Advancing the OreSat ADCS

Design & Implementation of an Open-Source Reaction Wheel System

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The Heart of Satellite Pointing: Reaction Wheels

- Reaction wheels are a core part of a satellite's Attitude Determination & Control System (ADCS), enabling precise, three-axis pointing without the use of limited propellants.
- They operate on the principle of conservation of angular momentum: by accelerating an internal flywheel, the satellite's body is forced to counter-rotate in the opposite direction.
- The primary engineering challenge is commanding the exact motor torque required to point the satellite with extreme accuracy, all while minimizing power consumption and preventing vibrations.

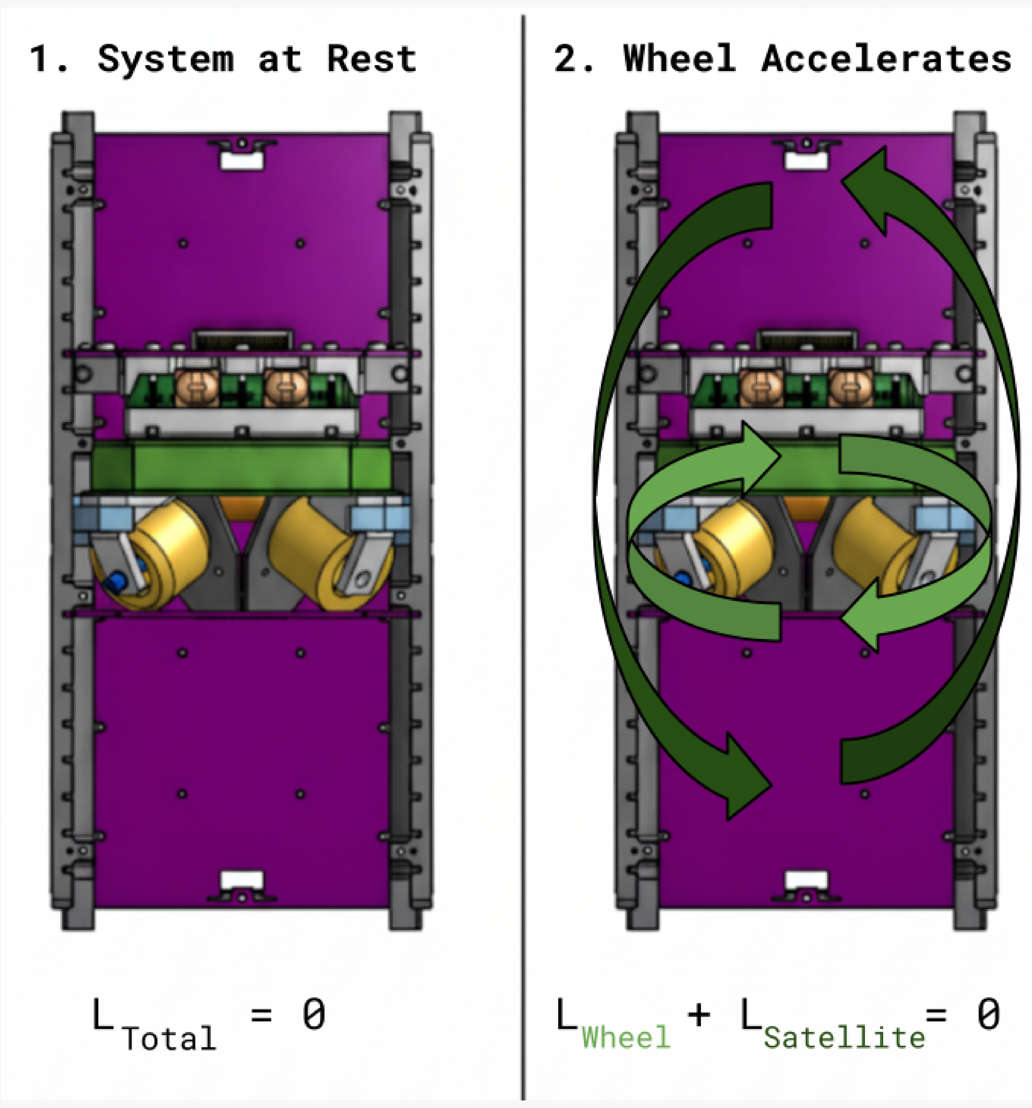

Figure 1. *Oresat 1.0 Reaction Wheel Hardware with Angular Momentum Visual*

Guiding Research Question & Objectives

