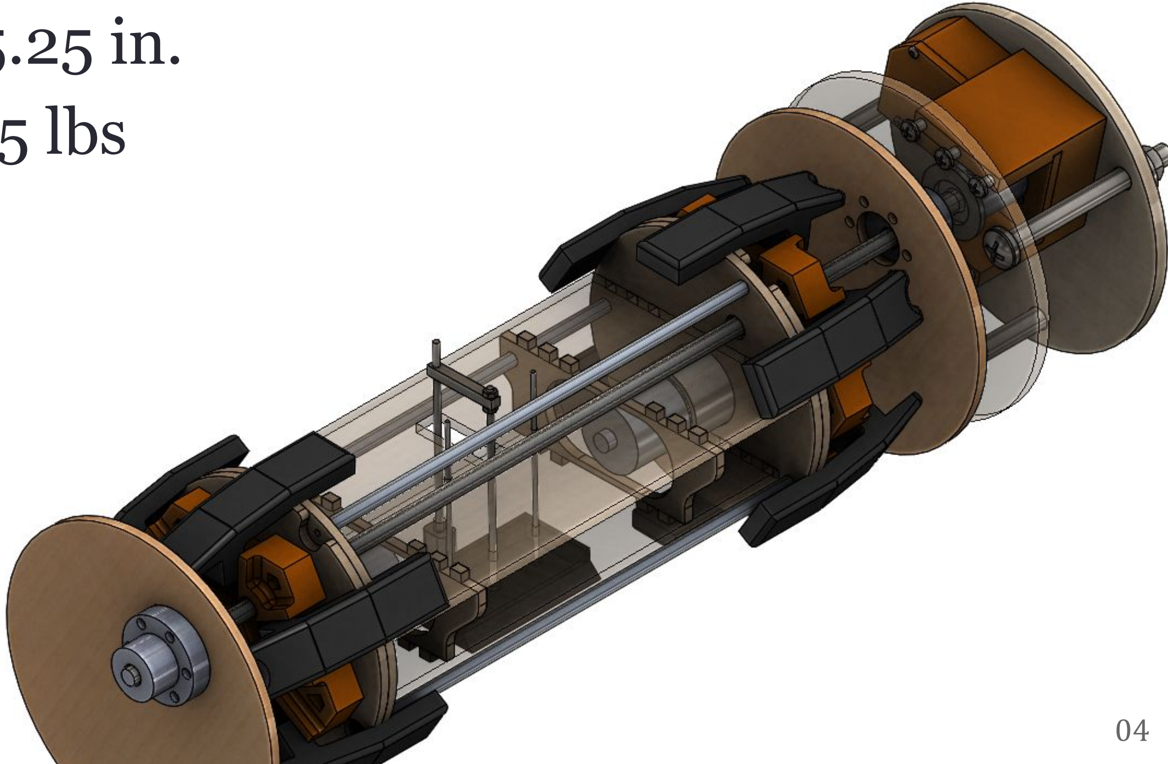
Weight: 60.9 lbf

Inner Diameter: 6.25 in.

Rail: 1515

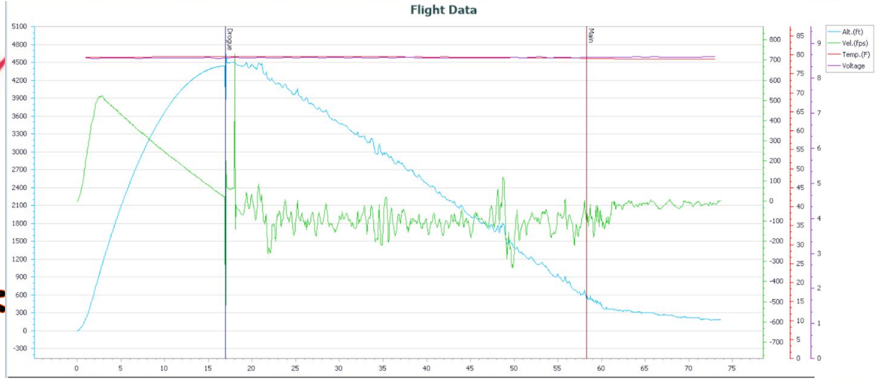
Payload Overview

- Total Length: 25.25 in.
- Total Weight: 6.5 lbs



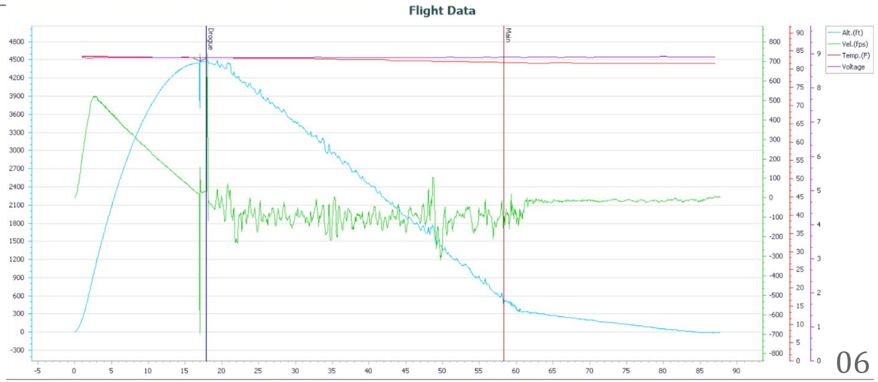
Launch Vehicle and Payload Demonstration

