FAMU-FSU College of Engineering

2025 NASA Student Launch

Team 509: Payload

Design Review 6

Authors: Matthew Archibald, Donovan Dwight, Nathan Hardie, Kyle Mahoney, Neil Maldonado

Everyone

Team Introductions

Matthew Archibald
ME – Fabrication Engineer

Donovan Dwight
ME - Test Engineer

Nathan Hardie
CE - Communications Systems Engineer

Kyle Mahoney
ME – Structural Engineer

Neil Maldonado
EE - Data Systems Engineer

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Faculty Sponsor and Advisor

Sponsor
Shayne McConomy, Ph.D.
ME – Teaching Faculty II

Advisor
Taylor Higgins Ph.D.
ME – Assistant Professor

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Kyle Mahoney

Project Objective

Design and integrate a payload into a high-powered rocket for the 2025 NASA Student Launch Competition.

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Kyle Mahoney

Project Overview

<u>2025 NASA Student Launch</u>

- Annual competition for universities nationwide
- Design, build, test, and fly and high-powered rocket
- New payload experiment every year

<u>Payload Experiment Goals</u>

- Collect a variety of flight data
- Transmit data via radio signals
- Safely transport four "STEMnauts"

Kyle Mahoney

Critical Design Attributes

- Structural Integrity
- STEMnaut Safety
- Data Collection
- Data Transmission
- Recovery

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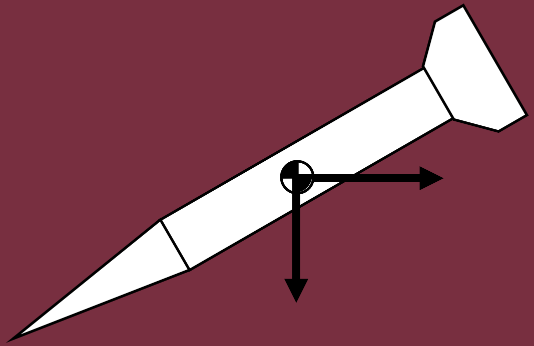
Structural Integrity



- Payload must survive flight demos
- Payload must be reusable after flight
- Payload must remain secured **inside** within rocket

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Critical Design Attributes

- Structural Integrity
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STEMnaut Safety

- Payload must contain four STEMnauts
- STEMnauts must survive the flight tests
- Creative aesthetic design

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Critical Design Attributes

- Structural Integrity
- STEMnaut Safety
- **Data Collection**
- Data Transmission
- Recovery

Data Collection

1. Velocity
2. Temperature
3. Apogee
4. Power Status
5. Flight Time
6. G-Forces
7. Orientation
8. Payload Orientation

Kyle Mahoney

Critical Design Attributes

- Structural Integrity
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Data Transmission

- Must transmit after landing
- Must transmit on 2-m band (144-147 MHz)
- Must transmit at or below 5W of power

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Critical Design Attributes

- Structural Integrity
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Recovery

- System must be reusable after flight
- Adversarial terrain at launch site
- Difficulty recovering rocket – payload system

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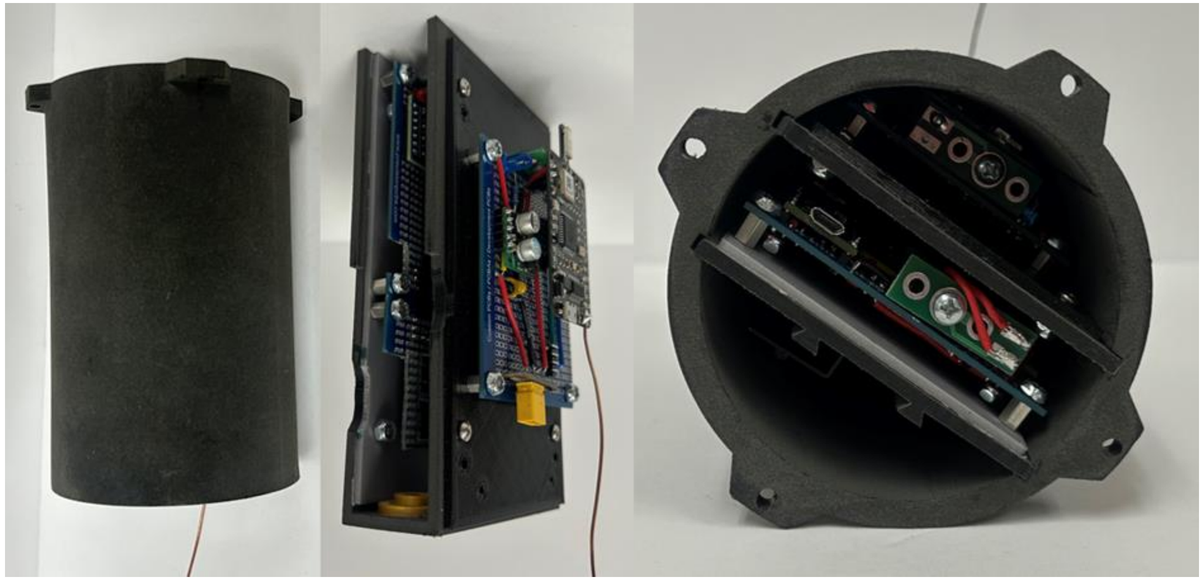

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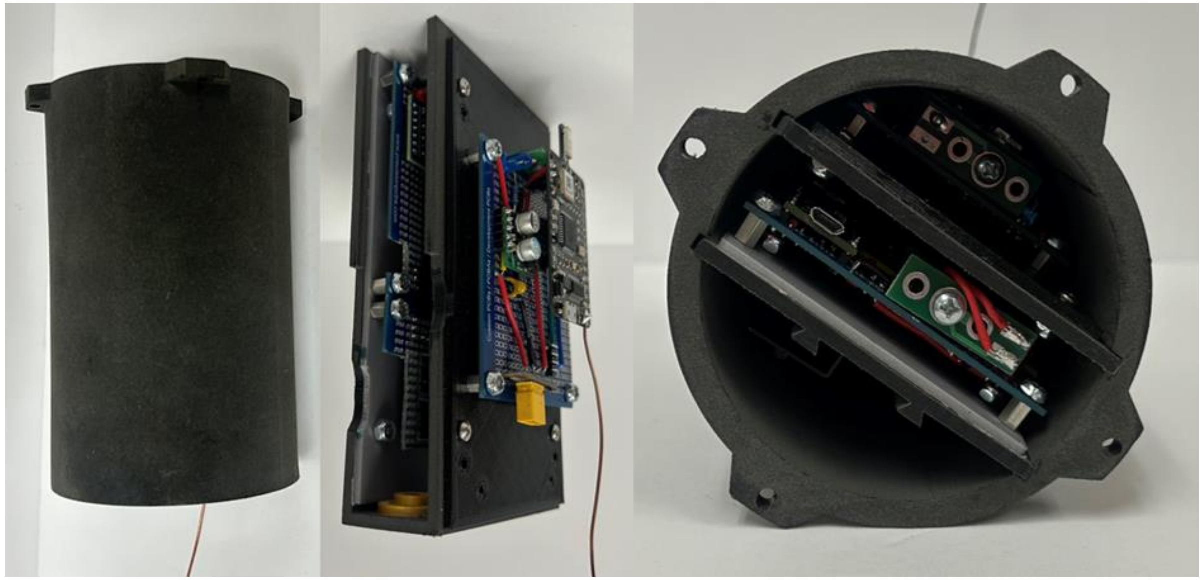

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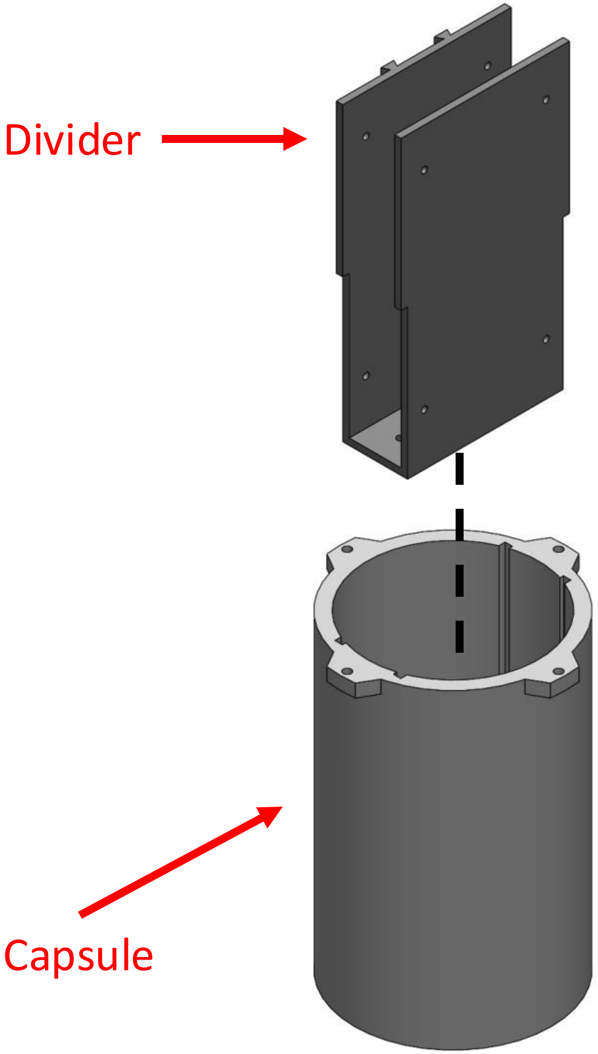
Structural Integrity

Matthew Archibald

Design Overview
- Two main components:
  - Payload Capsule
  - Payload Divider
- SLS printed Nylon-12
- Three chambers for electronics
- Secured at base of rocket nosecone



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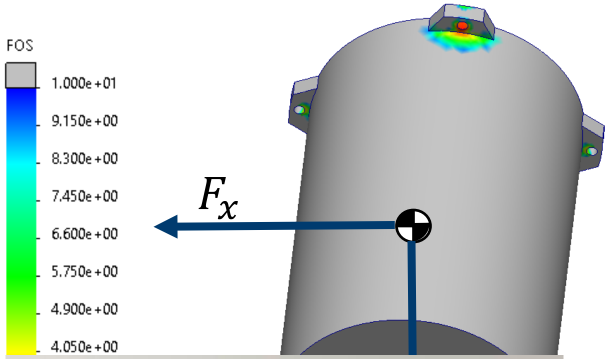
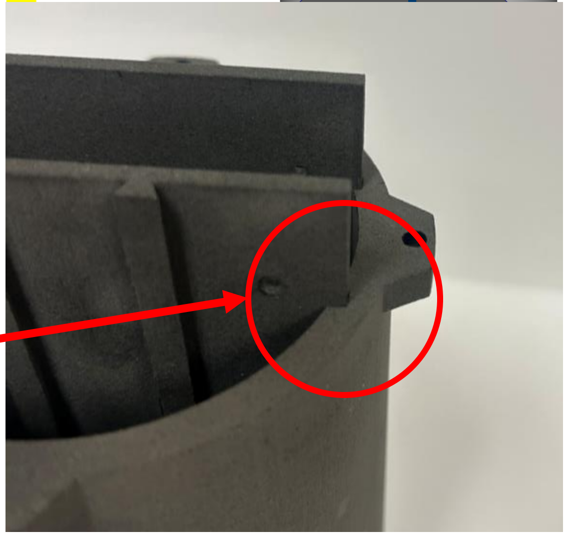
Matthew
Archibald

Structural Integrity

Reliability Analysis

- FEA to verify structural integrity
- Forces at landing calculated using momentum formula
- Loads calculated at **worst case landing conditions**
- Minimum factor of safety ~ 1.5
- Additional safety features:
    - Slots to prevent vibration





Slots for divider

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Structural Integrity

Integration and Retention

- Stainless steel heat-set inserts installed in the base of the nosecone
- #6-32 pan head screws with lock washer
  - Lock washer used to reduce likelihood of screw loosening from vibration
- Payload remains mounted to nosecone throughout the entire duration of flight

#6-32 x 0.266”
Heat-set Inserts

#6-32 x ½”, External-
tooth Lock Washer

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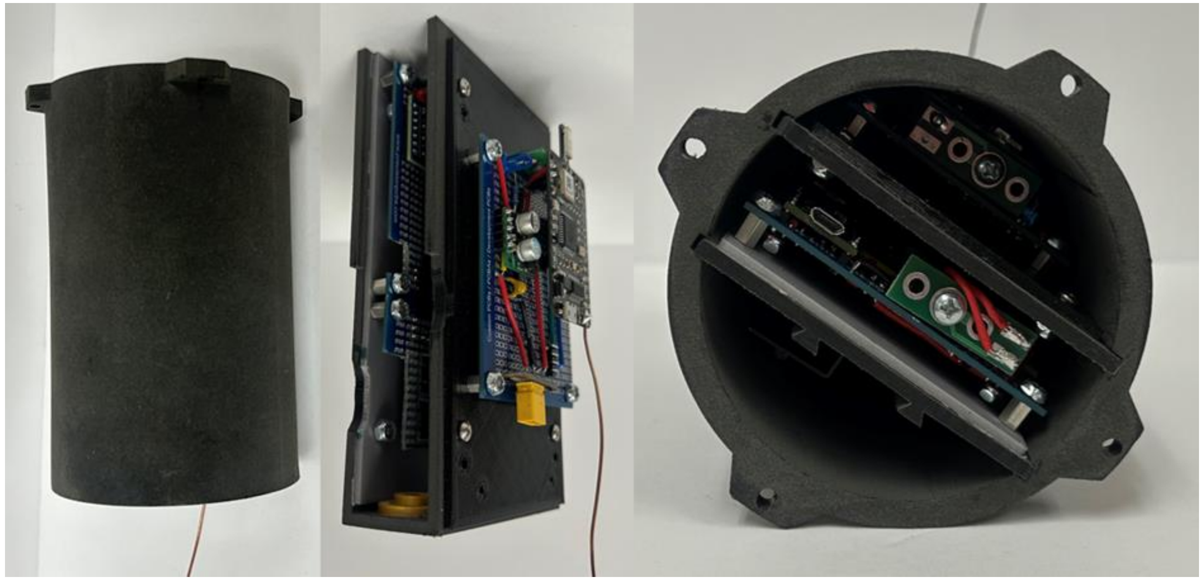

