Flight Readiness Review

March 5, 2020

Sample Acquisition:
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Presentation Overview

- Launch Vehicle Design
- Recovery Subsystem Design
- Demonstration Flight Results
- Payload Design
- Payload Integration Design
- Requirement Verification

Launch Vehicle Design

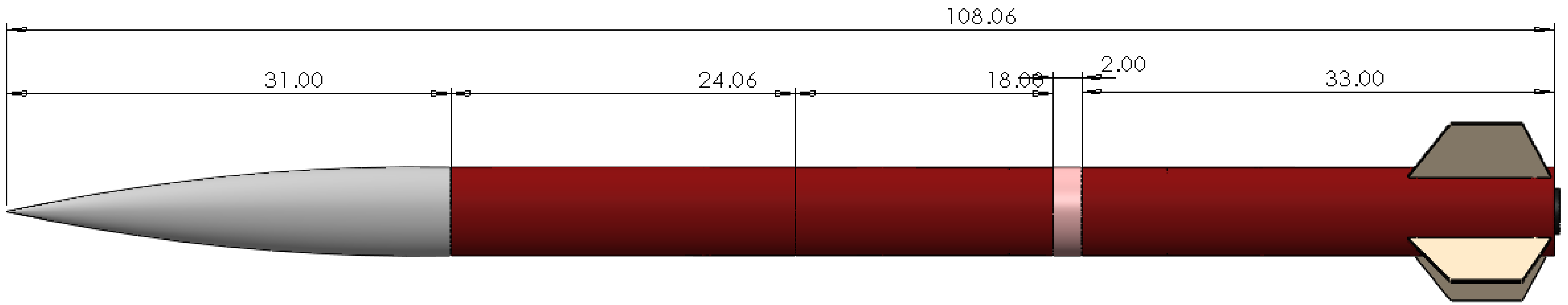
Dimensions

Performance Predictions

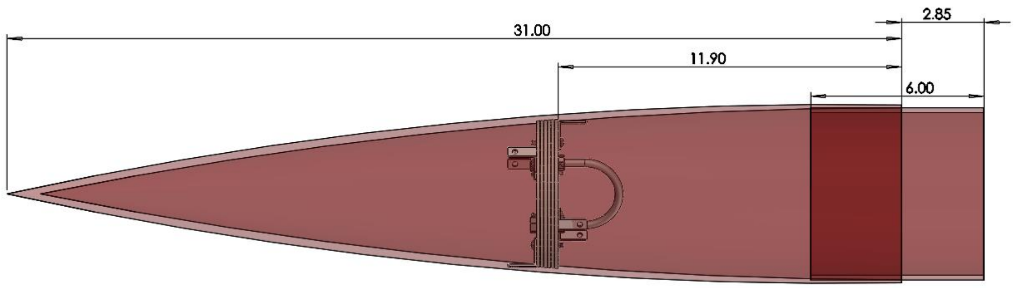
Test Results

Dimensions of Completed Launch Vehicle

- Final Vehicle Length: 108.06 in
- Filament Wound G12 Fiberglass
- Birch Plywood Fins

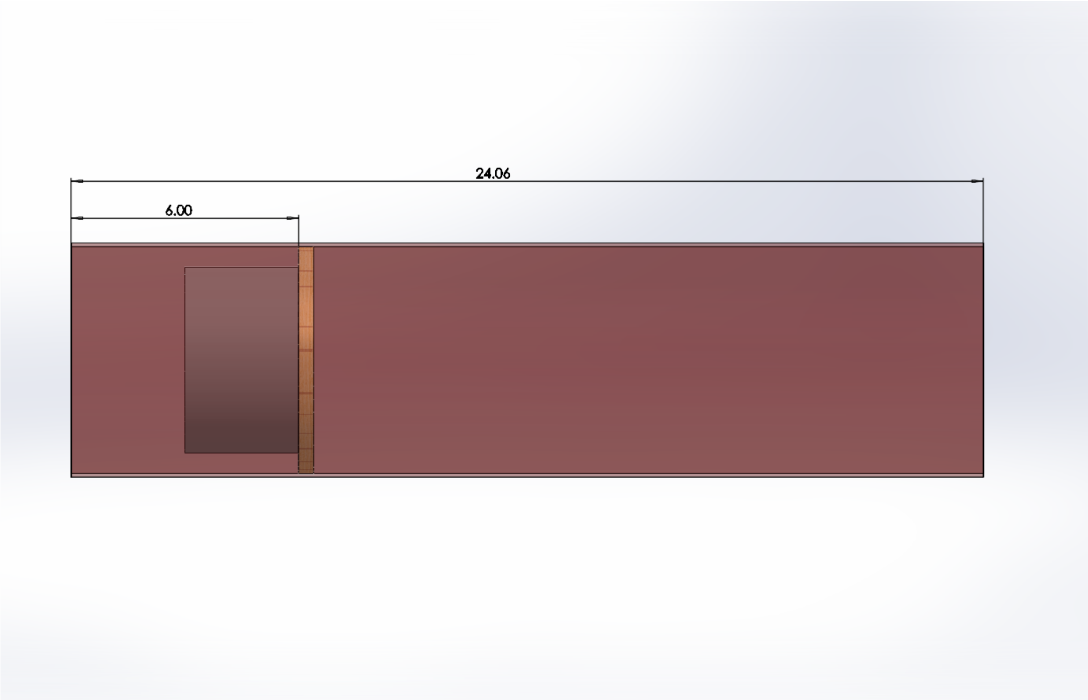


Nosecone



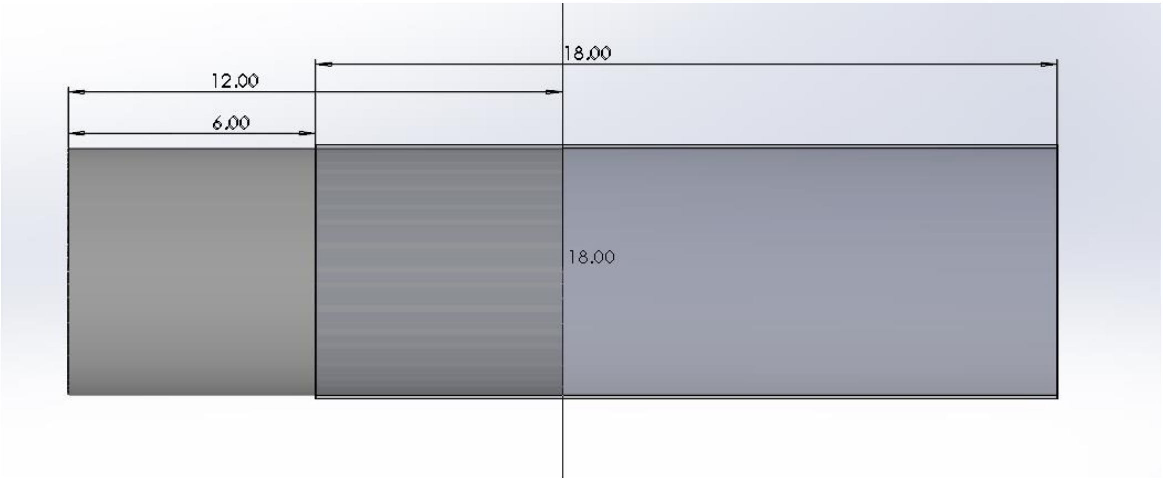
- 5:1 Ogive shape
- Final length: 31 in
- Metal Tip for reusability

Payload Bay



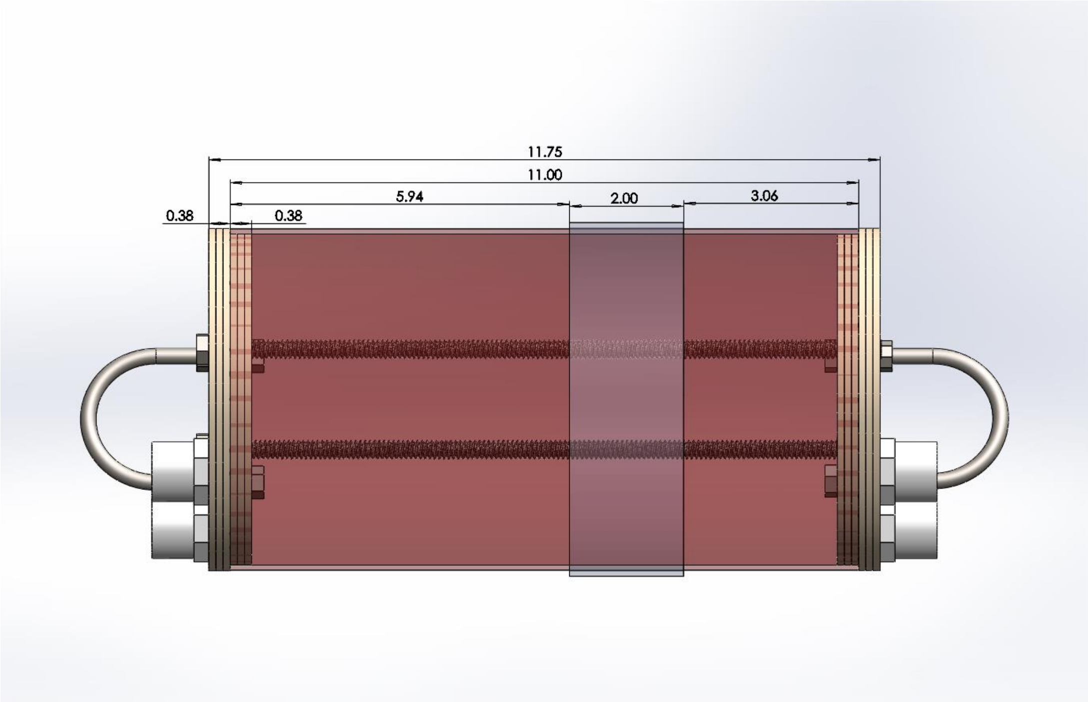
- Final length:24.06 in
- 4 metal screws attach FWD end to Nosecone
- Centering ring placed 6 in from Aft end
  - Allows for 6 in long coupler

Main Parachute Bay



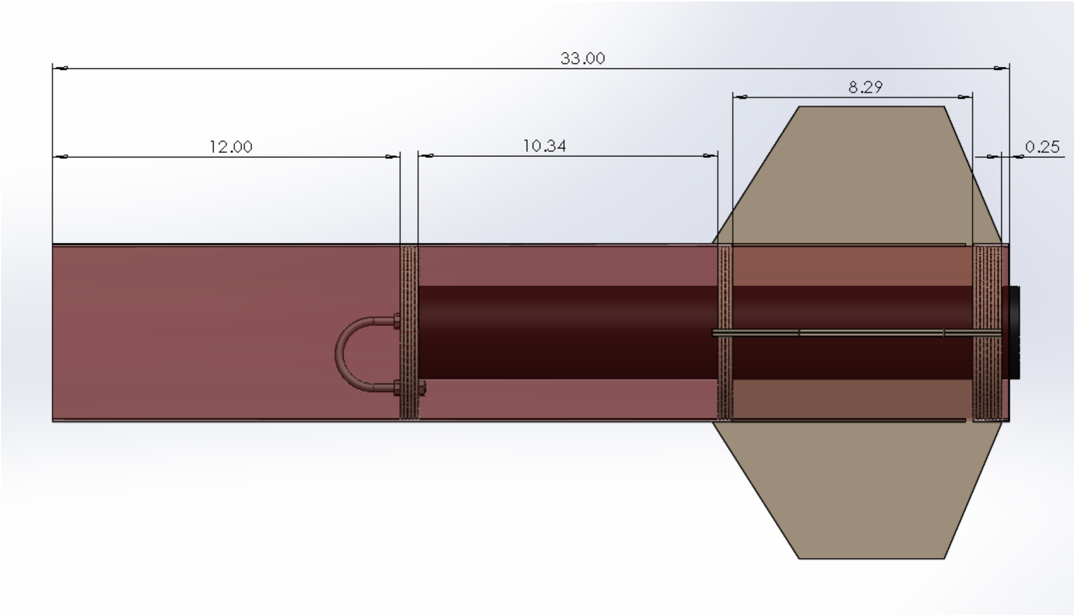
- Length: 18.0 in
- Coupler length: 12 in
  - 6 in exposed on FWD end
- Connects to Payload bay with nylon shear pins
- Connects to AV Bay with Metal Screws

