Model Rocket Telemetry and Launch Control

Team #10

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ECE 568 Embedded Systems
Research Project Presentation
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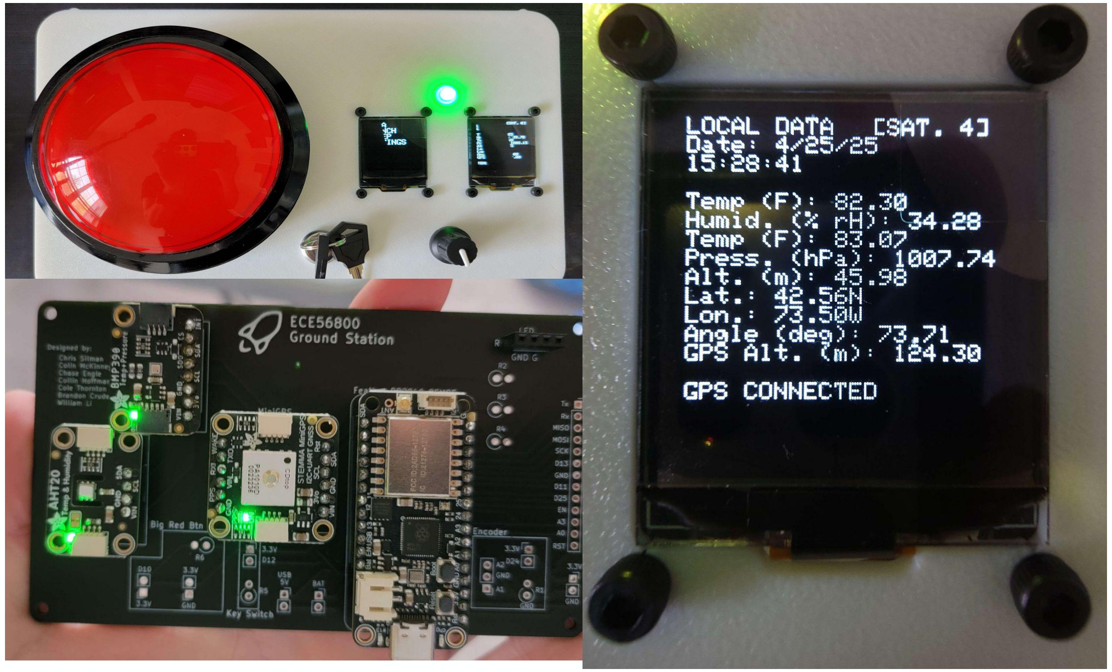
Project Goals

- Create two embedded systems for model rocketry: a ground station and flight computer, linked by RF, to control launch and collect and transmit flight telemetry.

- Outperform an existing consumer-grade product (JollyLogic) at a lower cost than an existing professional-grade product (Multitronix).



Ground: Sensors, UI, Custom PCB

Flight: MCU, Sensors, Rocket

Methodology: Hardware and Software

Hardware

- MCUs: Adafruit RP2040 Feathers w/ STEMMA QT and LoRa 915 MHz radio.
- 915 MHz RF is within unlicensed ISM band (FCC Part 15). Low power, long range.
- Ground: sensors, user interface, safety switch, launch control, antenna, custom PCB and housing.
- Flight: sensors, antenna, ignition control, parachute, custom payload housing.

Software

- Used C++/Arduino IDE instead of MicroPython, due to RF library.
- Modular class structure for reusability.
- Rocket and ground station operate as a linked state machine. Synchronous state transitions.
- DOF sensor information used to detect flight status changes.
- One-shot timer used to detect ignition failures.