RRC3 Graphs



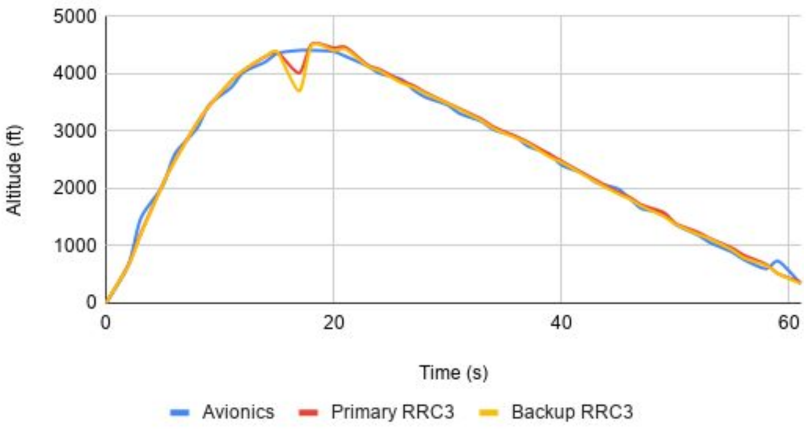
Primary RRC3 Data

Backup RRC3 Data

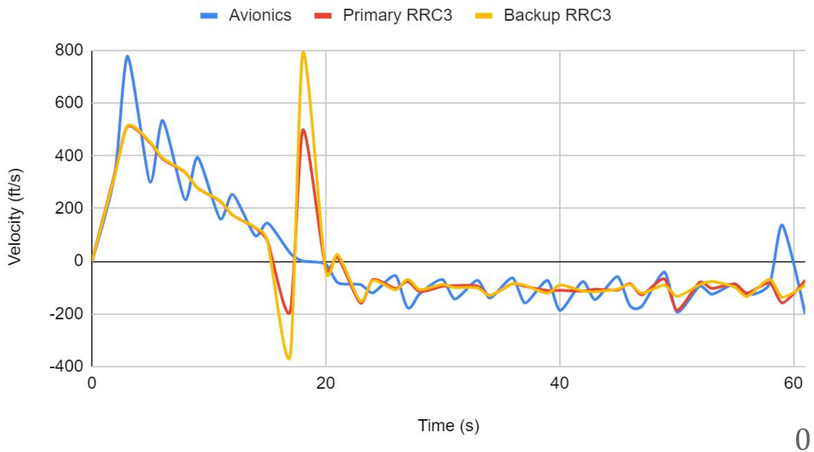


RRC3 and Avionics Graphs

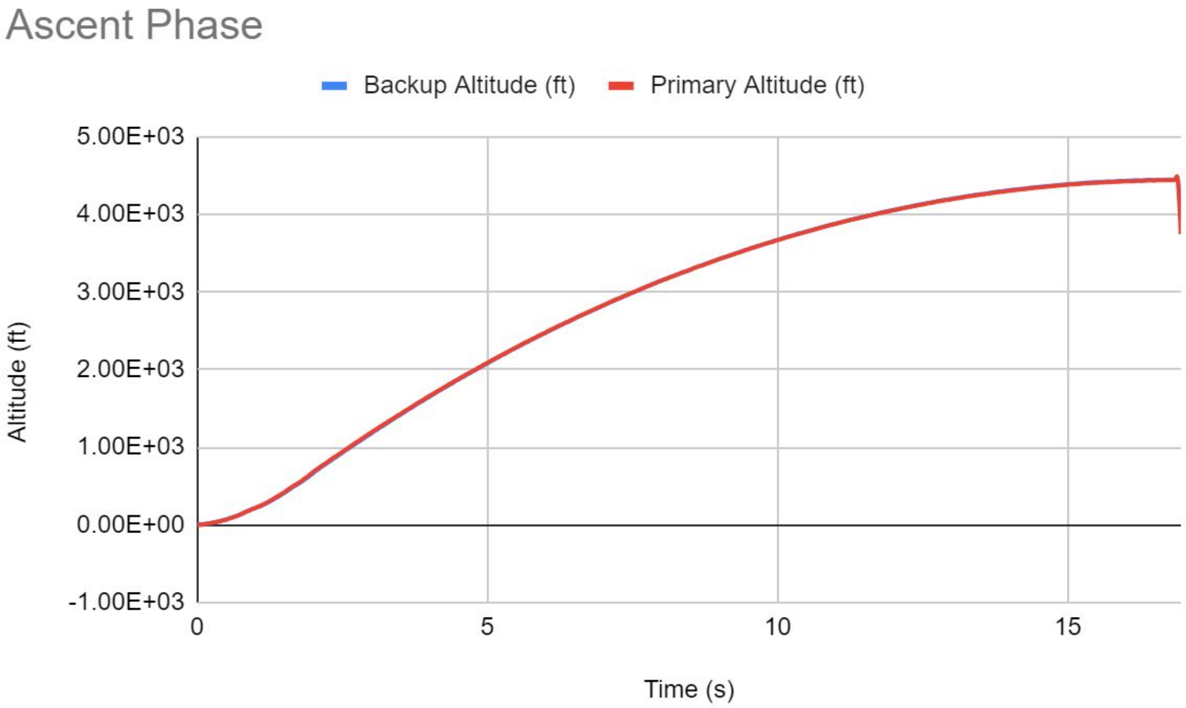
Avionics and RRC3 Altitude Comparison



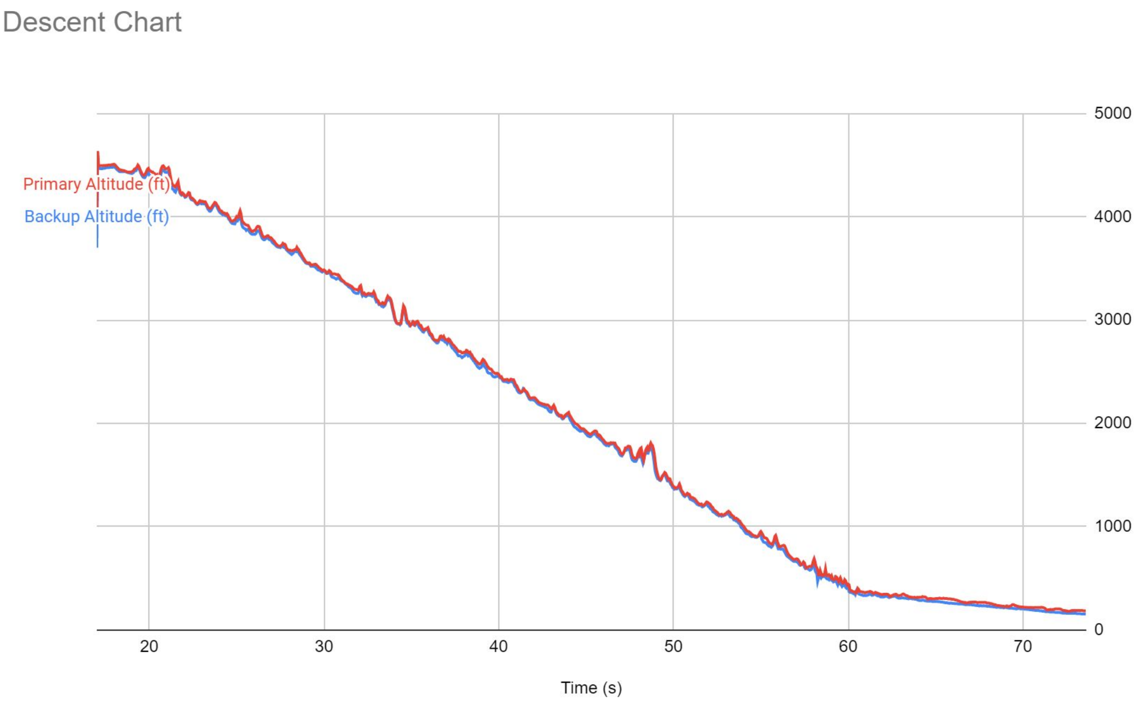
Avionics and RRC3 Velocity Comparison



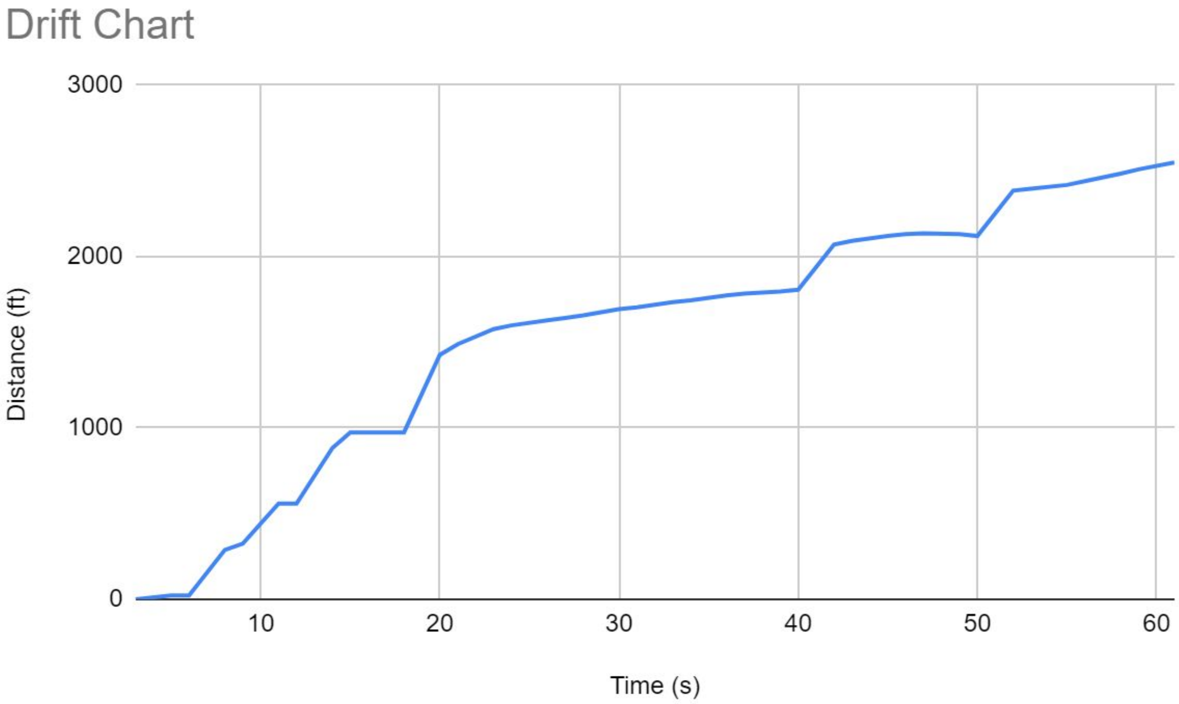
Ascent Graph



Descent Graph



Drift



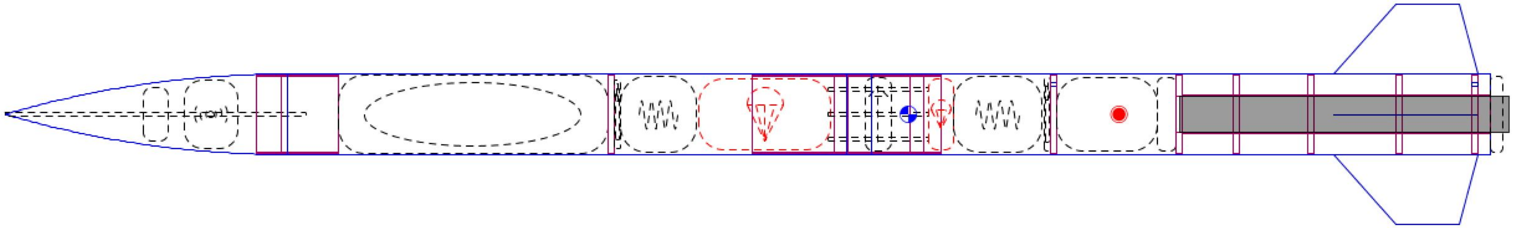
Drift Chart
3000
2000
1000
0
Distance (ft)
10
20
30
40
50
60
Time (s)

Aerodynamics and Recovery

Overview

- BEAVS 2.0
- Parachutes
- Recovery Hardware
- Deployment Energetics
- Testing

Stability Margin



With Motor

C_P = 88.65 in

C_G = 71.89 in

Stability: 2.62 calibers

After Motor Burnout

C_P = 88.65 in

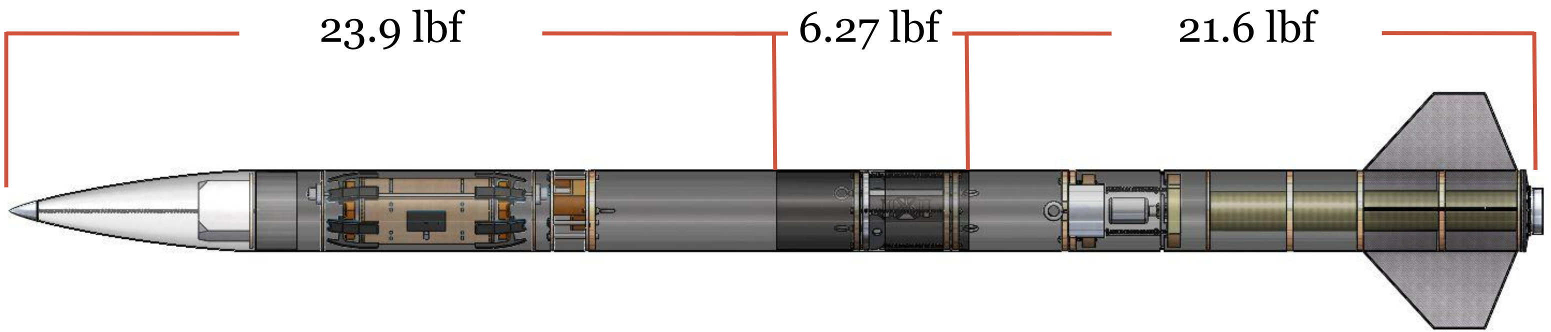
C_G = 68.414 in

Stability: 3.19 calibers

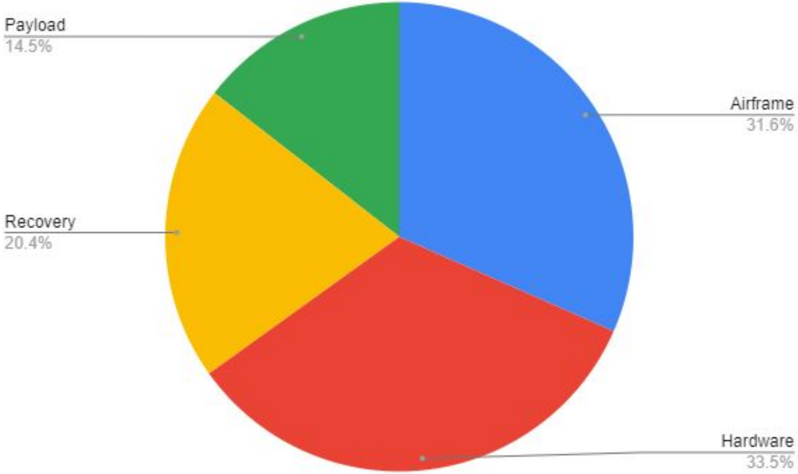
Predicted Altitude in Huntsville

Wind Speeds (mph)	OpenRocket Projected Altitude (ft)	Projected altitude with Ballast	Projected Altitude with Airbrakes
0	4658	4066 - 5.68 lb	4000
5	4650	4066 - 5.63 lb	4000
10	4637	4066 - 5.48 lb	4000
15	4603	4066 - 5.29 lb	4000
20	4570	4066 - 5.06 lb	4000

