

## **Abstract Title**

Stabilizing a Cosmic-Watch Payload with an Arduino-Controlled Gimbal for Balloon Flight

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## **Abstract Content**

We investigate whether actively stabilizing a **Cosmic Watch** payload during high-altitude balloon flight improves the accuracy of muon-count data. Crosswinds and gondola swing can pitch/roll the detector, introducing angle-dependent acceptance changes. We built a compact, two-axis gimbal and closed-loop controller to keep the detector level.

The detector consists of the standard Cosmic Watch PCB with SiPM and scintillator acrylic, paired with an Arduino Nano for logging counts. I designed and implemented the stabilization electronics and firmware: an Arduino Nano reads an MPU-6050 IMU and commands two micro-servos via PWM. The code performs sensor calibration, complementary filtering of gyro/accel signals, and a tunable PID loop to drive the gimbal toward a target attitude. I also wired power distribution, signal routing, and safe start-up/shut-down for ground tests. The gimbal structure was modeled in Fusion 360 and 3D-printed; the assembled payload was mounted as a pendulum to emulate balloon swing.

In bench tests, the controller reduced peak tilt during induced swings and returned the detector toward level between oscillations. However, latency and torque limits in the servos caused tracking error at higher swing rates, and recovery time increased when disturbances were large. These limitations point to the need for faster servos (or brushless gimbal motors), improved tuning, and better vibration isolation.

We conclude that active stabilization is a promising path to maintain detector orientation and reduce systematic error in count rates. Future work will integrate higher-speed actuators,

temperature management for electronics, torsional damping of the gondola, and in-flight characterization of angle-dependent acceptance.

### **Research Role**

I led the embedded programming and electronics integration. I wired the Cosmic Watch, IMU, servos, and power system; verified signal integrity and grounding; and wrote the Arduino/C++ firmware for IMU calibration, complementary filtering, and PID attitude control, including data logging and a serial debug mode for tuning. I tuned control gains, characterized latency and overshoot, and measured angular deviation during pendulum tests. I also coordinated firmware changes with mechanical revisions, documented build procedures and test results, and ensured reliable start-up/shut-down behavior for ground experiments.