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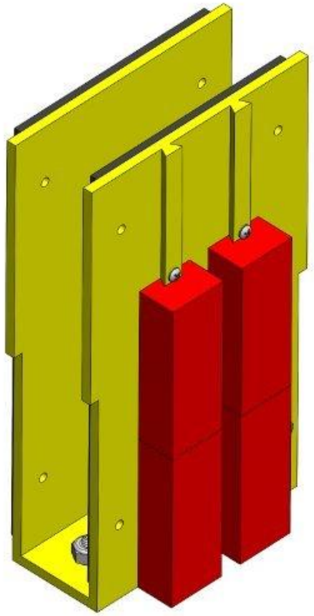
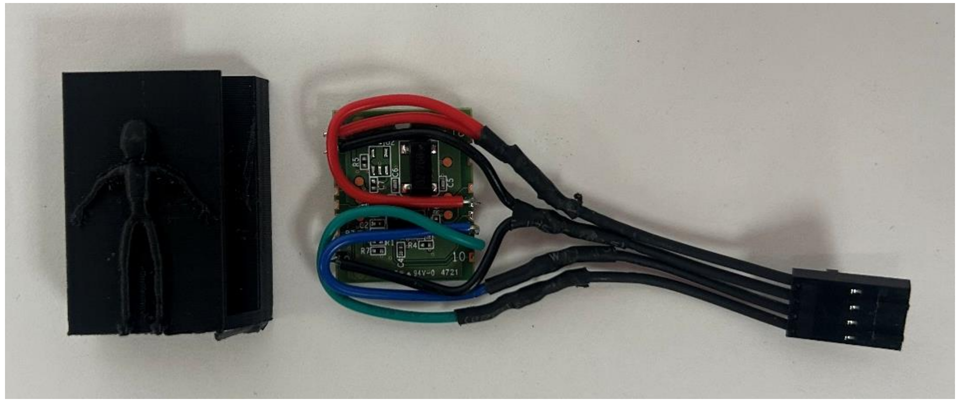
Matthew Archibald

STEMnaut Safety

Retention Method
- Mounted in bottom most chamber
- Dovetail joint to secure payload
- Screw to lock STEMnauts on dovetail
- 3D printed PLA

Survivability Metric
- Internal Measurement Unit (IMU) secured on back of STEMnaut
- IMU used to measure acceleration and displacement





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Donovan
Dwight

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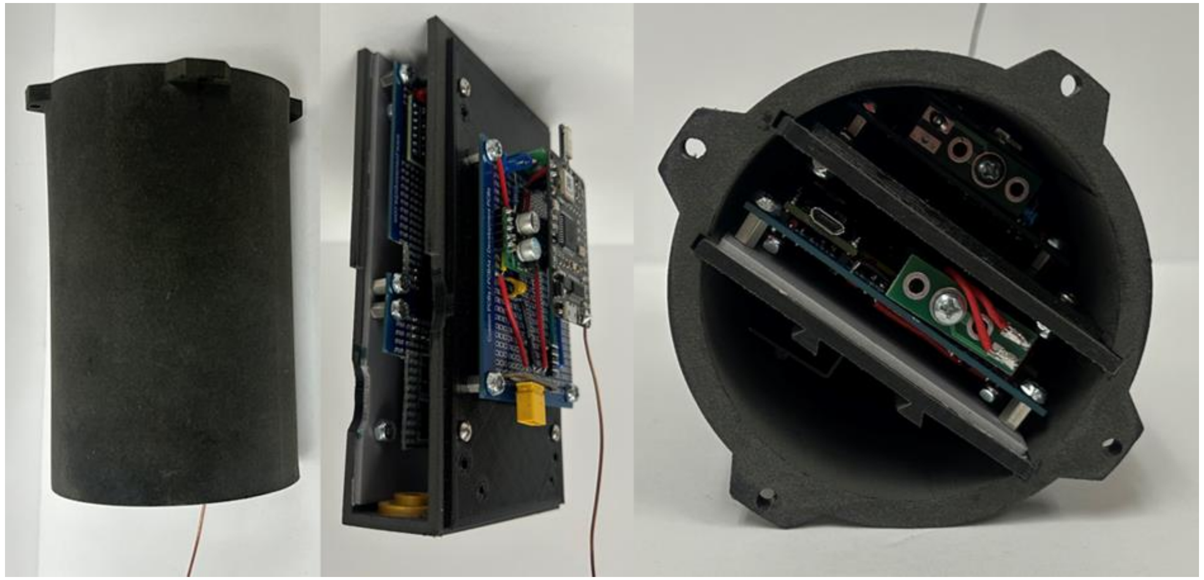

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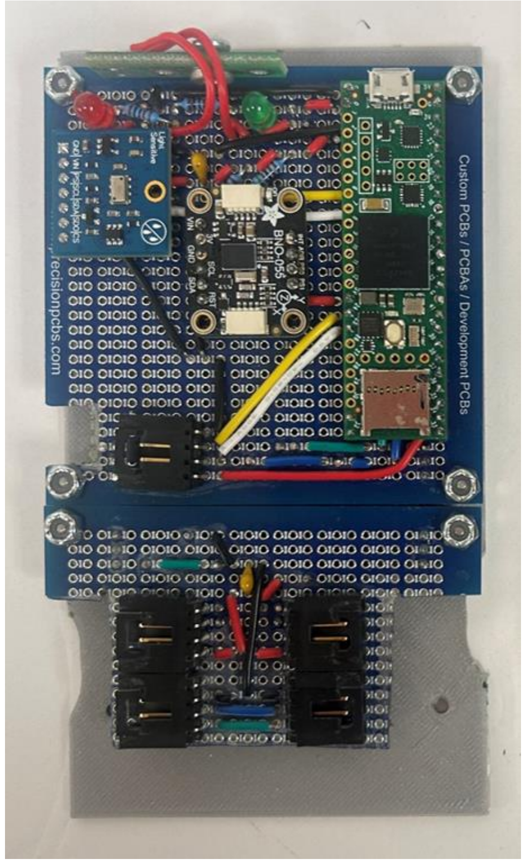
Data Collection

<u>Data Collection Board Layout</u>

- Located in middle chamber
- Main components:
    - IMU
    - Altimeter
    - Microcontroller
    - Inter-tray connectors
    - Arm switch



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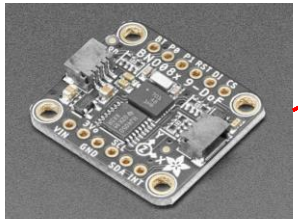
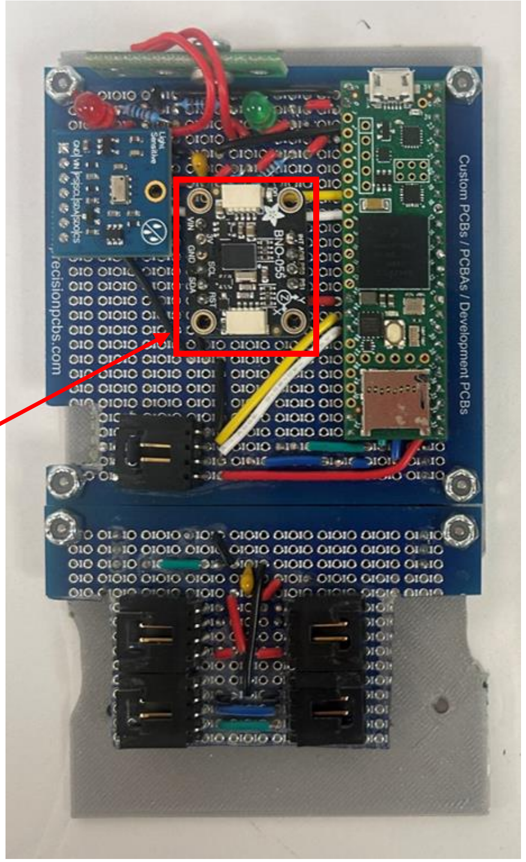
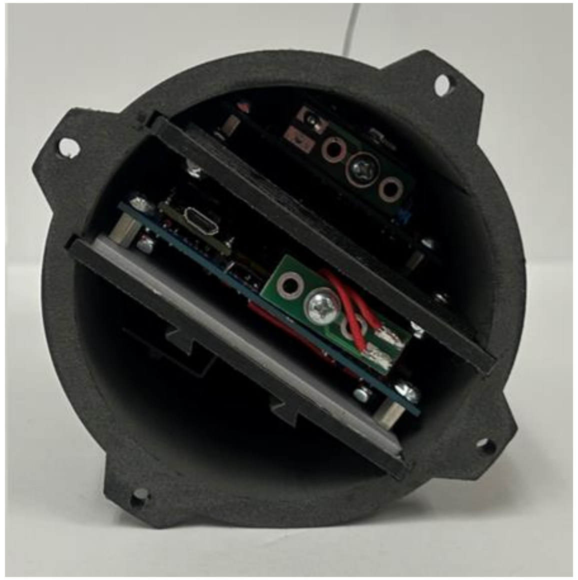


Inertial Measurement Unit (IMU)





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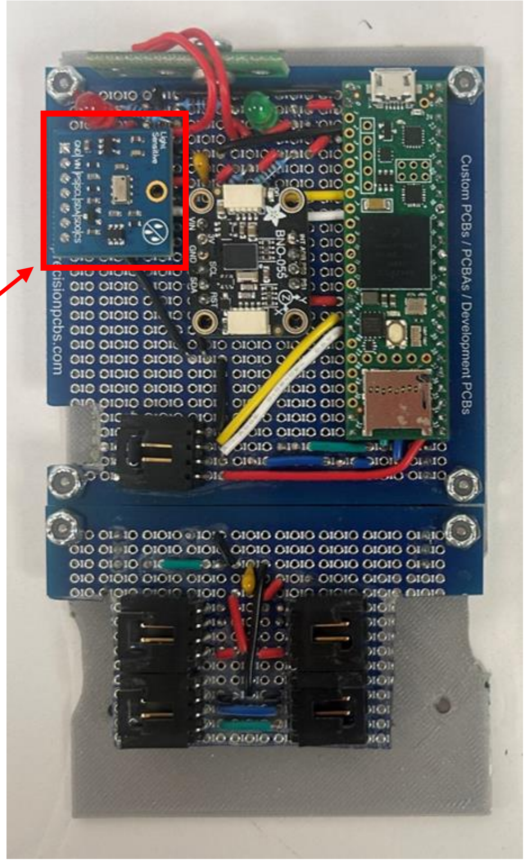
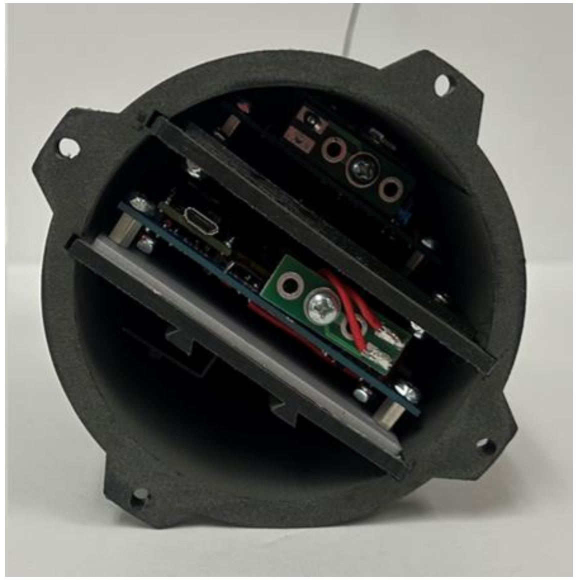
Altimeter





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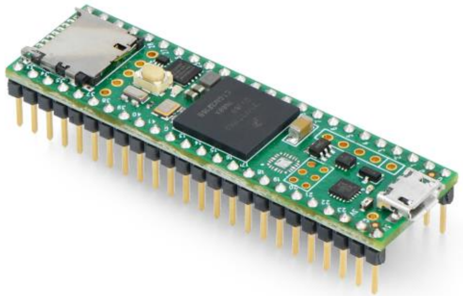
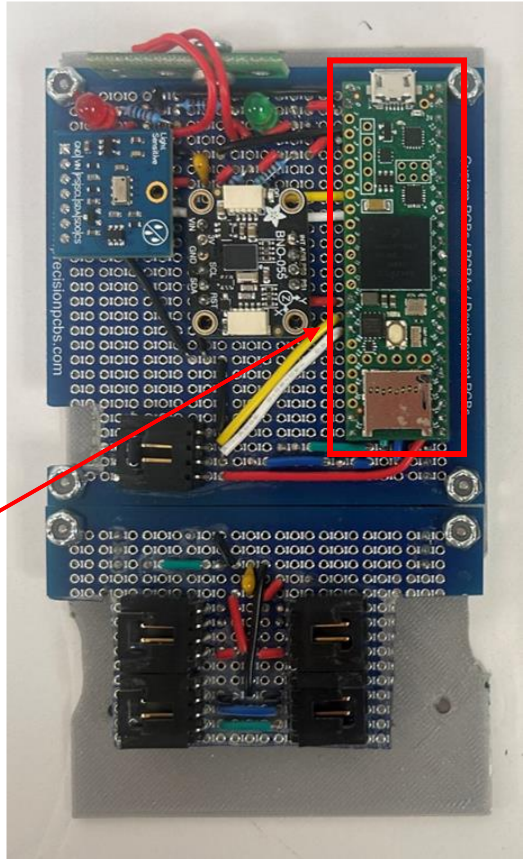
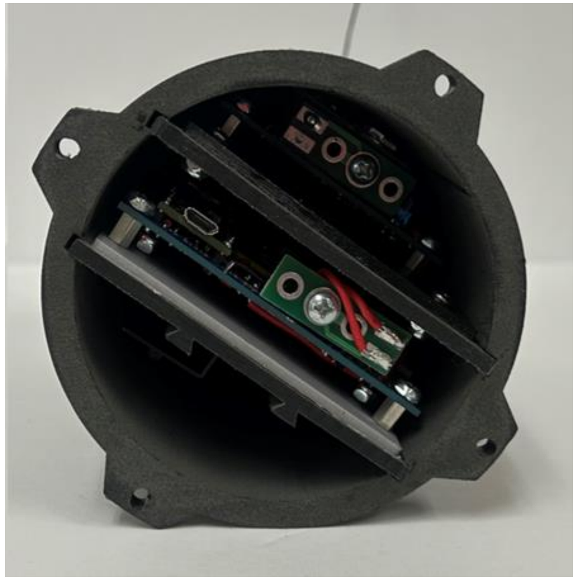


