Flight Readiness Review

March 28, 2025

Presentation Overview

- Launch Vehicle Design Overview & Verification Testing
- Recovery System Overview & Verification Testing
- Air Brakes Design Overview & Verification Testing
- VDF Results
- Launch Vehicle Requirements Verification
- Payload Design Overview & Verification Testing
- PDF Results
- Payload Requirements Verification
- Ground Systems

Team Introductions

Katelyn
Team Lead

James
Structures Lead

Aubri
Aerodynamics Lead

Trent
Recovery Lead

Megan
Safety Officer

Connor
Payload Software Lead

Ryan
Payload Structural Integration Lead

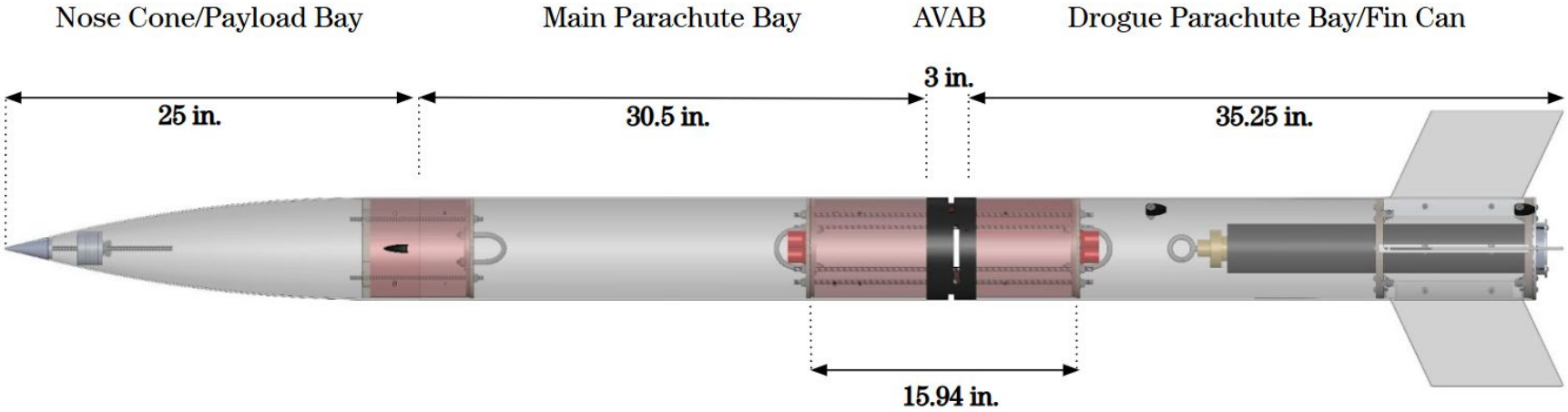
Samuel
Payload Electronics Lead

Abigail
Integration Lead

Launch Vehicle Design Overview

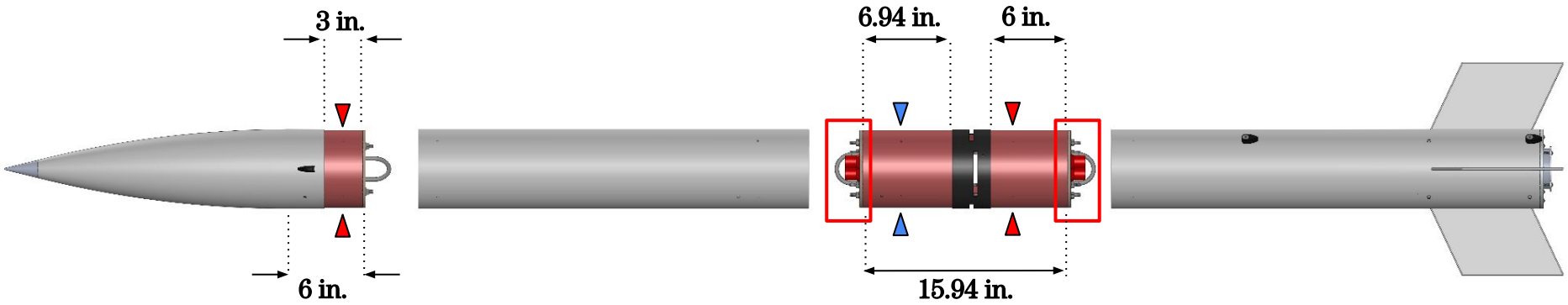
Launch Vehicle Dimensions

- As- built overall length: 93.75 in.
- CDR design length: 95.75 in.
- Maximum body diameter: 6.17 in.
- Aspect ratio: 16:1



Points of Separation

Nose Cone/Payload Bay | Main Parachute Bay | AVAB | Drogue Parachute Bay/Fin Can



- Dual deploy system
- Drogue parachute aft of the AVAB
- Main parachute forward of the AVAB
- AVAB contains all recovery electronics

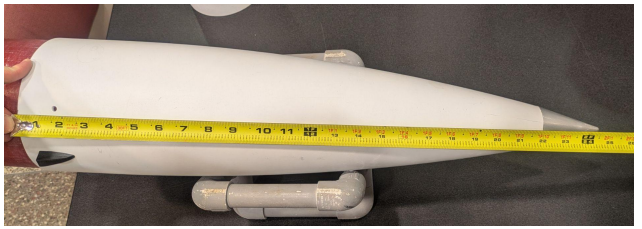
In-flight Separation Point

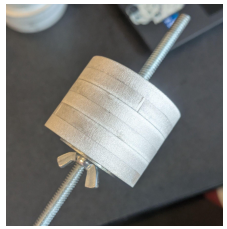
Non-in-flight Separation Point

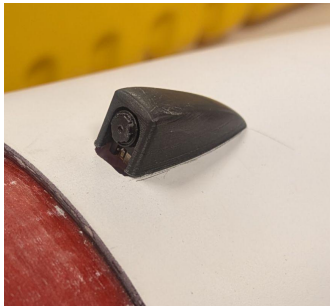
Location of Energetics

Nose Cone/ Payload Bay

- 25 in. as-built length / 27 in. planned
  - Shoulder: 3 in. coupler plus 0.225 in. exposed bulkhead
- 4:1 tangent ogive
- Aluminum ballast system attaches aft of the nose cone tip.
- Added small external aft-facing camera housing
- Secure physical interface with STEMCRaFT payload capsule
- Bulkheads 0.45 in. thick as-built / 0.5 in. planned

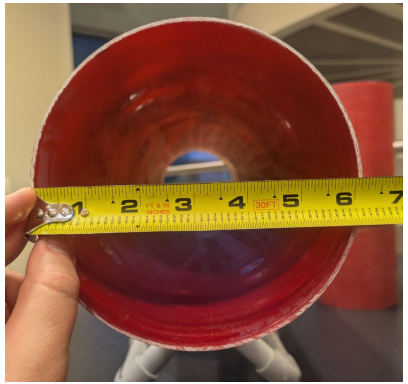


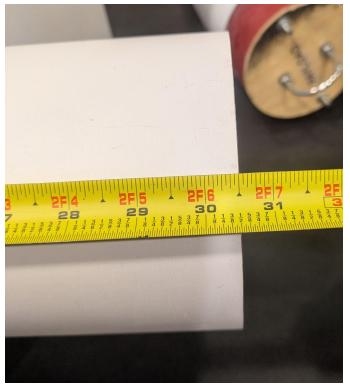


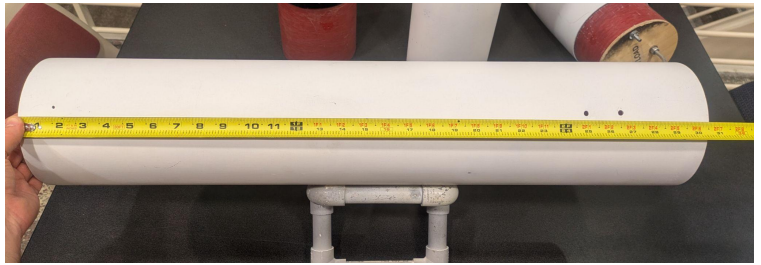


Main Parachute Bay

- 30.5 in. as-built / 30.5 in. planned
- Mates to Nose Cone shoulder with four, #4-40 shear pins
- Mates to AVAB forward coupler section with four nylon rivets
- Two ¼ in. diameter pressure port holes at the aft end for recovery avionics
- Houses main parachute, main parachute deployment bag, and associated shock cords

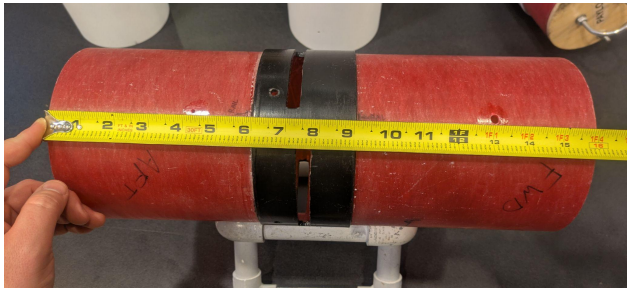


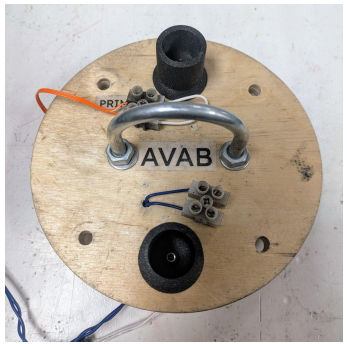




Avionics and Air Brakes Bay (AVAB)

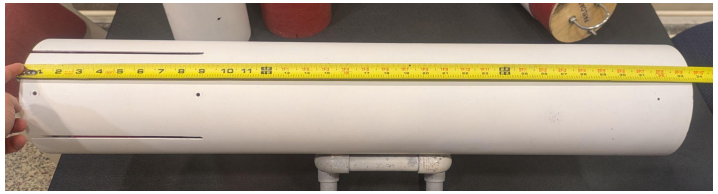
- 15.94 in. as-built length / 16 in. planned
- 6.94 in. forward shoulder, 3 in. switch band, 6 in. aft shoulder
- Recovery avionics in forward section
- Air Brakes mechanism/slots at switch band
- Air Brakes servos & electronics in aft section
- Bulkheads 0.45 in. thick as-built / 0.5 in. planned

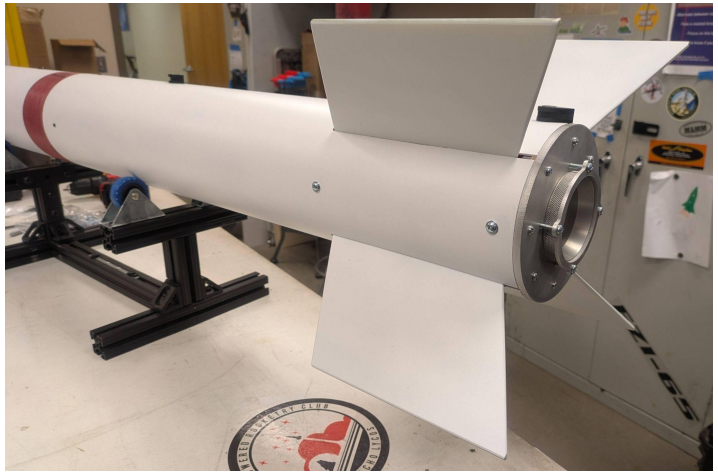




Drogue Parachute Bay/ Fin Can

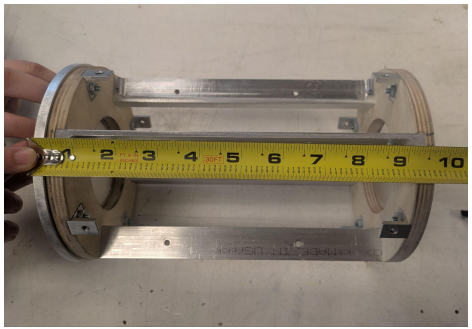
- Airframe 33.5 in. as-built length / 33.5 in. planned
- Overall 35.25 in. as-built / 35.25 in. planned
- Houses drogue parachute, drogue parachute nomex, and shock cord
- Forward rail button attaches via ¼ in. diameter machine screw and hex nut with washer and thin plywood backer.
- RMFS inserts into end-cut slots, fastens to airframe with #8-32 machine screws and aft rail button screw.

