
# Flight Readiness Review

March 21, 2023

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# Major Changes since CDR

- Drogue parachute has been changed from an 18” Fruity Chutes Compact Elliptical to a 15” Fruity Chutes Compact Elliptical.
- Shock cord has been changed from 2 x 30’ to one 17’ and one 23’.
- Increased number of rivets.
- Nose cone bulkhead moved 1 in. farther aft.
- Second buck converter and fuse added to SOCS electronics.
- New sled design uses two circular bulkheads and a battery holder and new unit mounts are designed to be stronger.
- HDMI to CSI adapters added to imaging electronics.


# Launch Vehicle Design

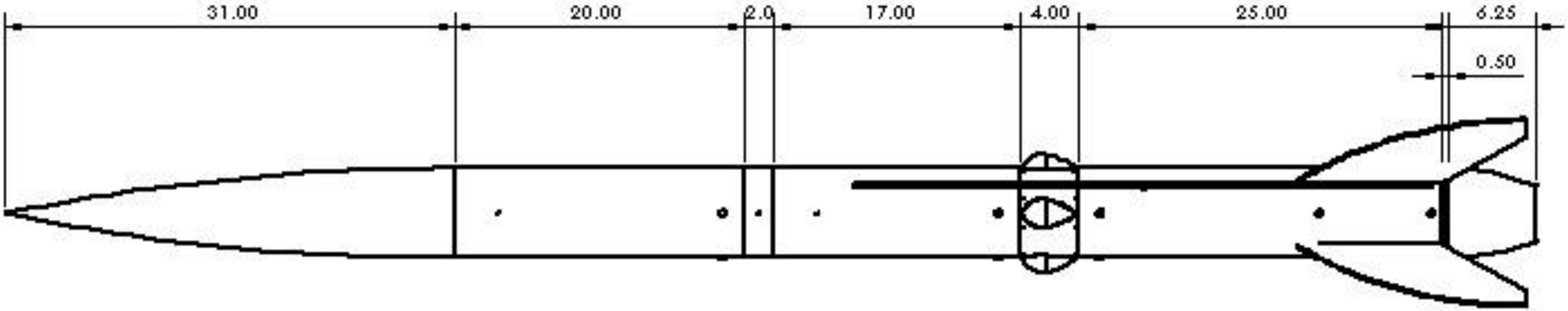
Material Selection

Airframe Sections

Fin Configuration

# Launch Vehicle Design

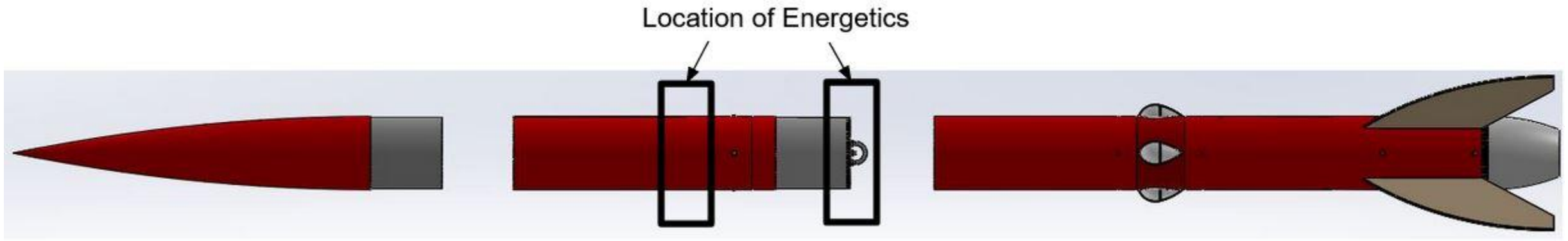
- Length: 105.75 in.
- Diameter: 6.17 in.
- Launch Weight: 42.5 lb.
- Airframe components fabricated to ±1/16 in.



# Separation Points

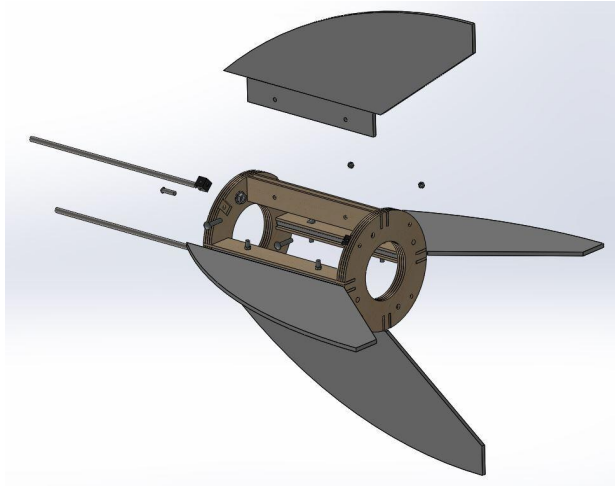
2 Separation Points:

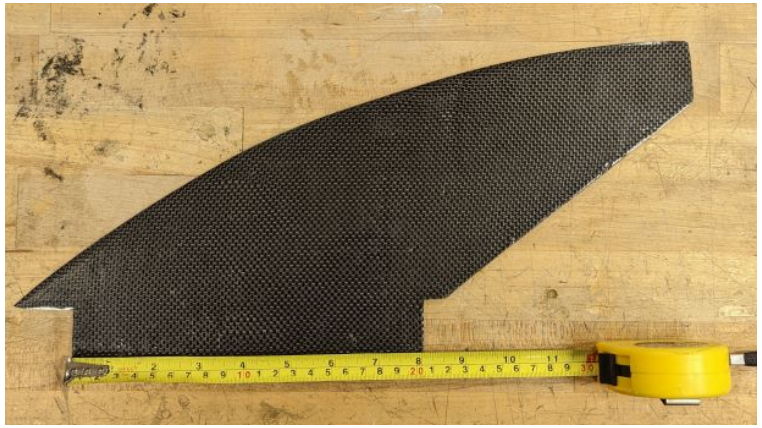
- Nose cone - Main parachute bay
  - 4 grams primary charge, 4.5 grams secondary charge
- AV bay - Drogue parachute bay
  - 2 grams primary charge, 2.5 grams secondary charge
- Ejection charges will be contained in PVC blast caps



# Four Fin Removable Configuration

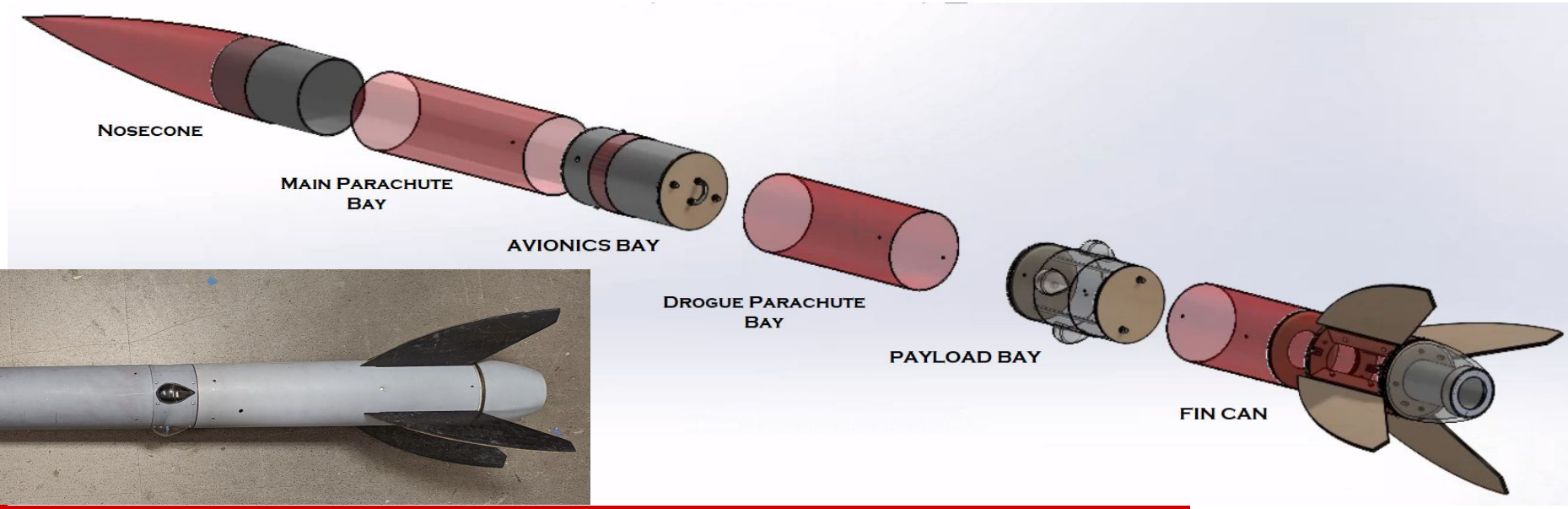
- Fins are bolted to runners that span the centering rings
- Thrust plate ensures motor force is directly transferred to the airframe
- Swept wing design moves a portion of the surface area well behind the fin can which aids in moving the center of pressure farther aft.





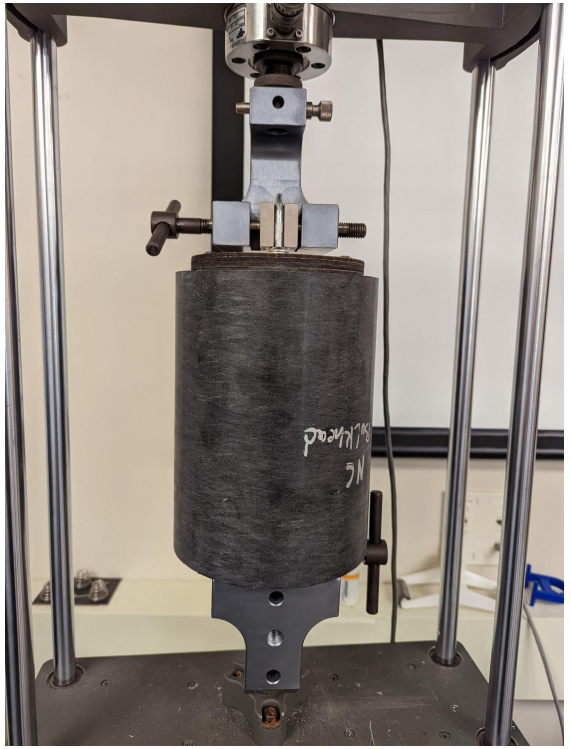
# Changes Since CDR

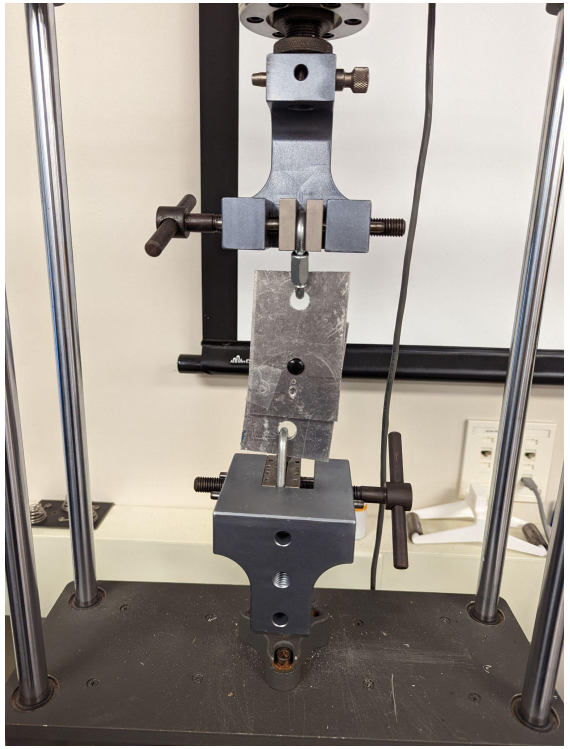
- Increased number of rivets
- Nose cone bulkhead moved 1 in. farther aft
- Shock cord lengths reduced
- Drogue parachute changed to 15 in.