Microcontroller – Teensy 4.1





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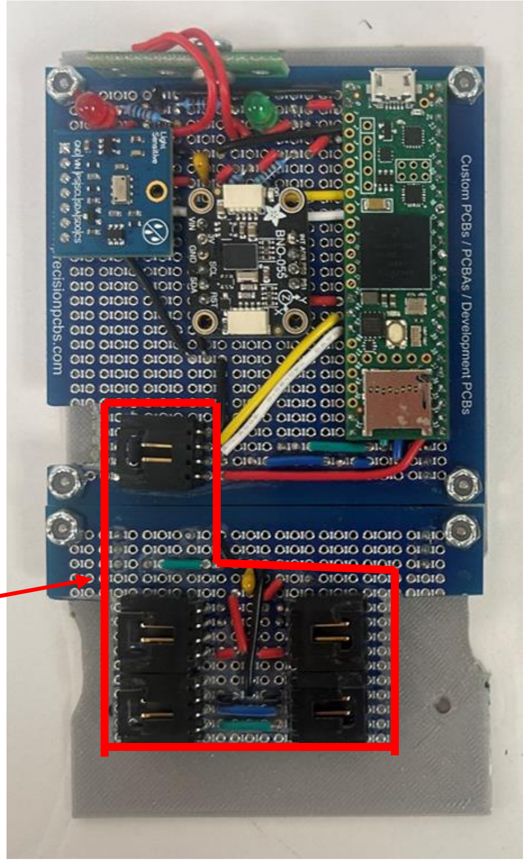
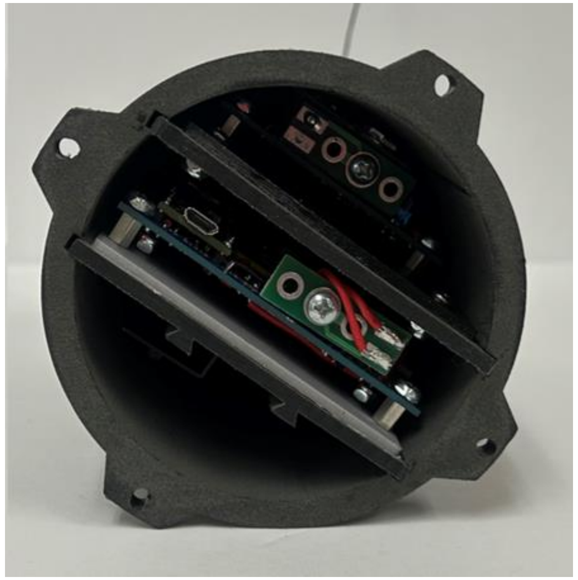
Molex KK Cables





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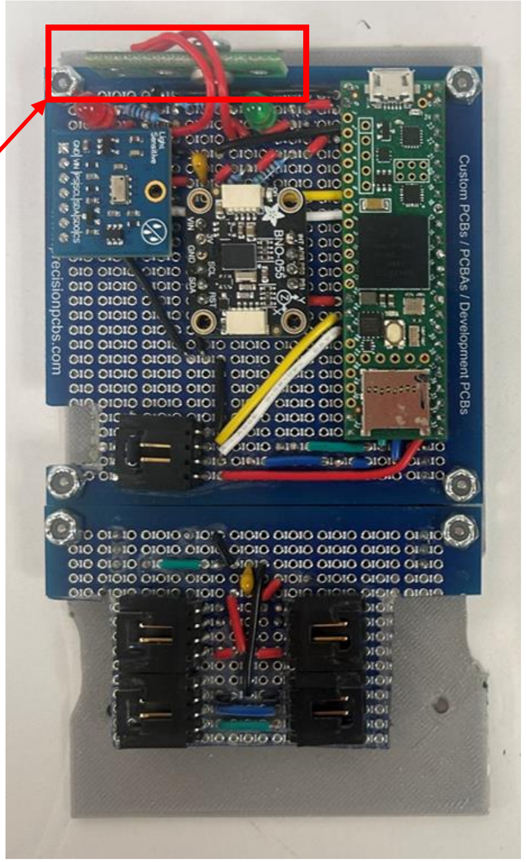
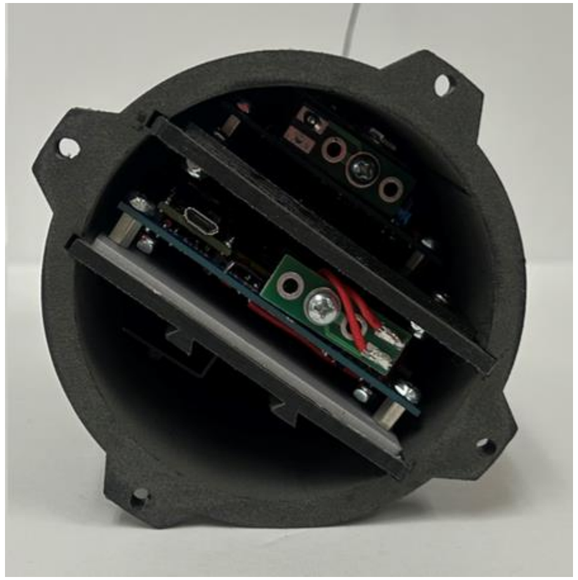
Arming Screw Switch





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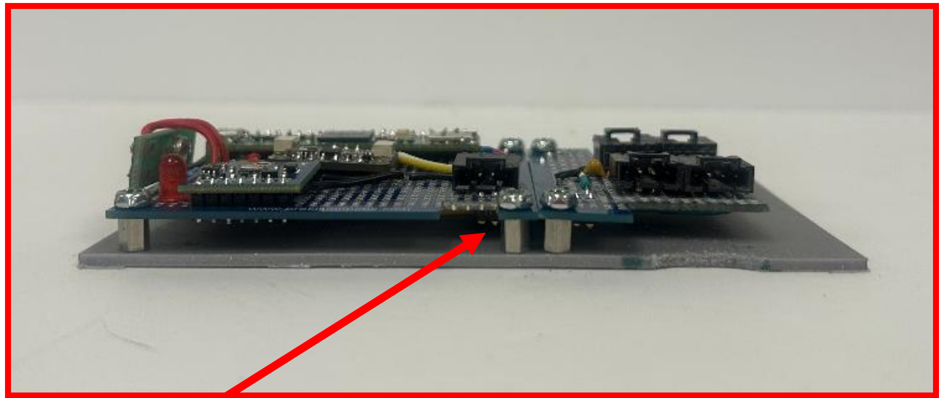
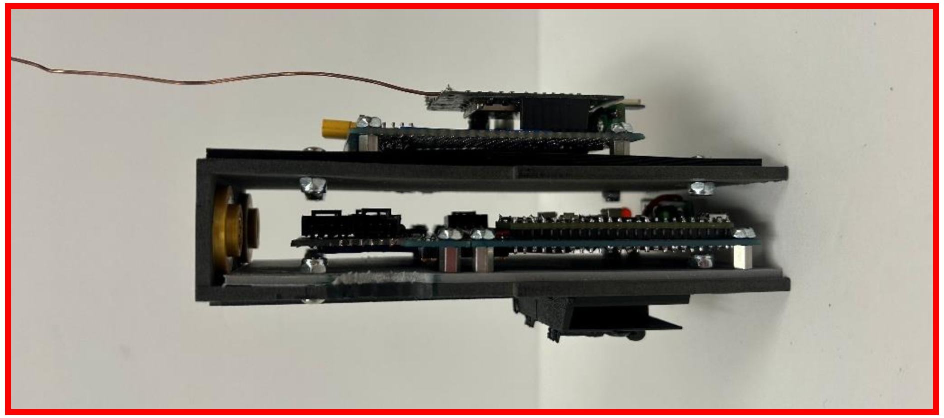
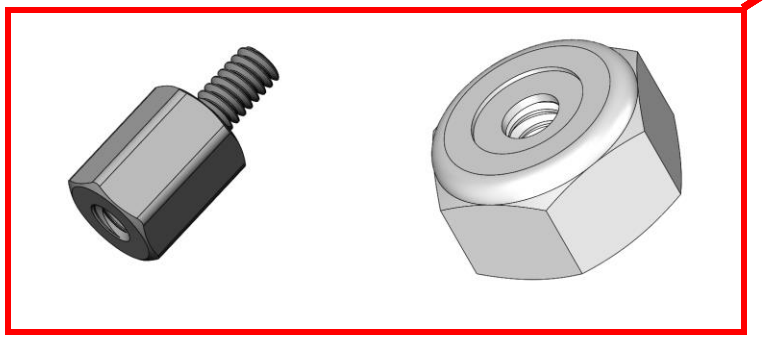
Data Collection

<u>Board securement</u>

- Boards mounted on trays
  - #2-56 x 1/4” hex body standoffs
  - #2-56 locknuts
- Trays mounted on chamber divider
- Chamber divider mounted to capsule







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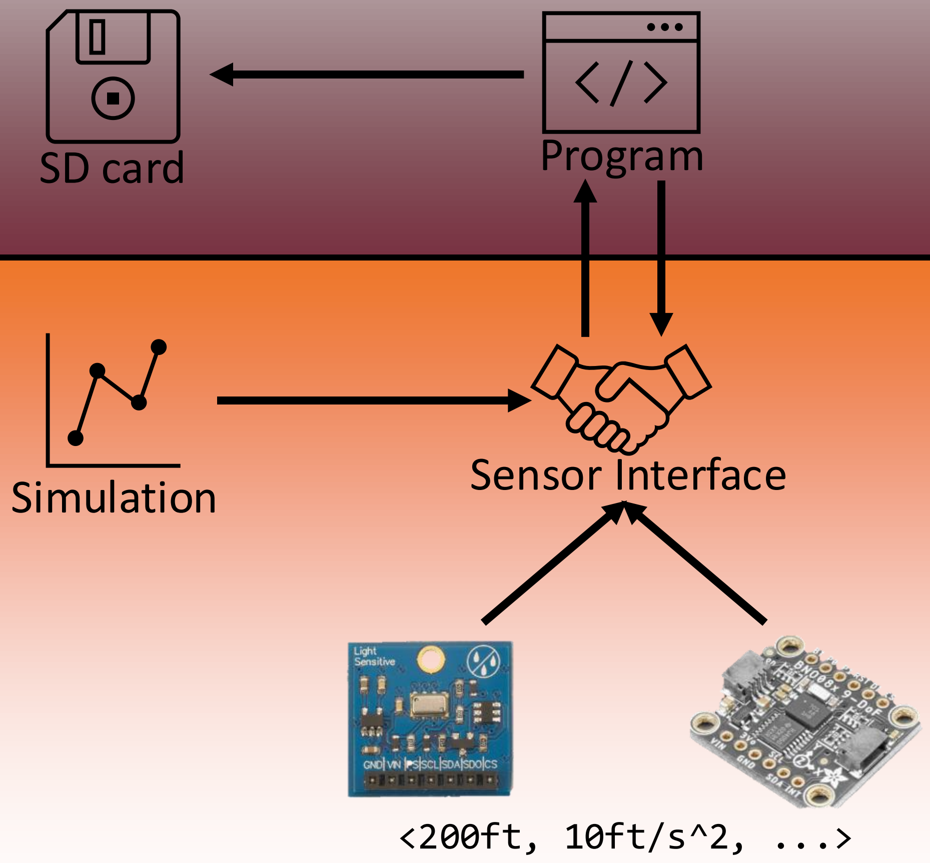
Data Collection

Data Collection Software

- SD card telemetry:
  - Post flight analysis
  - Event logging
  - Blackbox telemetry
- Hardware – in – the – loop
  - Hardware/backdoor selection interface for peripherals
  - SD card data-based simulation