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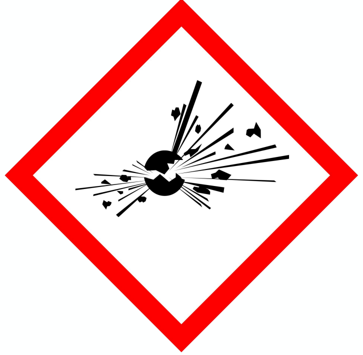
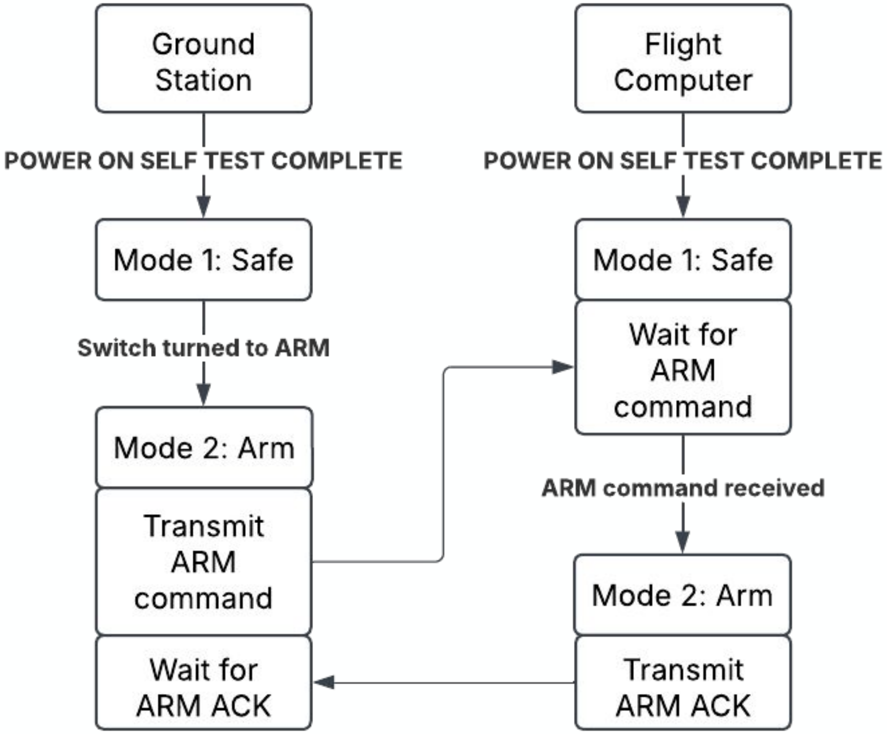
Methodology: Safety



- Rocket motors and igniters are **flammable** and **explosive**.
- **Critical** that systems are **fail safe**.
- Arming and launching required a **multi-step** and **human-centered** process, with **active verification**



Subset of UML State Diagram

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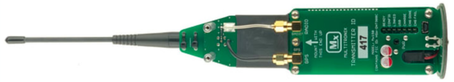
Test and Evaluation

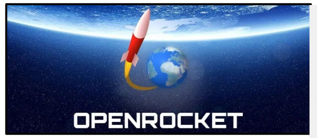
- **Build-up approach** including iterative hardware and software debug and integration for val/ver.
  - e.g. ignition interlocks, RF link
- Multiple **static and dynamic** ground and flight tests
  - e.g. commands, states, telemetry
- Comparison with existing COTS solutions for **size, weight, power, cost, performance**