AV Bay



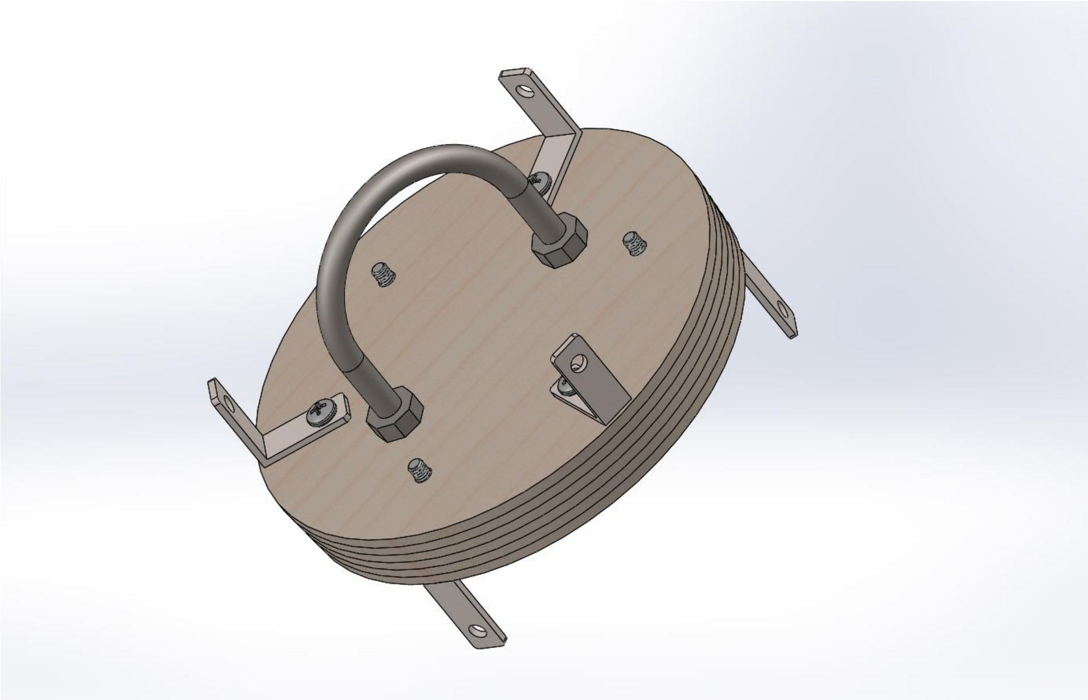
- Length 11.75 in
- 6 in coupler section on Aft end connects to Fin Can with Nylon Shear Pins
- Remains attached to the main parachute bay after main deployment

Fin Can



- Length: 33 in
- FWD cavity was expanded 0.5 in
- Motor retainer is attached to motor tube using 2-part epoxy

Changes Since CDR

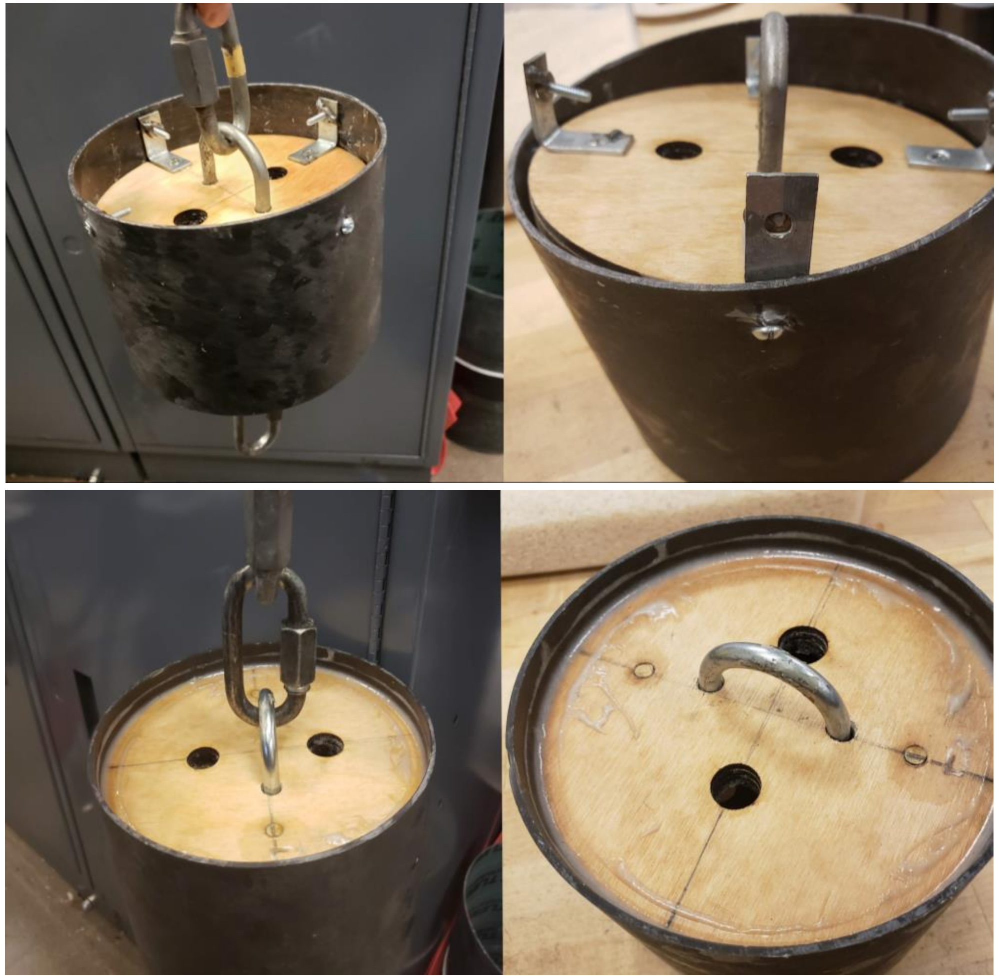


- Number of L-brackets on Nosecone bulkhead increased
  - From 4 to 6
- Placed at 60 deg. Offsets on alternating sides of bulkhead

Bulkhead Tensile Testing

- Bulkhead in tension
- Two-sided test sample
  - One Epoxied
  - One Bolted with #6 bolts

Results

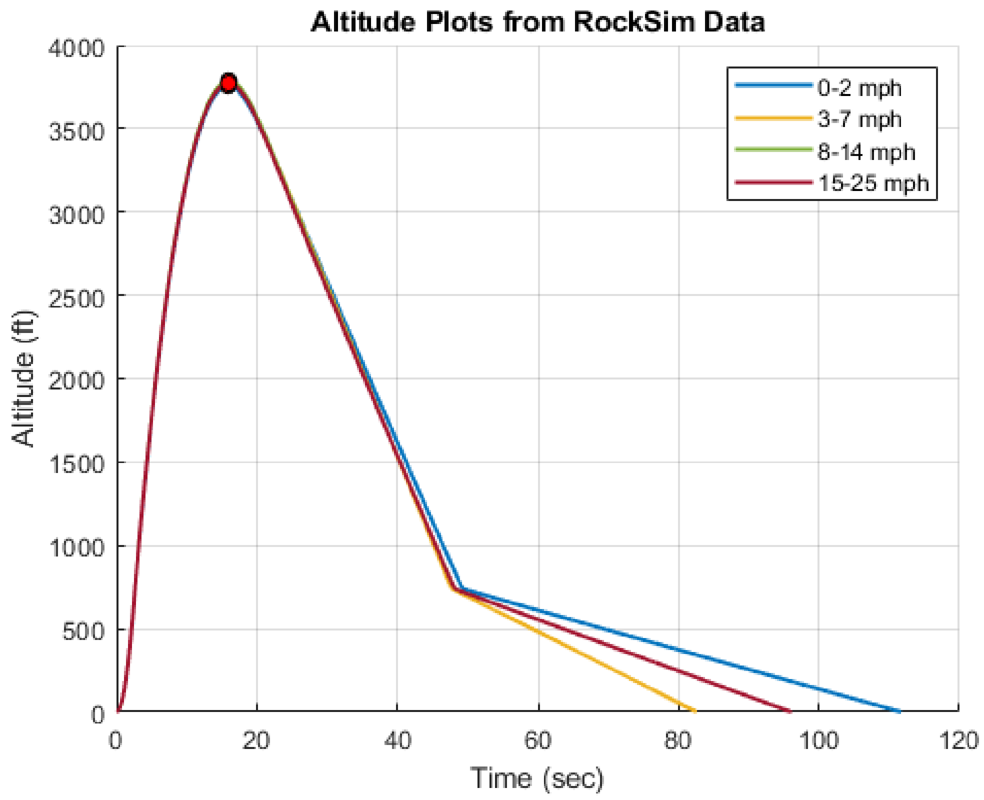


- Bolted Side Sheared at 1500 lbs.
  - Damage to Fiberglass
  - Head of two bolts removed from body
- Epoxied side undamaged
- No Visible Damage to U-Bolts

Performance Predictions

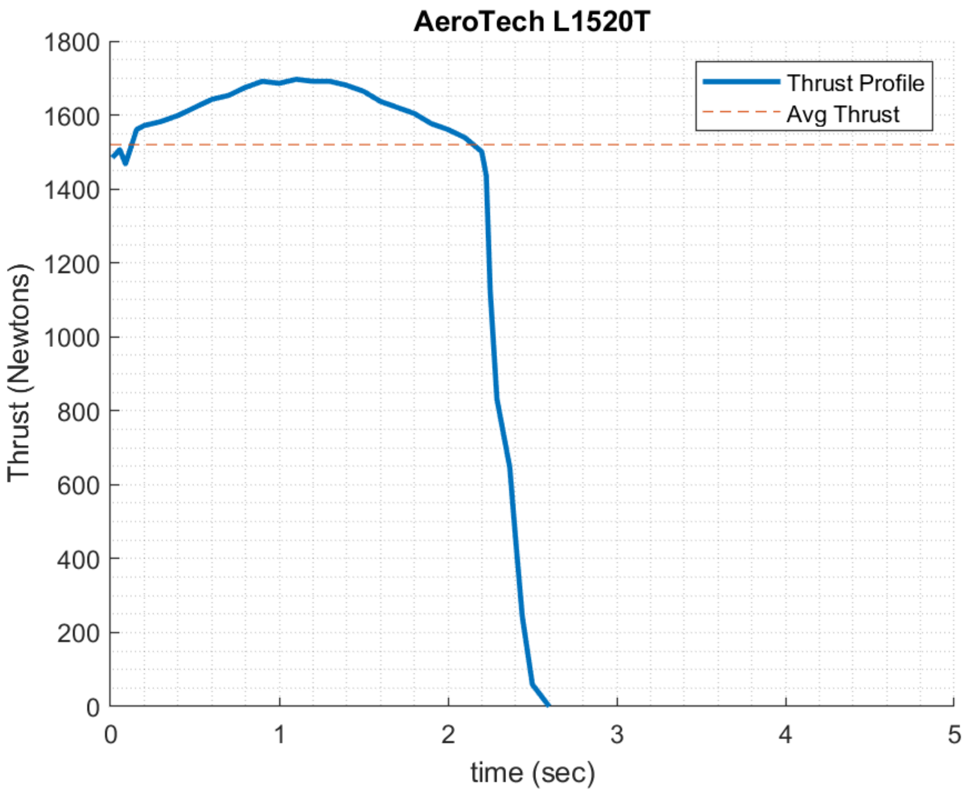
Apogee Predicition (ft)	
RockSim	BarrowMan
3,775	3,649

Critical Flight Data	
Stability (on rail)	2.18
Velocity (rail exit)	70.1 ft/s
Velocity (max)	497 ft/s
Max Mach	0.45



Performance Predictions

Vehicle Specifications	
Motor	L1520T
Mass (loaded)	47.5 lb
Thrust to Weight	7.42



Recovery Subsystem

Parachute Selection

Performance Predictions

Test Results

Parachute Sizing & Descent Rates

- Drogue: Fruity Chutes 24" Classic Elliptical
  - Diameter: 24 inches
  - Drag Coefficient: 1.47
  - Descent Rate: 88.0 ft/s
- Main Parachute: Fruity Chutes 120" Iris UltraCompact
  - Diameter: 120 inches
  - Drag Coefficient: 2.11
  - Descent Rate: 14.7 ft/s

Kinetic Energy

Section	Mass	Main Velocity	Kinetic Energy at Landing	Drogue Velocity	Kinetic Energy under Drogue
Nosecone	.5532 slugs	14.72 ft/s	60. ft-lb	88.00 ft/s	2142.4 ft-lb
Midsection	.3916 slugs	14.72 ft/s	42.4 ft-lb	88.00 ft/s	1516.5 ft-lb
Fin can	.3792 slugs	14.72 ft/s	41.1 ft-lb	88.00 ft/s	1468.3 ft-lb