Program Logic



Hardware Implementation

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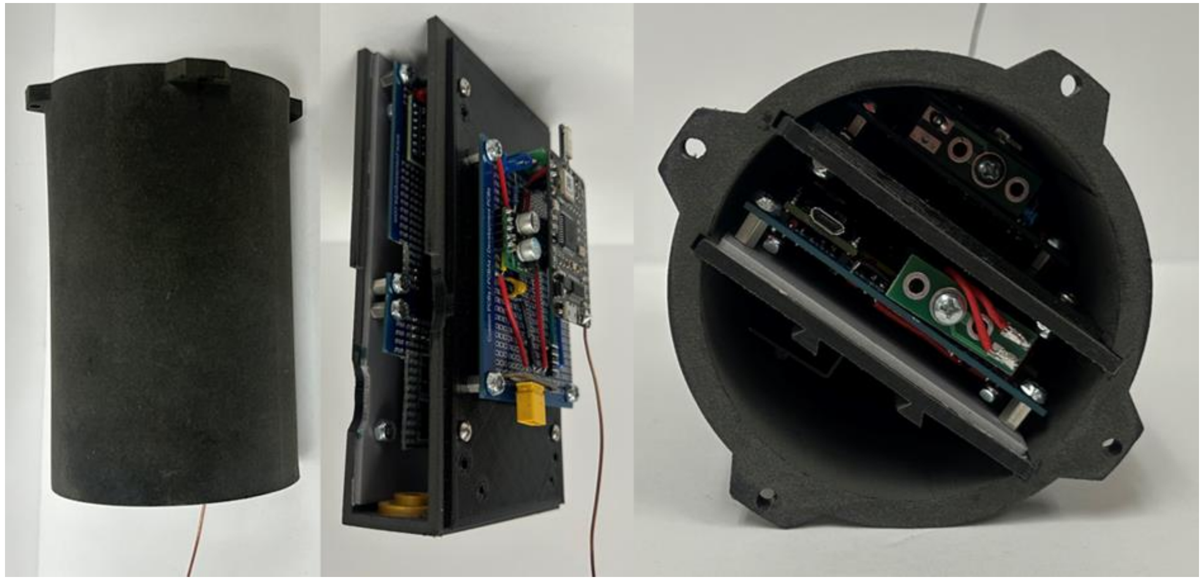
- **Data Transmission**
- Recovery



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Data Transmission

Transmission Board Layout

- Located in top chamber
- Main components:
    - Radio Frequency (RF) Module
    - Antenna
    - Power screw switch
    - Battery connector

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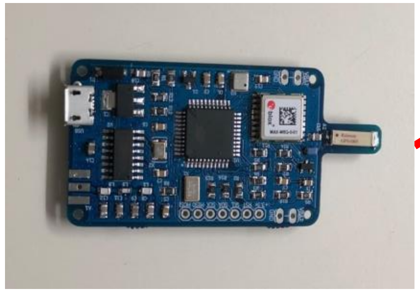
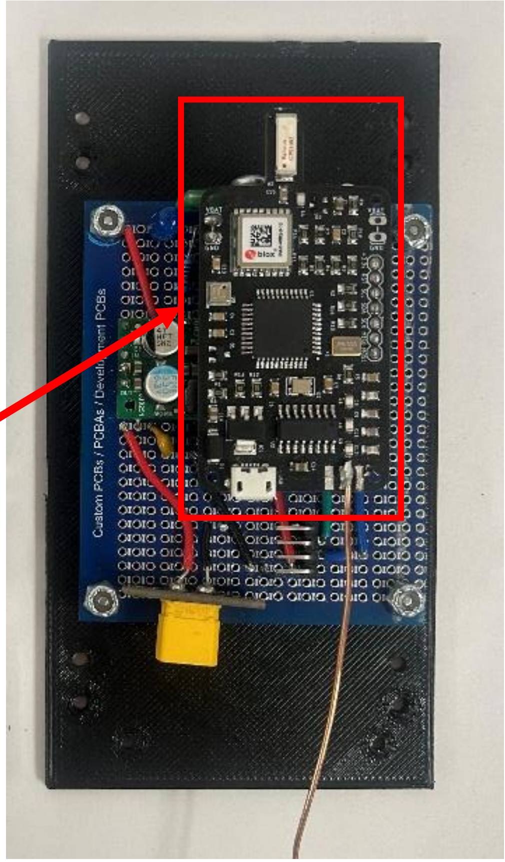
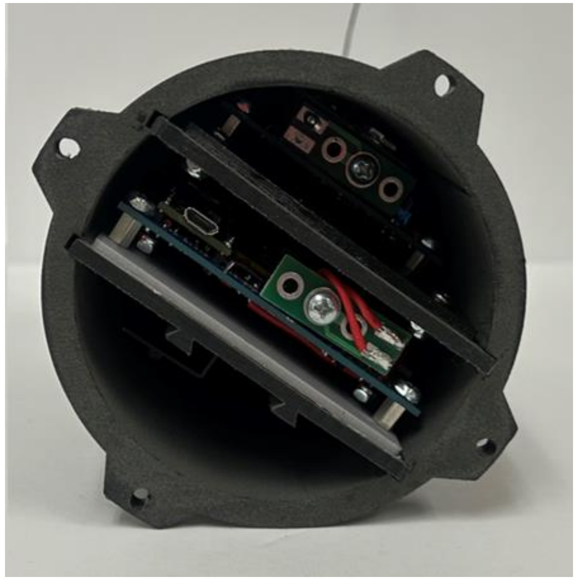


RF Module





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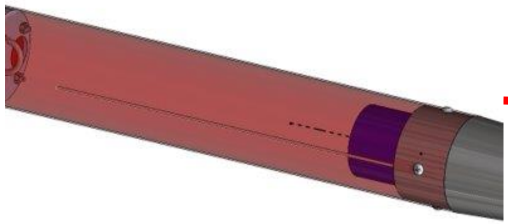
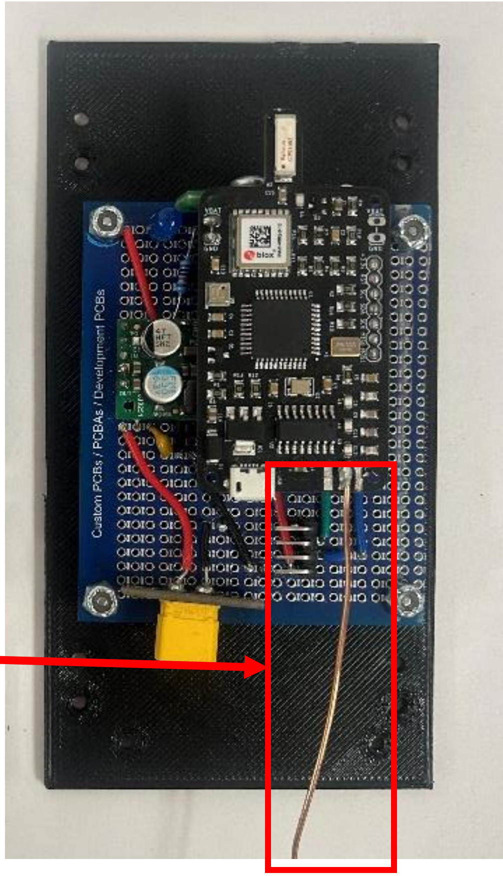
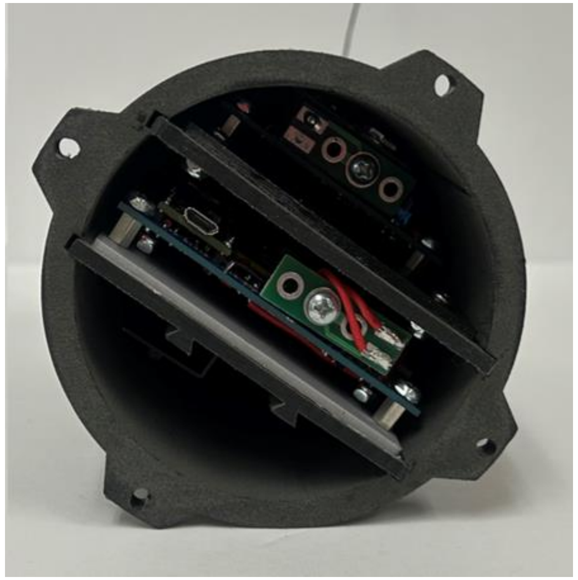


Antenna





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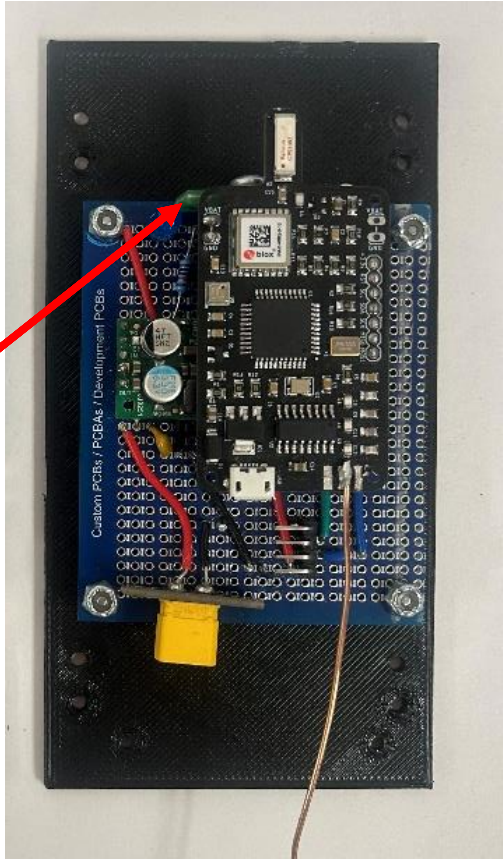
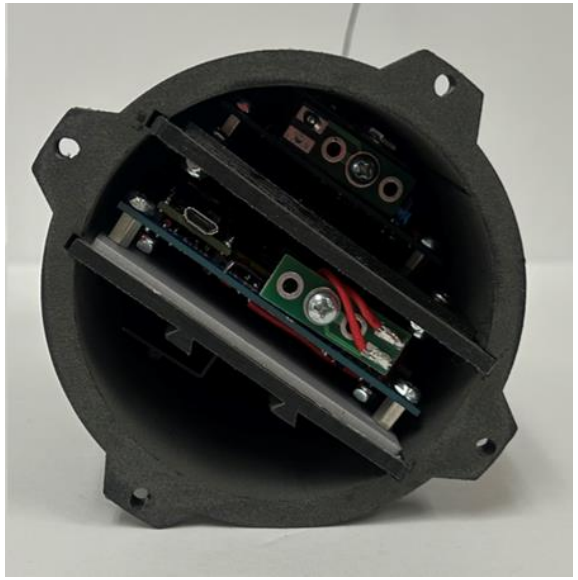
Power Screw Switch





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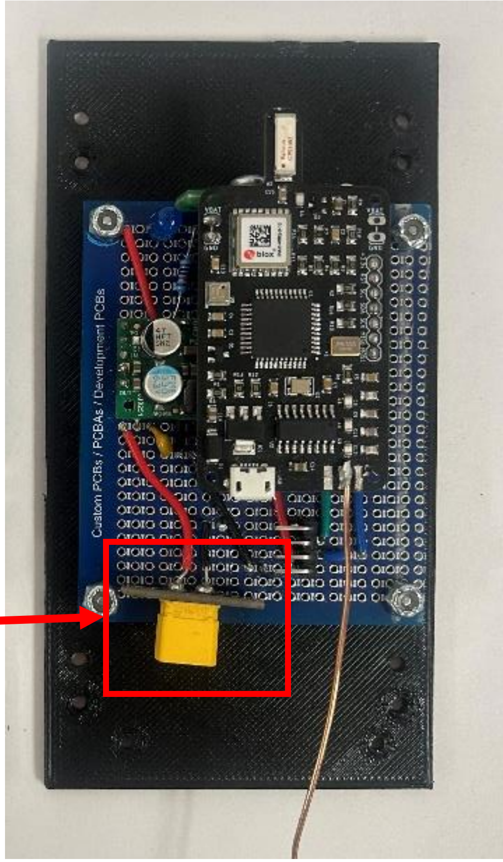
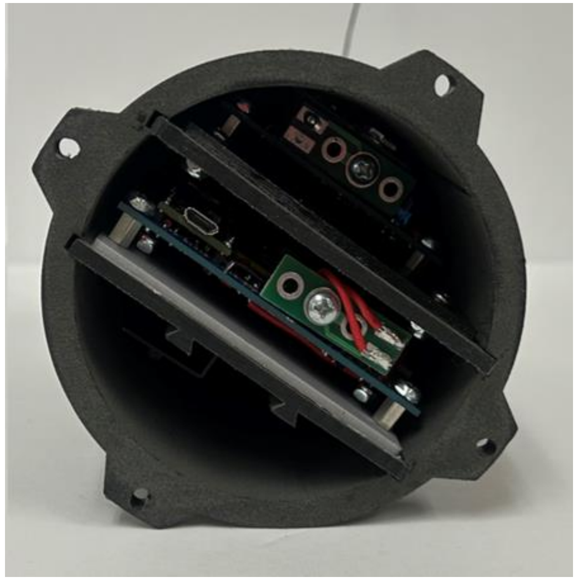
Battery Connector





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Data Transmission

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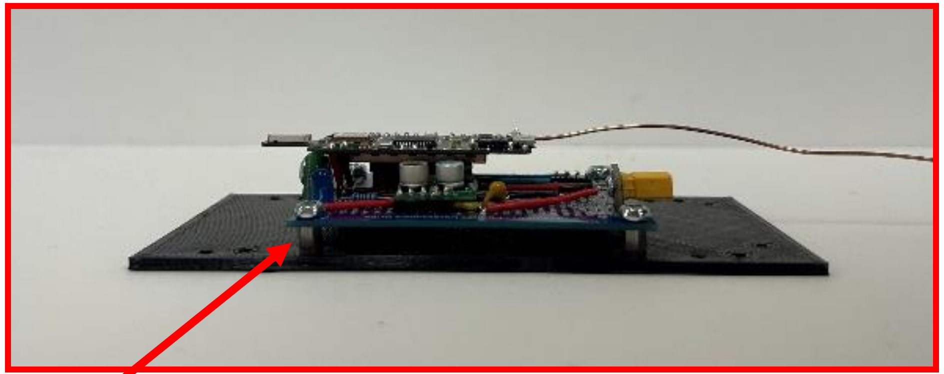

