# Attitude Control Final Report

C1C Connor Emmons, C1C Riley Lubic

Lt Col Collins

Section M4A

9 Dec 24

Documentation Statement:

# Abstract

To be completed with the project’s summary objectives, methods, and findings.

# Nomenclature

To be populated with the necessary symbols and definitions.

# Introduction

The objective of this project is to design and analyze an attitude control system for FalconSAT-9, a next-generation small satellite funded by the Air Force Research Laboratory (AFRL). The spacecraft will conduct advanced propulsion and space maneuvering experiments using an experimental Hall-effect thruster. FalconSAT-9 will be deployed into a 500 km altitude polar orbit as a secondary payload on a Falcon 9 launch vehicle. Upon deployment, the primary mission phases include detumbling the satellite and achieving precise orbit-fixed orientation during propulsion experiments.

The attitude determination and control system (ADCS) must counteract initial angular rates, environmental disturbances, and constant torques induced by propulsion misalignment. The system integrates multiple control modes to meet the spacecraft's mission objectives: Control Mode 0 focuses on detumbling, while Control Mode 1 ensures precise attitude during propulsion experiments. This report outlines the theoretical analysis, control design, and experimental validation necessary to meet these requirements.

# Theory

### Assumptions

The analysis assumes the satellite operates under idealized conditions, including:

1. A rigid-body spacecraft with mass properties derived from CAD body-fixed and principal frames.
2. The Earth is modeled as a perfect sphere with uniform density.
3. External disturbance torques include gravity gradient, atmospheric drag, and magnetic torques; solar pressure is negligible.

### Mathematical Techniques

The equations of motion (EOM) for the spacecraft are derived in the orbital local vertical/local horizontal (LVLH) reference frame. Nonlinear EOMs account for gravity gradient torque and reaction wheel control, with the LVLH frame origin at the spacecraft's center of mass. These EOMs are linearized about the nominal LVLH orientation for state-space representation.

The linearized state-space form is defined as:

where A, B, C, D matrices represent system dynamics, input, output, and feedthrough, respectively. Input u includes reaction wheel torques, while state x includes angular velocities and attitude deviations.

### Control Mode 0

Micro-thrusters are modeled with on-off (bang-bang) dynamics to detumble the spacecraft. A relay control law using proportional-derivative (PD) gains stabilizes the pitch axis within two degrees of the desired orientation. The thruster delay is modeled as a 0.1-second actuator response time.

### Control Mode 1

Reaction wheels provide continuous 3-axis control for precise slewing and disturbance rejection. Control laws are designed to meet steady-state and transient performance requirements under misalignment-induced and environmental disturbance torques. The ADCS Kalman filter integrates sensor data, including sun sensors, magnetometers, and star trackers, to estimate the spacecraft's attitude in real-time.

Theoretical predictions validate the control modes against nonlinear simulations. State-space models and block diagrams ensure the system meets mission requirements without saturating actuator limits.

# Theoretical Predictions

This section will be completed with the outcomes of the theoretical development once the calculations are finalized.

# Experimental Results

This section will present experimental or computational findings. To be completed post-data collection.

# Discussion

This section will analyze the results, compare experimental data with theoretical predictions, and discuss discrepancies or sources of error.

# Conclusions and Recommendations

To be completed with a concise summary of findings and recommendations for future work.

# Appendices

Include supplementary materials, calculations, and MATLAB Simulink block diagrams here.