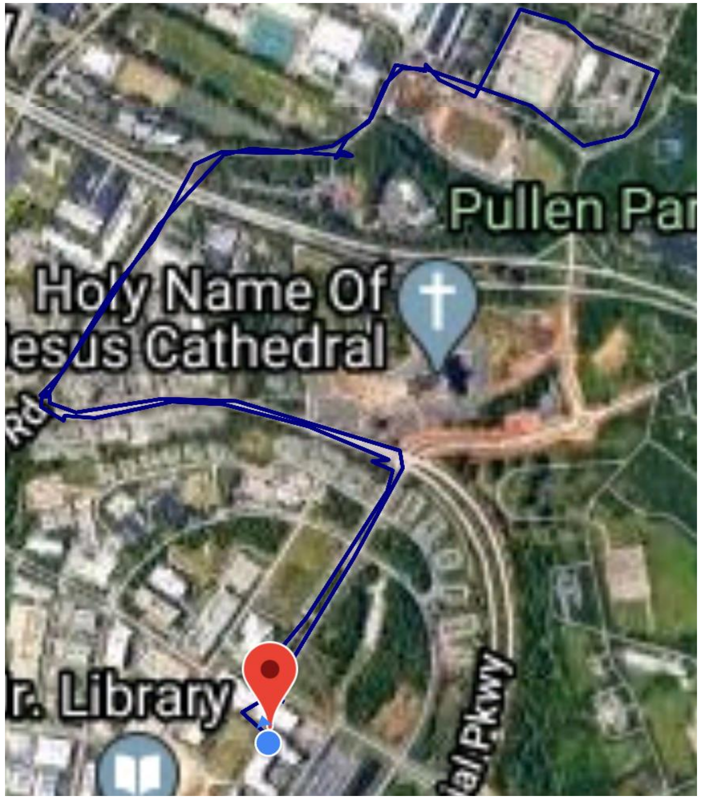
Wind Effects on Altitude and Drift

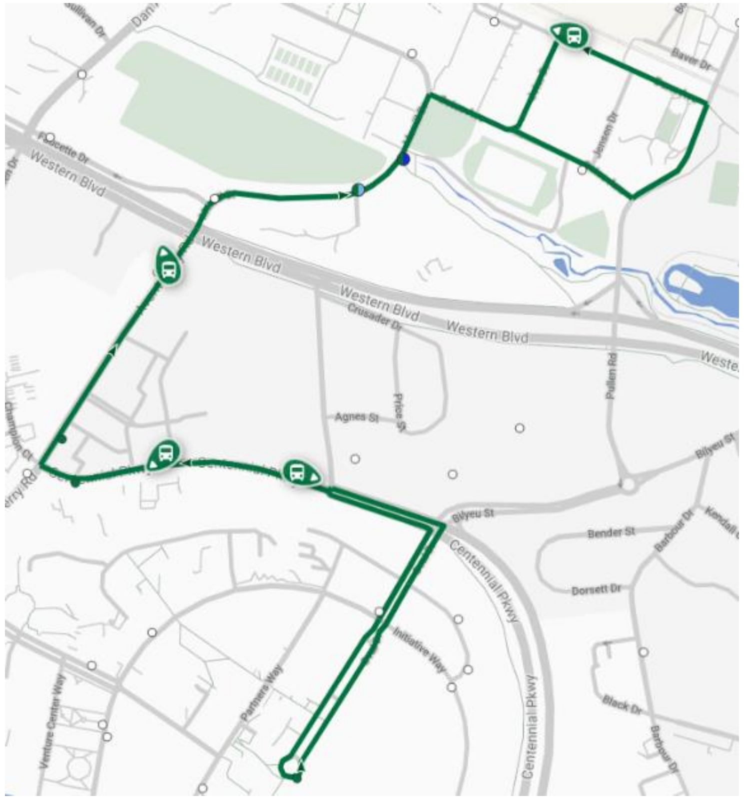
Wind Speed	Apogee	Descent Time	Drift Distance
0 mph	3801 ft AGL	67 s	0 ft
5 mph	3792 ft AGL	67 s	490 ft
10 mph	3761 ft AGL	66 s	976 ft
15 mph	3707 ft AGL	66 s	1443 ft
20 mph	3631 ft AGL	63 s	1855 ft

Ejection Demonstration

- Drogue charge 2.3 grams, main charge 5.5 grams
- Complete and vigorous separation
- Parachutes sustained no damage

GPS Operational Test





- Minimal deviation from known course, approximately 50 ft max deviation
- No delay except for transmission frequency (1/sec)
- TTFF of ~ 3 minutes

Tracker Ground Interface

- The GPS systems transmissions received by handheld receiver box
- Linked to Android phone via Bluetooth, uses Rocket Locator App to plot as previous slide

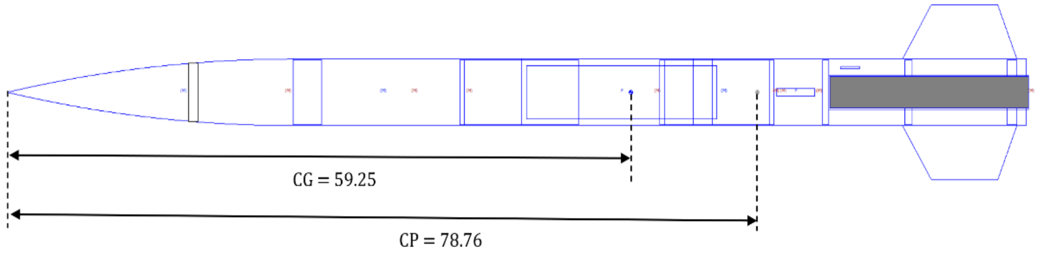
Demonstration Flight Results

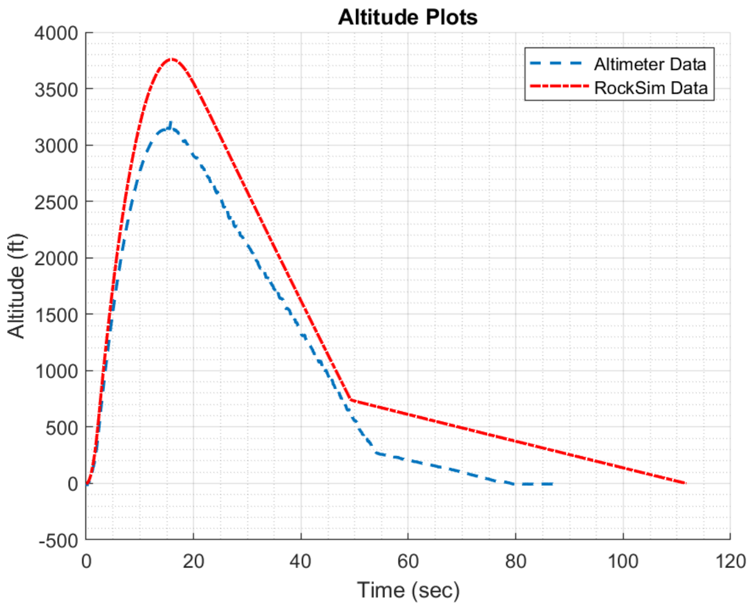
Vehicle Demonstration Flight

Payload Demonstration Flight

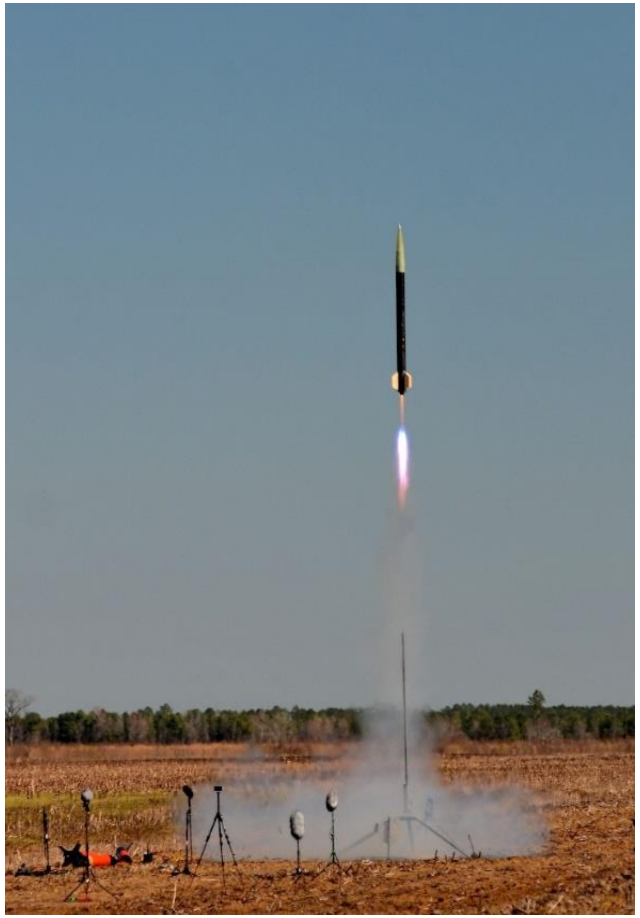
Vehicle Demonstration Flight

Critical Flight Data	
Stability (on rail)	2.17
Apogee	3,187 ft





Vehicle Demonstration Flight



Observations

- Minimal weathercocking at rail exit
  - Fin size was increased based on sub scale demonstration
- Low density altitude (-340 ft MSL)
- 3 lb heavier than predicted
  - Epoxy weight
  - Construction materials
- Recovery electronics and harnesses functioned nominally

Payload Demonstration Flight

- The payload was successfully retained during the demonstration flight.
- Due to potential water damage electronic components were not tested at the field