Mass Distribution



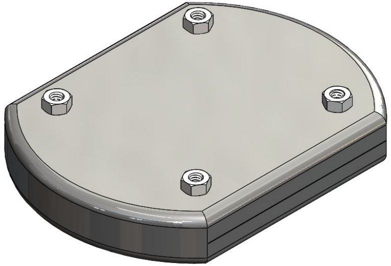
Mass Distribution



Blade Extending Apogee Variance System (BEAVS) 2.0

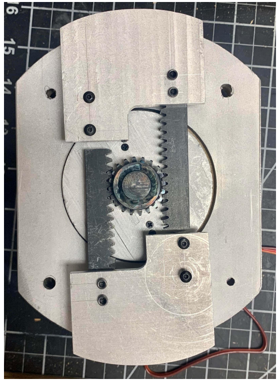
Passive System:

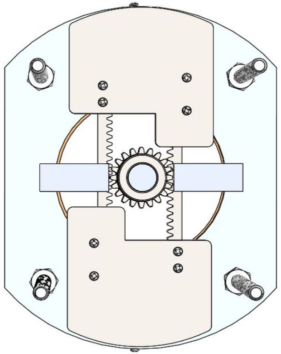
- Coupled ballast bays



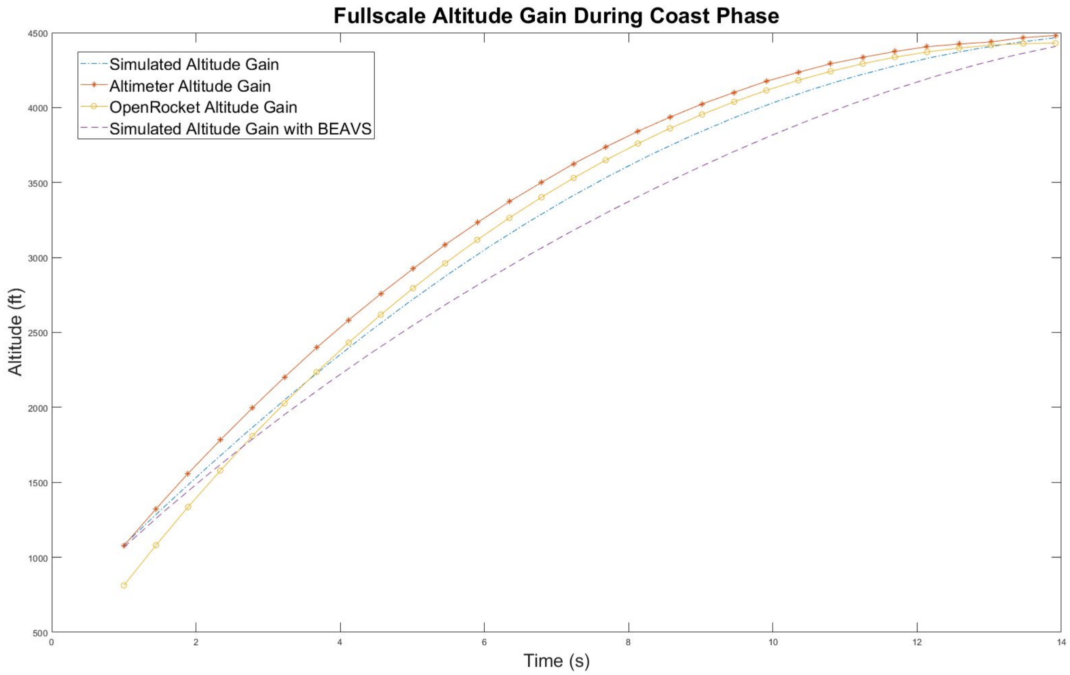
Active System:

- Driven by servo and sensors
- Decreases apogee altitude by 66 ft





BEAVS 2.0 Altitude Adjustment



Apogee Altitudes from Full scale 1:

Altimeter - 4456 ft

OpenRocket - 4430 ft

Simulated w/o BEAVS - 4466 ft

Simulated w/ BEAVS - 4400 ft

Parachutes

Main

- 12 ft Toroidal Parachute
- $C_d = 2.2$

Drogue

- 36 in. X-Form Parachute
- $C_d = 0.7$

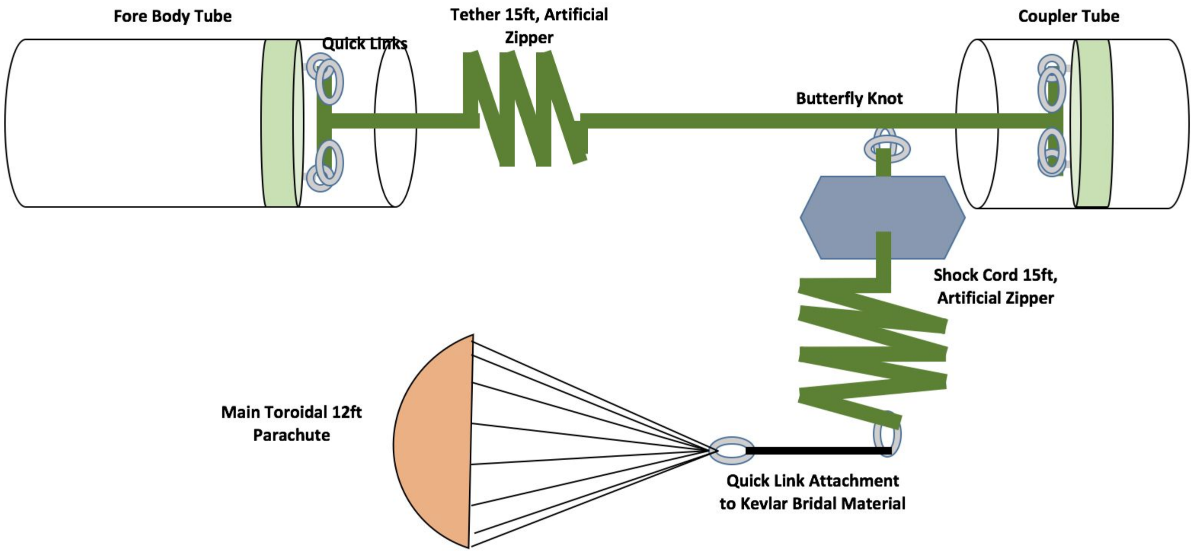
* Both purchased from Fruity Chutes

Shock Cord

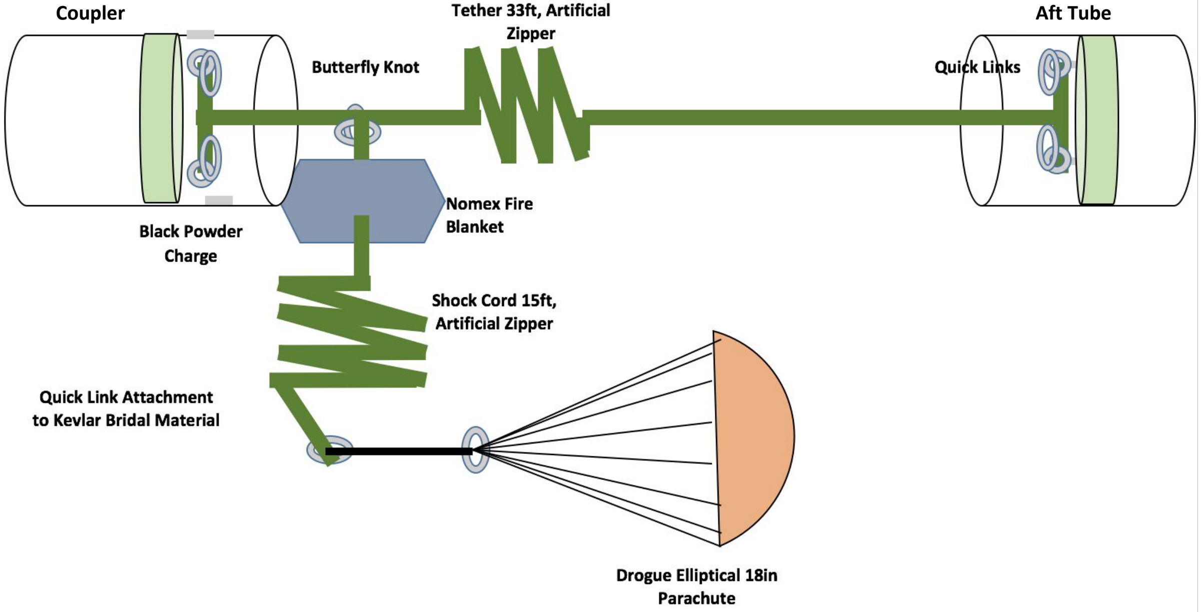
Fruity Chutes

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

Recovery Harness Main



Recovery Harness Drogue



Kinetic Energy Analysis

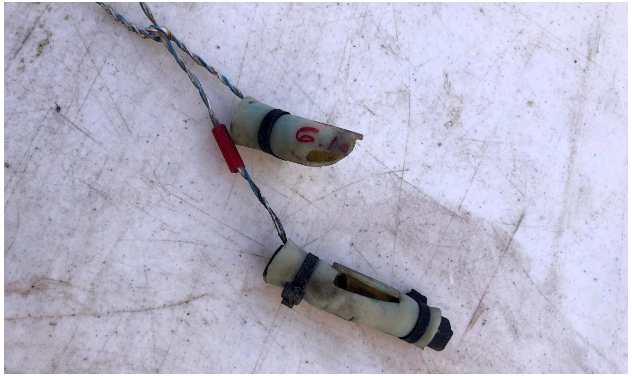
Measurement	Fore section	Coupler	Aft section
Weight (lbf)	24.05	6.4	24.7
Landing Velocity (ft/s)	14.1	14.1	14.1
Landing Kinetic Energy (ft-lbf)	73.19	19.47	74.9

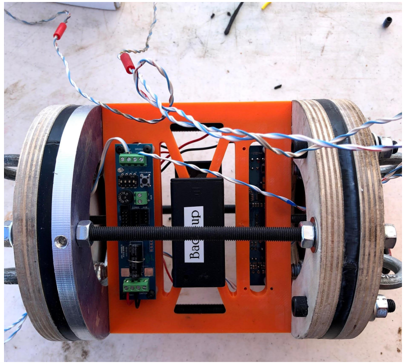
Descent Times and Drift

Wind Speed (mph)	0	5	10	15	20	Descent Times (s)
Matlab Drift (ft)	0	459	1100	1682	2103	**82**
OpenRocket Drift (ft)	12.4	125	565	990	1467	**76.6**

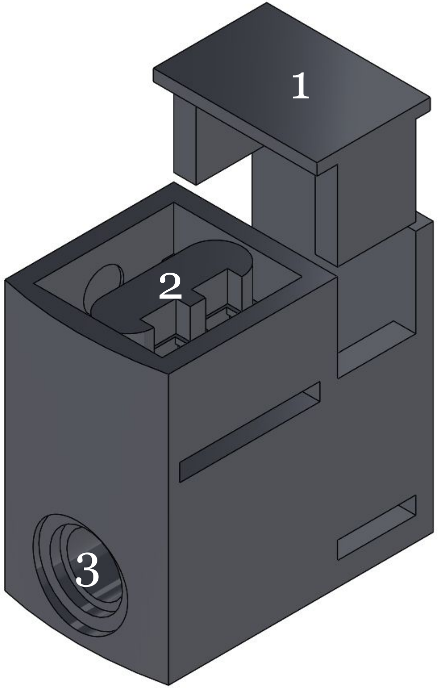
Ejection Charges

Drogue: Primary	2.4 g
Drogue: Back up	3.0 g
Main: Primary	5.3 g
Main: Back up	6.7 g





