

Problem

ADCs are expensive and hard to make, limiting satellite production rate and increasing the cost of experiments for NASA Ames Research Center's Technical and Educational Satellite (TES) program.

Objective

Build an ADCS that is inexpensive, simple to build, and made from off-the-shelf parts.

Requirements

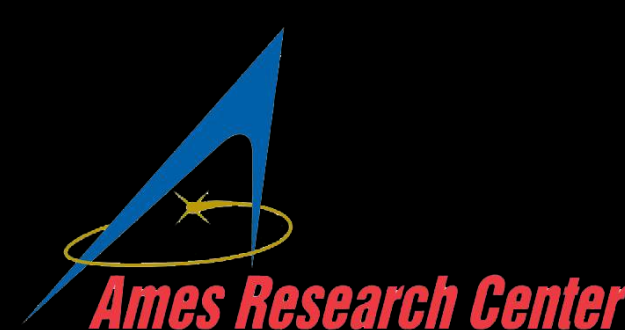
- Fit within 10cm x 10cm x 5cm
- Powered by 7-9V DC, up to 3A continuous
- Communicate over 3.3V UART or SPI bus
- Power system on/off controlled by 3.3V enable signal
- Include 1 reaction wheel, 2 magnetorquers, 4 sun sensors, 1 inertial measurement unit

Minimum Viable Product

Demonstrate full functionality of all subsystems: actuators, communications, sensors, and control loop.

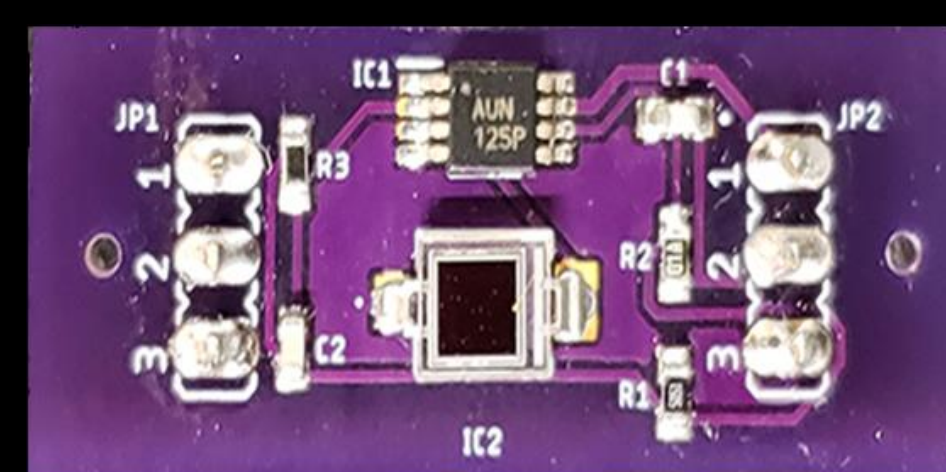


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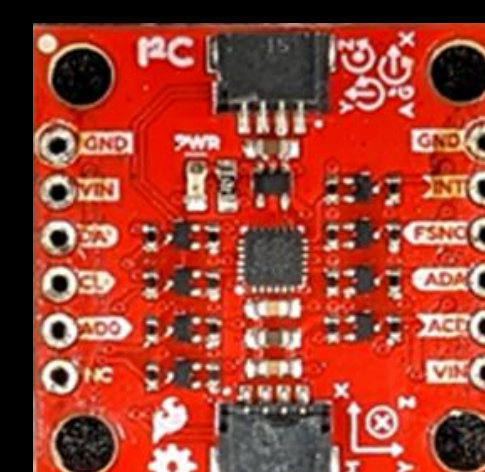


Sensors (Attitude Determination)

- ① 6 Sun Sensors: Determine direction of sun relative to spacecraft. One sensor per face.
- ② Inertial Measurement Unit
 - Magnetometer: Determines magnetic field vector.
 - Gyroscope: Measures spacecraft's angular velocity.