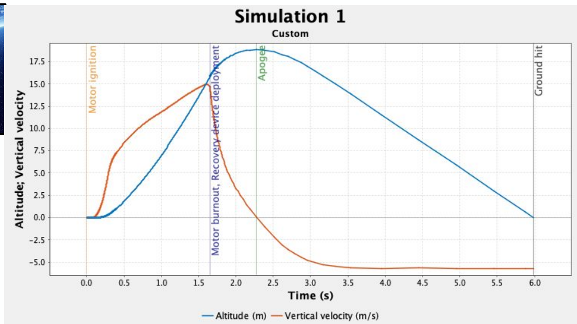
JollyLogic
AltimeterTwo

Multitronix
TelemetryPro

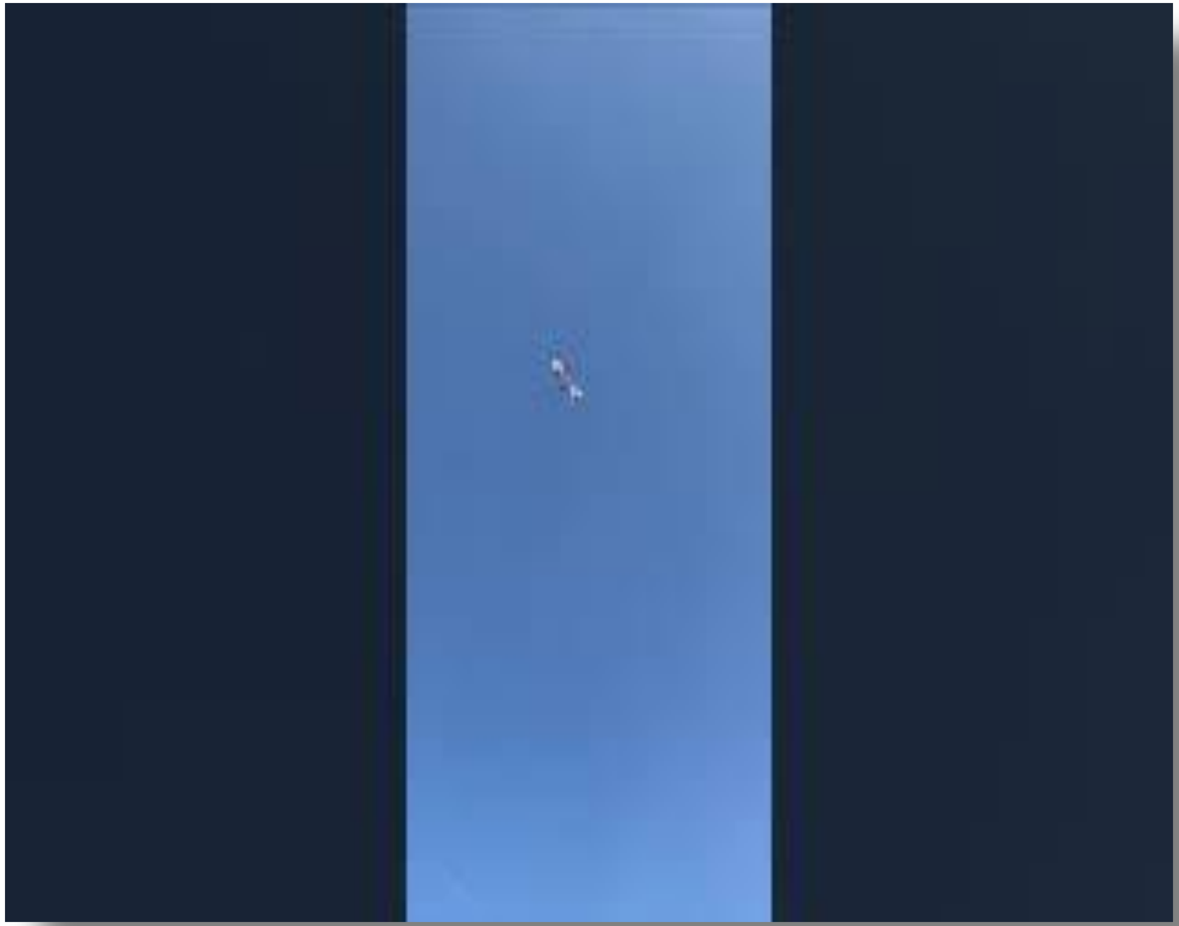


- "**Truth data**" from OpenRocket simulations, with ride-along data from a JollyLogic unit.





Video: *BOILER 7* mission launch (COREC Park, Purdue, 28 April 2025)



https://www.youtube.com/shorts/g5D2pSnxmoE

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Selected Results

Mission	Result	Details
Boiler 4	**Partial Success**	Apogee ~25 m. Data collection failure. Parachute deployment occurred too late. Action: Changed motor, improved code and data retention methods.
Boiler 7	**Success**	**Apogee** 16.1 m (flight computer) 22.6 m (Jolly Logic) 18.8 m (OpenRocket) **Peak velocity** 7.51 m/s (flight computer) 19.4 m/s (Jolly Logic) 16.5 m/s (OpenRocket)

Costs excluding rocket, motors, misc. parts:

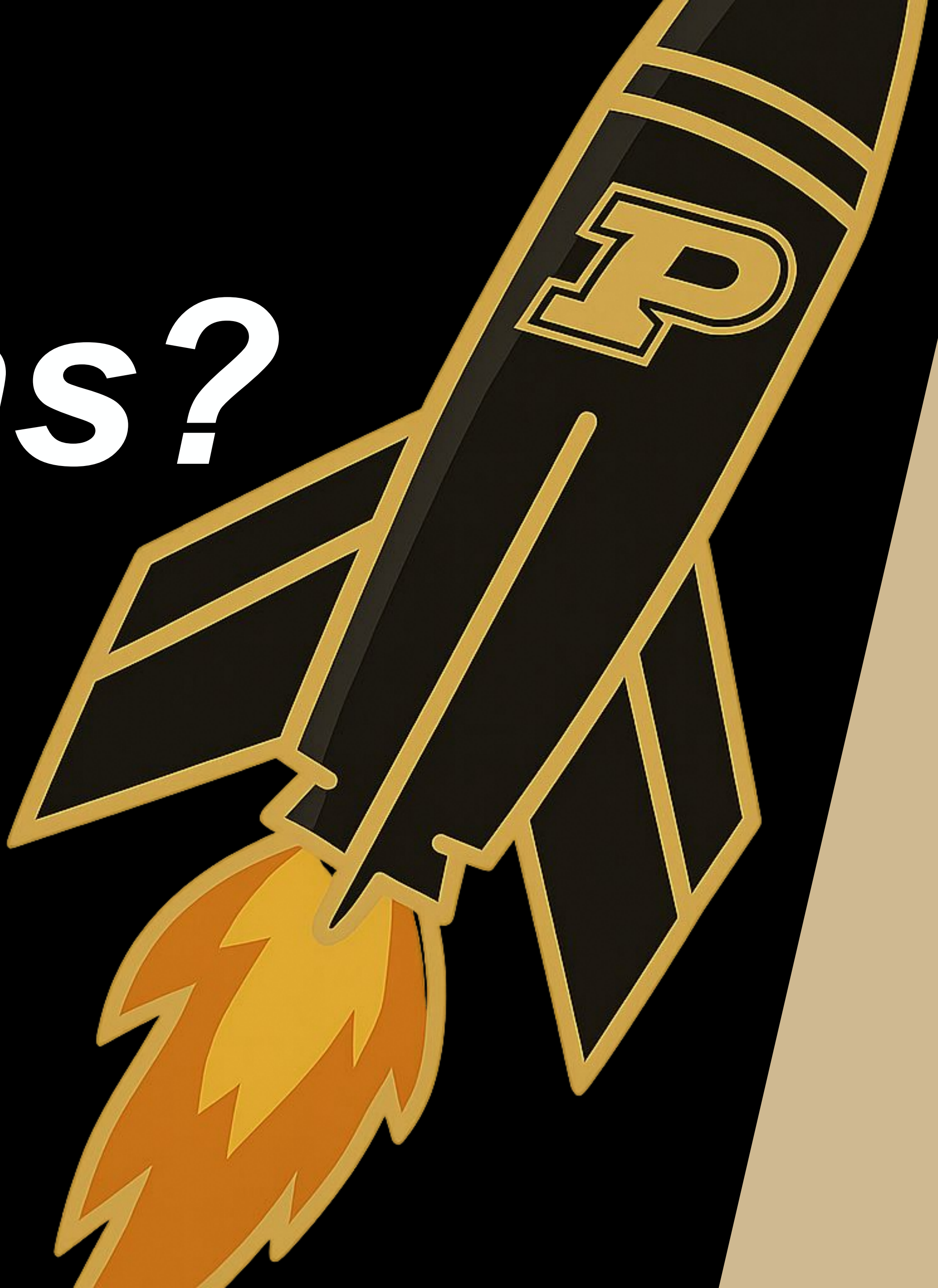
- Our units: ~$250 ($125 each)
- JollyLogic: ~$100
- Multitronix: ~$3,000

Future Work

- RF reliability was a significant challenge. Opportunity for growth!
- Design system to require two separate human operators.
- Develop PCBs with IC components to decrease payload mass.
- Improve sensor calibration and simulation parameters.
- Utilize auxiliary storage for enhanced data logging and reliability.

Questions?

Thank you for your attention!



