Critical Design Review

January 17, 2020

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Payload Vehicle:
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Payload Integration:
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Underclassmen Representative:
Frances McBride

Presentation Overview

- Full-Scale Launch Vehicle Design
- Subscale Flight Results
- Mission Performance Predications
- Recovery Subsystem Design
- Payload Design
- Payload Integration Design
- Test Plans
- Requirement Compliance Plan

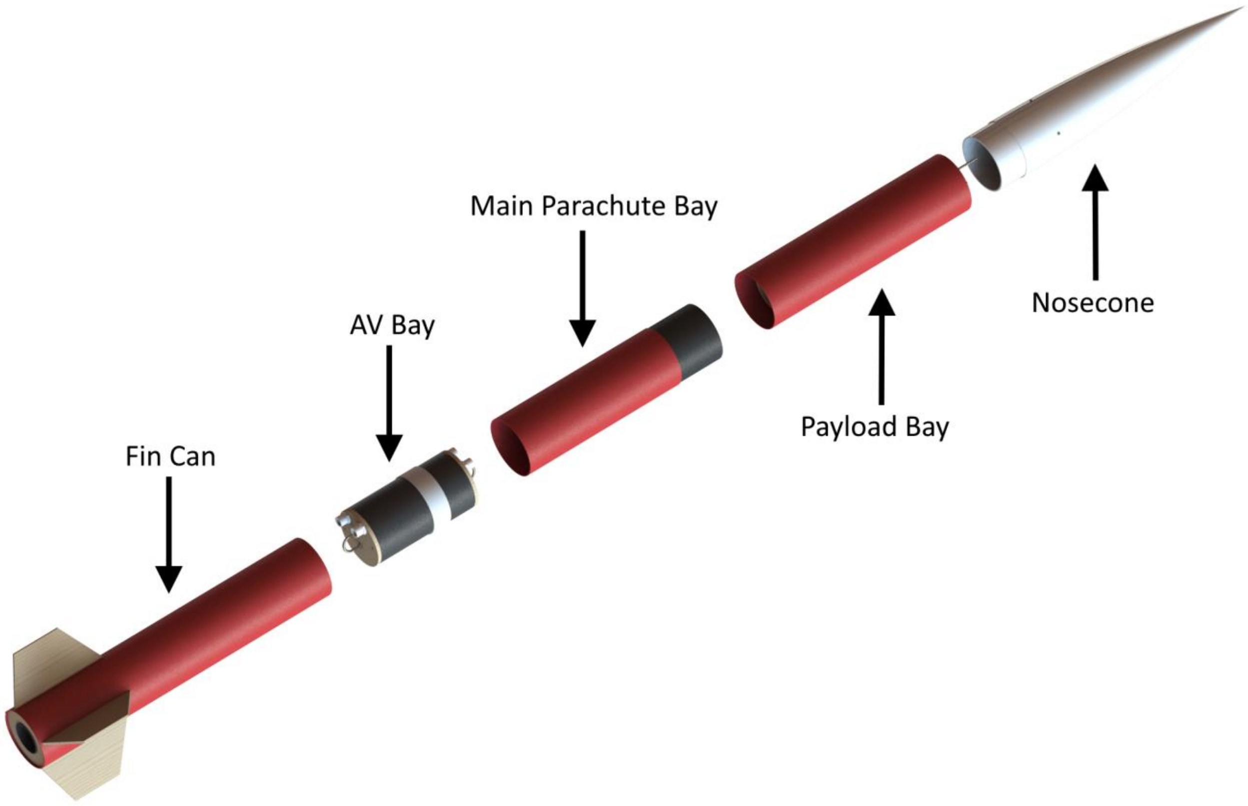
Launch Vehicle Design

Dimensions

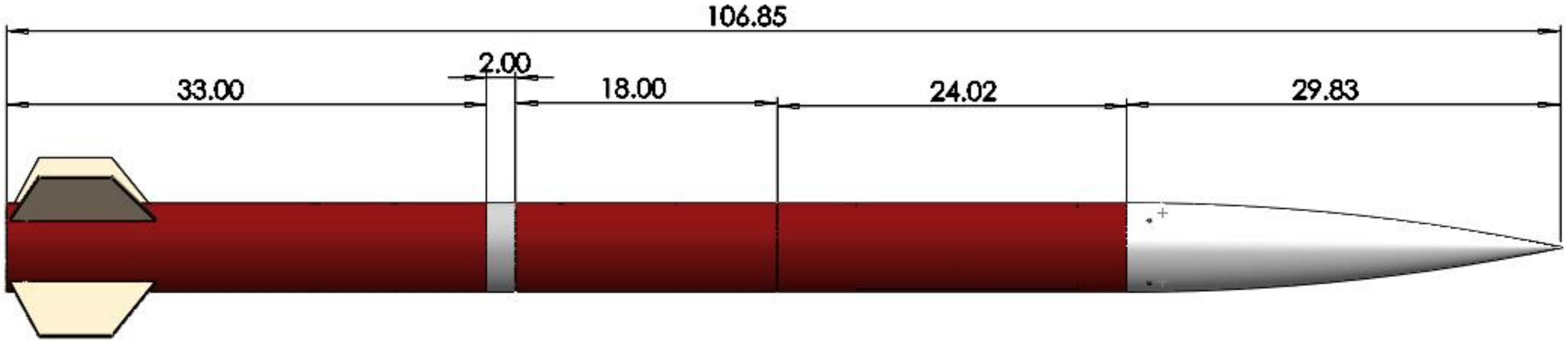
Design Features

Motor Selection

Launch Vehicle

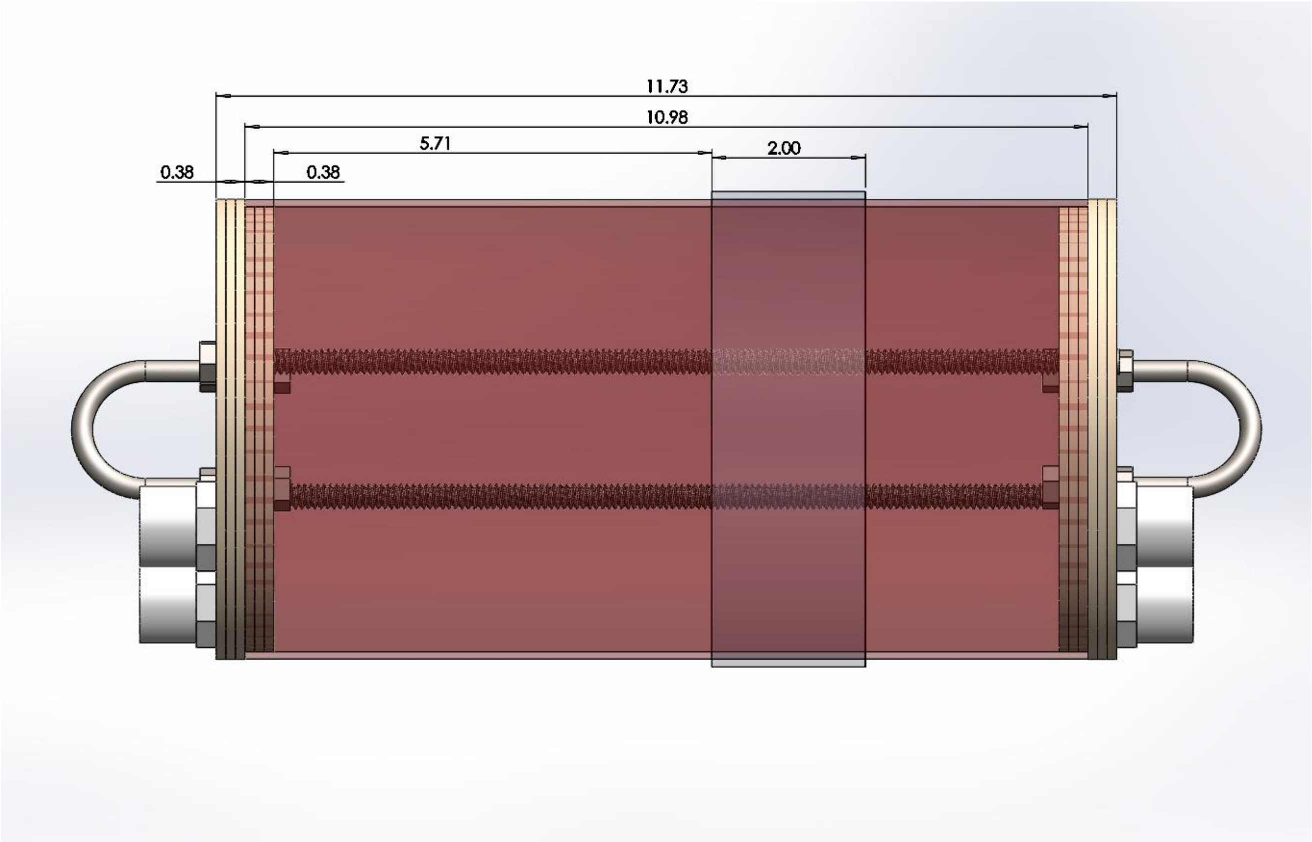


Launch Vehicle

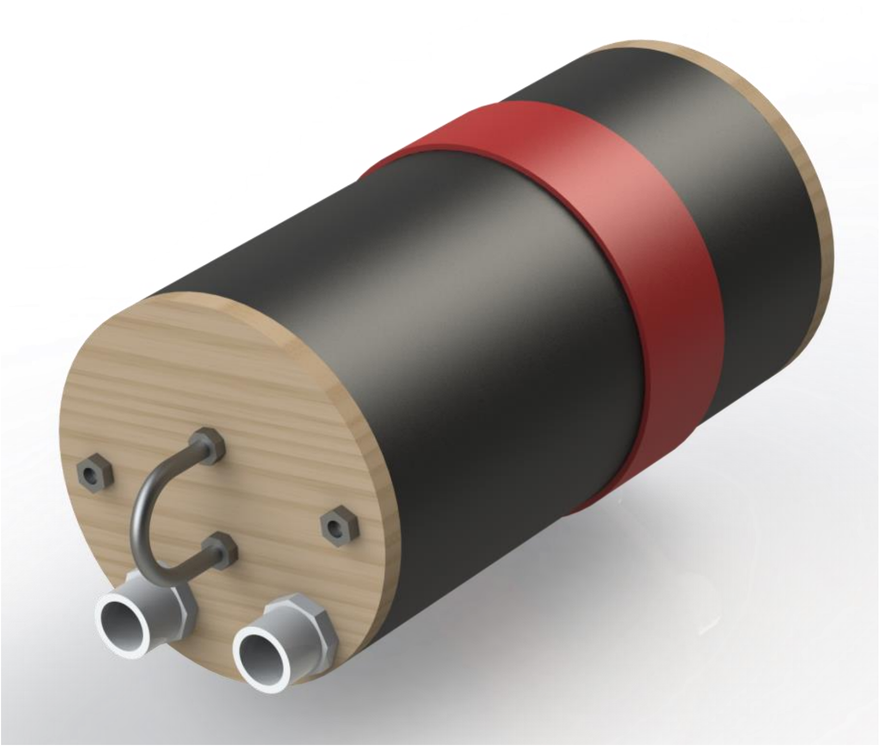


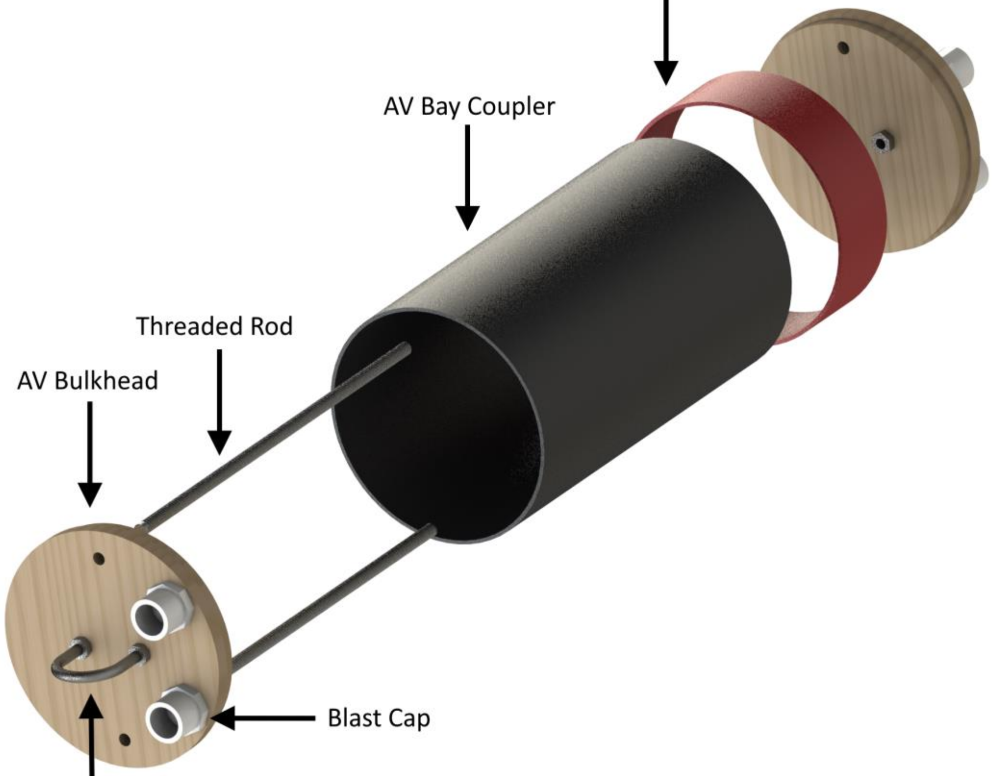
Avionics Bay

- Modular AV Bay
- Allows for the removal of the AV Bay during construction
  - Allows for faster preparation on launch day
- Blast caps are easily accessed
  - Allows for safer management of energetics
- Exposed wiring labels
  - Less chance of error



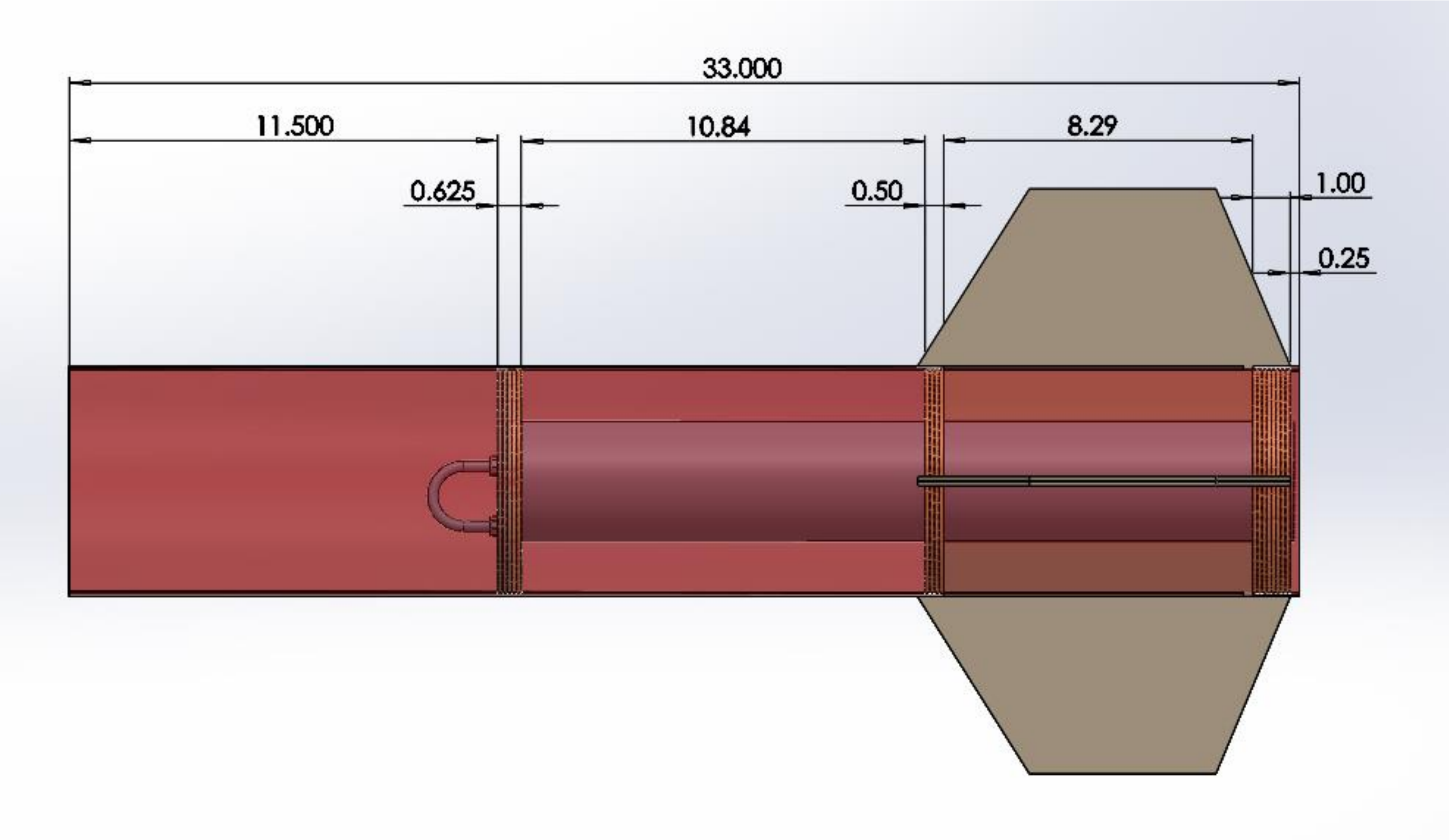
Avionics Bay



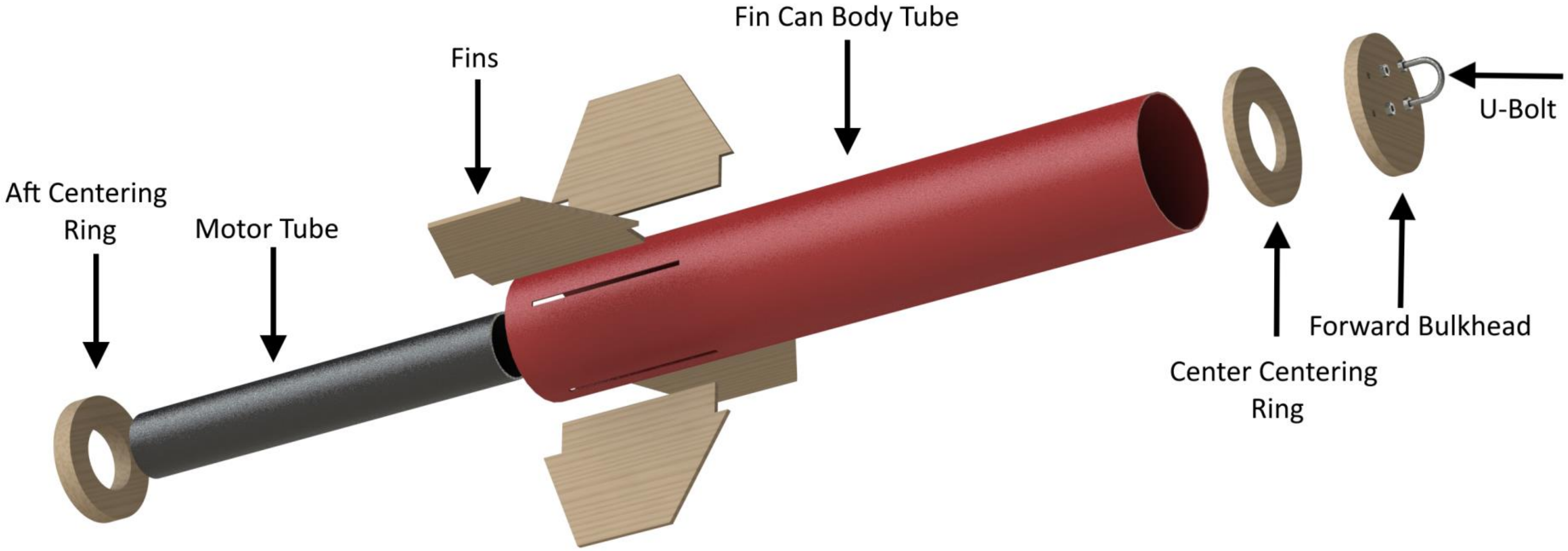


Fin Can

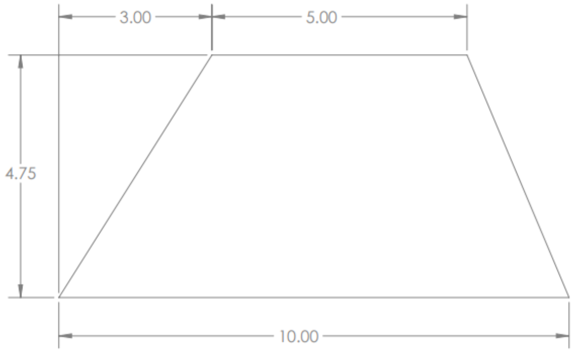
- Motor tube is held in place by a bulkhead and two centering rings
- This is to ensure that the motor tube is properly secured
- Since PDR, the drogue chute bay was extended to house a larger drogue chute