Energetic Mid-flight Black powder Ejection Reserve System (EMBERS)



Designed to enhance the safety of the parachute ejection system

3 sections:

1. Battery Chamber/Cap
2. Sliding Chamber/Slider
3. Switch Housing

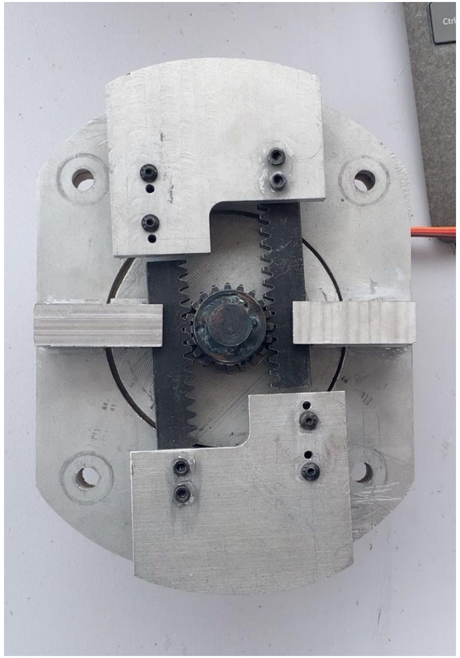
Testing

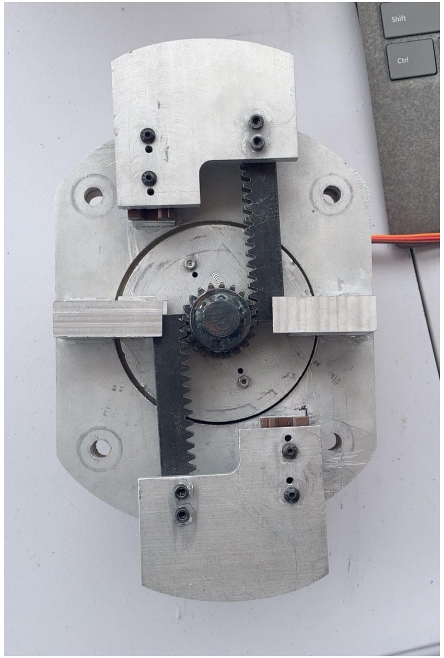
BP ground ejection testing

Testing

EMBERS testing

Testing



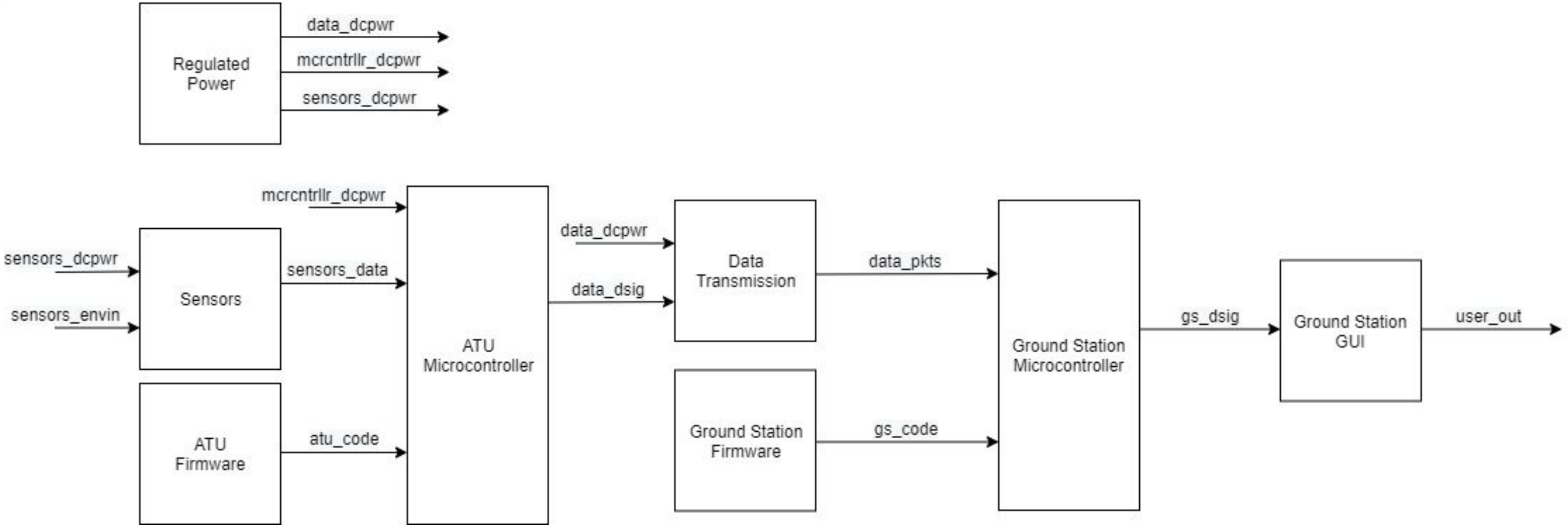


Avionics and BEAVS 2.0 Electronics

Overview

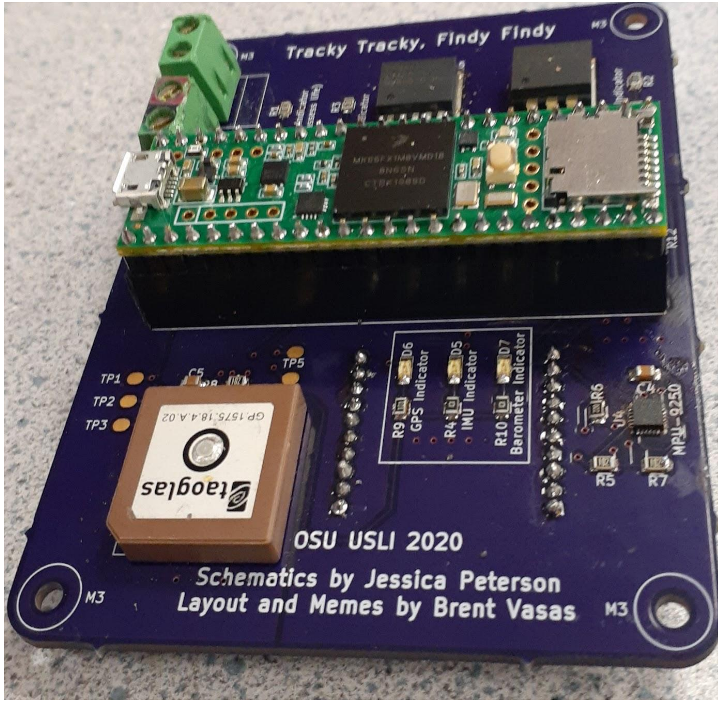
- Avionics:
  - Collects data: acceleration, altitude, location
  - Transmits data
- Ground Station
  - Analyses data
  - Visual display
- BEAVS
  - Collects data: acceleration, altitude
  - Actuates motor

Avionics

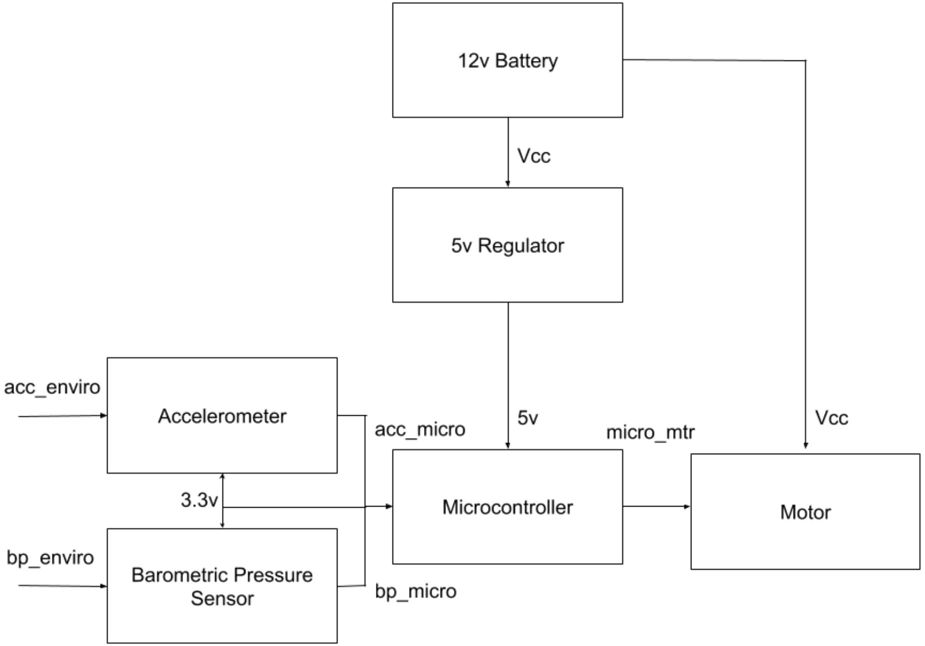

Regulated Power
data_dcpwr
mcrcntrllr_dcpwr
sensors_dcpwr
mcrcntrllr_dcpwr
sensors_dcpwr
sensors_envin
Sensors
sensors_data
ATU Firmware
atu_code
ATU Microcontroller
data_dcpwr
data_dsig
Data Transmission
Ground Station Firmware
data_pkts
gs_code
Ground Station Microcontroller
gs_dsig
Ground Station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

Parts

- Avionics:
  - Accelerometer: ICM2098
  - Barometric Pressure: MPL3115A
  - GPS: UBlox MAX-M8Q
  - XBee Transmitter
  - Teensy 3.6