Water Damage Avoidance

Removal from Irrigation Ditch

Drying BURRITO with Rice

Payload Design

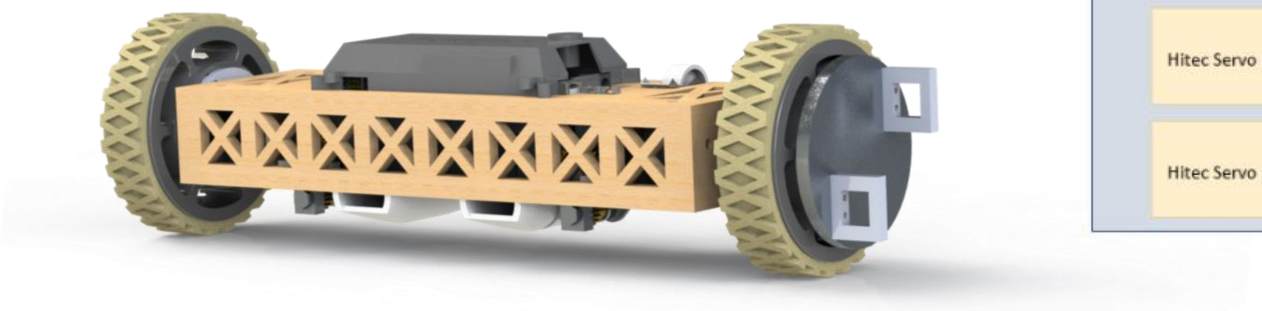
BURRITO

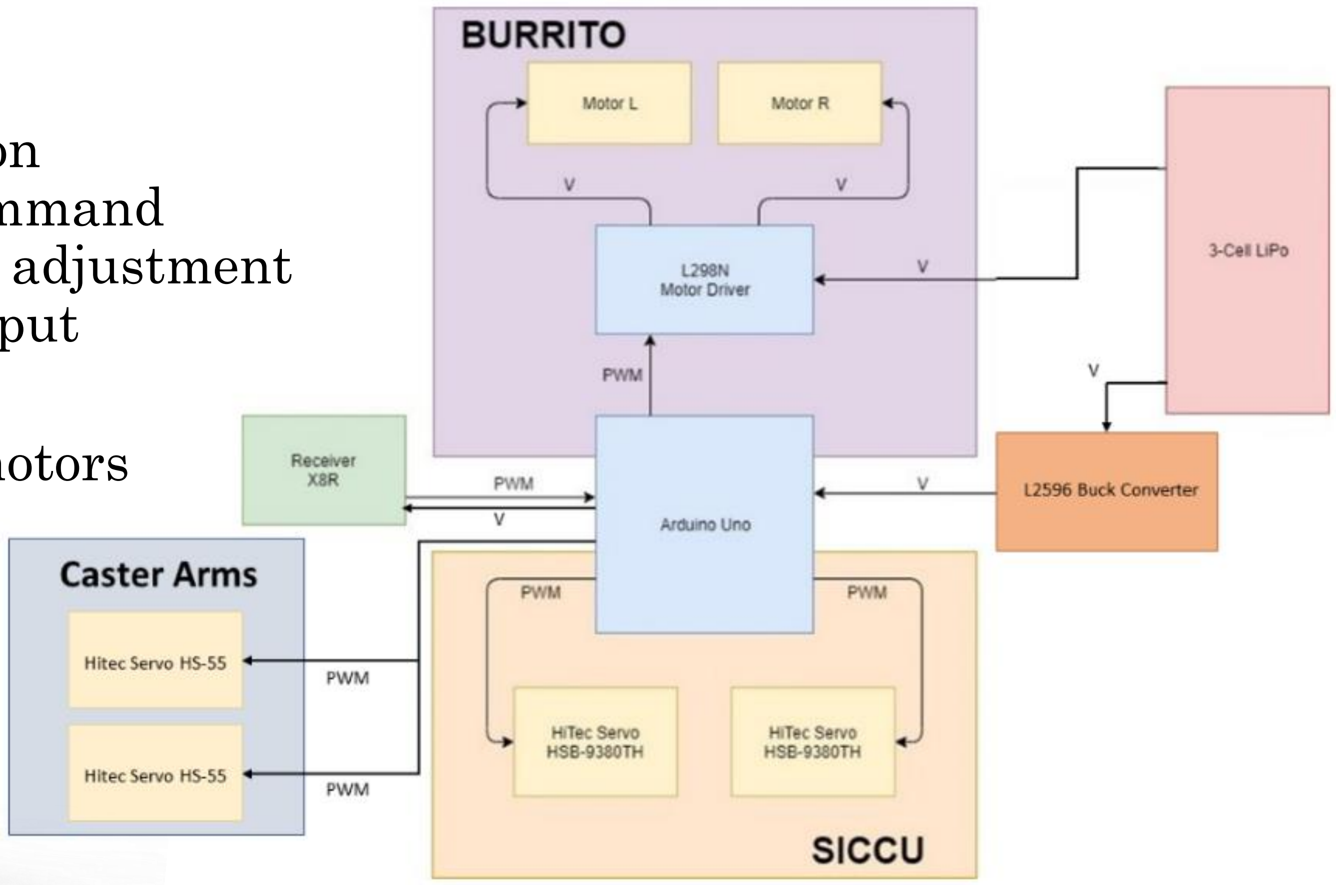
SICCU

Test Results

BURRITO Overview

- Chassis: laser cut plywood
- Electronics
  - Arduino Uno: program execution
  - L298N Motor Driver: motor command
  - L2596 Buck Converter: voltage adjustment
  - FRSkyX8R Receiver: control input
- Drivetrain
  - (2x) 350 RPM planetary gear motors
  - (2x) Deployable caster wheels

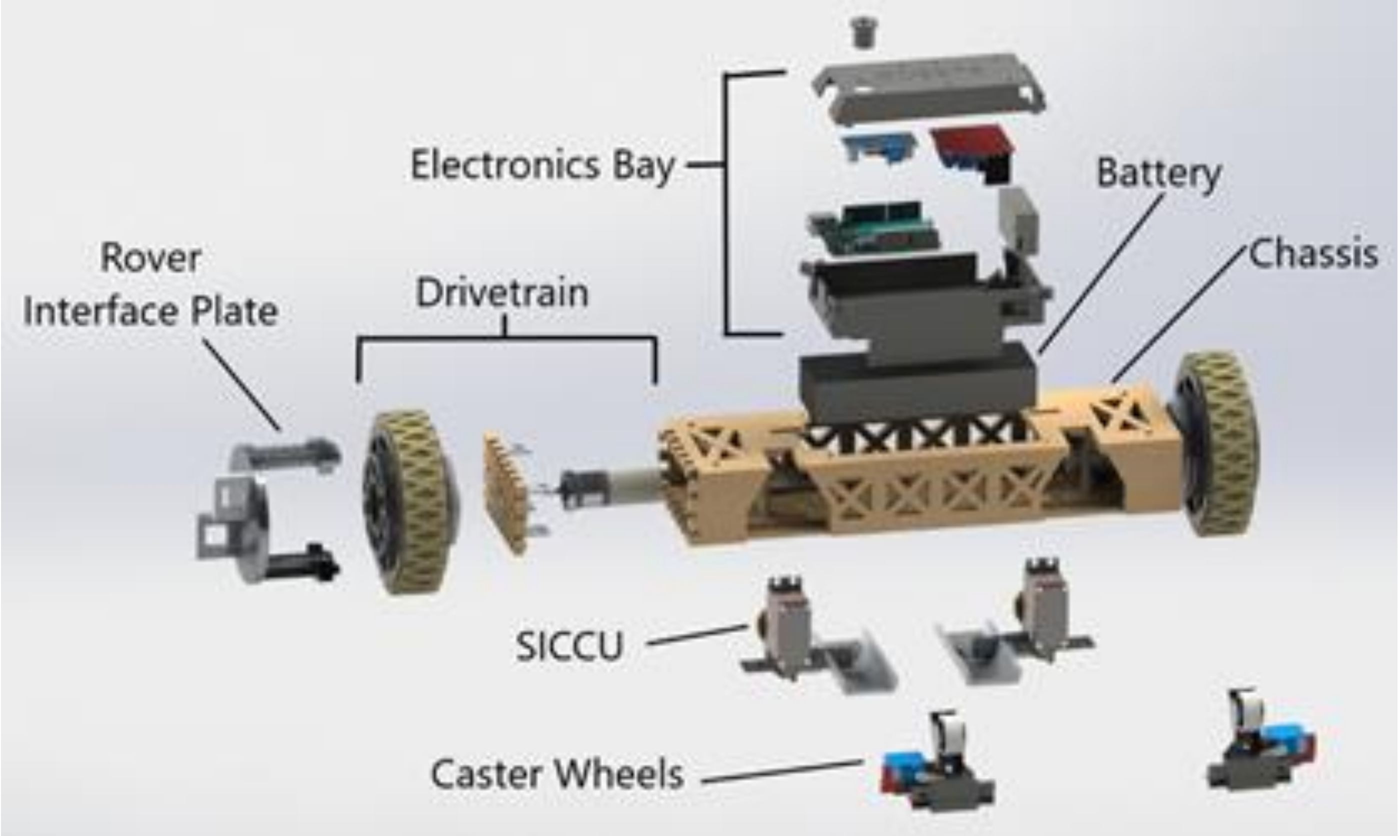




BURRITO Overview

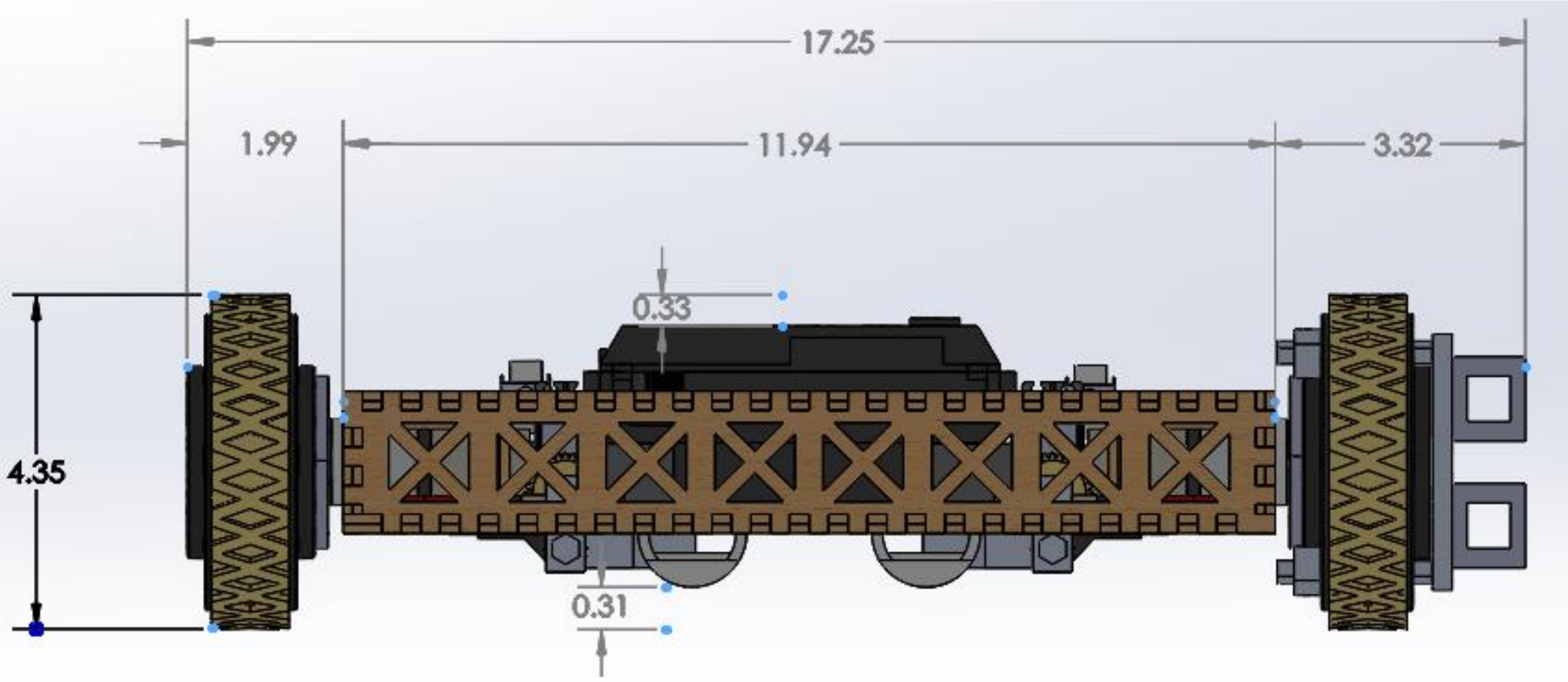
Notable Components:
- Chassis
- Electronics Bay
- Drivetrain
- Caster Wheels

Integration Systems:
- SICCU Servos
- Retention Plate



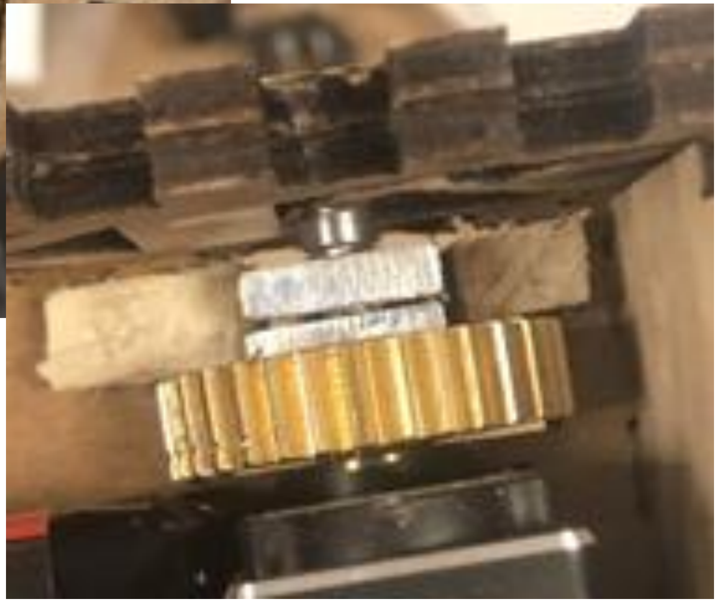
BURRITO Dimensions

Dimensions (in.)