How can the integration of a modern, RTOS-capable microcontroller and advanced motor control algorithms quantitatively improve the performance and reliability of the OreSat reaction wheel system?

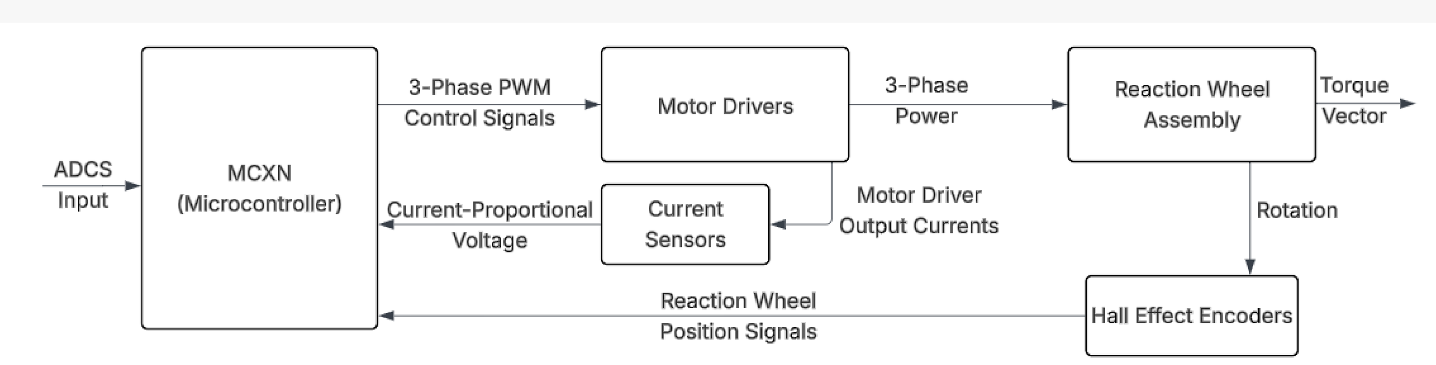

Figure 2. *Basic OreSat Reaction Wheel Controller Block Diagram*

- Determine the flywheel parameters required for optimal performance to support a hardware redesign.
- Develop a new control system PCB centered around an RTOS-capable microcontroller.
- Port the existing flight software to the new hardware to establish a functional baseline within the Zephyr RTOS.
- Implement and quantitatively compare Trapezoidal, Sinusoidal, and Field-Oriented Control (FOC) algorithms into Zephyr RTOS.
- Release a final, robust, and open-source system for PSAS and the student aerospace community.

System Modeling & Mechanical Design

- Developed a series of Python scripts to model OreSat inertial demands for both the 2U and 3U CubeSats to determine the optimal flywheel mass and dimensions for momentum storage.