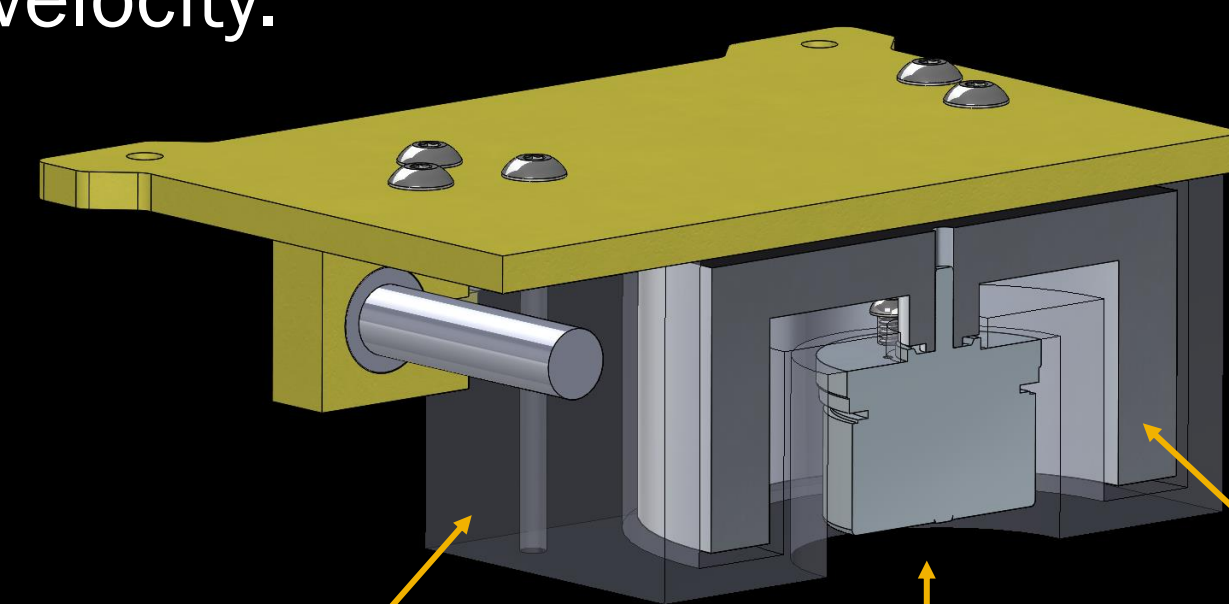
Sun Sensor



IMU

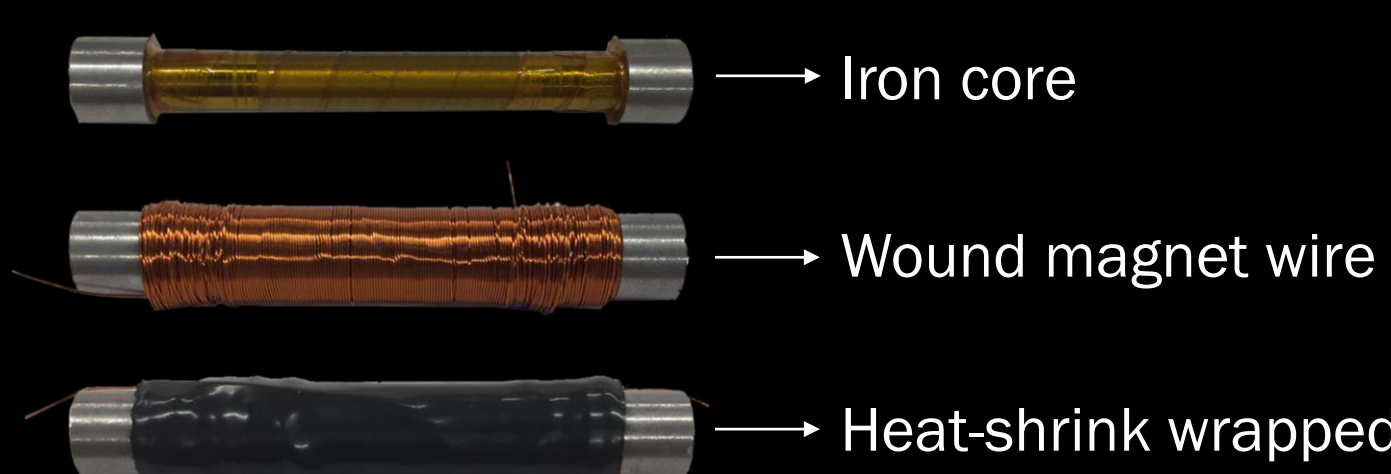
Actuators (Attitude Control)

- ③ Reaction Wheel: Transfers momentum from spacecraft to rotating mass. Reduces spacecraft's angular velocity.