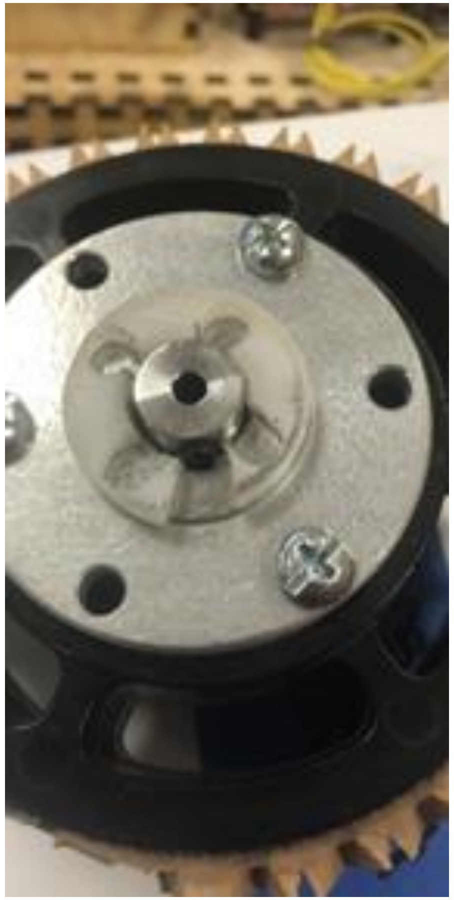
BURRITO Changes Since CDR

- Chassis Construction
  - Top: Removable upper plate
    - Top plate made removable so that interior could be accessed
    - Required adhering upward-pointing bolts to allow for fastening of plate
  - Bottom: Wood buffers
    - SICCU gear bracket needed larger hole cut; hole became oversized
    - Small L-shaped pieces were glued in place to prevent bracket movement



BURRITO Changes Since CDR

- Drivetrain Construction
  - Left: Motor Installation
    - Divot cut into axle to prevent wheel slipping
    - Holes for plate attachment bolts countersunk to allow wheel rotation
  - Right: Wheel Installation
    - Nylon washer drilled and sawed rather than laser cut
    - Base material was standard washer instead of raw material

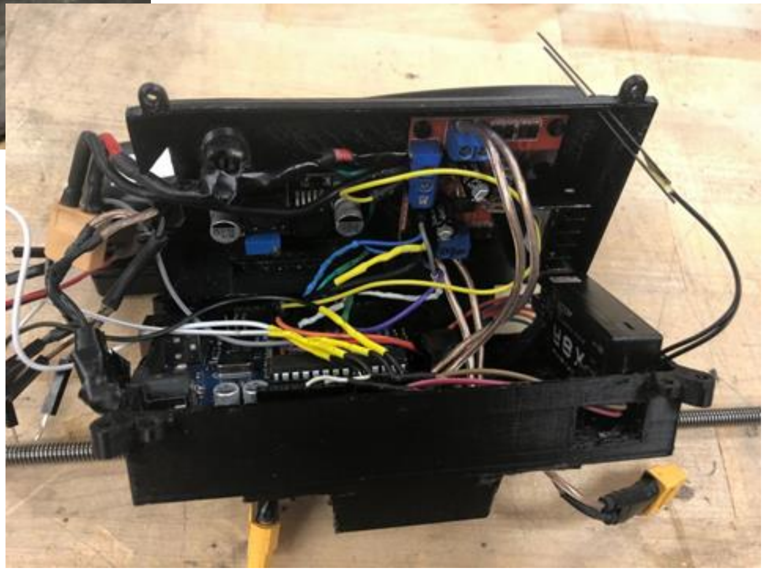


BURRITO Changes Since CDR

- Caster Wheel System
  - Top: Caster Deployment Servo
    - Added to prevent deployment inside of payload bay
    - 3D-printed support to adapt servo to existing chassis
  - Bottom: Caster Arm Assembly
    - Arm 3D printed to fit within drive wheel diameter and interface with caster deployment servo
    - Caster arms printed with dissovable supports

BURRITO Changes Since CDR

- Electronics Bay
  - Top: Lid Modifications
    - Added rotary switch for power toggling
    - Cut hole for power and signal wires to be routed
    - Raised for internal volume
  - Bottom: Inside Changes
    - Buck converter added for voltage regulation
    - Buck converter and motor driver attached to ceiling for internal volume



BURRITO Operational Tests

- Nominal Performance
  - Successful driving demo, ~4 mph
- Terrain Performance
  - Capable of driving in dirt, gravel, mud, grass, simulated ice
- Inclined/Declined Slopes
  - High torque able to summit slopes, no tipping forward or backward

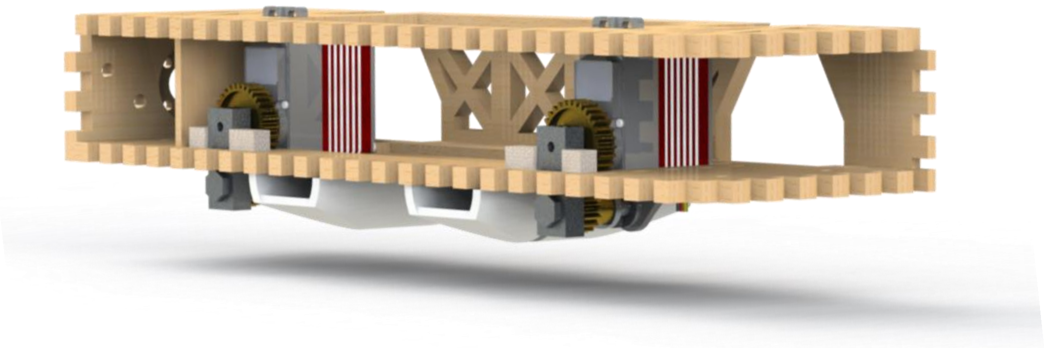
BURRITO Operational Tests

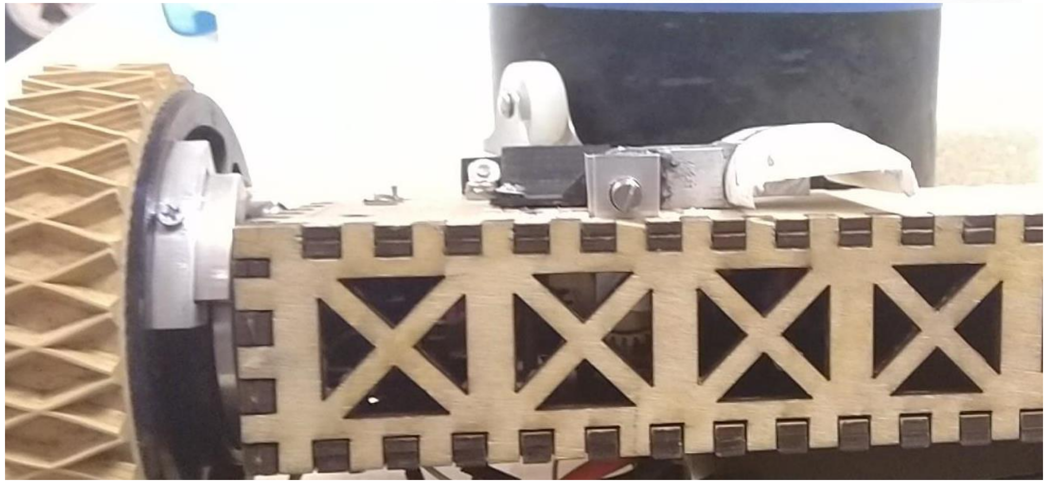
- Reorientation
  - Can return to upright position from both "nose-down" and upside-down positions
- Control Range
  - Radio control well beyond 15 ft
- Driving Range
  - Well above estimated maximum of 2550 ft

SICCU Overview

Notable Components:

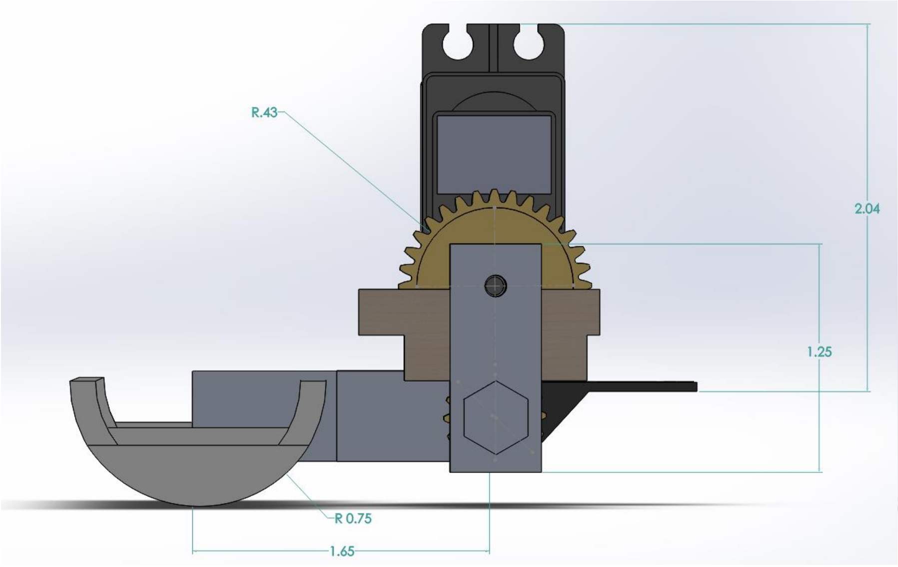
- Internal Servo
- 2-Member Gear Train
- Aluminum Brace
- Aluminum Arms
- PLA Retention Cover
- Formed and Chamfered Scoops

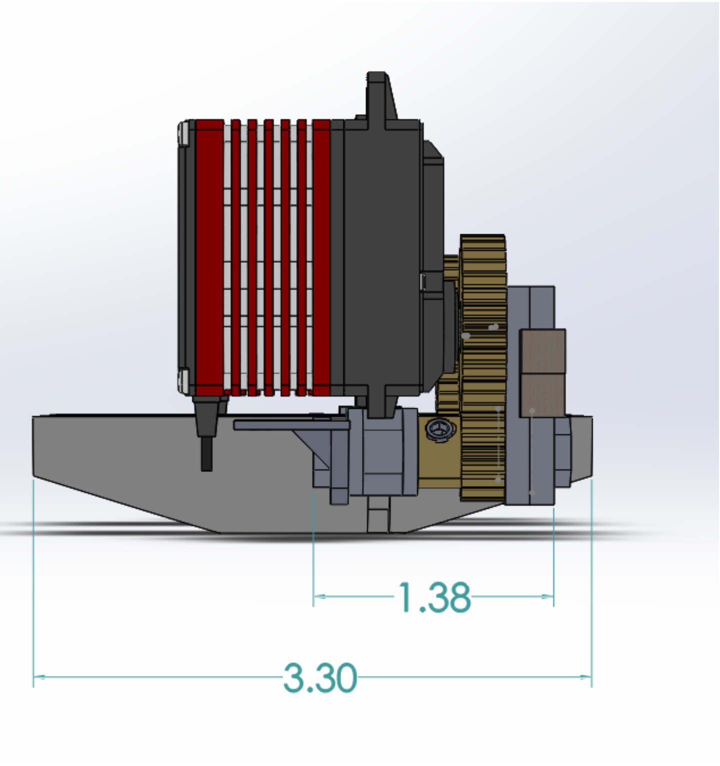




SICCU Dimensions

- Top of the Servo to Below Cover: 2.04”
- Aluminum Brace Length: 1.25”
- Arm Length: 1.65”





SICCU Changes Since CDR

- Profile of scoops reduced
- Gear diameter on arm reduced
- Changes driven by geometric constraints
  - Old design hindered BURRITO's maneuvering capabilities
  - Prevented deployment from payload bay

SICCU Operational Test

- Uncooked rice used as lunar ice simulate
- Each Scoop held 20 mL of rice under ideal conditions

