

# Guidance Navigation & Control

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# Agenda

- Design Overview
  - GNC Requirements, & Constraints
  - Hardware Overview
  - Operating Modes & Block Diagrams
- Components Selection
  - Integrated System Update
  - ADCS Breakdown
- Pointing Budget
  - Pointing Simulation
  - Ground Track
  - Results
- Subsystem Development
  - Risk and Risk Mitigation
  - Subsystem Status – CDR through FSR
  - Next Steps



# Design Overview

Detumble	Transmitting	Mission	Charging	Safe
When the satellite is first ejected it will be in tumble and the satellite will need to dump enough momentum to operate nominal ADCS maneuvers.	Transmitting allows for ease of access to telemetry data and command of the satellite. This mode will begin when the satellite is within line of sight with the ground station.	Mission mode is the mode POLAR enters to observe satellites in LEO and collect images	Charge mode is the mode POLAR enters to be as power positive as possible and charge the batteries for power negative tasks such as observation and image downlinking.	Safe mode is designed to be entered and remained in indefinitely to allow the ground team to perform system health checks, and troubleshoot any possible problems



# Assumptions

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POLAR will be deployed into an ISS orbit

The LEO Environment will be Stable

Detailed information about the observed LEO satellites, including their physical characteristics is available to the observation satellite

The mission assumes access to an accurate Earth gravity model for precise orbit determination and prediction

The mission assumes relatively stable atmospheric conditions that do not significantly affect the satellite's pointing accuracy

Sensors used for attitude determination are well-calibrated, with known accuracy and precision specifications

The field of view of the observation instruments is known and stable, allowing for precise satellite tracking



# Requirements

Requirement #:	Derived From:	Requirement:
GNC - 3	SAT - 1	The GNC subsystem shall be capable of slewing the satellite at a rate of at least 1.5 degrees per second.
GNC - 4	SAT - 1	The GNC subsystem shall provide three-axis attitude control with a pointing accuracy of 5.2 degrees.
GNC - 5	SAT - 1	The GNC subsystem shall be capable of attitude determination with an error of 0.5 degrees. (TBV)
GNC - 7	SAT - 26	The GNC subsystem shall not perform attitude control maneuvers for 15 minutes after ejection.
GNC - 9	GNC - 3	Reaction wheels shall provide at least 4.8mNms of momentum storage about any axis.
GNC - 10	GNC - 3	Reaction wheels shall be capable of a torque of at least 0.32 mNm about all three axes.



# Requirements

Requirement #:	Derived From:	Requirement:
GNC - 13	SAT - 1, SAT - 11	Magnetorquers shall provide a magnetic moment of at least 0.089 Am <sup>2</sup> .
GNC - 15	GNC - 5	Magnetometers shall be capable of reading geomagnetic field measurements of at least $\pm 1$ gauss.
GNC - 16	GNC - 5	Magnetometers shall not exceed a noise density of (TBV)
GNC - 18	GNC - 5	Gyroscopes shall be capable of providing angular rates of at least (TBV) degrees per second.