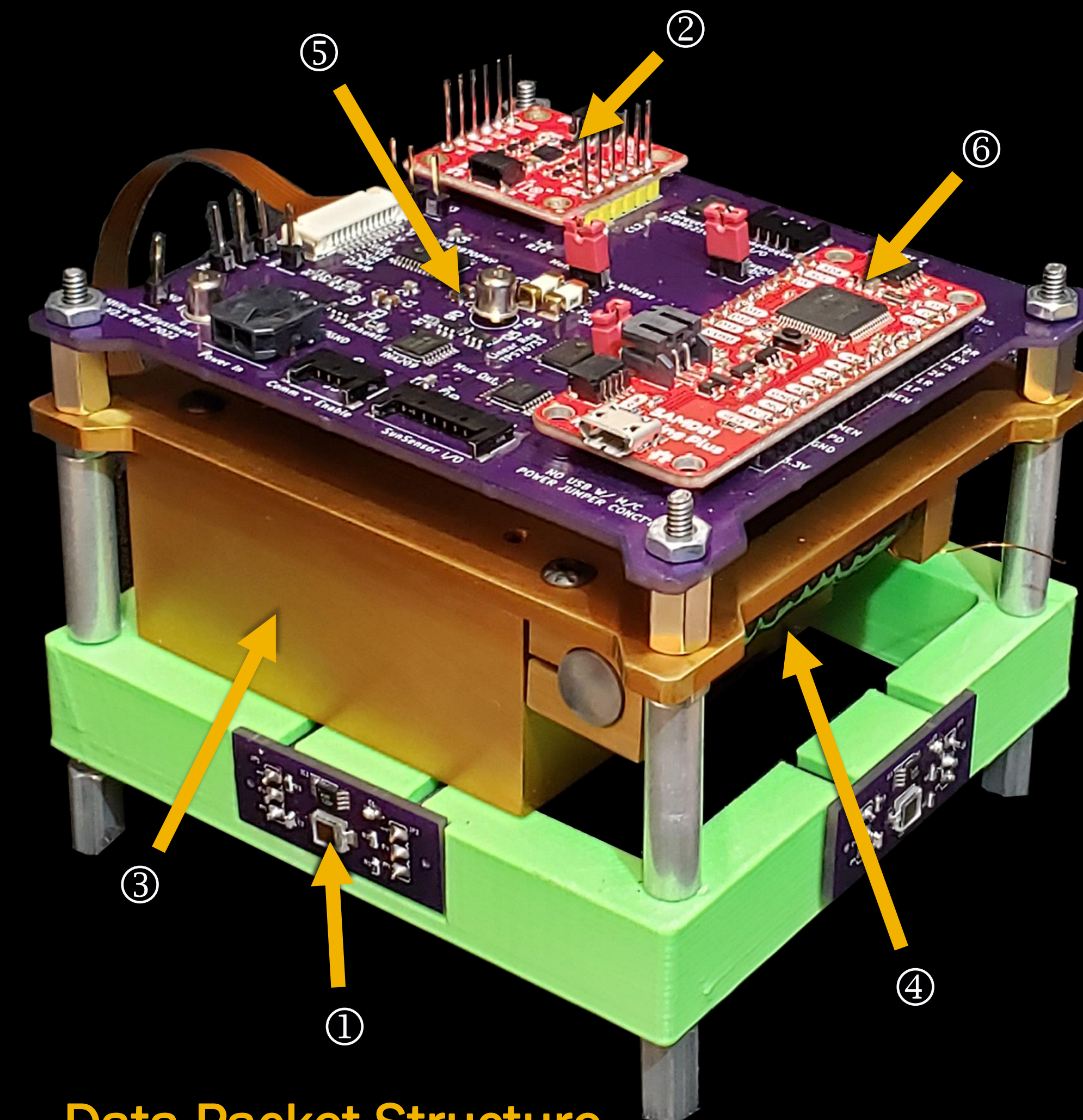
Integrated Motor Housing/Mount 5W Maxon BLDC Reaction Wheel

- ④ 2 Magnetorquers: Transfer momentum from spacecraft to Earth's magnetic field. Hold spacecraft stationary while reaction wheel slows down.



