Flight Readiness Review

March 8, 2021

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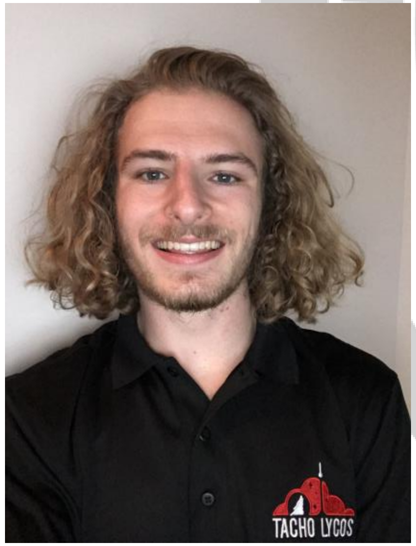


Evan Patterson
Payload Vehicle Lead

Daniel Jaramillo
Payload Integration Lead

Emma Jaynes
Payload Imaging Lead

Final Launch Vehicle Design

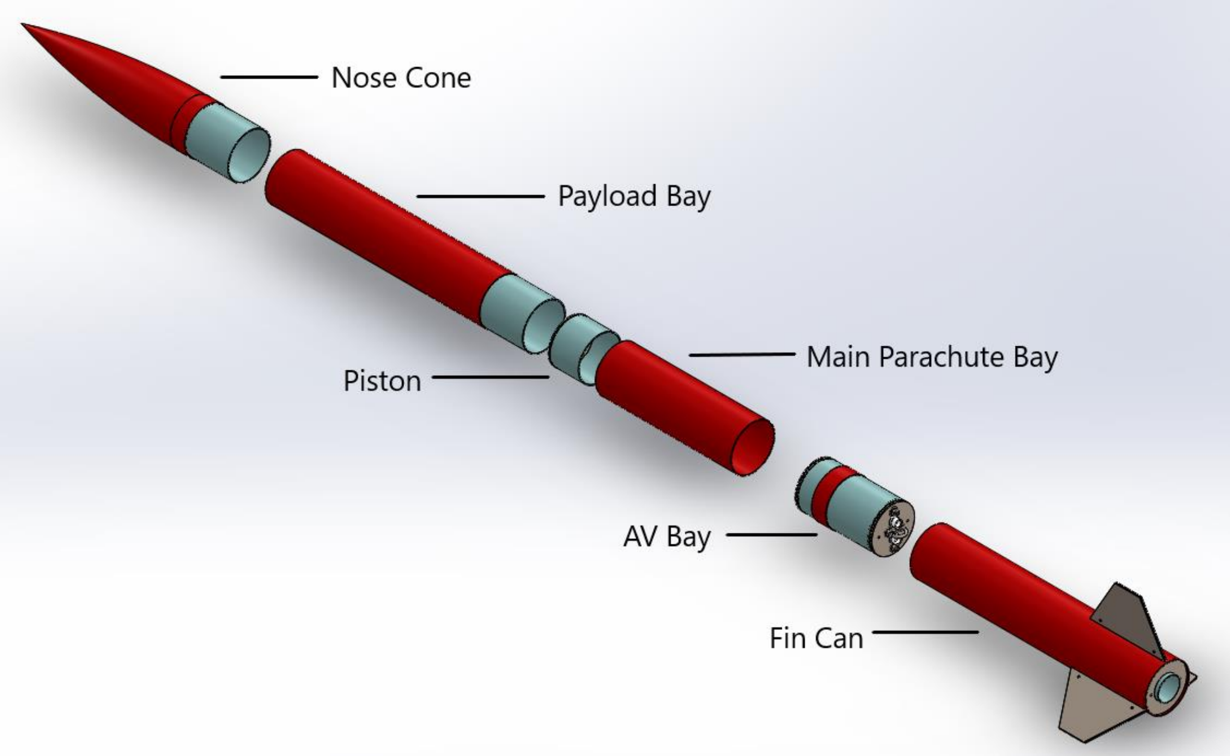
Design and Dimensions

Separation Points and Energetics

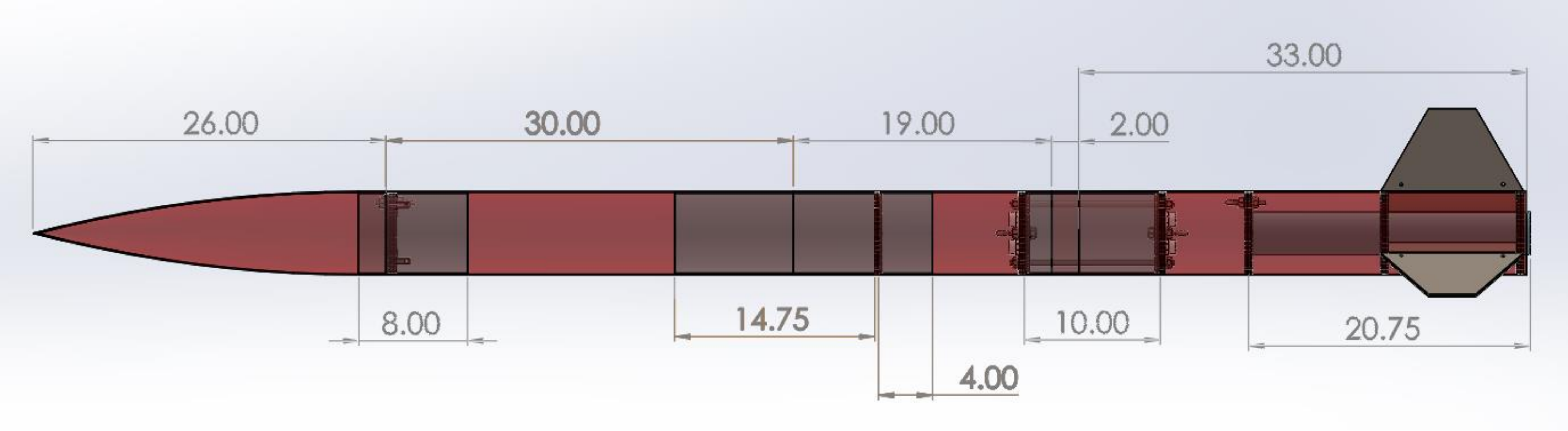
Key Design Features

Launch Vehicle Dimensions

- Length: 110.25"
- Diameter: 6"
- Launch Weight: 49.3 lbs
- Empty Weight: 43.6 lbs

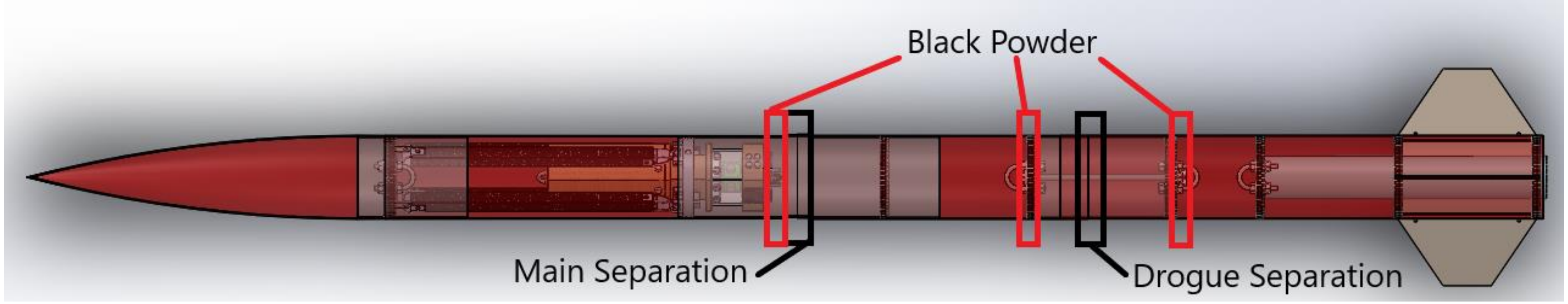


Launch Vehicle Dimensions



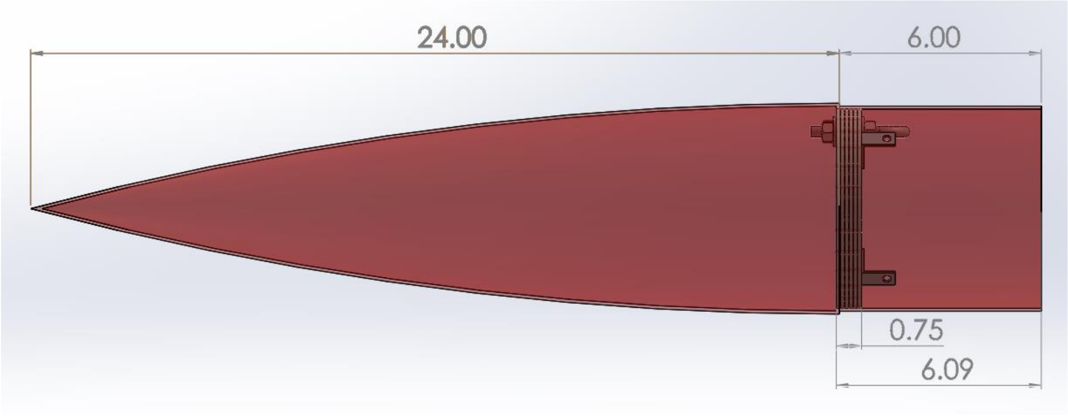
Separation Points and Energetics

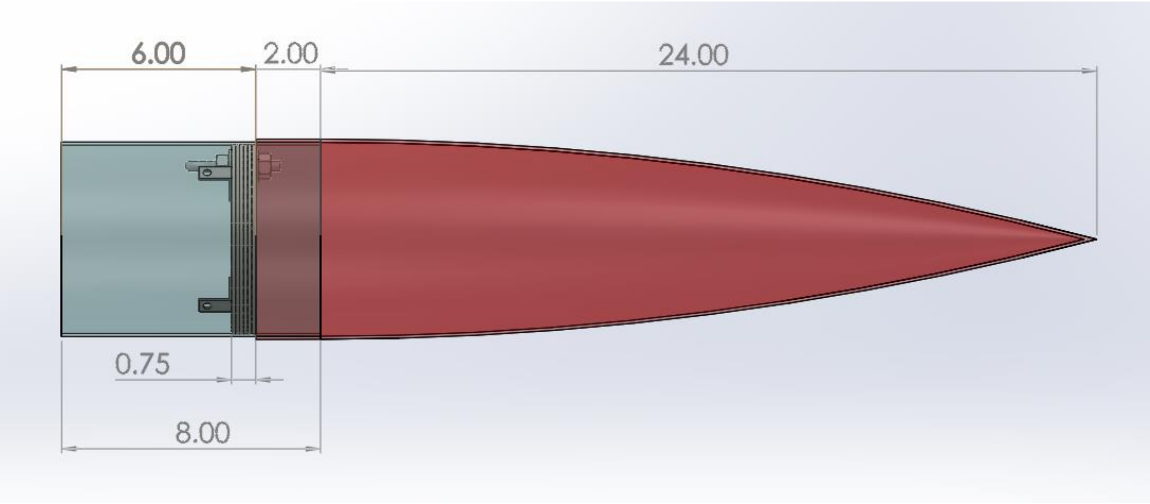
- The launch vehicle will separate between:
  - Payload bay and main parachute bay
  - AV bay and fin can
- Black powder will be in:
  - Blast caps on either end of the AV bay
  - ARRD on the payload



Design Changes Since CDR

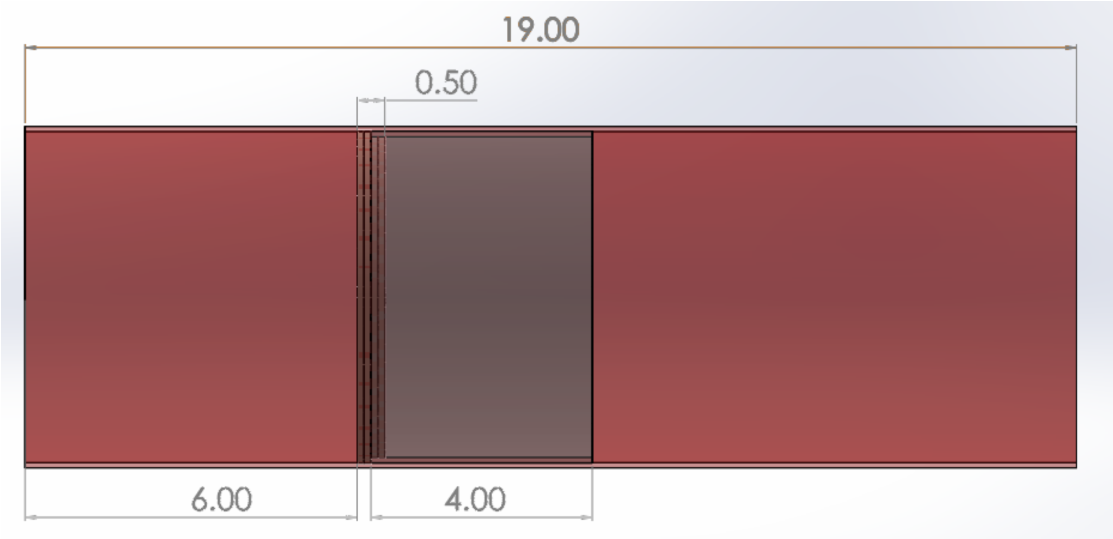
- Nose Cone - the parts we received had different dimensions than what was expected
  - Nose cone had an extra 2-inch straight section for coupler
  - Coupler came as a separate 8-inch part
  - Position of nose cone bulkhead is unchanged