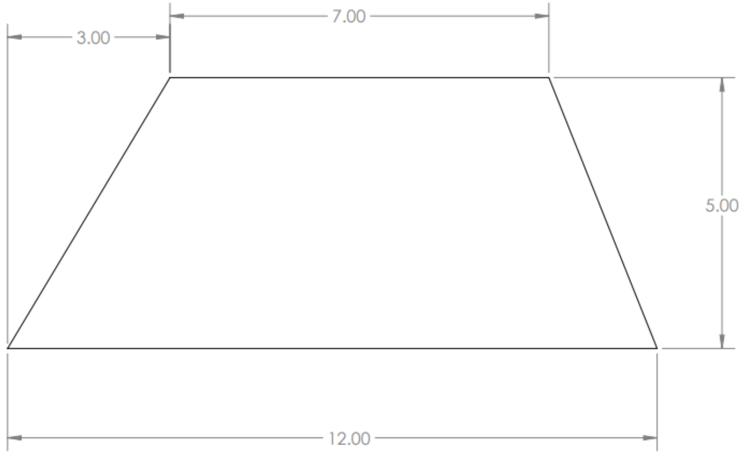
Fin Can


Fin Can Body Tube
Fins
U-Bolt
Aft Centering
Ring
Motor Tube
Forward Bulkhead
Center Centering
Ring

Fin Planform Area



PDR

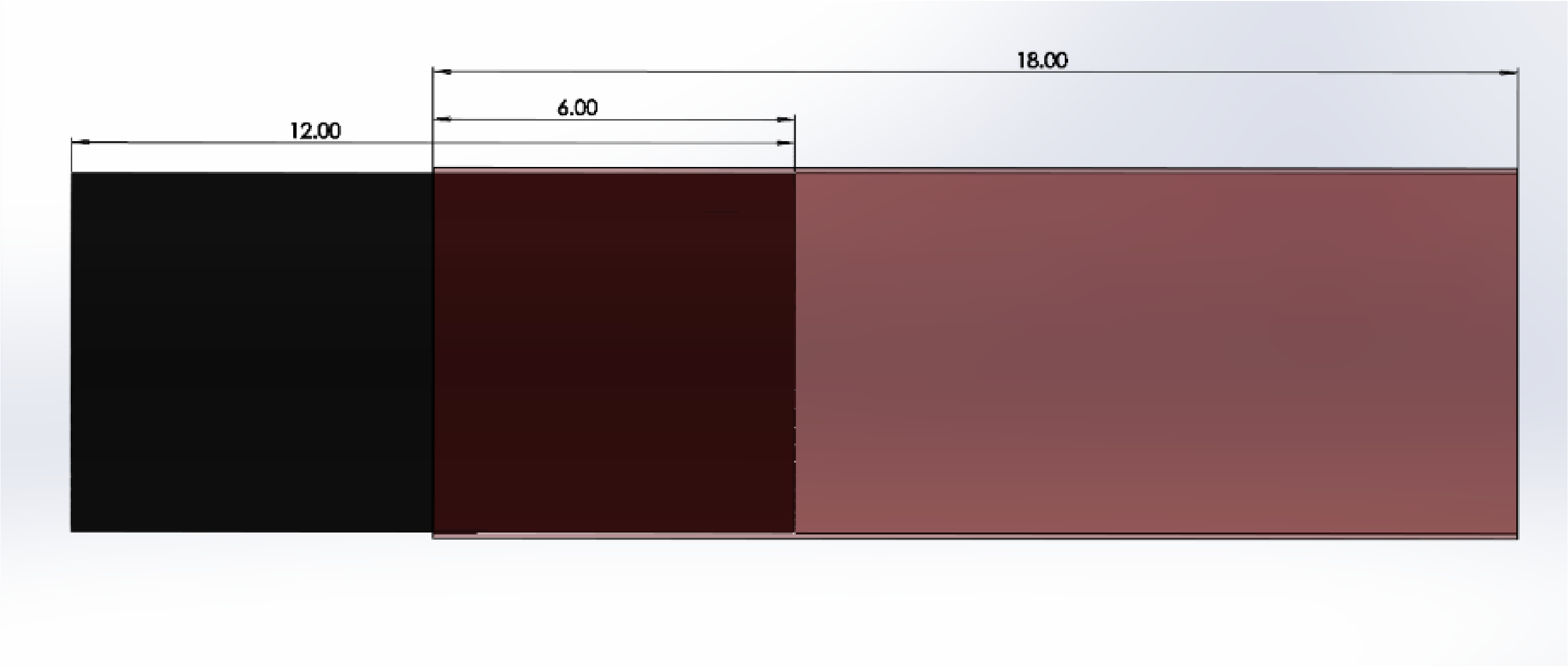


CDR

33% increase to fin planform area

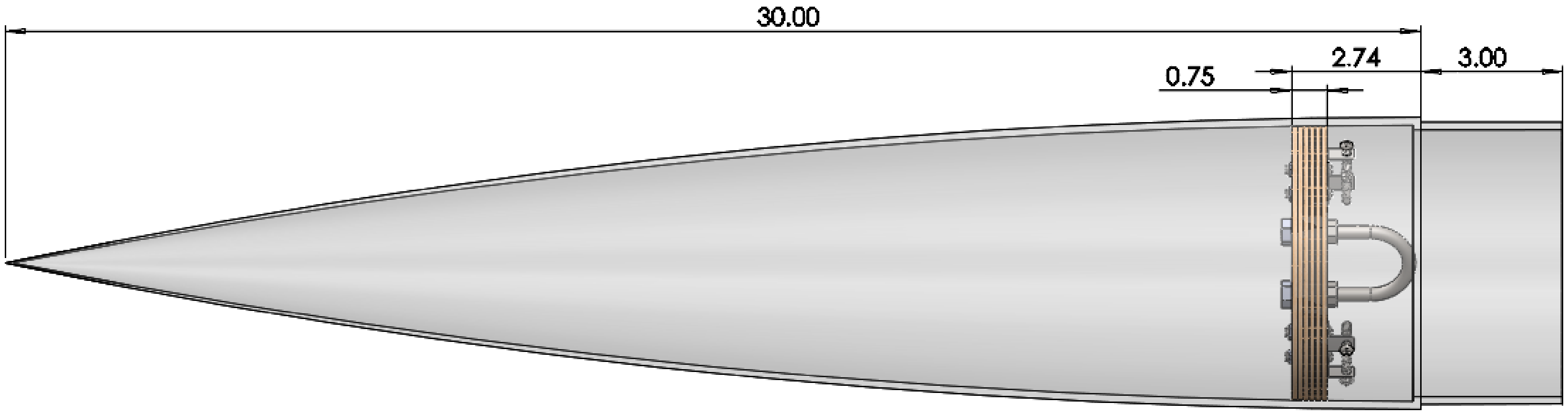
Main Parachute Bay

- AV bay attached by screws on aft end
- Attached after ejection charges are assembled
- Shortened by 2 inches from PDR to allocate to drogue bay

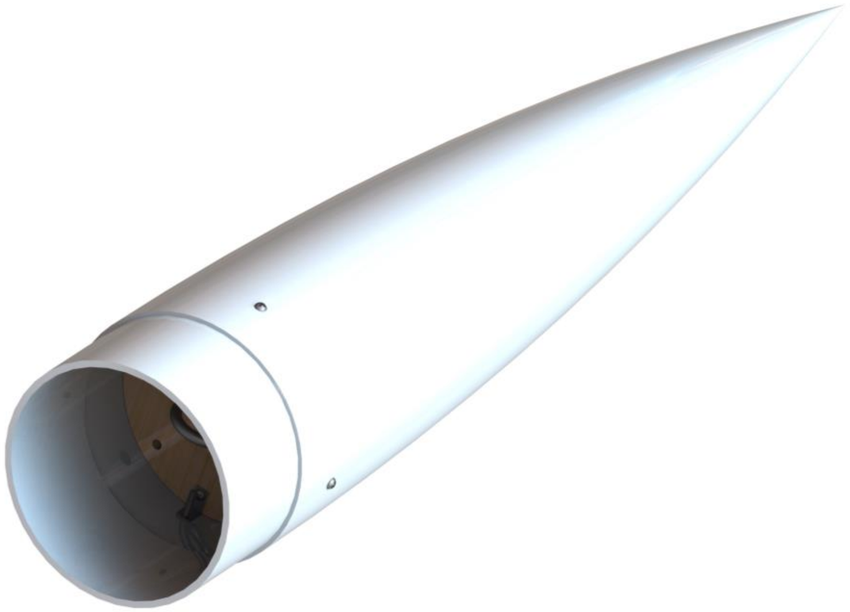


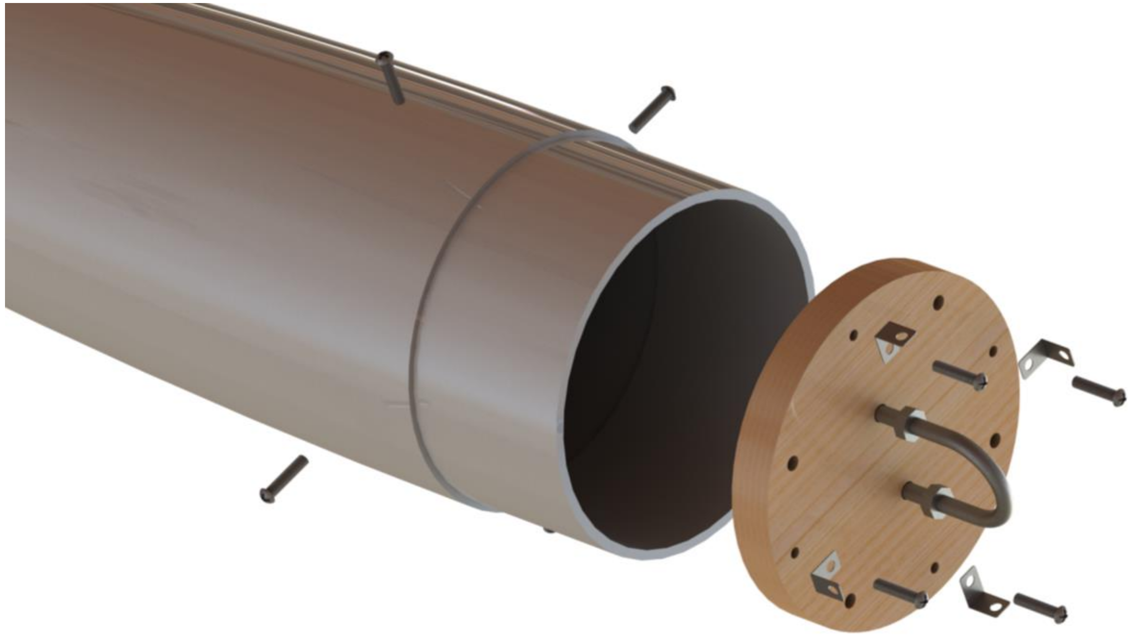
Nosecone

- 5:1 Ogive
- Commercially Available
- Priced within budget
- Removable Bulkhead
  - Allows for the addition and removal of ballast
  - Allows for correction in CG and thus stability margin



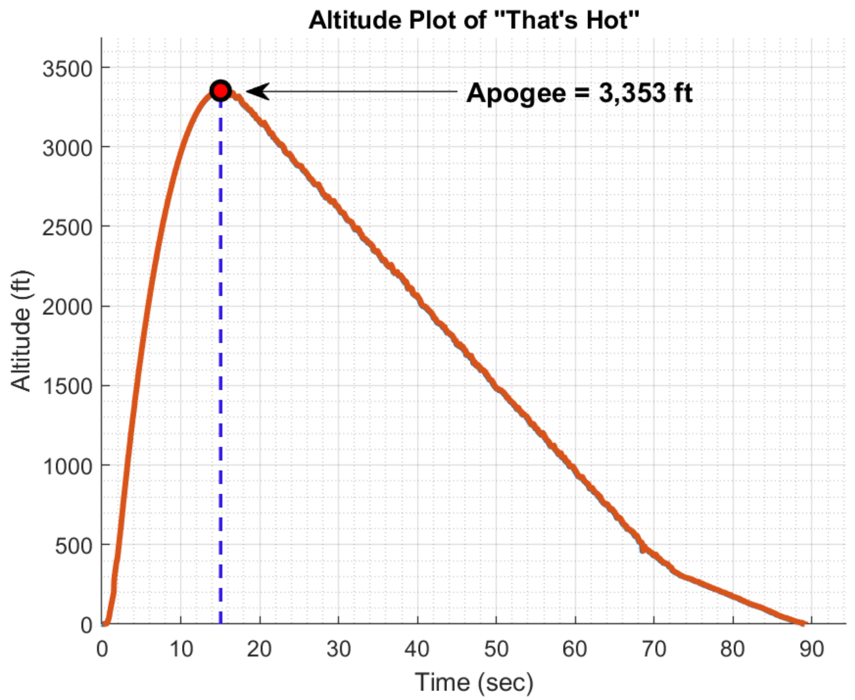
Nosecone

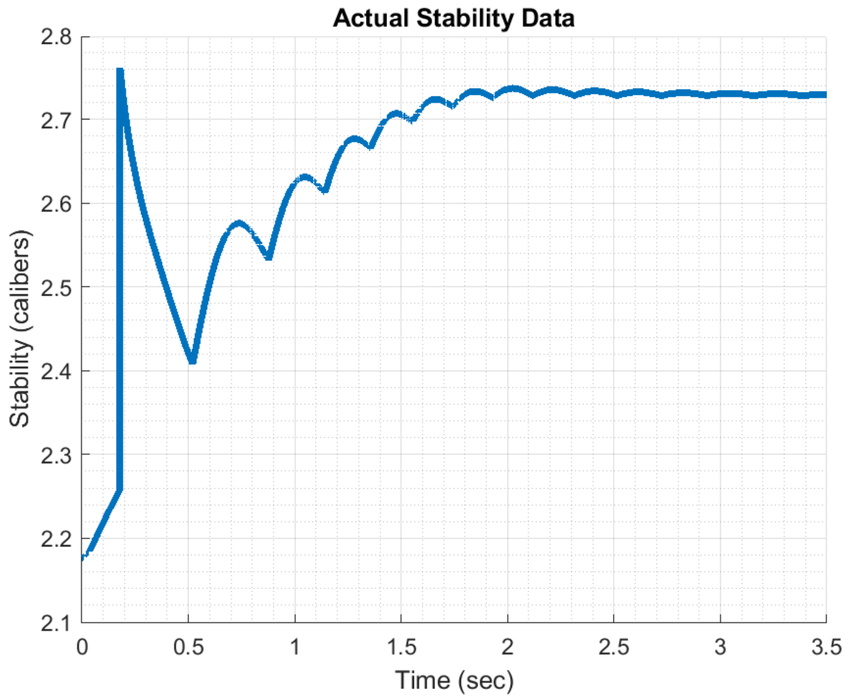




Subscale Flight Results

Subscale Flight Performance





Mission Performance Predictions

Stability Margin

Target Altitude

Kinetic Energy

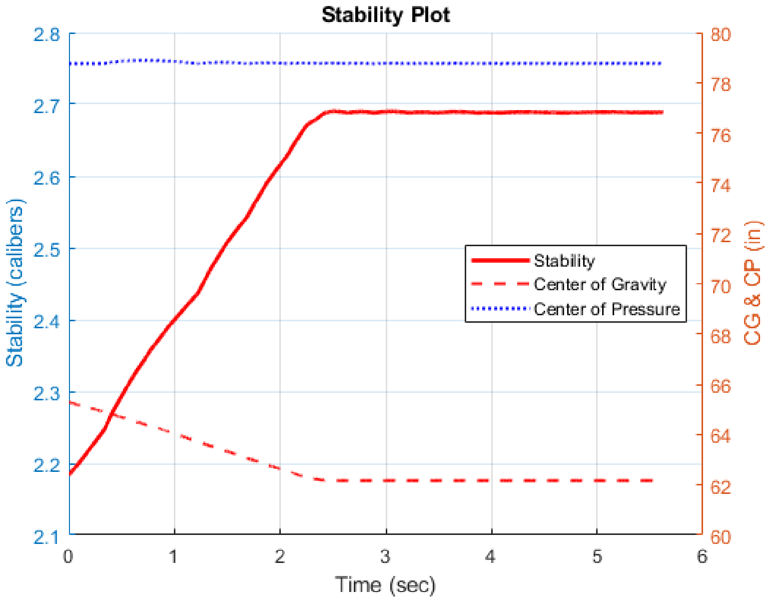
Drift/Descent Rate

Critical Flight Data

Vehicle State	Stability	Total Velocity (ft/s)
On Rail	2.18	0.0
Rail Exit	2.26	83.5
Motor Burnout	2.69	556.4