Payload Integration Design

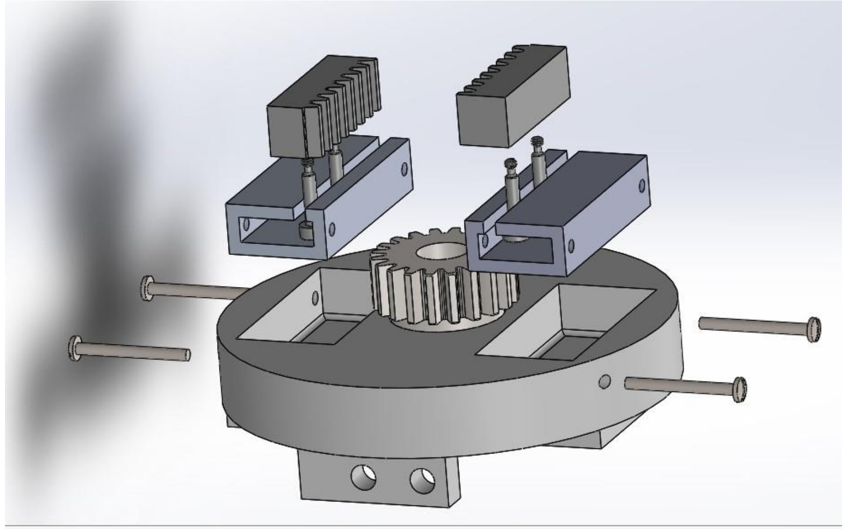
Payload Retention

Payload Deployment

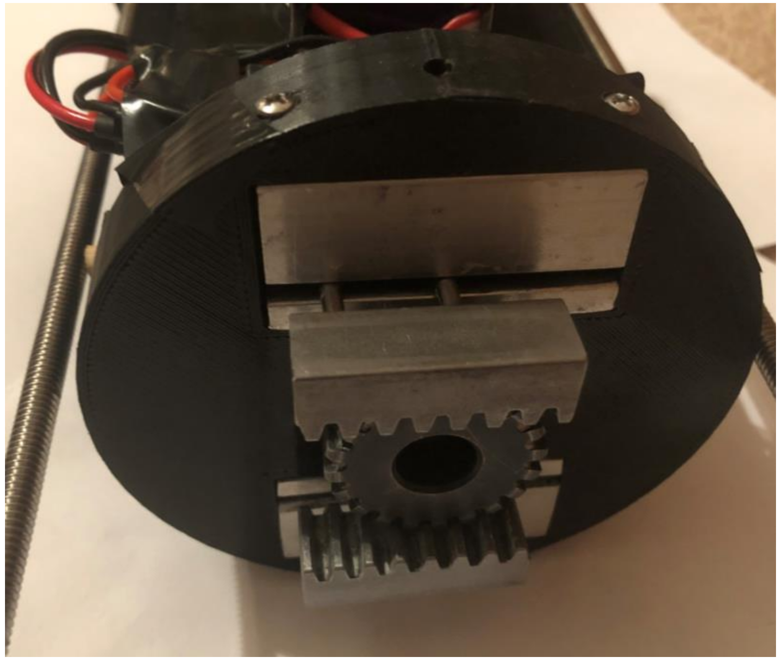
Test Results

Retention Plate Components

Finalized CAD



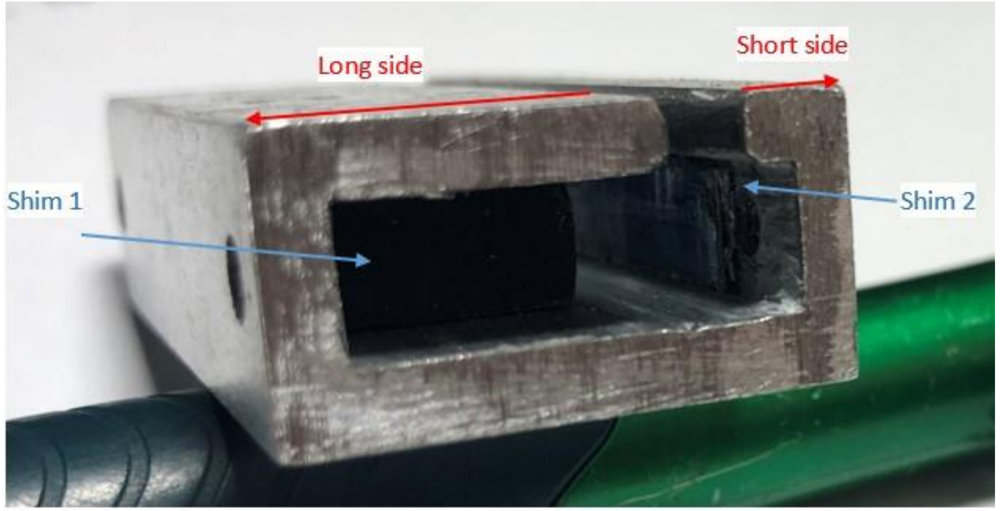
Manufactured



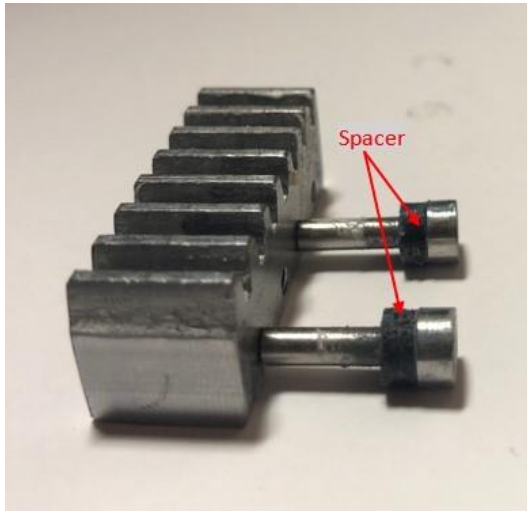
Retention Plate Modifications

- Small excess of tolerances within the guide track slot allowed for too much movement between the rover interface plate and the retention plate.

- Shims to eliminate rotation within track
  - Shim1 -3D printed
  - Shim2 – Two thin aluminum sheets



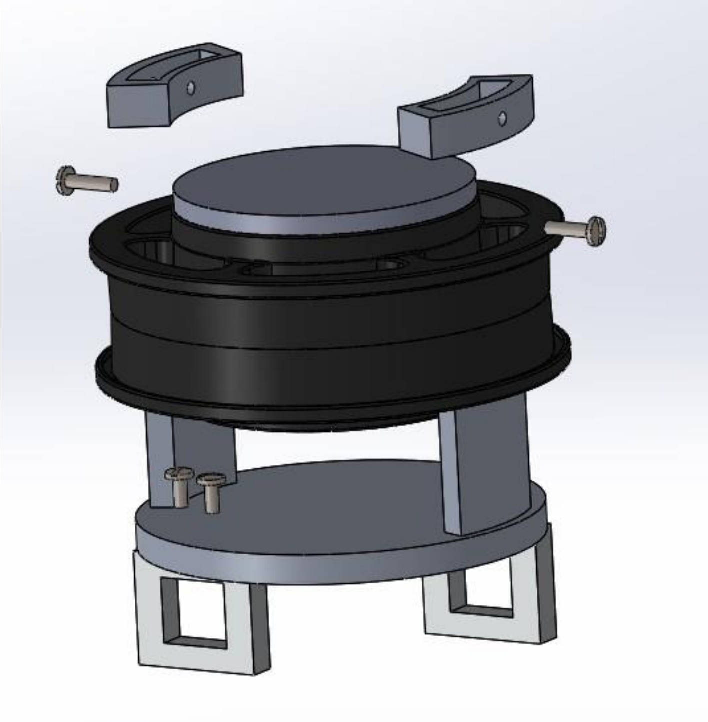
- Spacers to eliminate vertical motion within track
  - 3d printed spacers to fit height of inner channel



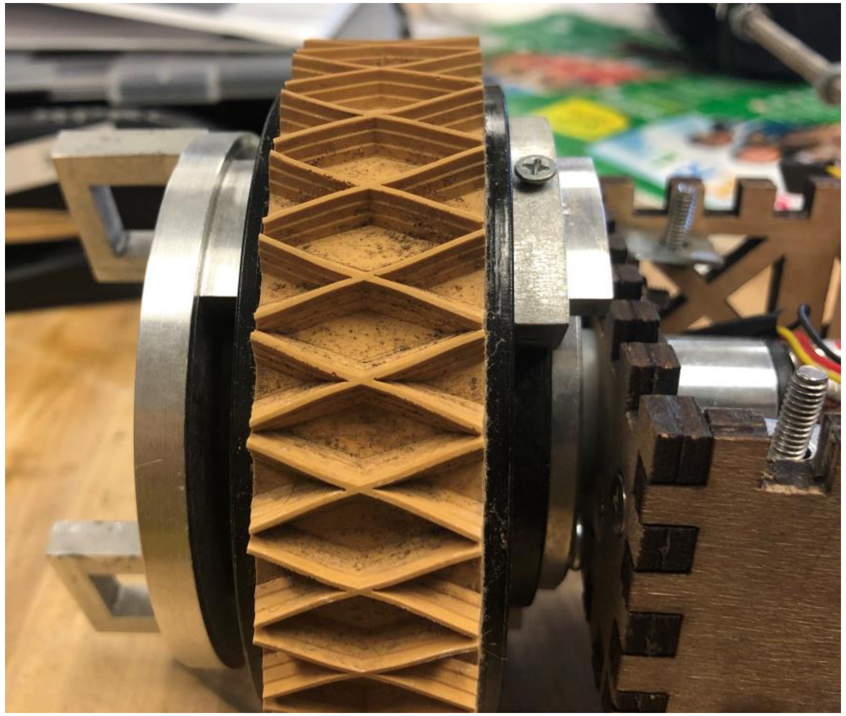
Rover Interface Plate

- All components for the rover interface plate were machined at the NCSU MAE Machine Shop. No modifications were required.

Finalized CAD

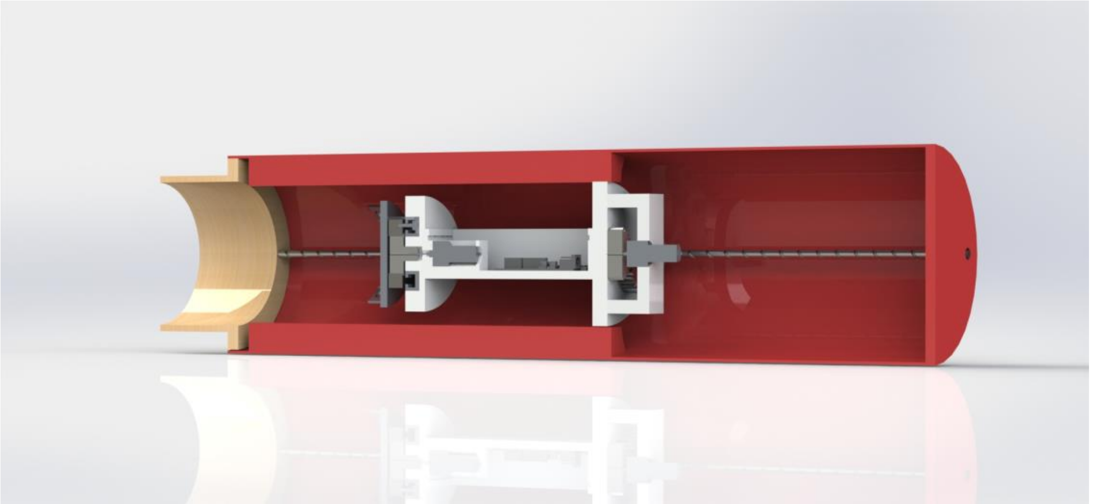


Manufactured



Radial Supports

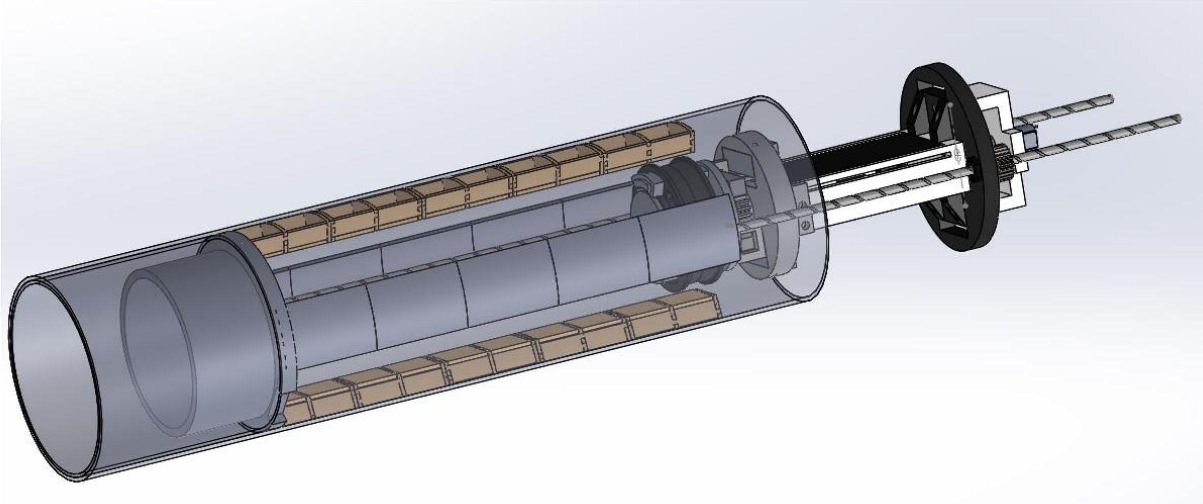
Initial Design



Problems:

- If landing orientation of lead screws is vertical
  - No supports causing flexing of lead screws
  - Failure to deploy

Finalized Design

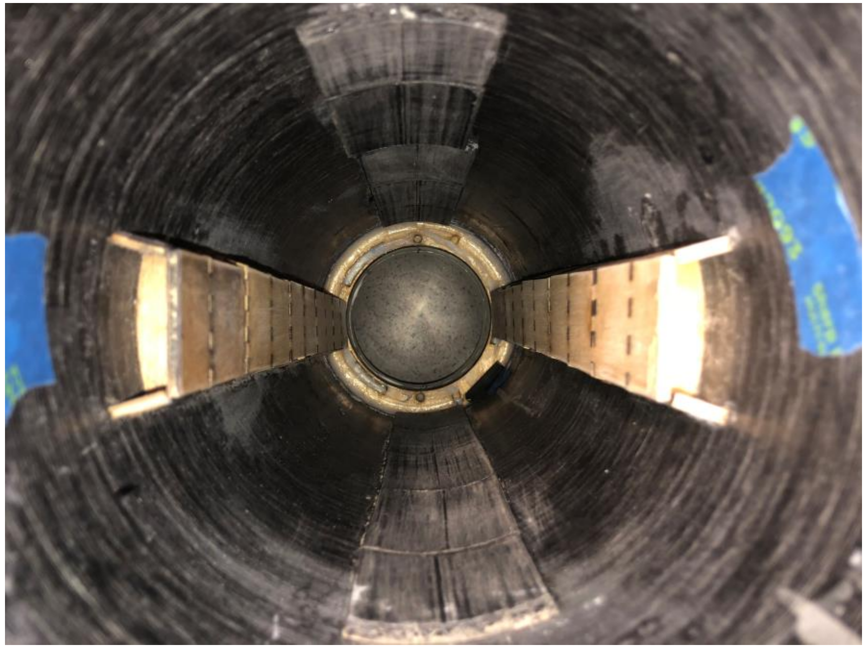


Solutions:

- Add supports at every 90-degree orientation
  - Supports driving plate
    - Minimizes lead screw flexing
  - Successful deployment

Manufactured Supports

Radial Supports

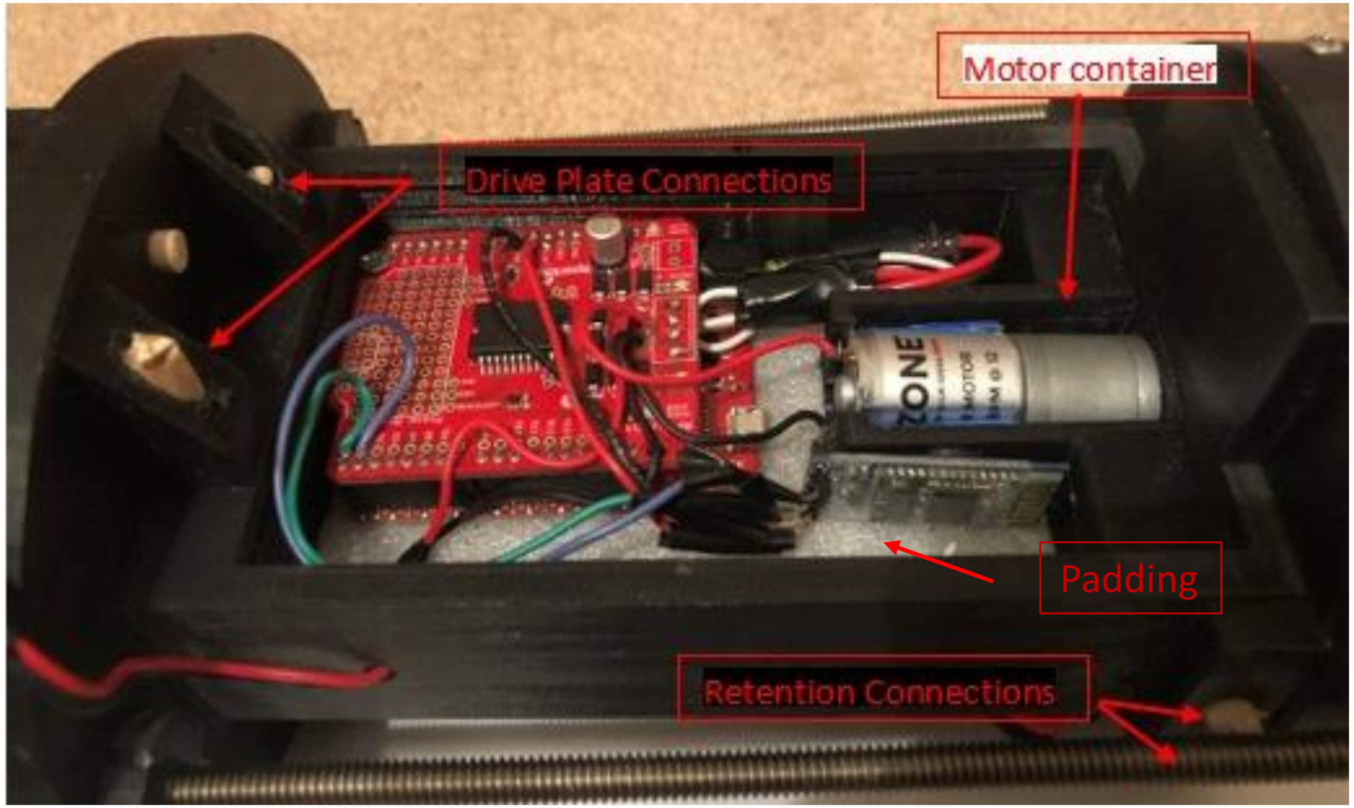


- Radial Supports every 90 degrees support integration system and rover regardless of landing orientation

Centering Ring and PVC Extrusion

- Enough clearance to avoid excess friction
- Tolerances small enough to adequately stifle radial motion

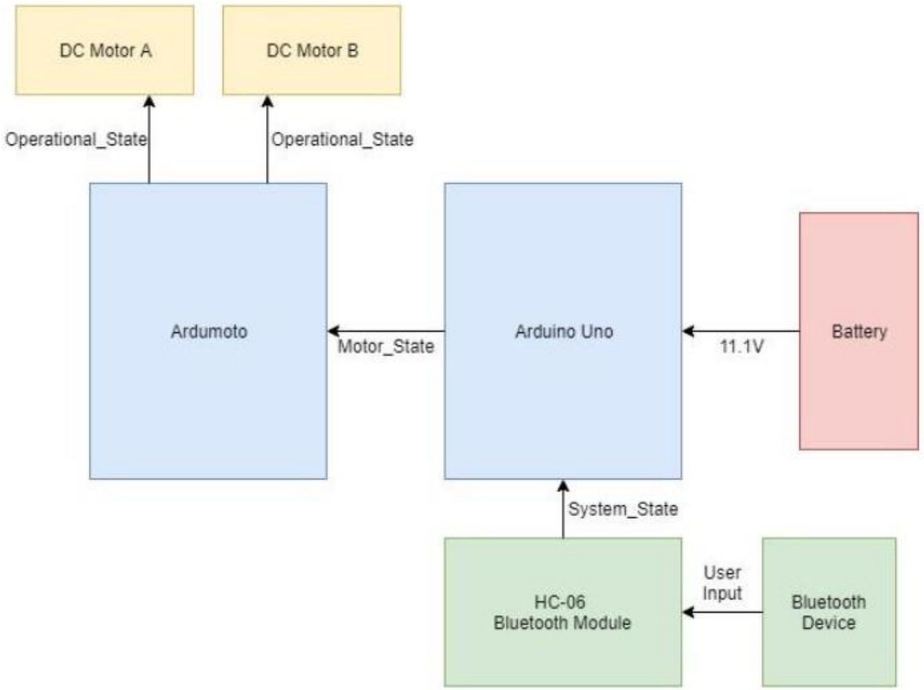
Electronics Bay



- All components soldered to Ardumoto motor shield as seen.
- Layer of padding implemented to cushion electronics during flight
- Two, quarter inch dowel rods used to connect drive plate to E-Bay
- Four, quarter inch dowel rods connect retention plate to E-Bay
- Shims used to restrain retention motor and components are super glued to the E-Bay

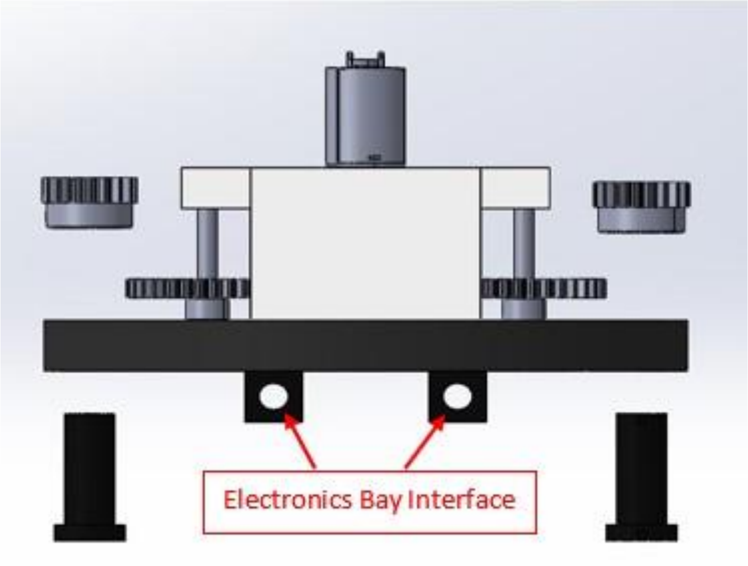
Logic and Software

- Once connected to the Bluetooth module within BLE Terminal
  - Send serial inputs (0-5) to operate independent motors operational states
- Software GUI records transmissions (outputs)
- Sparkfun Redboard paired with HC-06 module transmits back the operational state

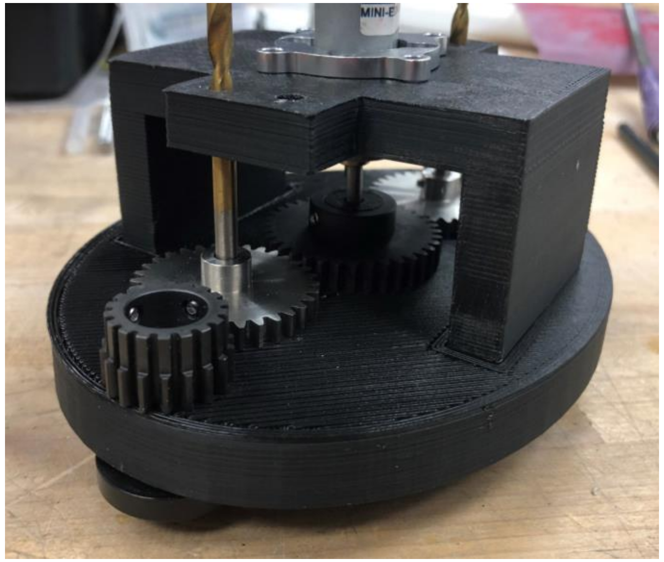


Drive Plate

Finalized CAD



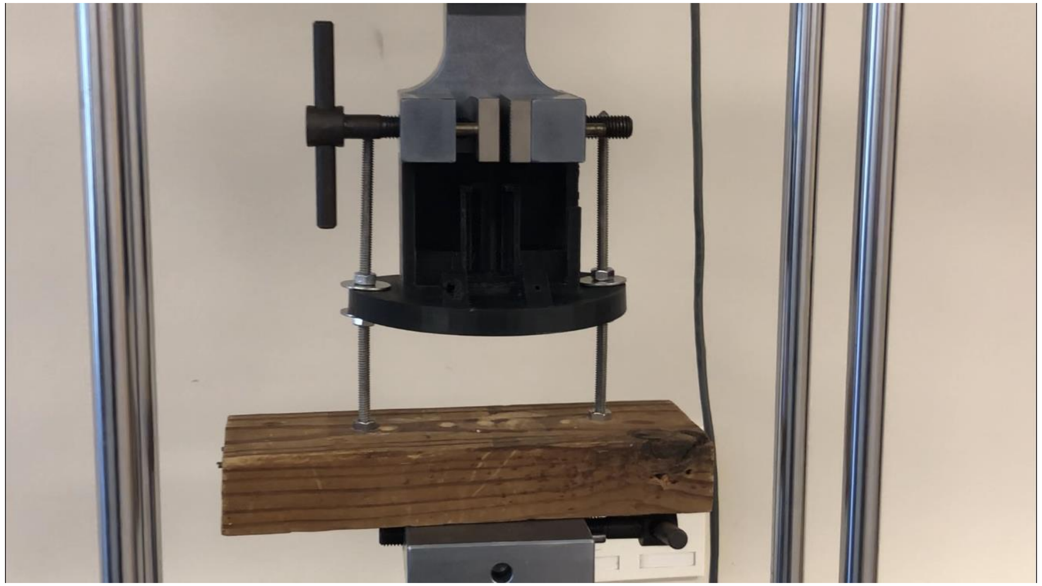
Manufactured



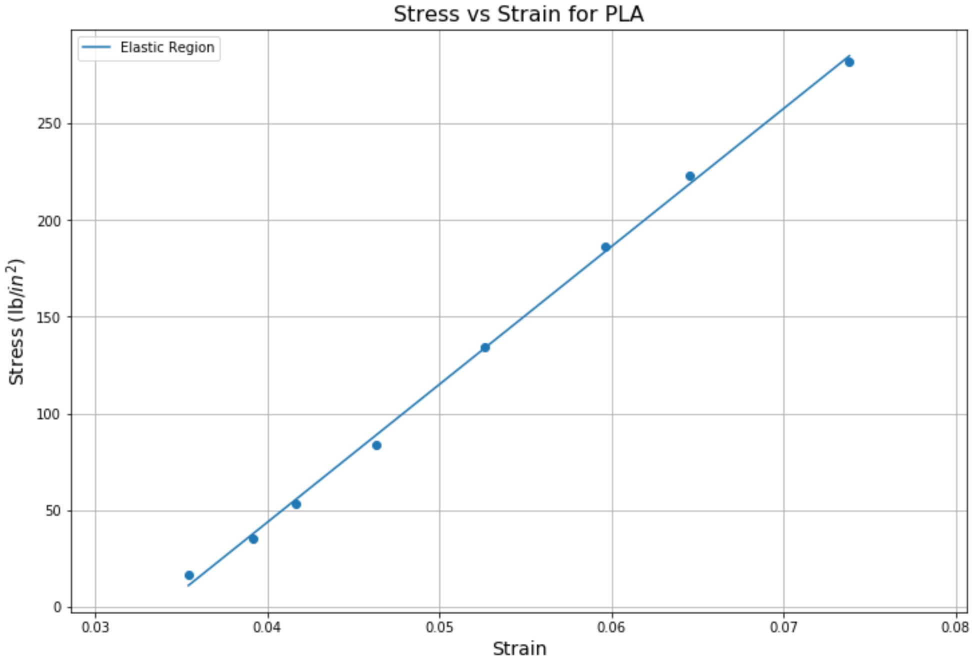
- External gears mounted by set screws into the nuts hub
- Mid gears mounted by a trimmed drill bit super glued into the motor table and into a small hole in the drive plate
- Drive gear mounted by set screws connecting the gear to the motor shaft