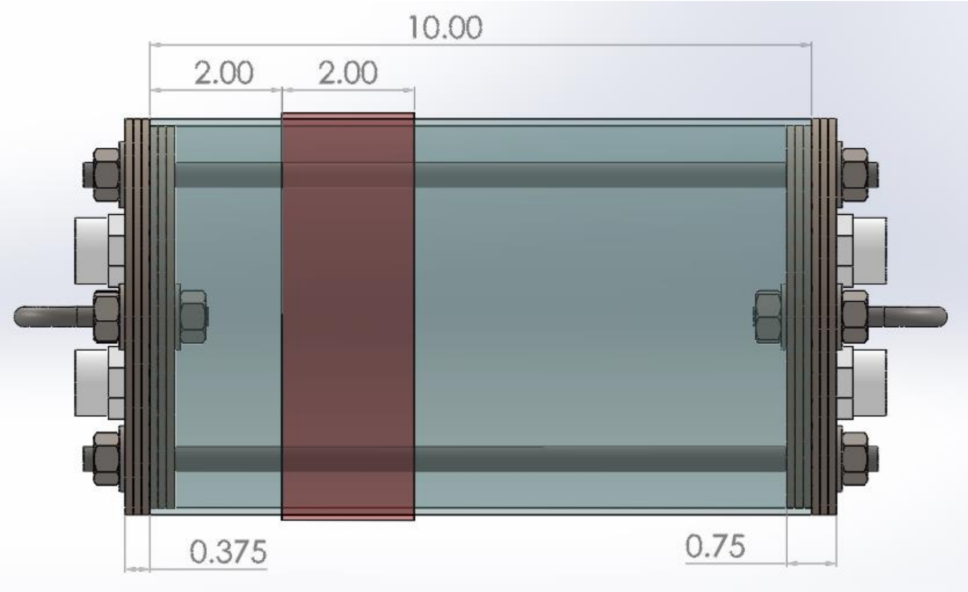




Design Changes Since CDR

- Main Parachute Bay and AV Bay – dimensions have been adjusted to give more space for parachutes
  - Main Parachute Bay lengthened from 17 inches to 19 inches
  - Forward end of AV Bay coupler shortened by 4 inches





Testing Plan

- Structural tests could not be completed by FRR submission due to COVID-related lab closure
- Will be completed prior to PDF

Recovery Subsystem

Parachute Selection

Performance Predictions

Test Results

Launch Vehicle Parachute Sizing & Descent Rates

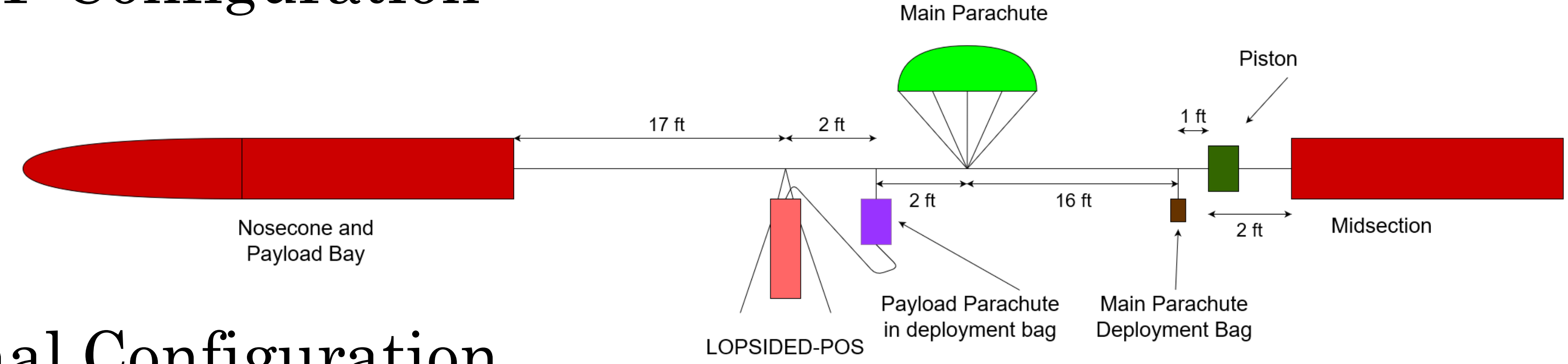
- Drogue: Fruity Chutes 18" Classic Elliptical
  - Diameter: 18 inches
  - Drag Coefficient: 1.43
  - Descent Rate: 117.8 ft/s
- Main: Fruity Chutes 120" Iris UltraCompact
  - Diameter: 120 inches
  - Drag Coefficient: 2.11
  - Descent Rate – DAVID Attached: 14.9 ft/s
  - Descent Rate – LOPSIDED-POS Attached: 14.6 ft/s
  - Descent Rate – Payload Separated: 13.3 ft/s

Payload Vehicle Parachute Sizing & Descent Rates

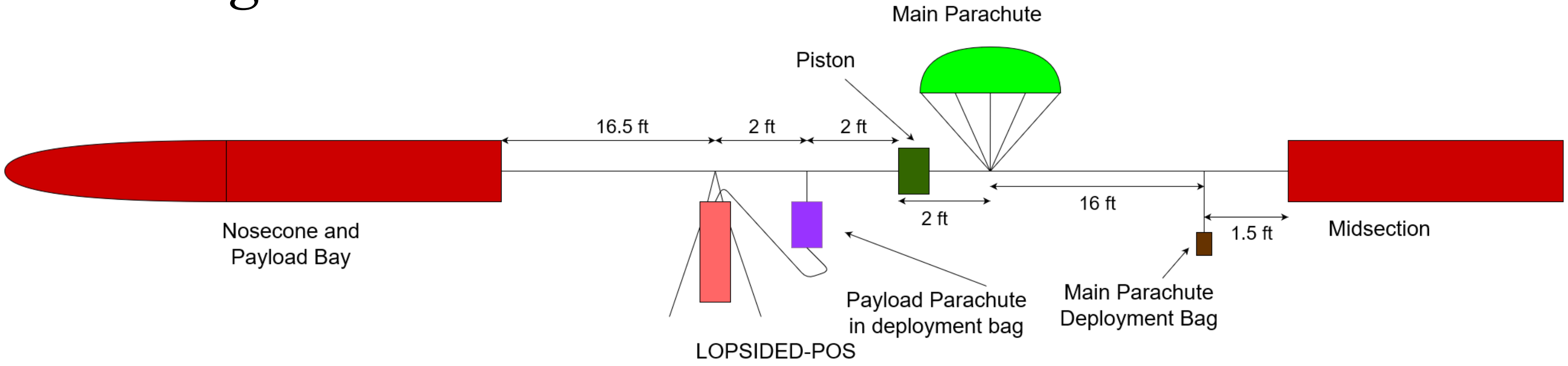
- DAVID Parachute: Fruity Chutes 60" Iris UltraCompact
  - Diameter: 60 inches
  - Drag Coefficient: 2.16
  - Descent Rate: 13.4 ft/s
- LOPSIDED-POS Parachute: Fruity Chutes 48" Classic Elliptical
  - Diameter: 48 inches
  - Drag Coefficient: 1.44
  - Descent Rate: 18.0 ft/s

Main Recovery Harness Detail

- VDF Configuration



- Final Configuration



Drogue and Payload Parachute Kinetic Energy

- VDF

Section	Mass	Descent Velocity	Kinetic Energy
Forward Assembly	1.0238 slugs	120.6 ft/s	7443.4 ft-lbf
Fin Can	0.3320 slugs	120.6 ft/s	2413.9 ft-lbf
Payload Mass Simulator	0.2797 slugs	13.4 ft/s	25.0 ft-lbf

- Final Configuration

Section	Mass	Descent Velocity	Kinetic Energy
Forward Assembly	0.9617 slugs	117.8 ft/s	6670.9 ft-lbf
Fin Can	0.3320 slugs	117.8 ft/s	2303.2 ft-lbf
Payload	0.2176 slugs	18.0 ft/s	35.4 ft-lbf

VDF Kinetic Energy at Landing

Section	Mass	Descent Velocity (Payload attached)	Descent Velocity	Kinetic Energy (Payload attached)	Kinetic Energy
Nosecone	0.3660 slugs	14.9 ft/s	13.2 ft/s	40.6 ft-lbf	32.2 ft-lbf
Nosecone w/ Payload Mass Simulator	0.6457 slugs	14.9 ft/s	N/A	71.7 ft-lbf	N/A
Payload Mass Simulator	0.2797 slugs	14.9 ft/s	N/A	31.0 ft-lbf	N/A
Midsection	0.3781 slugs	14.9 ft/s	13.2 ft/s	42.0 ft-lbf	33.3 ft-lbf
Fin can	0.3320 slugs	14.9 ft/s	13.2 ft/s	36.8 ft-lbf	29.2 ft-lbf

Final Kinetic Energy at Landing

Section	Mass	Descent Velocity (Payload attached)	Descent Velocity	Kinetic Energy (Payload attached)	Kinetic Energy
Nosecone	0.3660 slugs	14.6 ft/s	13.3 ft/s	38.8 ft-lbf	32.2 ft-lbf
Nosecone w/ Payload	0.5835 slugs	14.6 ft/s	N/A	61.8 ft-lbf	N/A
Payload	0.2176 slugs	14.6 ft/s	N/A	23.0 ft-lbf	N/A
Midsection	0.3781 slugs	14.6 ft/s	13.3 ft/s	40.0 ft-lbf	33.3 ft-lbf
Fin can	0.3220 slugs	14.6 ft/s	13.3 ft/s	35.2 ft-lbf	29.2 ft-lbf

Wind Effects on Altitude and Drift

- Downrange movement due to field wind conditions
  - Descent Time: 83 s
  - Launch Vehicle Drift @ 20 mph: 2448 ft
  - Payload Drift @ 20 mph: 2440 ft
  - Apogee assumed to be directly above launch pad
  - Blended calculation

Speed	Apogee	Descent Time	Drift Distance
0 mph	3688 ft	77 s	0 ft
5 mph	3710 ft	77 s	564.4 ft
10 mph	3715 ft	77 s	1129.5 ft
15 mph	3701 ft	77 s	1691.6 ft
20 mph	3665 ft	77 s	2246.6 ft

Main Parachute Opening Shock

- Kevlar shock cord rated for 6600 lbs.
- Opening shock FoS of ~17 at main parachute attachment point

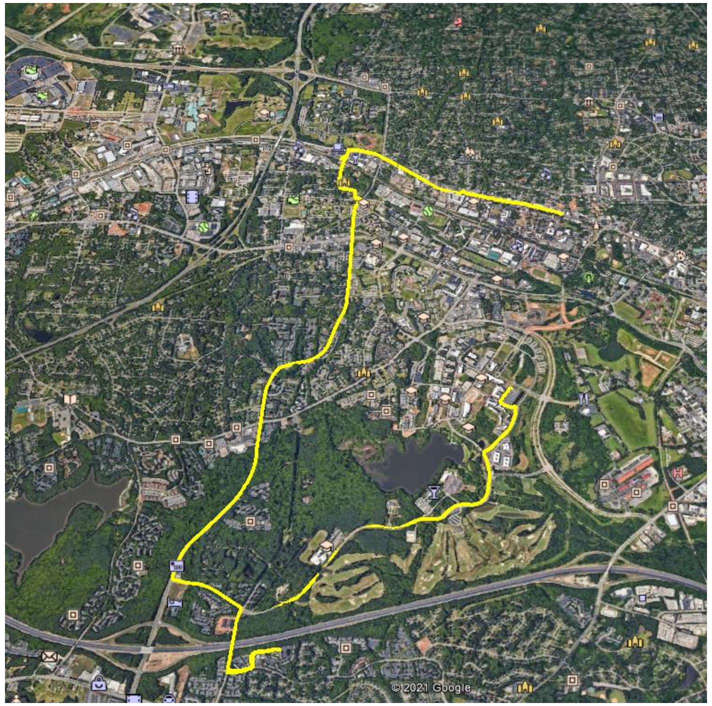
Section	Mass	Opening Shock
Forward Section	0.5835 slugs	177.4 lbf
Midsection + Fin Can	0.7102 slugs	327.1 lbf
Fin Can	0.3320 slugs	100.9 lbf
Launch Vehicle	1.2937 slugs	393.3 lbf

Ejection Demonstration

- Drogue charge of 2.6 g, main charge of 2.9 g
- Complete and vigorous separation
- Parachutes sustained no damage
- Piston ejection proven effective