# Vehicle Verification Testing

- Tensile tests on nose cone and AV bulkheads
- Shear tests on rivets and shear pins
- Fin Bending Test



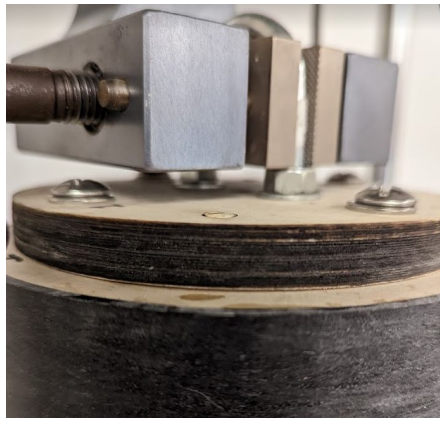
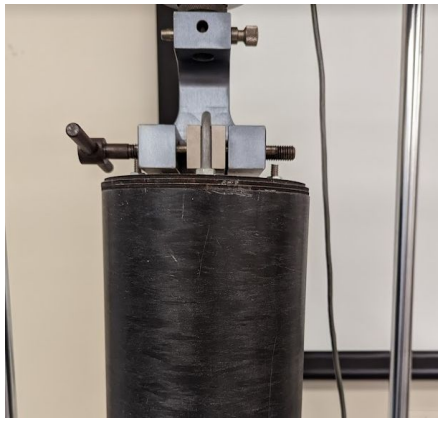


# Vehicle Test Results

- All launch vehicle tests have been performed and deemed to be passing (as of 1/23/2023)

| Component | Factor of Safety |
|---|---|
| AV bay bulkheads | 5.6 |
| Nose Cone Bulkheads | 16.4 |
| Rivet | 1.6 |



# Composite Fin Bending Test

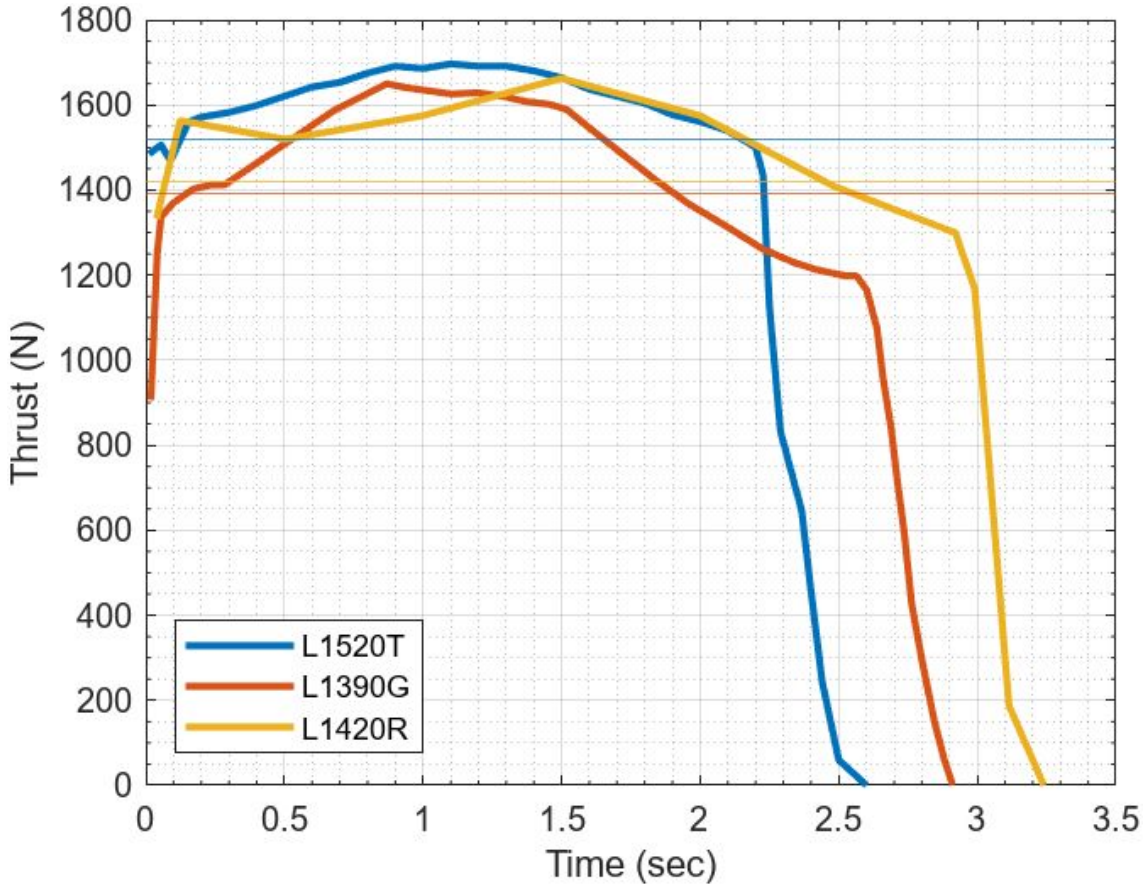
- Fin bending test was performed on 2/24/23.

| Component | Load | Deflection |
|---|---|---|
| Composite Fin | 80lbs | 5in |


# Mission Performance Predictions

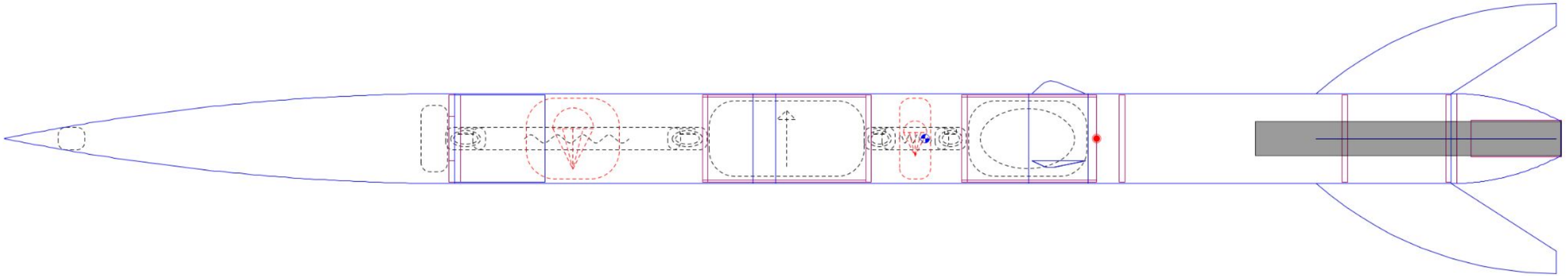
# Motor Selection

- Selected the Aerotech L1520T
  - 75 mm Diameter
  - 1,854 g of Blue Thunder Propellent
  - 2.4 s burn time
  - 1,567 N Average burn time
  - 3,715 Ns of Impulse



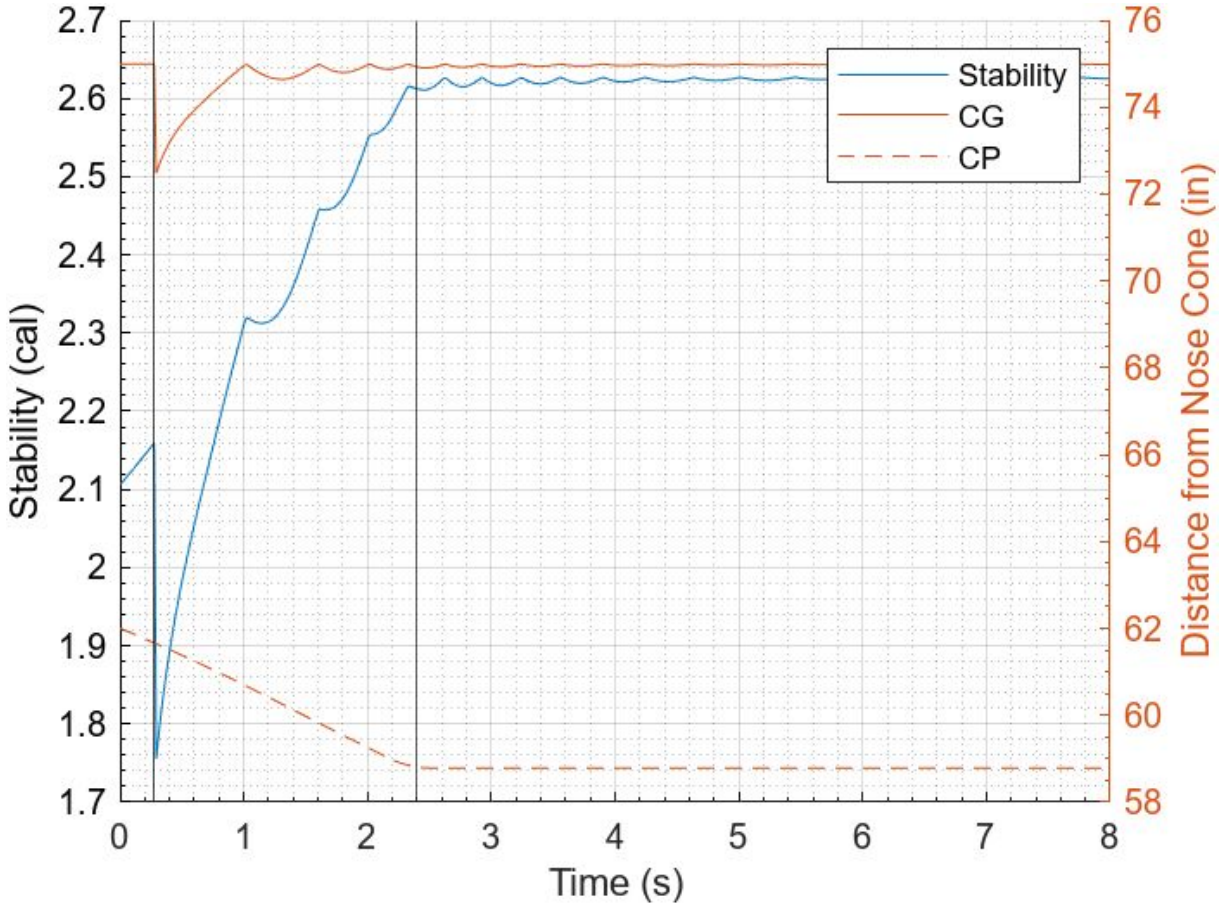
# Flight Stability Simulation

- RockSim Simulation
  - CP at 75 in.
  - CG at 62 in.