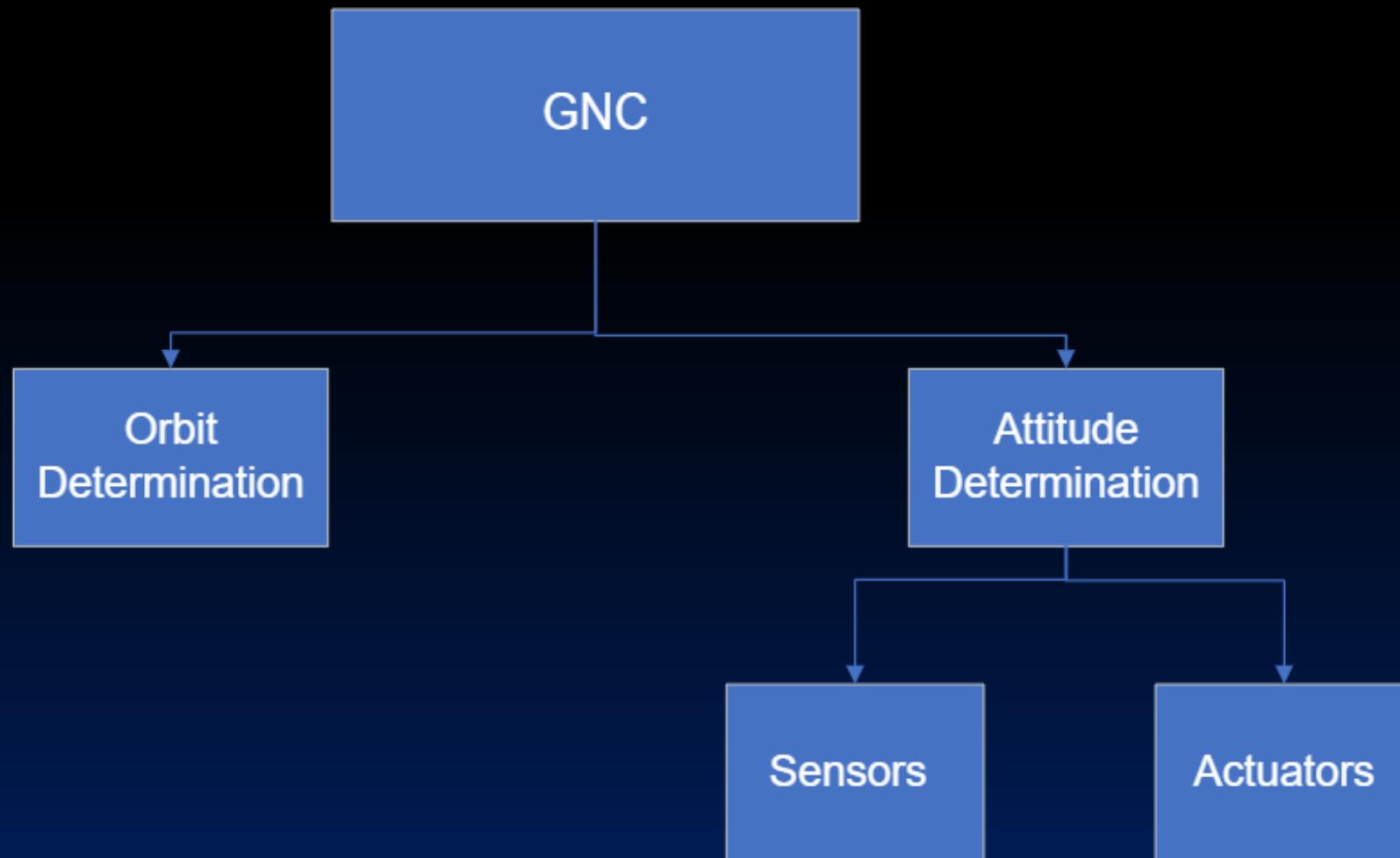


# Constraints

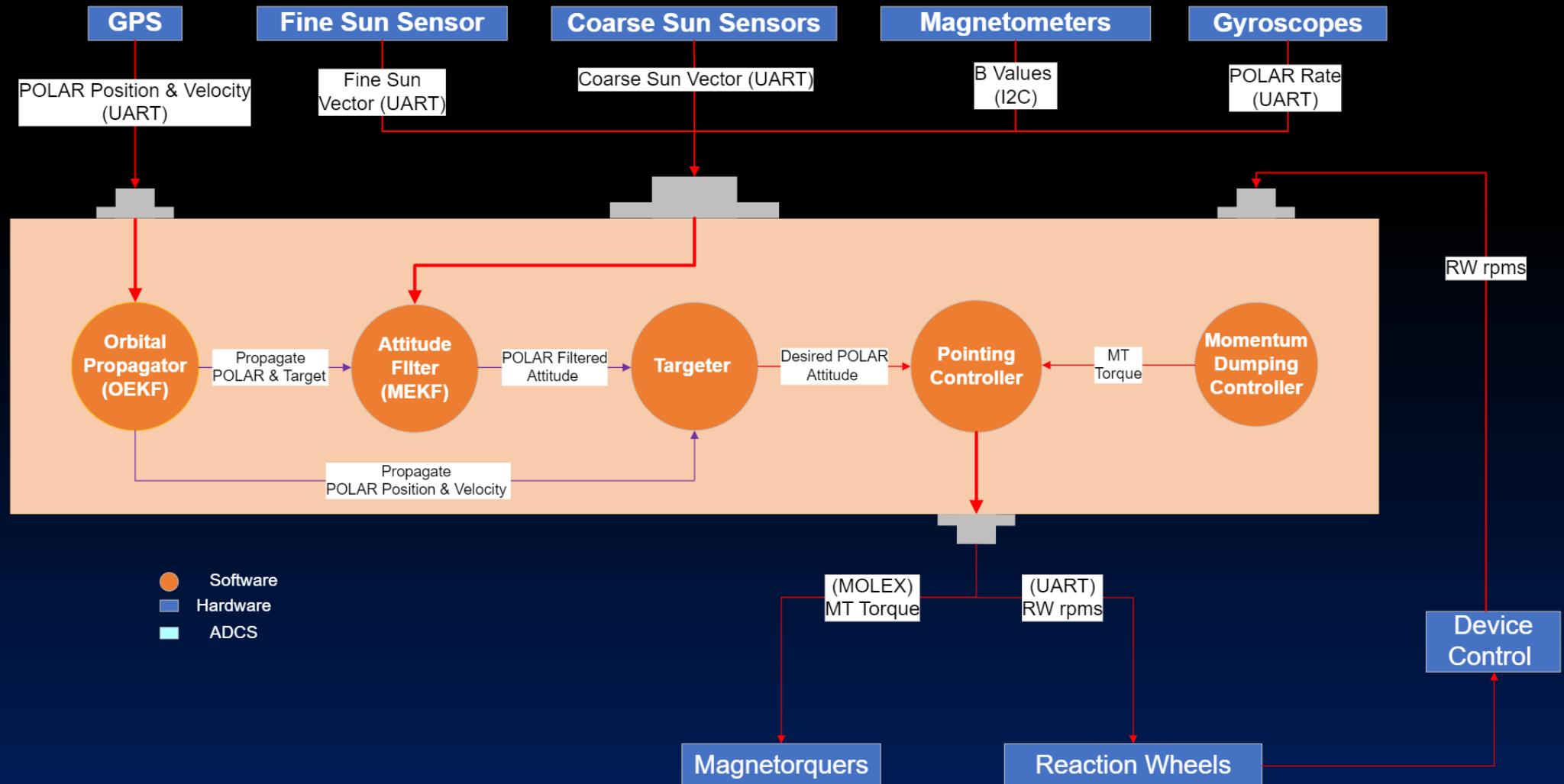
Constraints	Imposed by
<b>Attitude exclusion of 30 degrees on the +Z axis from the Earth and the Sun</b>	<b>Sensitivity of Payload</b>
<b>Can only do mission science on the sun side of the Earth</b>	<b>Requirements of Payload</b>
<b>Magnetometers cannot be used while utilizing magnetorquers</b>	<b>Requirements of Magnetometers</b>
<b>Must put the fine sun sensor on the opposite face of the optical payload</b>	<b>Requirements of the Payload</b>



# Subsystem Architecture

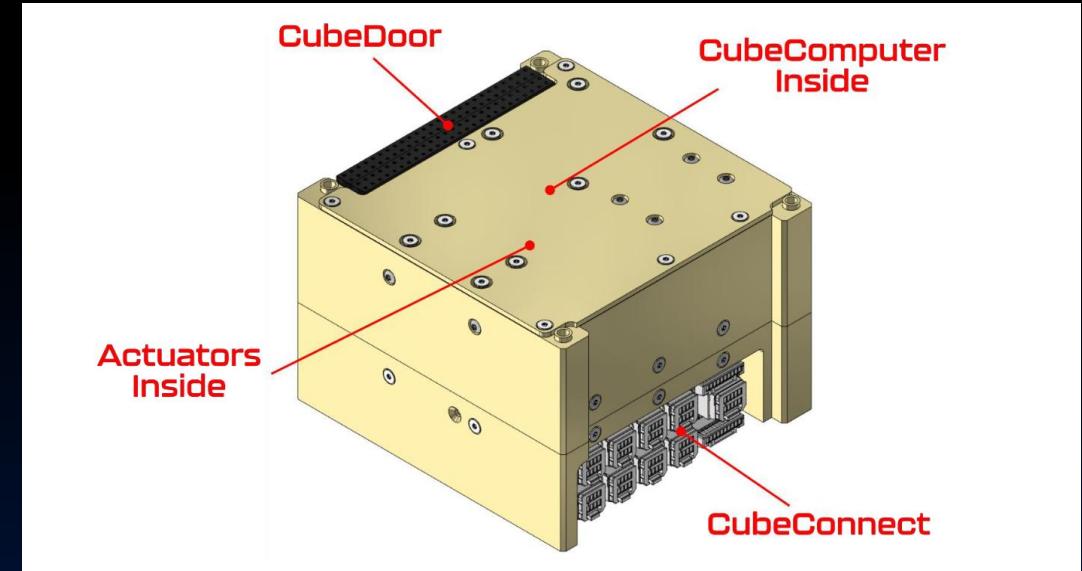
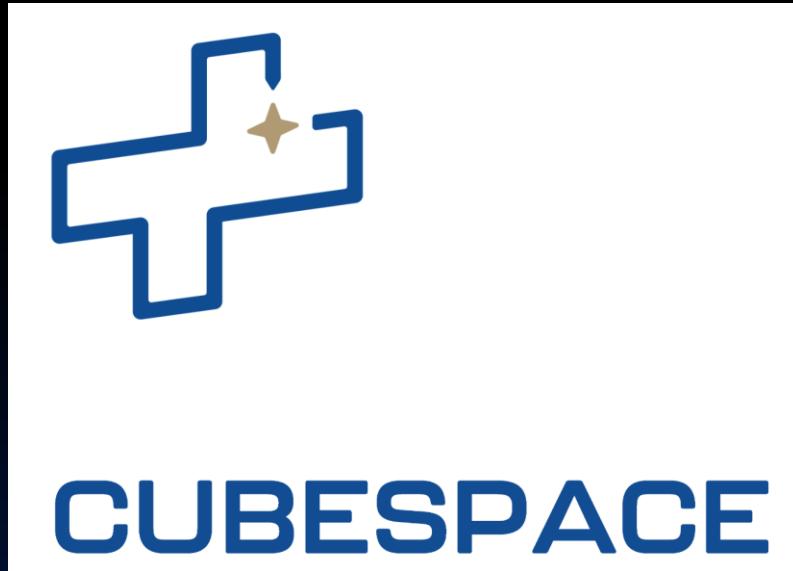