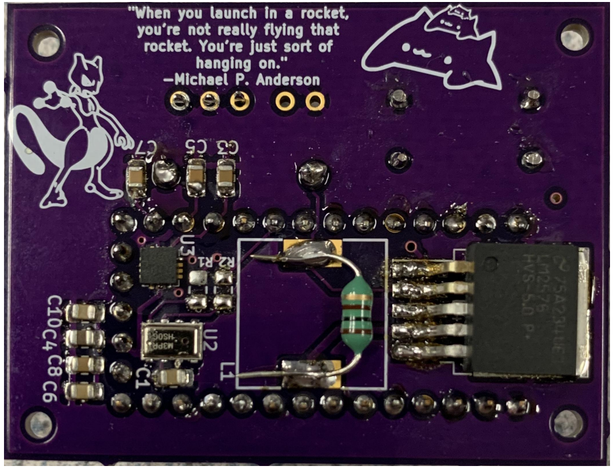
BEAVS

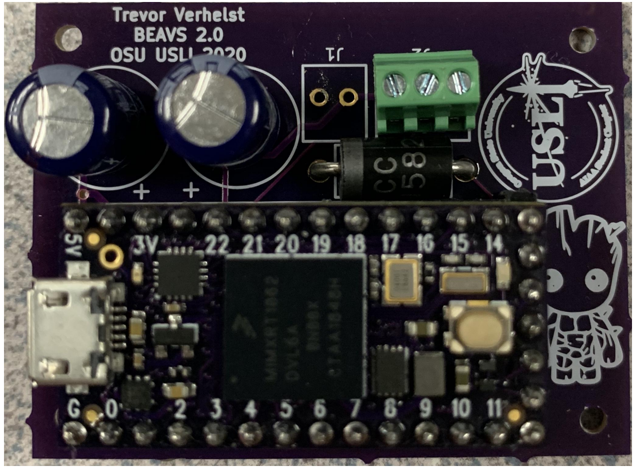


12v Battery
Vcc
5v Regulator
acc_enviro
Accelerometer
acc_micro
5v
micro_mtr
Vcc
3.3v
Microcontroller
Motor
bp_enviro
Barometric Pressure Sensor
bp_micro

Parts

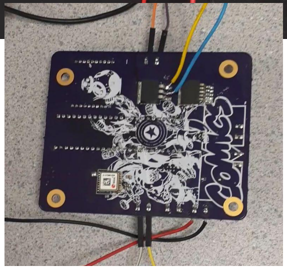
- BEAVS
  - Accelerometer: ADXL377
  - Barometric Pressure: MPL3115A
  - Teensy 4.0





Testing

- GPS accuracy:
  - Checked error based on fixed coordinates
  - Passed
- Barometric Pressure:
  - In flight compared with in flight altimeters
  - Passed
- Power:
  - Various input voltages and current loads
  - Passed



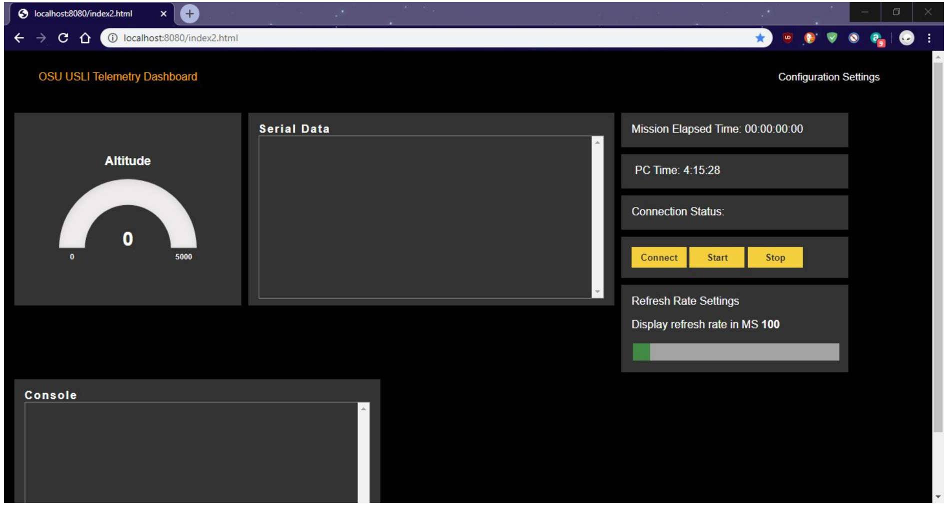
Avionics and BEAVS 2.0 Software

Overview

- 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

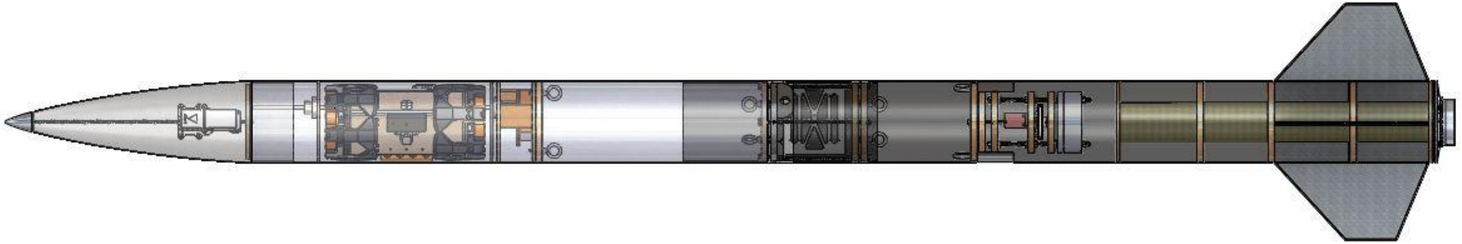


BEAVS 2.0

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

Launch Vehicle Structures and Propulsion

Overview

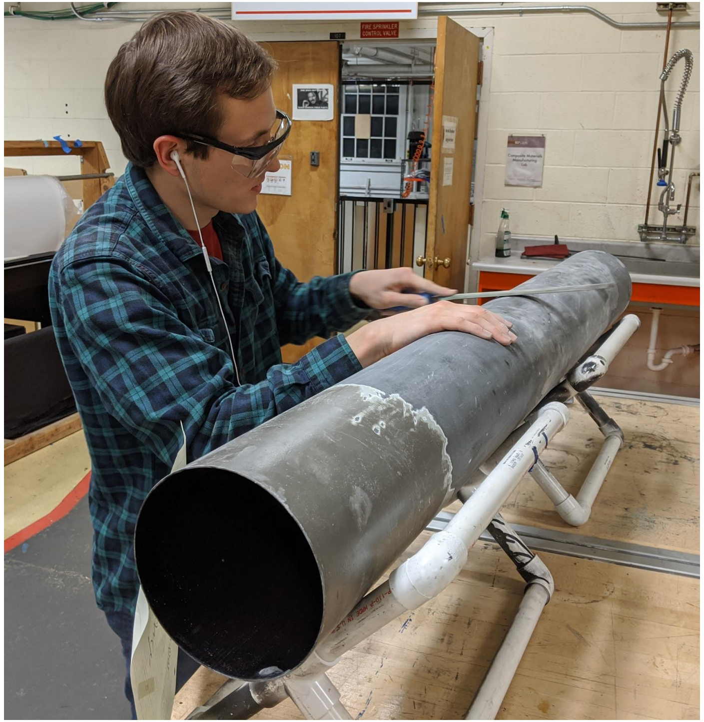


Airframe

- Tubes cut to size with custom fixturing
- Machined on manual mill to ensure accuracy and alignment

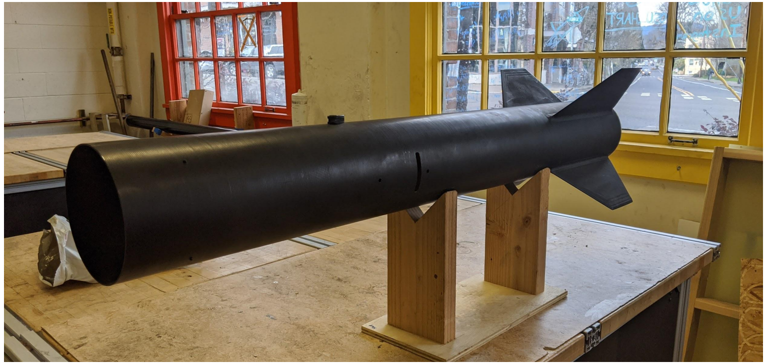
Fore Section

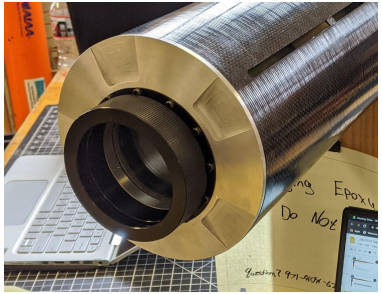
- Repurposed Fiberglass Airframe
- 44.5 inches in length
- Anti zippering for main parachute bay end
- Converted with patching of excess holes, removal of excess paint, cut down to correct size.



Aft Section

- Carbon fiber
- 49.2 inches in length
- Anti zippering on drogue parachute bay end
- Through wall mounted fins with large fillets
- Aero Pack 75mm motor retainer mounted to 6061 aluminum thrust plate



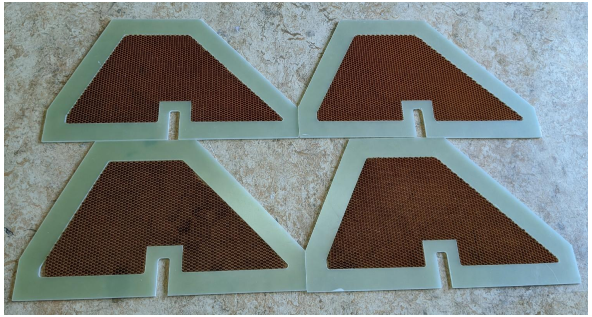


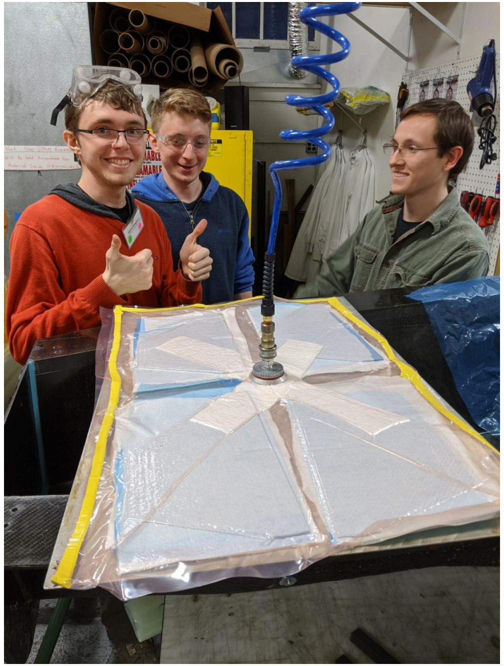
Bulkheads and Centering Rings

- 9 ply birch plywood
- CNC routed out of sheets
- Sanded to remove rough edges
- Epoxied in place with G5000 RocketPoxy
- 4 centering rings, 5 bulkheads

Fins

- FR4/nomex core, carbon exterior
- Quasi-isotropic layup
- Vacuum and heat cured in autoclave
- Epoxied to airframe with G5000 RocketPoxy