Retention Testing: PLA Structure

PLA Testing

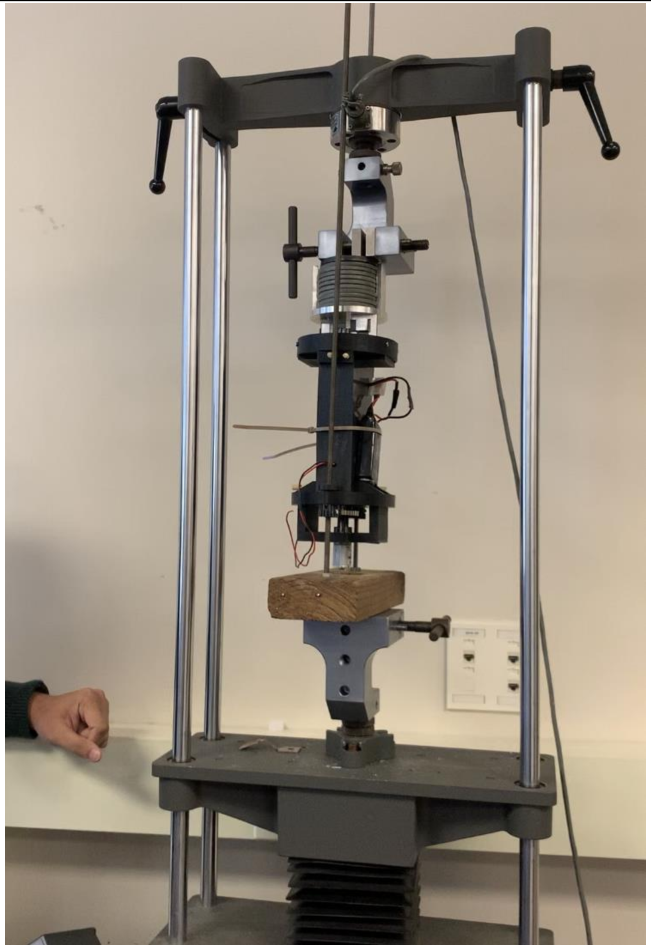


Results



- PLA Youngs Modulus: $2175\frac{lb}{in^2}$
- Yield Strength: $473\ \frac{lb}{in^2}$ (Failed at 710 lbf)

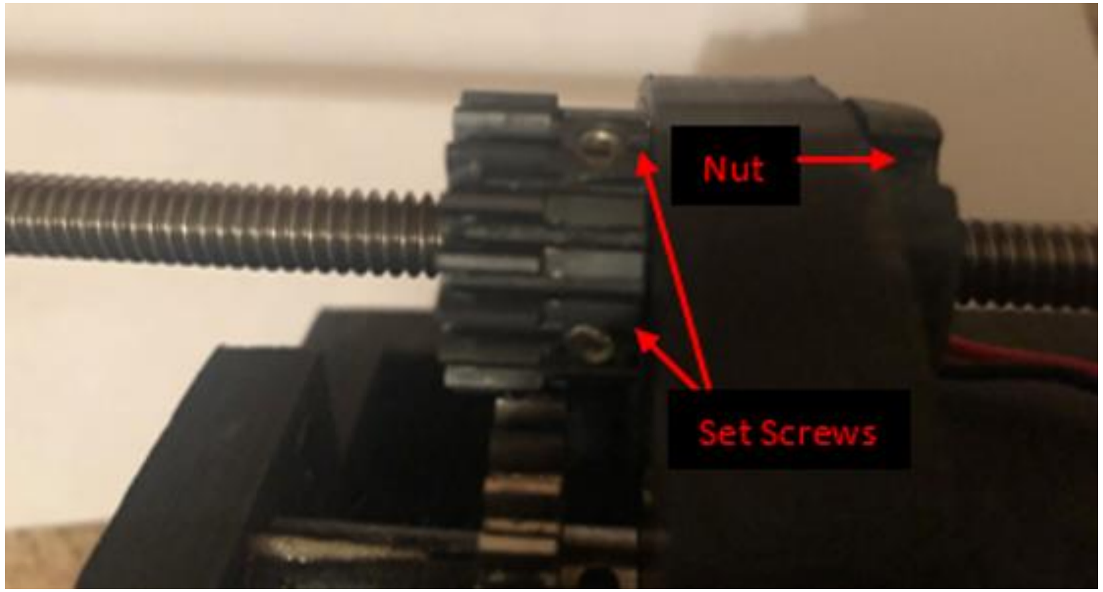
Retention Testing: Full Assembly



- Initial continuous loading to 200 lbf in compression
- Increments of 20lbf added until 360lbf reached
- Failure at 380lbf
- Offers a safety factor of 1.9

Retention Testing: Failure Point

Failure Point



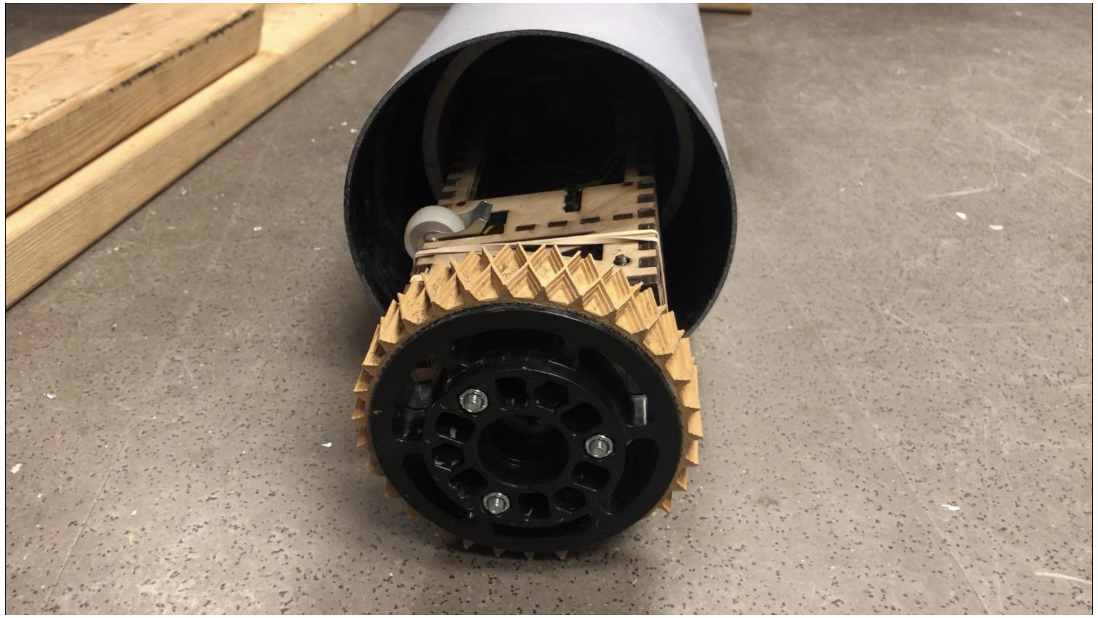
Results and modifications

- <u>No damage to structure</u>
- Failure during the full assembly was result of the drive net separating from main plate.
- Second set screw has been implemented, doubling the holding potential

Deployment Testing

Flight orientation

Deployment Process



Final Modifications:

- Problem: External Gears extruded past drive plate and were interfered with by radial supports
- Solution: Applied Bondo to widen drive plate and sanded new radial supports.

Deployment Process

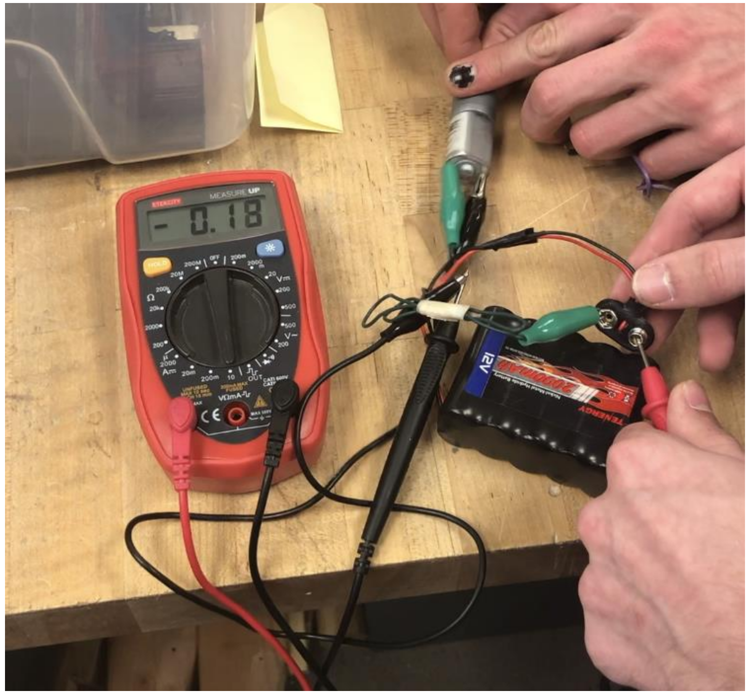
- From the deployment tests, it was determined that unlocking the rover post deployment introduces cantilever effects too large for the motor to overcome.

Process:

1. Initiate deployment
2. Halt deployment half-way
3. unlock rover
    1. Rover is still supported by radial supports at this location
4. Proceed with deployment until rover is free.

Electronics Testing

Testing



Results and modifications

Peripheral	Measured Current	Manufacturer Current
Retention Motor	0.36A	2A
Drive Motor	0.18A	2A
HC-06	Pairing: 0.038A Paired: 0.017A	Pairing: 0.04A Paired: 0.02A
Sparkfun Redboard	.927A	Comparable to Arduino Uno: 1A

- All measured values were under manufactured values
  - Expected result as maximum values were used in preliminary calculations
- Note: Redboard current measured with drive motor active and the results will vary dependent on which peripherals are active
- While unnecessary, the team has opted to switch to a 1500 mAh battery that will be capable of running electronics for over a 12 hour period

Requirement Verification

Compliance Plan Status

Launch Vehicle Requirements

Payload Requirements

Compliance Plan Status

- Requirements Verified
  - NASA Handbook Requirements: 131/131 (100%)
  - Team Derived Requirements: 40/40 (100%)
- All testing and demonstrations events have been completed for both Payload and Launch vehicle
- The Launch Vehicle and Payload are compliant with all requirements and are mission ready

Launch Vehicle Requirements

- The launch Vehicle shall not drift more than a 2,500 ft radius from the launch pad (NASA 3.10)
  - Complete. During the Launch Vehicle Demonstration Flight, the onboard GPS recorded a drift distance of approx. 1200ft
- The launch vehicle shall have a static stability margin between 2.0 and 2.3 upon rail exit (TDR 2.5)
  - Complete. Verified by RockSim analysis
- All critical components of the launch vehicle shall be designed with a minimum safety factor of 1.5 (TDR 2.7)
  - Complete. All points passing

Payload Requirements

- The payload retention system shall be designed to successfully endure flight forces (NASA 4.3.7.2)
  - Complete. Tested during Retention System Loading Test; all points passing
- The payload shall recover a lunar ice sample of a minimum of 10 milliliters (NASA 4.3.3)
  - Complete. Verified via SICCU Operational Test; all points passing
- The payload vehicle shall cover a range of at least 2000 feet (TDR 4.3)
  - Complete. Verified via BURRITO Range Test; all points passing

Questions?