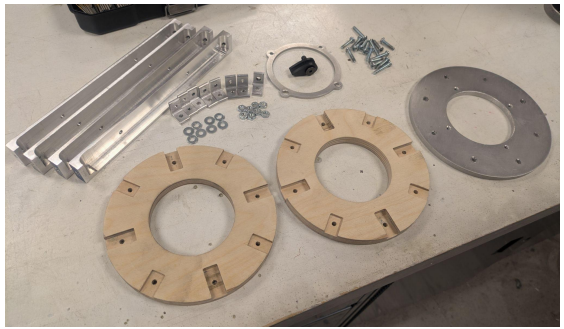


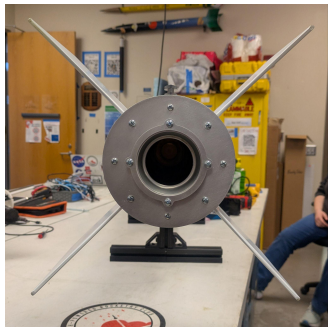


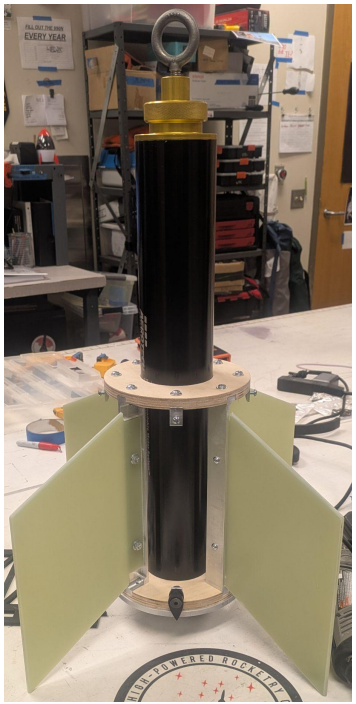
Removable Modular Fin System

- Main structure 9.65 in. as-built / 9.65 in. planned
- Structural assembly for fin and motor mounting
- Two birch centering bulkheads for motor casing
- Aluminum fin runners, threaded L-brackets, thrust plate and motor retainer ring
- Four non-tapered, swept, 3/16 in. G10 fiberglass fins

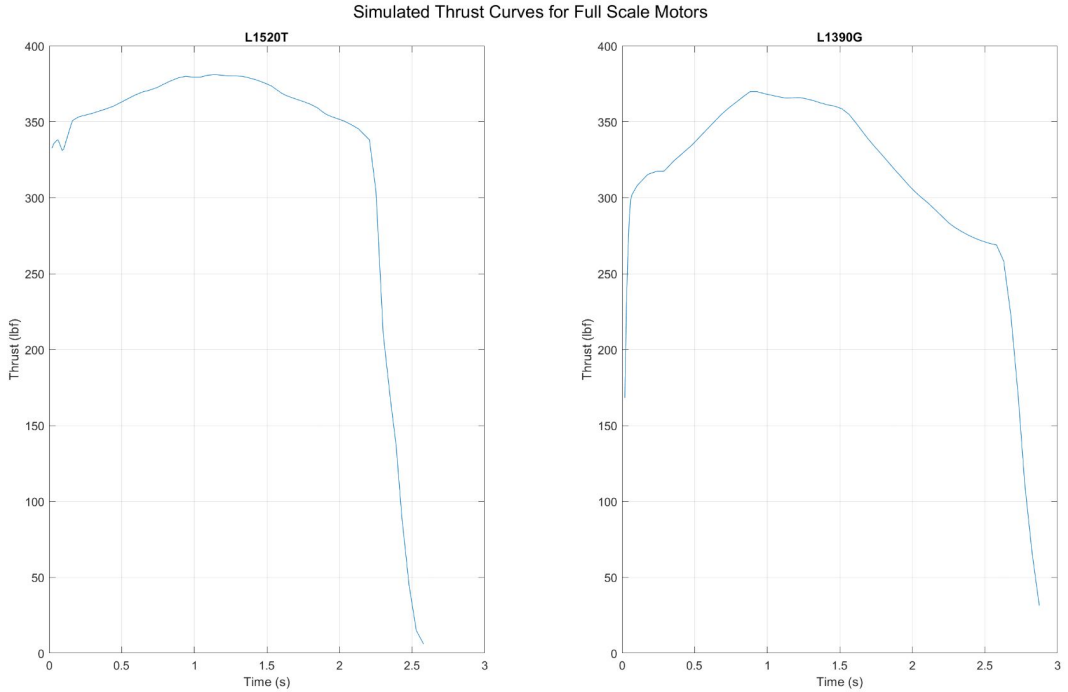








Motor Selection



Primary Motor

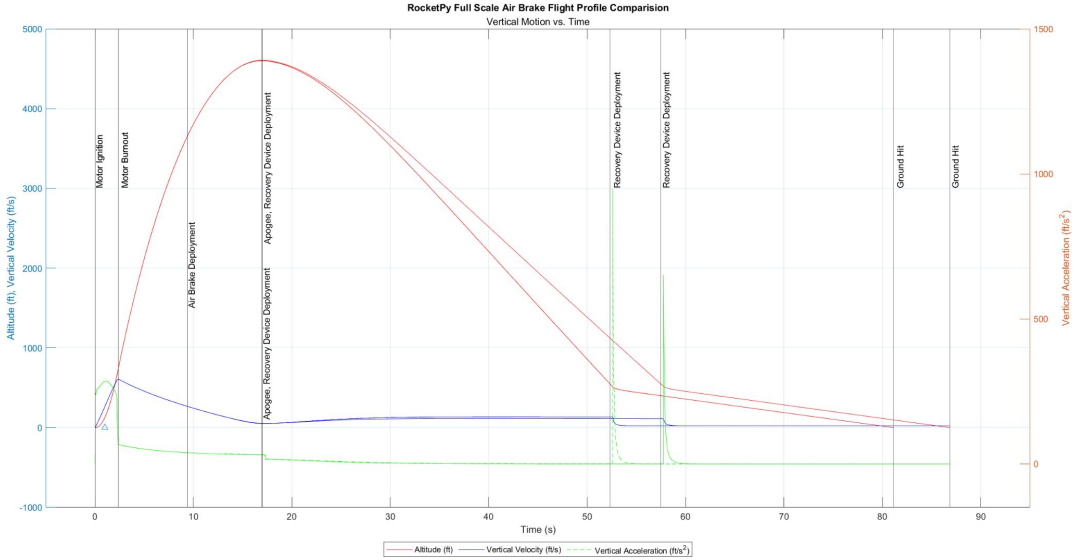
Motor	L1520T
Thrust to Weight	8.75
Velocity off Rail	78.5 ft/s

Back Up Motor

Motor	L1390G
Thrust to Weight	7.89
Velocity off Rail	74.9 ft/s

Target Altitude

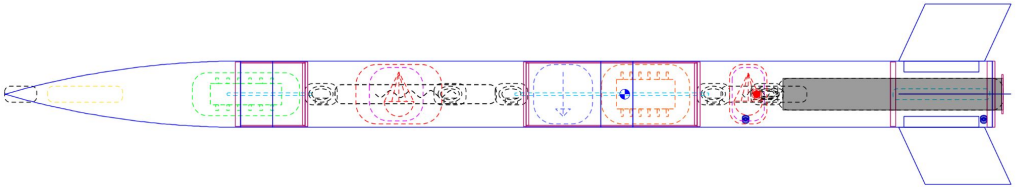
- Target Altitude = 4600 ft.
  - Apogee will be undershot if wind speeds are greater than 10 mph

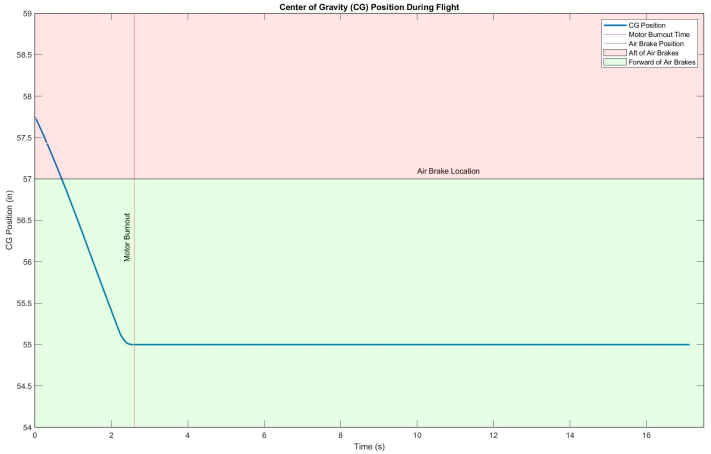


Wind Speed	Predicted Apogee
0 mph	4652 ft
5 mph	4640 ft
10 mph	4606 ft
15 mph	4548 ft
20 mph	4469 ft

Static Stability Margin

- Static Stability = 2.028 with 0.46 lbs. of ballast
- Burnout CG = 55.0” from Nose Cone
- Air Brake Slots = 57” from Nose Cone
  - Air Brakes 2” aft of burnout CG





Software	Center of Pressure	Center of Gravity	Stability Margin
OpenRocket	70.05 in.	57.75 in.	2.0 Calibers
RasAero II	69.94 in.	57.75 in.	2.0 Calibers
RocketPy	67.80 in.	57.24 in.	2.0 Calibers

Launch Vehicle Mass

Total Launch Vehicle Masses	
Configuration	Mass [lbs.]
Dry Mass (Unballasted)	30.8
Dry Mass + Predicted Ballast	31.3
Total Wet Mass + Ballast	39.7
Burnout & Landing Mass	35.6

Mass Growth Since CDR			
Section	CDR Est. [lbs.]	As-Built [lbs.]	Difference
Nose Cone/Payload Bay	8.81	7.90	-10.9 %
Main Parachute Bay	5.47	5.90	+7.56 %
AVAB	6.60	7.60	+14.1 %
Drogue Bay/Fin Can	17.51	18.28	+4.3 %
Total (Wet + Ballast)	38.39 lbs	39.68	+3.3 %

Launch Vehicle Verification Testing

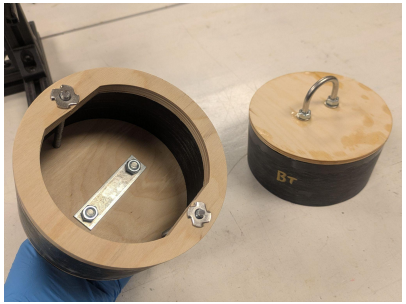
Moment of Inertia Test

- Moment of Inertia: 10.208 kgm^2
- Simulated value: 9.474 kmg^2
  - Percent error of 7.74 % - below the 20 % requirement
- Individual swing tests were within 0.5 kgm^2 of the average
- Verified flight profile simulation accuracy
  - Simulation softwares simulated this value based on mass and geometry inputs

Bulkhead Assembly Tensile Tests

- Tensile strength of Nose Cone/ Payload Bay and AVAB bulkhead assemblies tested via Instron Universal Testing Machine
- Test articles manufactured using same methods and materials as flight hardware.
- Ultimate failure loadings not reached, factors of safety well above team derived requirement of 1.5 were determined (TDR LVD.1)

Assembly	Max Tested Loading	Factor of Safety	Constituent Components
Nose Cone/ Payload Bay	1380 lbf.	> 4.4	ring bulkhead, threaded T-nuts, coupler epoxy bond, removable bulkhead, 2x threaded rods, U-bolt, hex nuts, washers
AVAB	1810 lbf.	> 7.5	2x removable bulkheads, 4x threaded rods, U-bolts, hex nuts, washers

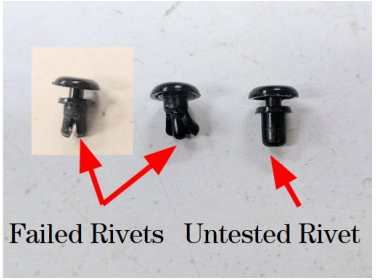


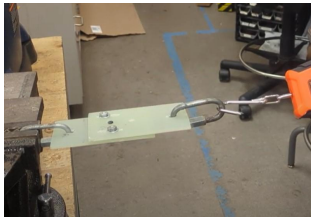
Shear Pin and Rivet Shear Testing

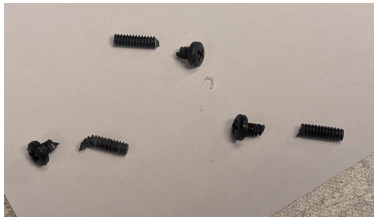
- Section fastener shear failure tested using G10 fiberglass plates
- Nylon rivets successfully tested to verify factor of safety >2 (TDR LVF.11)
- Shear pins successfully tested to verify expected failure load range of 40±5 lbf. (TDR LVF.12)

Rivet Test	Failure Load	Factor of Safety
1	194 lbf.	**2.4**
2	186 lbf.	**2.3**

Shear Pin Test	Failure Load	Status
1	45 lbf.	Successful
2	37 lbf.	Successful
3	38 lbf.	Successful

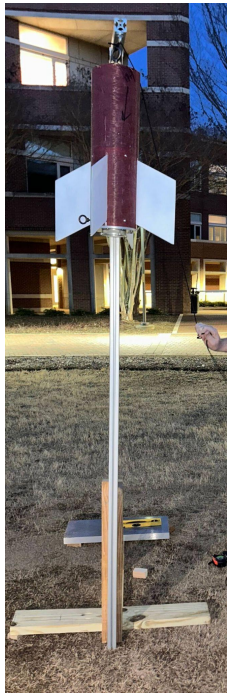






Fin Can Drop Testing

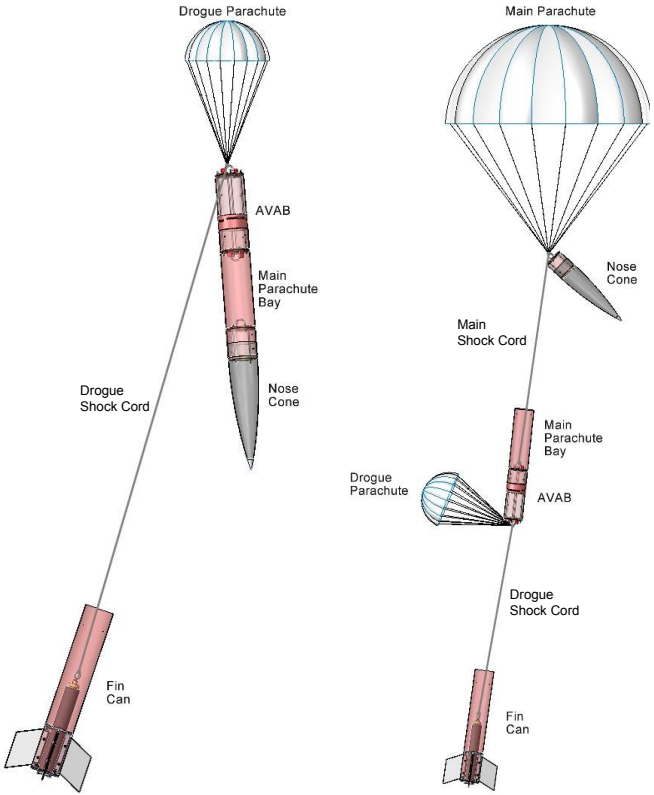
- Simulated repeated fin can landing impacts
- 75 ft-lbf. KE tested - test article ballasted to meet KE target when free-falling from calculated height of 5.5 ft (TDR LVD.1, NASA Req 3.3)
- RMFS, fins, motor casing, retainer all actual flight hardware. Airframe substituted.
- Dropped 3x in vertical orientation, 3x in horizontal
  - Fins dug in to turf/soil in vertical impacts
  - Assembly exhibited an elastic response in horizontal impacts
- Detailed inspections post-drop revealed no damage, no loosened/bent fasteners, and no other failures/concerns