Acknowledgements

Sponsor: Marcus Murbach & the TES team
Faculty Mentor: Dr. Feng Li
Graduate Student Mentor: Ian Glasgow

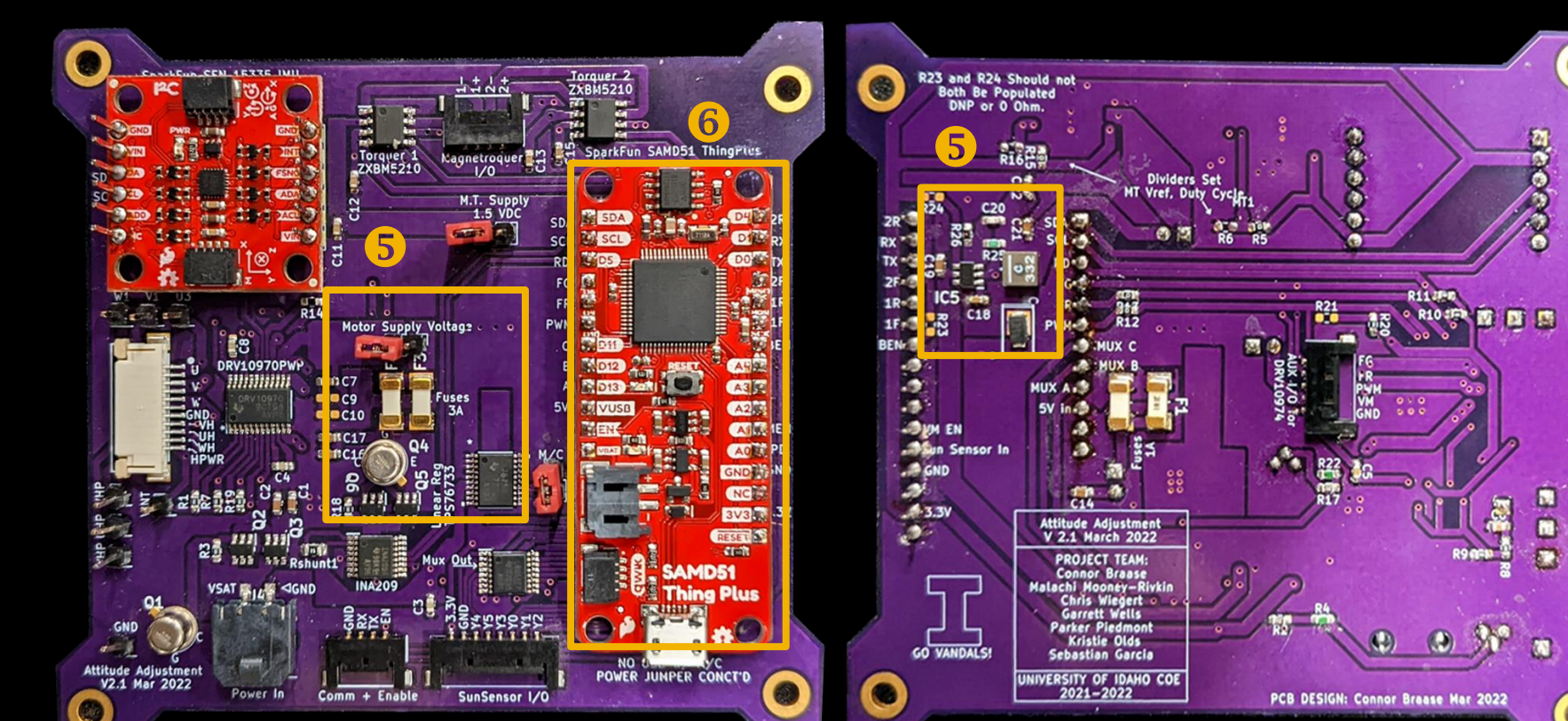


Data Packet Structure

Field	Data Type	Range	Step	Unit
Status	uint8_t	-	-	-
Voltage	fixed5_3_t	-16 - 15.875	0.125	V
Current	int16_t	-32,768 - 32,767	1	mA
Speed	int8_t	-127 - 128	1	RPS
Mag X	int8_t	-127 - 128	1	uT
Mag Y	int8_t	-127 - 128	1	uT
Mag Z	int8_t	-127 - 128	1	uT
Gyro X	fixed5_3_t	-16 - 15.875	0.125	deg/s