# Flight Stability Simulation cont.

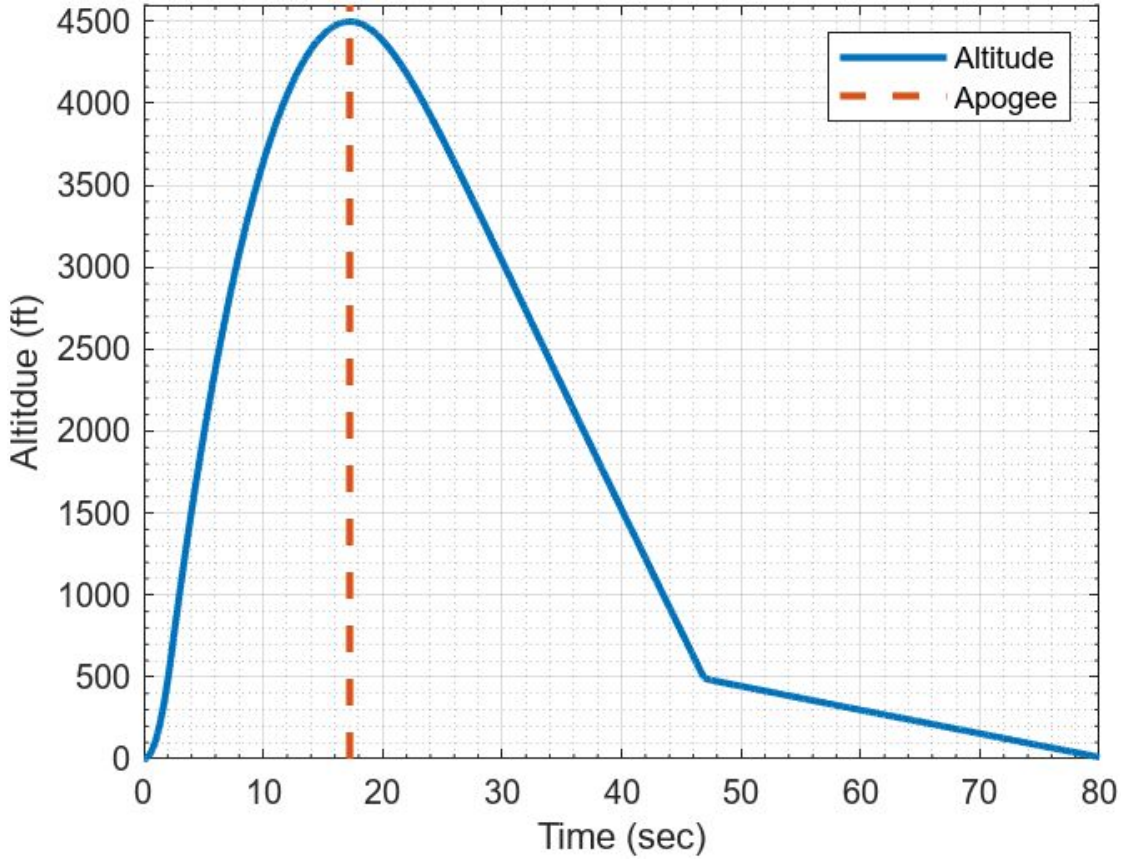
- Stability Simulation Results
  - 2.10 cal Static Stability
  - 2.16 cal at Rail Exit
  - 2.62 cal at Motor Burnout



# Predicted Launch Values

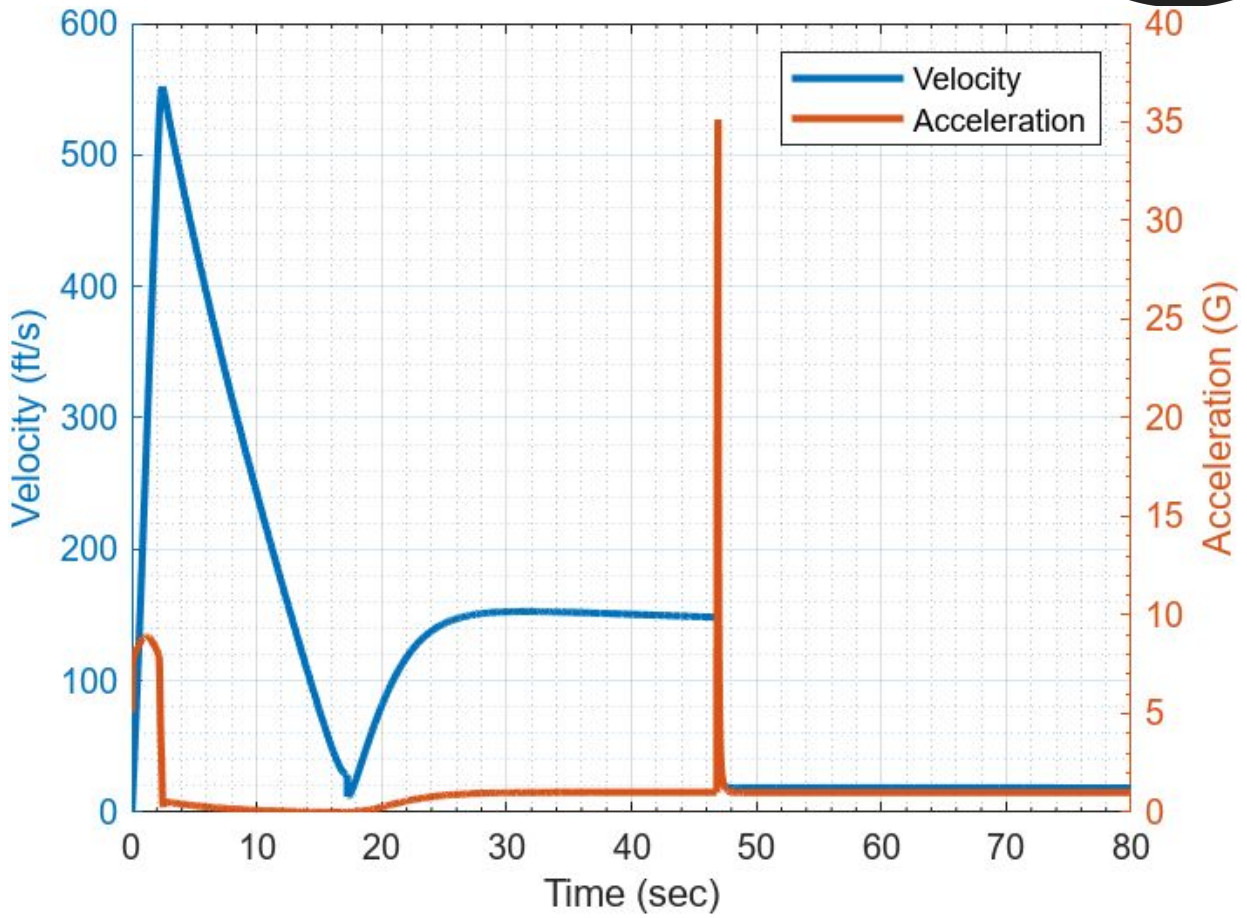
- Flight Simulation Results
  - 4,500 ft AGL
  - Apogee at 17.24 sec

| Parameter | Assumption | Justification |
|---|---|---|
| Launch Rail Angle | 5° | Handbook 1.12 |
| Launch Rail Length | 144 in. | Handbook 1.12 |
| Wind Speed | 10 mph. | Median Flight Condition |
| Launch Direction | Into Wind | Standard Procedure |



# Flight Performance

- Thrust to Weight Ratio
  - 8.35
- Rail Exit Speed
  - 60 ft/s
- Motor Burnout Speed
  - 552 ft/s



# Mass Statement and Margin VDF

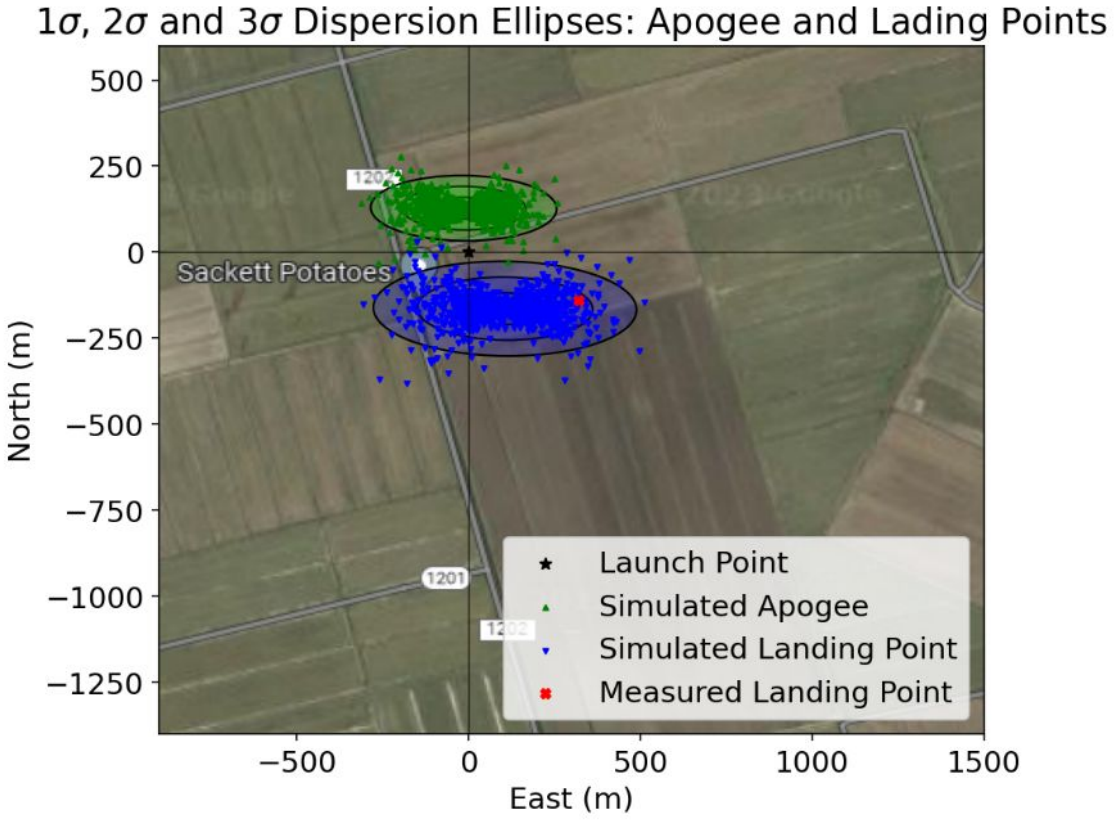
| Section | Mass (lbs) |
|---|---|
| Nose Cone | 9.21 |
| Main Parachute Bay | 5.48 |
| Avionics Bay | 3.90 |
| Drogue Parachute Bay | 3.67 |
| Payload Bay | 5.42 |
| Fin Can | 14.80 |
| Total | 42.48 |

# Current Design Mass Statement and Margin

| Section | Mass (lbs) |
|---|---|
| Nose Cone | 8.42 |
| Main Parachute Bay | 5.38 |
| Avionics Bay | 3.90 |
| Drogue Parachute Bay | 3.57 |
| Payload Bay | 5.42 |
| Fin Can | 14.46 |
| Total | 41.15 |

# RocketPy

- Open Source Python Library
- Six-degrees of freedom simulation
- Advanced Weather Profiles
- Trajectory Optimization
- Monte Carlo Dispersion Analysis



# Descent Velocity Updates

- Descent velocity predictions have been updated
- New descent velocities fit within both team derived requirements and NASA requirements
- Changes are from updated equation and drag coefficient

| Parachute | Old Descent Velocity | Updated Descent Velocity |
|---|---|---|
| Drogue Parachute | 136.69 ft/s | 88.7 ft/s |
| Main Parachute | 13.79 ft/s | 14.40 ft/s |