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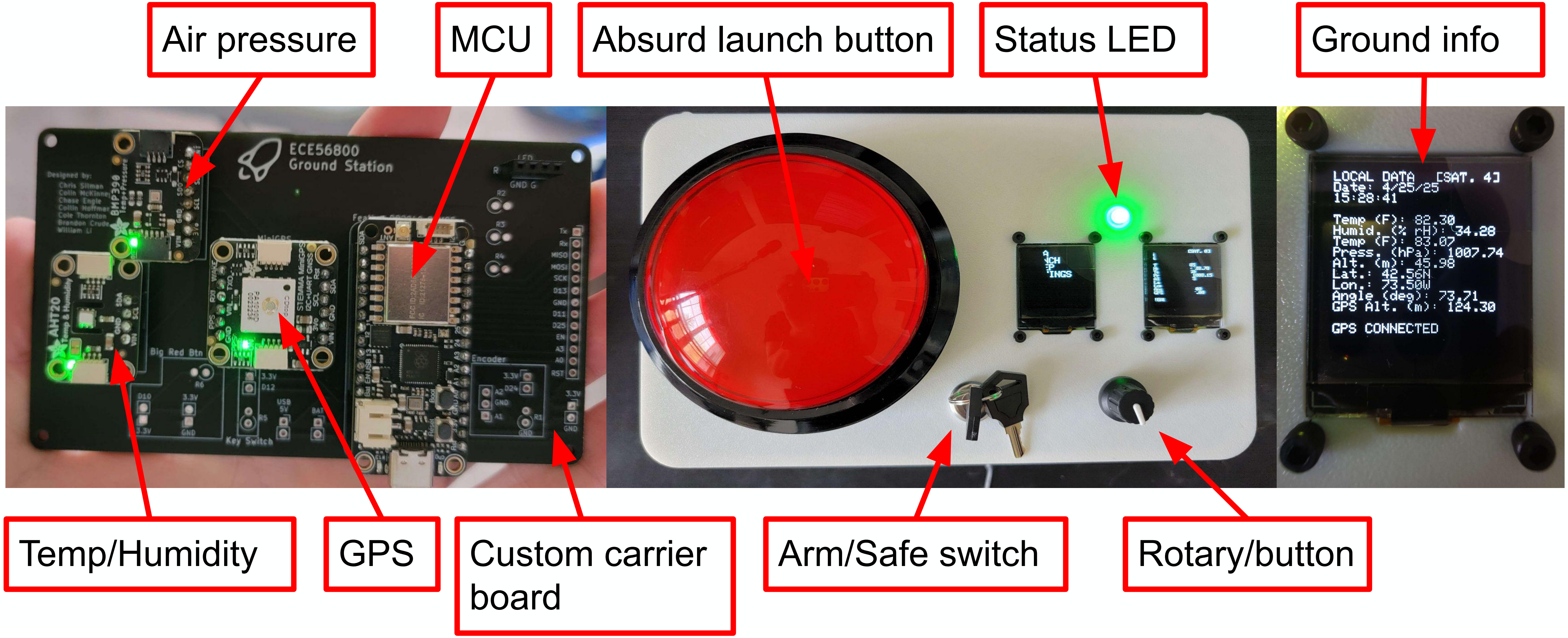
Backup Slides