Recovery System Overview

Recovery Overview

- Drogue deploys at apogee
  - Secondary charge set to one second after apogee
- Main deploys at 550 feet
  - Secondary charge set to 500 feet
- At least 10 feet of separation between all descending sections of the Launch Vehicle
- All sections of the Launch Vehicle remain tethered together for the entirety of the flight



Parachute Selection

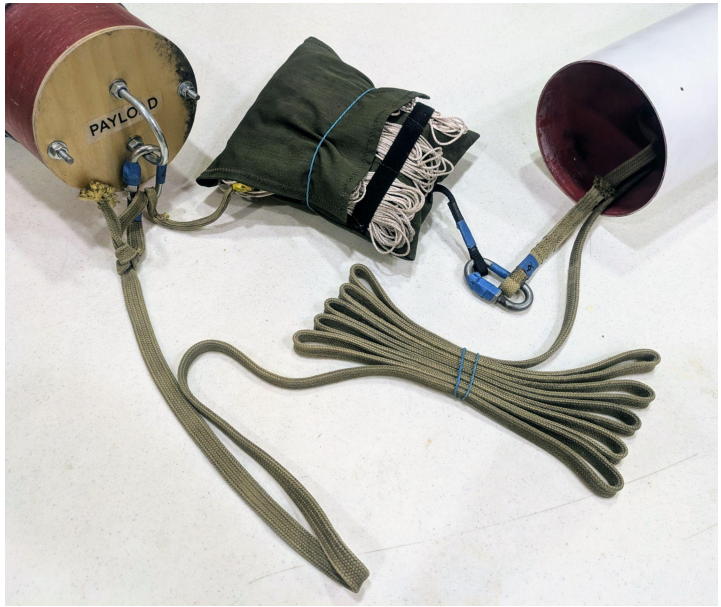
- Drogue
  - Fruity Chutes 15” Elliptical Parachute
  - Protected by Nomex Blanket
- Main
  - Fruity Chutes Iris Ultra 96” Compact Parachute
  - Protected by Fruity Chutes Deployment Bag
- Kinetic energy below 65 ft-lb
- Descent time below 80 seconds

Recovery Harness

- 5/8" Kevlar Shock Cord
- Strength Rating of 6600 lbs
- At connection points the shock cord is secured to quick links with a bowline knot, which are then attached to bulkhead U-bolts or eye bolts.

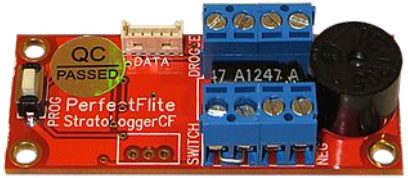
- Drogue Shock Cord Length: 216 inches
- Main Shock Cord Length: 192 inches
- Allows for 10 feet of separation between descending sections

- Force of Parachute Opening: 292.8 lbs
- Factor of Safety: 22.5



Avionics

Primary Altimeter: PerfectFlite StratologgerCF
- Drogue charge at apogee
- Main charge at 550 ft

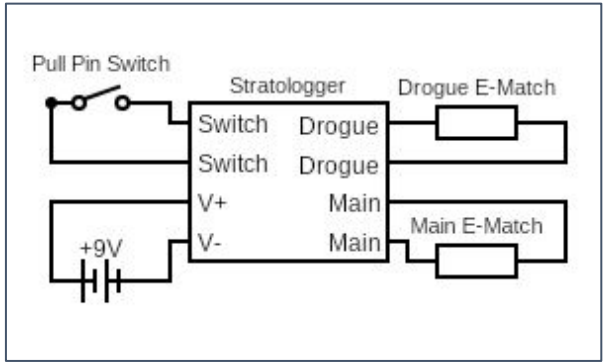


Secondary Altimeter: Altus Metrum EasyMini
- Drogue charge 1 second after apogee
- Main charge at 500 ft

GPS Tracker: Eggfinder Mini
- Transmitter frequency of 420.75 MHz
- Paired with Eggfinder LCD Receiver

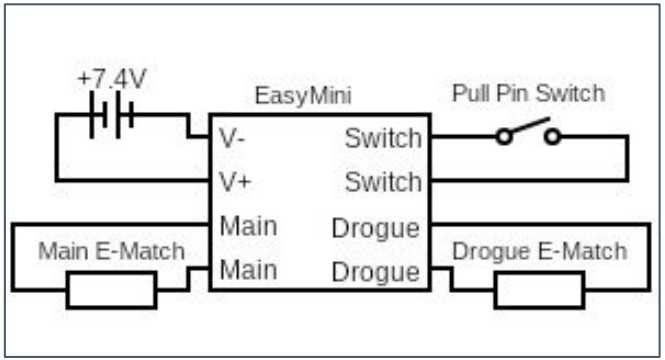
Wiring Diagrams

Primary Altimeter



PerfectFlite StratologgerCF powered by a 9V alkaline battery controlled by a pull pin switch

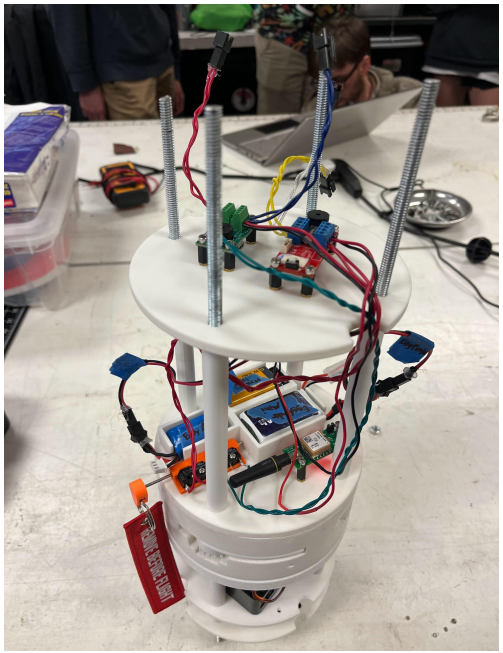
Secondary Altimeter



Altus Metrum EasyMini powered by a 7.4V 400mAh LiPo controlled by a pull pin switch

Avionics Sled Design

- Located at the forward end of the AVAB
- All avionics hardware mounted on two flat plates separated by 5 in.
- Wires run freely through wire holes along the outside of the flat plates
- Maximize separation of altimeters from frequency emitting devices:
  - 5 in. from GPS
  - 6.68 in. from Air Brakes Servo
- Lined the bottom of the altimeter plate in aluminum foil for extra shielding



Launch Vehicle Kinetic Energy

- Max KE at landing is 60.4 ft-lb
  - Meets bonus point threshold of 65 ft-lbs

Section	Mass (lbm)	Drogue Descent Velocity (fps)	Drogue Kinetic Energy (ft-lbf)	Main Descent Velocity (fps)	Main Kinetic Energy (ft-lbf)
Nose Cone	7.9	100.8	3381	16.6	33.8
AVAB + Main Bay	13.5			16.6	57.8
Fin Can + Drogue Bay	14.1	100.8	2228	16.6	60.4

Descent Time and Drift Distance

Assuming nominal flight - Apogee of 4600 feet and main parachute deployment at 550 feet:

- Descent Time: 73.3 s
- Meets bonus point threshold of 80 s

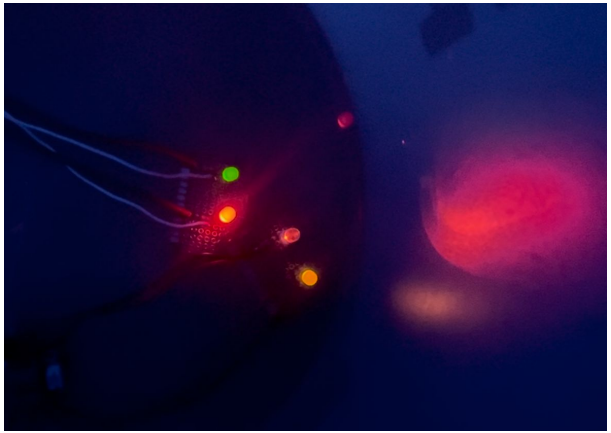
- Max Wind Drift: 2150 ft
- Meets 2500 ft requirement

Wind Speed (mph)	Drift Distance (ft)
0	0
5	537
10	1075
15	1612
20	2150

Recovery System Verification Testing

Altimeter Test

- Drogue and main deployment LEDs lit up at the appropriate times given the change in pressure
- Altimeter flight profiles indicated expected deployment times for primary and secondary altimeters
- Altitude plots were compared between altimeters which verified consistency and accuracy of pressure sensors



GPS Test

- Table shows percent difference between latitude and longitude measurements.
- Error was minimal over 0.7 miles with short/medium obstacles (trees & buildings)

Reciever Coordinates		Transmitter Location - Phone Measurement		Percent Difference	
Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
35.76605	-78.67481	35.76599	-78.67489	0.00016	-0.00010
35.76444	-78.67449	35.76444	-78.67455	-0.00001	-0.00007
35.76209	-78.67687	35.76200	-78.67692	0.00025	-0.00006
35.76105	-78.6802	35.76104	-78.68023	0.00003	-0.00004
35.76105	-78.6802	35.76028	-78.68308	0.00216	-0.00366
35.77043	-78.66994	35.77035	-78.66987	0.00023	0.00009
35.77033	-78.66536	35.77035	-78.66520	-0.00005	0.00020
35.76758	-78.66256	35.76761	-78.66260	-0.00007	-0.00005
35.77092	-78.66375	35.77089	-78.66381	0.00009	-0.00008

Ejection Test

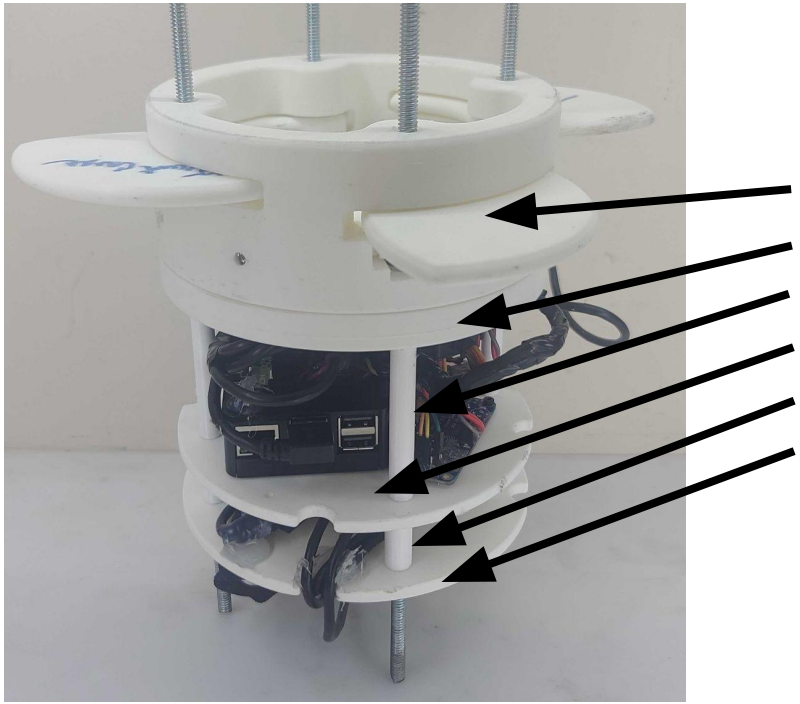
- Complete separation between Fin Can/ AVAB with 2.8 g black powder
- Complete separation between Nose Cone/ Main Parachute Bay with 3.1 g black powder
- No damage to the launch vehicle
- No damage to any recovery hardware

Parachute Deployment Test

- Main parachute: tested deployment bag & Fruity Chutes elliptical parachute packing method
- Drogue parachute: tested Z-fold & nomex folding method
- Quick deployment & minimal shroud line entanglement
- No damage sustained to simulated mass containers

Air Brakes Design Overview

Final Design Overview



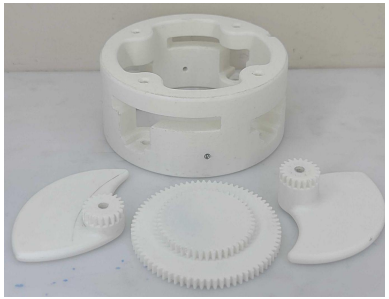
From top to bottom:

1. Staggered Actuation Mechanism
2. Servo Sled
3. Spacers
4. Flight Computer Sled
5. Spacers
6. IMU\Battery Sled

All 3D prints are PLA at 25% infill

Staggered Air Brakes

- 2 pairs of fins, offset in height
  - Designed with 20 tooth gear
  - Combined reference area of 30 in^2
- Housing
  - Threaded rod holds bearings & fins
  - Embedded nuts for mounting
- Central Gear
  - 74 toothed gear mated to 48 toothed gear
  - 1: 1.54 gear ratio



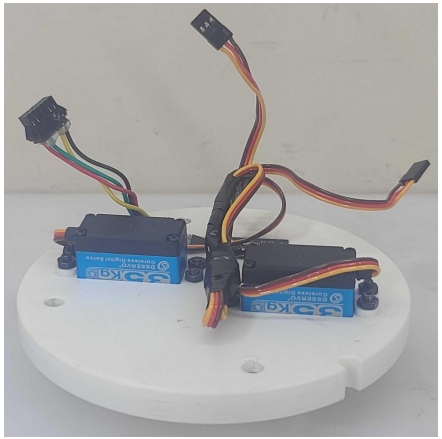
Servo Sled

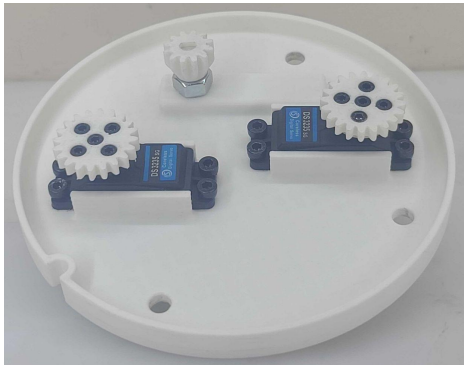
Two DS3235 SG Servos

- Combined power ~960 oz-in
- Synchronized via PCA9685
- Mounted with M3 through-bolts
- 20 toothed gears (3D Printed)

Encoder

- Tracks position of fin deployment
- Mounted with nut
- 15 toothed gear





Flight Computer Sled

Raspberry Pi

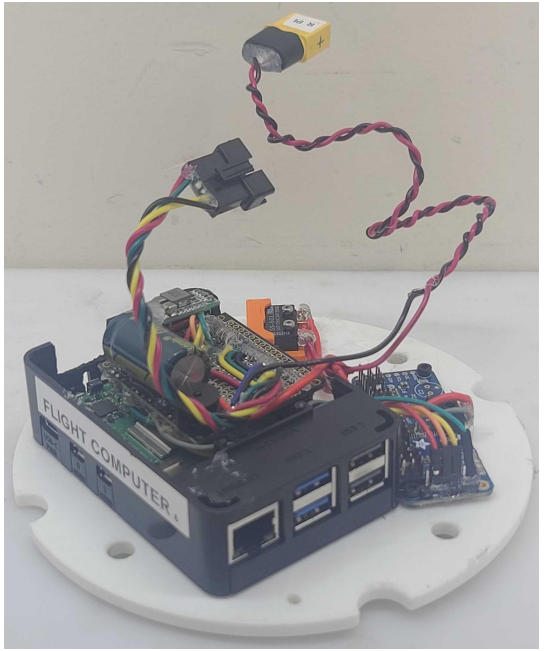
- Custom PiHat for wire management
- Attached with ¼ inch sheet metal screws

Pull Pin Switch

- Arms/disarms power
- M2.5 through-bolts

PCA9685

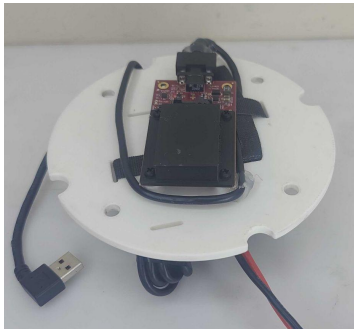
- I2C communication with Pi
- Controls PWM signal
- M3 through-bolts



IMU & Battery Sled

Top Side: IMU

- Mounted with M3 screws into Heat Inserts

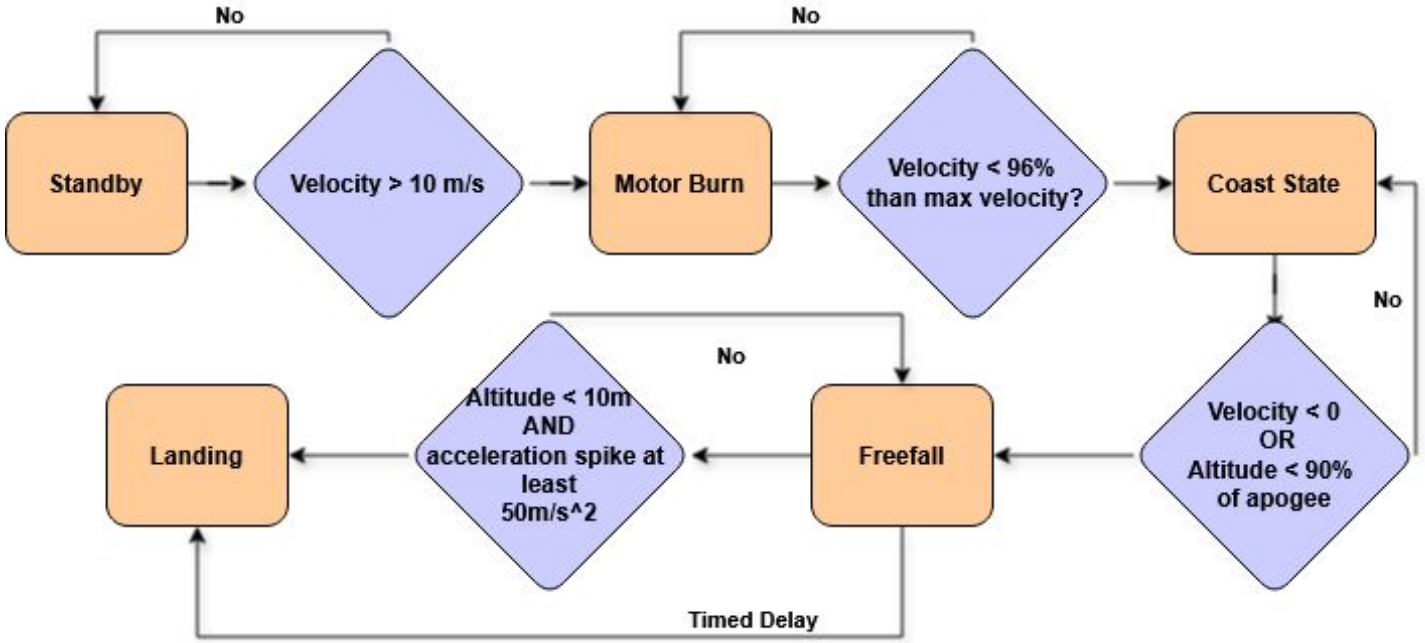


Bottom Side: 4s 2200mAh Battery

- Secured with velcro fasteners

Excess IMU cable is stored adjacent to Battery

Software- FSM



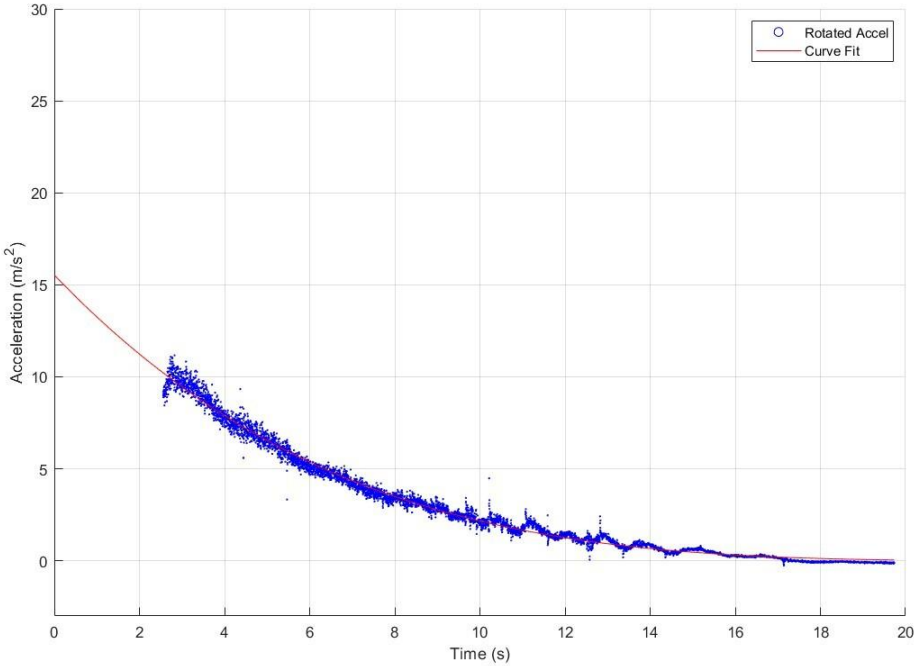
Software- Prediction

Curve-fit vertical acceleration

- Post-Motor burn stage
- Extrapolate future heights
- Extrapolate future velocities
- Generates Predicted flight profile

Backtested to 98\% Accuracy

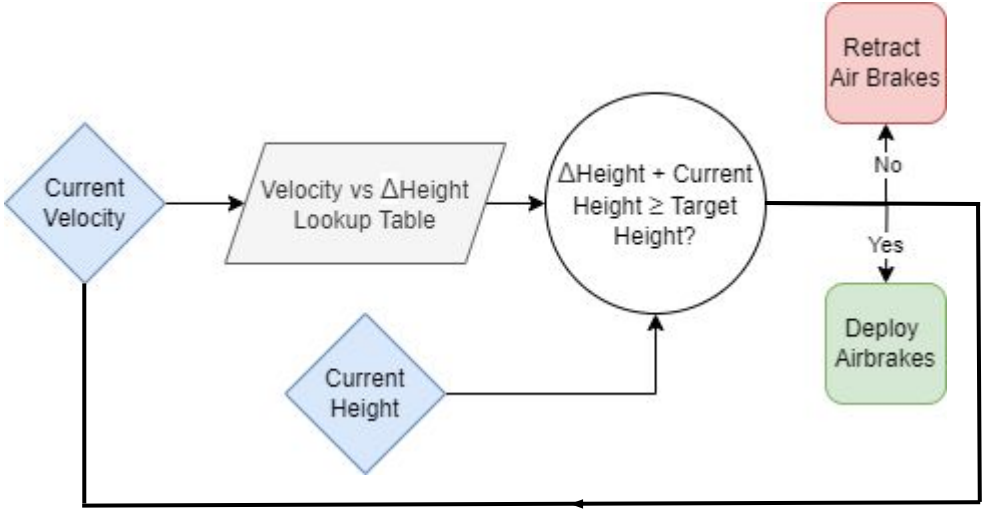
Launch Name	Convergence Time (sec)	Predicted Apogee (m)	Actual Apogee (m)
Interest Launch	1.60	1896	1855
Genesis Launch 1	1.78	454	459.3
Genesis Launch 2	1.50	459	463



Software- Control

Control algorithm

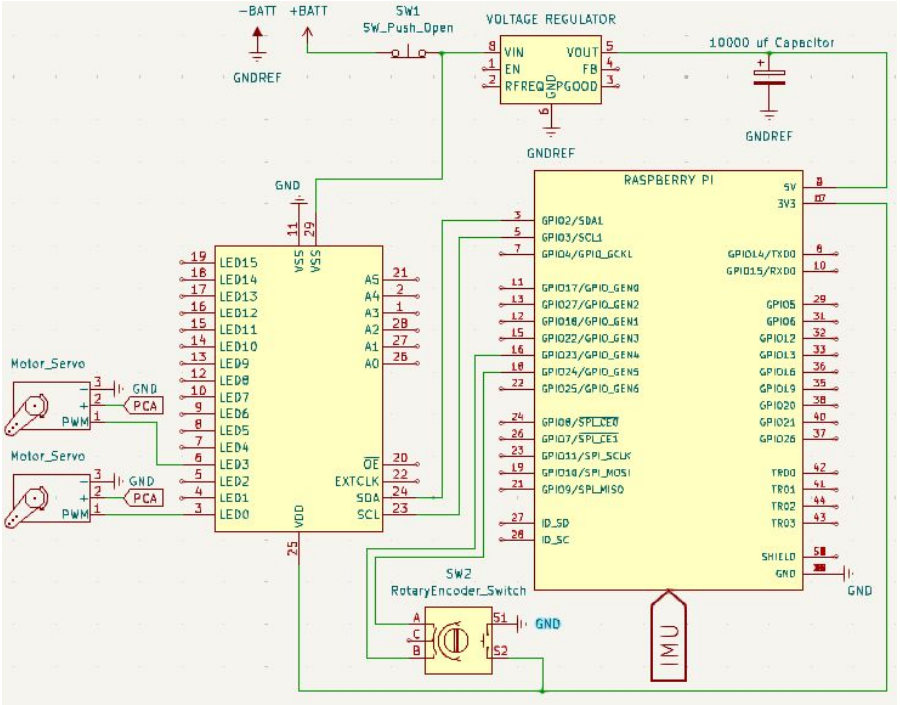
- References the predicted flight profile
- When Flight Profile converges, the fins:
  - deploy if overshooting target apogee
  - retract when undershooting



Electrical Schematic & Components

Powered by 4s LiPo (~16.4V)