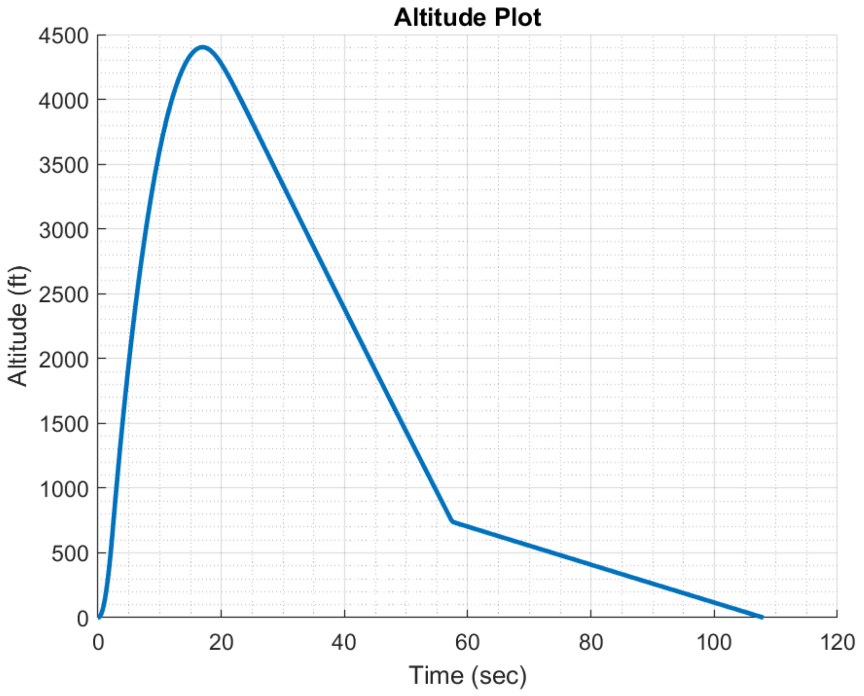
- **Requirements**

NASA 2.14	Stability Margin of 2.0 at rail exit
NASA 2.16	Minimum velocity of 52 ft/s at rail exit
NASA 2.22.7	Vehicle will not exceed Mach 1



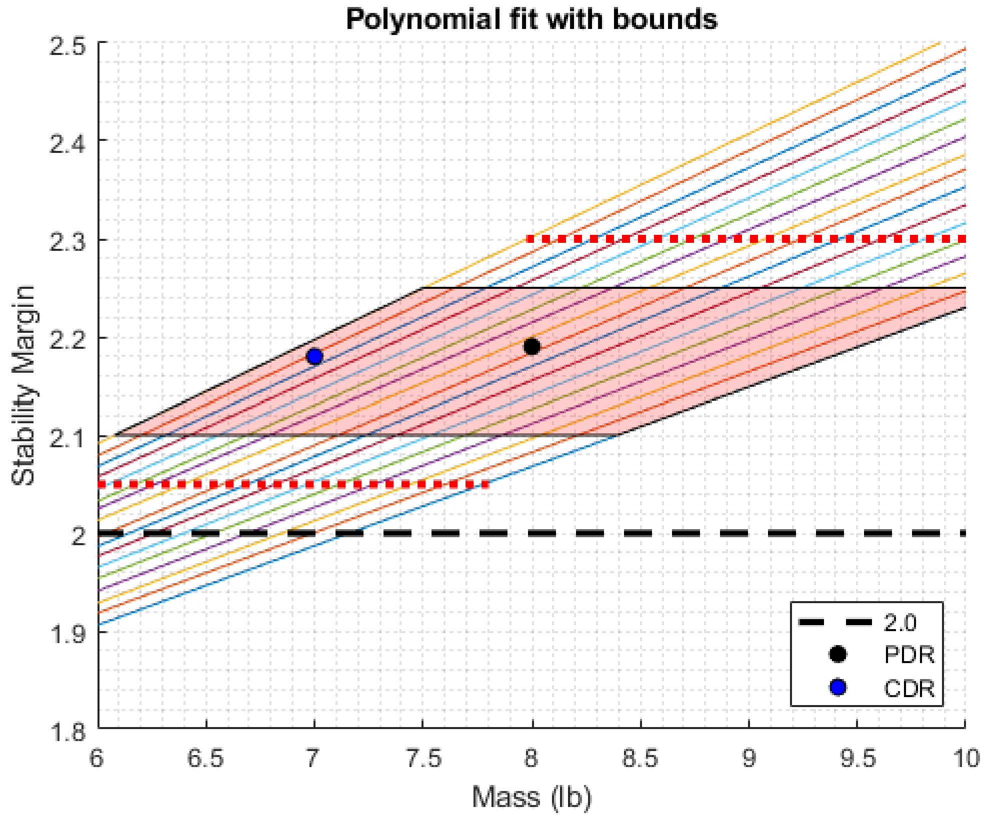
Target Altitude

- Motor – AeroTech L-1520T
- Mass – 43.5 lb
- Thrust to Weight – 8.1



Mass Margin

- 42.8 – 45.0 lb
- Results in acceptable apogee and stability
- Stability bounds (on rail) 2.1 – 2.25



Wind Drift

Wind Speed	Apogee	Descent Time	Drift Distance
0 mph	4425 ft AGL	81 s	0 ft
5 mph	4425 ft AGL	81 s	598 ft
10 mph	4425 ft AGL	81 s	1195 ft
15 mph	4425 ft AGL	81 s	1793 ft
20 mph	4425 ft AGL	81 s	2390 ft

Kinetic Energy

Section	Mass	Main Descent Rate	Kinetic Energy at Landing	Drogue Descent Rate	Kinetic Energy under Drogue
Nosecone	.5115 slugs	14.19 ft/s	51.5 ft-lbs	84.84 ft/s	1841.0 ft-lbs
Midsection	.3453 slugs	14.19 ft/s	34.8 ft-lbs	84.84 ft/s	1242.6 ft-lbs
Fin can	.3737 slugs	14.19 ft/s	37.6 ft-lbs	84.84 ft/s	1345.1 ft-lbs

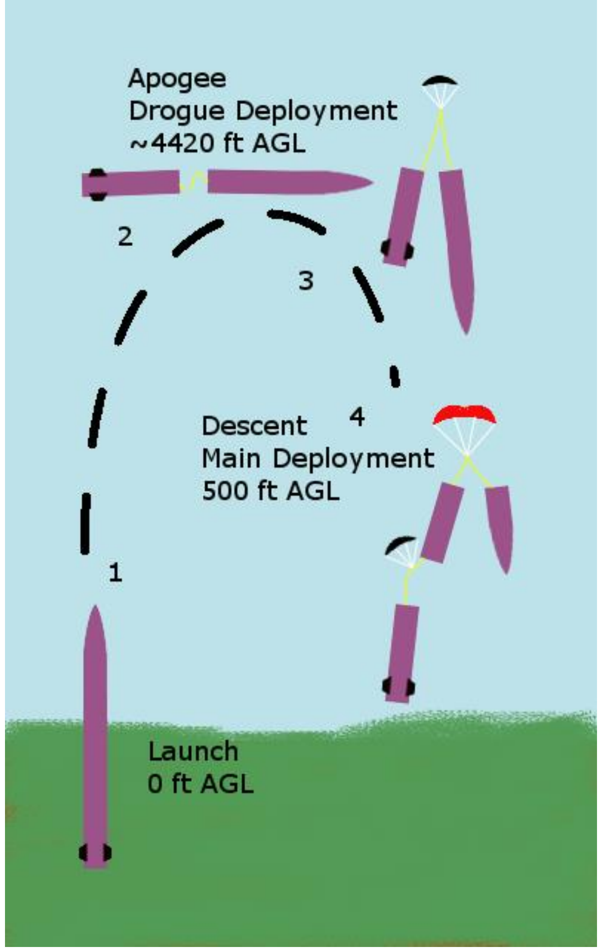
Recovery Subsystem Design

Parachute Sizing

Altimeter Selection

Tracking Device

Description of Events



Recovery System Components

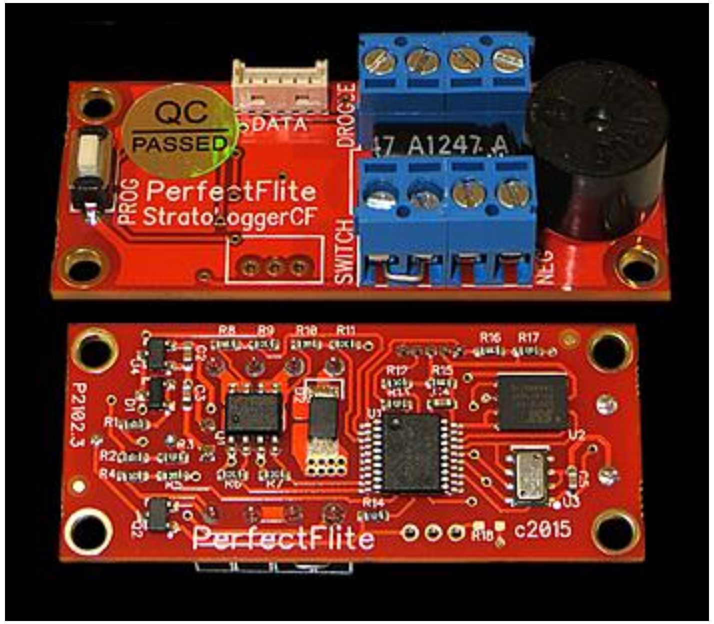
- Main Parachute: Fruity Chutes Iris UltraCompact 120”
  - Descent Rate: 14.19 ft/s
  - Packing Dim: 4.9”d x 10.1”l
- Drogue Parachute: Fruity Chutes Classic Elliptical 24”
  - Descent Rate: 84.84 ft/s
  - Packing Dim: 1.9”d x 4.3”l

Recovery Harness

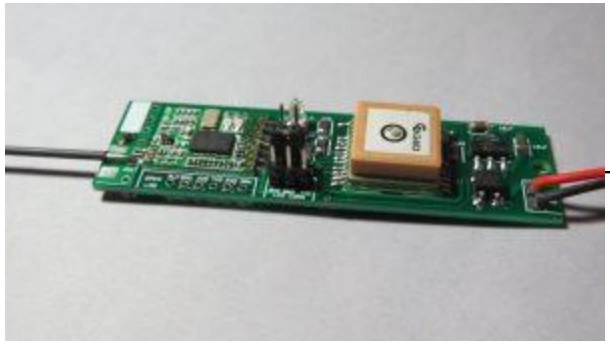
- 40 ft x 5/8" Kevlar Shock Cord
- Main parachute attached 1/3 of total length away from nosecone
- Piston ejection system attached 1/3 of total length from midsection
- Drogue parachute attached 1/3 of total length from midsection between fin can

Altimeters

- 2 PerfectFlite StratoLoggerCF altimeters
- Primary:
  - Drogue: Apogee, 2.0 g charge
  - Main: 500 ft, 6.1 g charge
- Secondary:
  - Drogue: Apogee +1 sec, 2.2 g charge
  - Main: 450 ft, 6.3 g charge