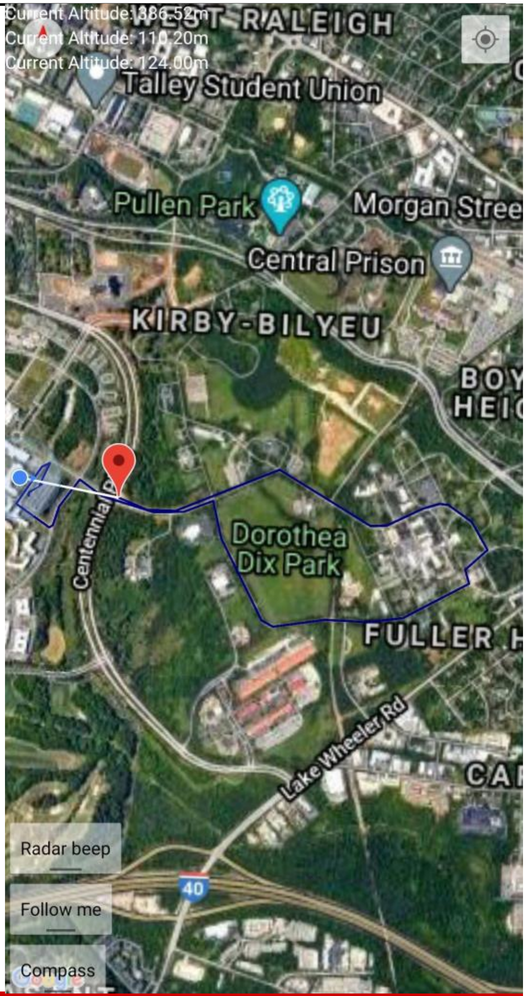
GPS Operational Test

- Minimal deviation from known course
- TTFF of ~3-5 minutes



- BRB900 Test Plot

- Eggfinder GPS Test Plot



Recovery Subsystem Changes Since CDR

- Main parachute moved aft of piston on main recovery harness
  - Allows all recovery hardware to be contained in the payload coupler and the main parachute bay
- The payload parachute has been switched from a 60" Iris UltraCompact to a 48" Classic Elliptical
  - As-built payload weight was lower than predicted, resulting in excessive wind drift under the 60" Iris UltraCompact

Mission Performance Predictions

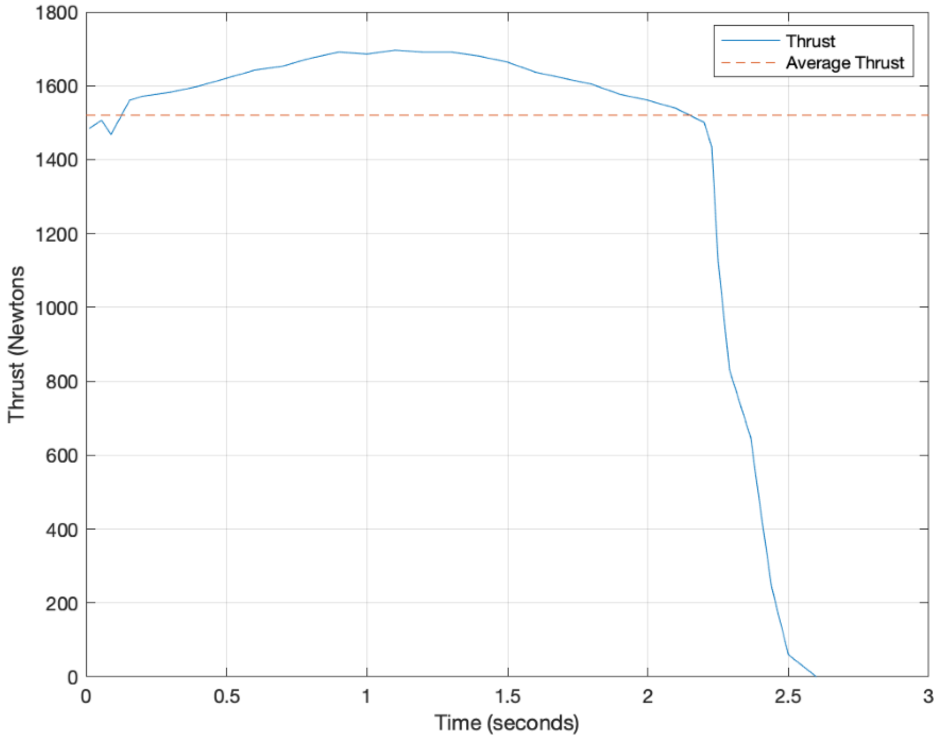
Apogee Predictions

Stability Predictions

Demonstration Flight Results

Motor Selection

- AeroTech L1520T
- Short burn time
- High Max and Average Thrust
- RMS 75/3840 Casing



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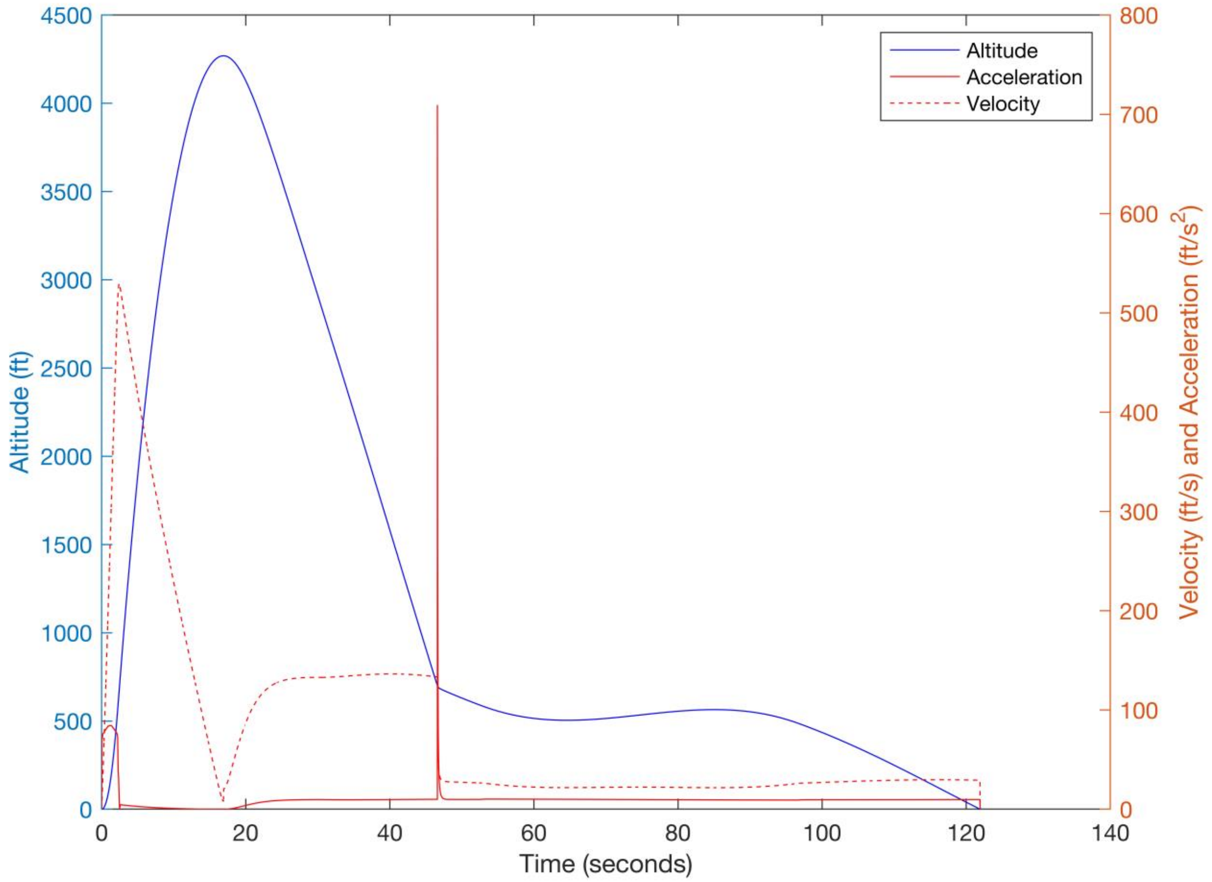
Target Altitude

4473 feet

Based on

- 3 - 14.9 MPH winds
- 5° cant of the launch rail
- 144" launch rail

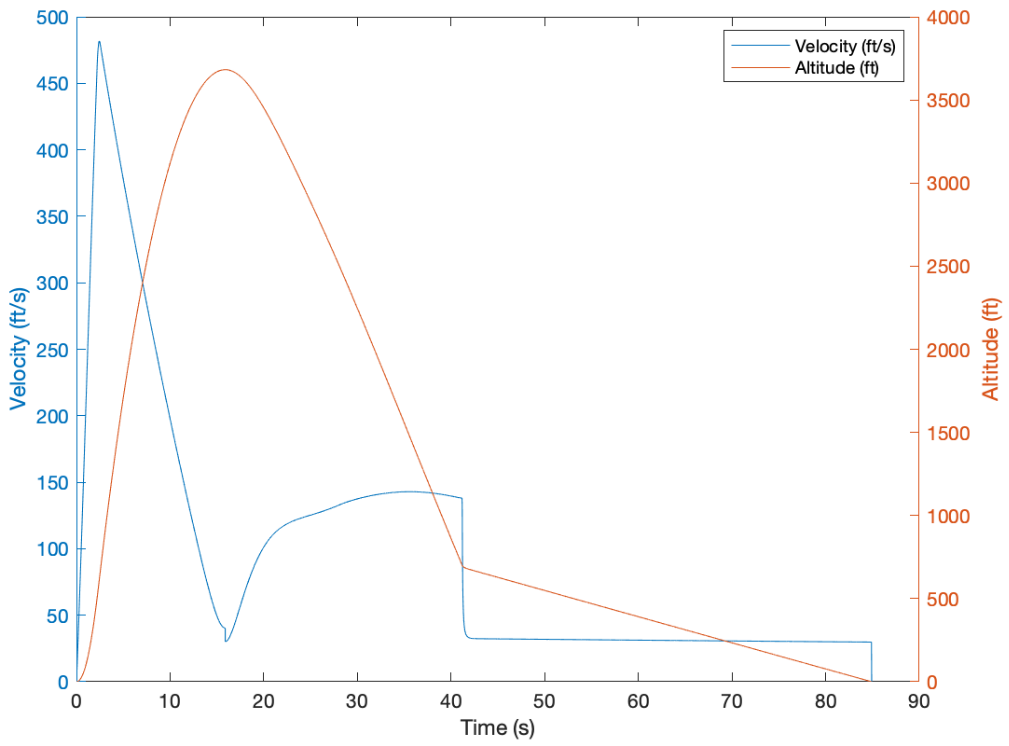


Predicted Apogee

3678 feet

Reason

- Weighing constructed parts rather than estimates
- Better accounting for small parts in simulations
- Increased weathercocking

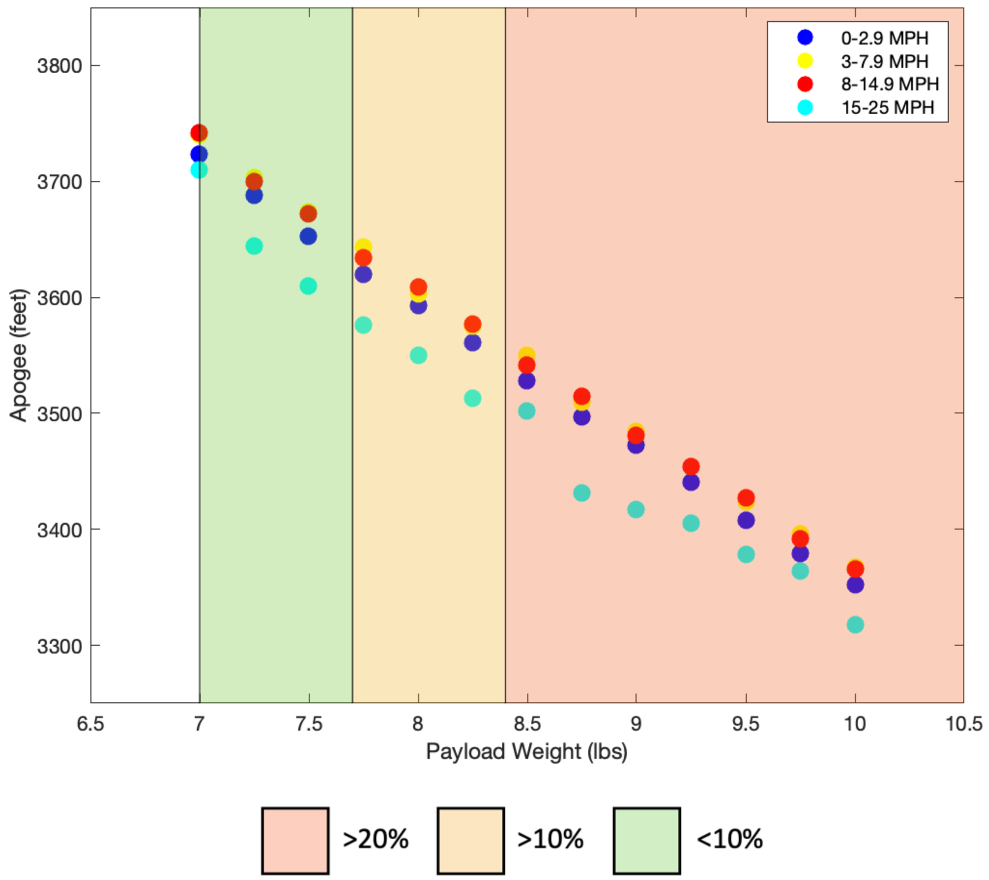


Other Key Flight Characteristics

- Velocity at Launch Rail Departure: 69.44 ft/s
- Peak Velocity: 481.32 ft/s
- Peak Mach: 0.428 Mach
- Peak Acceleration: 255.85 ft/s^2
- Thrust to Weight Ratio: 6.932