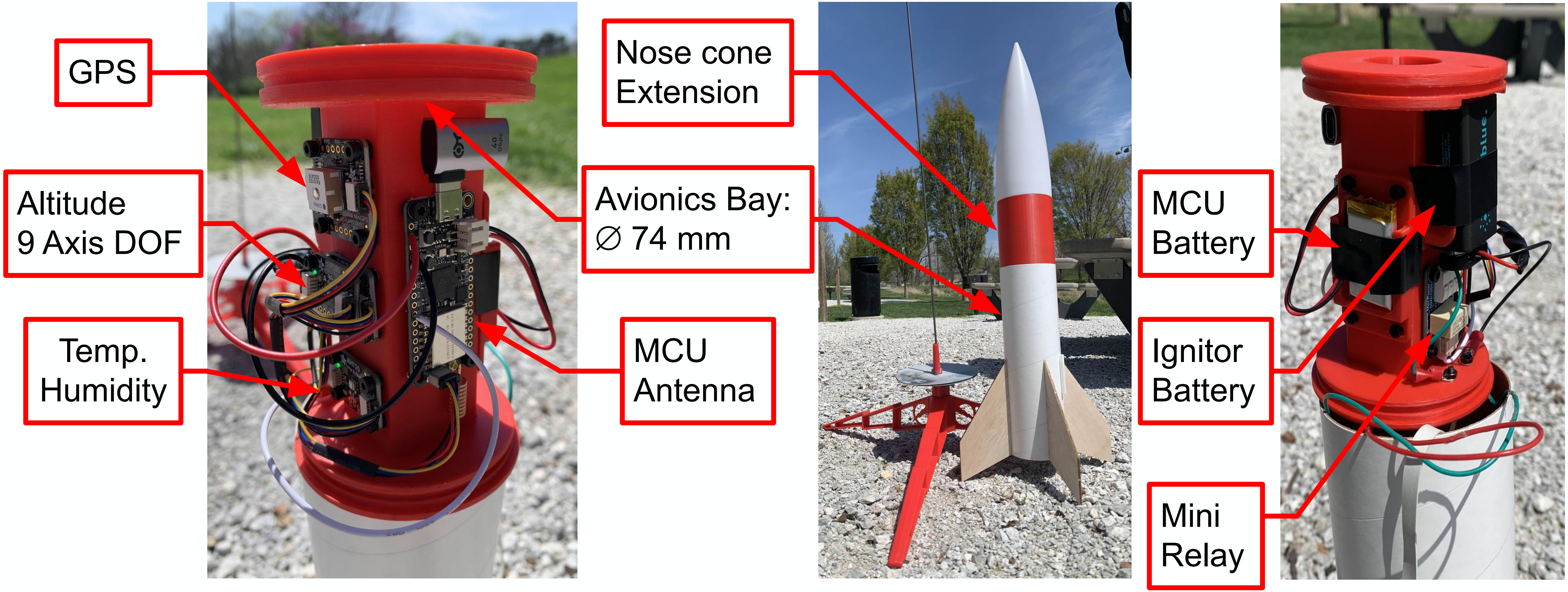
Ground Station

Launch Control and Data Collection System



Flight Computer and Rocket

Sensors for Data Collection, RF, and Motor Ignition Control; Nose cone extension



Areas for Improvement/Future Work

- RF reliability proved to be a significant challenge.
- Minitiarize flight computer to reduce payload mass and physical complexity.
- Improve sensor calibration to align with JollyLogic and OpenRocket values.
- Utilize auxiliary storage for enhanced data logging and reliability.

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Tests and Test Conditions

Table 2: Tests and Test Conditions (T&TC) Matrix

Test Point	Description	Remarks	Category
FC.G.1	Flight Computer (FC) operational checkout - ground	● Verify basic functionality of all discrete components: Adafruit microprocessor (MCU), sensors, Stemma QT I2C connections	Hardware/ Software
FC.G.2	FC avionics bay fit check	● Iterative verification/validation of size/fit until redesign suitable for safety of flight test (SOFT) with *BOILER* rocket	Hardware
GS.G.1	Ground Station (GS) operational checkout - Ground	● Verify basic functionality of all discrete components: Adafruit microprocessor (MCU), sensors, Stemma QT I2C connections	Hardware/ Software
RF.G.1	Radio Frequency (RF) link operational checkout - Ground	● Verify basic two-way reliable communication between FC and GS	Hardware/ Software
RF.G.2	Telemetry and sensor polling check	● Evaluate reliable transmission and receipt of FC sensor telemetry data to GS	Software
RF.G.3	GS command and control for rocket ignition - Ground	● Evaluate reliable remote command and control of FC state via GS wireless link (non live-fire)	Software
GS.F.1	GS command and control for rocket ignition - Flight	● Evaluate reliable remote command and control of FC state via GS wireless link (live-fire with *BOILER* rocket) ● May combine with FC.F.1 for test efficiency	Hardware/ Software
FC.F.1	FC avionics bay safety of flight test (SOFT)	● Evaluate FC avionics bay design suitability for flight in *BOILER* rocket with dummy load ● Iterative verification/validation until redesign suitable for flight with actual payload	Hardware
FC.F.2	FC payload mission	● Evaluate whole-of-system functionality, performance, and safety during mission profile with live and recorded telemetry data from *BOILER* rocket, including launch, flight, and recovery phases	Hardware/ Software

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Methodology: Software

- Used C++/Arduino IDE instead of MicroPython, due to RF library.

- Rocket and ground station operate in a state machine, and change state after receiving a command or status acknowledgement.

- DOF sensor information used to detect change from stationary to flight and flight to recovery; timer used to detect ignition failures (which happened).

Test Results

Table 3: Mission Log

Date	Mission(s)	Result	Remarks
8 April 2025	BOILER 1 BOILER 2 BOILER 3	SUCCESS FAIL PARTIAL SUCCESS	● Good static fire of B engine using 9V source. ● Multiple ignition failures using OEM (Estes) ignitors with C engines; good ignition with Apogee ignitor. ● Good C engine launch (dummy payload), parachute did not deploy, rocket redesign for body extension.
22 April 2025	BOILER 4 BOILER 5 BOILER 6	PARTIAL SUCCESS FAILURE FAILURE	● Good ignition, mass of rocket/payload impacted apogee, parachute ejection timing, no data recovered. ● Ignition failure, cause unknown. ● Ignition failure, cause unknown, updated SW for fault detection.
28 April 2025	BOILER 7 BOILER 8 BOILER 9	SUCCESS FAILURE PARTIAL SUCCESS	● Good D engine launch with SW update, on-board rocket data recovered but no telemetry received. ● Ignition failure, cause unknown. ● Good launch with E engine, no data recovered.