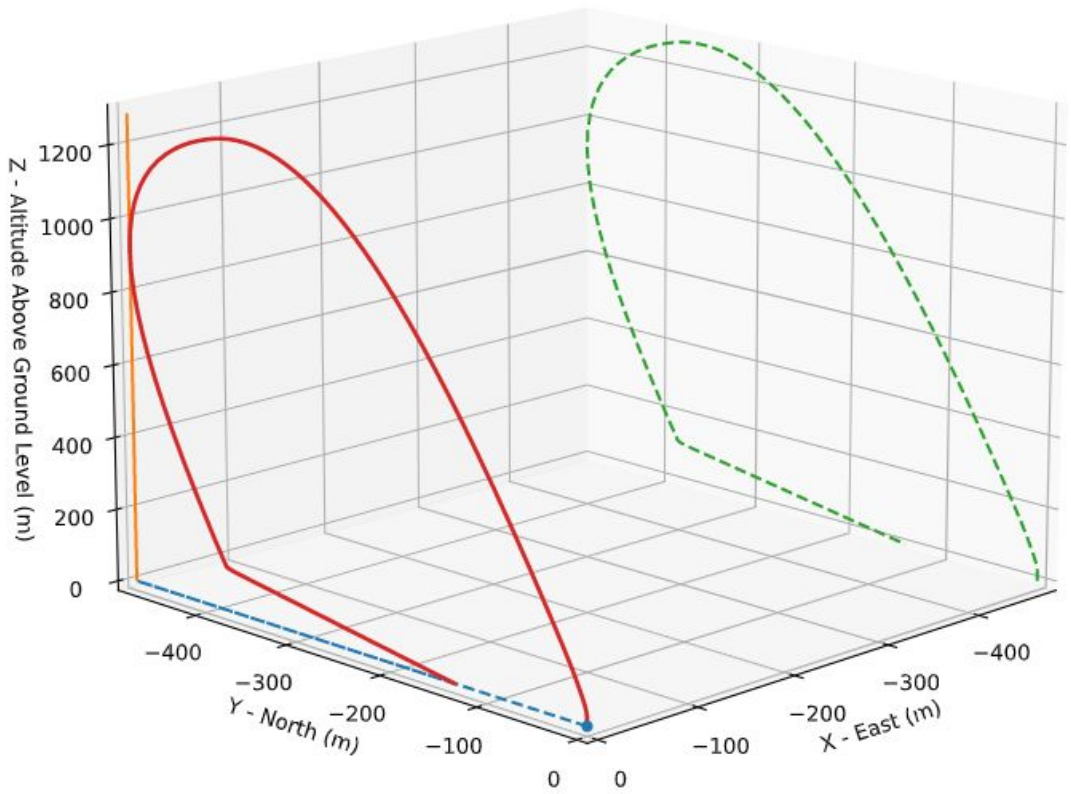
# Wind Drift and Descent Time

- Drift distance is total downrange movement based on wind conditions
- Based on descent time of 79.75 seconds
- Maximum drift expected to be 2340 feet
- Apogee is estimated to be directly above launchpad

| Wind Velocity | Drift Distance |
|---|---|
| 0 mph | 0 feet |
| 5 mph | 585 feet |
| 10 mph | 1170 feet |
| 15 mph | 1755 feet |
| 20 mph | 2340 feet |

# Alternative Wind Drift and Descent Time Calculations

- Using RockSim we can simulate the entire flight path of the vehicle
  - Total descent time is 75.95 seconds
  - Total drift distance is about 436 feet



# Kinetic Energy Upon Landing

- Highest impact force felt by fin can section
- Highest force is still below 65 ft-lbf to get bonus points

| Section | Mass of Section | Velocity Under Main Parachute | Impact Energy |
|---|---|---|---|
| Nose Cone | .280 slugs | 6.85 ft/s | 6.57 ft-lbf |
| Main Parachute Bay And Avionics Bay | .210 slugs | 11.42 ft/s | 13.70 ft-lbf |
| Drogue Parachute Bay, Payload Bay, and Fin Can | .445 slugs | 14.40 ft/s | 46.16 ft-lbf |

# Opening Shock

- Kevlar Rated at 6600 lbf
- Max loading: 215.219 lbf
  - Factor of Safety: 30

| Launch Vehicle Body Section | Body Section Mass | Main Parachute Opening Shock |
|---|---|---|
| Full Launch Vehicle | 1.304 slugs | 215.219 ft-lbs |
| Nose Cone | .280 slugs | 46.213 ft-lbs |
| Main Parachute Bay and Avionics Vay | .210 slugs | 34.660 ft-lbs |
| Drogue Parachute Bay, Payload Bay and, Fin Can | .445 slugs | 73.445 ft-lbs |


# Recovery System Design

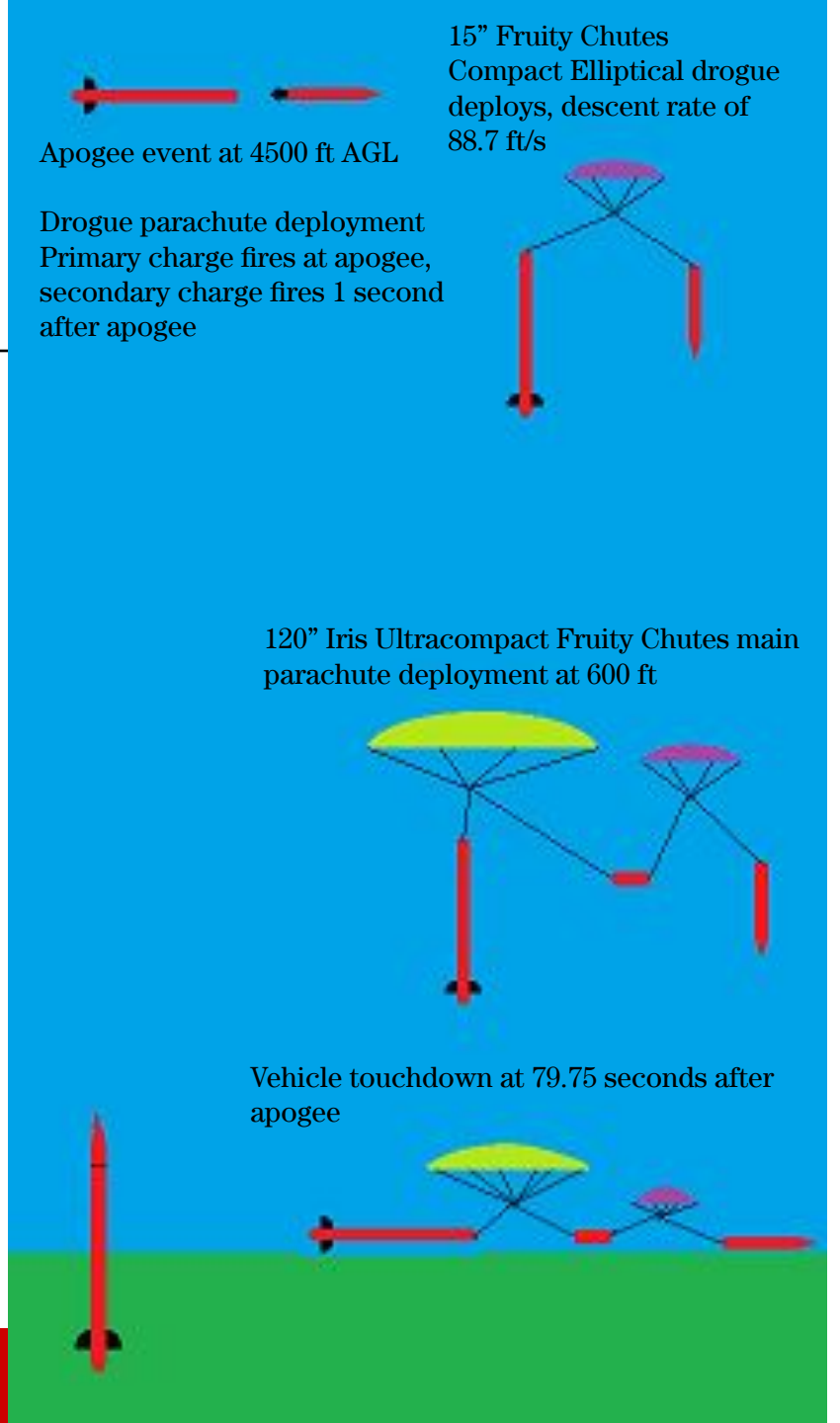
Parachute Size

Recovery Harness

Recovery Electronics

# Recovery Overview

- Recovery components consist of:
  - 2 RRC3 “Sport” altimeters
  - 1 Eggtimer Quasar GPS
  - 1 Eggfinder LCD Display
  - 1 18” Drogue Parachute
  - 1 120” Main Parachute
  - 2 20’ Kevlar shock cords
  - 4 ejection charges of FFF Black Powder.
    - Drogue charges: 2 and 2.5 grams
    - Main charges: 4 and 4.5 grams



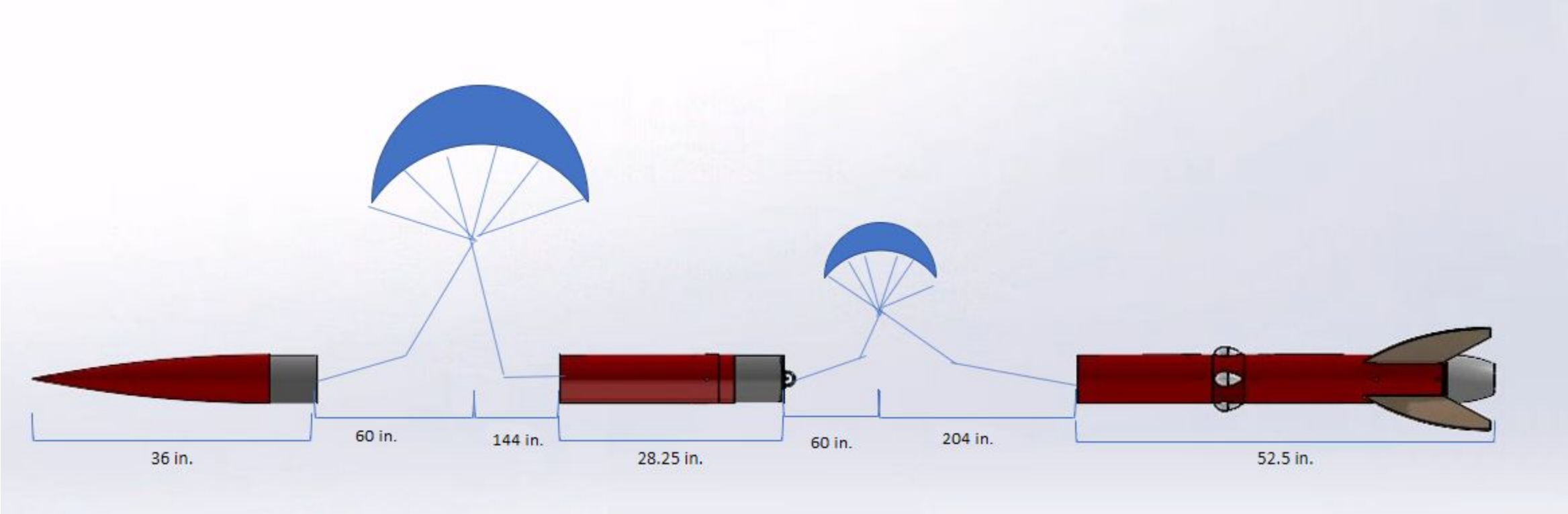
# Parachutes

- Drogue Parachute: Fruity Chutes 15” Compact Elliptical
- Main Parachute: Fruity Chutes 120” Iris Ultracompact
- Nomex cloth wrapped for protection against ejection charges
- Dog Barf insulation provides extra protection and ensures separation