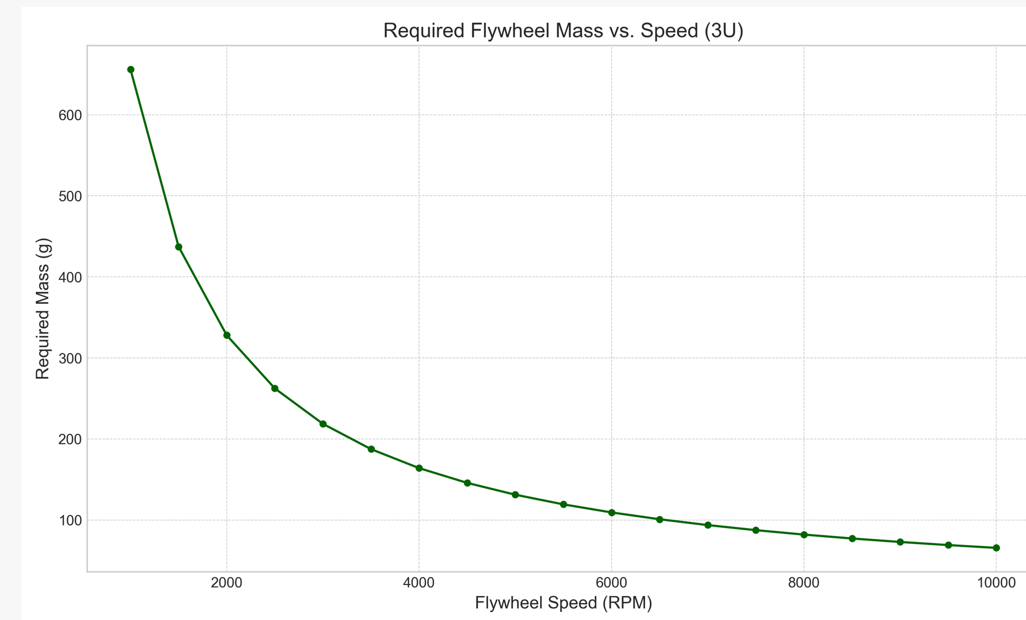

Figure 3. *Required Flywheel Mass vs. Speed (3U)*

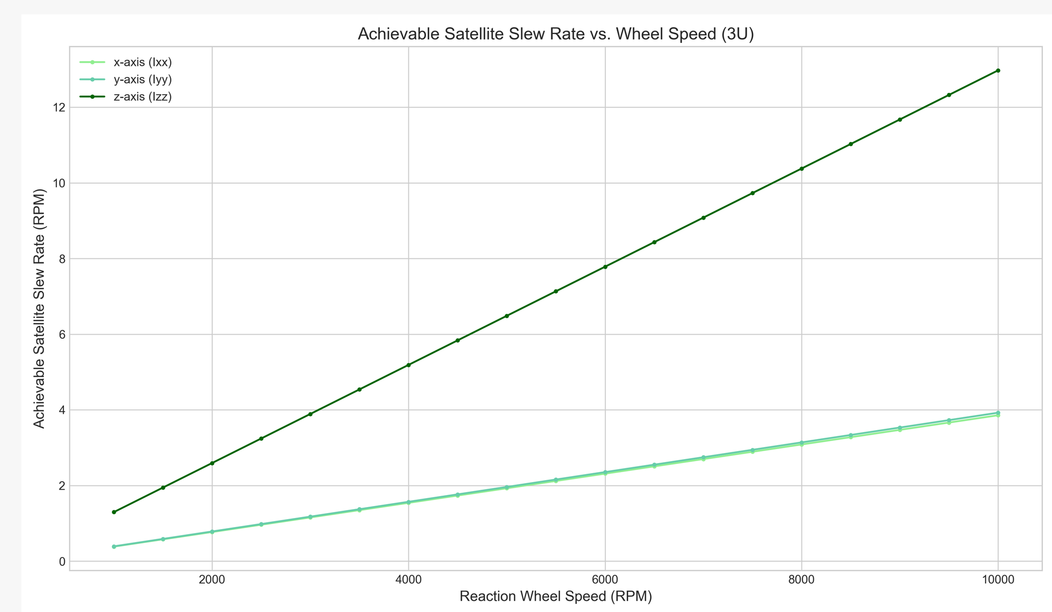

Figure 4. *Achievable Satellite Slew Rate vs. Wheel Speed (3U)*

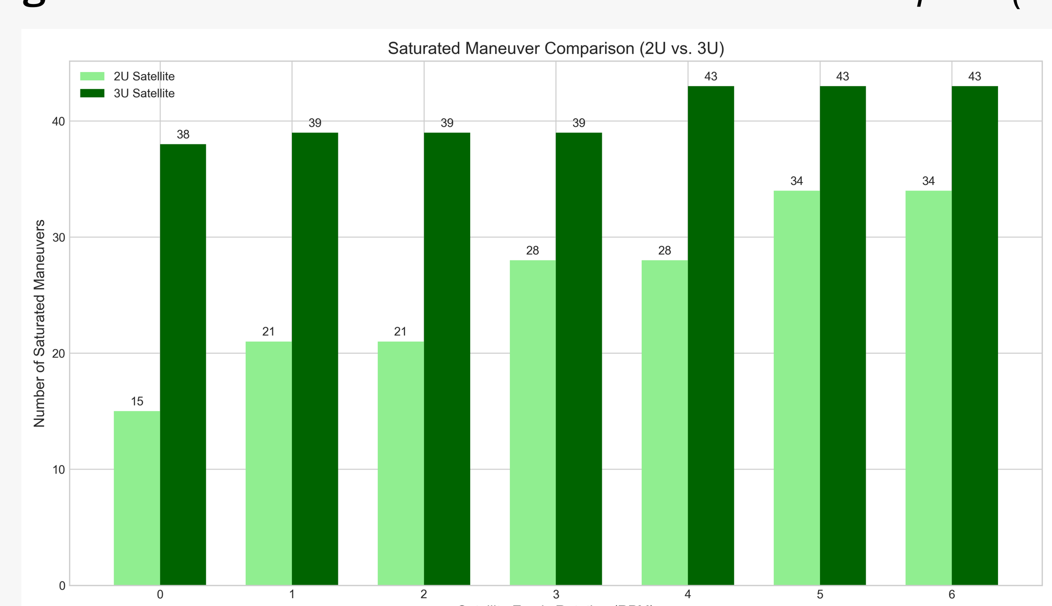

Figure 5. *Saturated Maneuver Comparison (2U vs. 3U)*

- Collaborated with the PSAS mechanical engineering team on the revised flywheel design, providing key specifications derived from system modeling.