# GNC ICD Schematic Interface

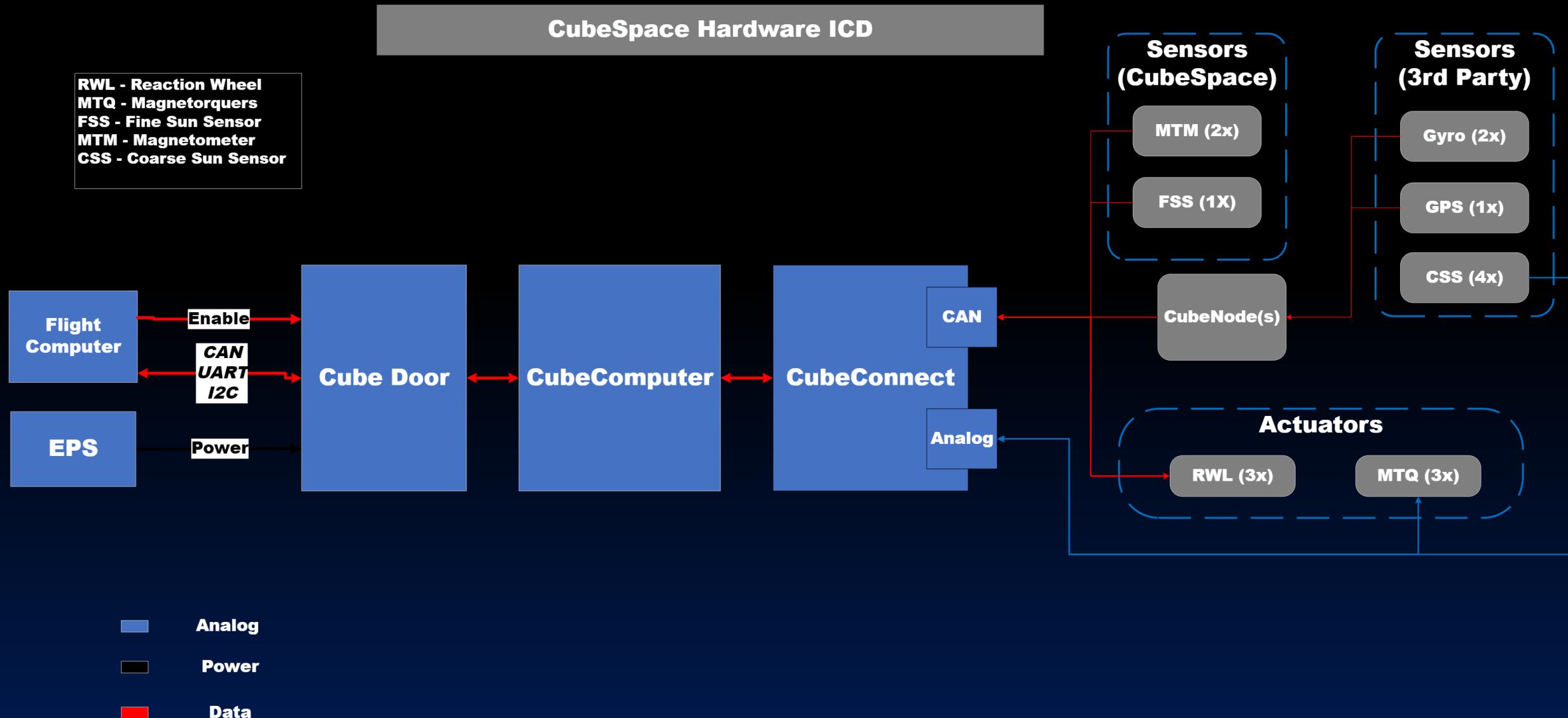




# Integrated System Update



CubeSpace - Gen 2 ADCS

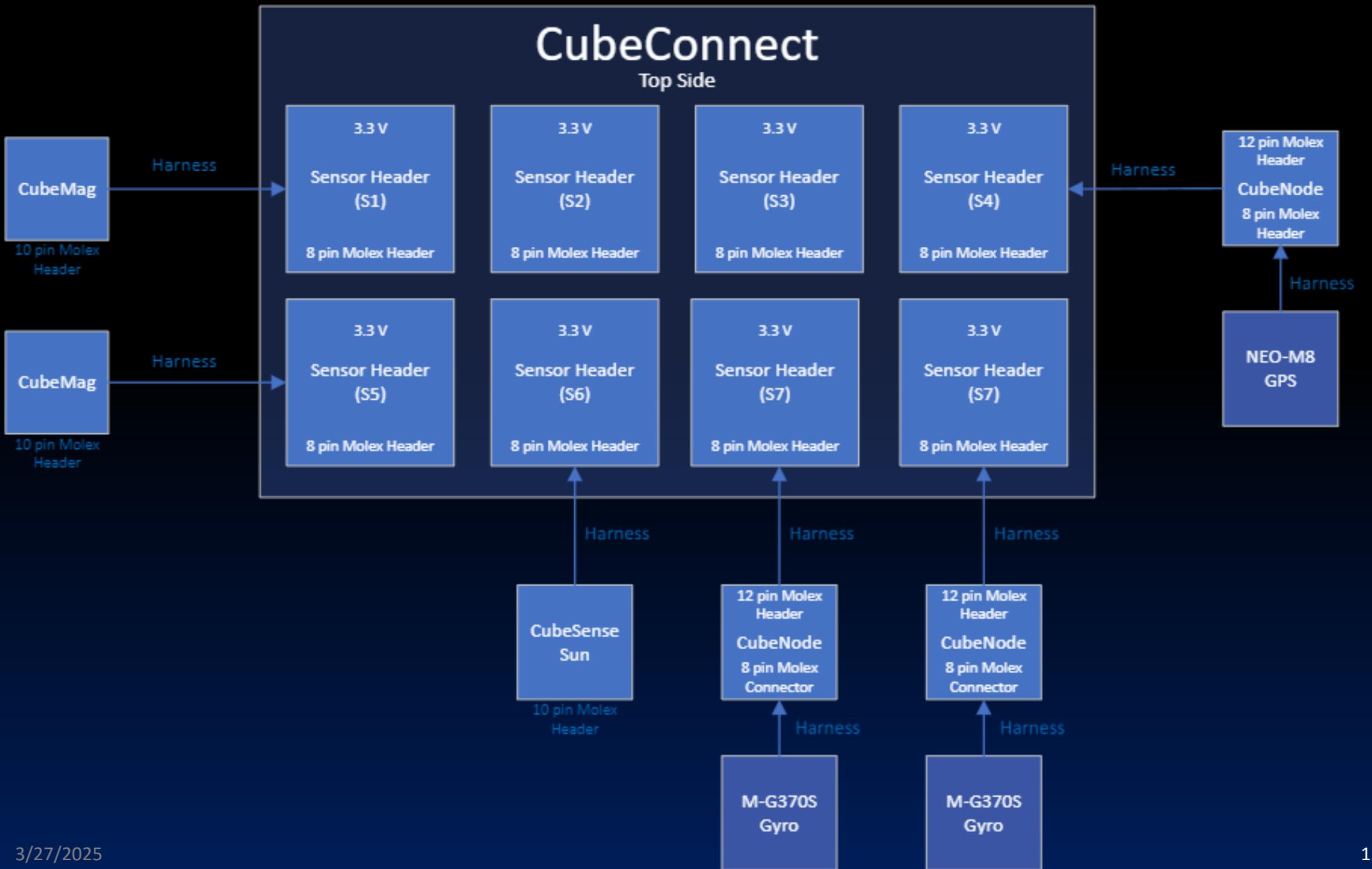




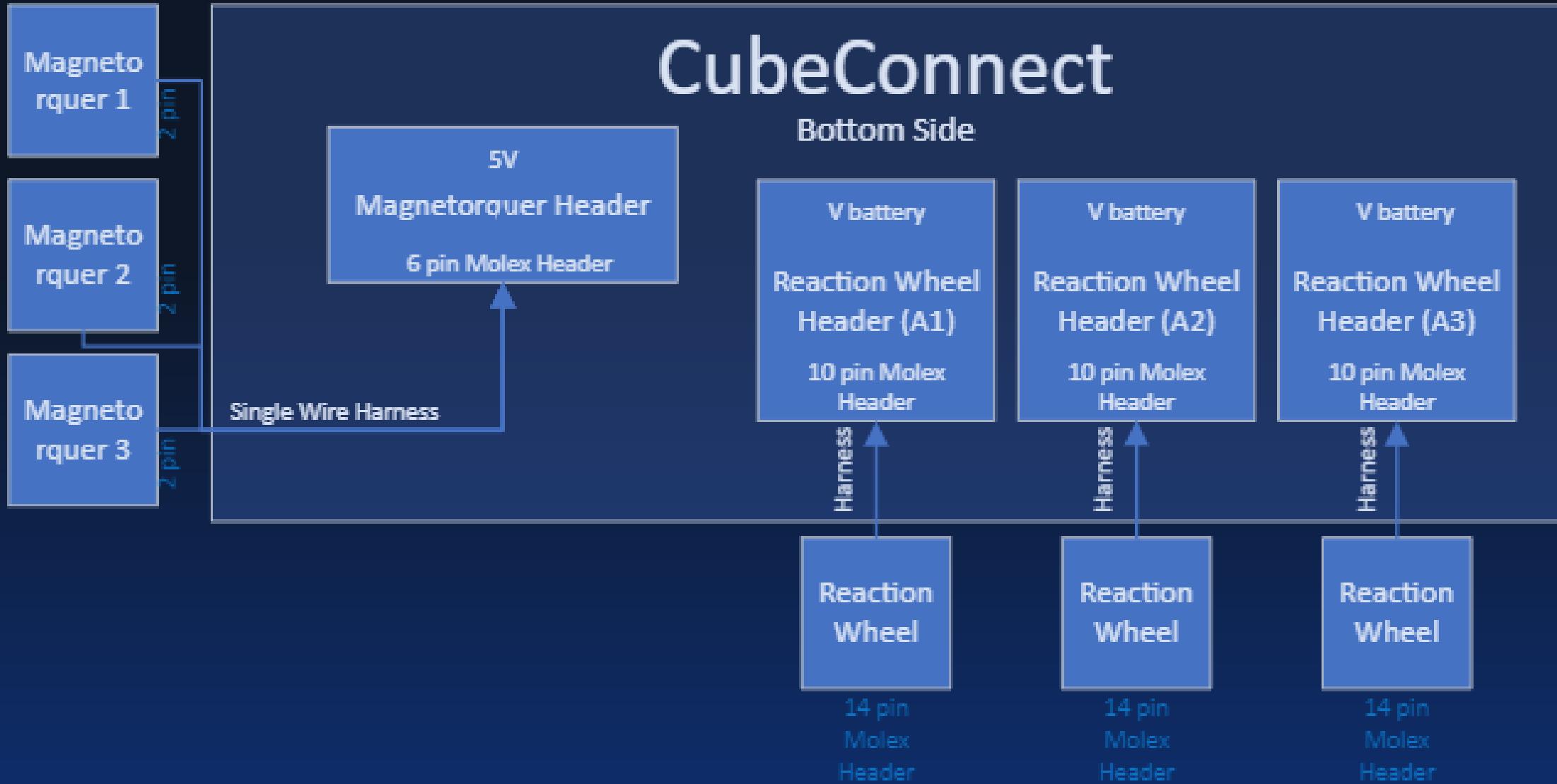
# Component Selection

- Actuators
  - CubeWheel CW0057 (3x) - Reaction Wheels
  - CubeTorquer CR0003(3x) - Magnetorquers
- Sensors
  - CubeSense Sun – Fine Sun Sensor
  - EnduroSat Panels (4x) – Coarse Sun Sensors
  - CubeMag Compact (2x) - Magnetometer
  - Epson US M-G370s (2x) - Rate Gyro
  - UBlox NEO-M8M (2x) - GPS