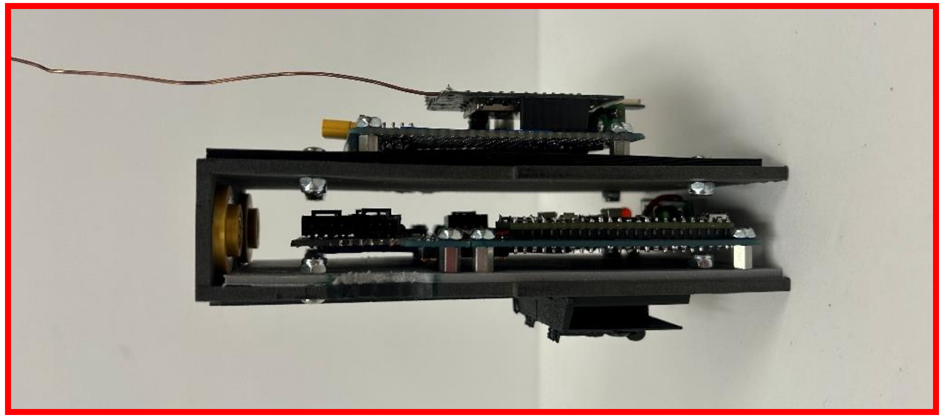

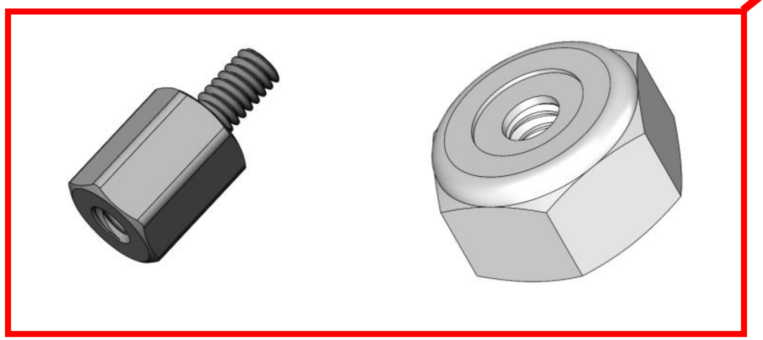

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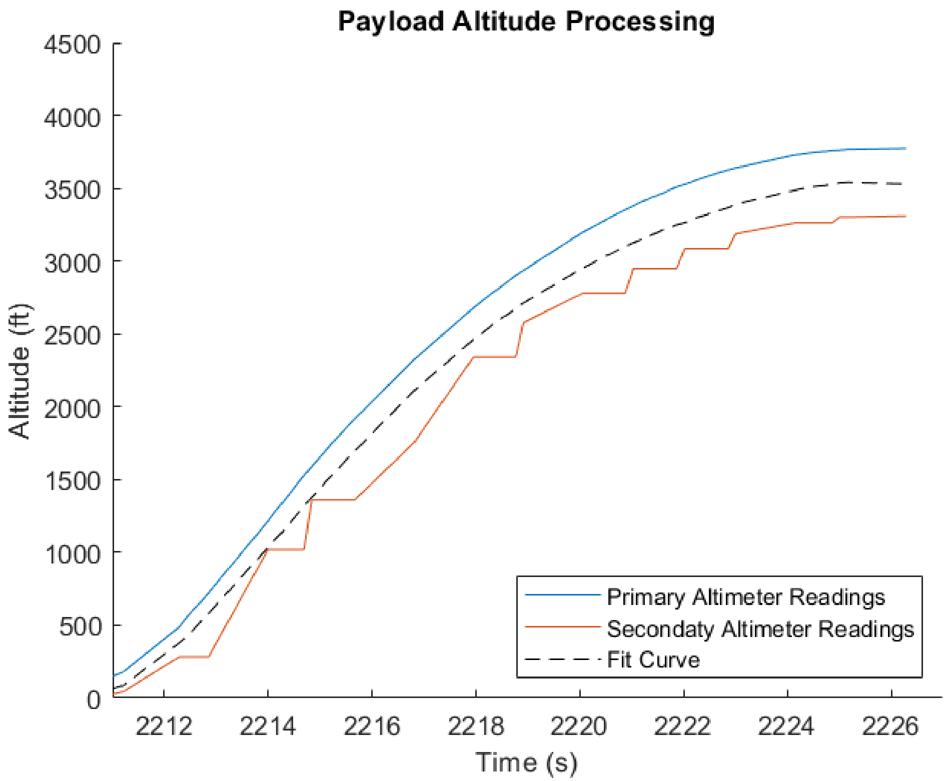
Data Transmission

Data Transmission Software

- Post flight SD card analysis
  - Remove outliers
  - Smooth data
  - Fit to known model
  - Compute required flight parameters
- Transmission packets
  - Single transmission per flight parameter
  - Duplicate packets



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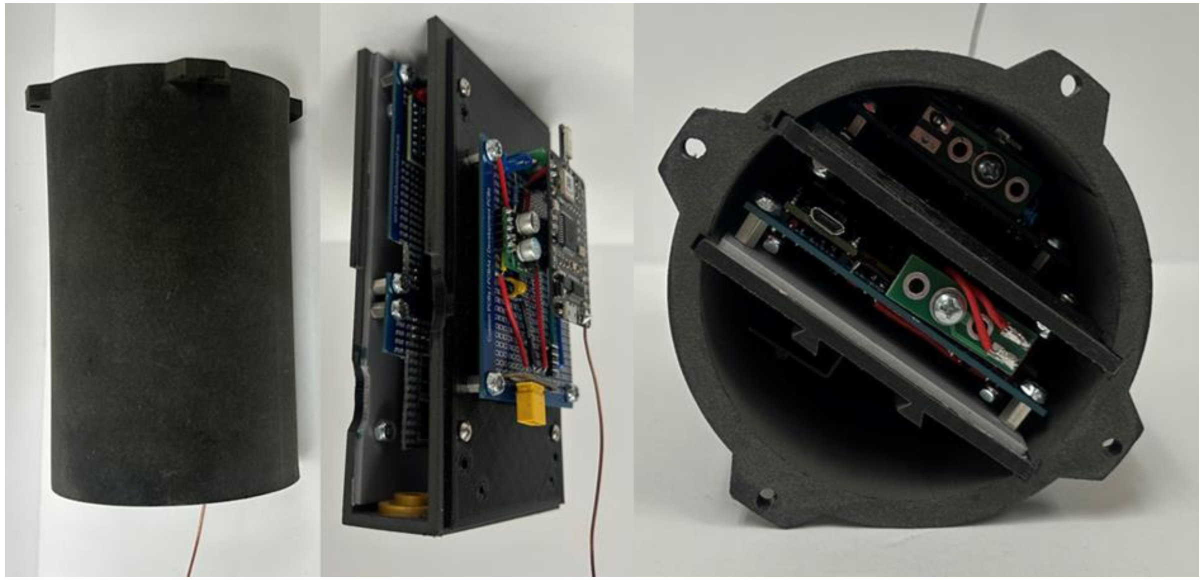
Neil Maldonado

Critical Design Attributes

- Structural Integrity
- STEMnaut Safety
- Data Collection
- Data Transmission
- **Recovery**



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Neil Maldonado

Recovery

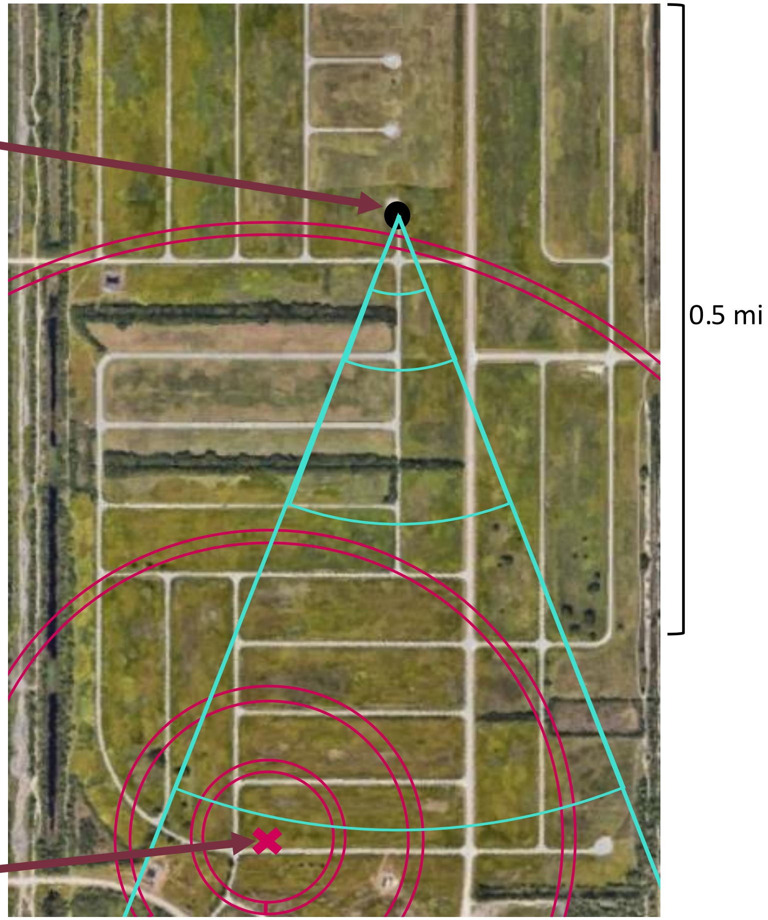
Situation

- Nearly lost vehicle during subscale testing
- GPS and high-power RF hardware on board to aid recovery efforts

Rocket Recovery Subsystem (RRS)

- The RRS program upon landing transmits GPS
- Low GPS visibility will transmit, chirps to the directional antenna

Launch Site
Single & multi-directional antenna



Landing Site
Payload sends GPS or chirp transmissions

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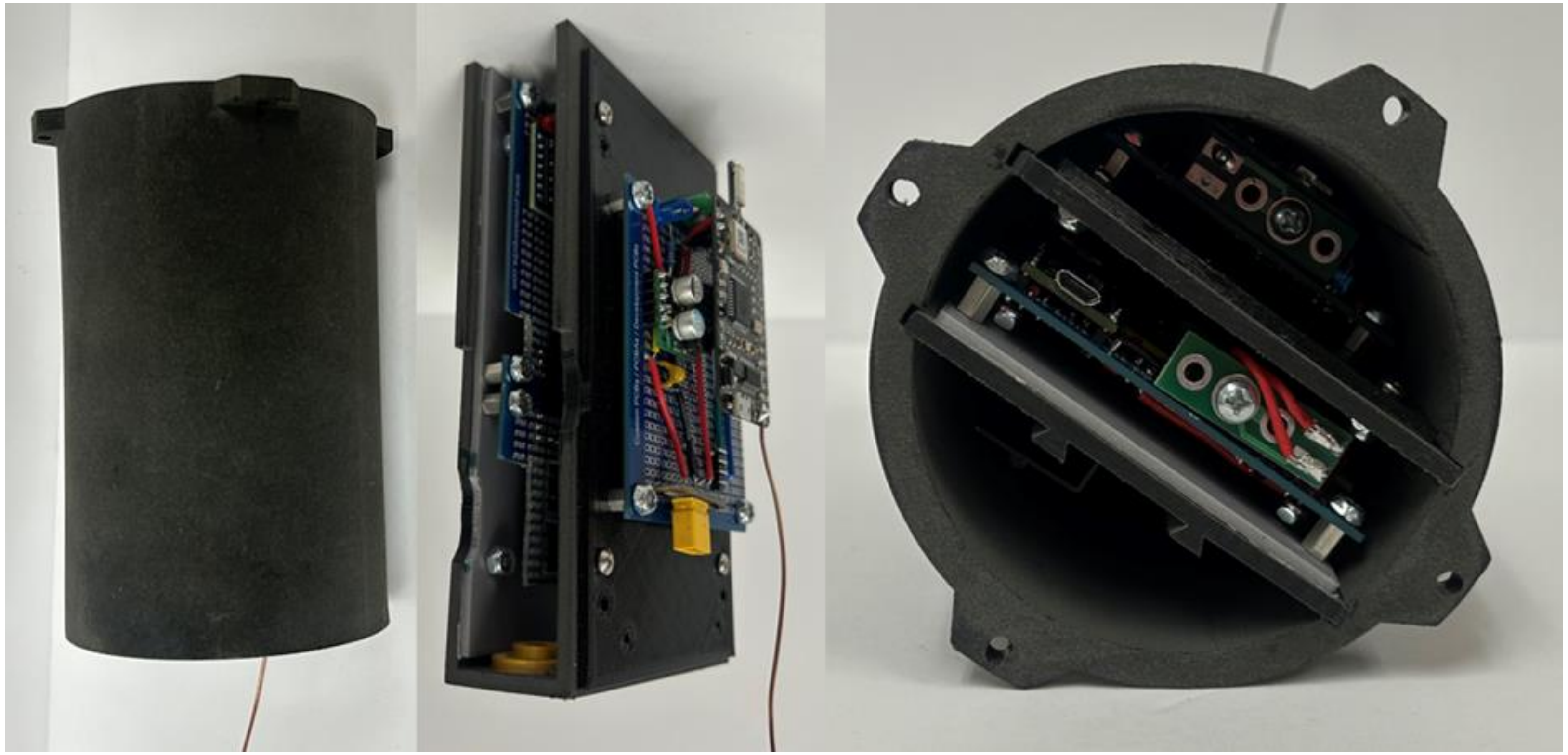
Payload Design