Gyro Y	fixed5_3_t	-16 - 15.875	0.125	deg/s
Gyro Z	fixed5_3_t	-16 - 15.875	0.125	deg/s
CRC	uint16_t	-	-	-

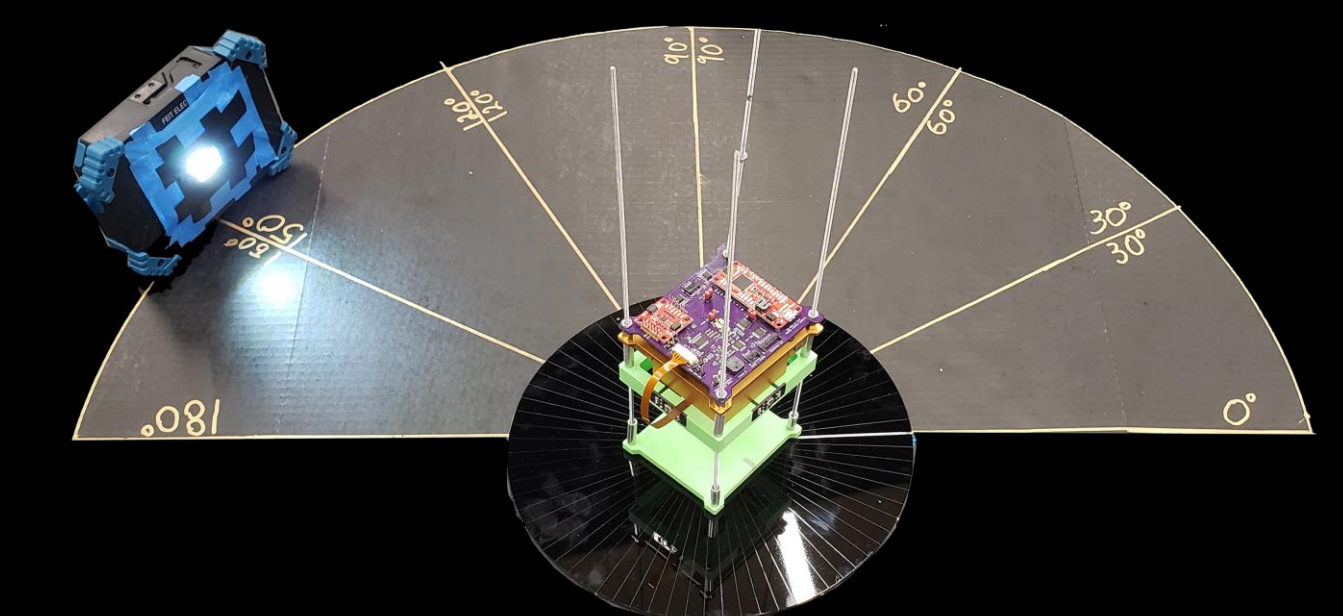
Electronics

- ⑤ Power System: Supplies 5V to microcontroller and 1.5V to magnetorquers. Routes 7.4V TES supply to reaction wheel.
- ⑥ Microcontroller: Determines angular velocity using sensors and self-stabilizes using actuators. Powers sensors with 3.3V. Software tasks scheduled using FreeRTOS.