# Recovery Harness

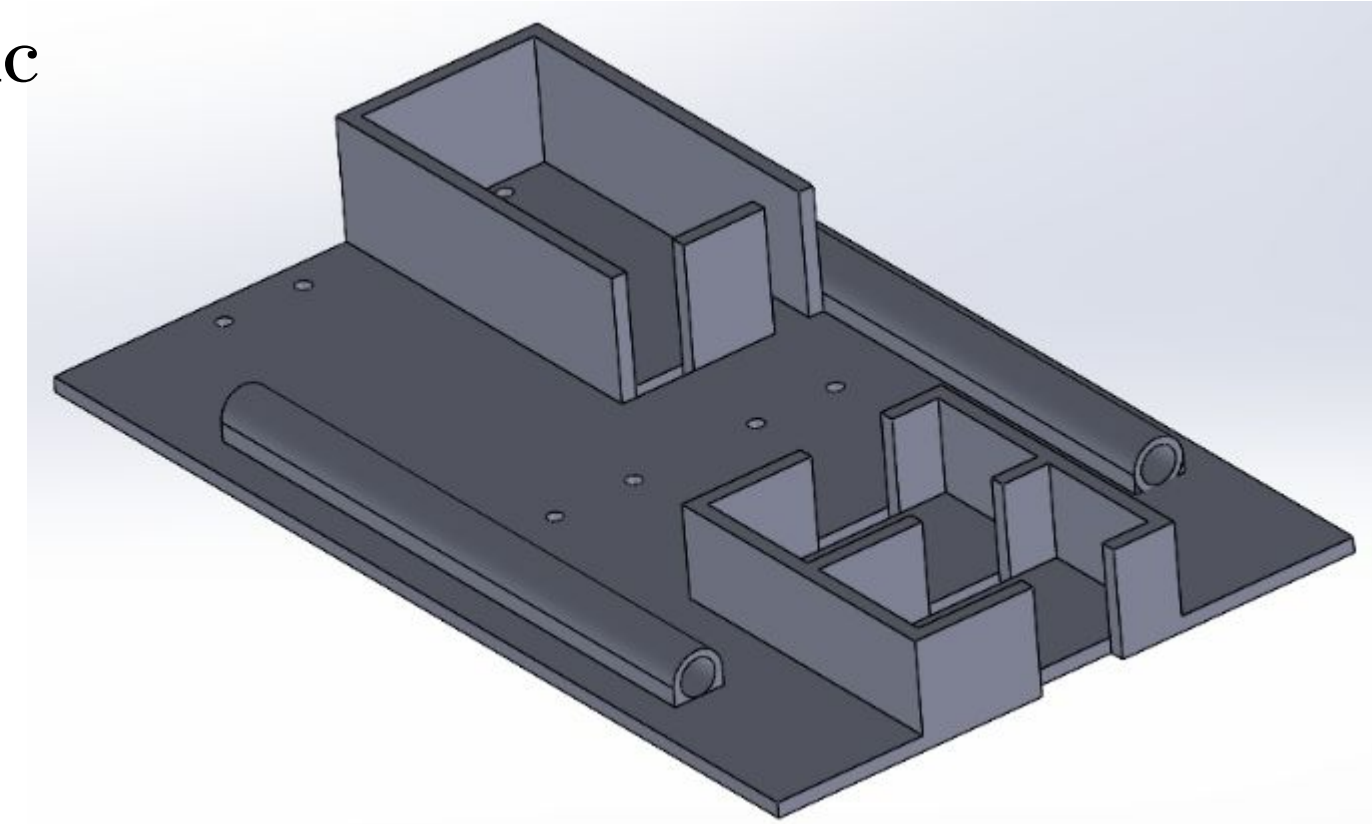
- Each parachute has a ⅝ inch thick Kevlar shock cord attaching to U-bolts on bulkheads connected to the launch vehicle.
- Length of main recovery harness is 17 ft
- Length of drogue harness is 23 feet

# Main Recovery Harness Lengths



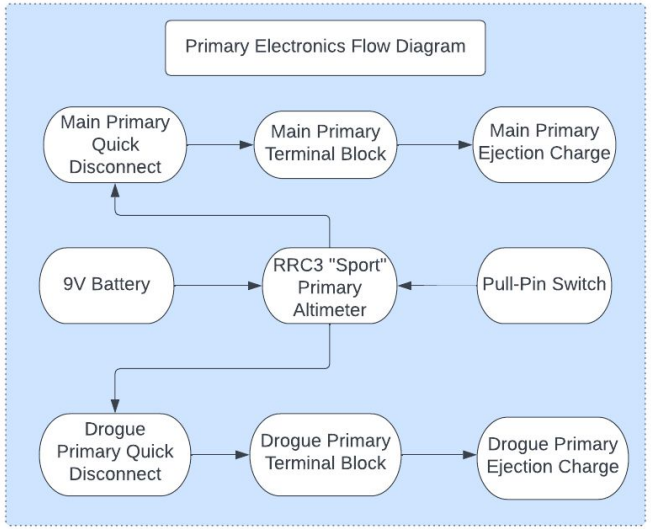
# Avionics Sled

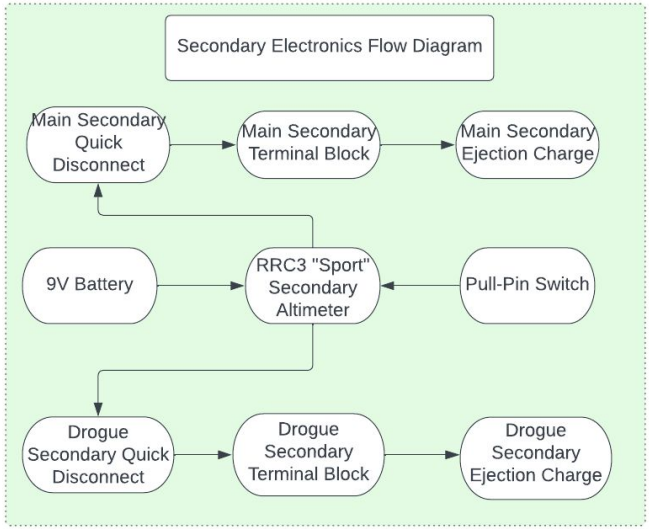
- 3D printed using PETG Plastic
- Separate slots for 2 9V batteries and a 2 cell LiPo battery
- Pre-allocated holes to accommodate altimeters
- Mounting space for GPS
- Mounting space for 2 pull pin switches by Lab Rat Rocketry

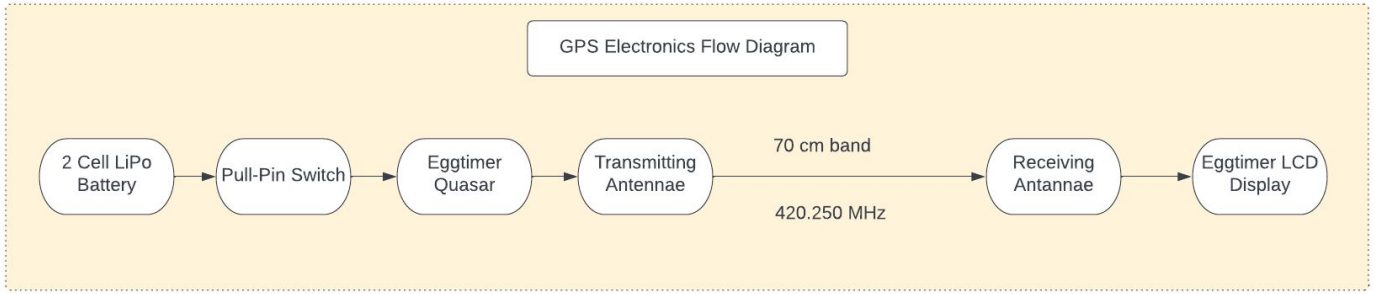


Avionics Sled

# Recovery Avionics

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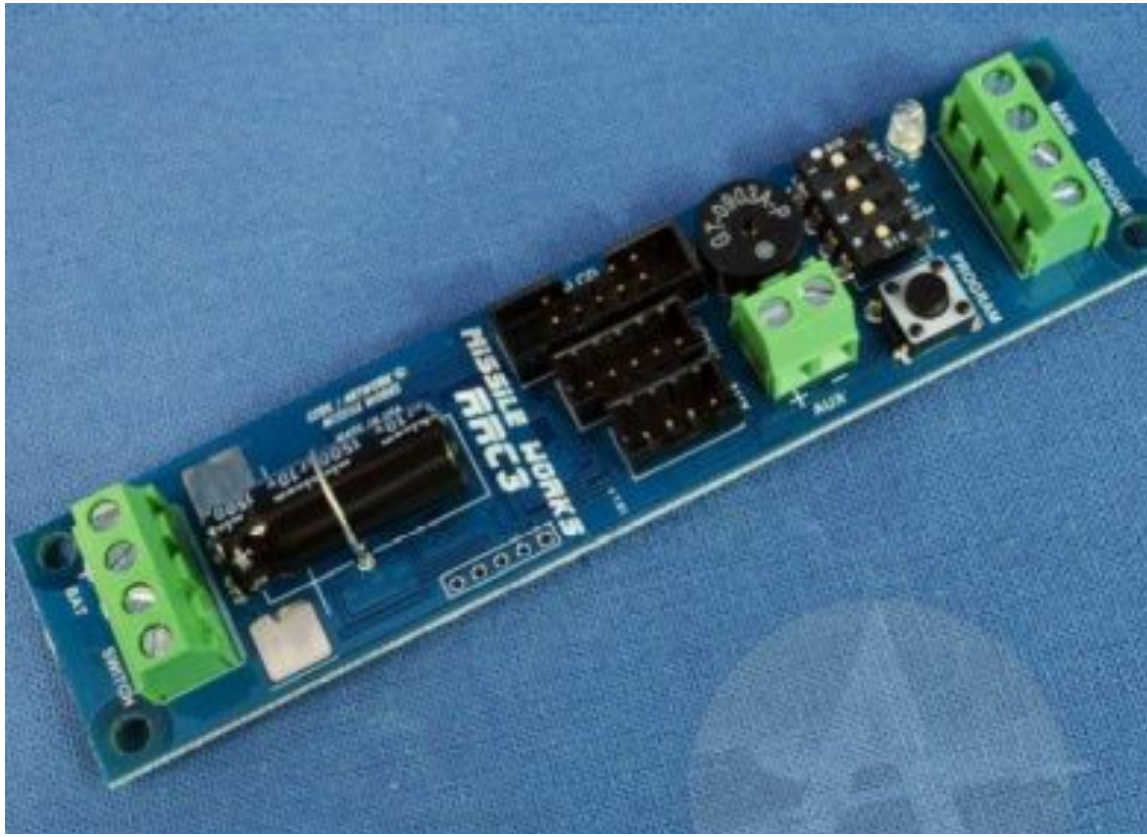
# Altimeters

- Selected RRC3 “Sport” Altimeter from MissileWorks

- Primary:
  - Drogue at apogee
  - Main at 600 feet AGL

- Secondary:
  - Drogue at 1 second after apogee
  - Main at 500 feet AGL



# Tracker

- Eggtimer Quasar dual altimeter and GPS.
  - 70 cm bandwidth transmission (420.250 MHz)
  - Altimeter functionality will not be utilized
  - It will be paired with the handheld Eggfinder LCD Receiver