Test Results (Cont.)

Table 4: Summary of Experimental Test Results (*BOILER* Mission Series)

Parameter	Objective(s)	Results	Compliance
Rocket Flight Computer (FC) Control and Telemetry	• Control rocket ignition for launch • Transmit various telemetry data • Minimize size, weight, power, and cost (SWAP-C)	• Processed arm and launch commands from GS using finite state machine (FSM) architecture • Tx GPS position (lat/long) @ 1 Hz (recovery only) • Tx temp (deg F) • Tx humidity (%RH) • Tx baro pressure (hPa) • Tx altitude (m) • Total FC payload weight was causal factor to severely limited apogee and time of flight. • Total FC payload cost of $250 (compare to Multitronix Kate-3 at $1,440)	**Met** **Met** **Partially Met**
Radio Frequency (RF) Data Link	• Establish and maintain a two-way wireless link between FC onboard rocket and remote GS • Ensure reliable data link	• Implemented two-way RF link using Adafruit RFM95W transceivers with 915 MHz band LoRa. • Reliable data link used packet error correction method to minimize telemetry loss (RadioHead Arduino library for reliable datagrams)	**Met** **Partially Met**
Ground Station (GS) Command and Control	• Safely command remote rocket launch sequence • Display received telemetry	• Implemented/tested GS with PCB and federated system elements using safety interlocks for command/initiation of remote rocket launch sequence within FSM architecture • Displayed formatted telemetry data on GS miniature screen	**Met** **Partially Met**

Results

Boiler 4 launch (22 April) (D12-3)
flight computer lost data, no data transmitted over RF. Approximate apogee of 25 m (JollyLogic). Parachute deployment failure.

Boiler 5 and 6 failed to launch (ignition failures)

Software improved after this to detect ignition failures and better preserve data even if RF transmission fails. New engine selected (D12-0).

Boiler 7 launch (28 April) (D12-0)

Apogee
16.1 m (flight computer)
22.6 m (Jolly Logic)
18.8 m (OpenRocket)

Max velocity
7.51 m/s (flight computer)
19.4 m/s (Jolly Logic)
16.5 m/s (OpenRocket)