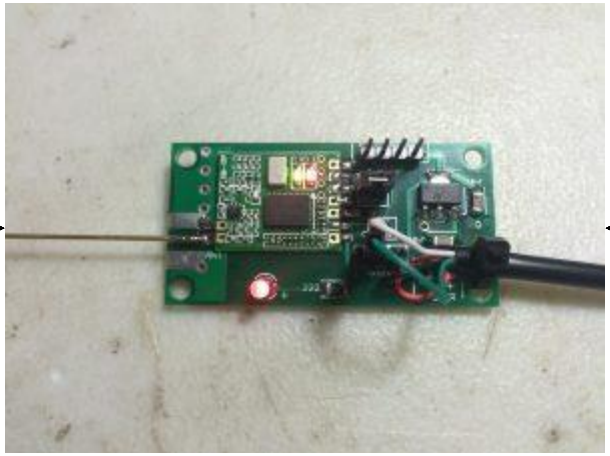


Eggfinder GPS Tracking System



Eggfinder TX Transmitter

909 MHz
RF



Eggfinder RX "Dongle" Receiver
With Bluetooth

Bluetooth

Android phone with
Rocket Locator app

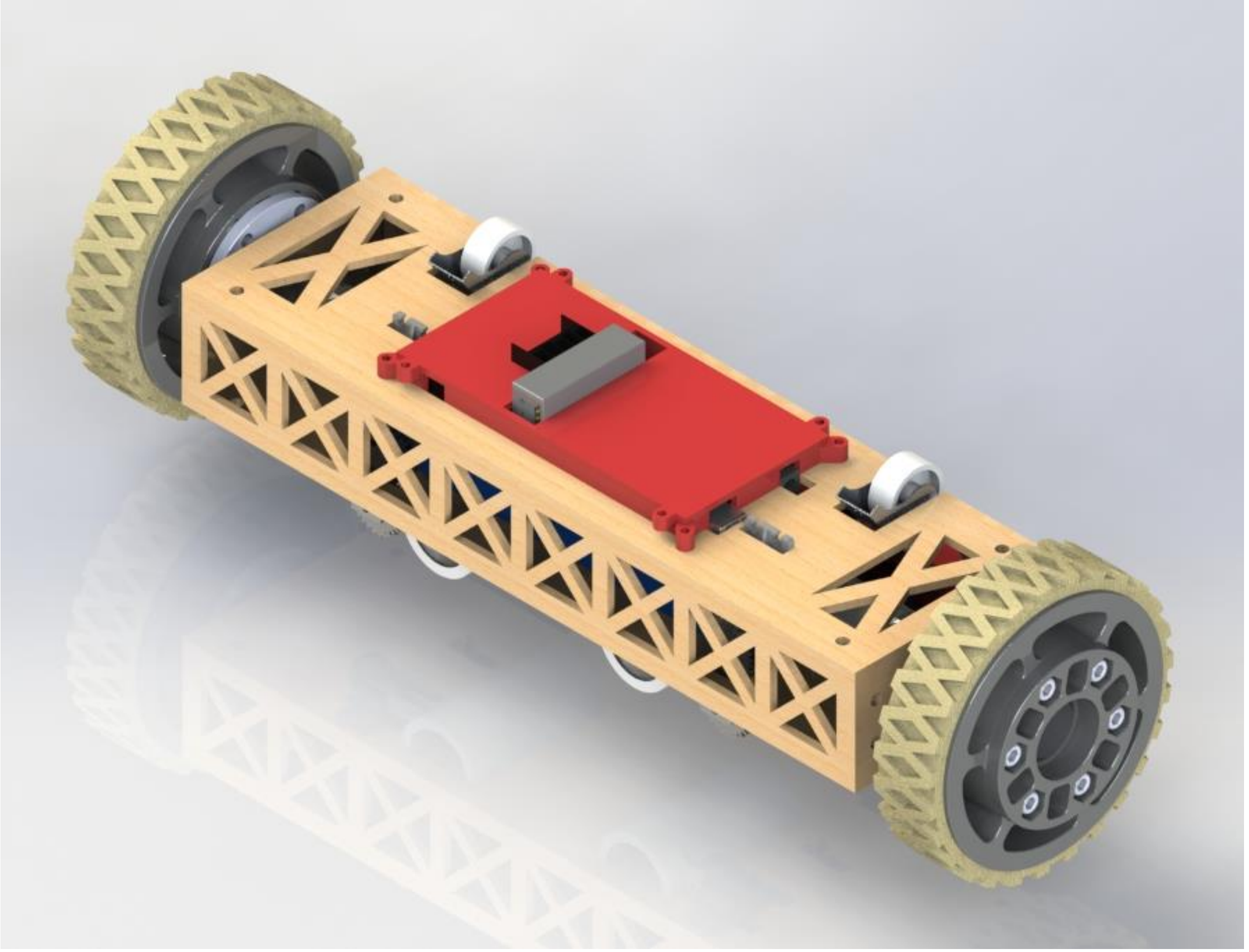
Payload Design

BURRITO

SICCU

Rover (BURRITO) Components

- Overview
- Structure
- Drivetrain
- Electronics
- SICCU

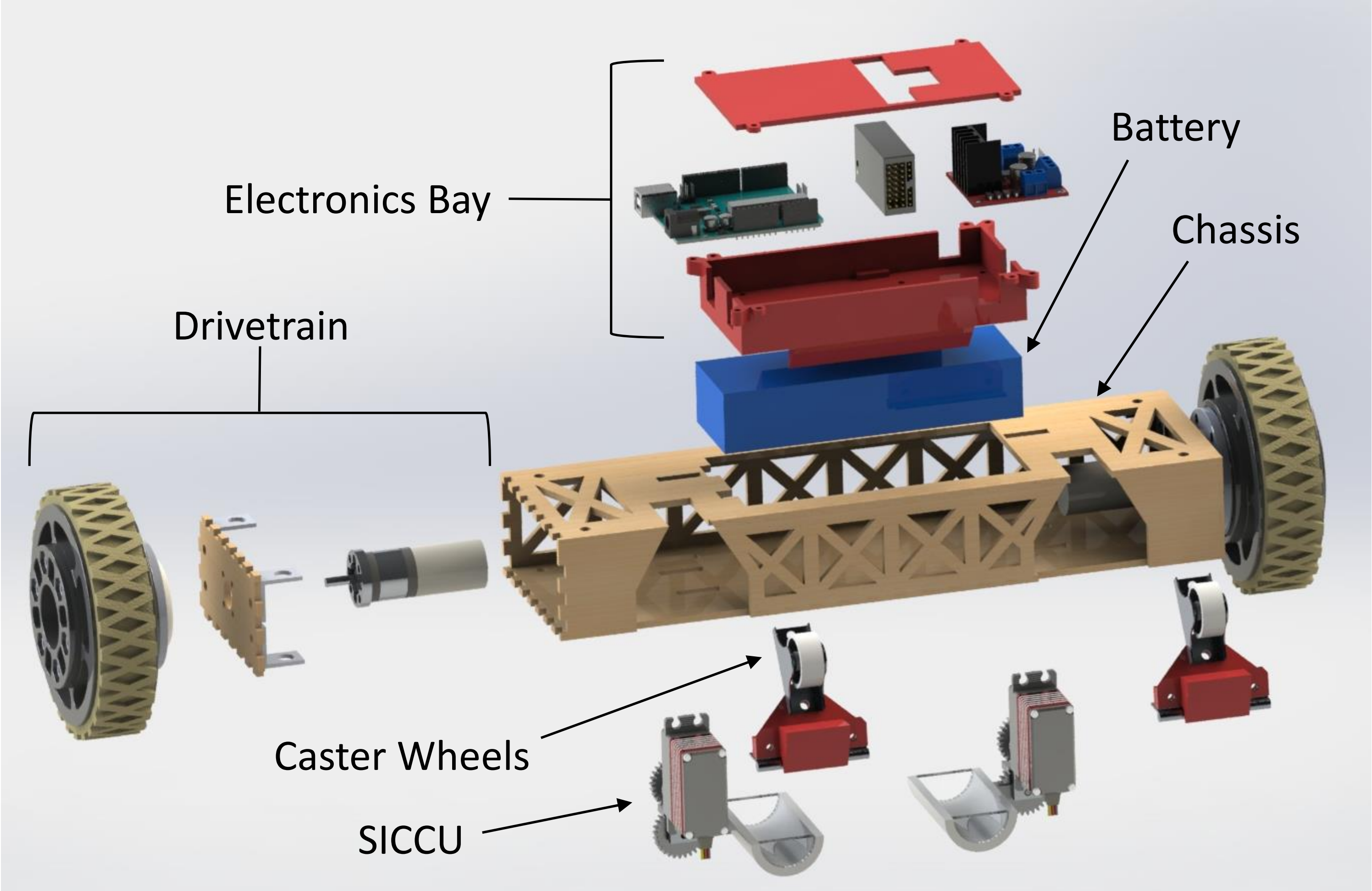


Overview

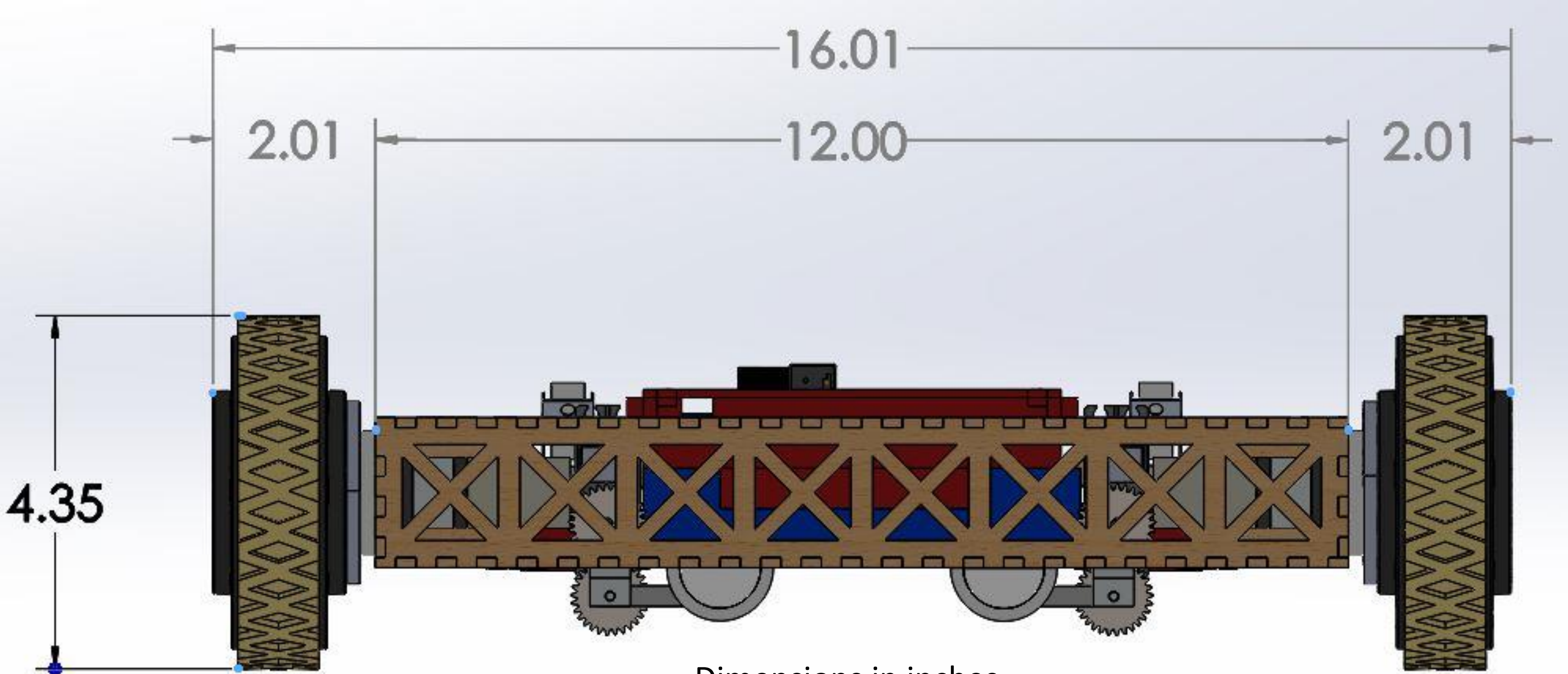
Bilateral
Uptake
Rover

for

Regolith
Ice
Transport
Operations



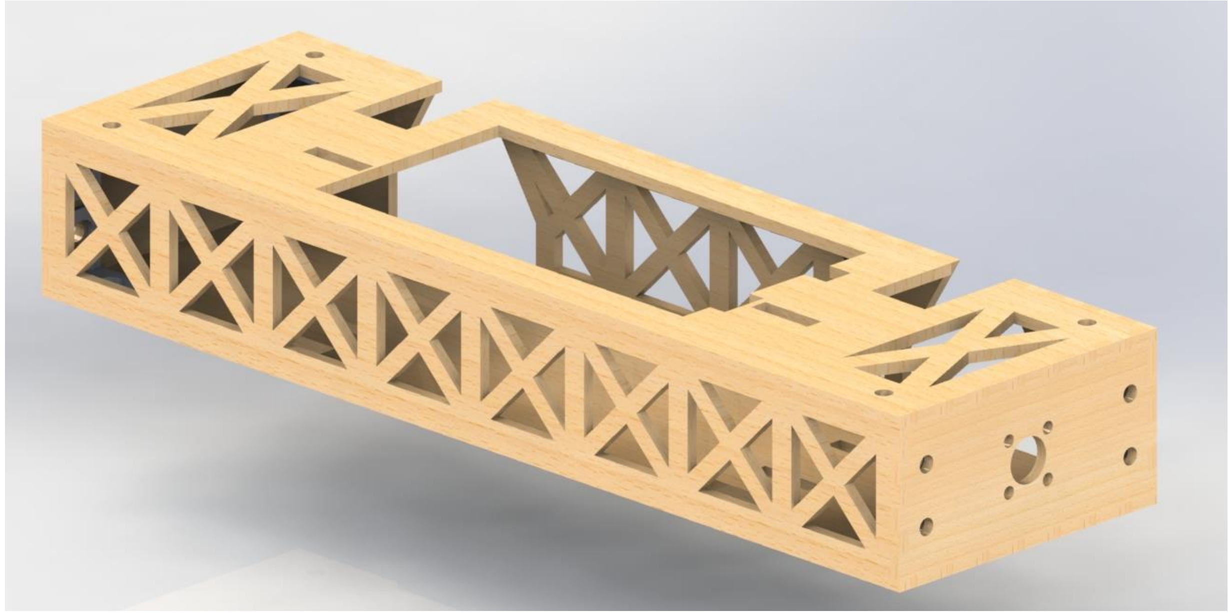
Overview



Dimensions in inches.

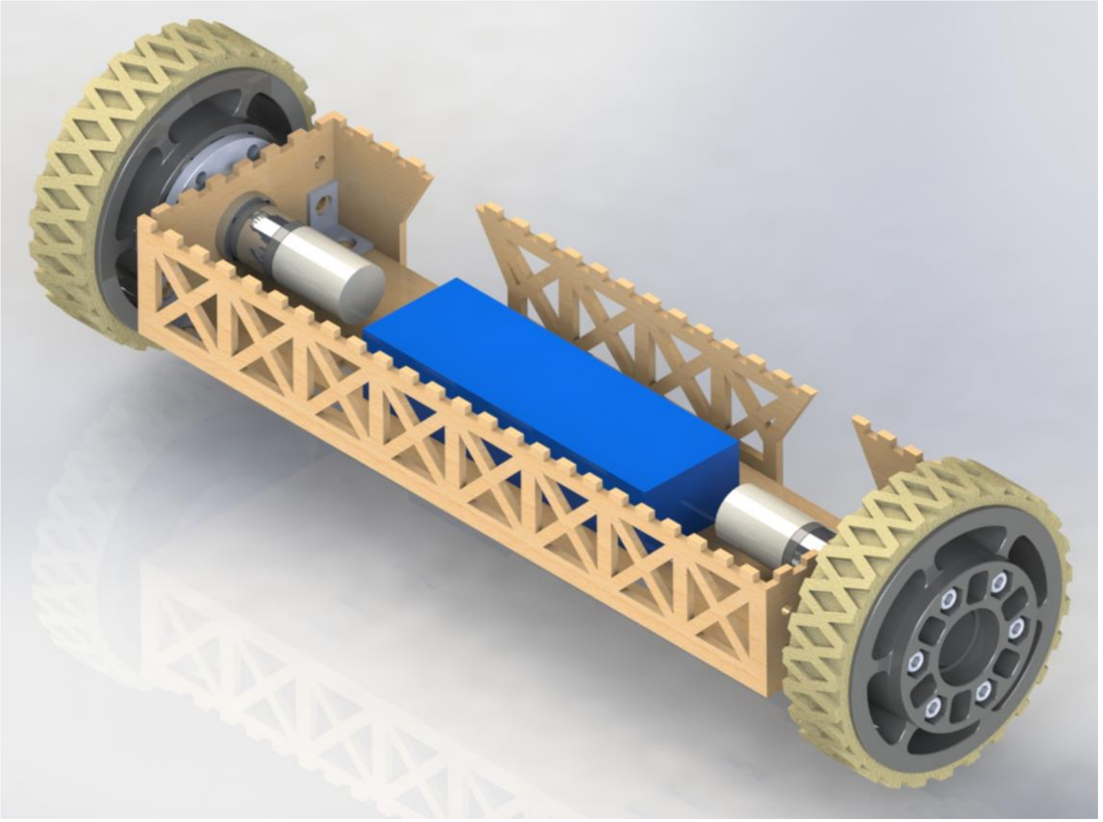
Structure

- Plywood "puzzle piece" construction w/ epoxy.
- Left and right end plates are screwed in place to allow easy access to the motors.
- Holes cut for protruding parts and weight savings.
- Precedent in avionics bays of previous rockets.



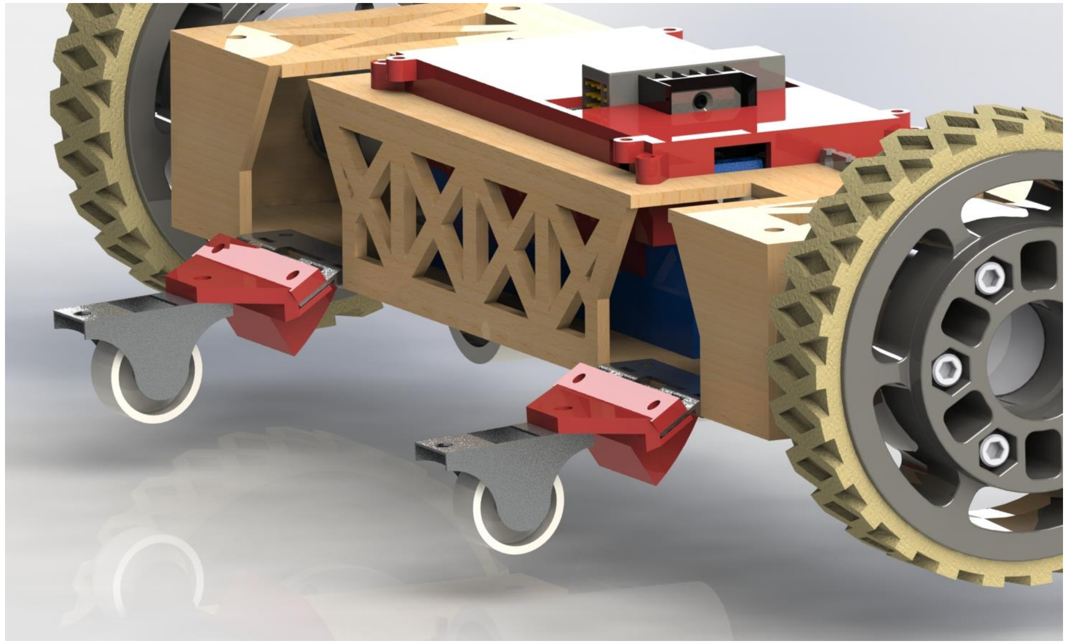
Drivetrain

- 4000 mAh, 11.1 V Lithium-Polymer battery.
- (2x) 350 RPM electric motors.
- (2x) 4.25-in. wheels w/ plaction treads for rough terrain.
- (2x) "bearings" made of plastic covered in teflon prevent launch loads through axles.
- Range of at least 2000 ft, the maximum distance from a recovery site.



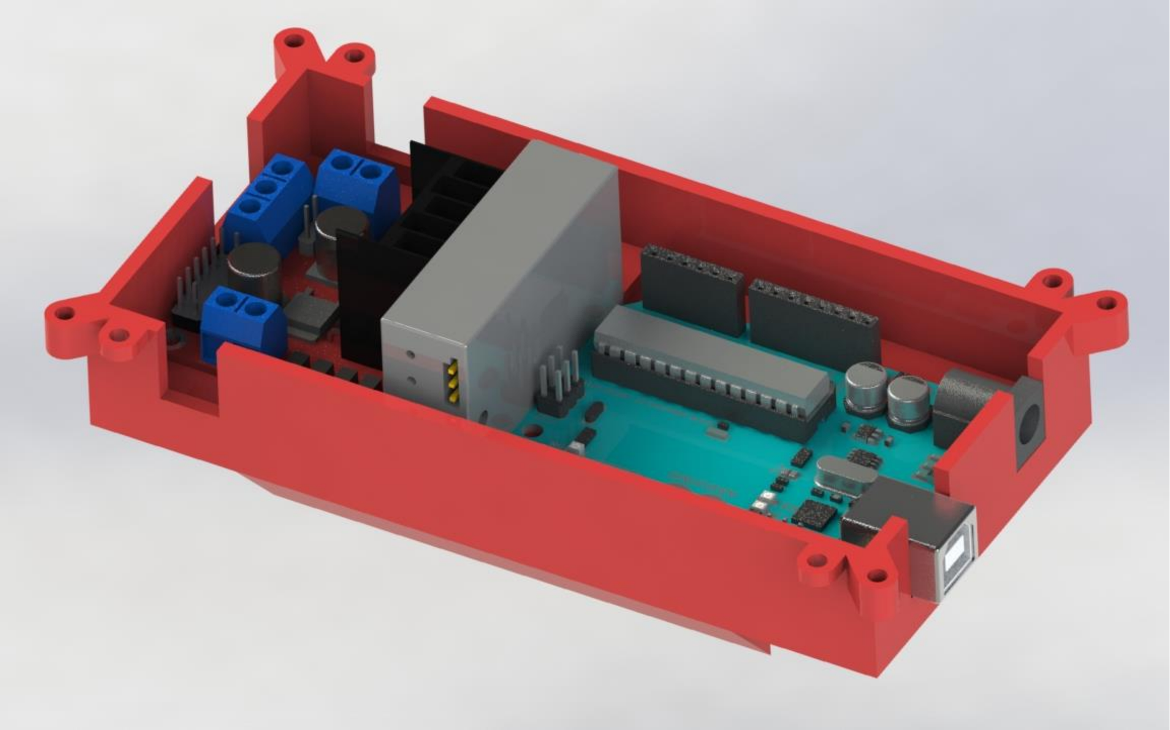
Drivetrain

- Uses two deployable caster wheels on springs for added stability.
- 3D-printed parts shaped so that caster wheels do not deploy early.
- Assists rotation into correct orientation after deployment from payload bay.



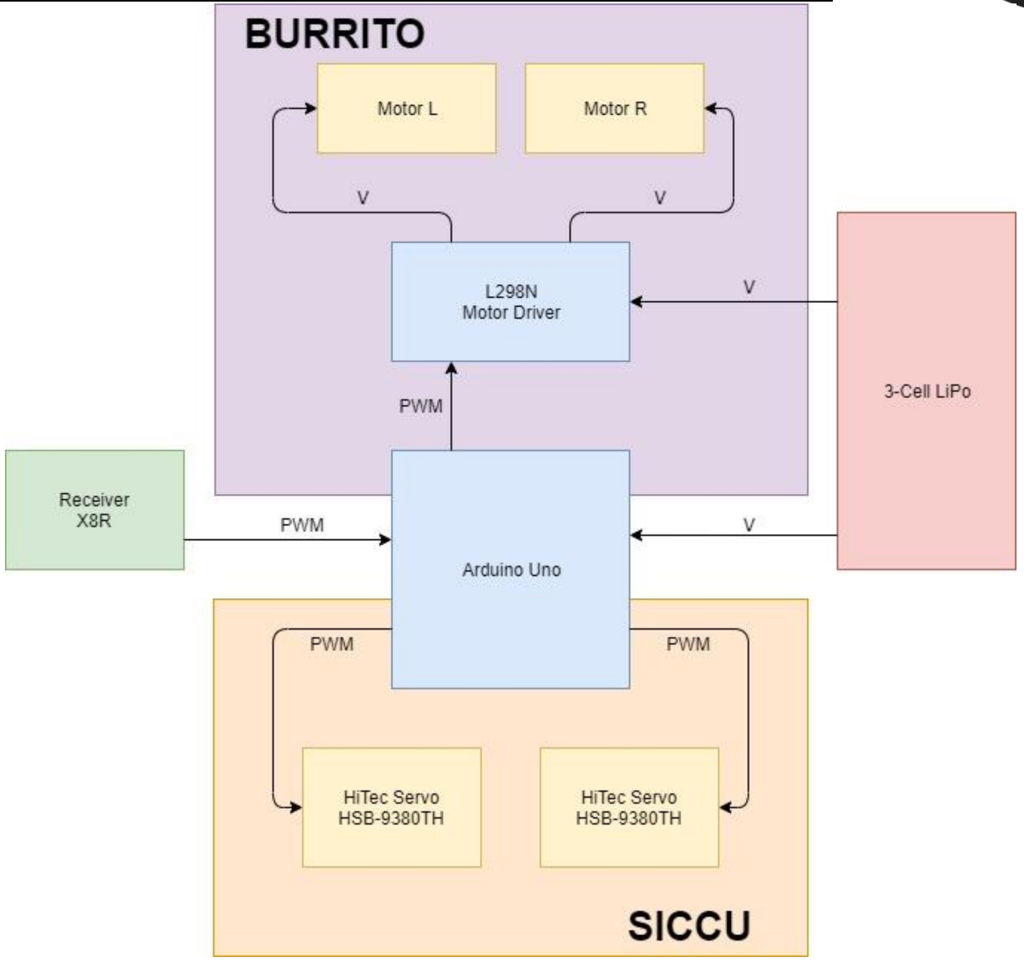
Electronics

- Arduino Uno commands motor controller and servos based on signals from 2.4 GHz radio receiver.
- 3D-printed container w/ outlets for motor, power, and servo wires.
- Container also holds battery in place underneath
- Power controlled by switch; voltage monitored by indicator.



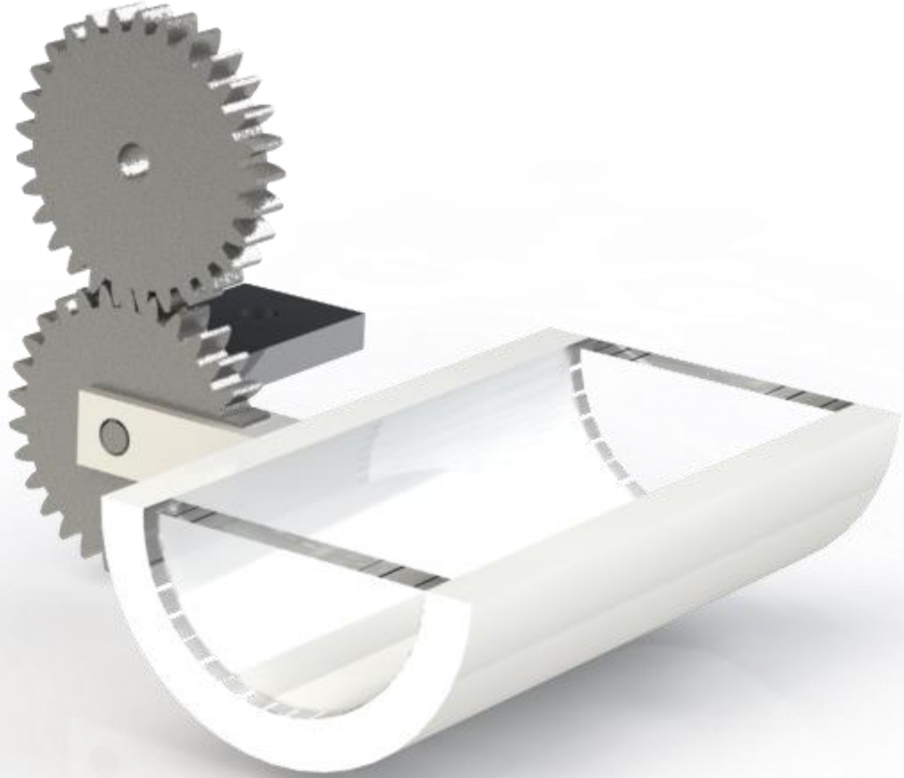
Electronics

- Sequence walkthrough:
  - Operator moves left stick up.
  - Signal on left stick channel is picked up by receiver.
  - PWM signal on corresponding channel from receiver is interpreted by Arduino.
  - Arduino sends a PWM signal to the motor driver.
  - The motor driver supplies power to the left motor in the forward direction.