# CubeADCS Stack





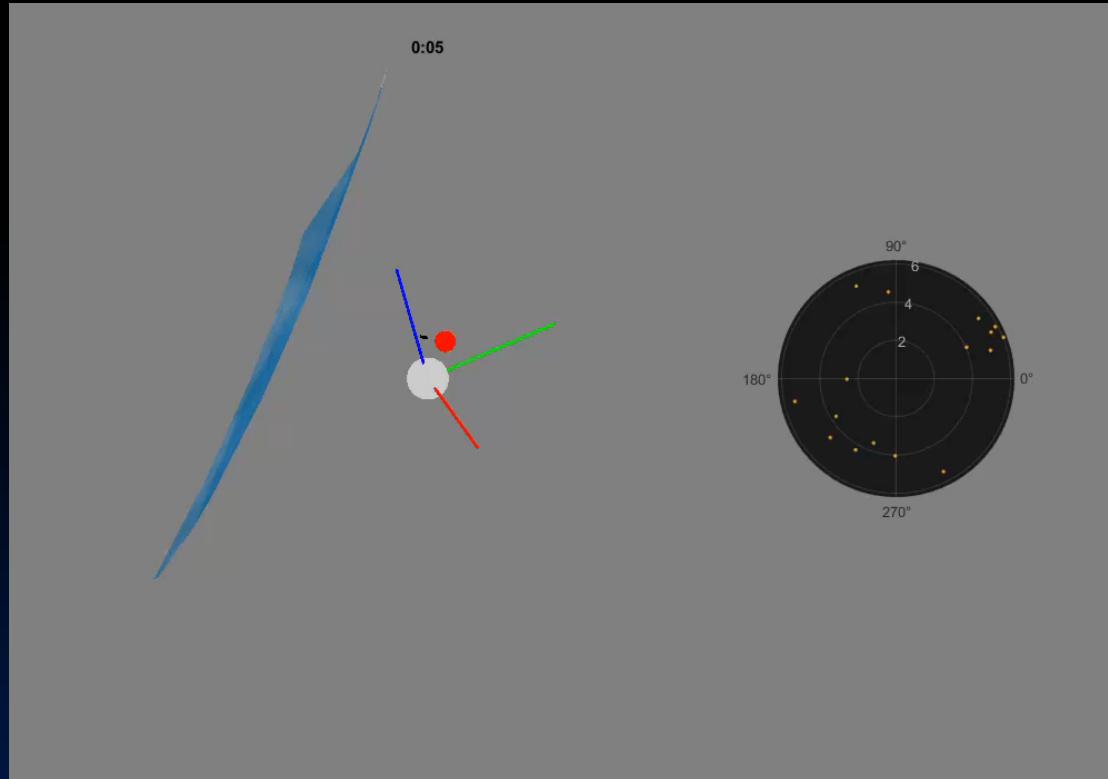
# Pointing Simulation

## Updates:

- Implemented a Charging Mode
- Transmitting Mode now includes a Ground Track for improved accuracy
- Implemented a 40 run Monte Carlo simulation to analyze initial conditions on POLAR's tracking
- Updated sensor and actuator specs to accurately represent all the noise and bias associated with the mission specific hardware

## Future Development:

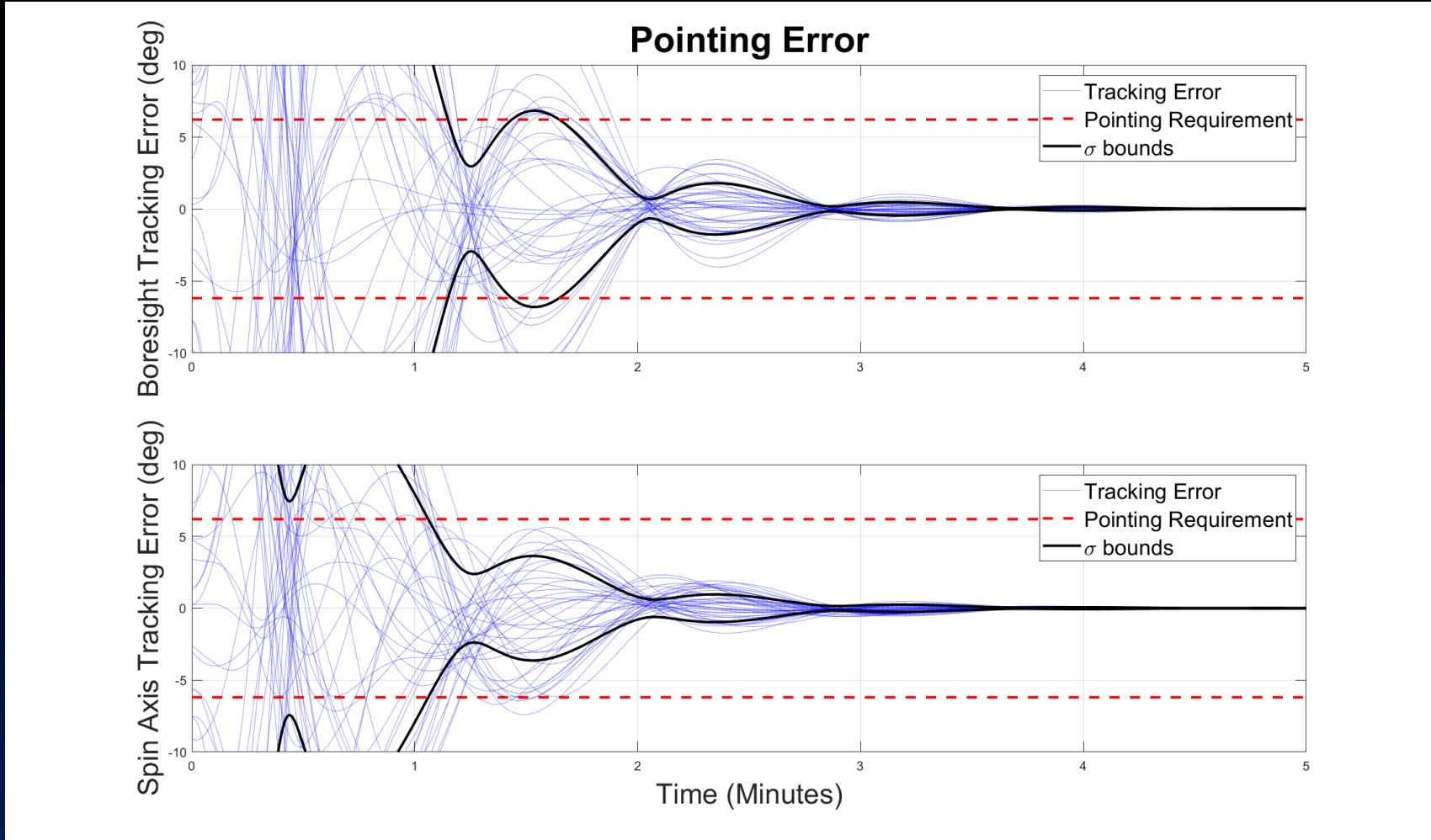
- Implement Data Product/Comms
- Integrate MMAE Algorithm
- Add real TLE data for observable satellites
- Ability to simulate a full mission where POLAR enters multiple modes sequentially