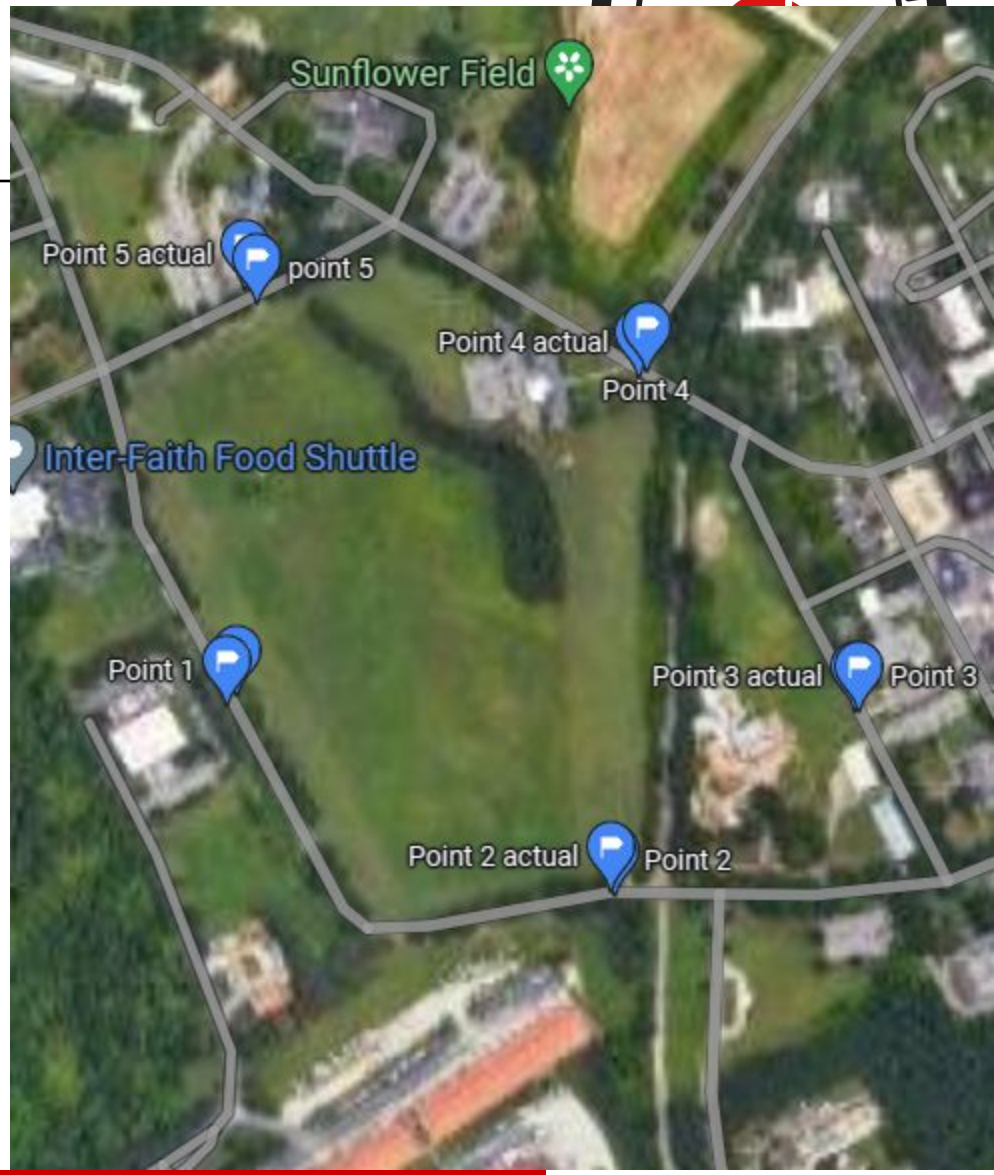

# Ejection Tests

- Forward charge 4 grams
- Aft charge 2 grams
- Complete and vigorous separation
- No damage to recovery components

# Tracking System Test

Minimal deviation in the actual coordinates versus Quasar reported coordinates

Consistent accuracy of within 10 feet



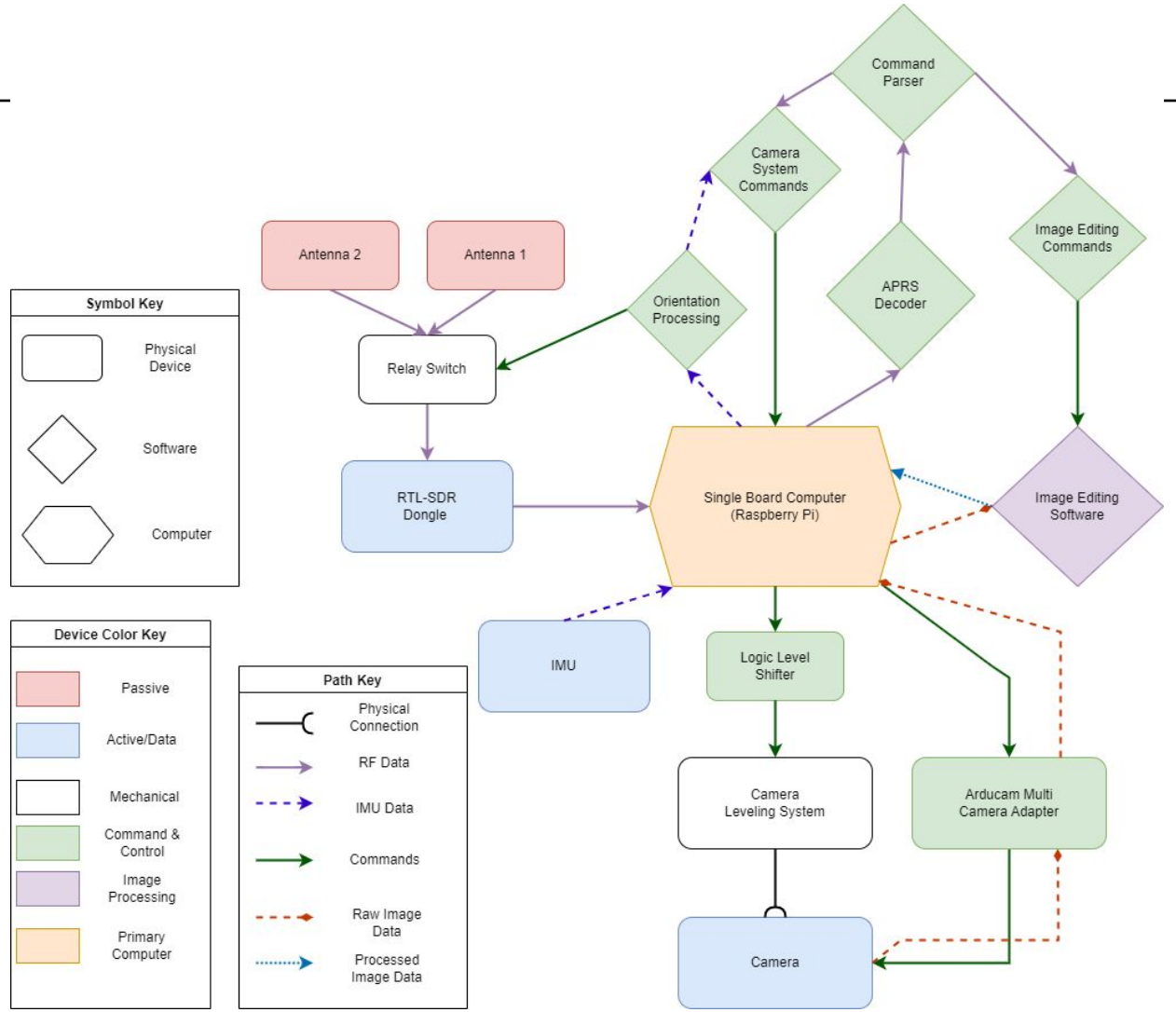

# Payload

SOCS - Surrounding Optics and Camera System

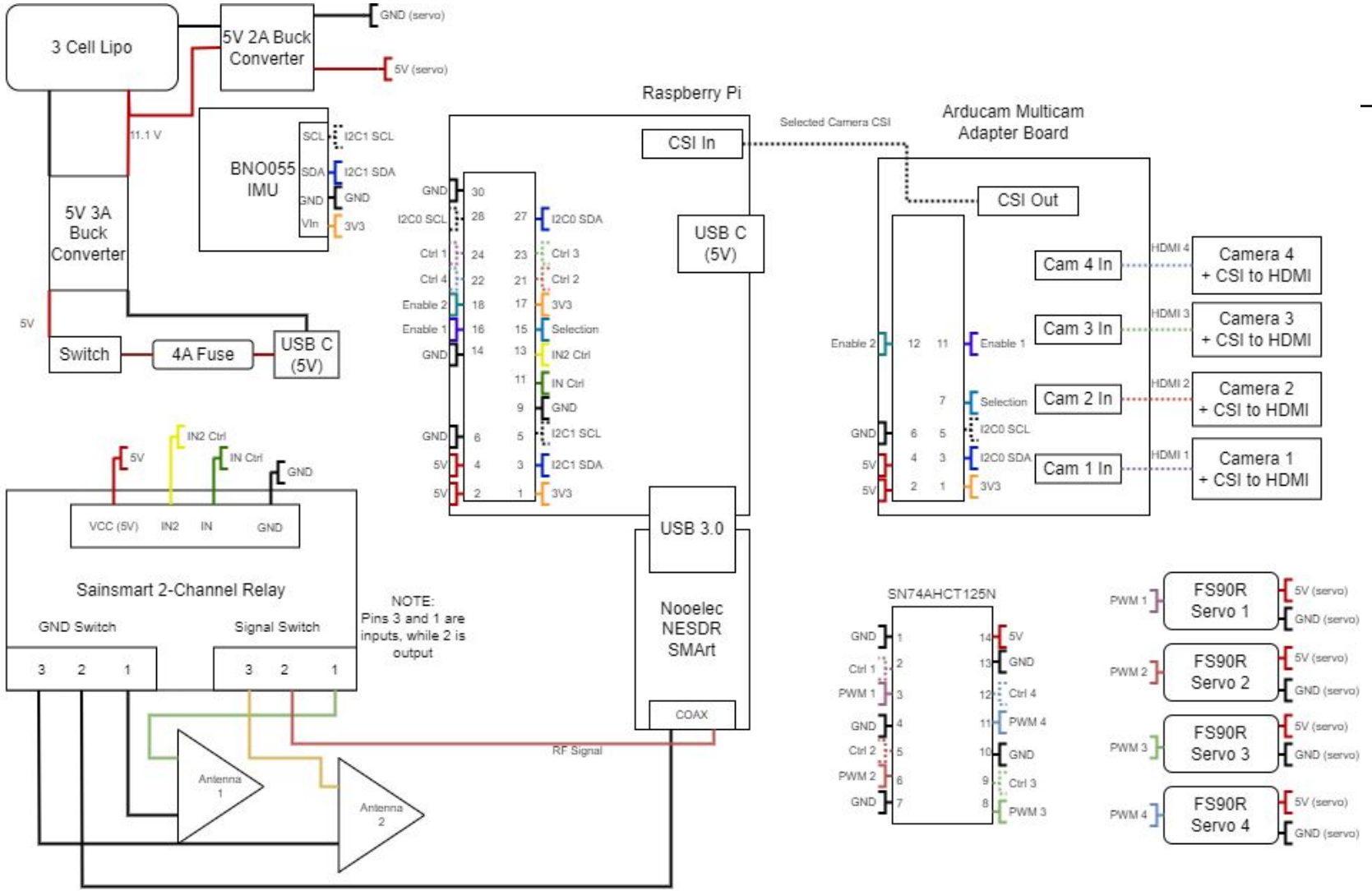
# System Overview

- SOCS consists of two subsystems and a central computer
  - RAFCO subsystem
  - Camera subsystem
  - Raspberry Pi single board computer
- SOCS receives APRS commands using the RAFCO subsystem, processes these commands, and then instructs the camera subsystem to fulfill these commands

# System Flow Chart



# Wiring Diagram



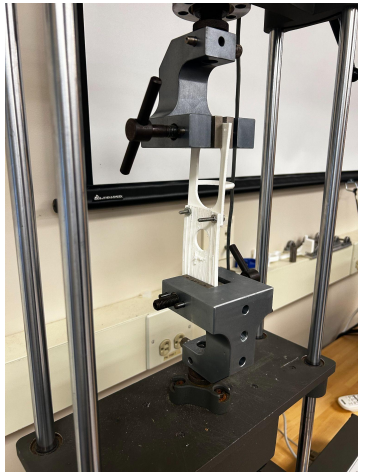
# RAFCO Subsystem Tests

- Antenna SWR Test
  - Objective: Determine and correct antenna SWR to between 1 and 2.2
  - Driving Req: SWR determines antenna gain
  - Results: both antenna 1<SWR<2.2
- Orientation Detection and Switching Test
  - Objective: Determine if RAFCO system correctly detects orientation and switches to the correct antenna
  - Driving Req: Orientation detection is essential for system operations
  - Results: Subscale RAFCO system test correctly determined orientation, and switched antennas. Full scale test was similarly successful.
- APRS Reception and Decoding Test
  - Objective: Determine if RAFCO subsystem is capable of receiving and decoding APRS signals
  - Driving Req: Command and Control is transmitted over APRS
  - Results: Subscale and fullscale systems successfully received and decoded APRS transmission

# Structures Testing

- Camera Housing Test
  - Determine if the Supports can withstand the forces experienced during launch and landing.
  - Used the Universal testing Machine to load supports until failure.
  - Results: Supports can withstand a force of 55lbs.
- Camera Unit Mount Test
  - Determine if the Unit Mount can withstand the shear forces experienced during launch and landing.
  - Used Universal Testing Machine to load Unit Mounts laterally.
  - Results: Subscale and fullscale systems successfully received and decoded APRS transmission.