Apogee Uncertainty

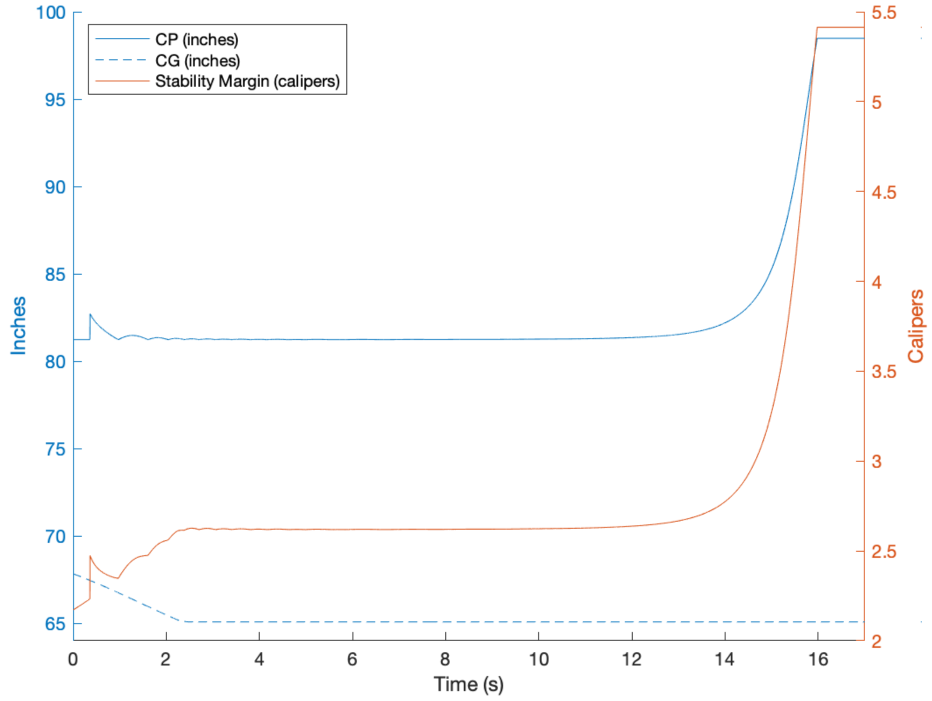
Uncertainty
- Wind Speed
- Payload Weight



Static Stability Margin of Launch Vehicle

- Initial: 2.17
- At departure of Launch Rail: 2.23

Computational Method	Static Margin (Calipers)
Barrowman's Method	2.23
RockSim	2.17



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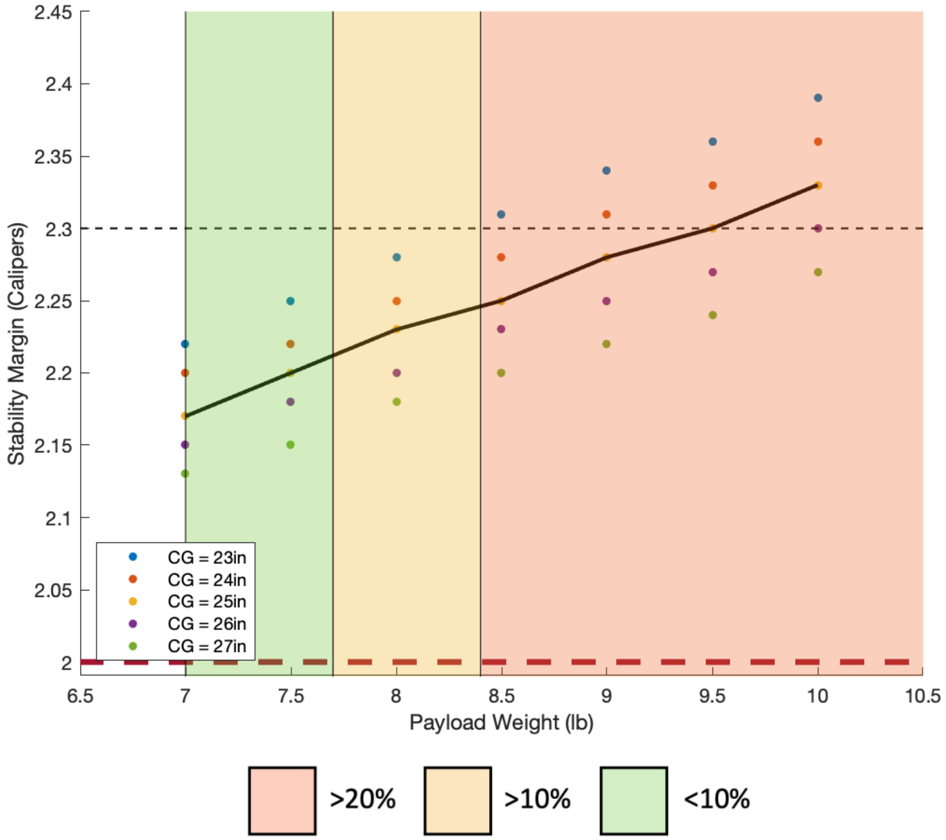
Stability Margin Uncertainty

Uncertainty

- Payload Weight
- Payload CG



Vehicle Demonstration Flight

Predicted Apogee

3431 feet

Achieved Apogee

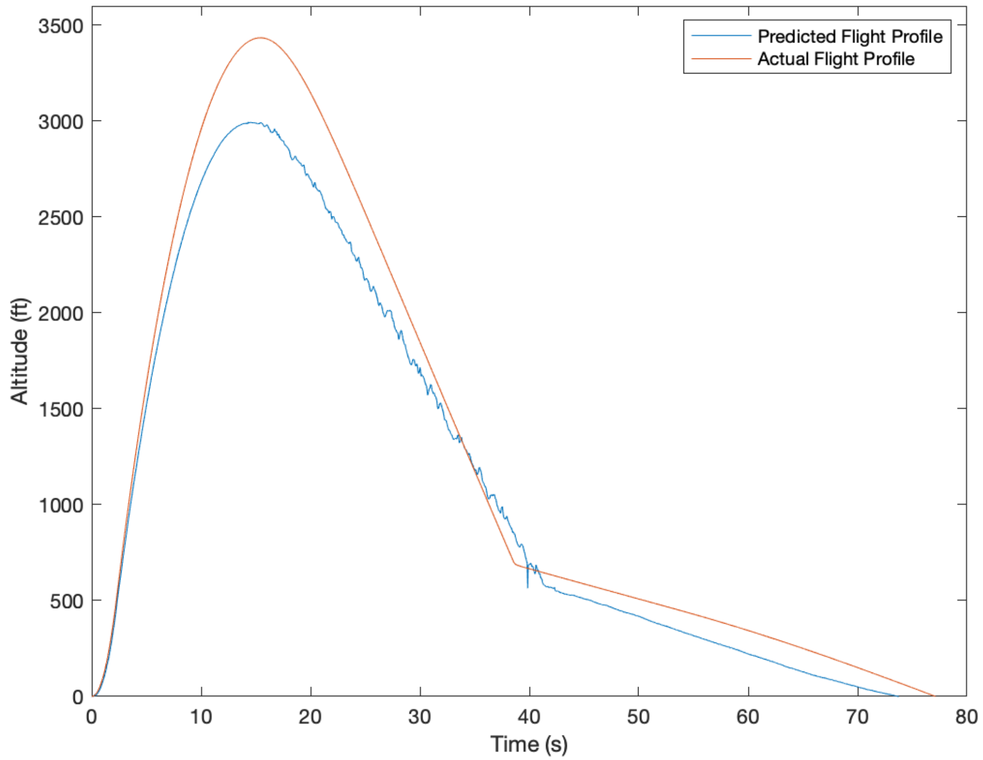
2995 feet

Weight

52.7 lb

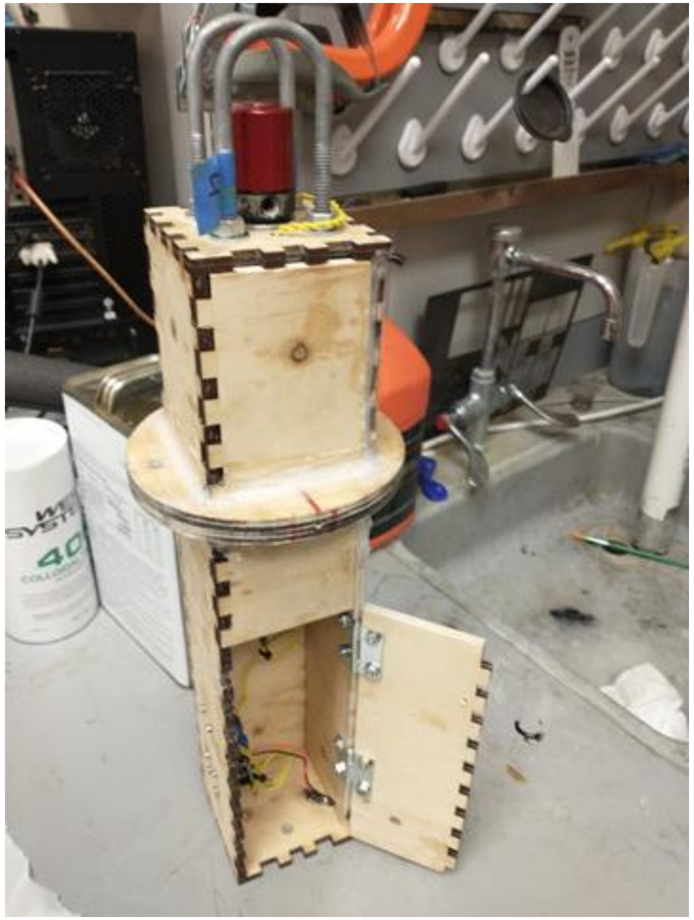
Stability Margin

2.25



Vehicle Demonstration Flight

- Flew mass simulator that was retained and deployed in the same manner as the final payload
- DAVID (Device for Assisting in Validation of Integration and Deployment)

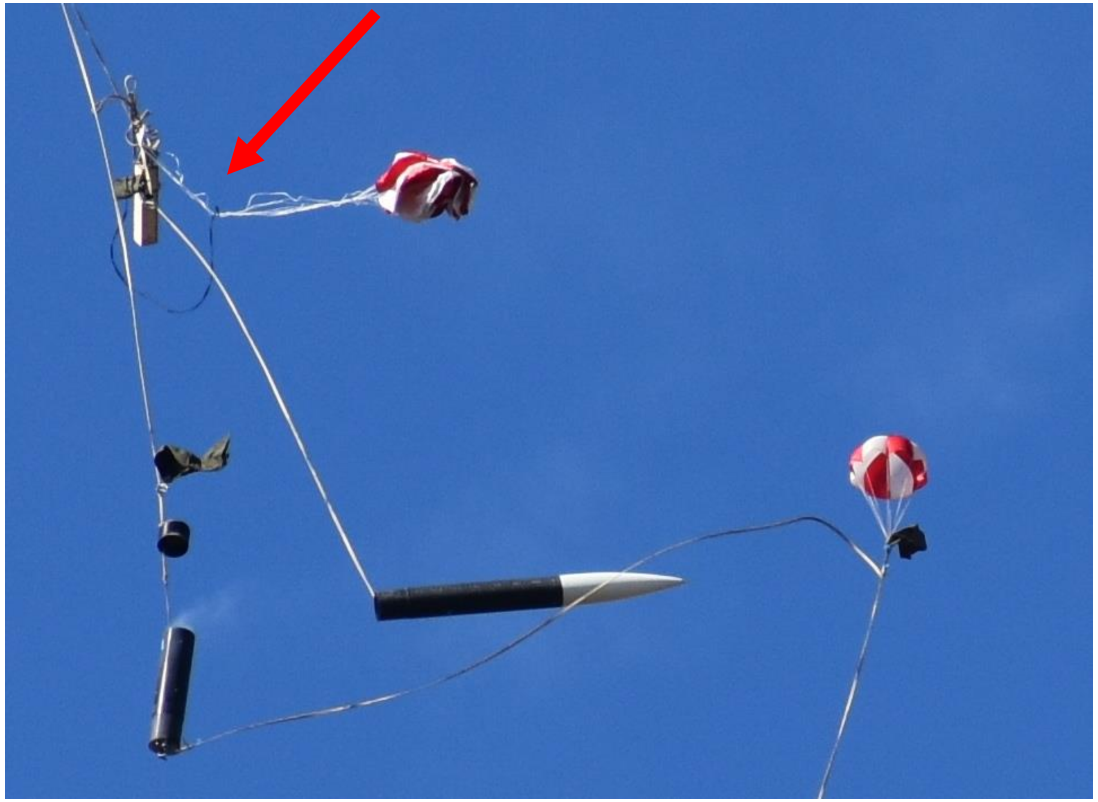


Vehicle Demonstration Flight

Deviations:

Tangling of deployment bag

Failure of ARRD release



Vehicle Demonstration Flight

Successful recovery system performance, no damage to launch vehicle

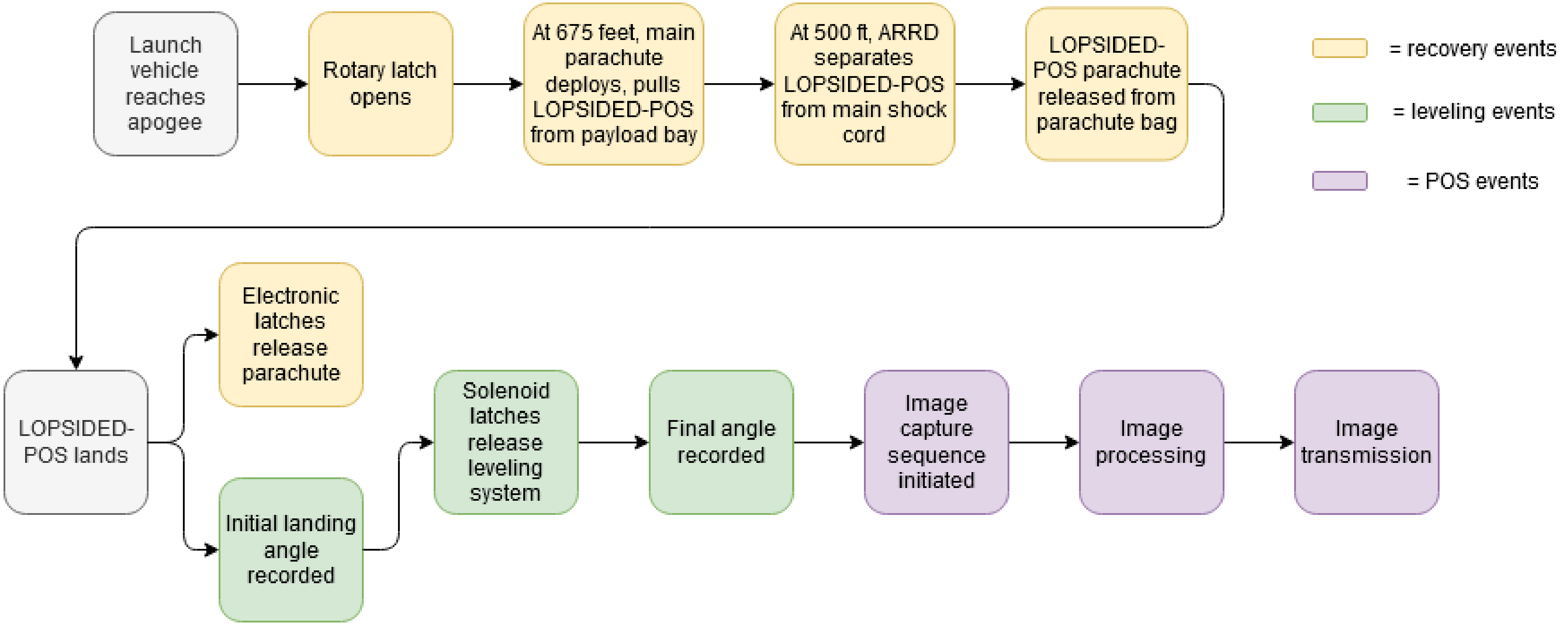
Payload Design

LOPSIDED

POS

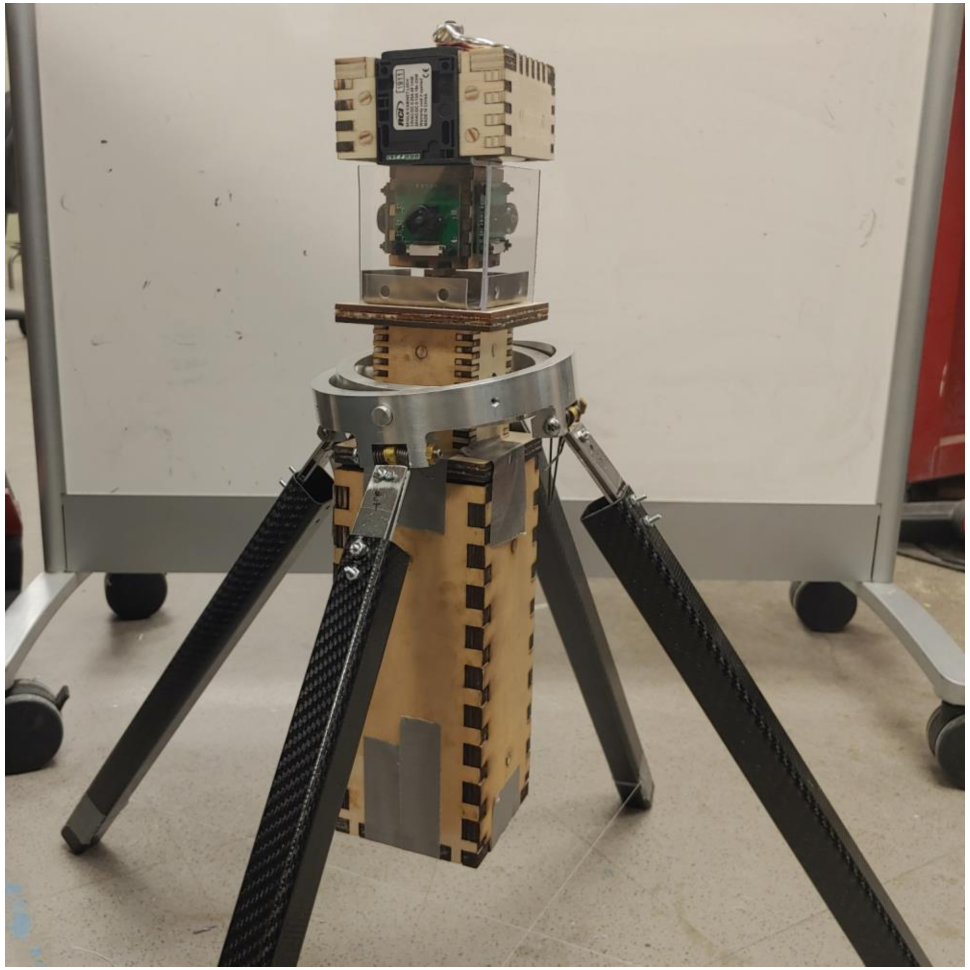
Testing

Mission Overview



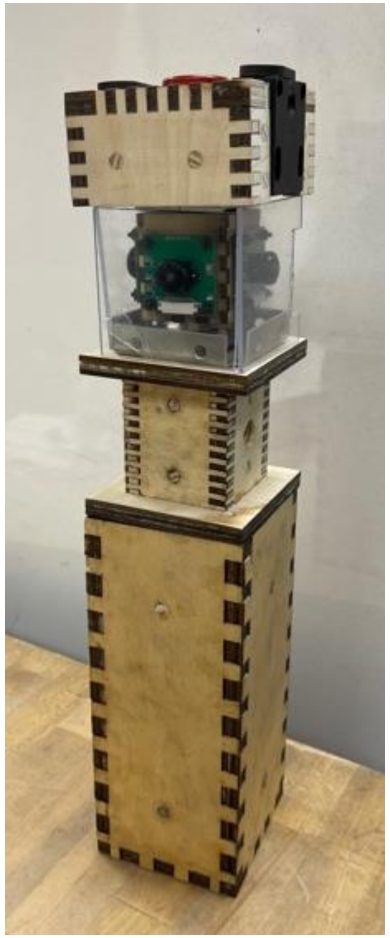
LOPSIDED-POS

- Two Assemblies
  - Body
  - Support/Leveling
- Levels using gyroscopic rings
- Lightweight and durable to endure parachute and landing loads



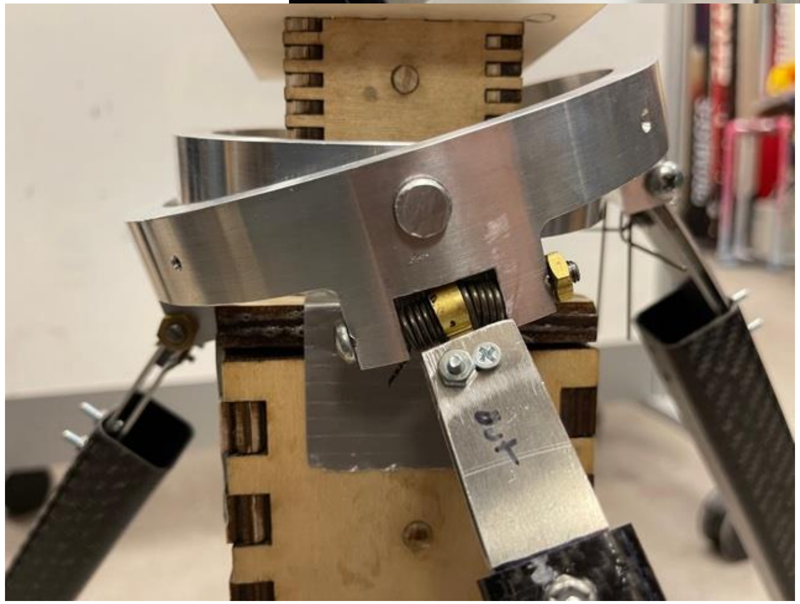
LOPSIDED Body and Chassis

- Body
  - Upper – Houses ARRD, latches, and POS
  - Middle – Interfaces with Leveling System
  - Lower – Houses most electronics
- Chassis
  - Connects all sections
  - Bears most loads



LOPSIDED Leveling

- Two concentric leveling rings
  - Lockable with a pair of solenoid latches per axis
- Outer ring features a mounting block for each of the four legs
- Hinge and torsional springs connect to plates which hold legs
- Cable connected from outer ring to leg plate controls individual splay angle

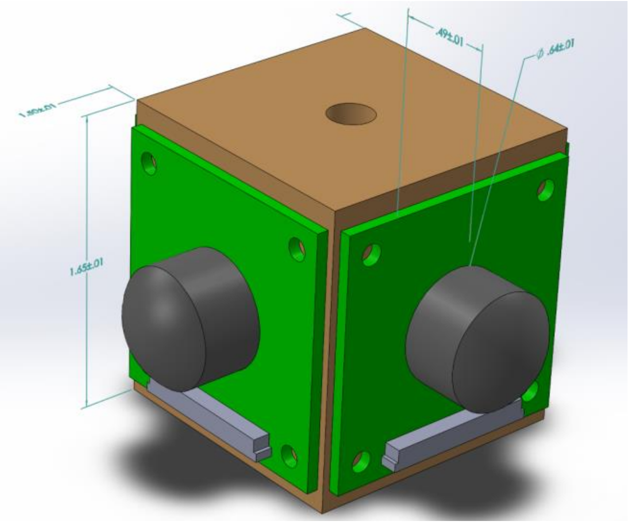


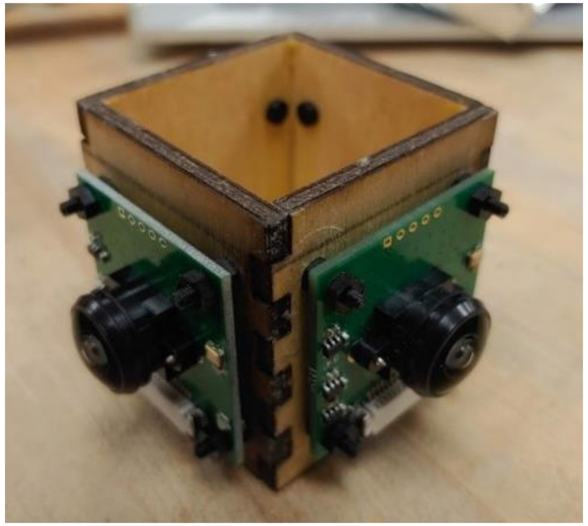
LOPSIDED Leveling Range

- With leg splay angle at 60 degrees
- Maximum tilt range of 23-26 degrees
  - Smallest max tilt along its legs
- With 5-degree tolerance, can handle field grades of 28-31 degrees