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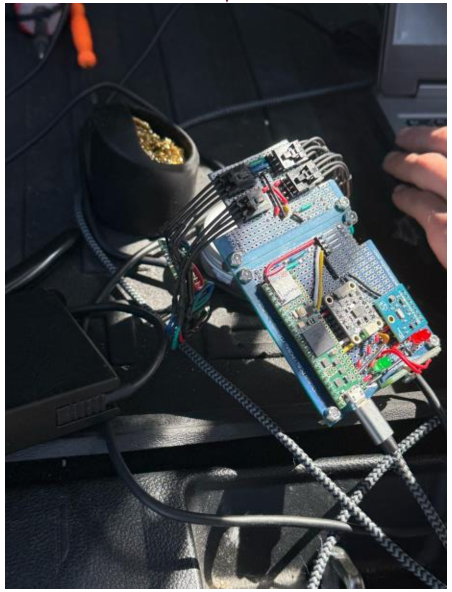
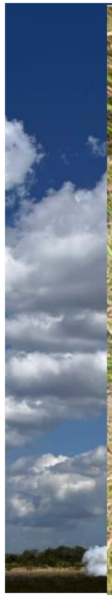
Flight Demonstration One

Saturday, March 15 in Palm Bay, FL

Arm Payload → Launch Pad → Rocket Flight → Rocket Landing





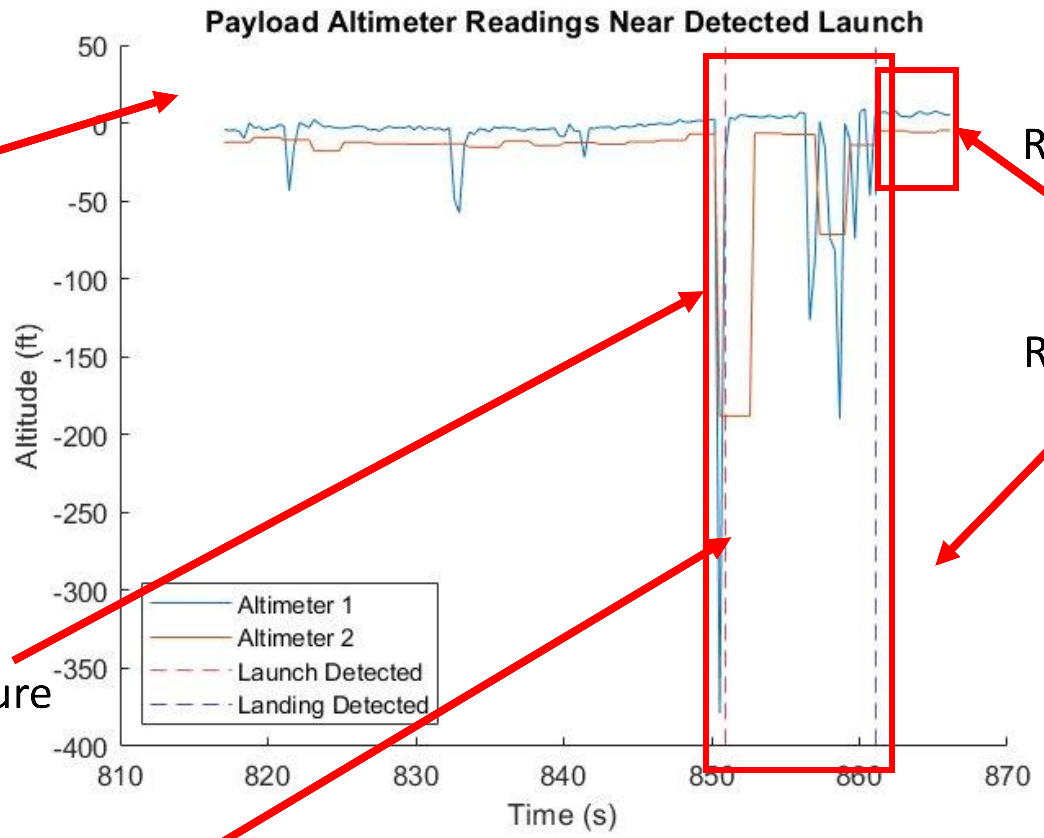
Nathan Hardie

Detection System Anomaly

Fastening payload to the nosecone

Momentary high-pressure event

Carrying out to the launch pad



Rotation onto the launch rail

Return to nominal readings

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Nathan Hardie

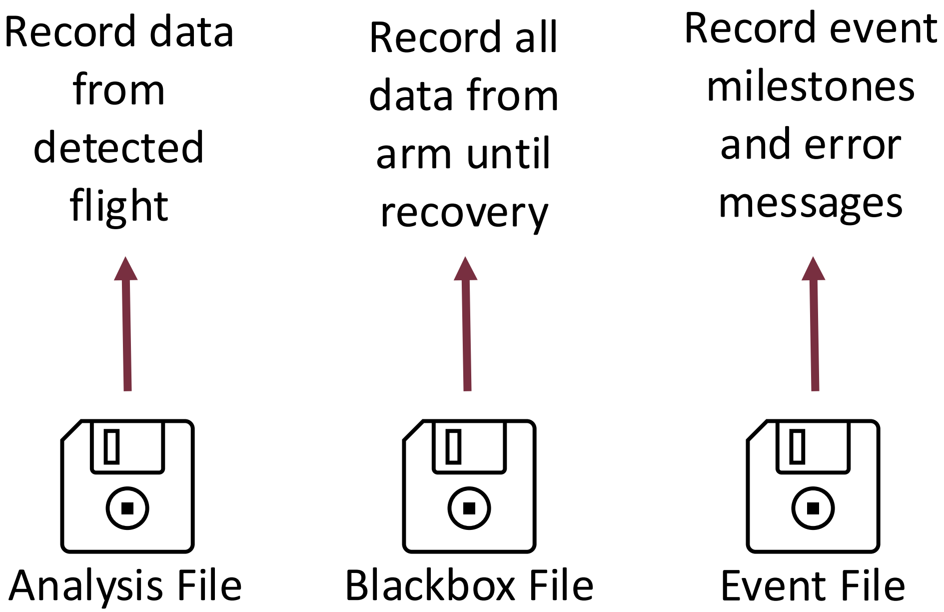
Takeaways and Lessons Learned

Structural Integrity
- All payload systems survived
- Improve pressure equalization capability

STEMnaut Safety
- Revisit cable housings

Data Collection
- Improve detection system
- Backup logging system

Transmission
- Rewrite transmission protocol



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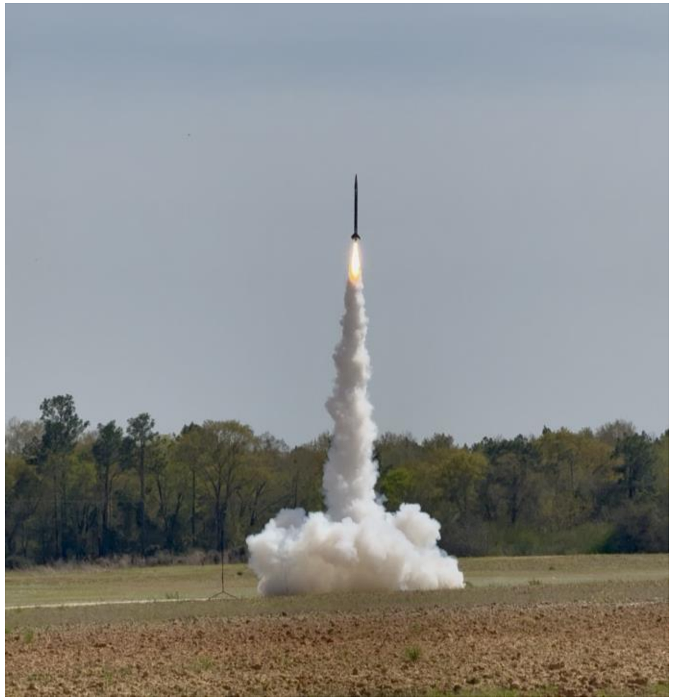
Flight Demonstration Two

Sunday, March 23 in Samson, AL

Flight Overview
- Main parachute deployment at apogee
- Safe landing

Results
- No damage
- Flight data for all sensors
- Accurate detection of flight events
- No transmissions observed or received
- Payload unresponsive upon recovery



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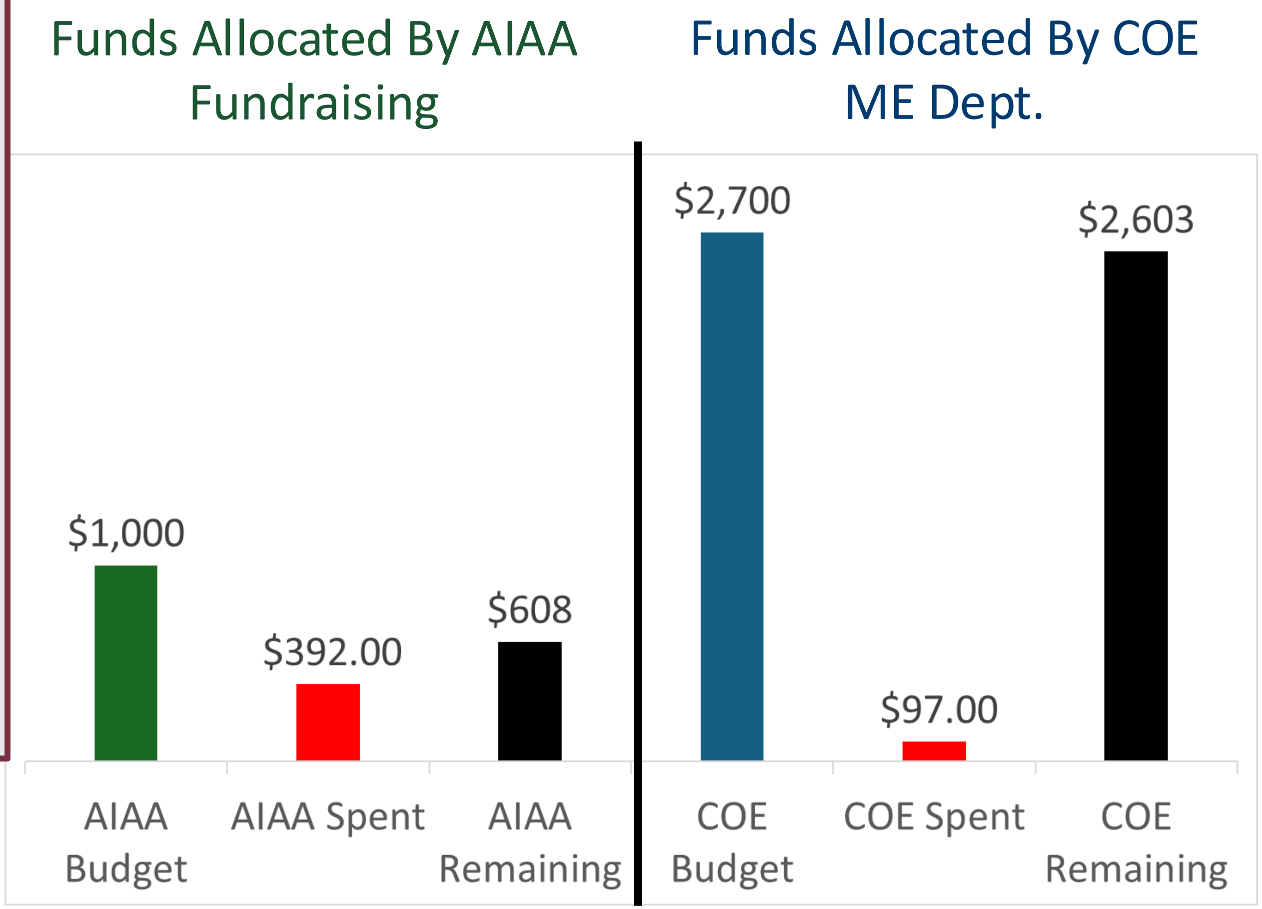
Budget Updates

AIAA Budget

- Source of funds for all purchases thus far
- Remaining funds will be re-allocated to Team 508

COE Budget

- Plans to use for testing
- More than $500 to be spent on Nylon-12 for backup payload parts
- Remaining funds will be re-allocated to Team 508



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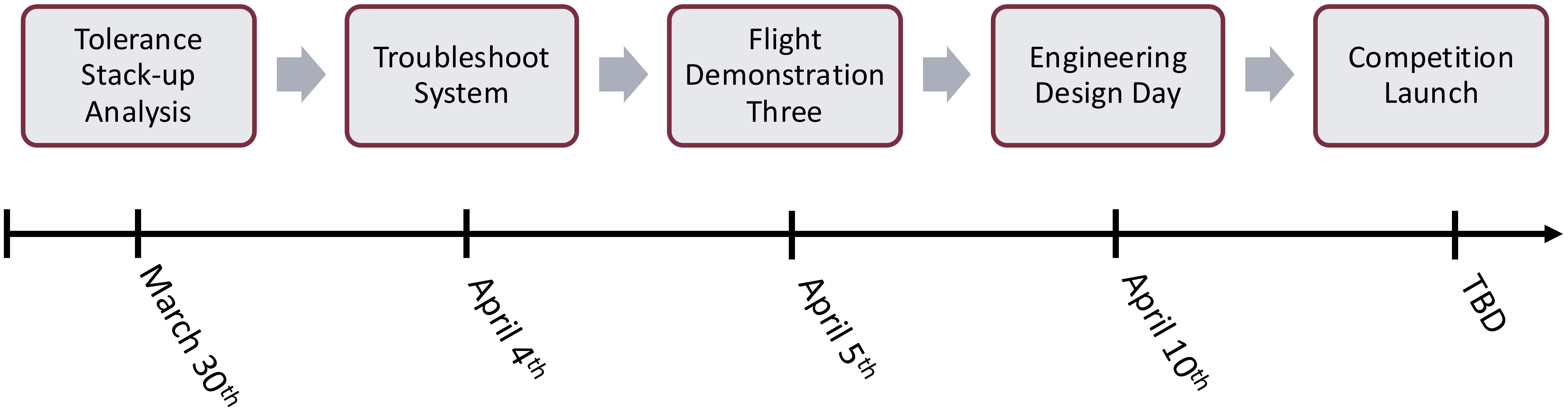
Future Work