*Mission Mode in Polar Mission Sim*

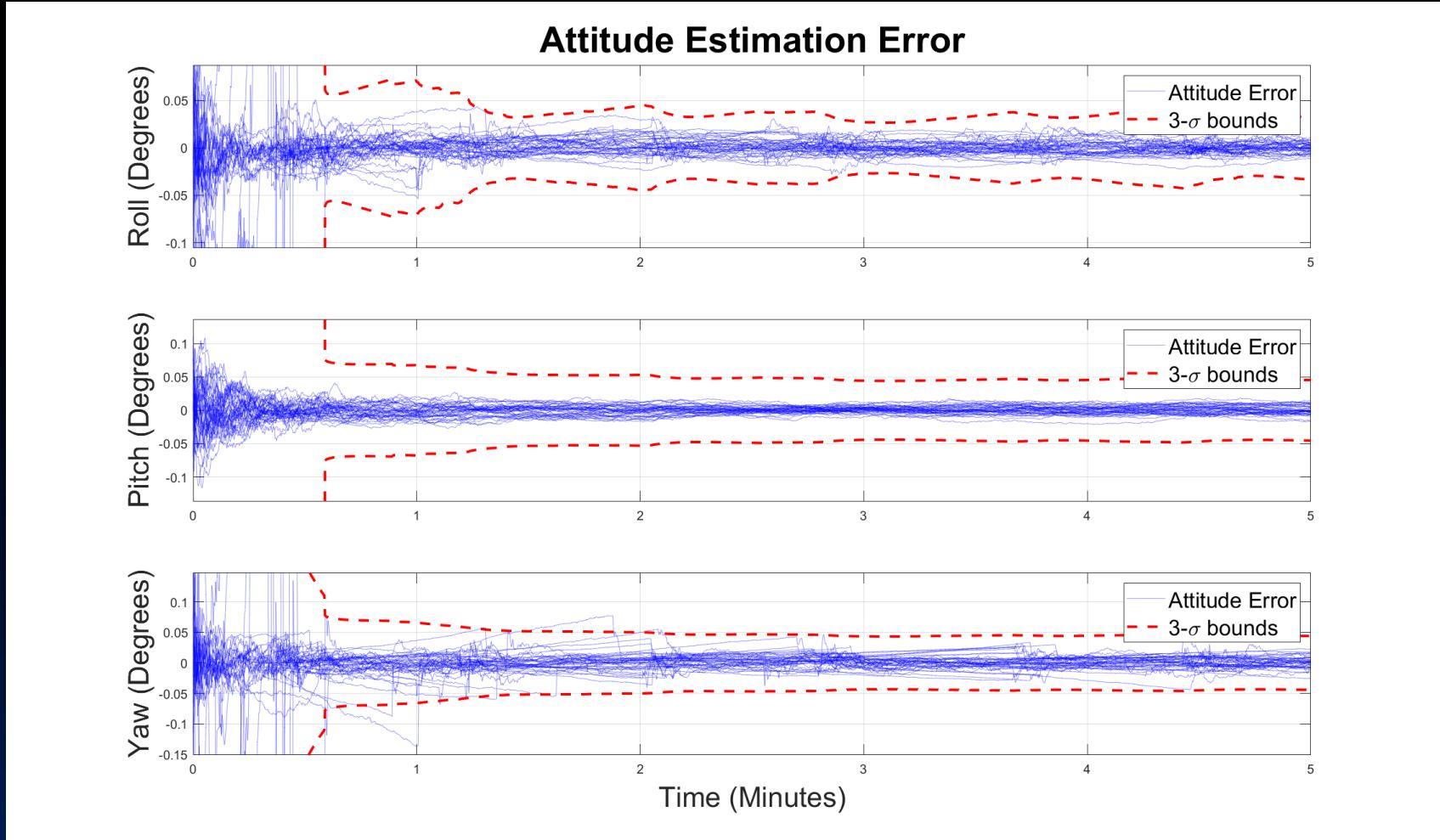


# Charging Mode - Pointing



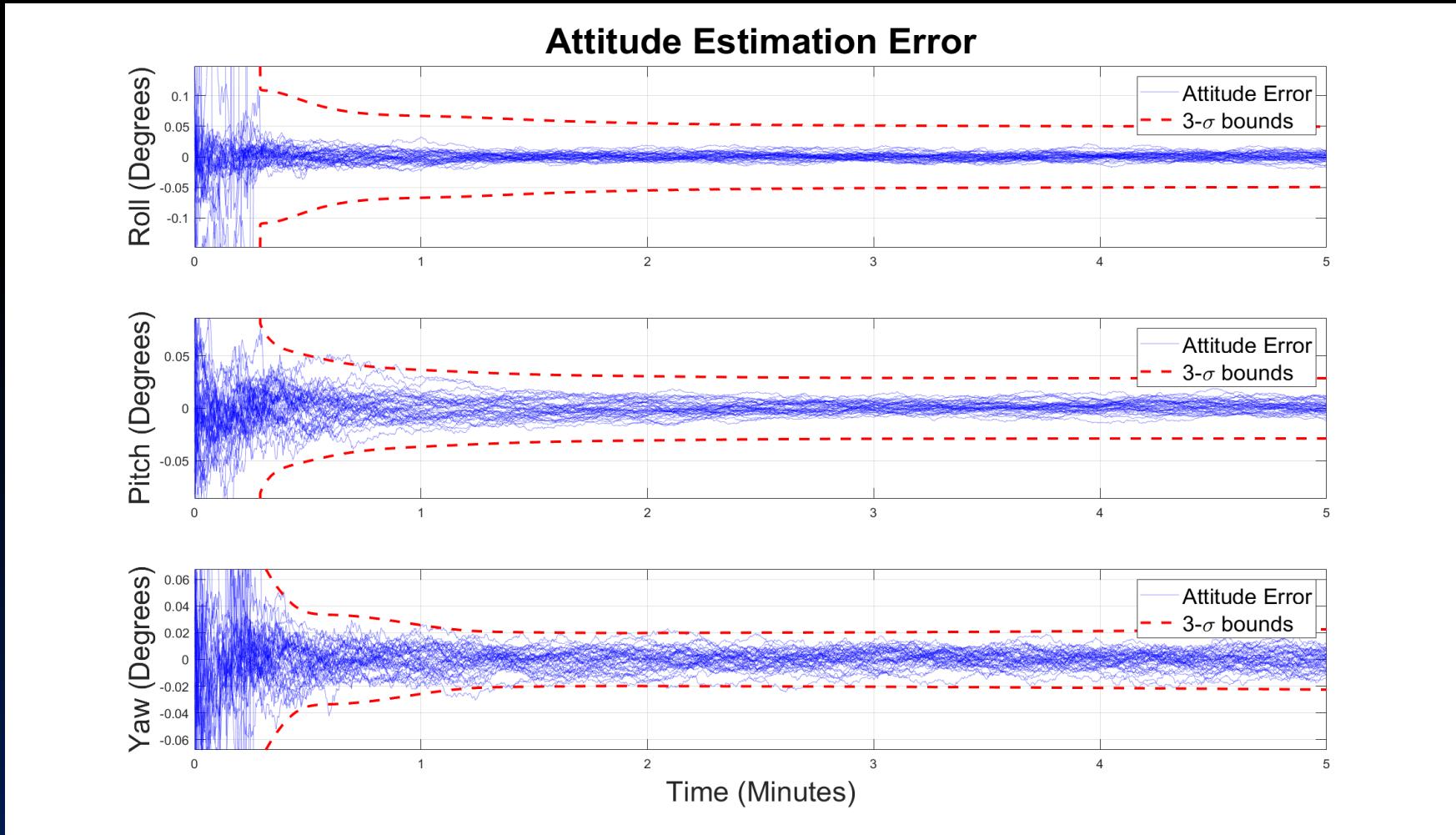