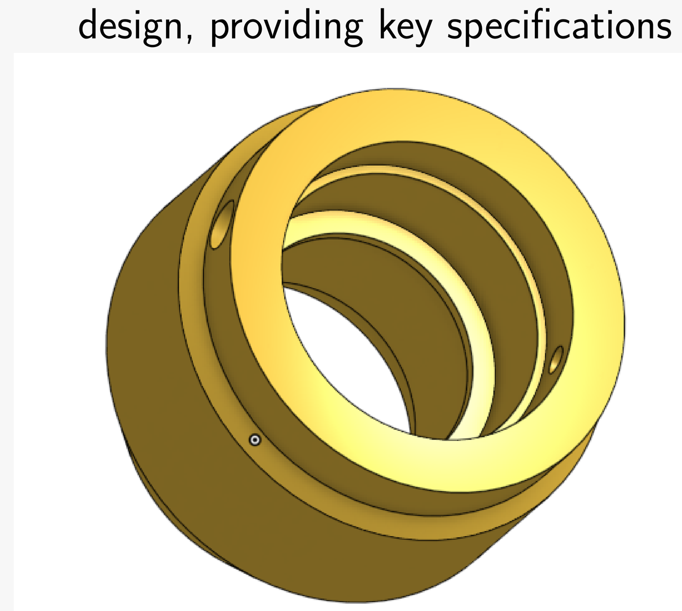

Figure 6. *Old Flywheel (42.168g)*

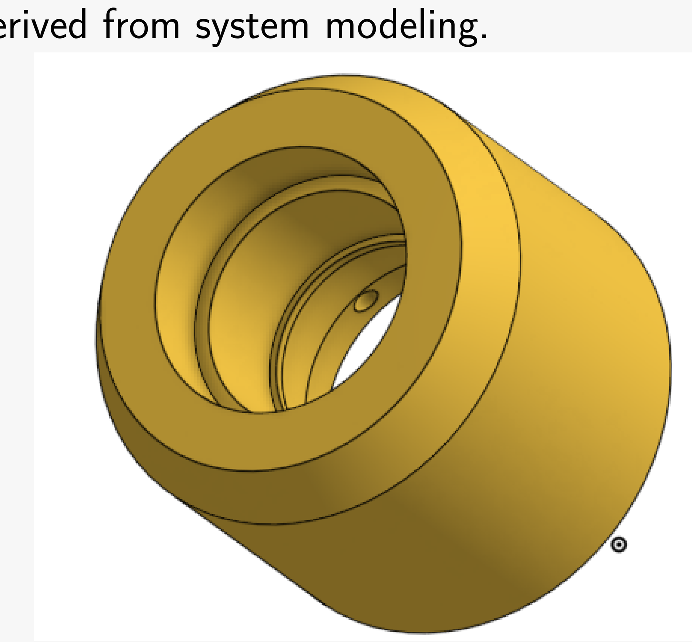

Figure 7. *New Flywheel (70.49g)*

Motor Control Algorithm Comparison

- **Trapezoidal Control:** Simple to implement but creates high "torque ripple," causing vibrations that interfere with sensor stability.
- **Sinusoidal Control:** Reduces vibration with sinusoidal currents but can be inefficient at high speeds.
- **Field-Oriented Control (FOC):** Uses real-time current feedback to precisely control the motor's internal magnetic field, resulting in the smoothest torque and highest efficiency across the entire speed range.

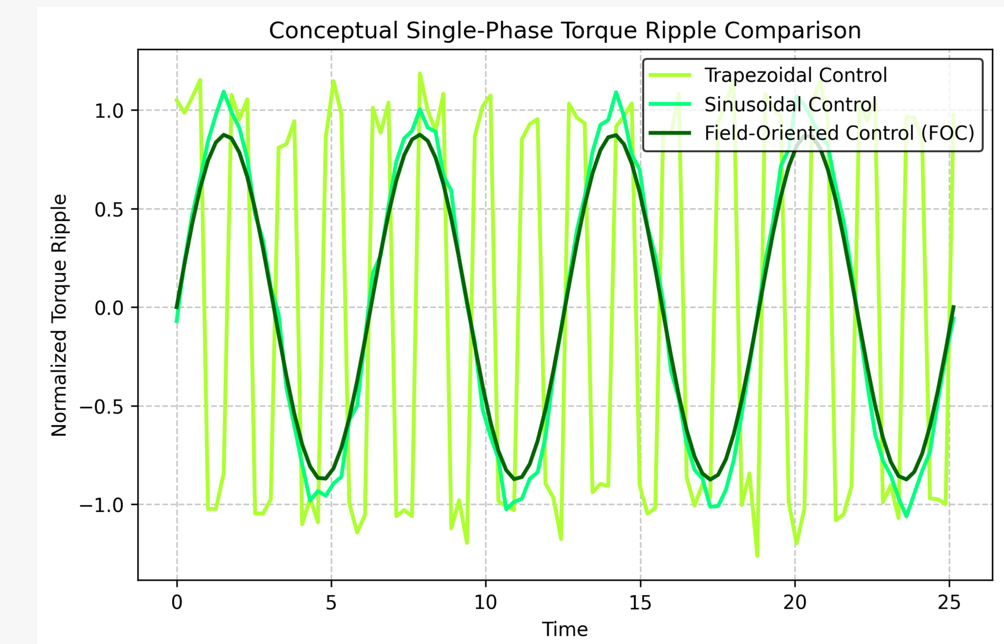

Figure 7. *Conceptual Torque Ripple Comparison*

Next-Generation Control Hardware

- **To Point Accurately and Efficiently:** As the computational core, this board executes real-time control algorithms on an RTOS, generates high-frequency PWM commands for the external power stage, and processes all feedback from external sensors.
- **To Ensure Reliability:** A 6-layer design with dedicated ground, power, and signal planes provides excellent EMI immunity and signal integrity, creating a robust system tolerant to the noise inherent in motor control.