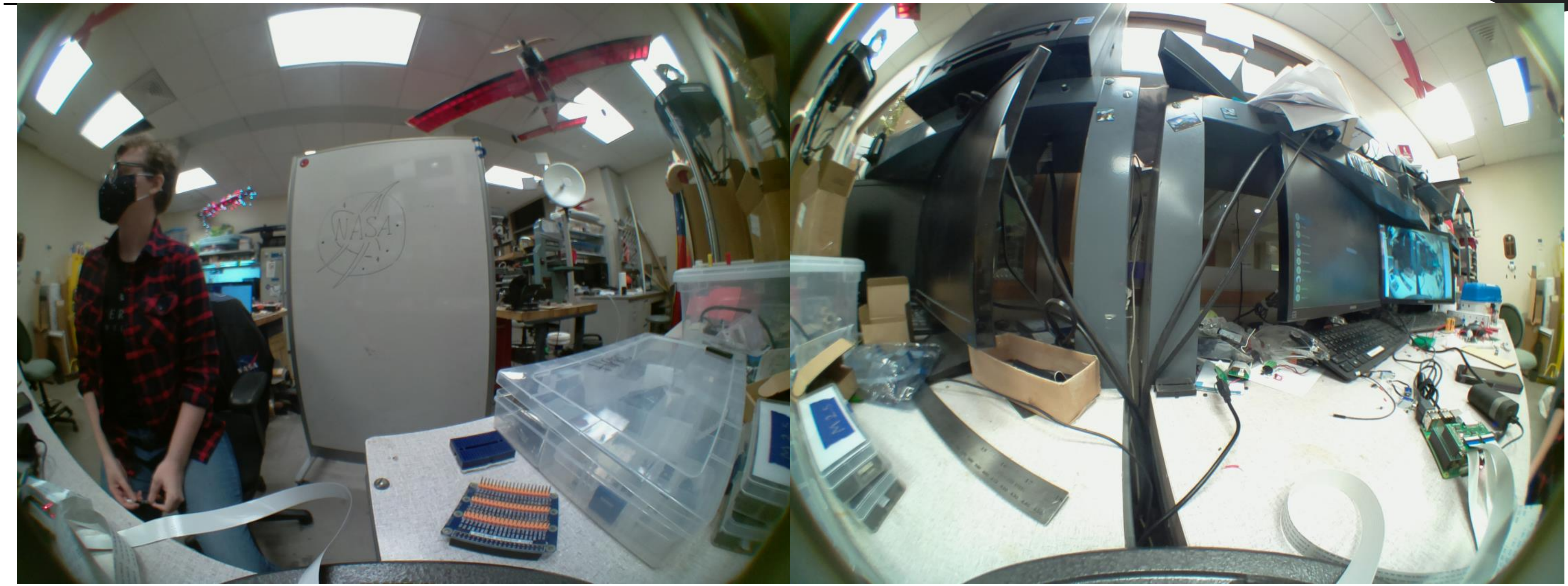
POS Imaging

- Four Arducam Fisheye Raspberry Pi Camera modules
  - HFOV = 194°
- Located in Upper LOPSIDED section
- Interface directly with Raspberry Pi 3B+ using Multi-Camera Adapter Board





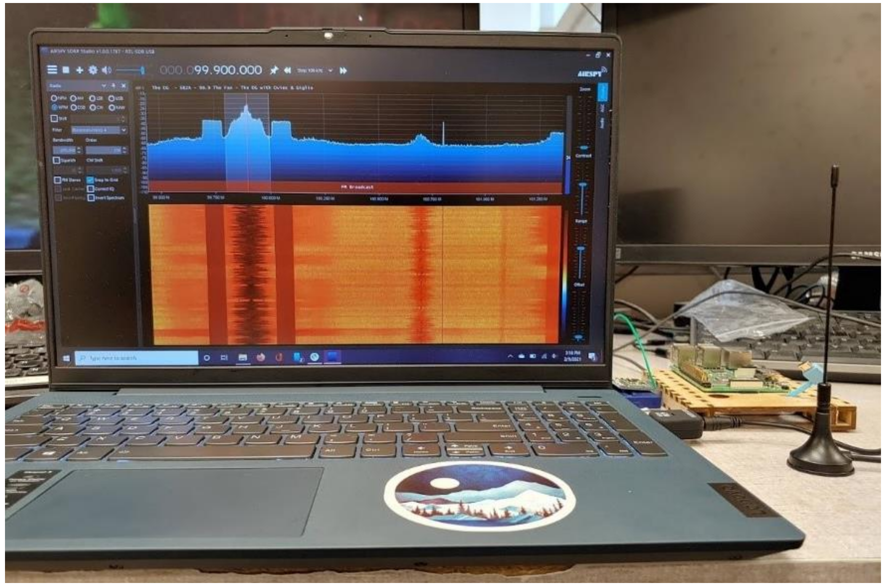
POS Imaging

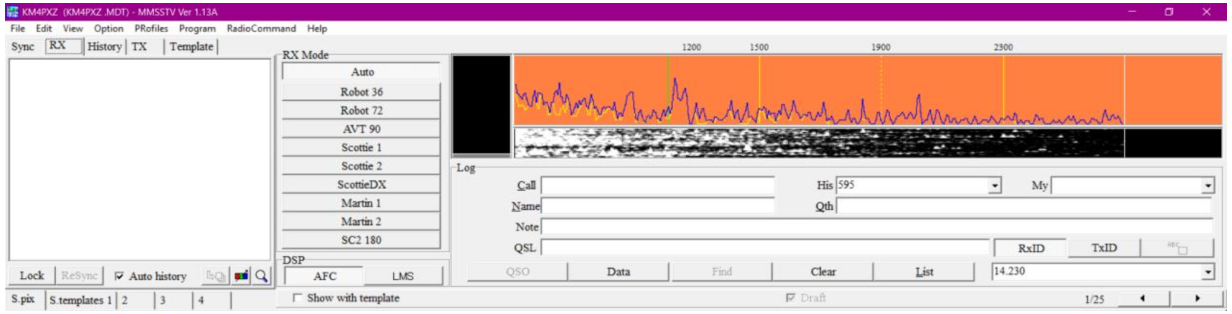


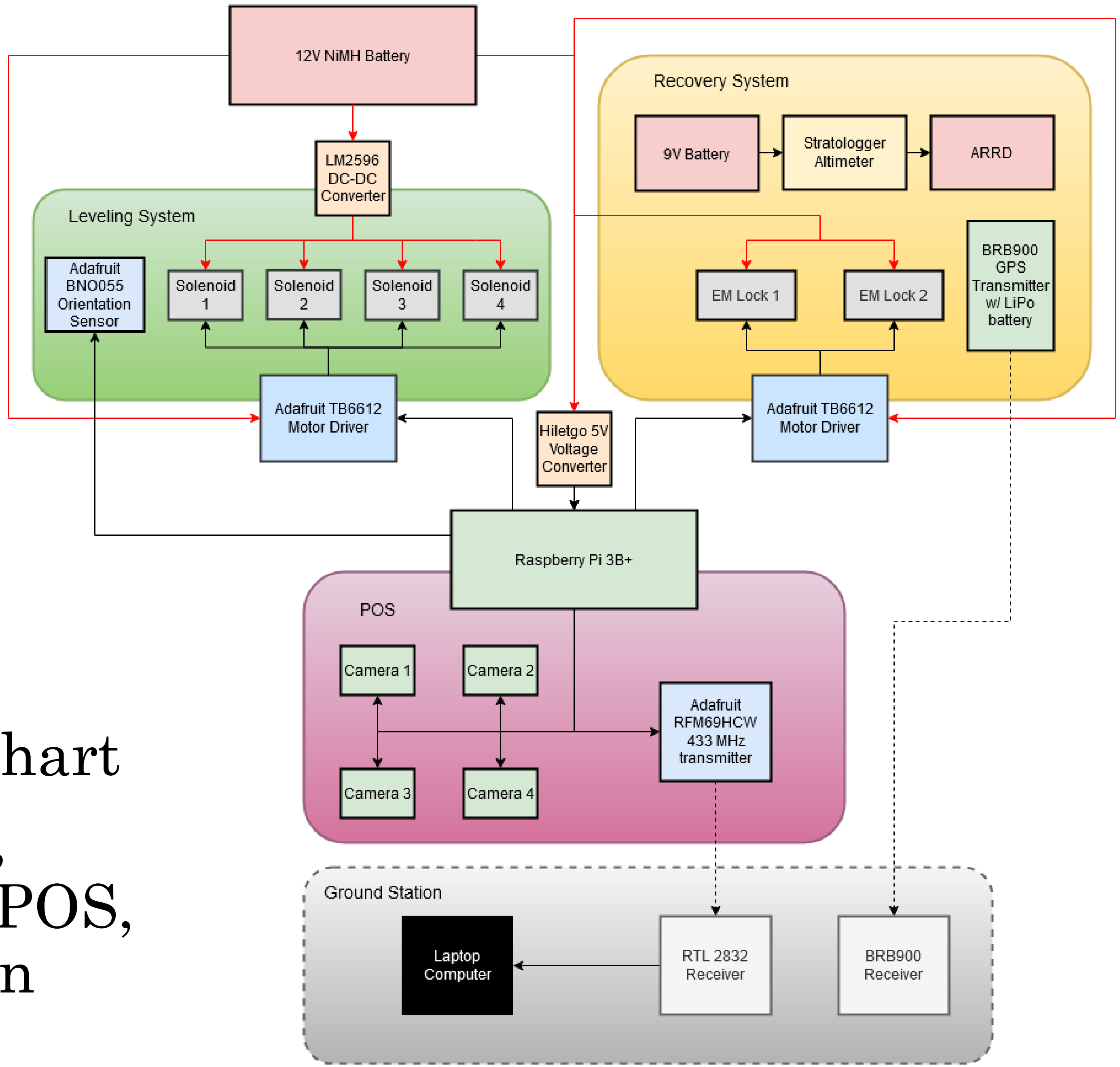
- Example of 360° view captured by two POS cameras

POS Image Transmission

- Slow-Scan Television (SSTV)
  - Utilizes voice radio frequencies to send static images
- Transmitter = RFM69HCW 433 MHz radio transmitter
  - Powered by Raspberry Pi
- Receiver = Adafruit SDR Radio USB
  - Interfaces with laptop computer
- MMSSTV software to demodulate incoming images







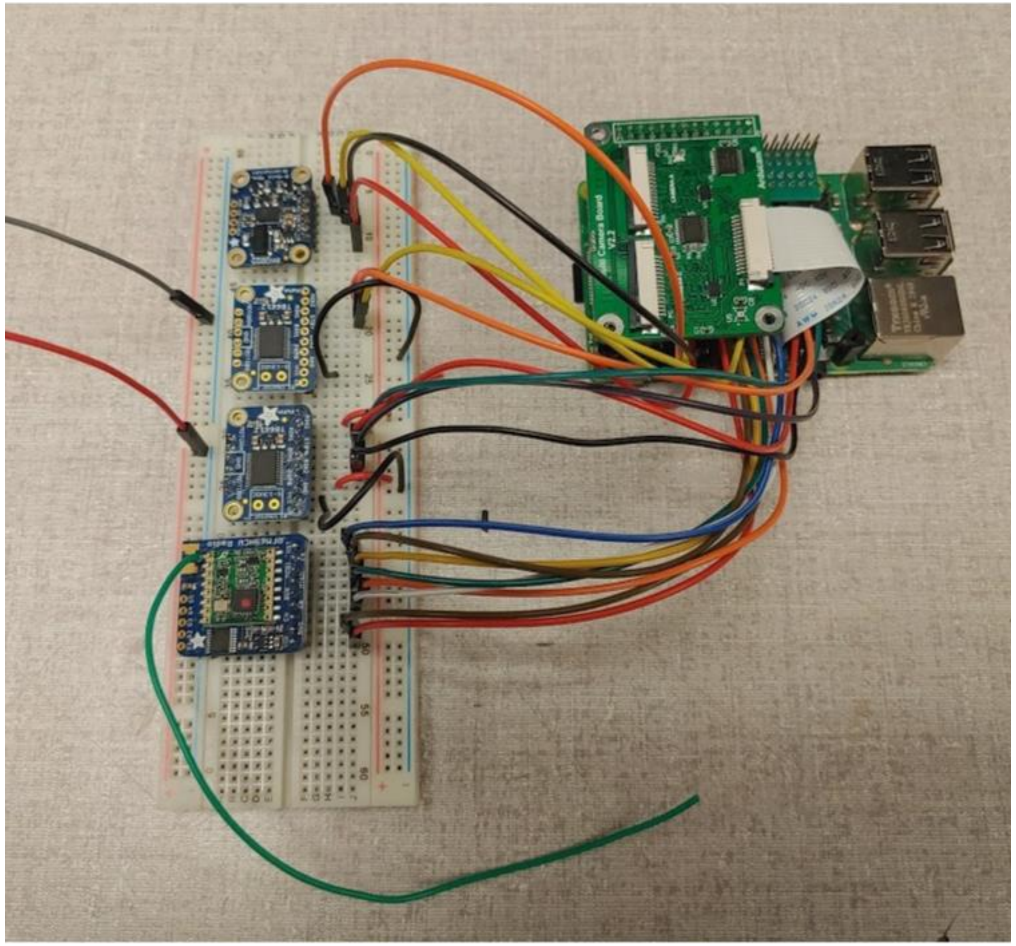
- LOPSIDED-POS electronics flow chart
- Recovery system, leveling system, POS, and ground sation

LOPSIDED-POS Battery Selection

- Battery for Altimeter: 9V Alkaline battery
- Battery for BRB900: Own LiPo single cell battery
- Other components: 1600 mAh NiMH 12V battery pack
  - Capacity required is 1,077 mAh for 2 hours of power