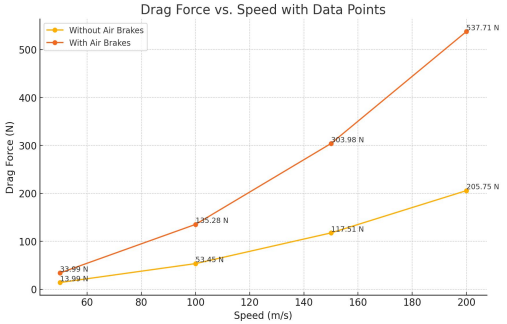
- Armed via Pull pin
- 5v switching voltage regulator
- Capacitor for Brownout protection
- Raspberry Pi powers:
  - The Encoder
  - The PCA9685
- Servos powered from 4s LiPo



Air Brakes Testing

Deployment Test

- Hung A.B. by bulkhead from test stand
- Hung platform from test fins with rope
- Connected to power supply to monitor current draw of servos
- Minimum weight needed:
  - 186N (41 lbf) @ 150m/s
- Fins successfully deployed at 70lbs
- Results: No servo stalling, no stripped gears, no broken components



Battery/ Endurance Test Comparison

Dual Battery	Time	Voltage
Start	9:35am.	8.33V & 8.35V
Stop	11:40am.	6V & 8.25V
Totals	2 hours 5 minutes	-2.33V & -.10 V

RasPi disconnected before 3-hour target, insufficient endurance

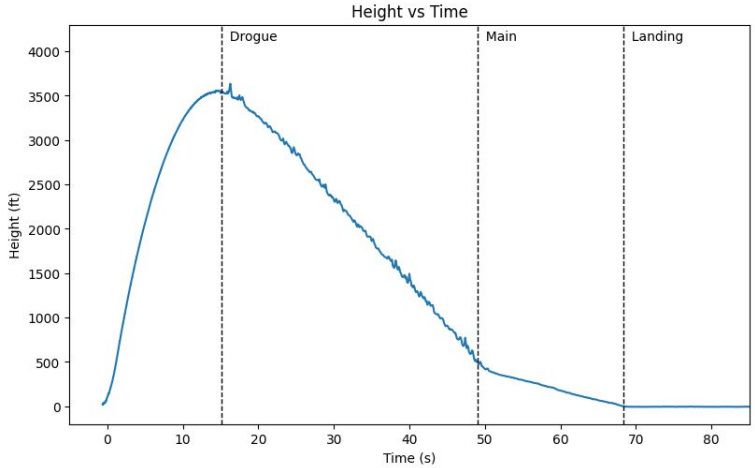
Single Battery	Time	Voltage
Start	5:50 PM	16.23V
Stop	9:00 PM	13.98V
Totals	3 hours 10 minutes	-2.25V

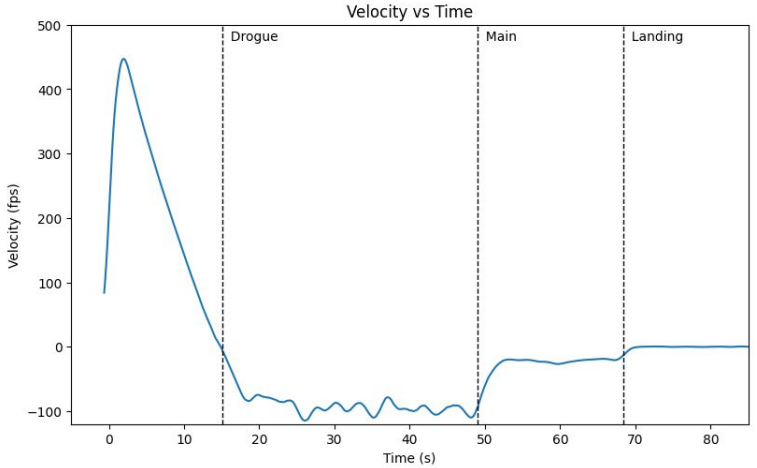
No system failures, met requirements, outperformed dual-battery

VDF Results

Flight Results

- Launch Date: 3/8/2025
- Stability: 2.63
- Launch Angle: 5°
- Wind Speed: 20 mph
- Ballast: 3.7 lbs
- Motor: L1520T

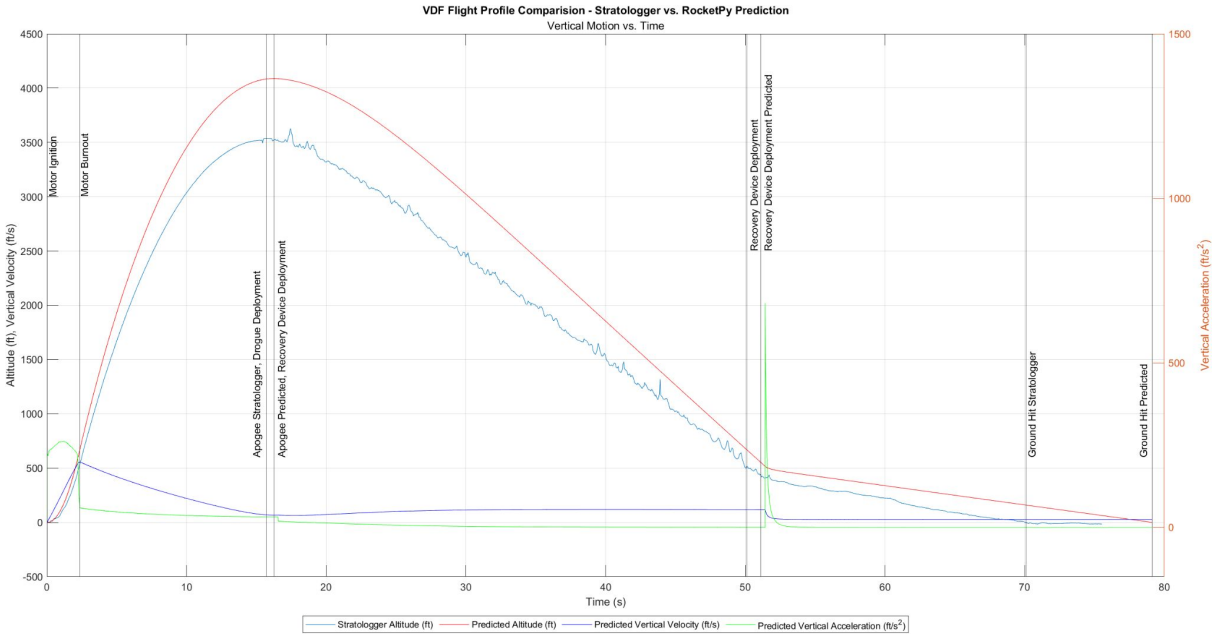




Predicted vs Actual Flight Data

- Altitude reached: 3571 ft
- Altitude predicted: 4088 ft

- Discrepancy due primarily to high surface winds and significant weather cocking off rail



Recovery Descent Configuration

Recovery Landing Configuration

Full Landing

Aft Landing

Forward Landing

Note: Due to high wind conditions, the main parachute was deflated prior to taking recovery photos. The vehicle was not otherwise moved.

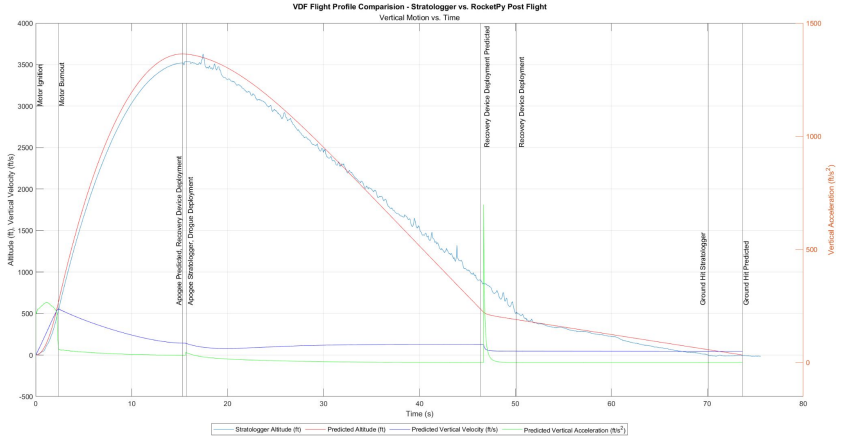
Descent Data Comparison

Parameter	Actual Value	Predicted Value	Difference
Drogue Descent Velocity (fps)	91.4	105.3	13.2%
Main Descent Velocity (fps)	16.4	17.3	5.4%
Total Descent Time (sec)	54.7	70.2	22.1%
Nose Cone Landing KE (ft-lbf)	46.4	51.8	10.5%
AVAB + Main Bay Landing KE (ft-lbf)	56.4	63.0	10.5%
Fin Can Landing KE (ft-lbf)	58.9	65.8	10.5%

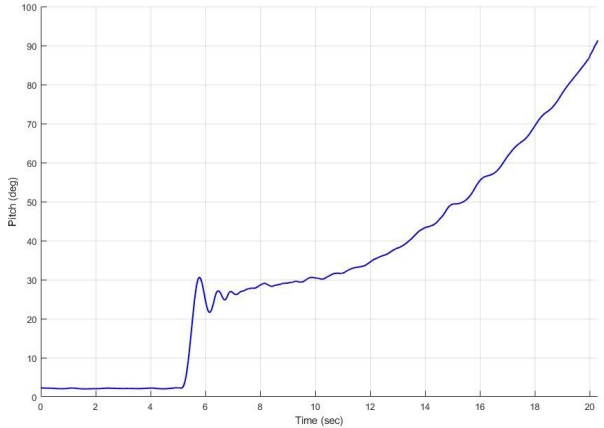
- Lower descent speeds likely caused by inaccurate bluff body drag estimates
- Lower descent time caused by delayed main parachute inflation

Post Flight Analysis

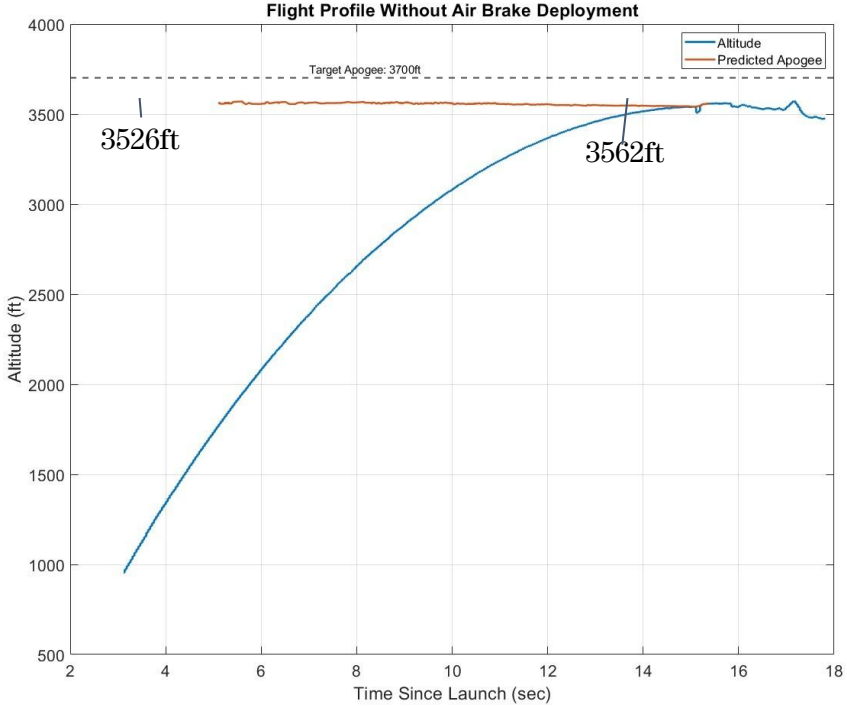
- Simulated separate wind inputs
  - Ground winds: up to 20 mph
  - Winds aloft: up to 30 mph
- Simulated apogee: 3629 ft
  - 58 feet off of actual apogee



- Further discrepancies:
  - Weather cocking off of the rail
  - Marginally stable rail



Air Brakes - VDF Attempt 03/08/25



Data from A.B. IMU

- 'Altitude' from raw data
- 'Predicted Apogee'

