ADCS Fault Injection and Threshold Breach Analysis

1. Introduction

The On-Board Computer (OBC) is central to satellite operation, managing subsystems and ensuring mission requirements are met. In this challenge, we focused on the Attitude Determination and Control System (ADCS). The objective was to test system behavior under two fault conditions — **gyro bias** and **actuator saturation** — and verify whether performance thresholds were maintained.

2. Methodology

The ADCS simulation was executed inside a Dockerized environment. The workflow was split into three parallel processes:

- **ADCS Loop (C++ app):** Runs the control loop at 50 Hz.
- **Telemetry Logger (Python):** Captures state variables via UDP and stores them in CSV.
- **Fault Injector (Python):** Sends commands to introduce sensor bias and actuator saturation.

This setup replicates realistic OBC fault scenarios.

3. Experiments

Three cases were executed:

1. **Nominal Case:** No faults applied. ADCS successfully reduced angular rates towards zero.
2. **Gyro Bias:** Bias of 0.03 rad/s introduced. Angular rates exhibited an offset and failed to converge exactly to zero, but control continued.
3. **Actuator Saturation:** Torque saturation of 0.02 Nm applied. Controller outputs were capped, preventing the system from reducing angular rates below the threshold.

4. Results

Figure 1. Angular Rate Norm (‖w‖ vs Step):

- Nominal: Converges.
- With Bias: Offset persists.
- With Saturation: Fails to meet threshold (‖w‖ > 0.1 rad/s).

Figure 2. Actuator Saturation Flag (Sat vs Step):

- Value = 0 (nominal, bias).
- Switches to 1 after saturation fault injection.

CSV logs confirm the above behaviours.

5. Discussion

- **Gyro Bias** degrades estimation, but system continues partial control.

- **Saturation** fundamentally limits actuator authority, breaching performance requirements.
- Demonstrates the importance of designing margins in actuator sizing and implementing robust fault detection.

6. Conclusion

The OBC/ADCS system functions nominally and under bias fault but fails under actuator saturation. This demonstrates a clear **performance threshold breach** when actuators are limited, fulfilling the challenge requirement.