Motor Selection

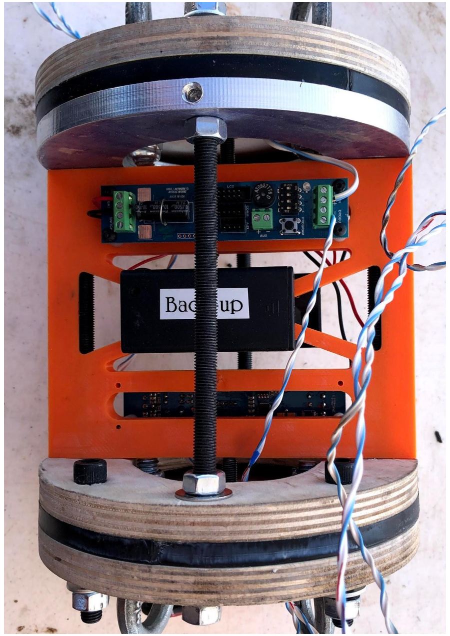
- Motor selection as of FRR - AeroTech L2200G
- Estimated apogee: 4601 ft
- Burn Time: 2.32 seconds
- Average Thrust: 494.6 lb-s
- Total Impulse: 1147 lb-s
- Diameter: 2.95 in.
- Thrust to weight: 11.4:1
- Rail exit velocity: 73.4 ft/s

Aft Parachute Mounts

- Milled out of 6061 aluminum
- Steel eye bolts mounted prior to epoxy
- Affixed to airframe with G5000 RocketPoxy
- Rail guid mounted in mount through airframe wall
- Seal against sealing bulkhead

Pressure Seals

- 2 seals on either end of the recovery avionics bay
- Single sealing bulkhead on top of BEAVS bay
- Uses compressing bolts to compress o-ring gasket sealing against inside of airframe



Coupler

- Fiberglass and carbon fiber construction
- Unidirectional fiberglass layup
- Carbon fiber outer band
- Protects recovery avionics bay
- 6.25 inch outer diameter with couplings extending 6.5 inches into fore and aft sections
- Fully loaded, 6.5 lbf

Nose Cone Failure

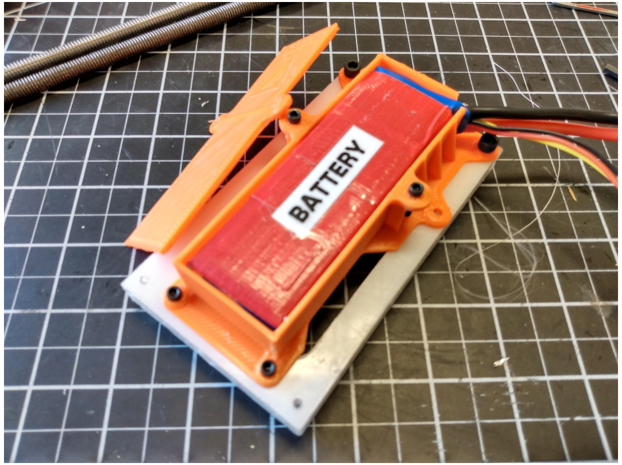
- Failure of shear pin retention resulting in nose cone falling from 500 ft AGL
- Analysis of flight revealed possible causes
  - Shear Pin size
  - Excess velocity
  - Added ballast
- Mitigation of future failures to take place along with redesign of nose cone retention system
- Payload retention system will be integrated into the nose cone retention with a factor of safety greater than 2.

Nose Cone

- Manufactured out of 7.5 inch 5:1 ogive nose cone
- 26.5 inches tall, 5.4 lbf
- Damage from Full-Scale 1 has been repaired
- Repaired with a scarf joint repair method

Nose Cone Avionics Bay

- Mounts of aluminum threaded rod in center of nose cone
- 3D printed mounting case for battery
- HDPE mounting for PCB
- Requires repairs after nose cone failure



Testing Results

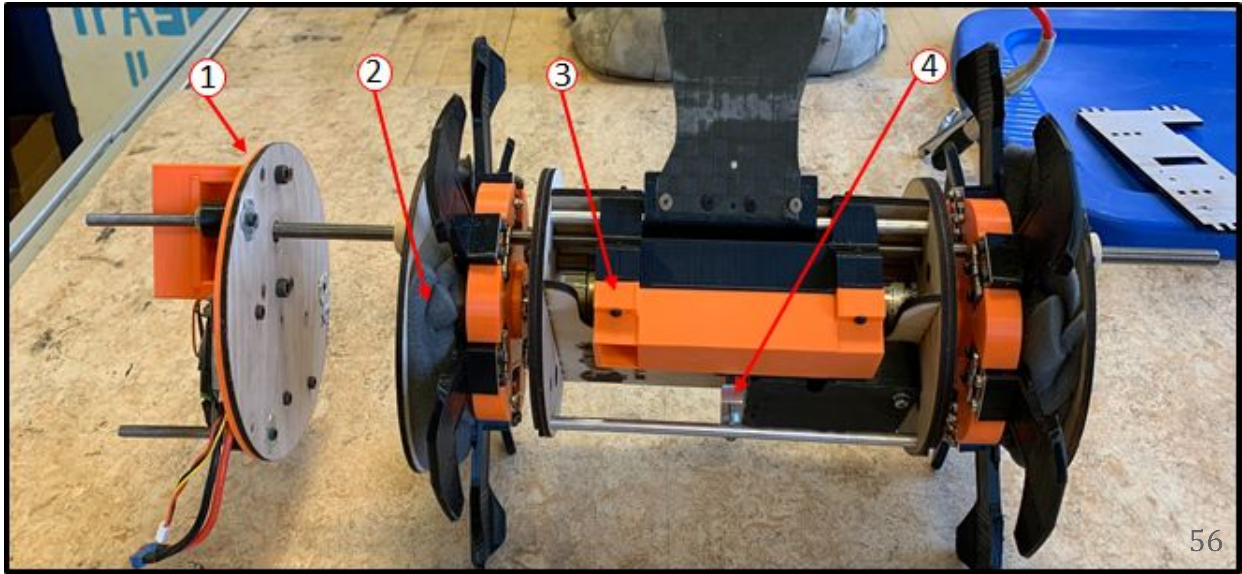
- Ejection testing of BEAVs sealing bay
  - Successful after adjustment of sealing gasket and multiple ejection tests
- Testing of assembled avionics bay venting
  - Successfully igniting E-match at simulated apogee verifying required venting
- Impact testing of Fins
  - Completing full scale landing, after being drug 10 feet through gravel and dirt fins showed minimal damage, only showing light scratching
- Full scale test launch
  - No visible damage to launch vehicle airframe components save for nose cone. No signs of strain or buckling in thrust plate, parachute mounting points, or recovery bay structure