- Apogees -

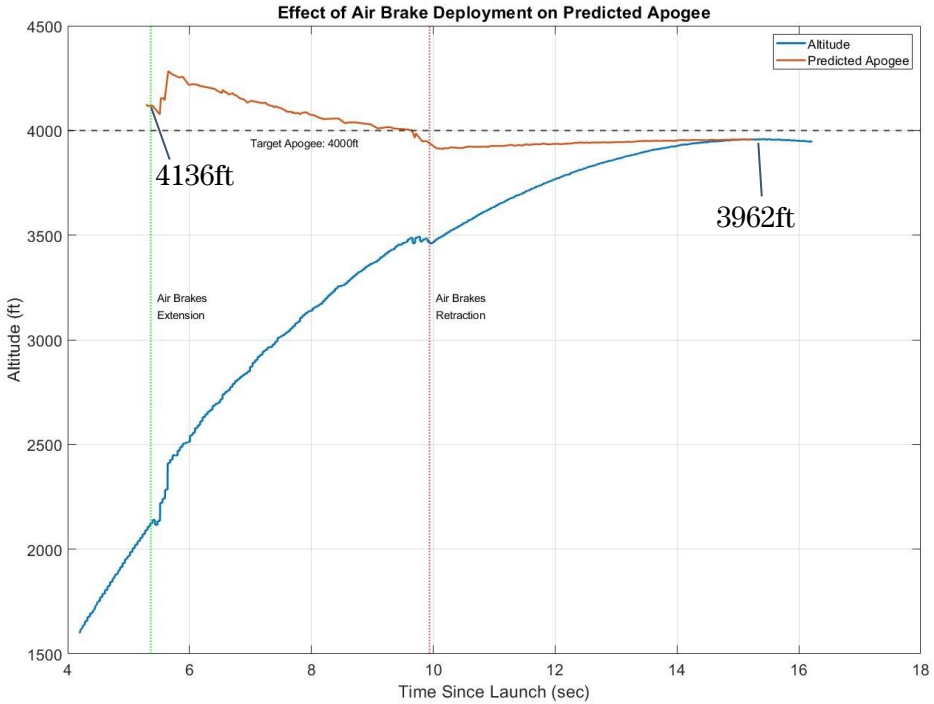
Pre-Launch Simulation: 4088 ft

Target: - - - 3700 ft

A.B. Prediction:- - 3526 ft

A.B. Actual: - - - 3562 ft

Air Brakes - VDF Attempt 02/22/25



-Apogees -

Pre-Launch Simulation: 4200 ft

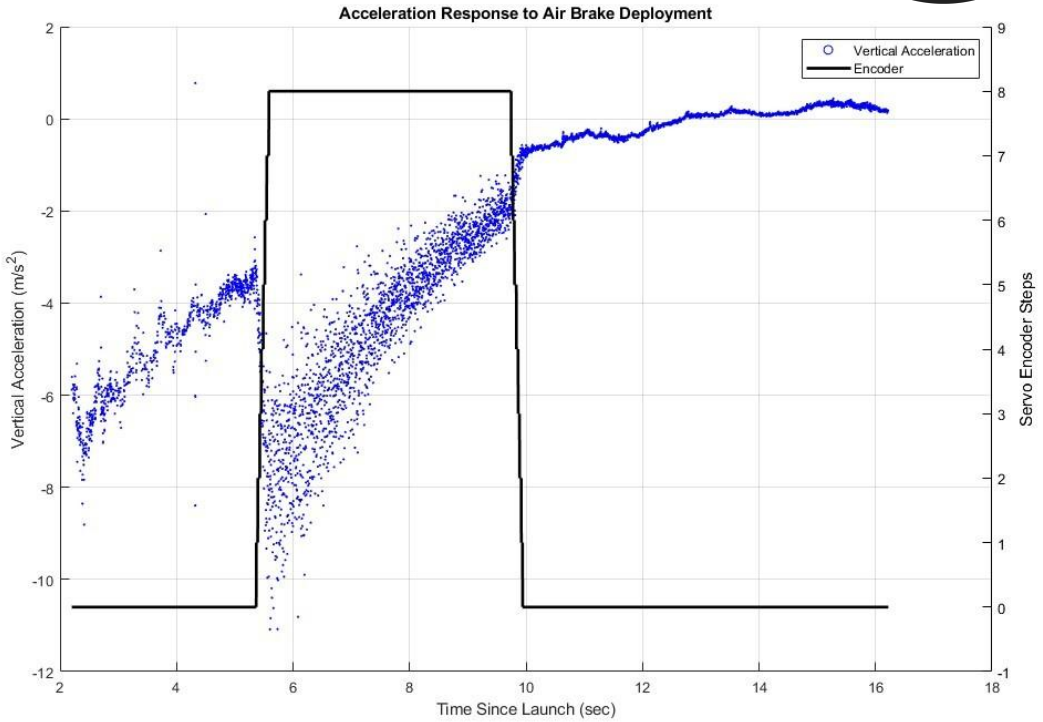
Target: - - - 4000 ft

A.B. Prediction:- - 4136 ft

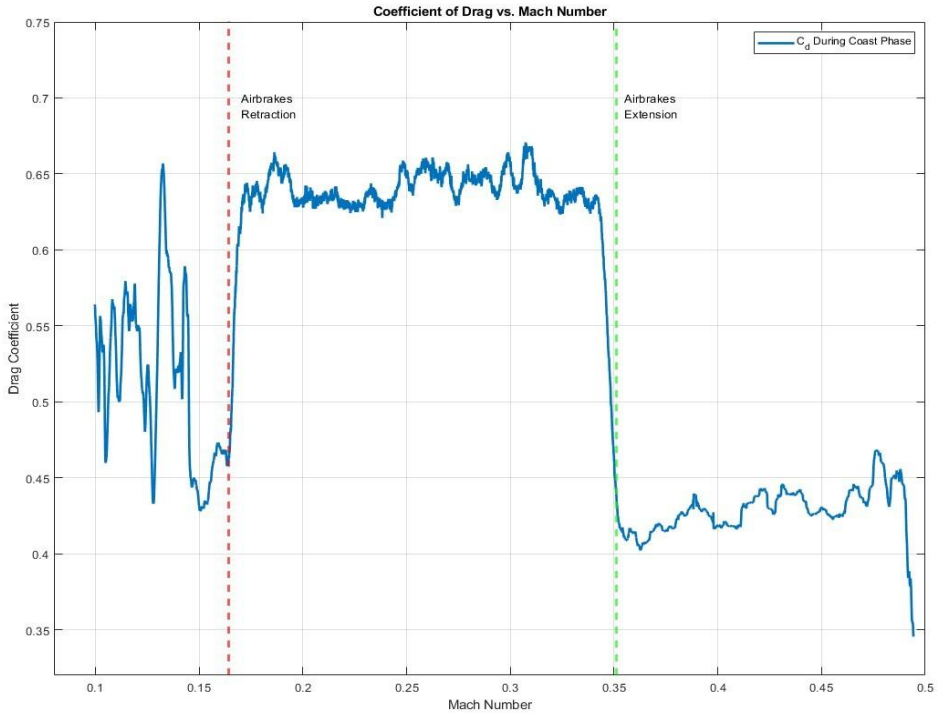
A.B. Actual: - - - 3962 ft

Air Brakes - VDF Attempt 02/22/25

- Encoder value represents fin deployment angle
- Increase in negative acceleration during fin deployment
- Acceleration returns to original flight curve during retraction



Air Brakes - VDF 02/22/25



- Deployment resulted in a .2 increase in coefficient of drag
- Maximum force of drag experienced is 20.4 lbf applied to all 4 fins

Launch Vehicle Requirements Verification

Launch Vehicle Requirements

- 67 NASA vehicle req. & 23 NASA recovery req. = Verified
- 37 TDR LV req. & 46 TDR recovery req. = Verified

Test	Requirement Verified	Date	Status
Subscale Ejection Test	NASA Req. 3.2, TDR RF.10, TDR RF.22	November 15, 2024	Verified
Subscale Dry Run	TDR LVF.2, TDR LVF.3	November 15, 2024	Verified
Subscale Demonstration Flight	NASA Req. 2.18	November 16, 2024	Verified
Moment of Inertia Test	TDR LVD.1	February 21, 2025	Verified
Nose Cone Bulkhead Tensile Test	TDR LVD.1	February 12, 2025	Verified
AVAB Bay Tensile Test	TDR LVD.1	February 12, 2025	Verified
Rivet Shear Loading Test	TDR LVD.1, TDR LVF.11	February 12, 2025	Verified
Shear Pin Shear Loading Test	TDR LVD.1, TDR LVF.12	February 20, 2025	Verified
Fin Can Impact Test	TDR LVD.1	February 18, 2025	Verified
Altimeter Test	TDR RF.13	February 26, 2025	Verified
GPS Test	TDR RD.5	February 26, 2025	Verified
Parachute Deployment Verification	TDR RF.17, TDR RF.18	February 21, 2025 and February 26, 2025	Verified
Full-scale Ejection Test	NASA Req. 3.2, TDR RF.10, TDR RF.22	March 3, 2025	Verified
Full-scale Dry Run	TDR LVF.2, TDR LVF.3	March 7, 2025	Verified
Full-scale Demonstration Flight	NASA Req. 2.19, TDR PF.2, TDR PF.6, TDR PF.9	March 8, 2025	Verified

Payload Design Overview

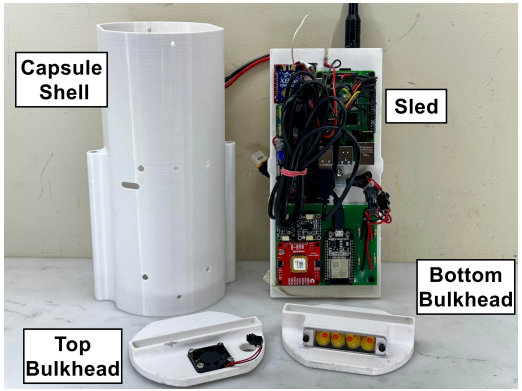
Changes Since CDR

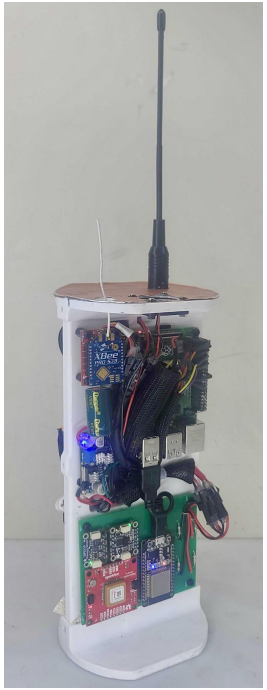
- 2S LiPo replaced with 4S LiPo on CPU power system
- MOSFET implemented between Raspberry Pi and SA858 transmitter
- 10,000 µF 16V capacitor added between 4S LiPo and LM2596 buck converter
- SA858 transmitter changed from 5V regulated power to being wired directly to transmission system 2S LiPo battery
- Increased STEMCRaFT length by 1.5”
- Added an integrated camera system

STEMCRaFT Design Overview

- Sled: Retains electronic components
- Top bulkhead: Includes ventilation fan
- Bottom Bulkhead: STEMnaut housing
- Capsule shell: Interfaces with launch vehicle

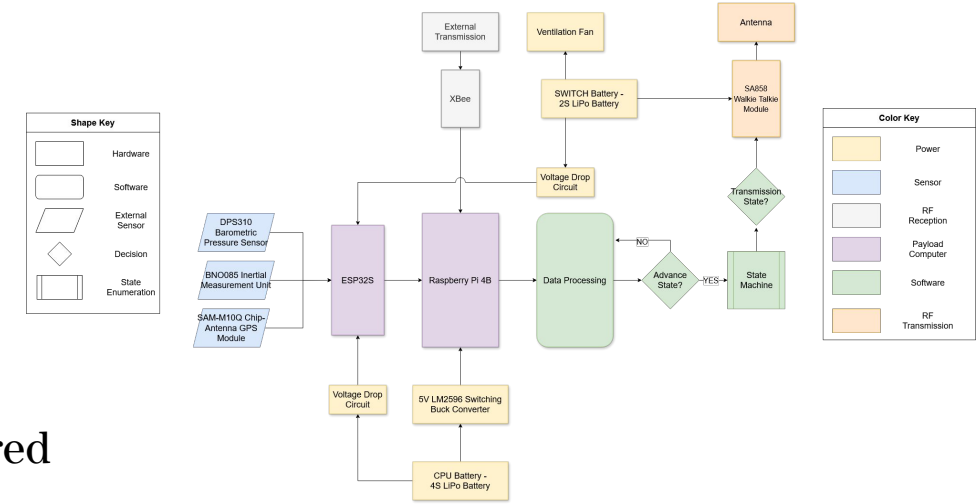
- Height
  - 10.00” (capsule shell)
  - 17.25” (with antenna)
- Cross section
  - 5.50” x 4.61”
- Mass
  - 2.55 lb





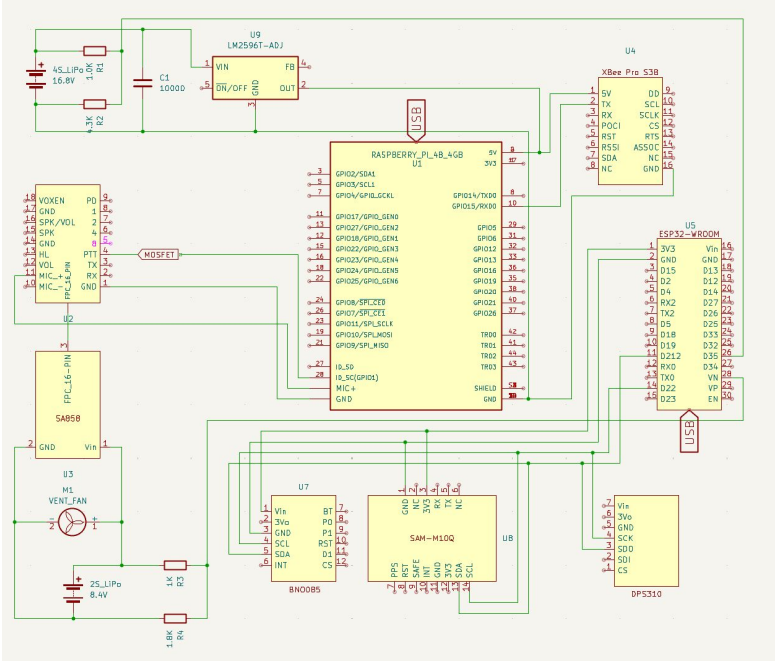
WARHEAD Payload Design

- **W**ireless **A**PRS **R**elay for **H**igh-altitude **E**nvironmental & **A**tmospheric **D**ata
  - CPU: Raspberry Pi 4B
  - Processes & utilizes data from multiple subsystems
  - Housed in STEMCRaFT capsule
- Design largely unchanged from CDR
  - Broken into more defined subsystems
  - SA858 and ventilation fan wired directly to battery