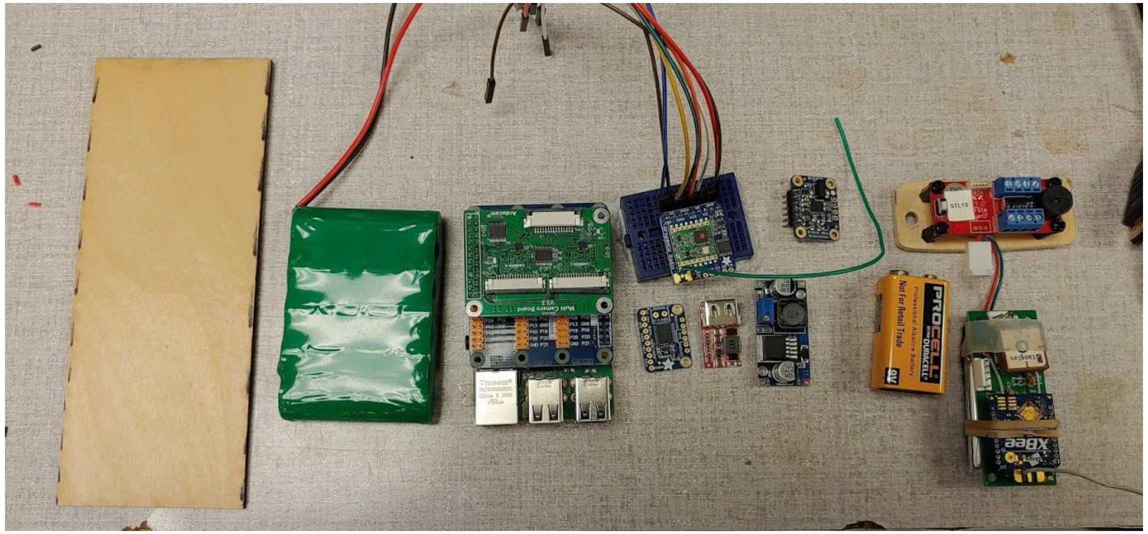
LOPSIDED-POS Computing

- Raspberry Pi 3B+ used for all on-board LOPSIDED-POS components
- Raspbian OS with Python 3
- Python scripts initiate parachute release, leveling, image capture, and image transmission
- SD card saves leveling angle measured by orientation sensor



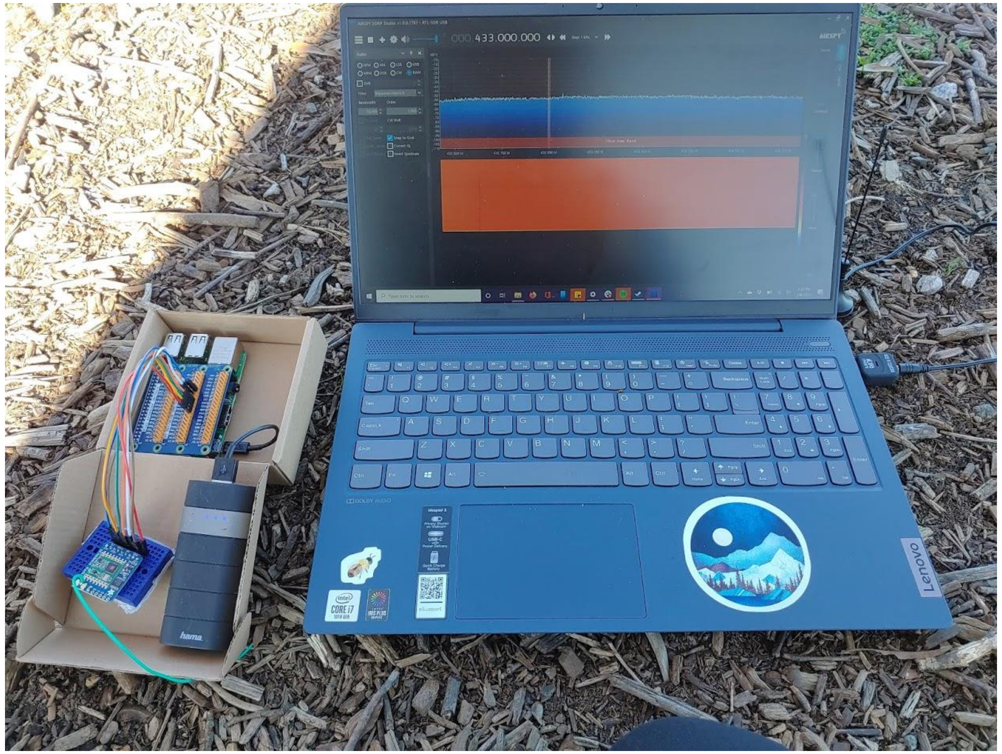
Electronics Sled

- Cut from single layer of aircraft grade plywood
- Houses all LOPSIDED-POS electronics, excluding the cameras, solenoid latches, and parachute latches
- Will be offset from the central vertical axis of LOPSIDED



POS Transmission Range Test

- To verify TDR 4.14
  - Modified from CDR to require a transmission range of 2500 feet
- Test procedure was modified due to delays in the development of SSTV transmission
- Geography of the test field prevented personnel from reaching the desired 2500 feet
- Despite this, the POS maintained strong contact with the SDR receiver until the furthest reached distance of 1091 feet
- The original test procedure will be completed at an acceptable location and documented in the FRR addendum



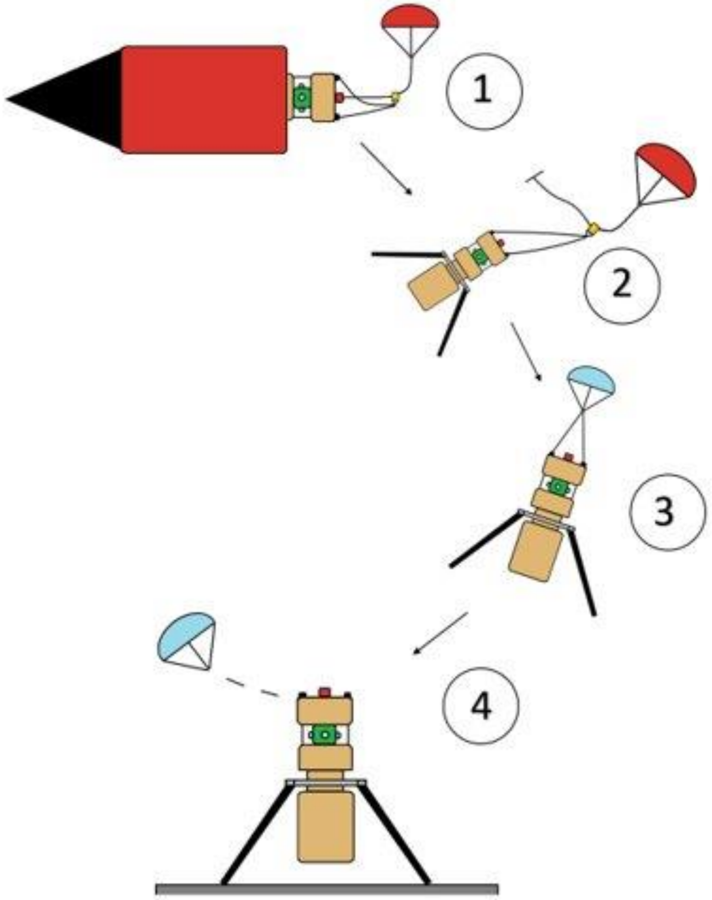
LOPSIDED-POS Retention and Deployment

1.Payload is pulled by the main parachute deployment at ~675 ft AGL. Altimeter ignites at 500 ft AGL separating payload from main chord.

2.LOPSIDED exits and pulls the payload parachute from the bag attached to the main parachute shock cord.

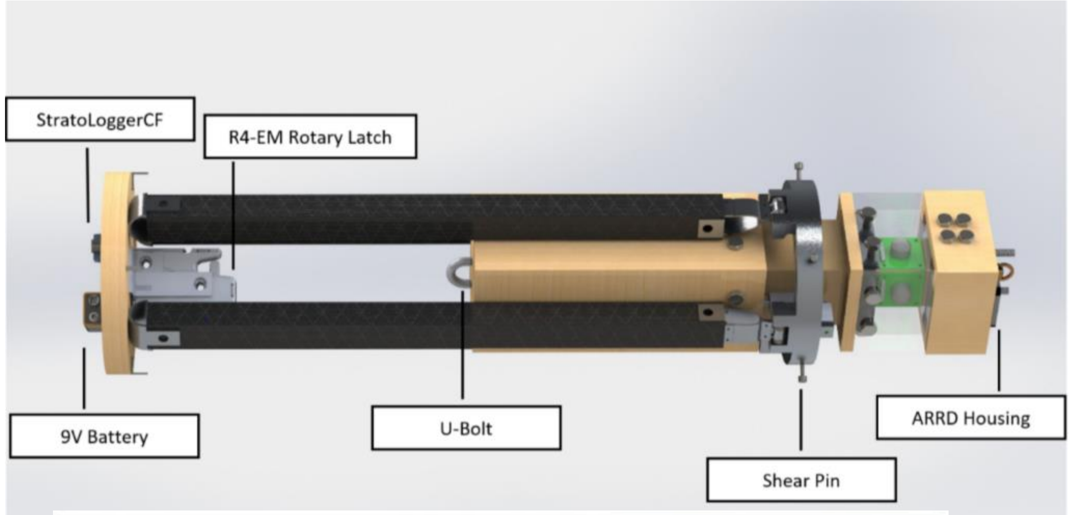
3.Payload proceeds to fall under a parachute.

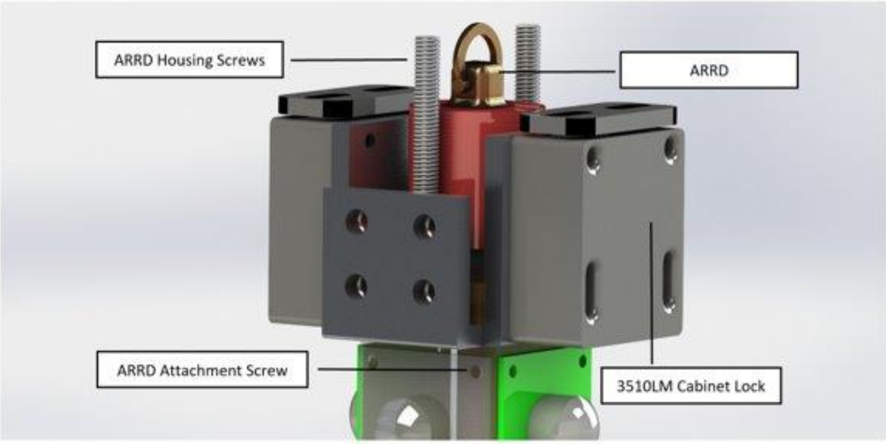
4.Accelerometer detects impact and signals the electromechanical locks to release parachute upon landing.



Retention and Deployment

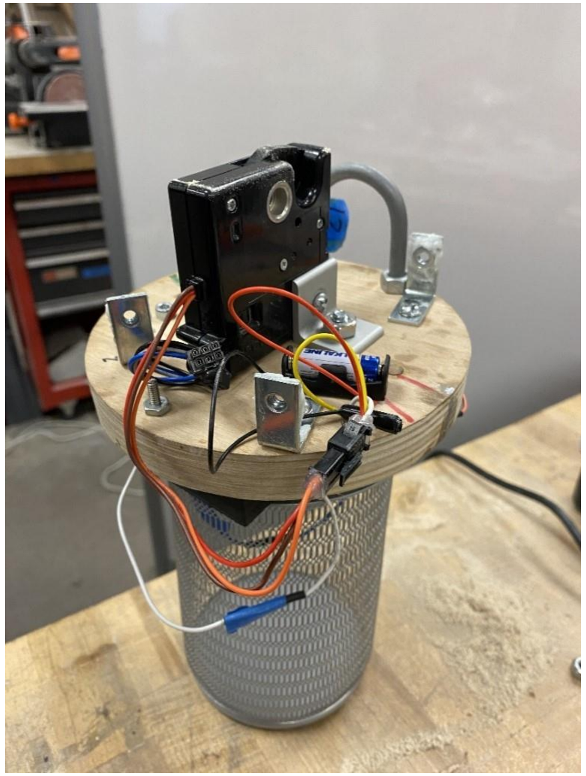
- Advanced Retention Release Device (ARRD)
  - Altimeter sends electric signal through e-match to ignite the ARRD's black powder
  - Activated at 500 ft AGL
  - Supports up to 2,000 lbf
  - ARRD is attached to LOPSIDED using the ARRD housing shown
- Electromechanical lock
  - Model: Dormakaba 3510LM Cabinet Lock
  - Holding Force: 250lbf
  - Dimensions: 1.65in x 1.65in x 0.79in