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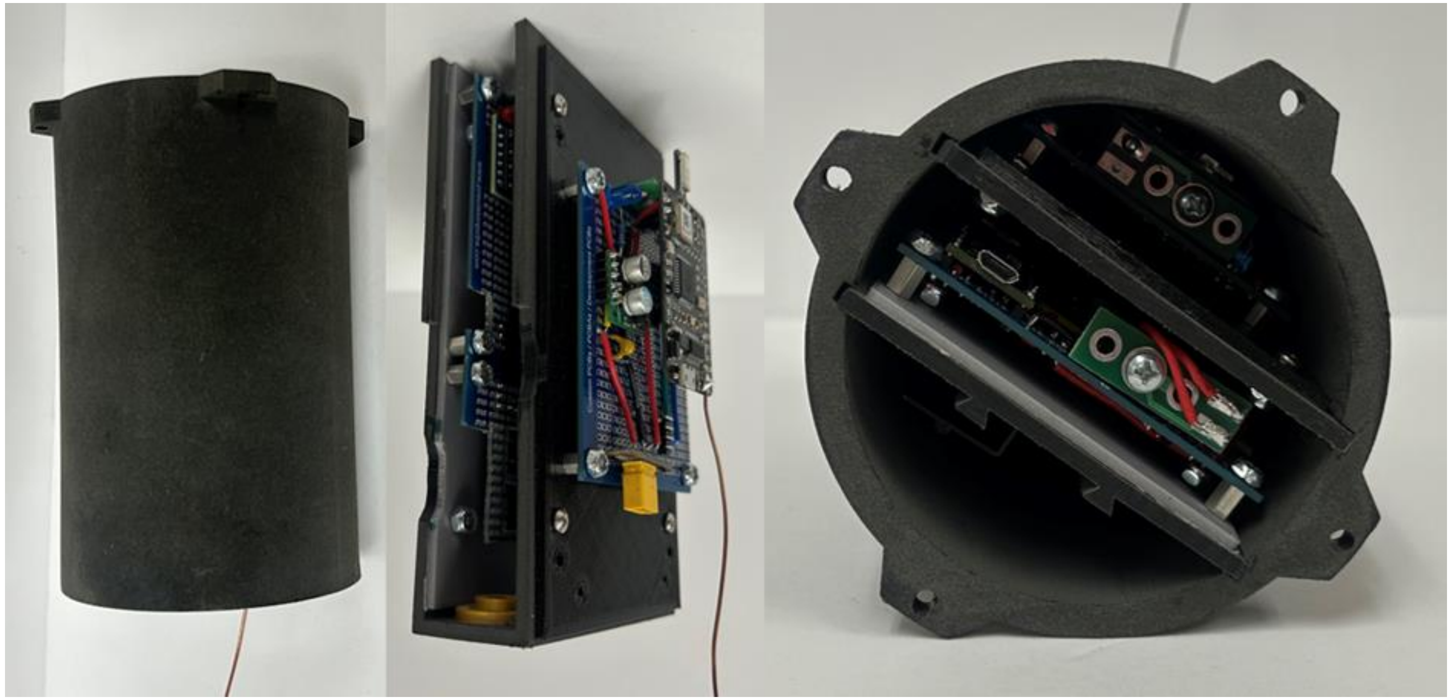
Thank you for listening!



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Subscale Testing:

Intact heat inserts post launch

Subscale Flights 1 & 2

- Recovery system failure
- Heat inserts in nylon-12 parts performed **remarkably**
- Demonstrated flight stability of the rocket with payload mass simulator

Adversarial terrain

Successful payload mass simulator

Subscale Flight 3

- Demonstrated successful recovery of the payload mass simulator
- Locating the rocket took several hours due to auditory locator failure and adversarial terrain

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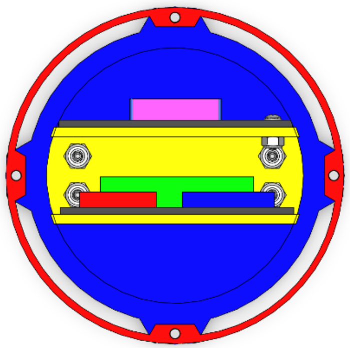
Initial Design Overview:

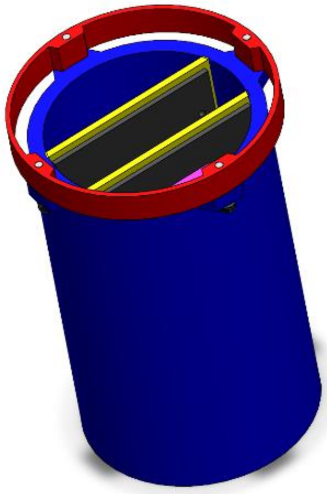
Structural Design Overview

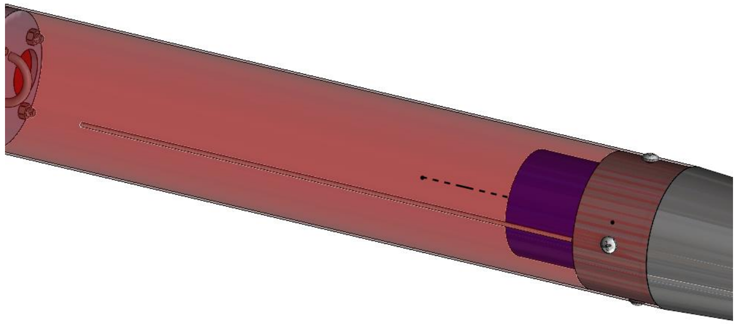
- **Structural Body -** SLS-printed Nylon-12
- **Mounting Method -** AL6061 bracket, epoxied to nosecone
- **Chambers –** Three separate areas for Data collection, Transmission, and STEMnauts
- **Electronics –** Stored on trays inside the capsule

Electrical Design Overview

- **Electronics Trays -** RF, Sensor, STEMnauts
- **Sensors –** Payload IMU, Altimeter and STEMnaut IMU's connected via I2C
- **Transmitter –** APRS tracker
- **Antenna –** 50cm copper wire







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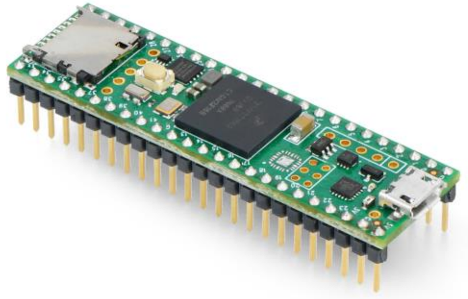
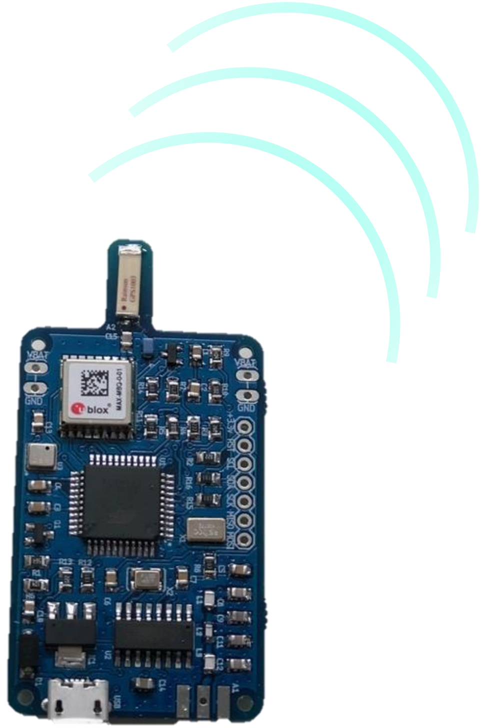
Transmitter Glitch



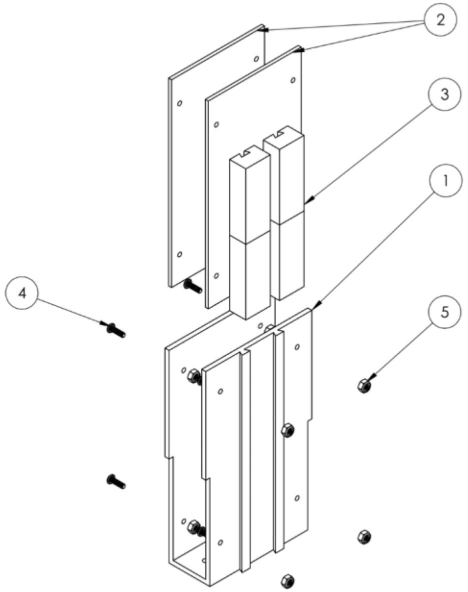


“STEMnaut”

“ S T E M n a u t ”

Structure Design

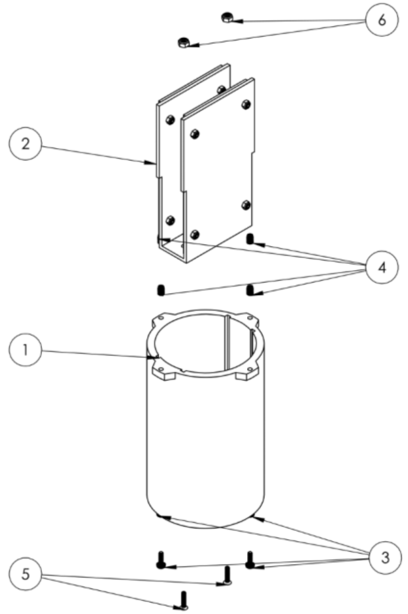
Electronics System Assembly:



ITEM NUM	PART NUM	DESCRIPTION	QTY
1	ZENITH-10-004	CHAMBER DIVIDER - PAYLOAD	1
2	ZENITH-10-005	ELECTRONICS TRAY - PAYLOAD	2
3	ZENITH-10-006	STEMNAUTS	4
4	91772A108	#4-40 PAN HEAD SCREW	8
5	90631A005	#4-40 LOCKNUT	8

TITLE: ELECTRONICS ASSEMBLY - PAYLOAD
SIZE A | DWG. NO. ZENITH-10-003 | REV 4
SCALE: 1:2 | WEIGHT: - | SHEET 1 OF 1

Payload System Assembly:



ITEM NUM	PART NUM	DESCRIPTION	QTY
1	ZENITH-10-002	STRUCTURAL BODY-PAYLOAD	1
2	ZENITH-10-003	ELECTRONICS ASSEMBLY - PAYLOAD	1
3	90402A148	#6-32 PAN HEAD SCREW	4
4	94459A427	#6-32 HEAT-SET INSERT	4
5	90471A432	#6-32 FLAT HEAD SCREW	2
6	90631A007	#6-32 LOCKNUT	2

TITLE: PAYLOAD ASSEMBLY
SIZE A | DWG. NO. ZENITH-10-001 | REV 4
SCALE: 1:3 | WEIGHT:1.73lbs | SHEET 1 OF 1

Data Collection Design

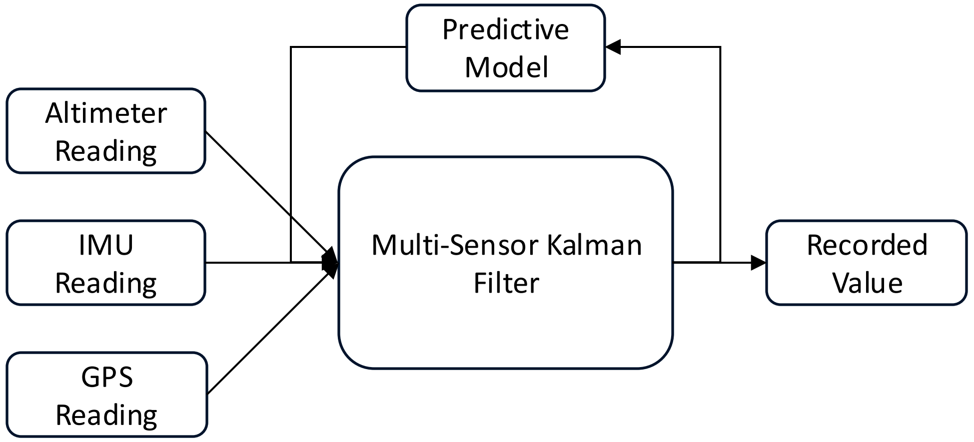
Sensor Fusion by Multi-Sensor Kalman Filter

- **IMU Readings –** Accurate dead-reckoning navigation
- **Altimeter Readings –** Frequent vertical positioning
- **GPS Readings –** Provides infrequent absolute positioning

Single Sensor Data

- **Temperature Readings –** Temperature sensor on the Altimeter
- **Power Readings –** Power supply connected to ADC
- **Time –** Hardware timer on the microcontroller

Sensor Fusion Block Diagram



Eight Pieces of Required Data	
STEMnaut Survivability	Temperature of landing site
Apogee Reached	Orientation of on-board STEMnauts
Landing velocity, G-forces sustained	Time of landing
Maximum velocity	Battery check/power status

Data that uses Sensor Fusion (left column)

Data with a single source (right column)