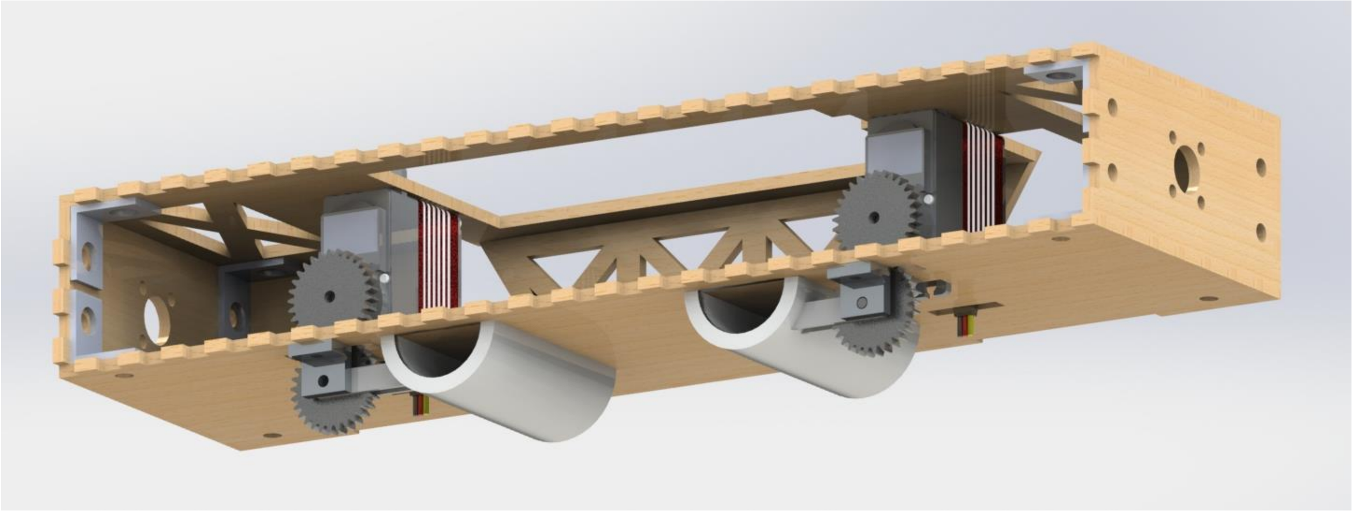
Simulated Ice Collection and Containment Unit (SICCU)

- Body: Schedule 40 1” PVC
- Arm: 0.25” Channeled Aluminum
- Caps: 0.125” Acrylic
- Gear Ratio: 1:1
  - OD: 1”
  - Width: 0.125”
- L-Bracket
- Adhesive: PVC Cement



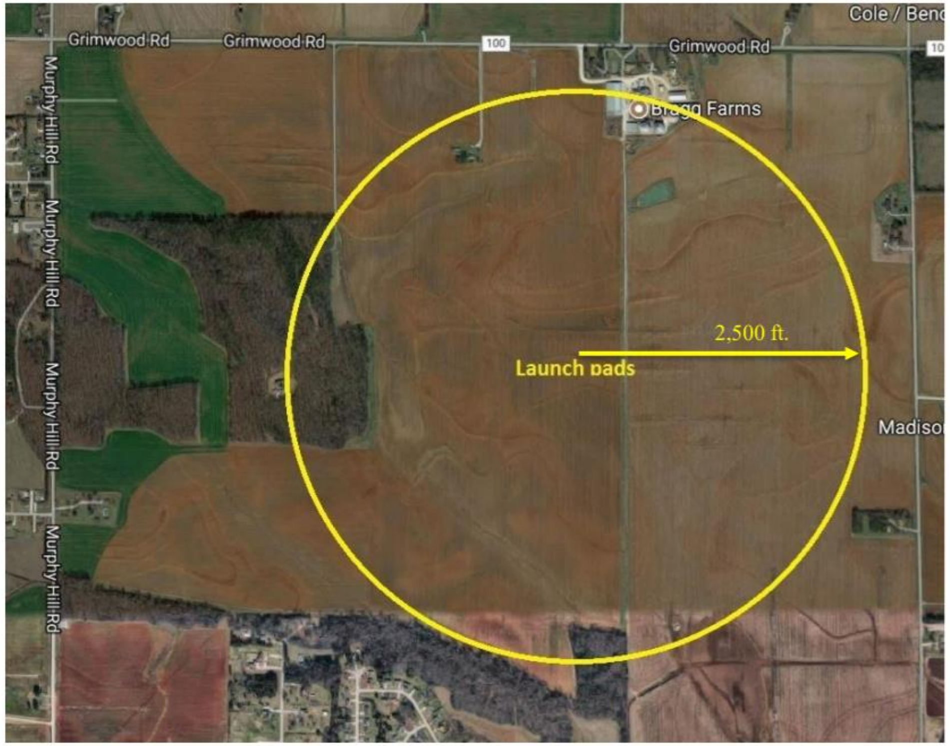
Simulated Ice Collection and Containment Unit (SICCU)

- Inside Rover Chassis: Two D951TW Servos
- 1:1 Gearing Ratio for Power Transmission
- 0.93" Between Axes
- L-Bracket Secures SICCU to the chassis

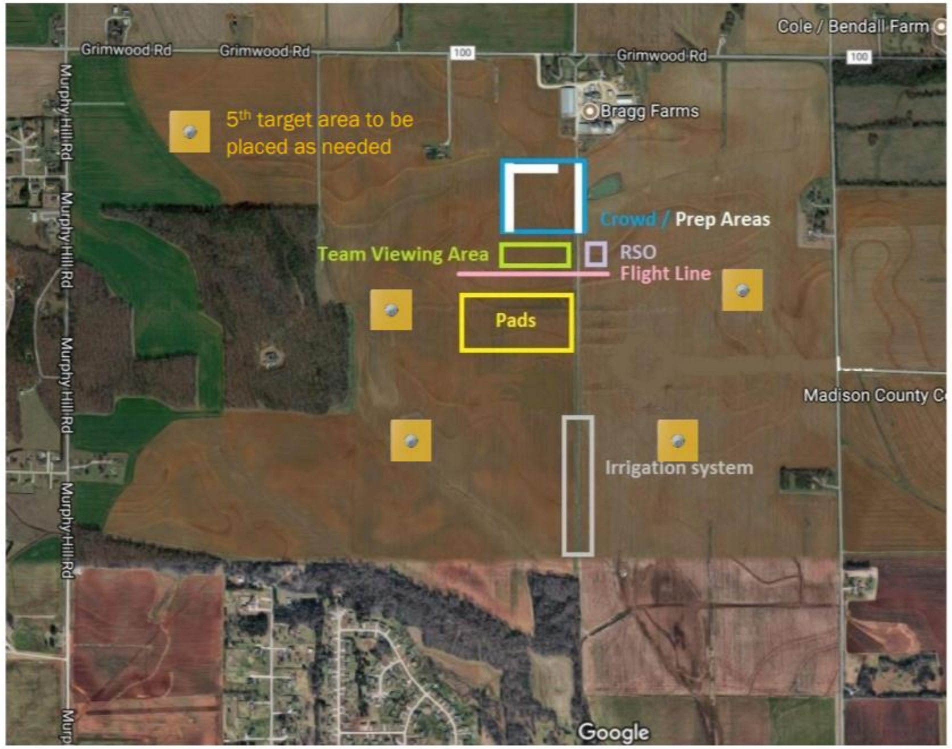


Changes Since PDR

Payload Information – Launch Field



2,500 ft. (radius) recovery area

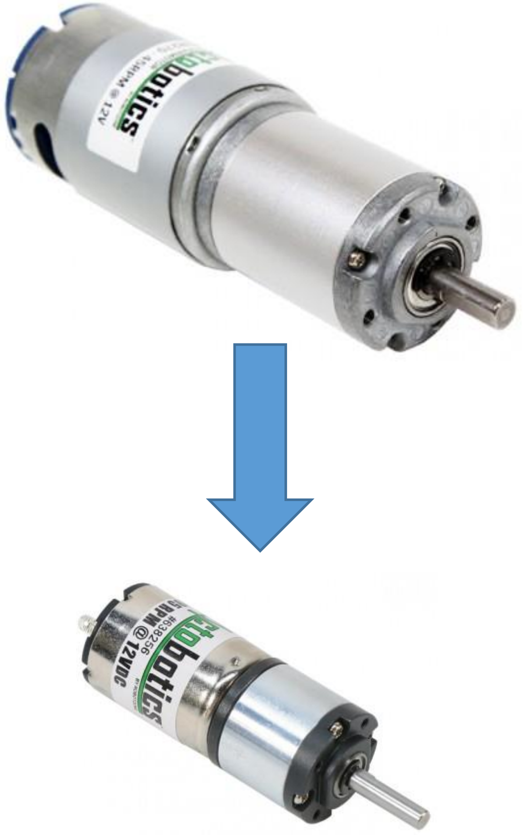


NOTE: Sample areas are approximate and not to scale.

Final locations will be determined during launch week and will depend on field conditions, weather, and the final launch pad location chosen by NAR.

Changes Since PDR

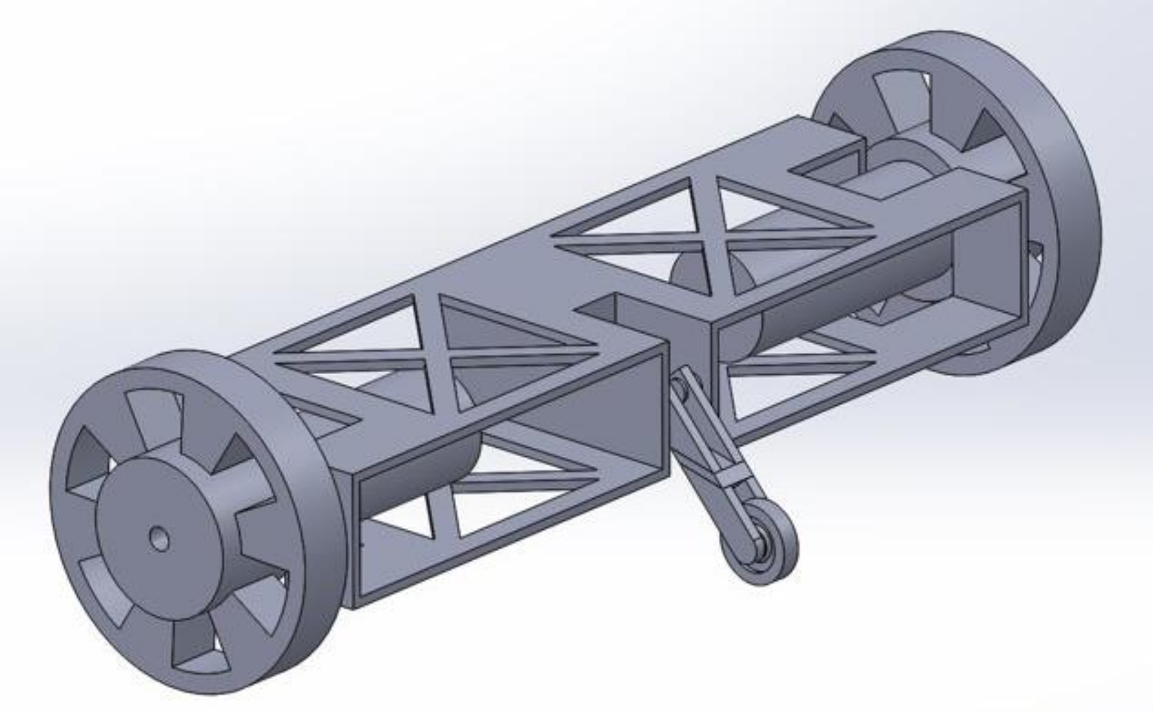
- Motor size was changed based on a re-evaluation of rover characteristics.
- Original calculations assumed a rover of 6 lbs
- Revised calculations used a rover of 2.73 lbs
- Weight loss was largely due to switch to lighter motors.

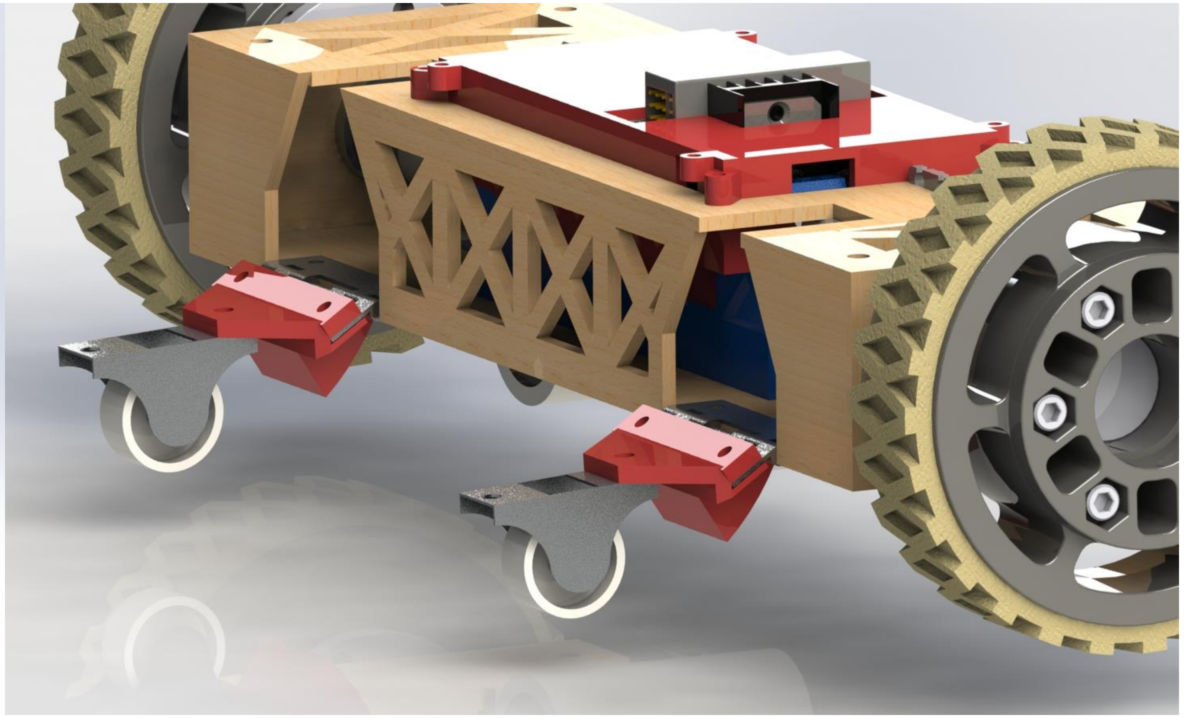


Changes Since PDR

- Increase in range and volume constraints prompted switch from 12 V NiMH batteries to an 11.1 V LiPo battery.
- LiPo is more energy dense and does not suffer from "memory" effects; no need to fully discharge and charge before storage.