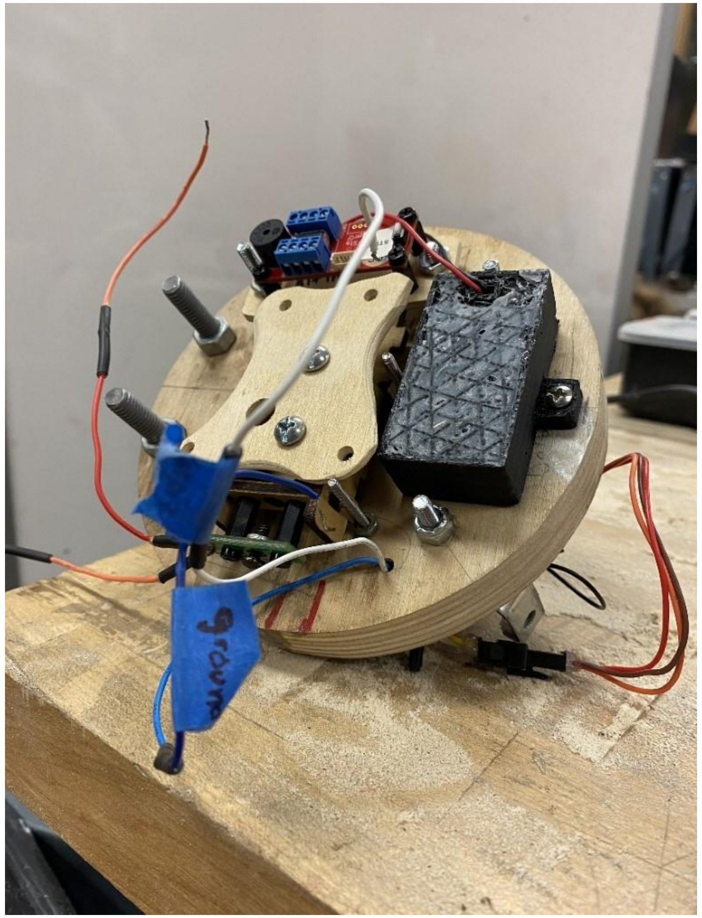




Retention System Construction

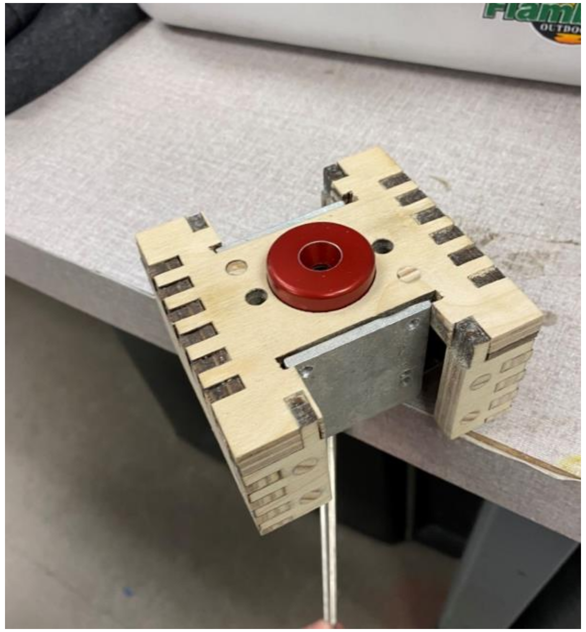
- Rotary latch attached to aft side of bulkhead using aluminum L-brackets
- 12V battery attached with a screw
- StratologgerCF attached to forward side of bulkhead
- Dedicated 9V battery attached using 3D-print house
- Altimeter switch (accessible at launch pad) attached using wooden house
- Wooden platform for Arduino Nano attachment





Deployment System Construction

- L-brackets adapted for electromechanic locks to attach
- Aluminum plates screw onto upper section of LOPSIDED
- Ttaches to plates with a screw that goes through
- Machinde using drill press and angle grinder



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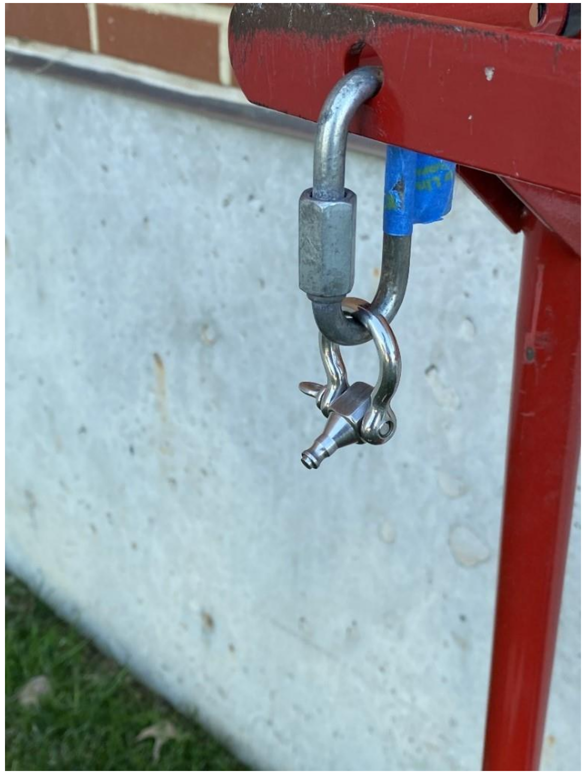
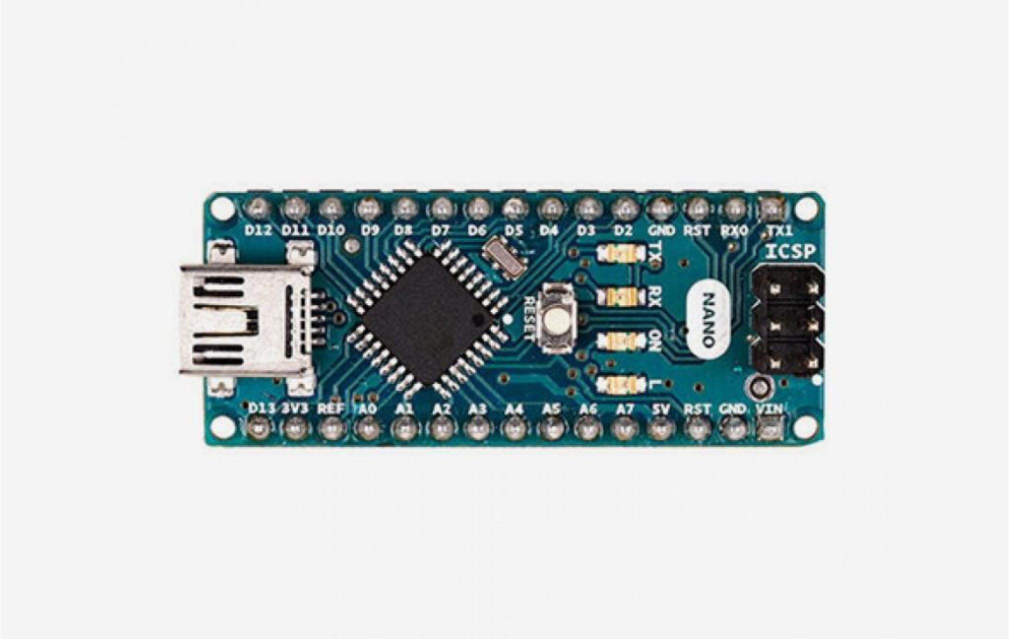
ARRD Ejection Test

- ARRD did not eject during vehicle demonstration flight; however, black powder charge did ignite
- Multiple tests led to conclusion that the spring used for the ARRD was too stiff for charge pressure build up to push on push cap.
- Test conducted outside with at least 5 feet of distance between ARRD and personnel
- New springs ordered and a method of ensuring ARRD will work is to test if the push cap and spring can be pushed with thumbs before assembly



Payload Deployment Chnagnes Since CDR

- Complications during vehicle demonstration flight included the rotary latch on the nosecone bulkhead remaining locked to the payload
- Tests at the lab lead to conclusion that the electric signal to the latch needs to be extended for lock to remain unlocked passed payload deployment
- Addition of Arduino Nano to the bulkhead for retention electronics to control latch



POS Changes Since CDR

- POS utilizes SSTV instead of Digital SSTV (DSSTV)
  - DSSTV is more difficult to implement with Python on Raspberry Pi
  - SSTV is more widely used, and has better documentation of procedures and troubleshooting methods
- Electronics sled geometry has been simplified, and will be offset from the central vertical axis of LOPSIDED
  - To account for the weight of the payload battery
  - Will improve tolerance of final leveling angle

Launch Vehicle Requirements

- All launch vehicle NASA and team-derived requirements have been verified except for NASA 2.1, 2.19 and 2.19.1
  - Apogee less than 3,500 feet, will attempt to verify at Payload Demonstration Flight
  - The Vehicle Demonstration Re-Flight, Payload Demonstration Flight, and FRR Addendum still need to be completed
  - These will be verified at FRR Addendum
- Previously unverified requirements pertained to construction and the Vehicle Demonstration Flight

Payload Demonstration Flight Plans

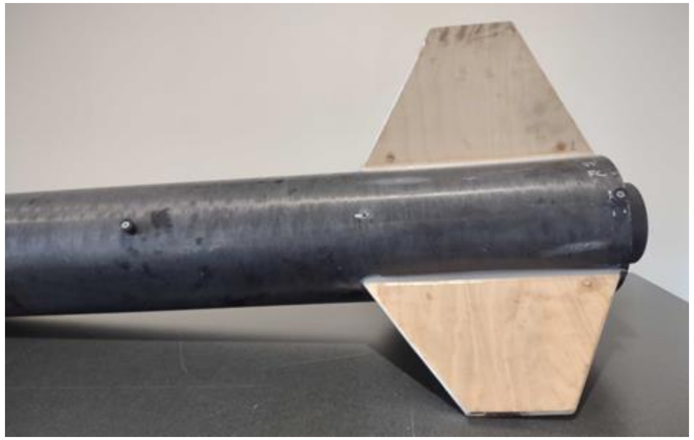
- March 20th at the Tripoli launch site in Bayboro, NC
- Also counting as the Vehicle Demonstration Re-Flight for the Main Parachute Bay changes
- Backup opportunity on March 27th

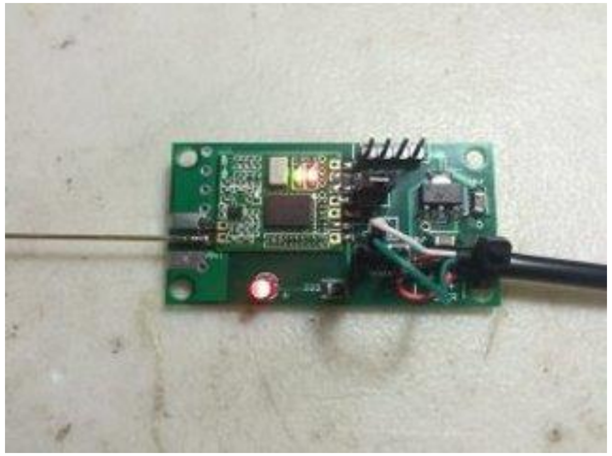
Payload Requirements

- Payload Demonstration Flight related requirements (NASA 2.18.2 - 2.19.2) cannot be verified until FRR Addendum
- Certain payload-related requirements are set to be verified at the Payload Demonstration Flight (NASA 4.2 - 4.3.4.1, 4.4.2, TDR 4.6, 4.14, 4.16)
- NASA 5.4 and 5.5 will be verified at the Payload Demonstration Flight
- NASA 4.3.4.4 (image submission at PLAR) cannot be verified until PLAR

Launch Vehicle Ground Interfaces

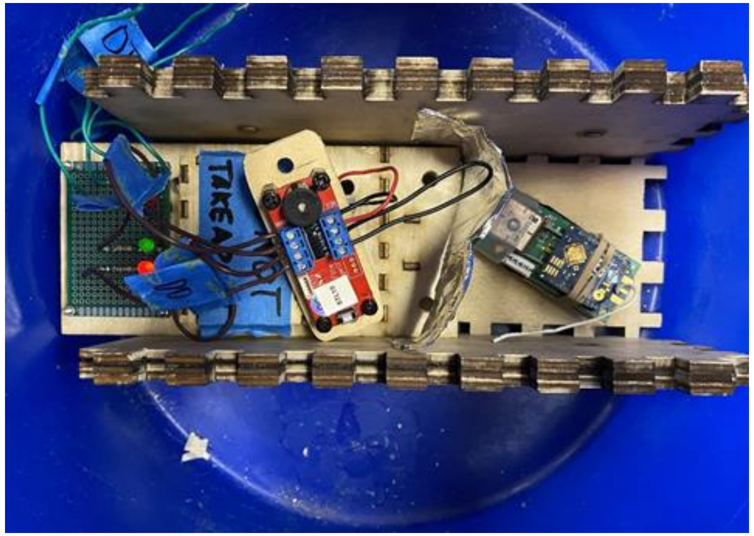
- Rail buttons
  - Interface with 12-foot 1515 launch rail
- EggFinder TX/RX
  - Launch vehicle tracker and receiver
- Screw switches
  - Launch pad altimeter arming

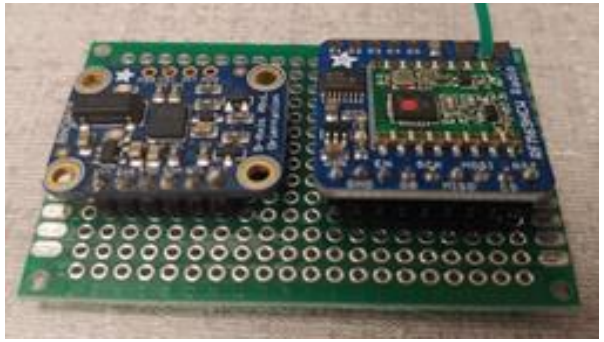




Payload Ground Interfaces

- BigRedBee BRB900
  - Payload tracker/receiver
- 433 MHz SSTV Transmitter
  - Image transmission
- Screw switch
  - ARRD altimeter arming





Questions?