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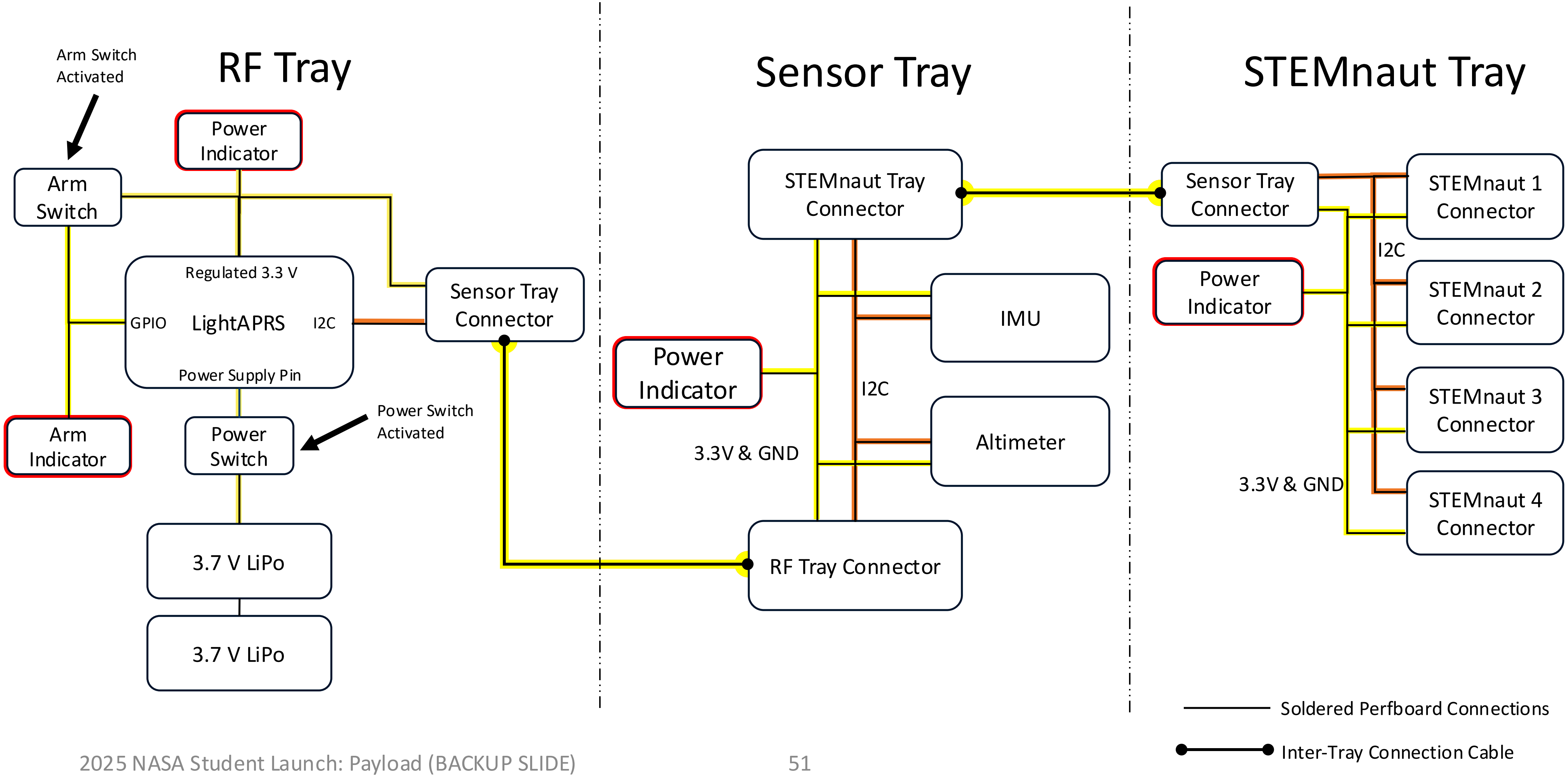
Electronics Block Diagram



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Software Design

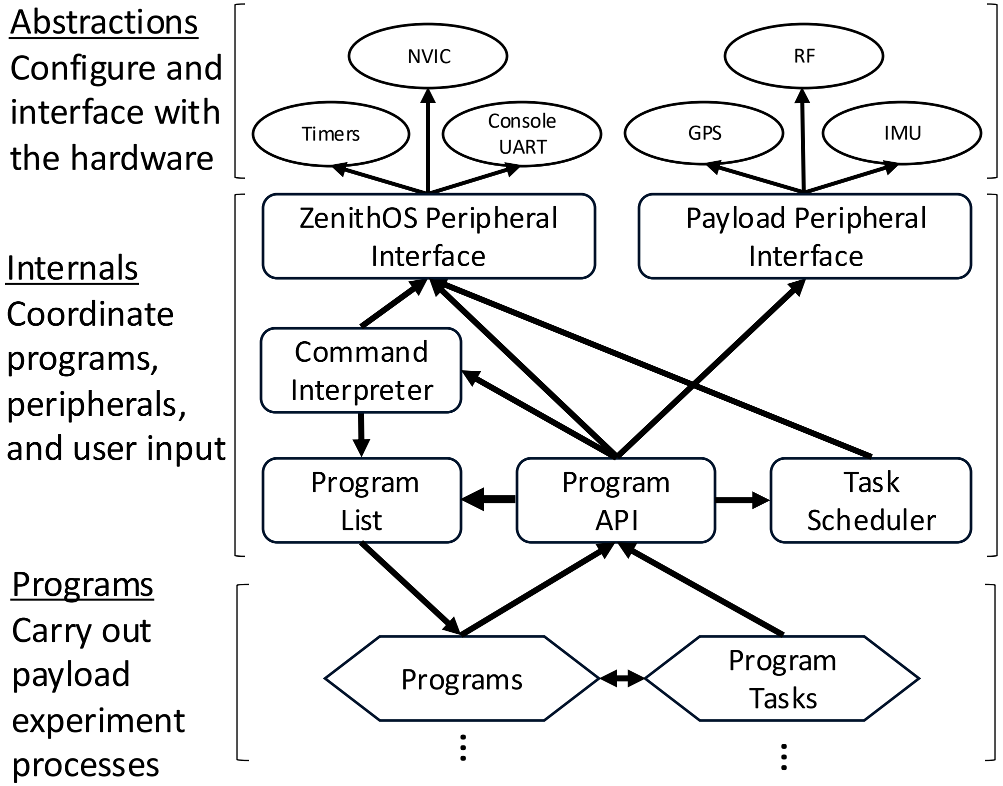
LightAPRS with Atmega1284P-AU Microcontroller

- **Timers –** 2x 16-bit hardware timers (one dedicated to time of landing)
- **I2C Pins –** 1x set available on LightAPRS
- **Core –** 1x Low-Power 8-bit AVR Microcontroller

Payload Software Requirements

- **Time Sensitive –** Sensor readings, Sensor Fusion, Data Loging
- **I2C Sensors –** 5xIMU, Altimeter
- **Simultaneous –** Flight Monitoring, Sensor Fusion, Data Interpretation, Logging

ZenithOS Block Diagram



ZenithOS Framework

- **Multitasking –** Allows for multiple independent programs: Flight monitor, Data logger, Sensor fusion, Data interpreter
- **Resource Allocation –** Manages tasks, logging, CPU time, and peripheral requests for multiple programs
- **User Interface –** Terminal interface allows the user to start/stop programs, run diagnostics, and send commands at runtime
- **Hardware Abstraction –** A single implementation can be thoroughly tested and used by all programs

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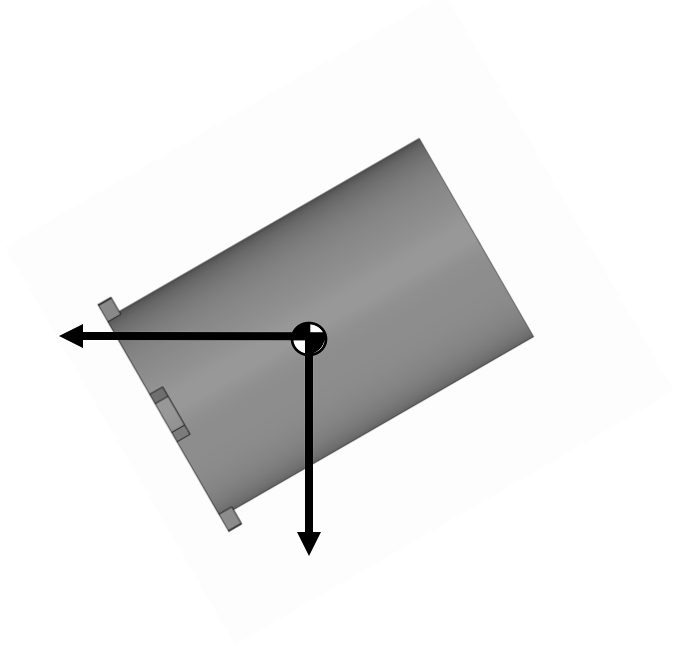
Landing Condition Calculations

Analysis:

- Landing conditions of rocket (orientation and velocity) obtained from simulation
- Mass of payload know (1.41 lbs)
- Impact time (dt) assumed:
  - 10 – 50 microseconds
  - Tall grass at launch site provides cushion
- Combined load: 130 – 150 lbf



$$F = ma = m\frac{dv}{dt}$$

$$m = 1.406\ lbm$$
$$v = 15\ - 20\ mph$$
$$dt = \ .01\ -\ .05\ sec$$

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Preliminary Analysis

Hypotheses	Evidence For	Evidence Against
Overheating	• Event log and Blackbox end at computationally intensive steps • Long preflight activities on a hot day • Slowed SD card logging	• Altimeter temperature readings of 108F • 250F operating temperature • Multiple transmission steps recorded
Program Crash	• Missing data for sensors on transmission board • Unexpected symbols in analysis file • Power cycling restored the payload	• Successful HIL processing of analysis file • Multiple transmission steps recorded
Power Issues	• Last telemetry recorded during transmission step	• No program reset observed • Nominal post flight battery voltage

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Software Changes After Flight Demonstration One

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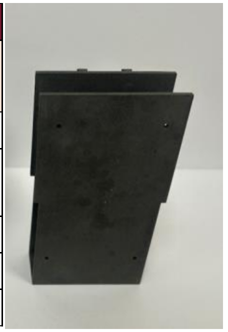
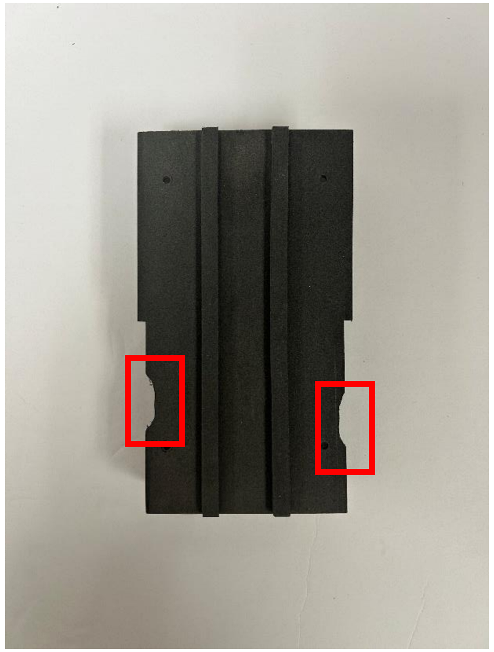
Manufacturing Errors

Payload Chamber Divider SLS Printing Error Analysis			
Feature	Designed Dimension (in)	True Dimension (in)	% Error
Wall Thickness	0.125	0.135	7.41%
Tray Mounting Hole Dia.	0.150	0.149	0.66%
Dovetail Max Width	0.250	0.249	0.40%
Dovetail Min Width	0.125	0.140	12.0%
Dovetail Height	0.125	0.131	4.80%



Payload Capsule SLS Printing Error Analysis			
Feature	Designed Dimension (in)	True Dimension (in)	% Error
Outer Diameter	3.800	3.798	0.05%
Wall Thickness	0.250	0.260	4.00%
Flange Thickness	0.250	0.262	4.80%
Mounting Hole Dia.	0.150	0.155	3.33%

- Expected that positional tolerance was higher than expected
- Plans to perform tolerance stack-up analysis and modify dimensions



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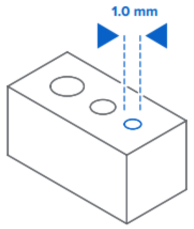
Tolerance Stack-up Analysis

Tolerance Analysis

- Difficult finding tolerance specs for Fuse1+ SLS system
- Assumptions made based on data sheet
- Plans to create excel spreadsheet to perform analysis

"Assumed" SLS Printing Tolerance	
General Tolerance	± .006
Positional Tolerance	± .008
Angular Tolerance	± 2°

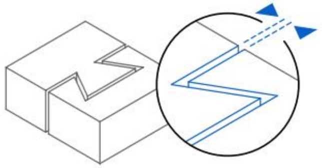


MINIMUM HOLE DIAMETER

1.0 mm

Holes with a diameter less than 1.0 mm may close off during printing.

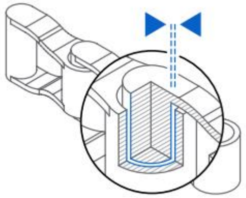
Note: For precisely concentric holes, design an undersized pilot hole and use a reamer to open the hole to its intended diameter.



MINIMUM ASSEMBLY TOLERANCES

Features less than 20 mm^2: 0.2 mm
Features greater than 20 mm^2: 0.4 mm

Leave a slight clearance between printed parts intended to mesh or interface after printing, like assembly joints or gears.



INTEGRATED ASSEMBLY CLEARANCE

Features less than 20 mm^2: 0.3 mm
Features greater than 20 mm^2: 0.6 mm

For parts that will be printed together in an integrated assembly, leave clearance to prevent the parts from fusing together during the print.

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