Changes Since PDR

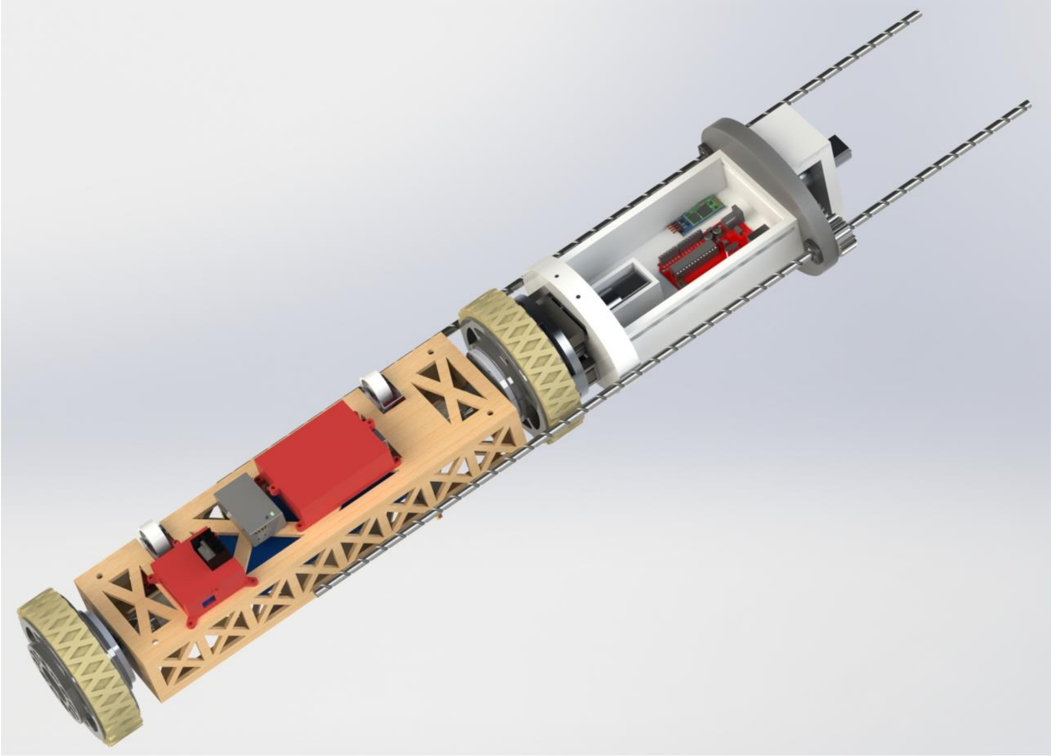




Payload Integration

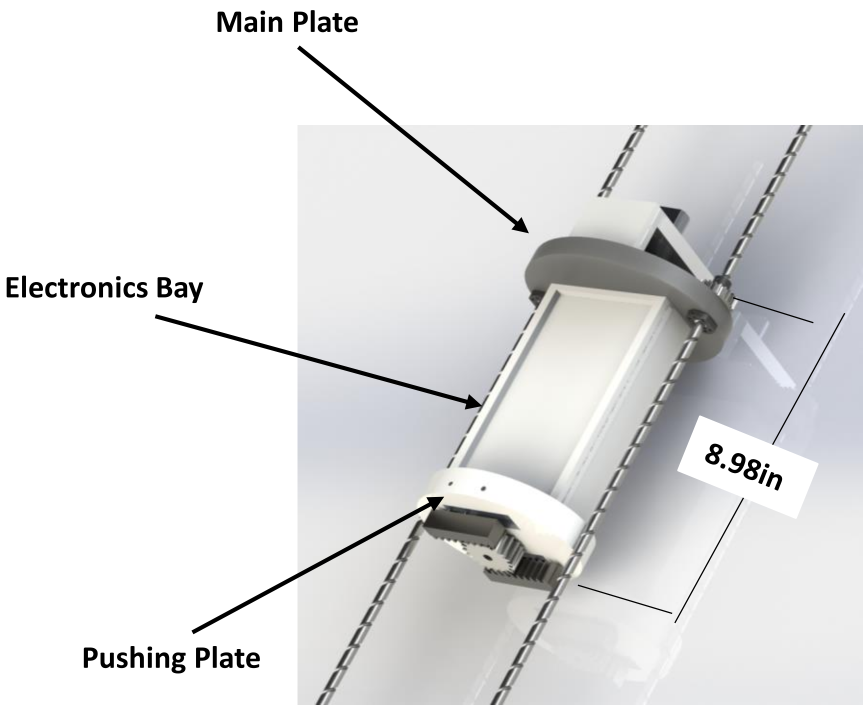
Integration Components

- Base Design
- Power Transmission
- Electronics
- Retention



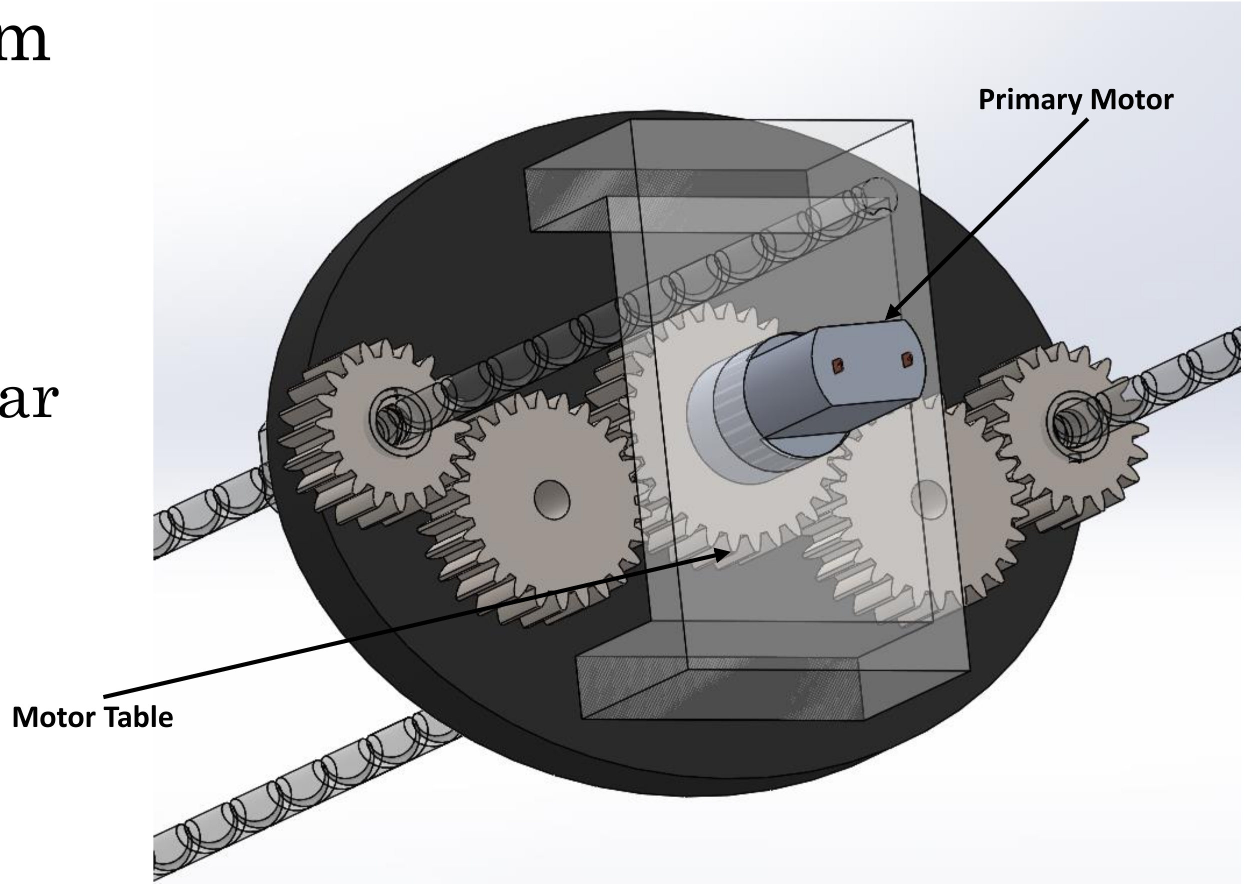
Base Design

- Linear Actuated design
  - Two fixed lead rods
  - Rotating nut
- Main Plate
  - Power Transmission
- Electronics Bay
  - Power supply
  - Controls
  - Compensates for coupler section
- Pushing Plate
  - Retention system



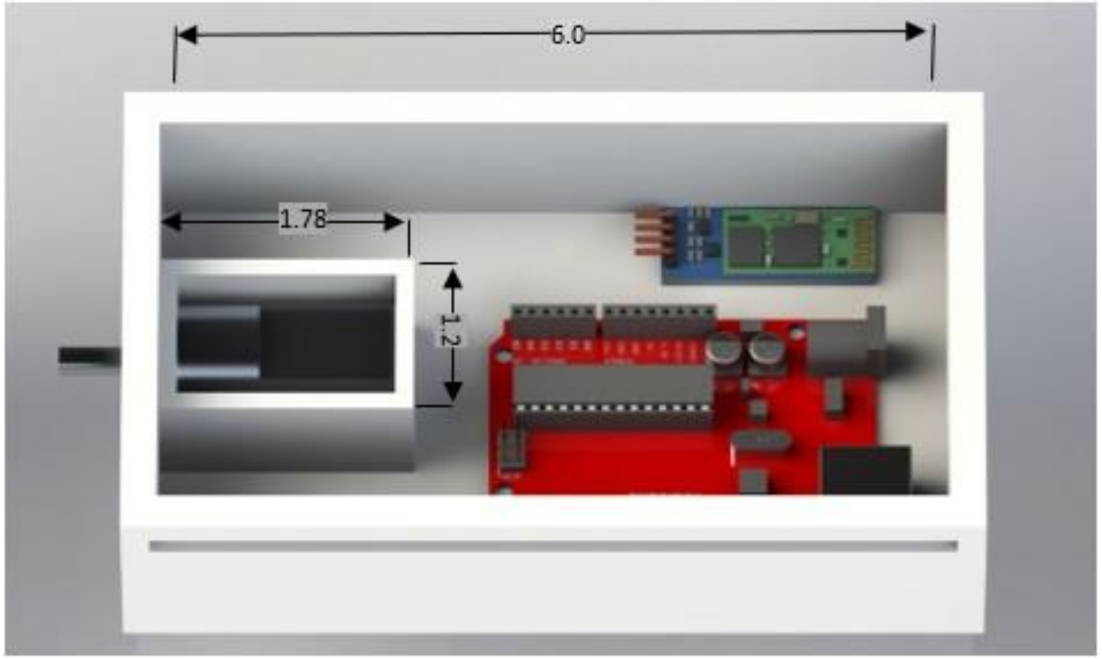
Power Transmission

- 5-gear transmission system
  - Gear Ratio: 1.5
- Motor table
  - Mounts motor and drive gear
- DC Motor
  - Speed: 163 RPM
  - Torque: 104 oz-in



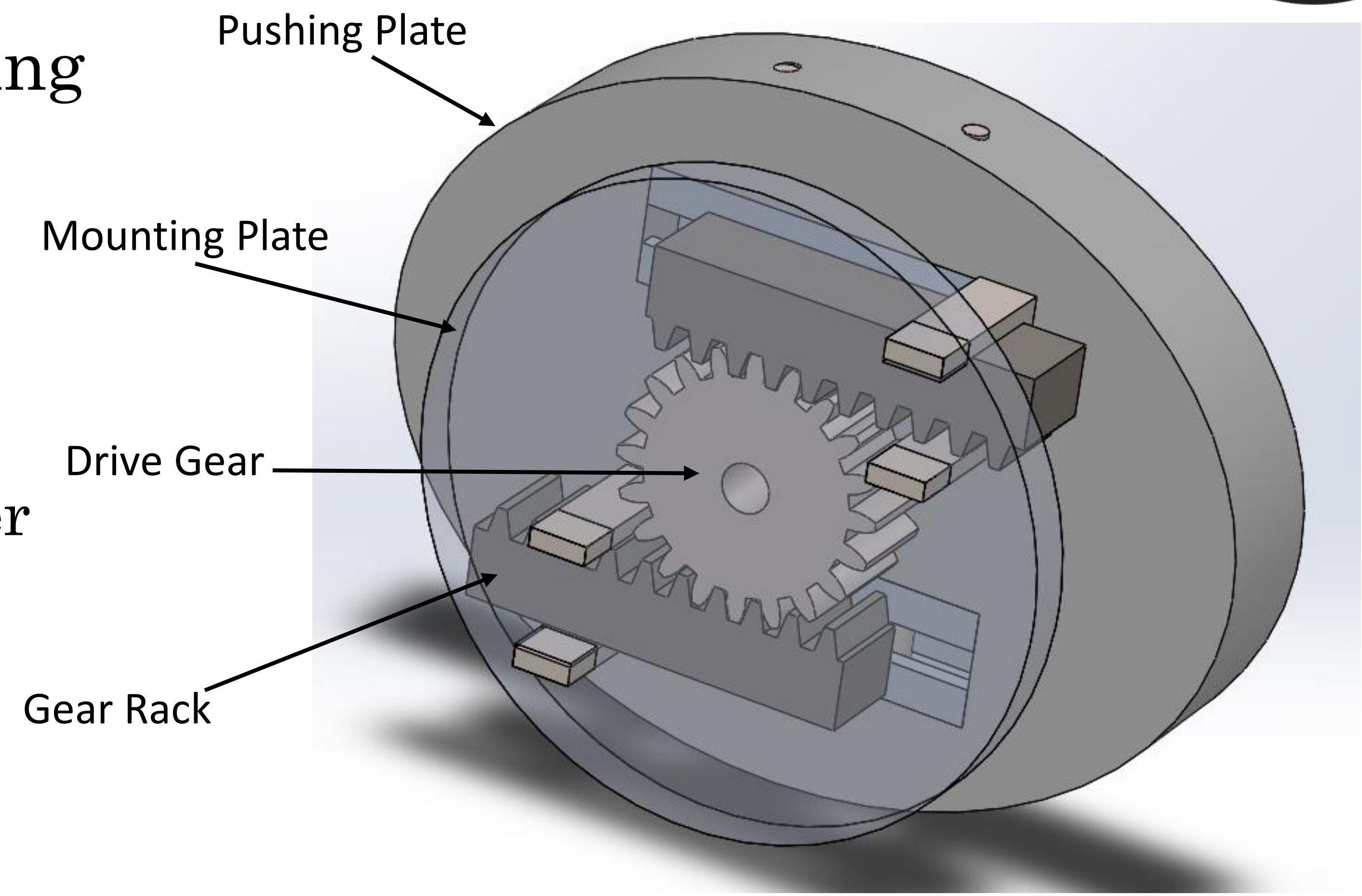
Electronics Bay

- Micro Controller
  - Sparkfun Redboard
  - Consumption: 100 mAh
- Bluetooth Module
  - HC-06
  - Consumption: 40 mAh
- Retention motor
  - DC motor
  - Consumption: 1.67 mAh



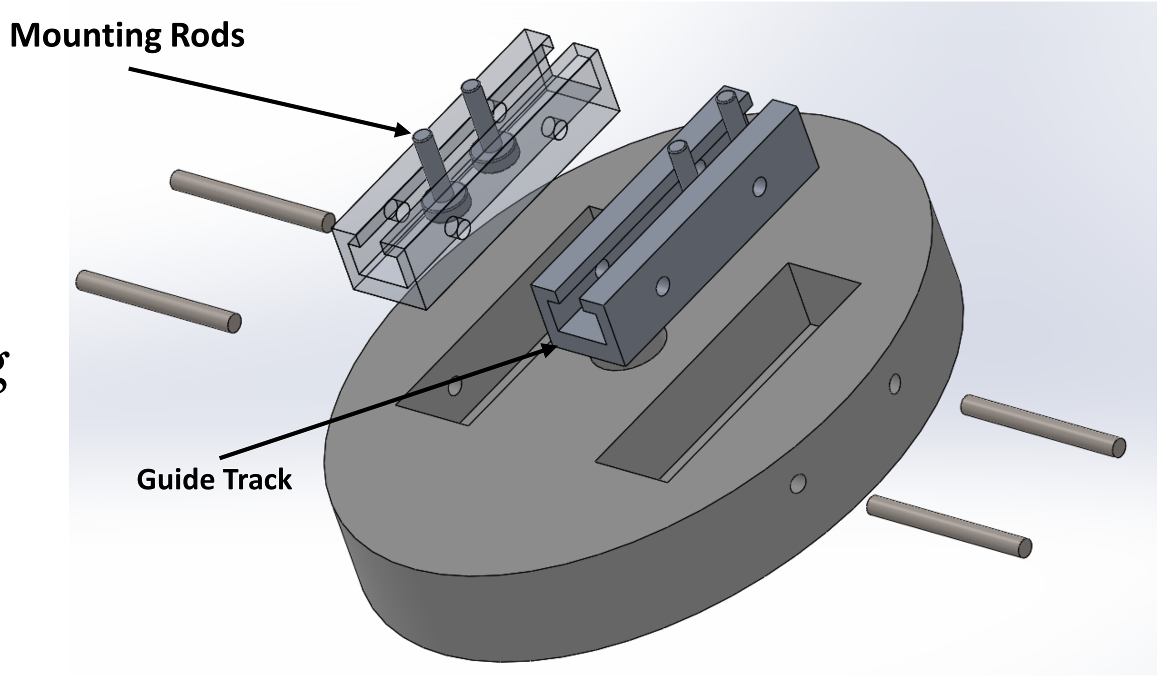
Retention System

- Guide Tracks/Mounting Rods
  - Material: Aluminum
- Gear/Gear Rack
  - Material: Carbon fiber
- Rover Interface
  - Material: Aluminum



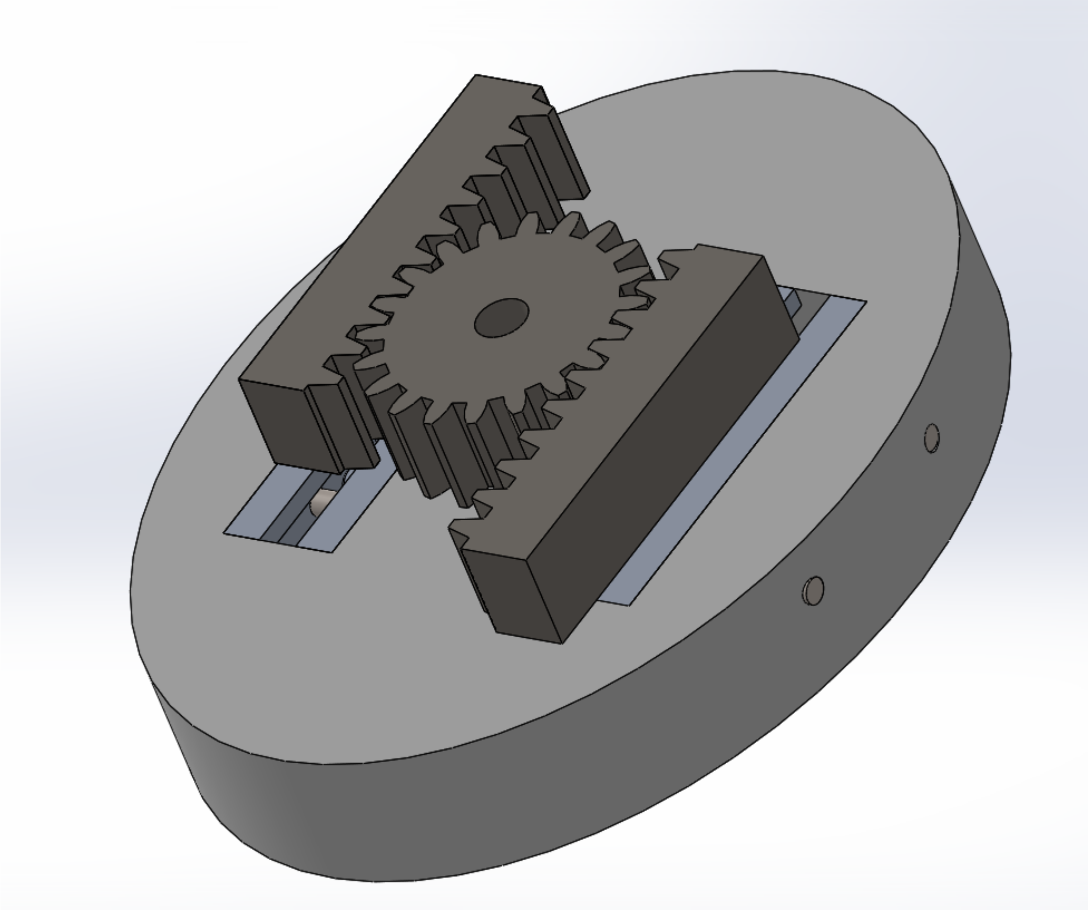
Retention System

- Guide Tracks
  - Provide linear path for gear racks
- Mounting rods
  - Connect gear racks to pushing plate