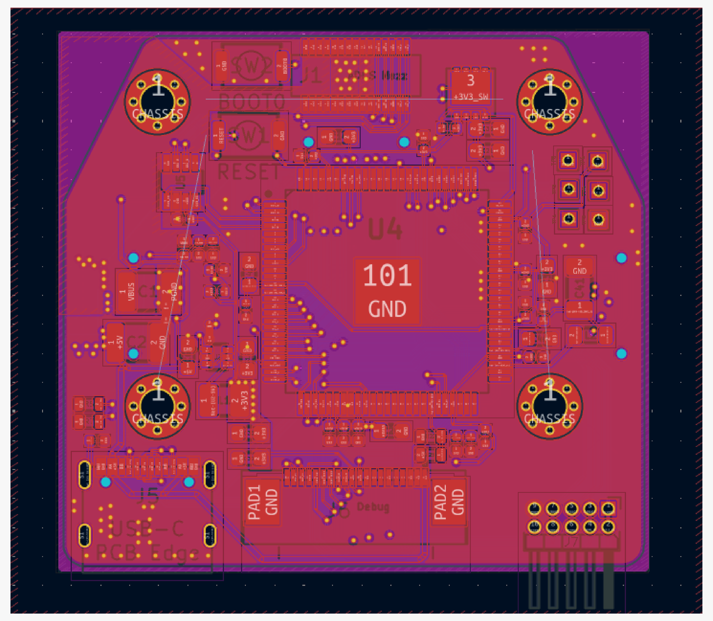

Figure 8. *Control PCB Front Layer*

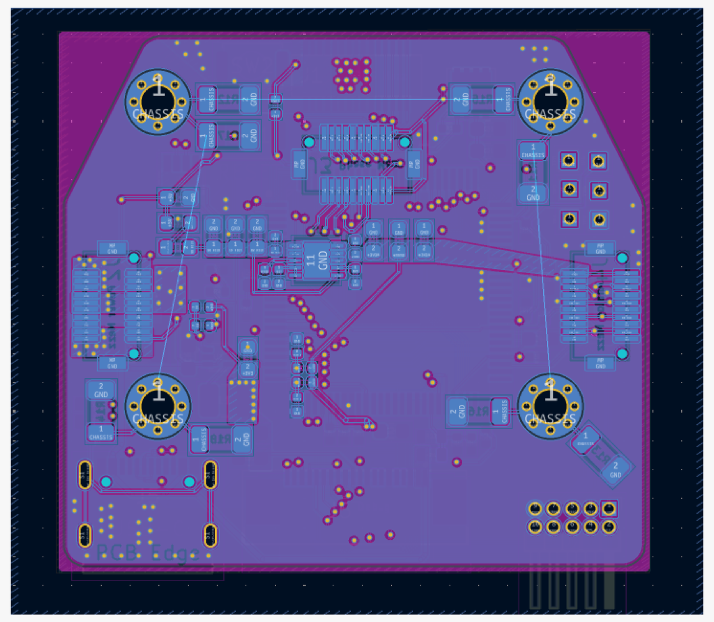

Figure 9. *Control PCB Back Layer*

Future Work & Open-Source Impact

- **Phase 1 (Fall 2025): Software Implementation**
  Port baseline code and implement all three control algorithms in Zephyr RTOS..
- **Phase 2 (Winter 2026): Quantitative Comparison**
  Rigorously test and collect performance data to select the optimal algorithm.
- **Phase 3 (Spring 2026): Final Integration & Thesis**
  Implement the winning algorithm in flight-ready software and fully document all findings in my M.S. thesis.

This research will produce a verified, open-source design that empowers OreSat and the next generation of student-led space missions by providing a high-performance, low-cost alternative to commercial reaction wheel systems.

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