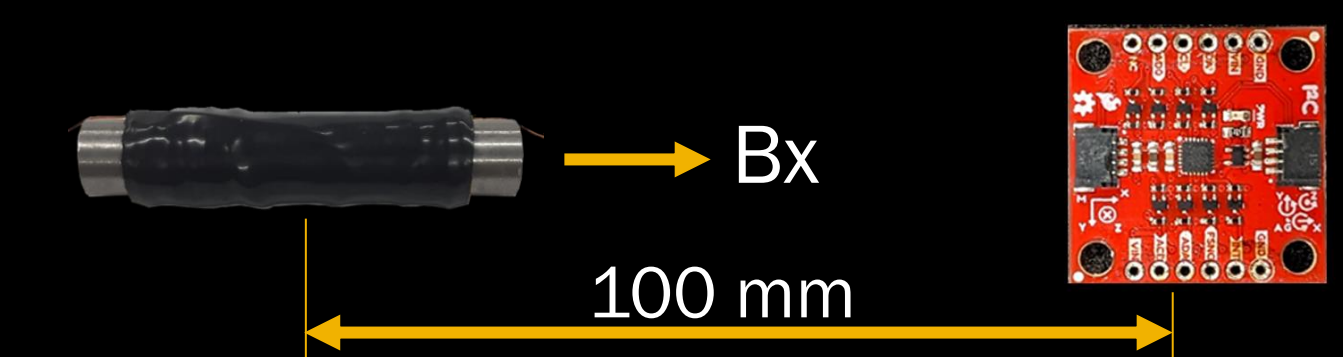


Design Validation

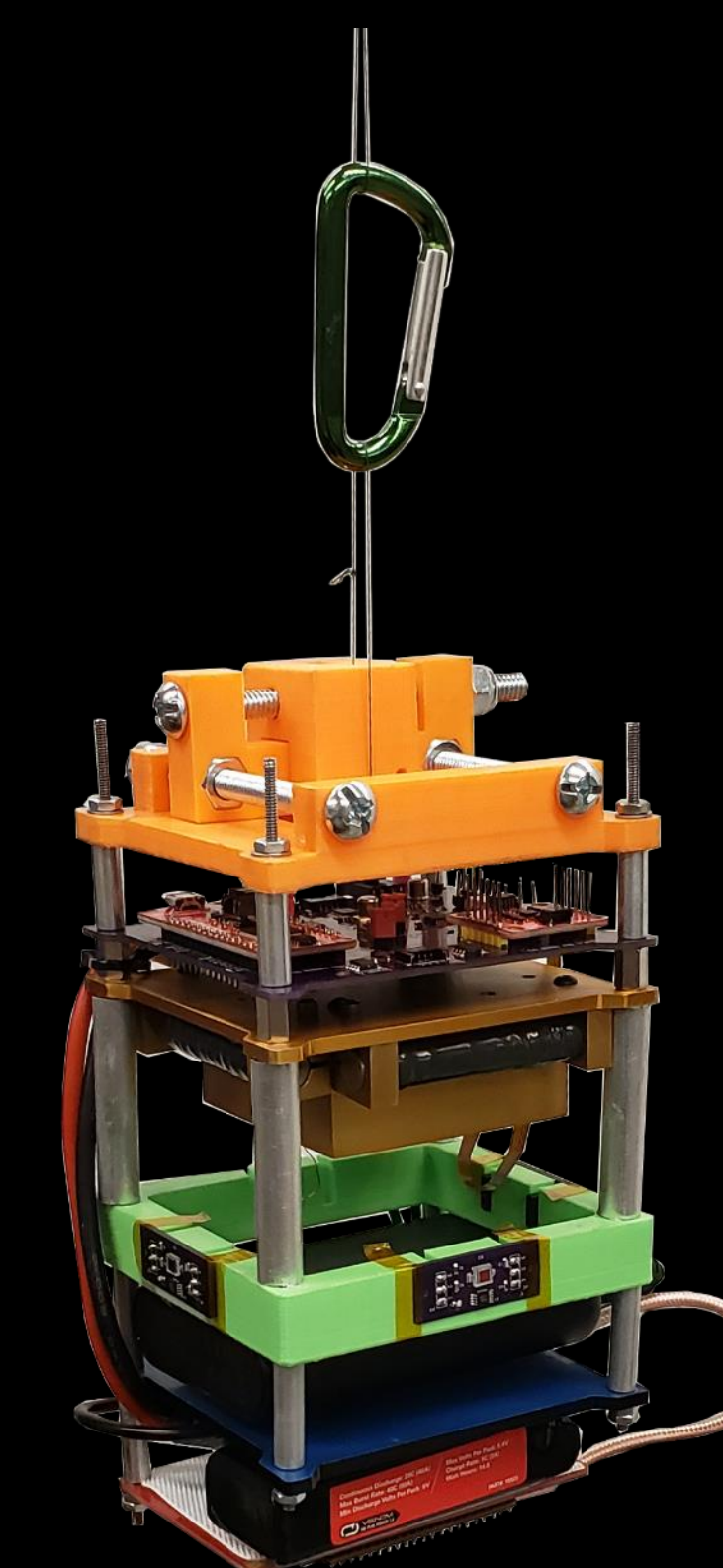
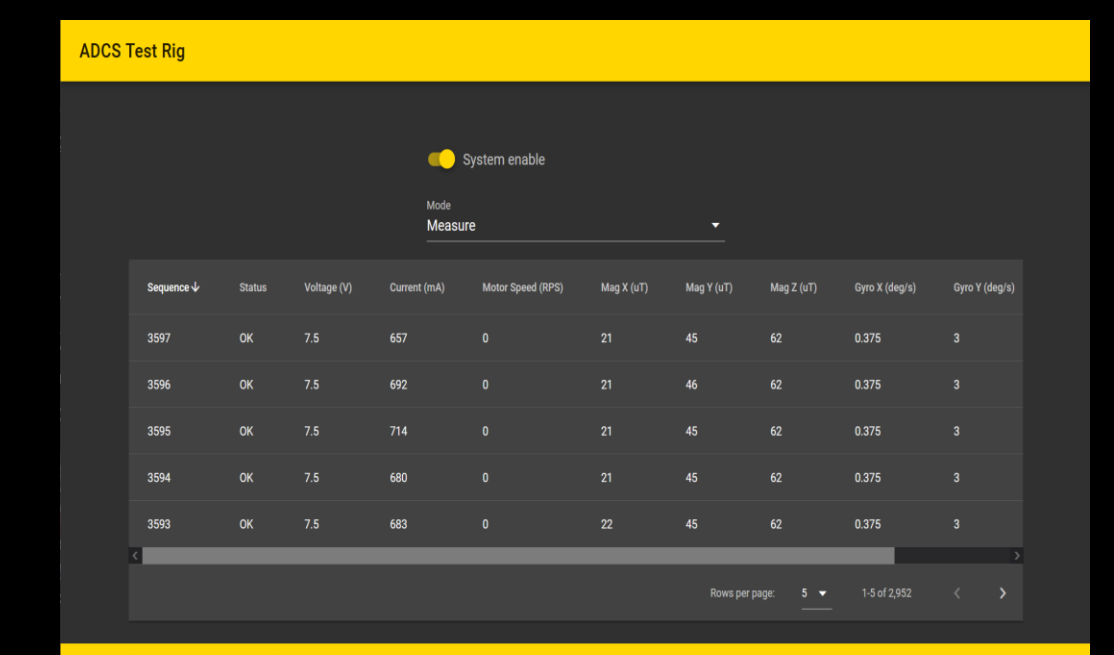
Sun Sensors: Photodiode response and operational amplifiers evaluated by simulating the sun with LED lamp and gimbal.



Magnetorquers: Dipole moment validated experimentally using magnetometer $[0.3 \text{ A} \cdot \text{m}^2]$.



Control & Communication: Web control interface hosted on ESP32 microcontroller sends commands wirelessly to ADCS and logs ADCS data.



Hanging by a Thread

Single-axis microgravity simulation with final assembly including external power and TES emulation. Demonstrates detumbling control loop.



Wiring test probes for validation