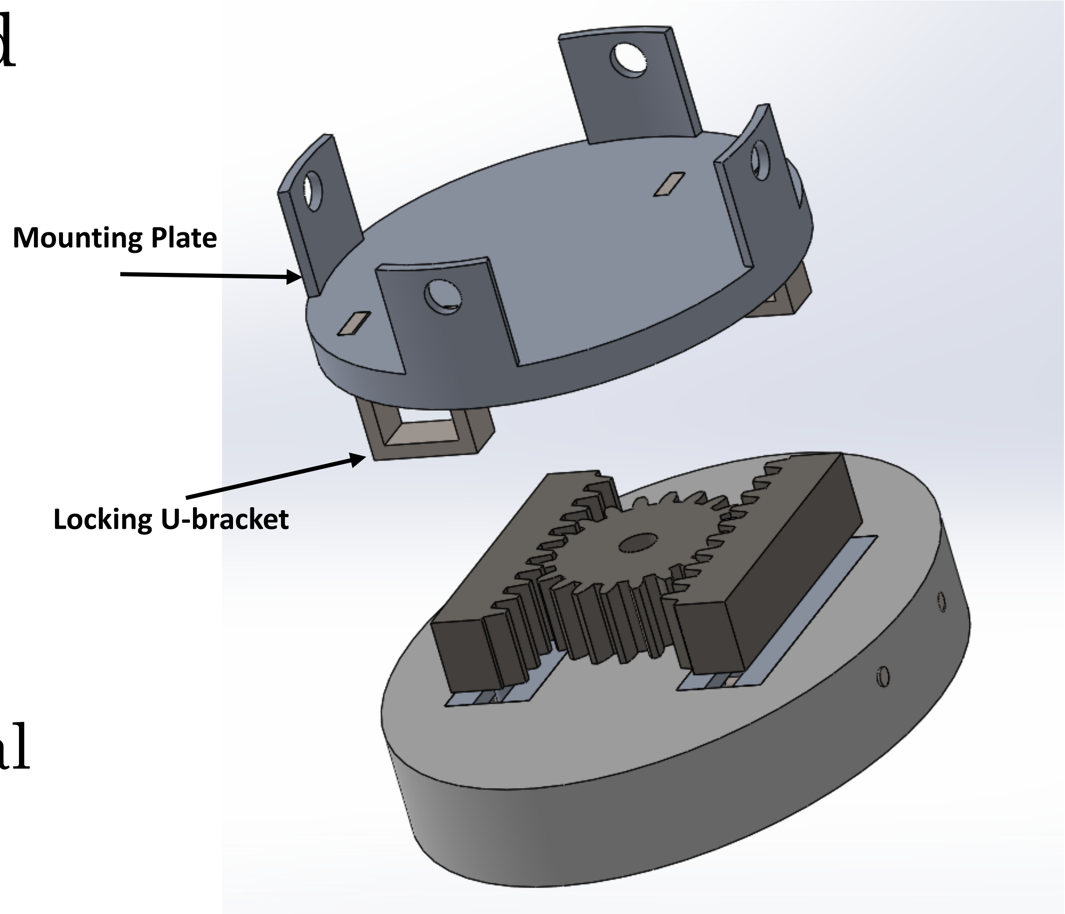
Retention System

- Gear
  - Powered by DC motor within electronics bay
- Gear Rack
  - Interface with gears to transform rotational motion to linear motion
  - Interfaces with rover in locking position

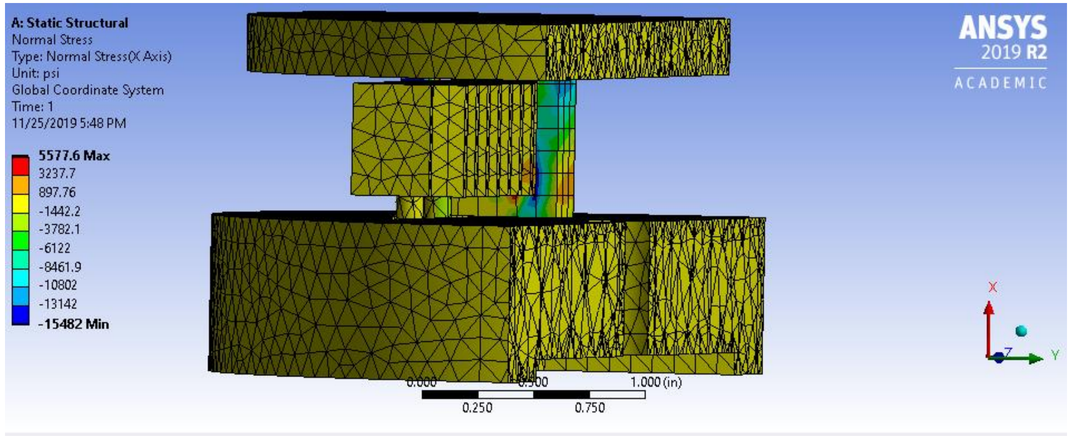


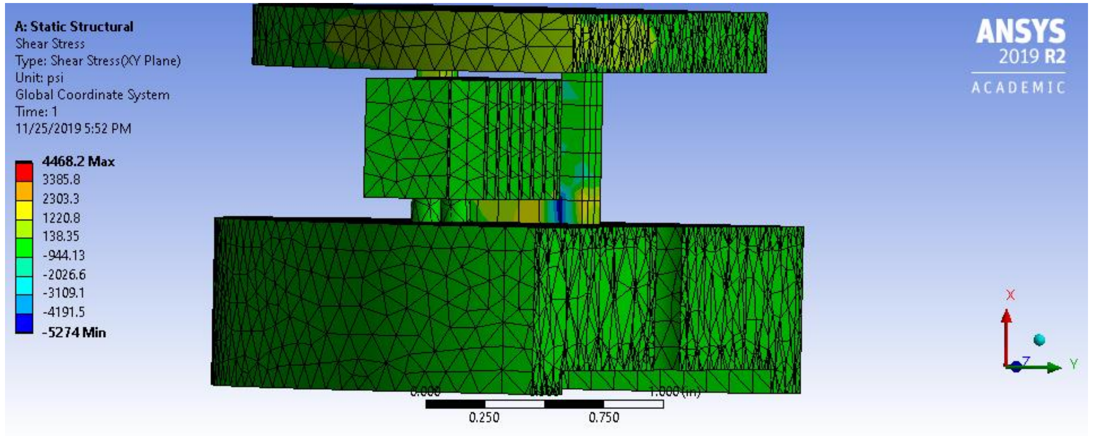
Retention System

- Mounting plate will be fixed to the forward rover wheel
- Locked position
  - Gear racks slide into the U-brackets, securing during flight
- Unlocked position
  - Gear reverses direction, pulling gear racks to a central position.



Retention Analysis





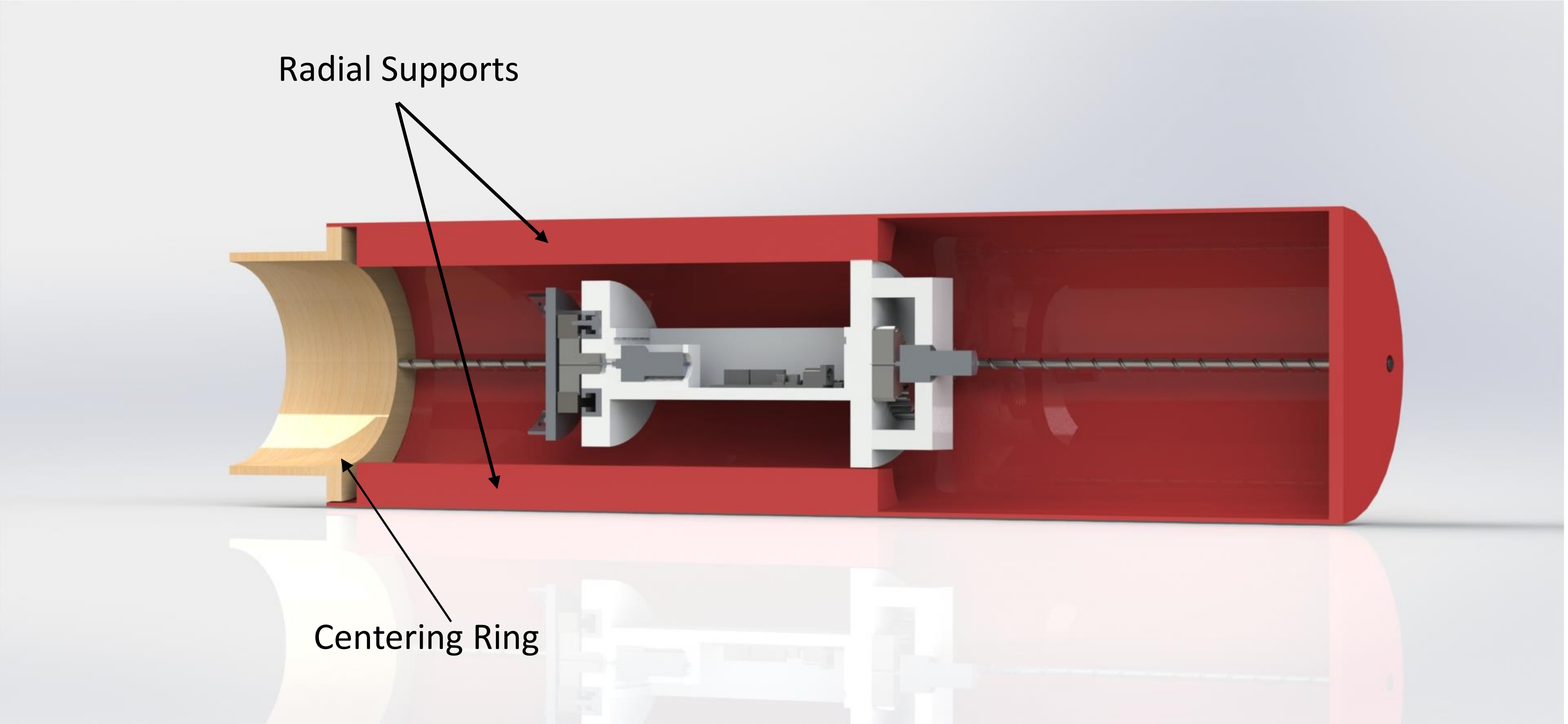
- Normal Stress
  - Absolute max = 15.48 ksi

- Shear Stress
  - Absolute Max = 5.27 ksi

Materials of Concern:

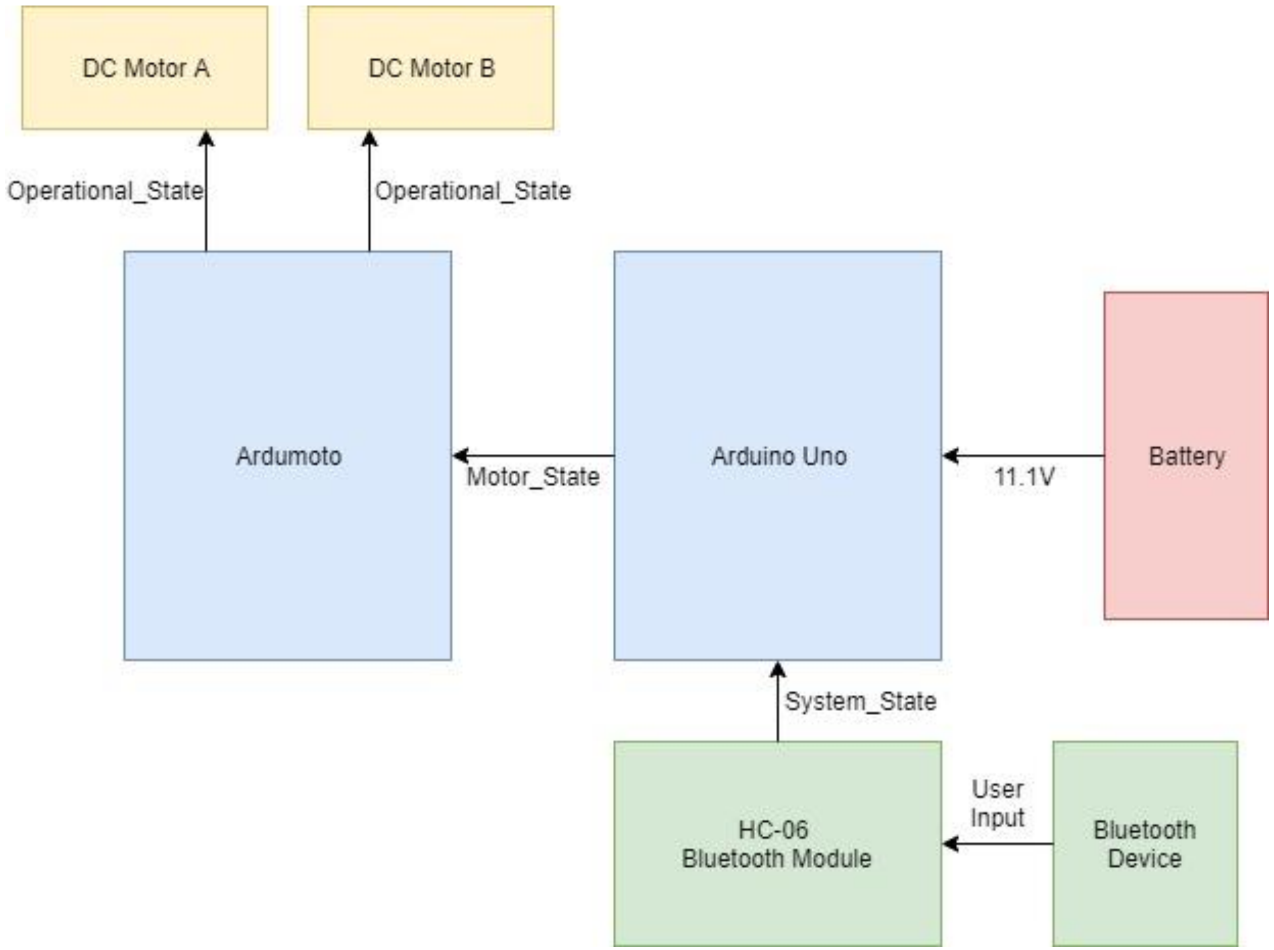
- ABS
  - Yield Stress: 6.1 ksi
- Aluminum
  - Yield Stress: 21 ksi
  - Ultimate Shear: 17 ksi

Additional Supports



Deployment System Block Diagram

- BlueTerm Android app allows users to interface with microcontrollers via mobile devices through Bluetooth
- Within 30' of payload, the users can connect to the microcontroller.
- Operational States 0-5
  - Motor A: 0-2
  - Motor B: 3-5

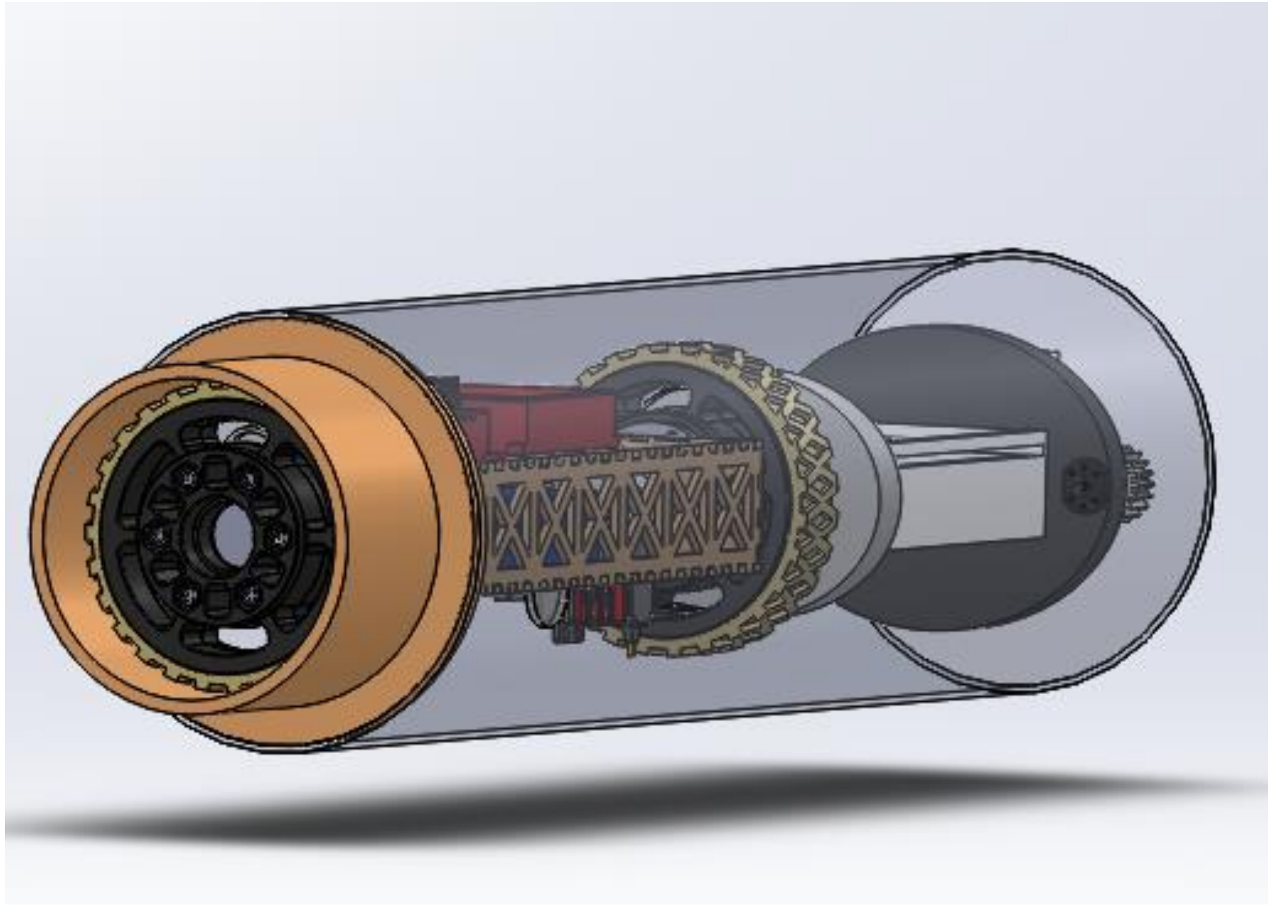


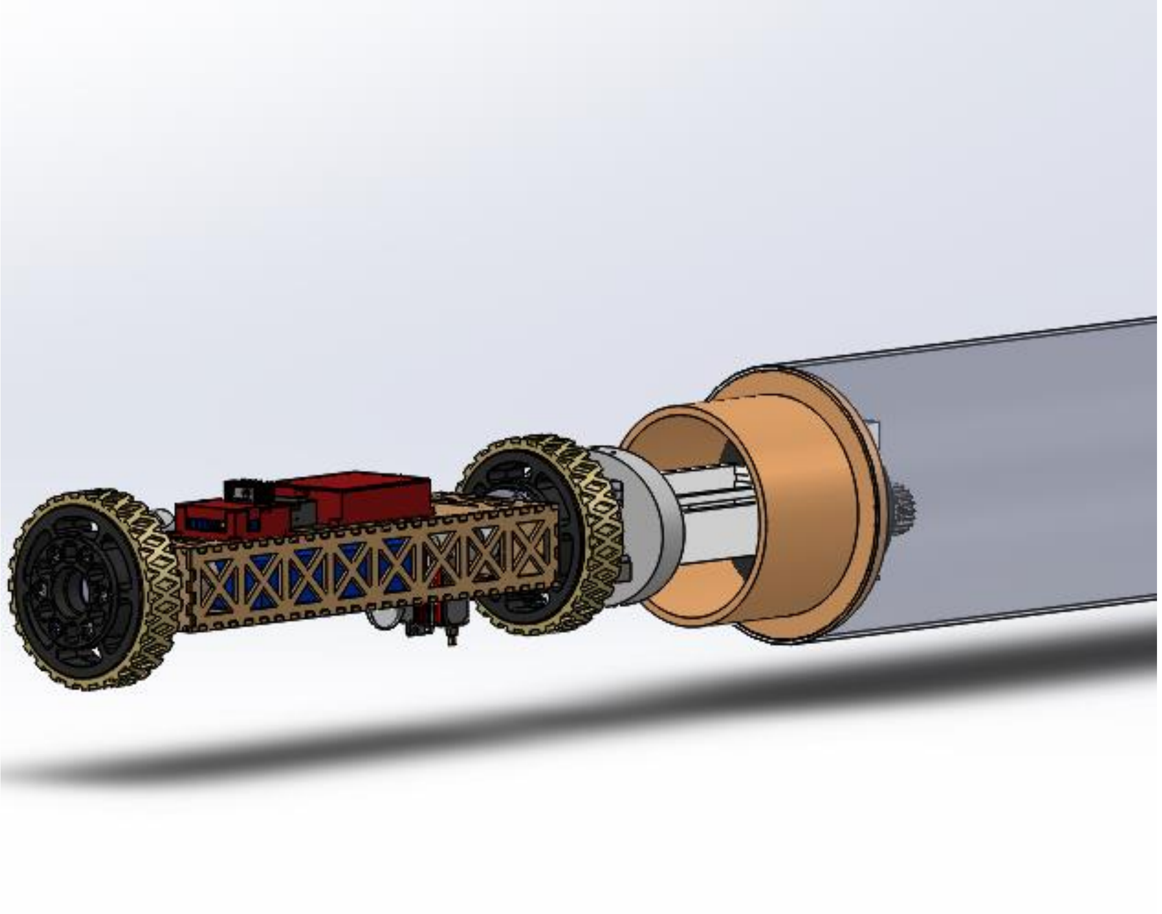
Changes since PDR: Controls

- PDR control system:
  - Autonomous based design
  - Accelerometer detected flight stages
  - Communication via transceiver (up to 2,000 ft)