# Charging Mode - Attitude



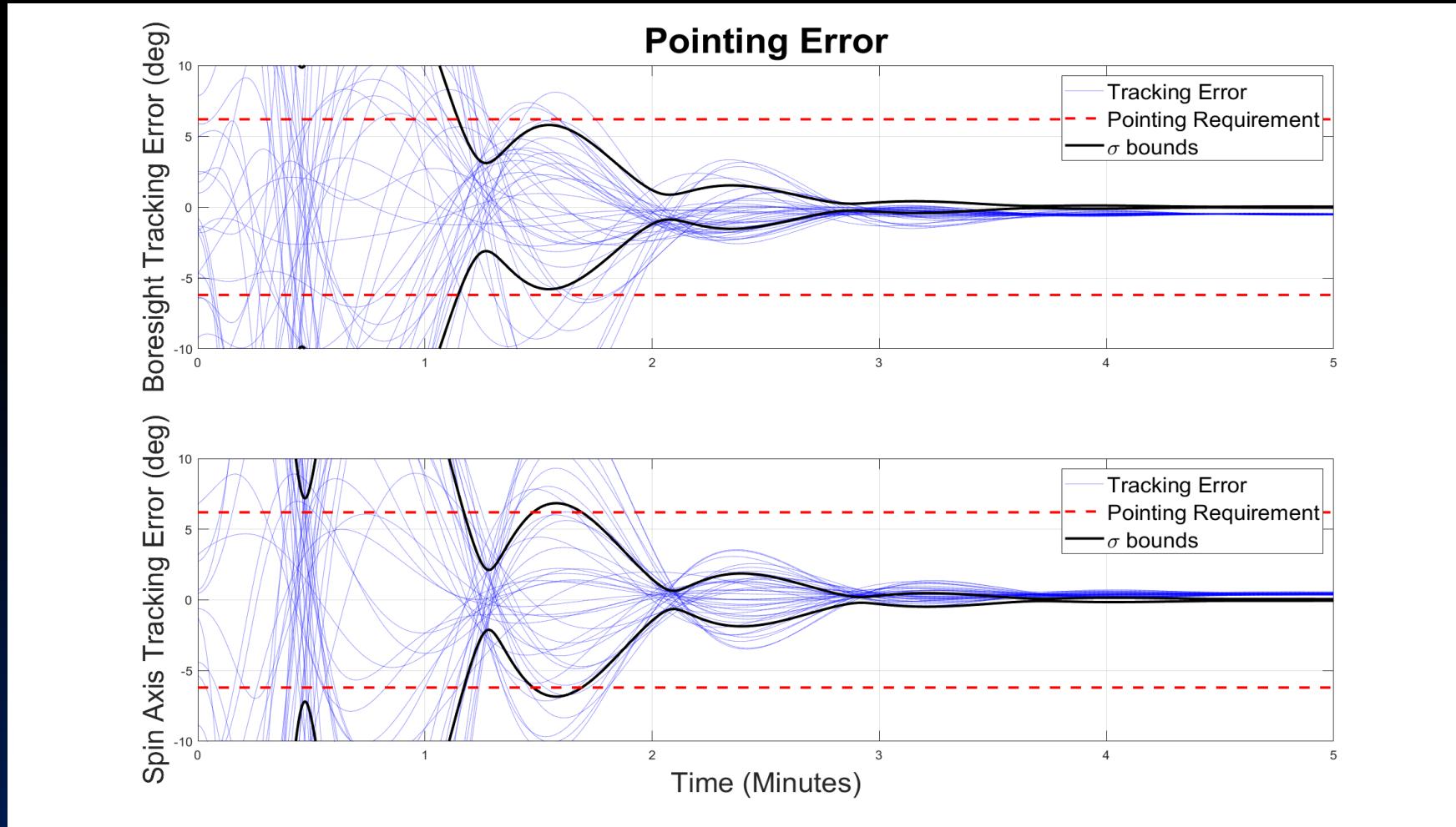


# Mission Mode - Attitude



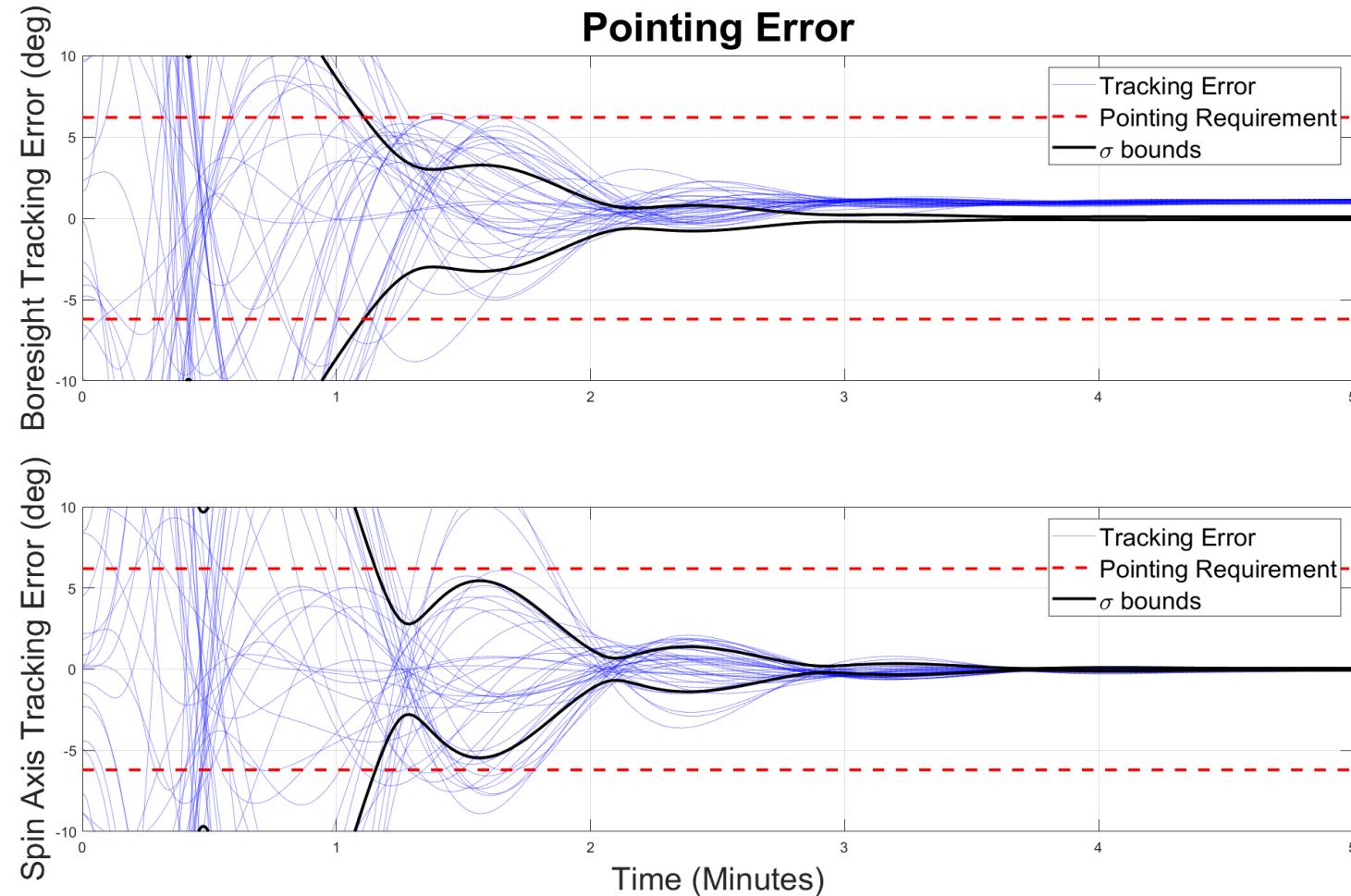