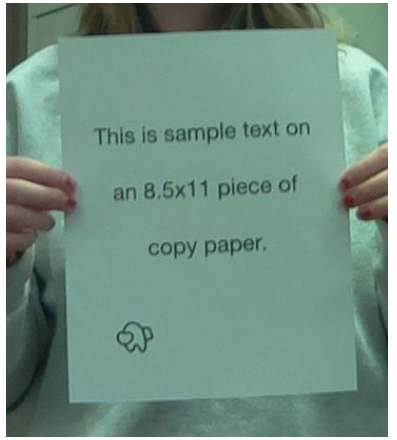
Camera Housing Test



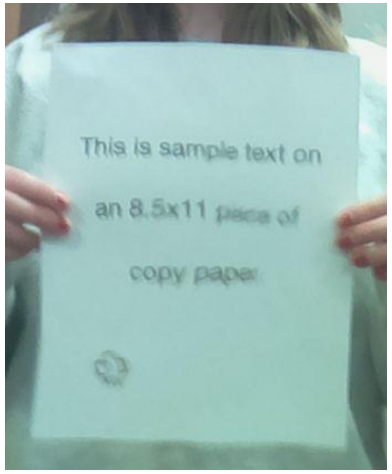
Camera Unit Mount Test

# Camera Tests

- Objective: Determine functionality and clarity of cameras
- Driving Req: Cameras shall capture clear view of field
- Results: All four cameras captured and saved clear images with correct filenames



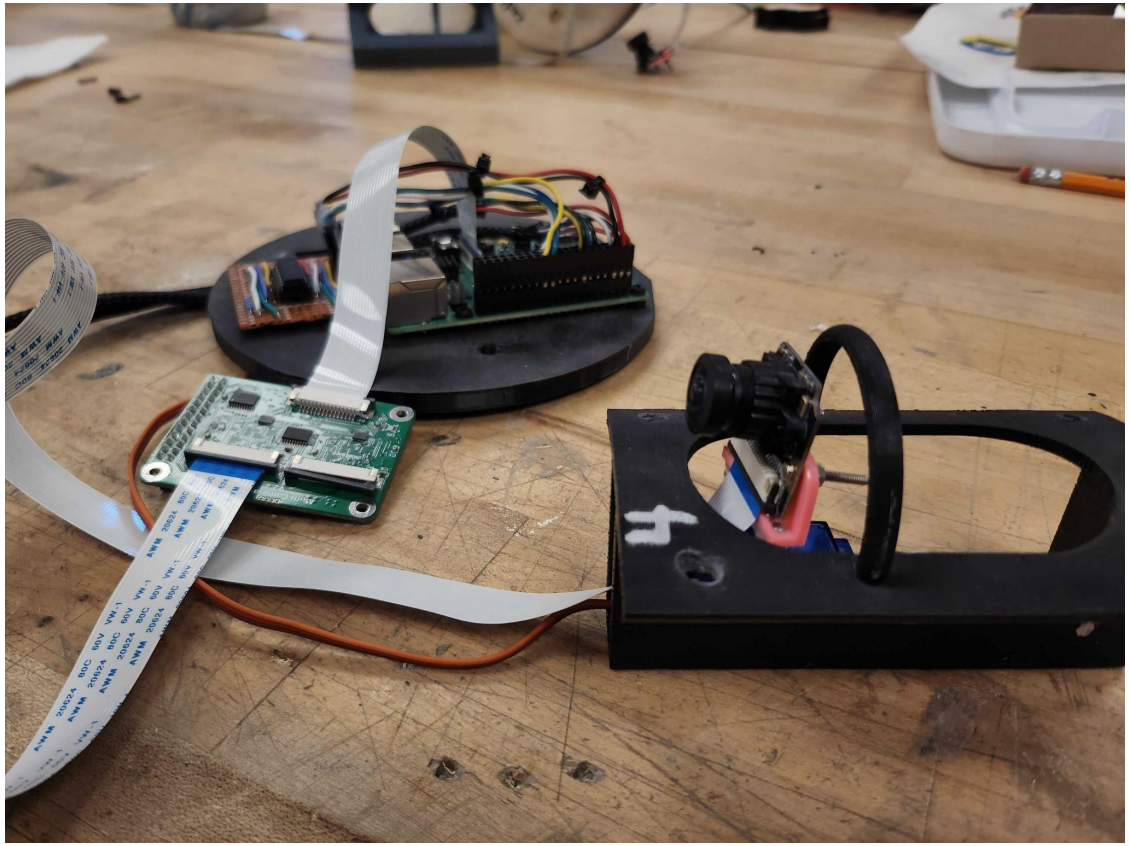

Without cupola




With cupola

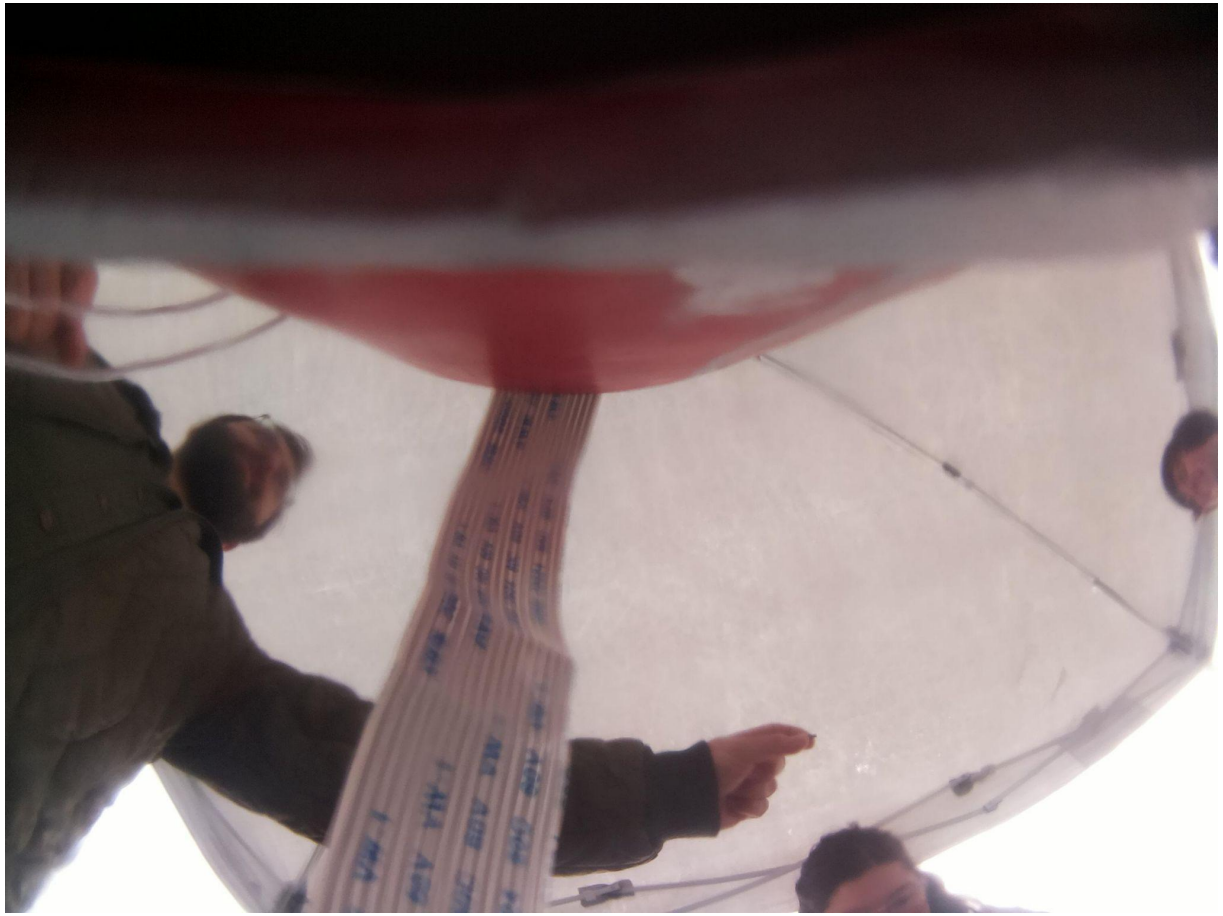
# Camera System Integration Test

- Objective: Ensure functionality of multicam adapter
- Driving Req: Four cameras shall capture images
- Results: Cameras can toggle and capture images from correct camera with servo motion



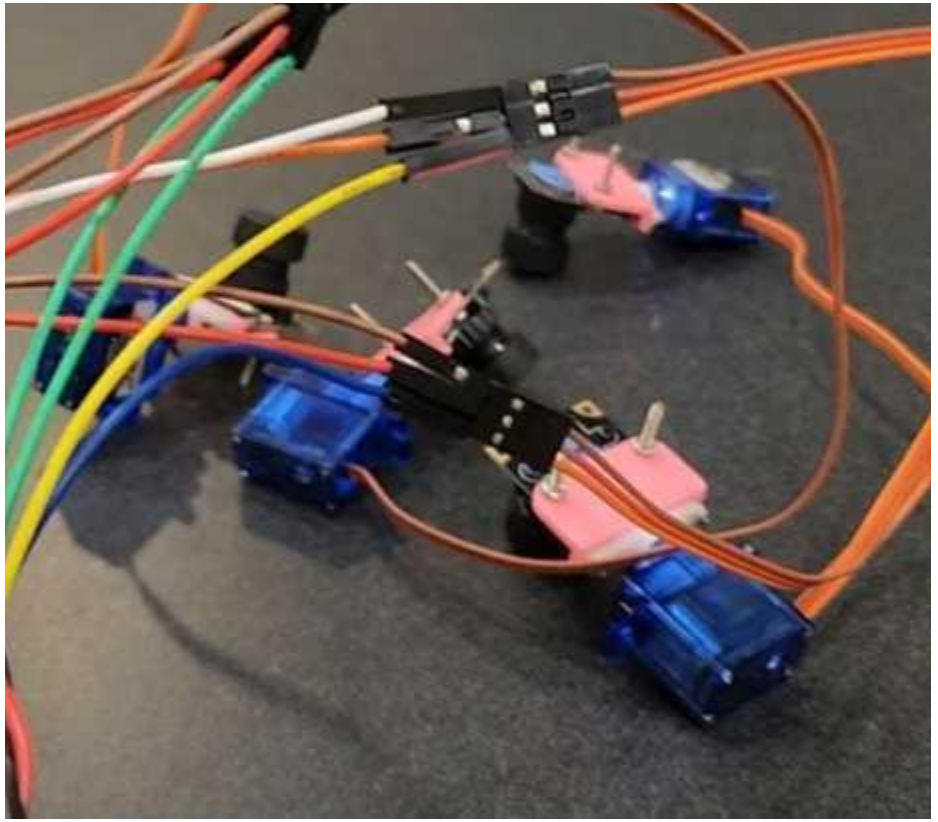
# Camera System RAFCO Test

- Objective: Execute camera commands from RAFCO info
- Driving Req: Command and control is transmitted via APRS
- Results: Camera system correctly interprets and executes commands