- CDR control system:
  - Direct user input through smart phone controls
  - Communication via Bluetooth module

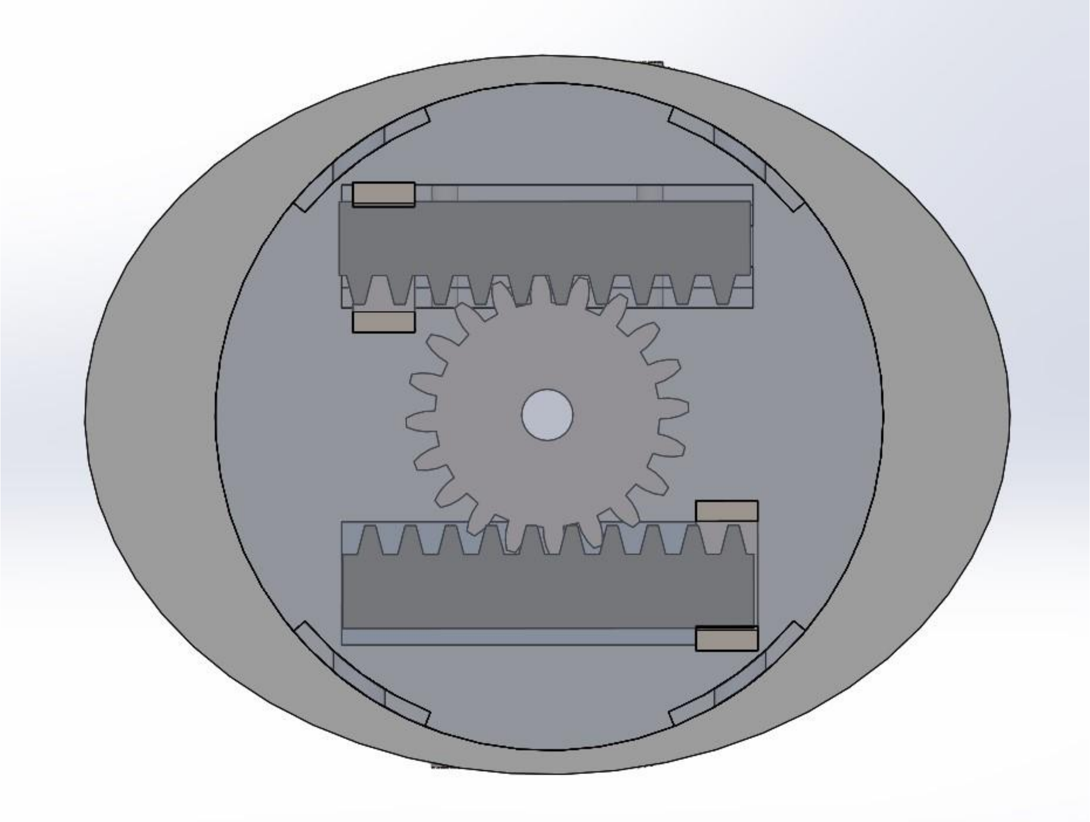
Deployment Procedure

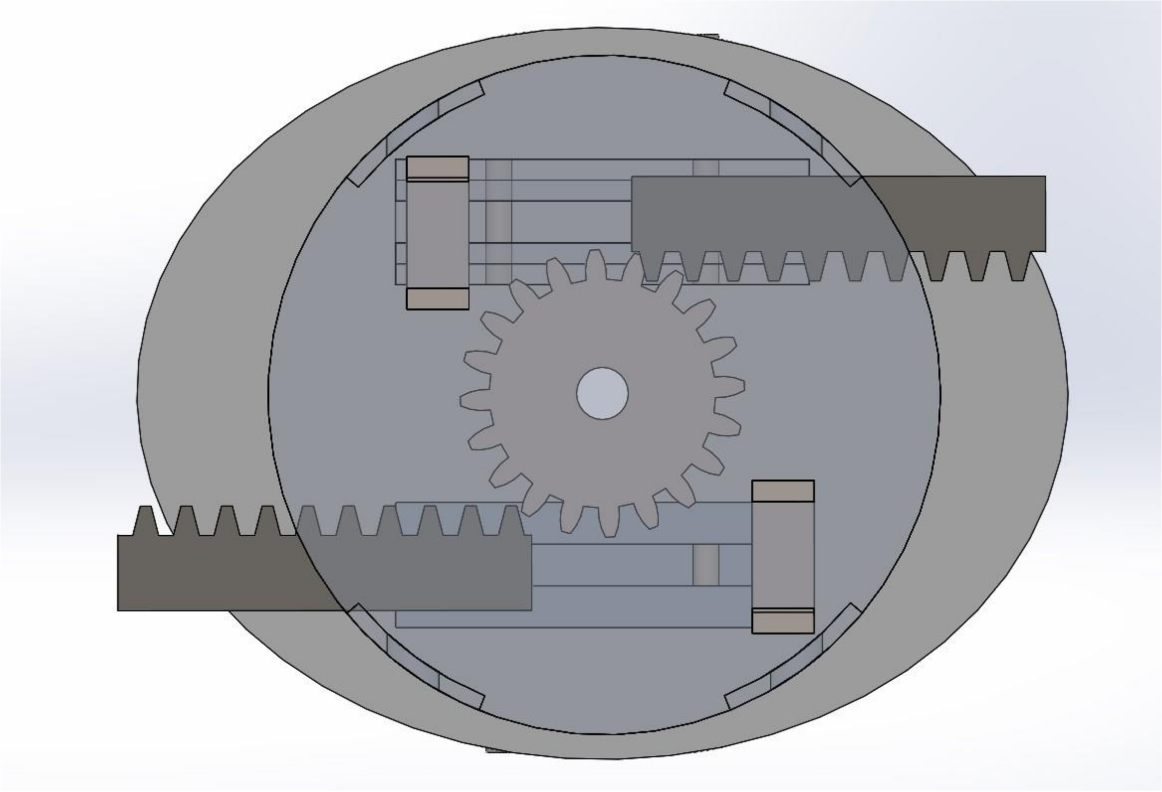




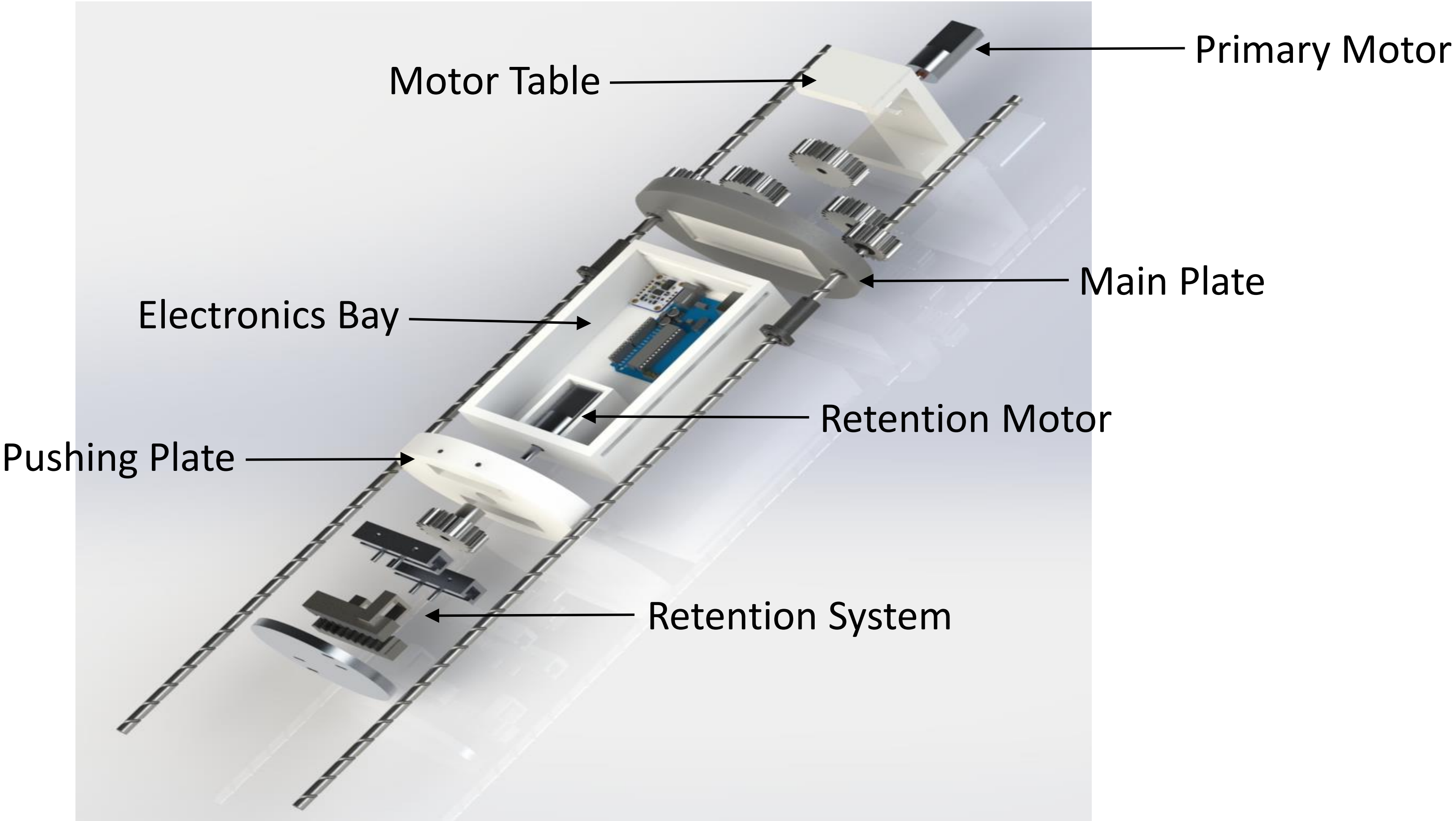
HIGH-POWERED ROCKETRY CLUB
TACHO LYCOS

Deployment Procedure





Component Overview



Testing Plans

Launch Vehicle Test Suite

Payload Test Suite

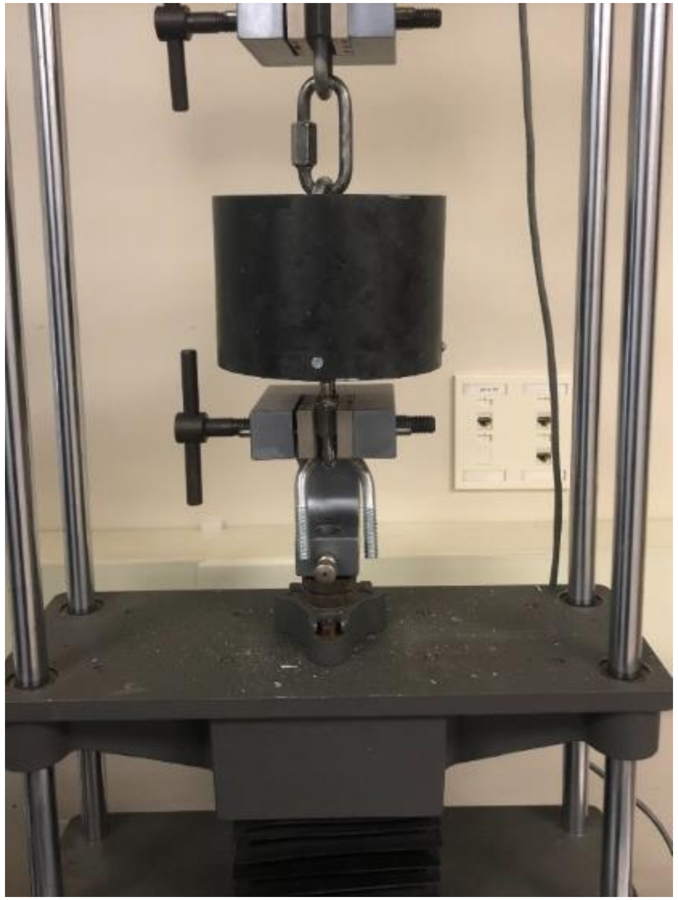
Sample Procedures

Launch Vehicle Test Suite

- Contains 11 procedures
- Testing complete by 2/22/2020
- Components Tested
    - Bulkhead Securement
    - Recovery Electronics
    - Ejection Demonstrations

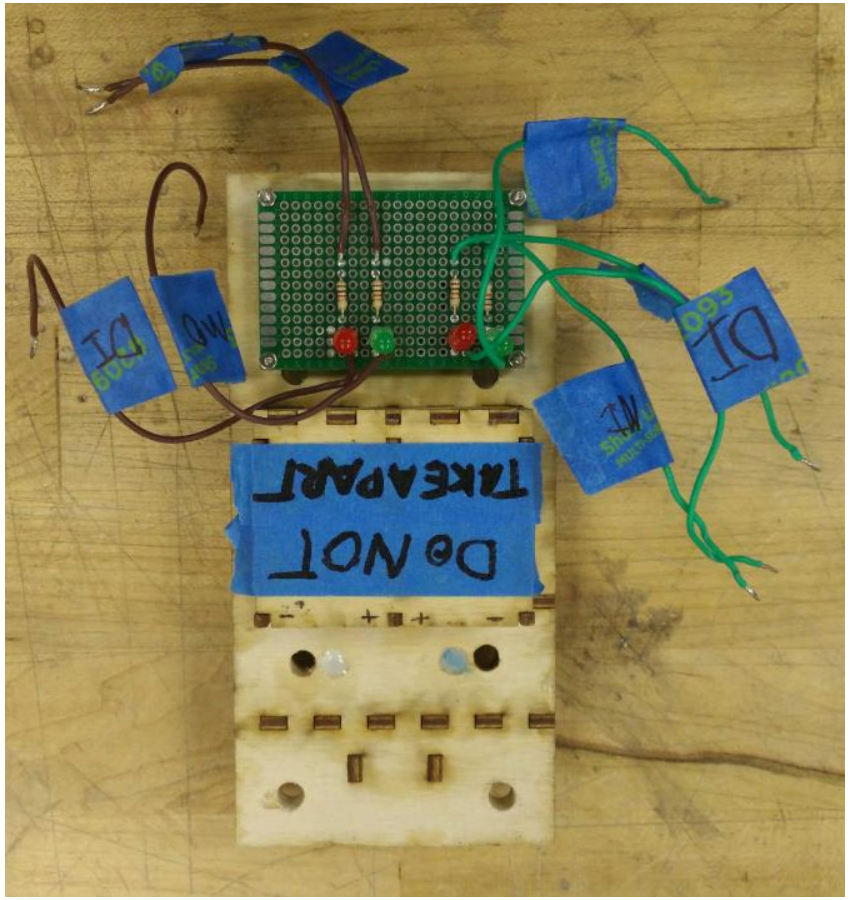
Bulkhead Tensile Loading Test

- Verifies requirement TDR 2.7
- Success Criteria
  - Sample withstands load over 1000 lbf
  - Sample withstands load over 900 lbf applied over 10 seconds
  - Sample has no visible damage after test completion



Altimeter Operational Demonstration

- Verifies requirements NASA 3.1, NASA 3.1.3, NASA 3.2
- Success Criteria
  - LED #1 lights when the altimeter senses apogee
  - LED #2 lights when the altimeter senses 500 feet
  - Pre-Flight beeps match the beep sheet
  - Post-Flight beeps do not indicate any in-flight errors



Full Scale Ejection Demonstration

- Verifies Requirements NASA 3.1, NASA 3.1.3, NASA 3.2
- Success Criteria
  - Vigorous and complete separation at the main parachute bay
  - Vigorous and complete separation at the drogue parachute bay
  - No damage to recovery devices
  - No damage to launch vehicle

Payload Test Suite

- Contains 12 procedures
- End date 2/17/2020
- Components Tested
  - BURRITO
  - SICCU
  - Integration/Retention System

BURRITO Terrain Performance Test

- Verifies Requirements NASA 4.3.4, TDR 4.2, TDR 4.5, TDR 4.11
- Success Criteria
  - The rover maintains forward progress across soil
  - The rover maintains forward progress across large-grain gravel
  - The rover maintains forward progress through wet mud
  - The rover maintains forward progress through tall, thick grass
  - The rover maintains forward progress through 2-inch deep simulated lunar ice

SICCU Operational Test

- Verifies Requirements NASA 4.3.2, NASA 4.3.3, TDR 4.9, TDR 4.10, TDR 4.13
- Success Criteria
  - After all trials of scooping, the average scoop volume is greater than or equal to 15 mL
  - The scoop tops are flush with the bottom plate of BURRITO when stowed
  - During BURRITO operation, the stowed SICCU does not hinder rover movement
  - A separate power supply is not required
  - The SICCU does not activate unless commanded by the operator

Retention System Loading Test

- Verifies Requirements NASA 4.3.7, NASA 4.3.7.2, TDR 4.14
- Success Criteria
  - The test sample withstands a load of 360 lbf
  - The test sample has no visible damage after test completion

Requirement Compliance Plan

Compliance Plan Status

- Requirements Verified
  - NASA Handbook Requirements: 80/131 (61%)
  - Team Derived Requirements: 28/40 (70%)
- All remaining requirements to be verified before the FRR Milestone submission
  - Most are reliant on demonstration/test requiring Full Scale components

Launch Vehicle Requirements

- The launch vehicle shall not drift more than a 2,500 ft radius from the launch pad (NASA 3.10)
  - Incomplete. RockSim analysis and hand calculations indicate this requirement will be met. Adherence will be verified during the vehicle demonstration flight.
- The launch vehicle shall have a static stability margin between 2.0 and 2.3 upon rail exit (TDR 2.5)
  - 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)
  - Incomplete. This will be verified with tests in the Launch Vehicle Test Plan.

Payload Requirements

- The payload retention system shall be designed to successfully endure flight forces (NASA 4.3.7.2)
  - Incomplete. This will be verified during the Retention System Loading Test.
- The payload shall recover a lunar ice sample of a minimum of 10 milliliters (NASA 4.3.3)
  - Incomplete. This will be verified in the SICCU Operational Test.
- The payload vehicle shall cover a range of at least 2000 feet (TDR 4.3)
  - Incomplete. This will be verified during the BURRITO Range Test.

Questions?