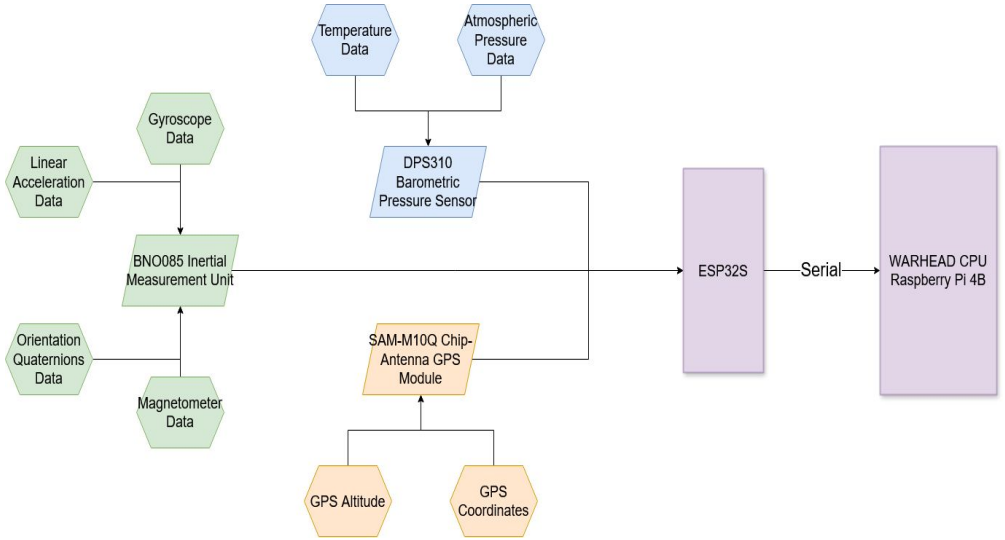
WARHEAD Payload Design

- Wiring schematic reflective of as-wired payload
- Covered in detail in the next slides
  - FUSE Subsystem
  - SWITCH Subsystem
  - CHARGE Subsystem



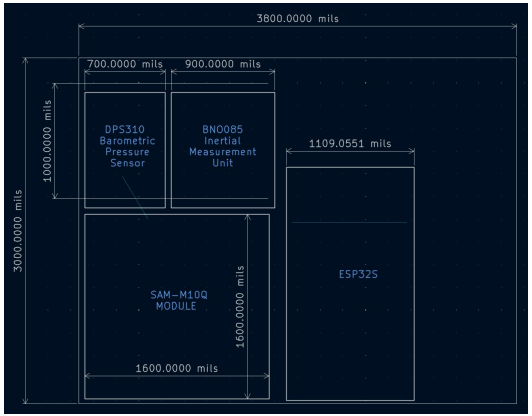
FUSE Subsystem Design

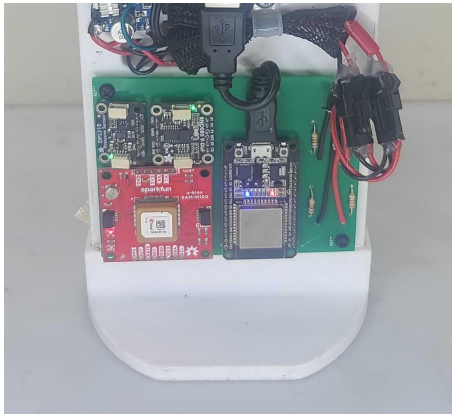
- Obtains environmental / kinematic data
  - IMU Data
  - GPS Data
  - Barometric Pressure Data
- Data is compiled into binary packets
  - Communicates with primary CPU via USB cable



FUSE Subsystem Design

- Prototyped using on-campus CNC PCB mill
  - Utilized during the Data Collection Test (1/25)
- Dimensions:
  - 3” x 3.8” x 0.063”
- Mounted using 3M hardware
- Sensors soldered directly to PCB

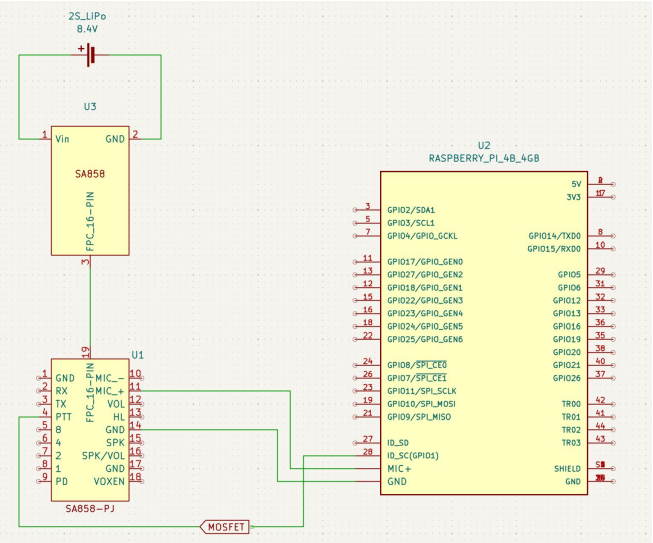




SWITCH Subsystem Design

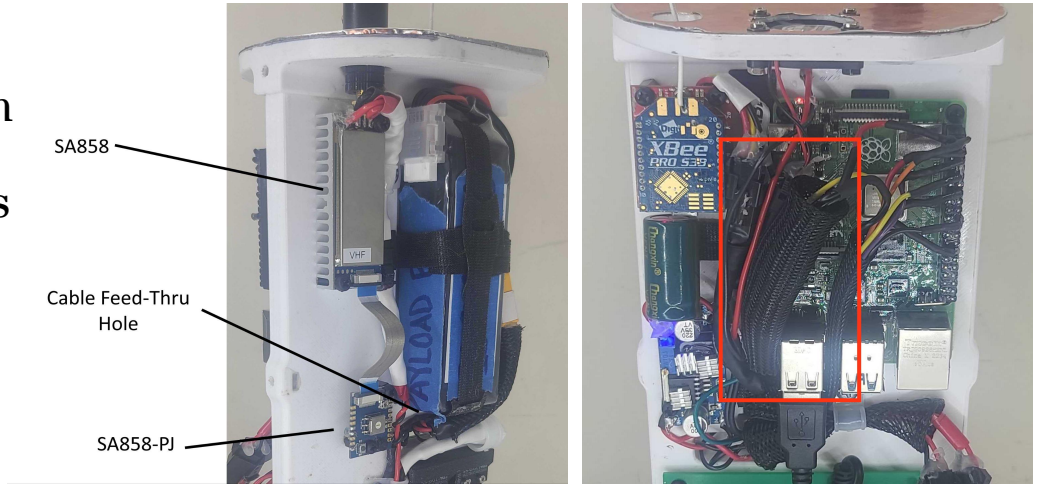
- **S**cheduled **W**ireless **I**nformation **T**ransmission & **C**ompilation **H**ub
  - SA858 Transmitter
  - APRS format
  - Brief delay upon landing for GPS fix
  - MOSFET gate for improved Push-to-transmit performance

- Transmits a single data packet
  - Contains all desired data points
  - Transmit periodically, up to 5 minutes after landing



SWITCH Subsystem Design

- APRS(AX.25 protocol) received from CPU via 3.5mm audio cable
  - Soldered directly between CPU and SA858
- Raspberry Pi GPIO pin enables push-to-transmit through MOSFET
  - MOSFET wired in-line within wire loom
- Diodes assist in preventing back EMF damage to components



APRS Packet Format

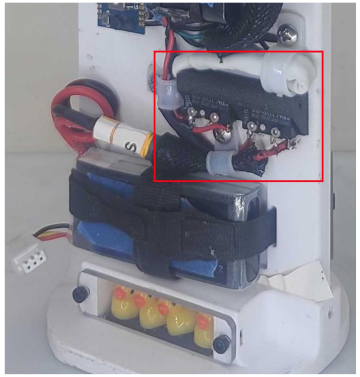
- Example APRS transmission
  - Representative of competition transmission format
  - May include NCSU/NCSU-HPRC identifier

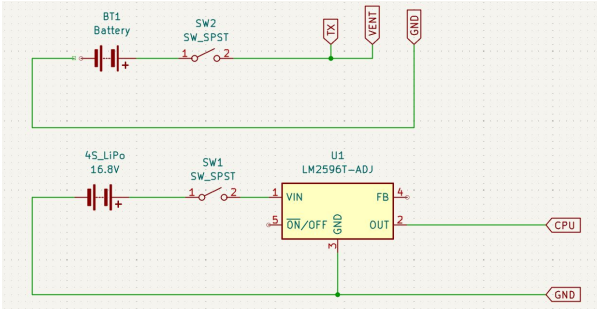
```
"T=59.69°F,A=2015.70ft,BAT=CPU:0.00%|TX:0.00%,O=(R=-5.56,P=-55.20,Y=69.96),TL=04:18:23,MV=2752.39ft/s,LV=0.00ft/s,CS=84.5%"
```

- Temperature of landing site
- Apogee Reached
- Battery Check/Power Status
  - CPU & TX batteries
- Orientation of STEMCRaFT
  - Roll, Pitch, Yaw
- Time of landing
- Maximum Velocity
- Landing Velocity
- Crew Survivability
  - Acceleration, Pressure & Temperature

CHARGE Subsystem Design

- Current Handling & Automatic Regulation for Grid Energy (CHARGE)
  - 4S 16.8V LiPo for CPU
    - Regulated to 5V
    - Powers FUSE Subsystem
    - Powers XBee Receiver
  - 2S 8.4V LiPo for TX & Ventilation
    - Wired directly to components
- Both batteries wired through externally accessible pull-pin switches





Payload Integration

- Indentation on the bottom of the Nose Cone bulkhead allows the STEMCRaFT to sit flush on top of the removable bulkhead

- Antenna on top of STEMCRaFT does not interfere with Nose Cone walls or removable ballast
  - 5” clearance between antenna and ballast

Payload Retention

- STEMCRaFT rests between the Nose Cone permanent ring and removable bulkheads
- Two threaded rods are used to attach the removable bulkhead and align the STEMCRaFT
- Removable bulkhead secured with two ¼” hex nuts fastened to the threaded rod

Payload Verification Testing

Nose Cone Impact Test

- Tested payload retention system and electronics mounting
- Dropped from calculated height to achieve 75 ft.-lbf. of kinetic energy
- Nose Cone and STEMCRaFT successfully withstood the drop test without sustaining structural damage
- Electronics remained functional and properly mounted throughout the test

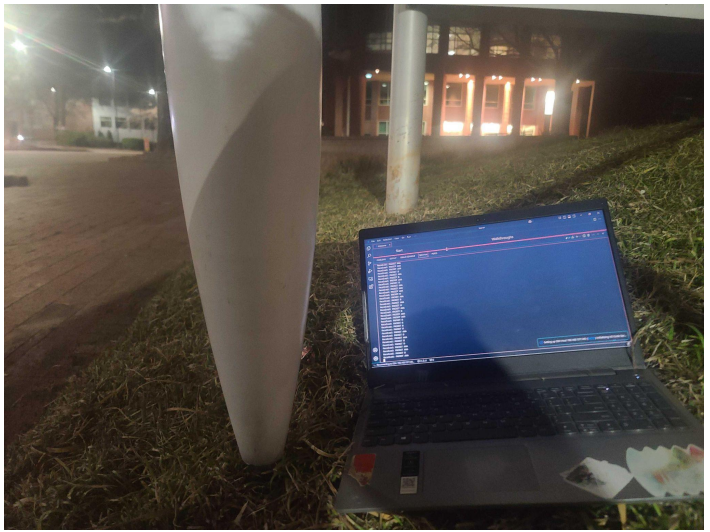
Transmission Range Test

- Evaluated transmission capabilities over long distances
- Transmissions received at distances up to 2165 ft (660 m)
  - Received and decoded in both ballasted & un-ballasted configurations


```
0,1741673522,2025-03-11T06:12:02Z,KQ4VOH,KQ4VOH,148(32/37),0,!,KQ4VOH,SO,0.000000,0.000000,,,,,,,"DireWolf, WB2OSZ",,,"time=22.3333,acceleration=264.1333,battery=5.3334,orientation=(r=0.3330,p=0.3330,y=0.3330),timelanding=05:15:25,maxvelocity=3403.633,landingvelocity=0.0333,crewsurvivability=1003"
0,1741673561,2025-03-11T06:12:41Z,KQ4VOH,KQ4VOH,165(32/40),0,!,KQ4VOH,SO,0.000000,0.000000,,,,,,,"DireWolf, WB2OSZ",,,"time=22.3333,acceleration=264.1333,battery=5.3334,orientation=(r=0.3330,p=0.3330,y=0.3330),timelanding=05:15:25,maxvelocity=3403.633,landingvelocity=0.0333,crewsurvivability=1003"
0,1741673666,2025-03-11T06:14:26Z,KQ4VOH,KQ4VOH,158(32/39),0,!,KQ4VOH,SO,0.000000,0.000000,,,,,,,"DireWolf, WB2OSZ",,,"time=22.3333,acceleration=264.1333,battery=5.3334,orientation=(r=0.3330,p=0.3330,y=0.3330),timelanding=05:15:25,maxvelocity=3403.633,landingvelocity=0.0333,crewsurvivability=1003"
```