Payload

Overview

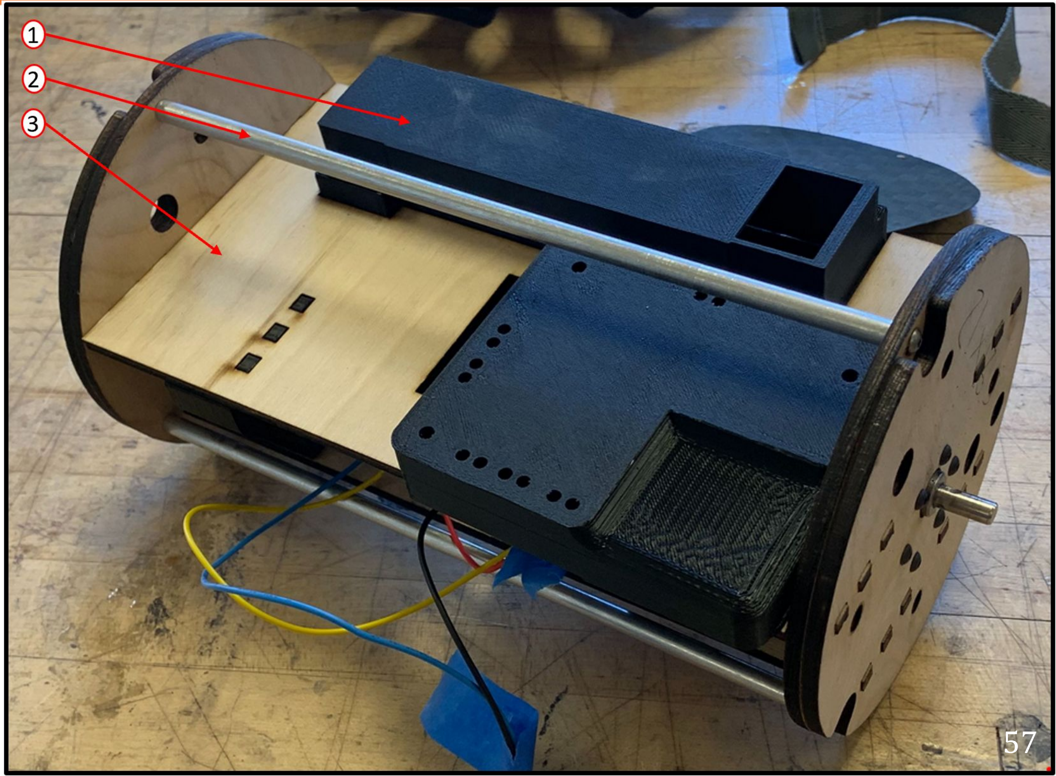
Sub-Systems

1. Ejection\Retention
2. Push Plates
3. Chassis
4. Collection
5. Drivetrain



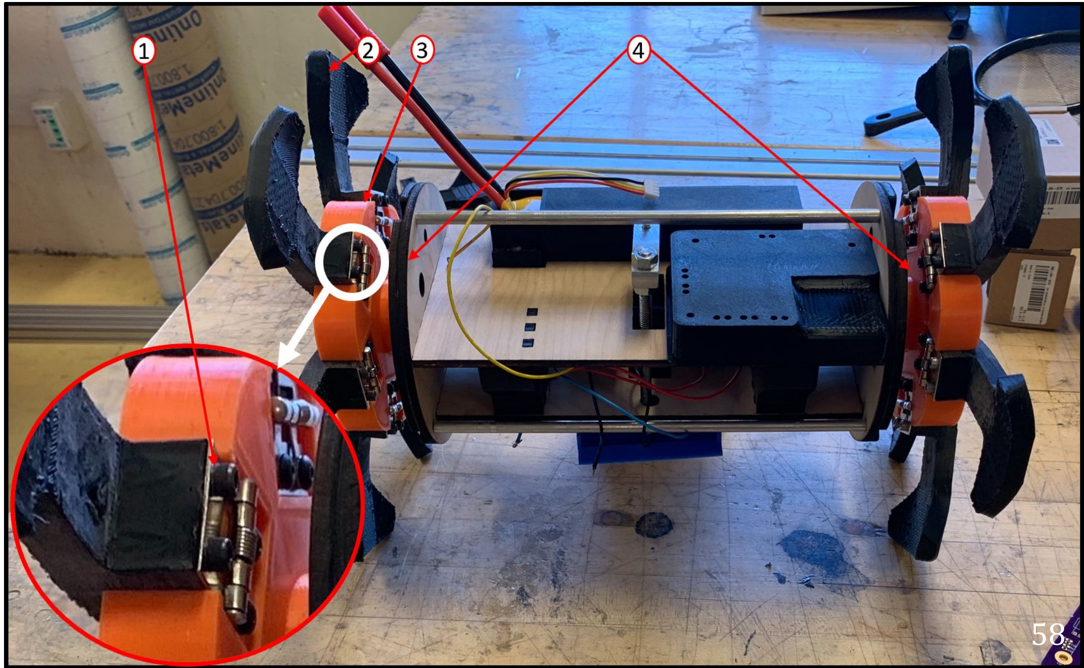
Chassis

1. PLA, battery, and PCB cases
2. Aluminum supports
3. Laser cut wooden plates



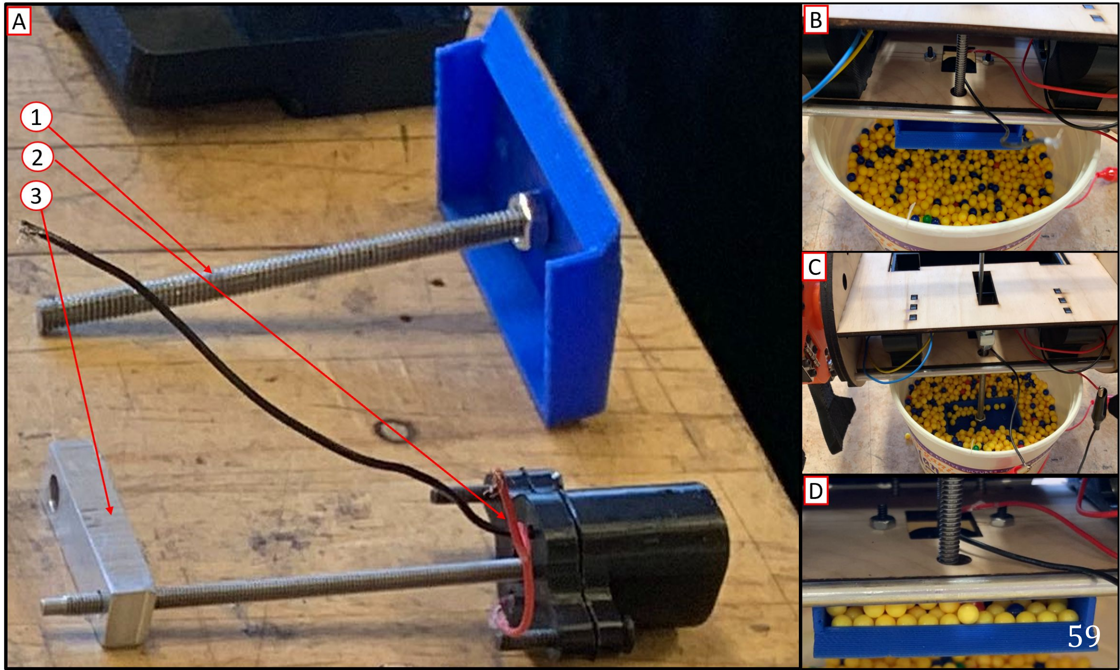
Drivetrain

1. Spring hinges
2. Spokes
3. Hubs
4. Bi-axial



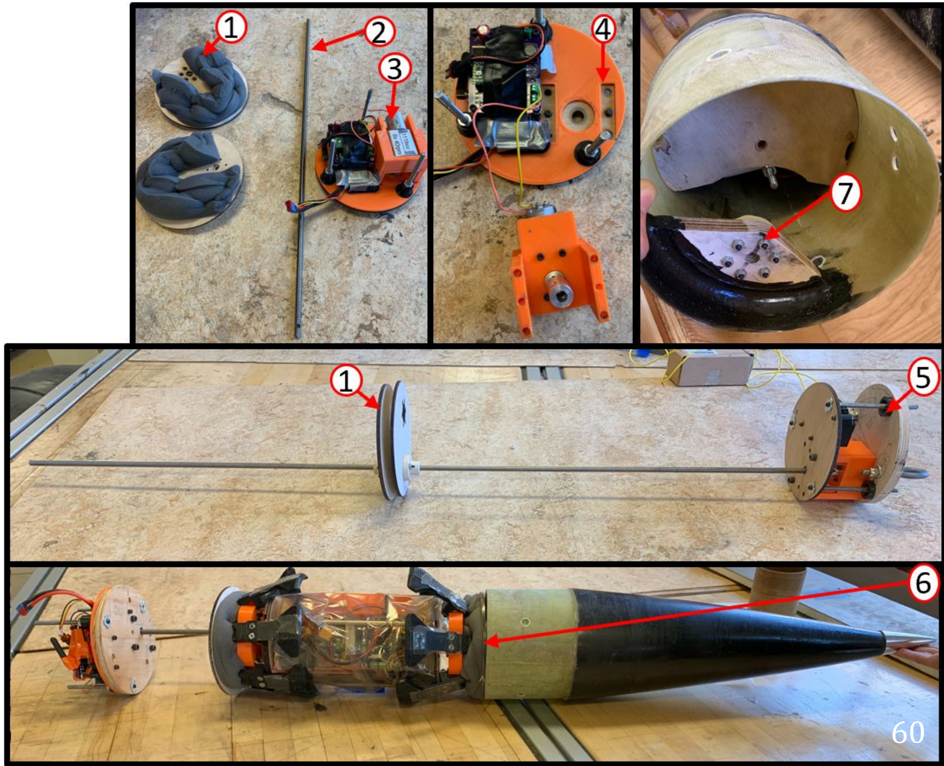
Collection System

1. Scoop
2. Motor Mount
3. Bracket
4. B,C, and D show the system in action



Ejection/Retention System

1. Push Plates
2. Lead Screw
3. Ejection Assembly
4. Electronics Mount
5. Full Assembly
6. Assembly w/ Payload
7. Nose Cone Thread

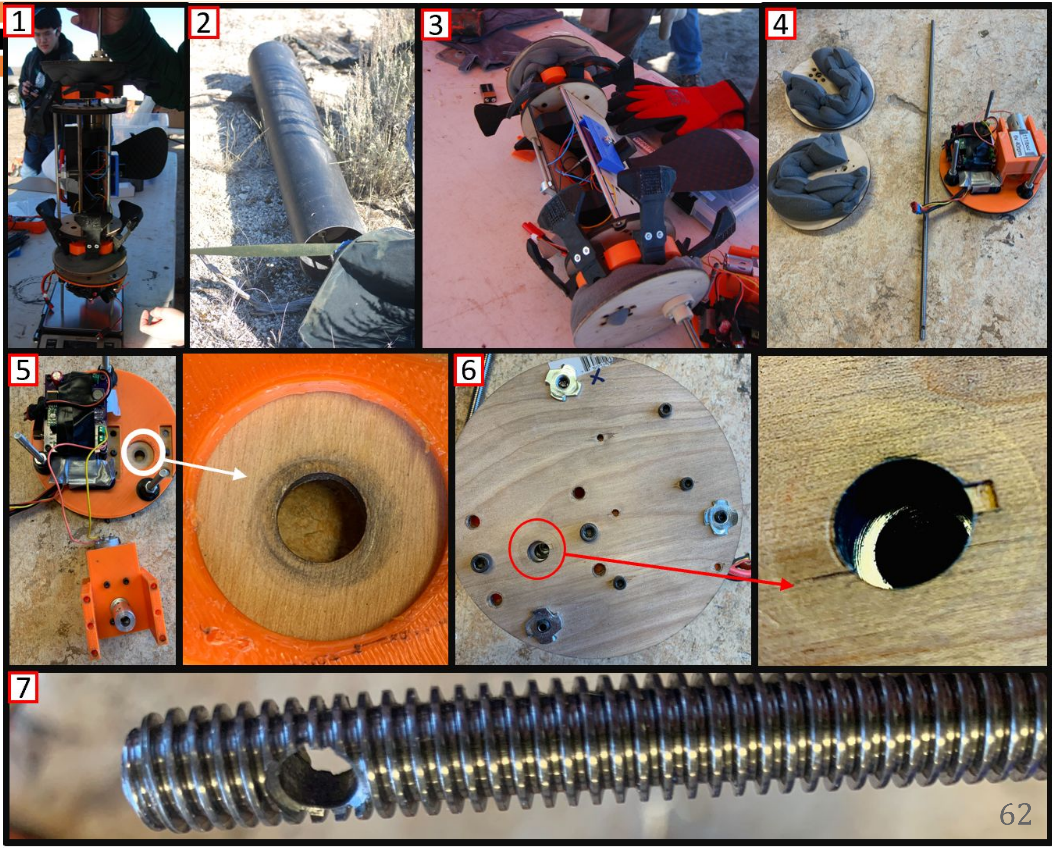


Testing

Test/System	Number/Type	Status	Results	Notes
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	Complete	Successful	
	Drive Testing	In Progress	N/A	
	Battery Life Testing	In Progress	N/A	
	Ejection System Testing	Complete	Successful	
	Retention Strength Testing	Complete	Successful	
	Retention Robustness Testing	Complete	Successful	

Testing, Test Launch Review

1. Pre launch
2. Fore-section landing
3. System post launch
4. Retention assembly (post launch)
5. Bulkhead damage
6. Bulkhead damage (fore side)
7. Lead screw