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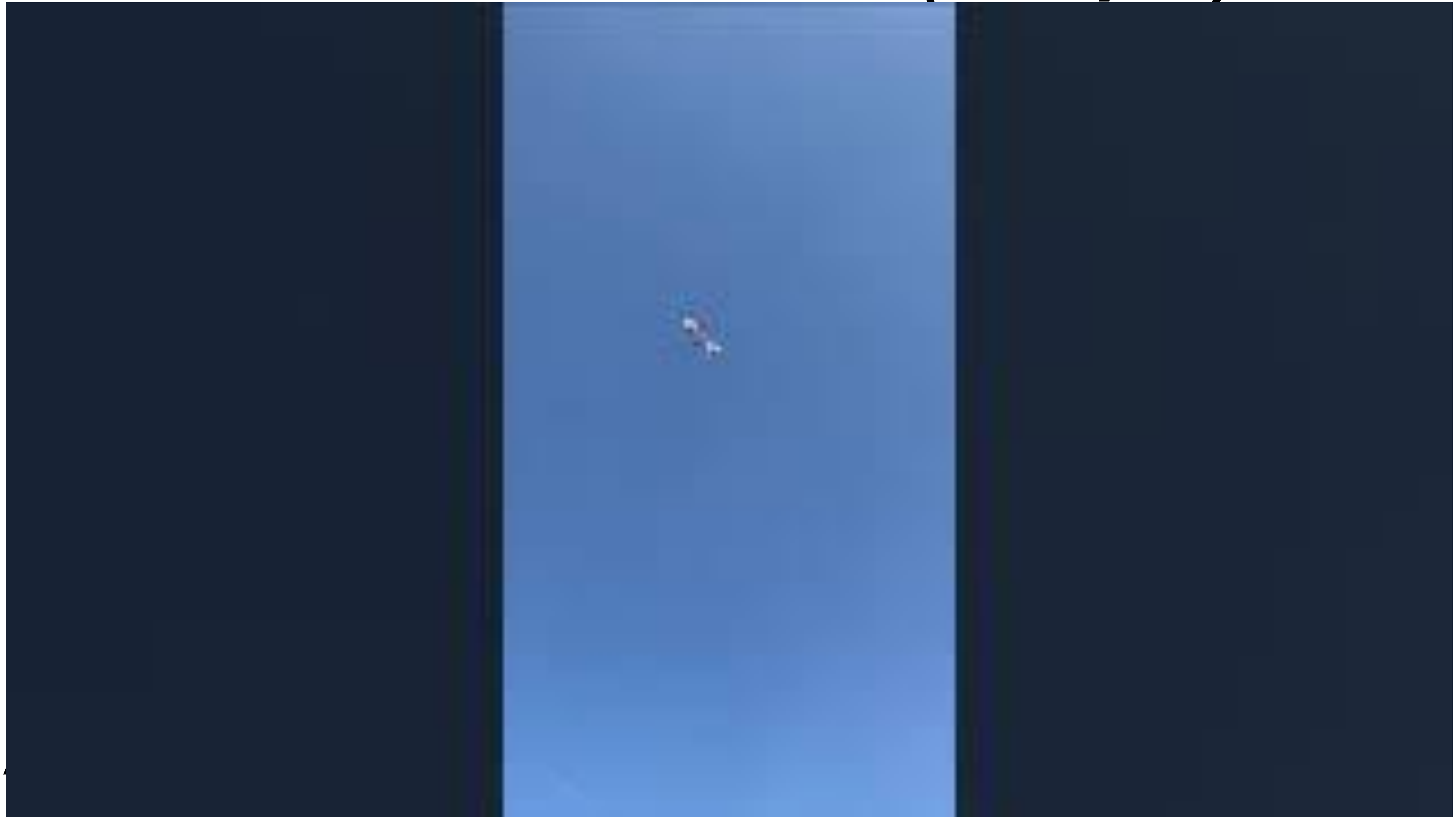
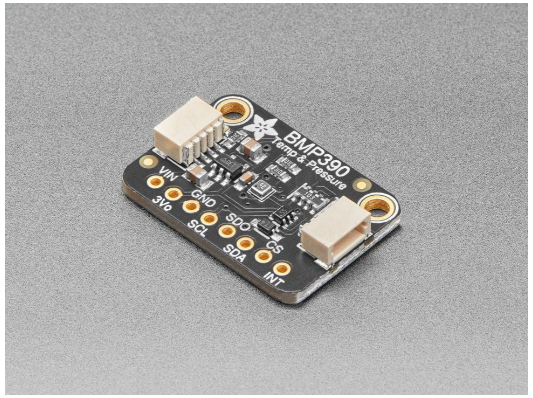
Boiler 7 Launch (28 April)



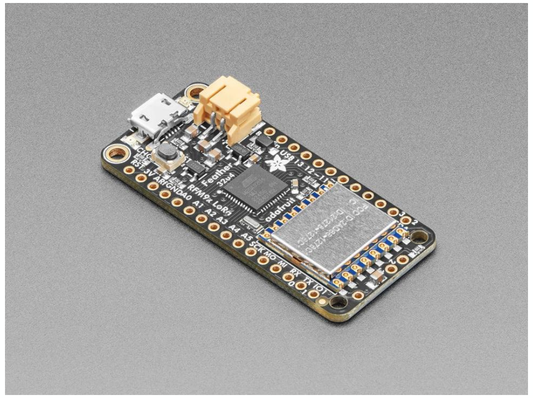
Boiler 4 Launch (22 April)

Project Goals

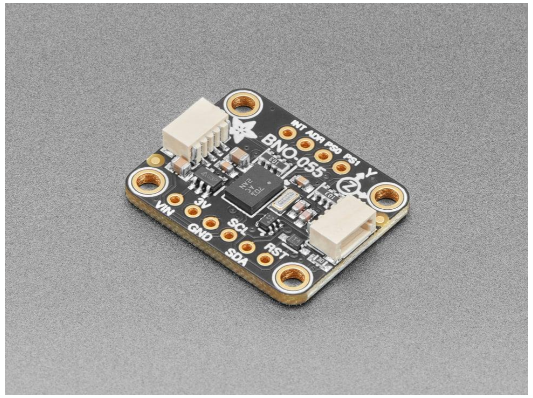
- **Goal:** create a pair of low-cost, versatile embedded systems for low power model rocketry.
- **Flight computer** collects telemetry data and ignites rocket motor when commanded by ground station.
- **Ground station** collects telemetry data, sends launch command to rocket.
- **RF / Communications** sends telemetry data during and after flight.



Barometric Pressure



Feather & LoRa



9-axis DoF

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