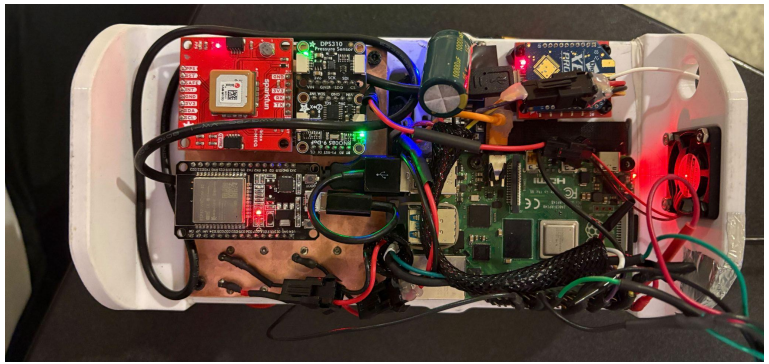
XBee Transmission Range Test

- Evaluated range capabilities of remote override system
- Remote override received at distances up to 2088 ft (636 m)
  - Exact range varies with orientation of payload
  - High success rate at ~2000ft distance



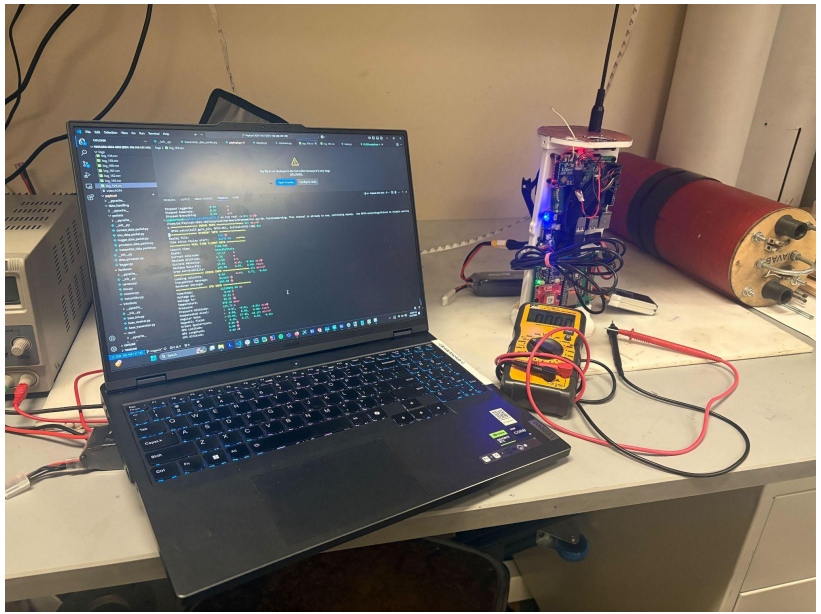
Data Collection Flight Test

- Evaluated capabilities of sensors using 4” diameter rocket
  - Identical sensors / transmission components
- Able to collect sensor data throughout entire flight
- Collected data utilized for flight simulations in further testing



Power Supply Verification Test

- Revealed limitations of 2S LiPo
- Motivating factor for making design change to 4S LiPo
- Verified for 4.5+ hour lifespan while performing standard sensor processing
- 16.84V -> 14.07V | 8.28V -> 7.52V across 4.5 hour testing period



FSM testing (Vacuum Bucket)

- Tested and verified triggers for FSM
- Tested landing state code
  - Verified transmission initialization
  - Verified data was formatted correctly
  - Verified transmission automatically shuts off

Final APRS Message

```
KQ4VOH audio level = 146(29/37)    |||||____
Audio input level is too high.  Reduce so most stations are around 50.
[0.2] KQ4VOH>APDW18:!0000.00N\00000.00EOtemperature=76.91°F,apogee=90.96ft,battery_status=CPU:92.02% | TX:75.78%,orientation=(roll=60.69,pitch=20.21,yaw=-47.07),time_landing=07:39:15,max_vel=945.51ft/s,landing
_vel=0.00ft/s,crew_survival=100.0%
"100.0" in comment looks like it might be a CTCSS tone in non-standard format.
For most systems to recognize it, use exactly this form "T100" at near beginning of comment, after any frequency.
Position, Rocket w/overlay S, DireWolf, WB2OSZ
N 00 00.0000, E 000 00.0000, PL 100.0
temperature=76.91°F,apogee=90.96ft,battery_status=CPU:92.02% | TX:75.78%,orientation=(roll=60.69,pitch=20.21,yaw=-47.07),time_landing=07:39:15,max_vel=945.51ft/s,landing_vel=0.00ft/s,crew_survival=100.0%

KQ4VOH audio level = 145(30/37)    ||||____
Audio input level is too high.  Reduce so most stations are around 50.
[0.2] KQ4VOH>APDW18:!0000.00N\00000.00EOtemperature=76.91°F,apogee=90.96ft,battery_status=CPU:92.02% | TX:75.78%,orientation=(roll=60.69,pitch=20.21,yaw=-47.07),time_landing=07:39:15,max_vel=945.51ft/s,landing
_vel=0.00ft/s,crew_survival=100.0%
"100.0" in comment looks like it might be a CTCSS tone in non-standard format.
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Position, Rocket w/overlay S, DireWolf, WB2OSZ
N 00 00.0000, E 000 00.0000, PL 100.0
temperature=76.91°F,apogee=90.96ft,battery_status=CPU:92.02% | TX:75.78%,orientation=(roll=60.69,pitch=20.21,yaw=-47.07),time_landing=07:39:15,max_vel=945.51ft/s,landing_vel=0.00ft/s,crew_survival=100.0%
```
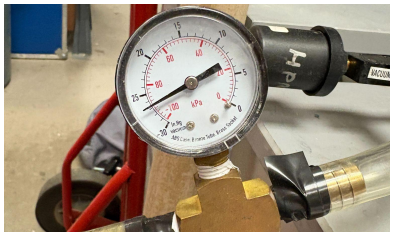



Additional VV&T Testing

- Simulated Flight Transmission Testing
- Remote Override Verification Testing
- Data Transmission(APRS Packet) Verification Testing
  - Verify APRS formatting for data packets
- Antenna Polarization Verification Testing
- Data Collection Subsystem Frequency Testing
  - ~125 Hz data packet collection rate
- Camera Logging Endurance Testing
  - 3 hour, 1080p, 21.6 GB video file

PDF Results

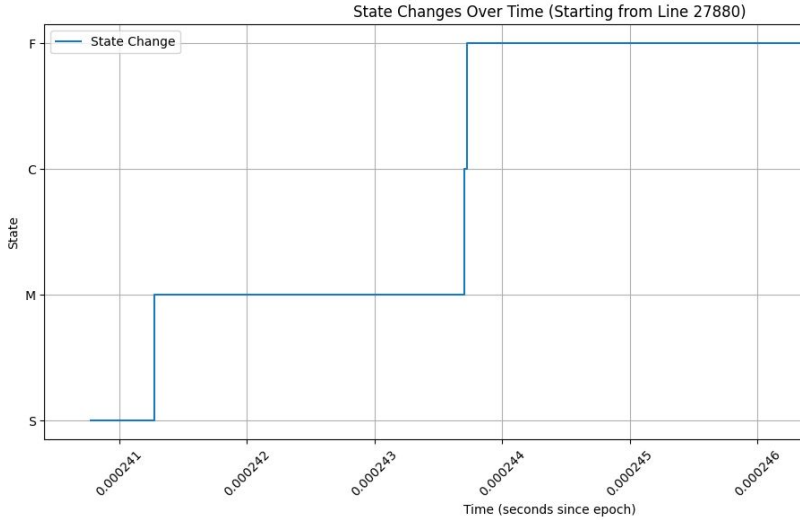
Retention System Performance

- Payload retention system worked as intended
- STEMCRaFT remained securely housed in the Nose Cone
- No damage was sustained to the retention hardware
- STEMCRaFT housing protected the electronics and remained undamaged

Post Flight

Software & Electronic Performance

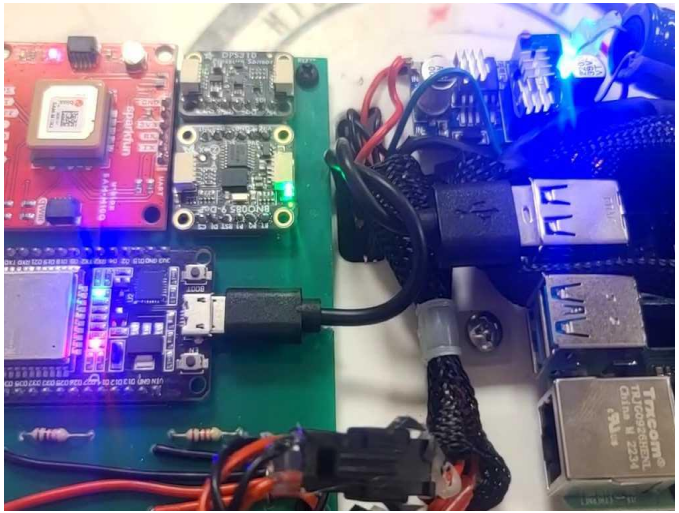
- The state change started prematurely while on launch rail
  - Pressure decrease in the Nose Cone from high winds
  - Sensitive Altimeter
- States changed to MotorBurn - > Coast -> Freefall in under .01 seconds
- Script crashed upon landing state due to “Input/Output error”
  - Hardware level interruption



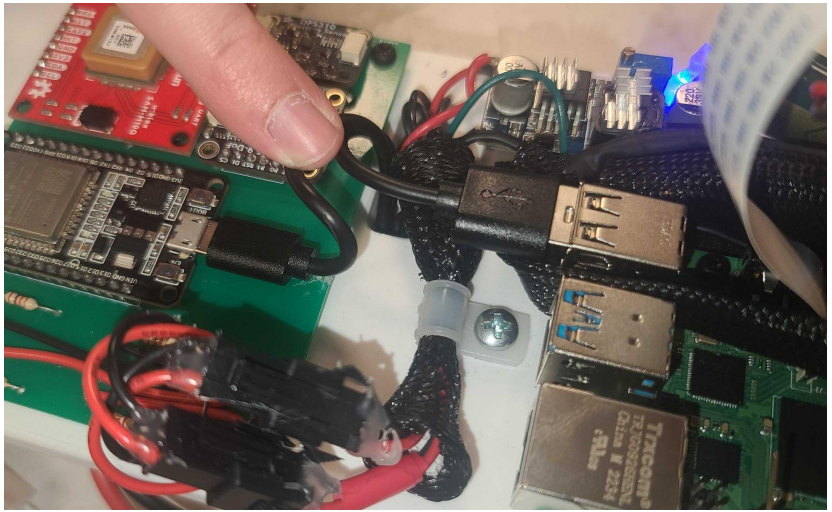
Electronic Failure Analysis

- Data cable was prone to losing connection due to internal damage

Before Bending Cable



After Bending Cable



Payload Requirements Verification

Payload Requirements

- 23 NASA payload req. & 44 TDR payload req. = Verified

Test	Requirement Verified	Date	Status
WARHEAD Data Collection Flight Test	TDR PF.1, TDR PF.5, TDR PF.6, TDR PF.7, TDR PF.8, TDR PF.9, TDR PF.10, TDR PF.11, TDR PF.12, TDR PF.13, TDR PD.4	January 25, 2025	Verified
WARHEAD Simulated Flight Transmission Test	TDR PF.4	February 28, 2025	Verified
WARHEAD Remote Override Test	TDR PF.1	February 28, 2025	Verified
WARHEAD Data Transmission Verification	TDR PF.1, TDR PD.9	March 5, 2025	Verified
WARHEAD Power Supply Verification	TDR PF.9	March 4, 2025	Verified
WARHEAD Transmission Range Test	TDR PF.1, TDR PD.8	February 21, 2025	Verified
WARHEAD Antenna Polarization Test	TDR PF.1, TDR PF.16	February 21, 2025	Verified
WARHEAD FUSE Data Collection Frequency Test	TDR PF.1, TDR PF.12, TDR PF.13	February 21, 2025	Verified
WARHEAD Remote Override Range Test	TDR PF.1, TDR PF.10, TDR PF.17	February 21, 2025	Verified
WARHEAD Vacuum Chamber Test	TDR PF.1	February 21, 2025	Verified
Nose Cone with STEMCRaFT Drop Test	TDR PF.7, TDR PF.18, TDR PF.19	February 21, 2025	Verified
Camera Logging Endurance Test	TDR PF.1	March 6, 2025	Verified
Air Brakes Deployment Test	TDR ABF.1, TDR ABF.2	February 20, 2025	Verified
Air Brakes Flight Simulation Test	TDR ABF.4, TDR ABF.5	January 31, 2025	Verified
Air Brakes Effectiveness Flight Test	TDR ABF.1, TDR ABF.2, TDR ABF.3, TDR ABF.4	January 25, 2025	Verified
Air Brakes Battery Life Test	TDR ABF.4, TDR ABF.5	March 6, 2025	Verified

Ground Systems

GPS Receiver

The Eggfinder LCD Receiver receives GPS information from the Eggfinder Mini throughout the flight and after it has landed.

The display provides information on:

- GPS Coordinates
- GPS Altitude
- Number of Satellites in View
- Timer that shows length since last valid GPS fix

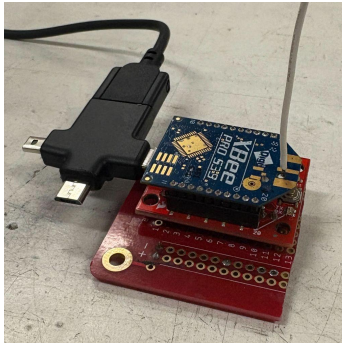
WARHEAD ground station.

The handheld is connected to the Ground Station computer to receive and decode APRS

- 144.39 MHz

The XBee connects to the Ground Station computer to transmit remote override commands

- ~900 MHz



Questions?