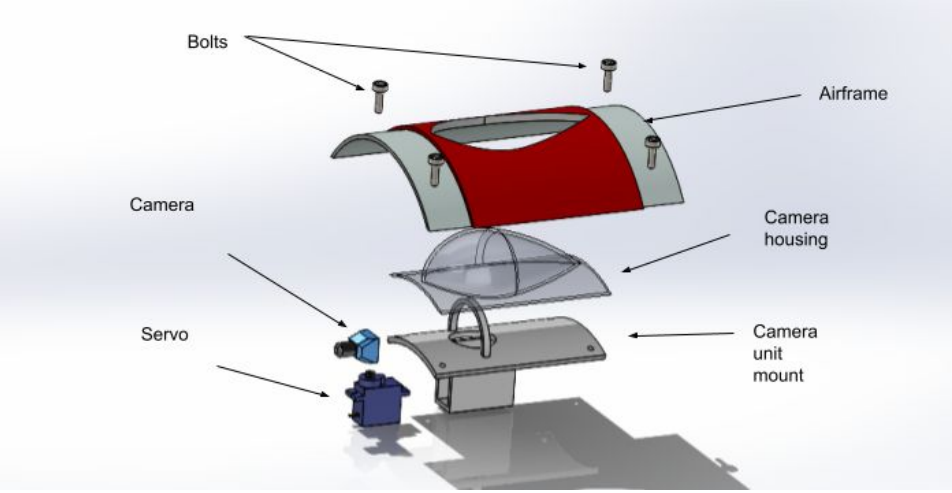
# Servo Tests

- Objective: Move servo from Raspberry Pi control
- Driving Req: Cameras shall move according to RAFCO signals
- Results: All servos moved according to commands

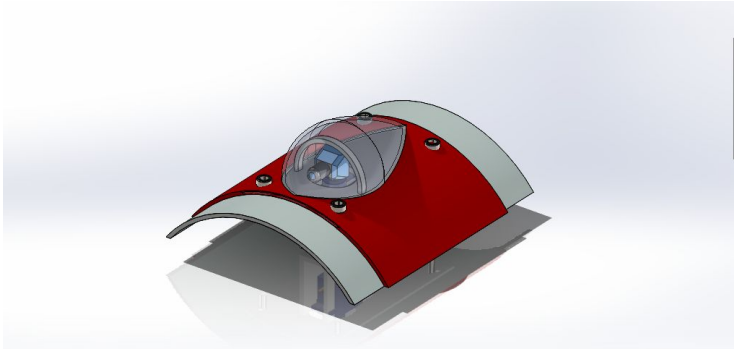


# Imaging Subsystem Assembly

- Order of Assembly
  1. Camera unit mount
  2. Camera housing
  3. Airframe
- Components bolted together with four #6-32 bolts
- Servo secured inside camera unit mount with electrical tape
  - Camera sees through camera housing
- Camera unit attached to rotating servo shaft

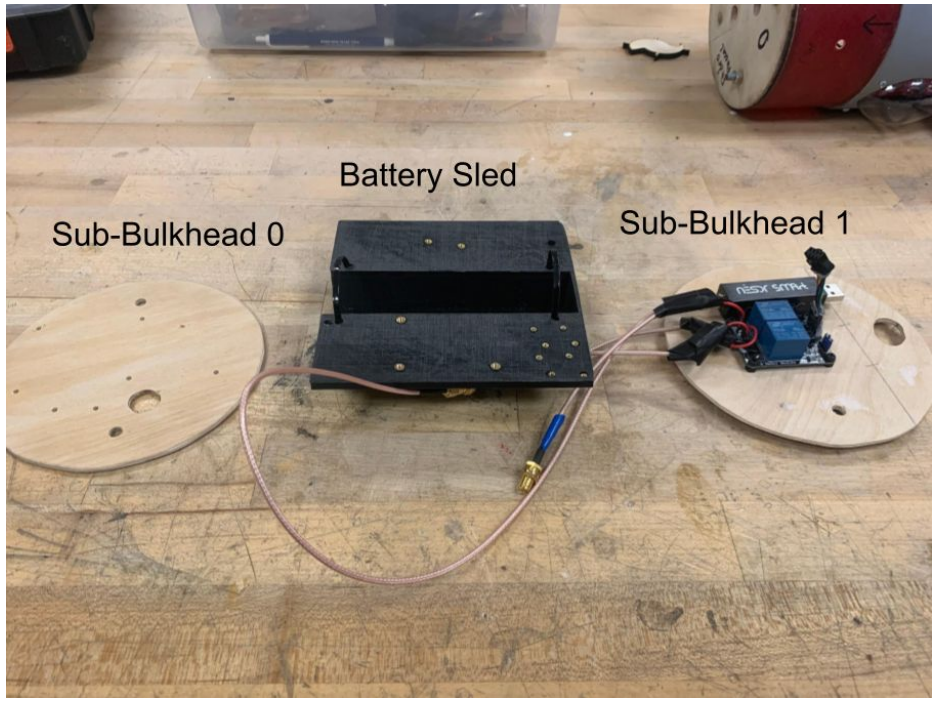


Exploded view of the payload assembly.


Assembled view of the payload.

# Payload Retention

- Payload sled and bulkheads held in place by two ¼-20 in threaded rods which run the length of the bay
- PDF Launch
  - Battery holder 3D printed
  - Bulkheads made from plywood
- Final Design
  - Sub-bulkheads 3D printed
  - Battery holder angled 45°




PDF payload sled pieces

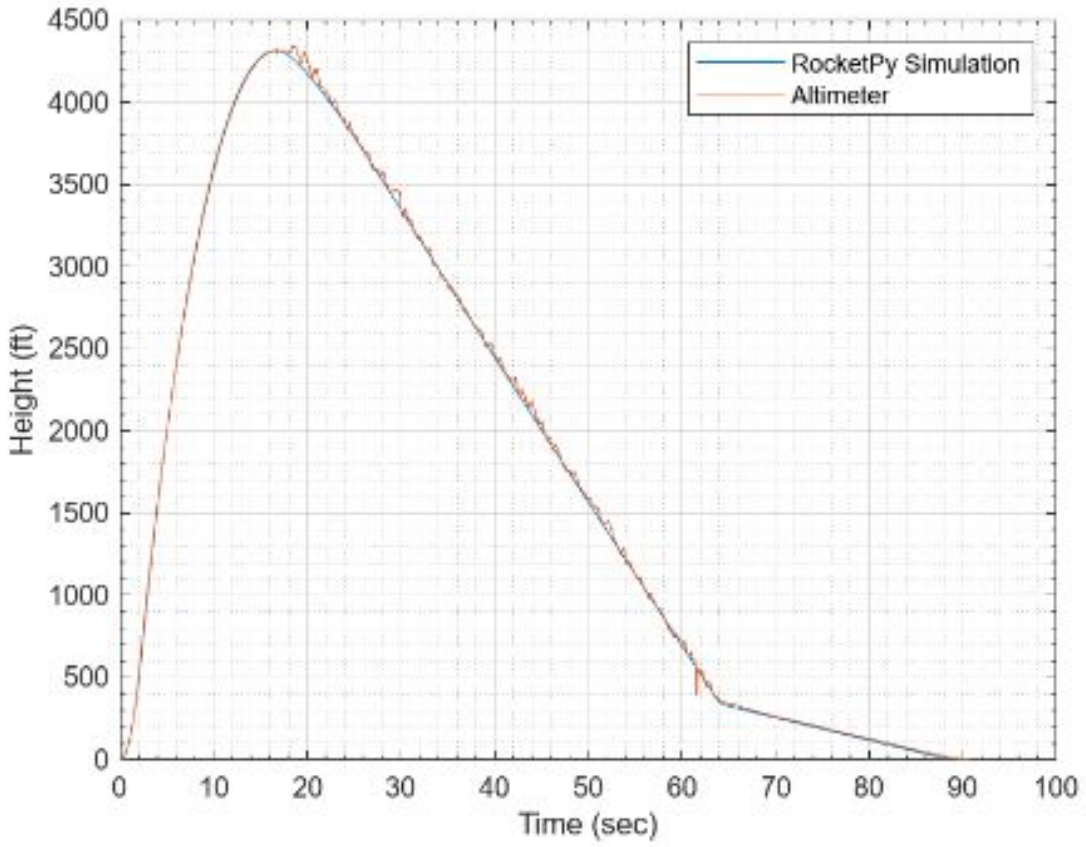

# VDF/PDF Launch Results

# VDF Flight Data

| Demonstration Flight Data | |
|---|---|
| Date | 2/26/2023 |
| Location | Paul Farm, Bayboro, NC |
| Temperature (F) | 64 |
| Pressure (mmHg) | 30.34 |
| Wind (mph) | 7 |
| Motor Flown | L1520T |
| Ballast Flown (lb) | 3.7 |
| Payload Flown | Yes, Powered On |
| Airbrakes | None |
| Target Altitude (ft) | 4,500 |
| Predicted Altitude (ft) | 4,800 |
| Measured Altitude (ft) | 4,313 |

# Modification to RocketPy Parameters

- Increase drag curve by 3.25%
- Increase time of main parachute delay
- Increase CdS of drogue to match descent rate



# PDF Results

## SUCCESSES

- SOCS remained powered throughout flight
- SOCS retention system functioned nominally

## FAILURES

- Antennas lost connection
- Wearable components damaged
- No water-tight seal


# Requirements Verification

Requirements Verification Status

Launch Vehicle Requirements

Payload Requirements

# Requirements Verification Status

- Requirements Verified
  - All NASA Handbook Requirements: 135/135 (100%)
  - Team-Derived Requirements 37/37 (100%)
- All testing and demonstration 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 have a stability margin between 2 and 2.7 upon rail exit (LVD 5)
  - Complete, verified by RockSim analysis
- The launch vehicle shall not exceed Mach 1 at any point during flight (NASA 2.23.6)
  - Complete, verified by RockSim analysis
- All structural components of the launch vehicle shall be designed with a minimum safety factor of 1.5 (LVD 1)
  - Complete, verified by RockSim analysis

# Payload Requirements

- The camera SHALL time stamp each photo taken. The time stamp SHALL be visible on all photos submitted to NASA in the PLAR (NASA 4.2.1.3)
  - Complete, verified in the Camera System Integration Test
- Each housing SHALL withstand all loads encountered during the flight and landing of the launch vehicle (PD 4)
  - Complete, verified in the Camera Housing Structural Test
- The RTL-SDR dongle SHALL only accept RF commands from one antenna. (PF 3)
  - Complete, verified in the Orientation Detection and Switching Test


# Questions?