Payload Electronics

Overview

Sensors

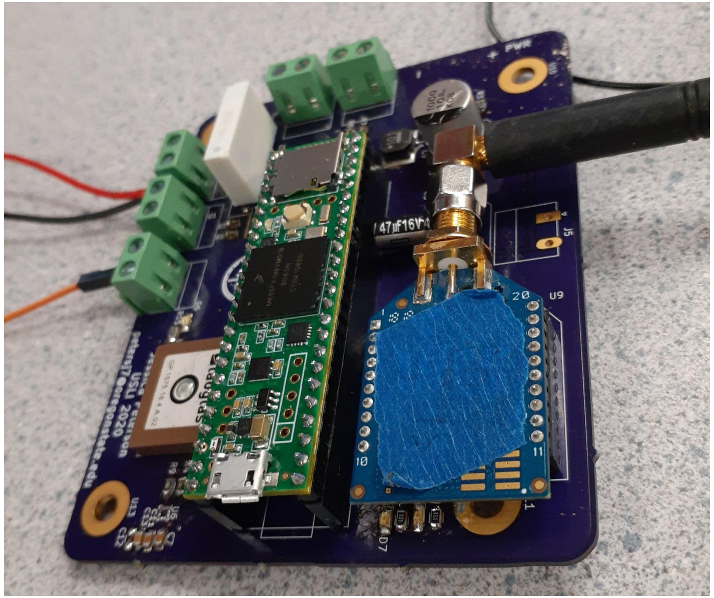
- GPS
- Gyroscope

Movement

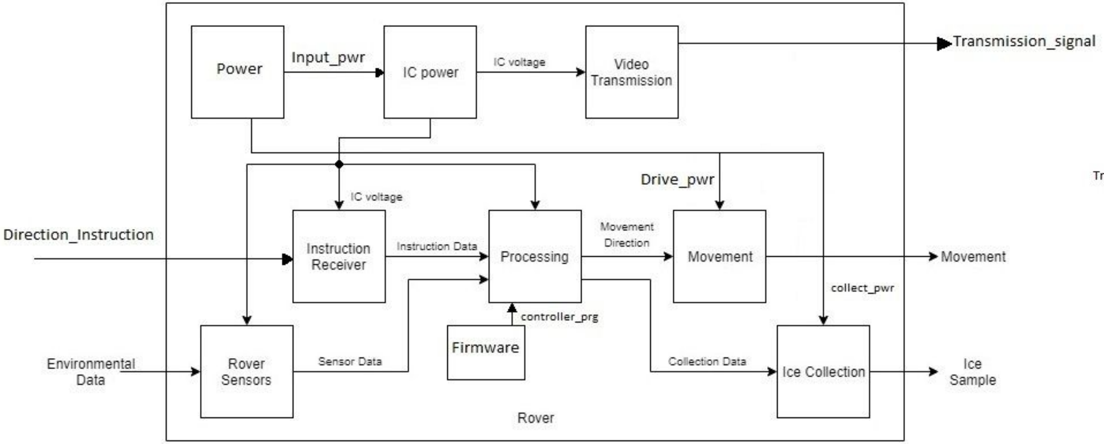
- 3 motor drivers
- 3 - 12 V motors

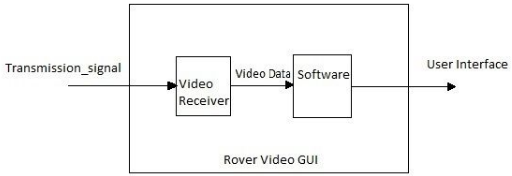
Control

- Xbox controller
- Transmitter



Block Diagram





Testing

- Power Testing:
  - Power supplies are able to supply necessary power
  - Passed
- Sensor testing:
  - GPS and accelerometer
  - Passed
- Motor Driver:
  - In progress: Manufacturing errors
- Control:
  - Passed

Payload Software

Overview

GUI:

- Displays sensor, camera, and map data

Control Program:

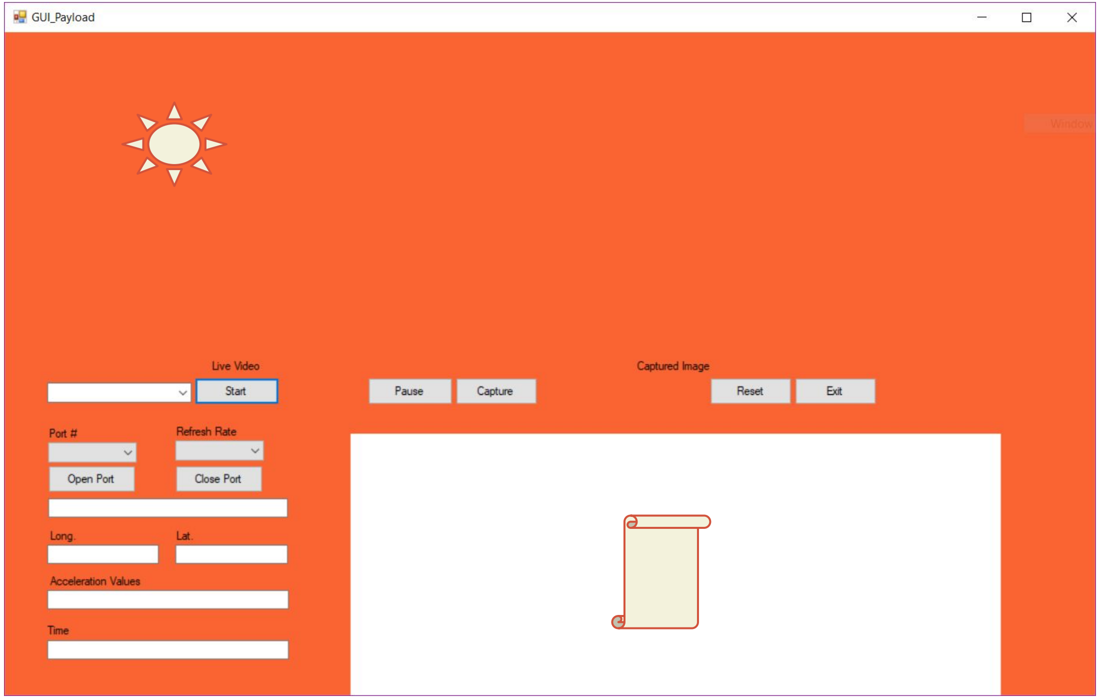
- Controls the rover wirelessly via Xbox remote

Testing

GUI testing:

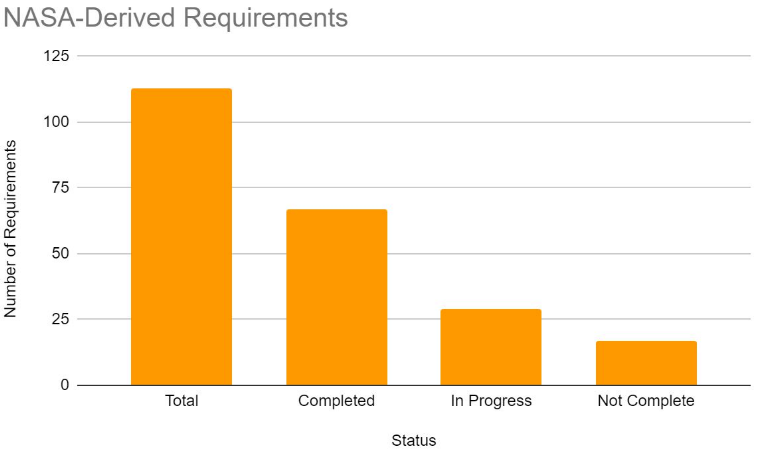
- Testing displayed data vs “actual data” to confirm correctness
- Limiting user input to reduce breakage
- Testing usability by team members

Payload GUI


GUI_Payload
Live Video
Start
Pause
Capture
Captured Image
Reset
Exit
Port #
Refresh Rate
Open Port
Close Port
Long.
Lat.
Acceleration Values
Time

Testing and Requirement Verification

Requirement Verifications



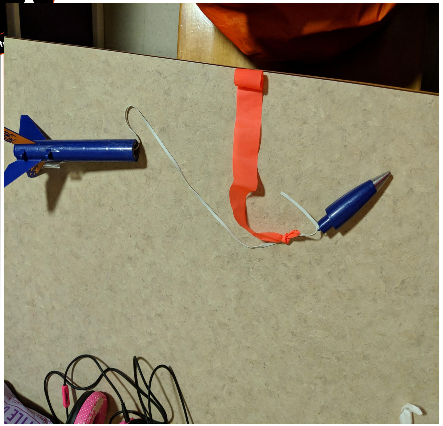
Total Requirements: 113
Not Complete: 17
In Progress: 29
Completed: 67

Total Requirements: 44
Not Complete: 6
In Progress: 26
Completed: 7

STEM Engagement

Overview

- OSRT has brought our STEM Engagement efforts out of the state of Oregon and into California.
- OSRT has reached a total of 2,038 community members.



Building a Bridge

Directions:

Give a short introduction to the forces involved with building a bridge

The students will be asked to build a bridge out of paper that they will be able to drive their toy cars across

Supplies: Paper, tape, small toy cars

Learning objectives: Finding different ways to fold and roll the paper in order to create more stable structures, experimenting with different forces to see them in action

Assessment method: watching the students test their bridges by driving the toy cars across them

Climbing Water Lesson Plan

Grade Level: K-2
Materials: water, food coloring, paper towels, two cups
Goals: Students will learn about the capillary action of water
Directions:

1. Fill one of the cups with water
2. Add food coloring to the water
3. Dip the paper towel in the water and use it to transfer the water from one cup to the other

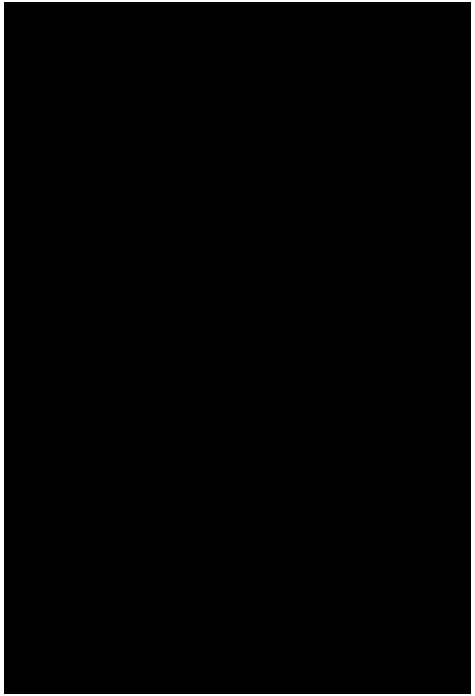
Full List of Events/Schools Visited

Date	Event	Engagement Number
Oct.12th	Football Table	24
Oct. 25th	Fir Grove Elementary	15
Nov.1st	Science Saturday Happy Valley, OR.	75
Nov. 4th-5th	OSU Discovery Days	1,109
Nov. 8th	Football Table	57
Nov.12 &14th	Football Table	56
Nov.16th	Football Table	45
Nov. 20th	Saint Thomas More Catholic School	27
Nov. 21st	Basketball Table	20

Date	Event	Engagement Number
Dec.13th	Monte Vista HS	26
Jan.10th	Basketball Table	20
Jan. 17th	Lake Oswego Junior High	93
Jan. 25th	Evergreen Air and Space Museum	44
Jan. 31st	Talmadge MS	32
Feb. 25th	Saint Thomas More Catholic School	25
Feb. 27th	Periwinkle Elementary	350
Feb. 29th	Rocketry Workshop Eugene, OR.	20

Pictures


AIAA
Shaping the Future of Aerospace
AIAA Oregon State
University Branch
OSUAIAA



Safety

Detailed and Responsive

Checklist Iteration

Averted Incident Reports

Checklist Improvement

More safety considerations

More inspector interaction

Actionable, discrete steps

Making Use of A “Near Miss”

Non-emergency reporting

Chain of command revision steps

Continue to improve, even during success

Questions?