# Mission Mode - Pointing



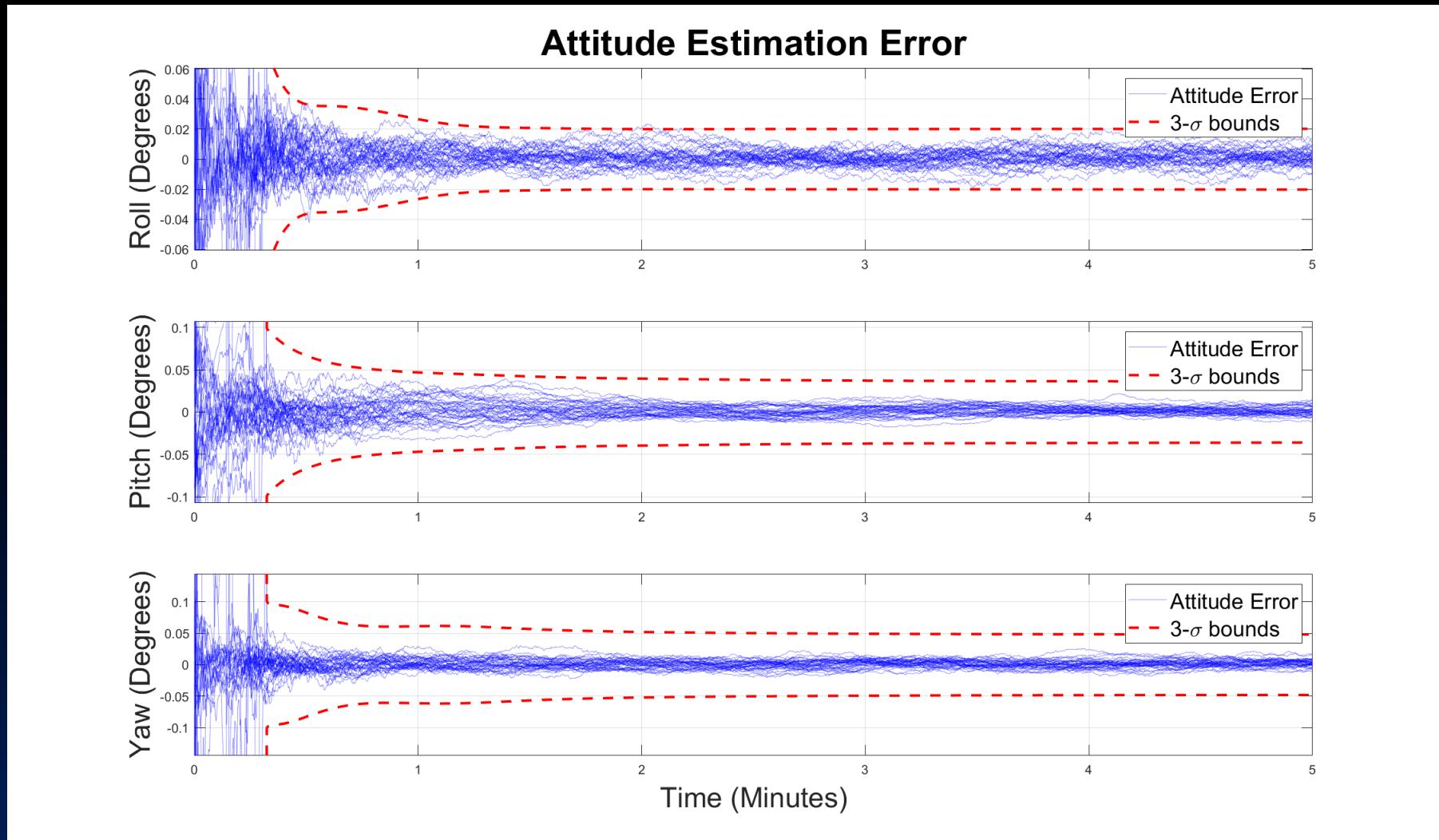


# Transmitting Mode - Pointing



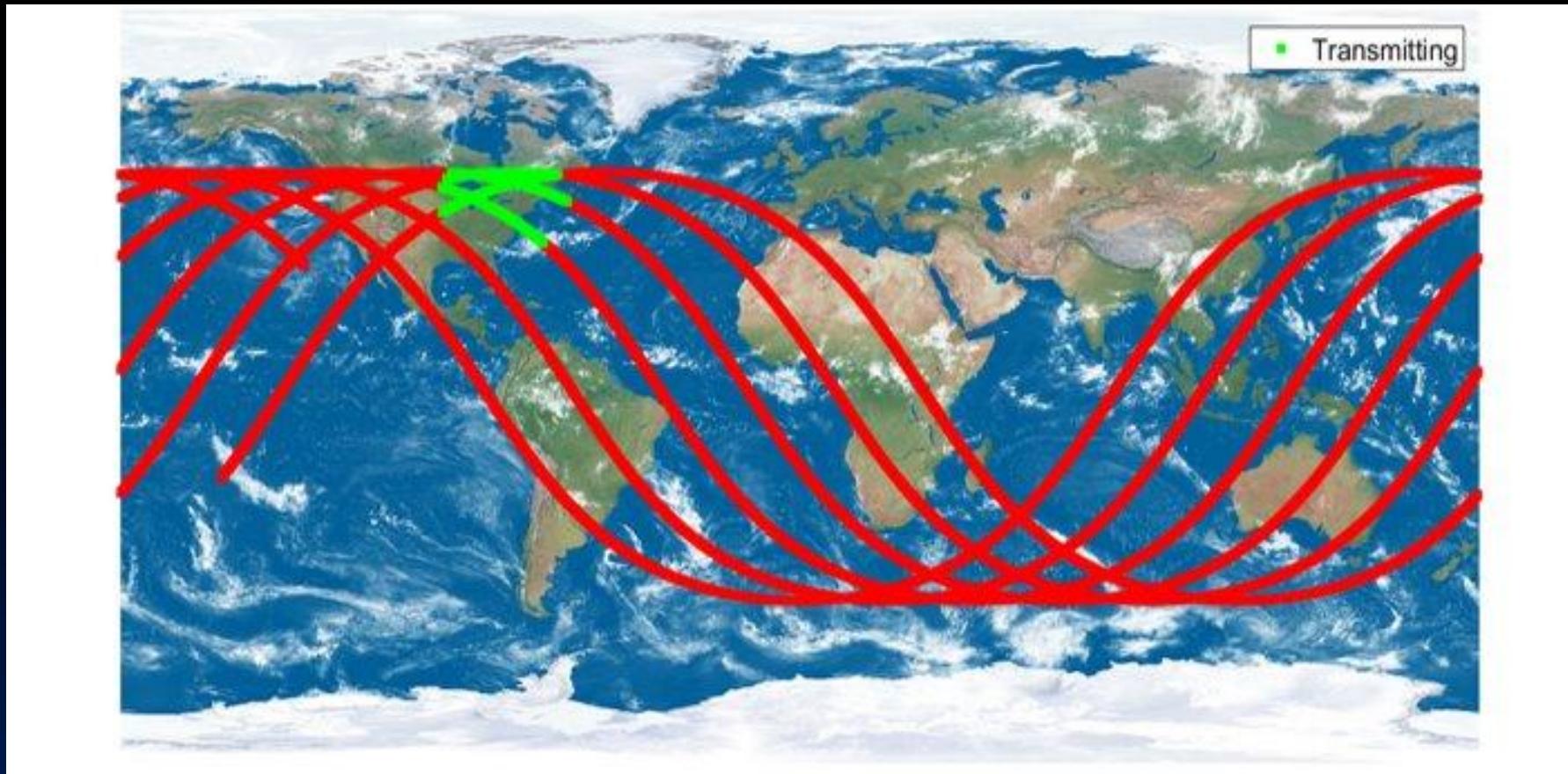


# Transmitting Mode - Attitude



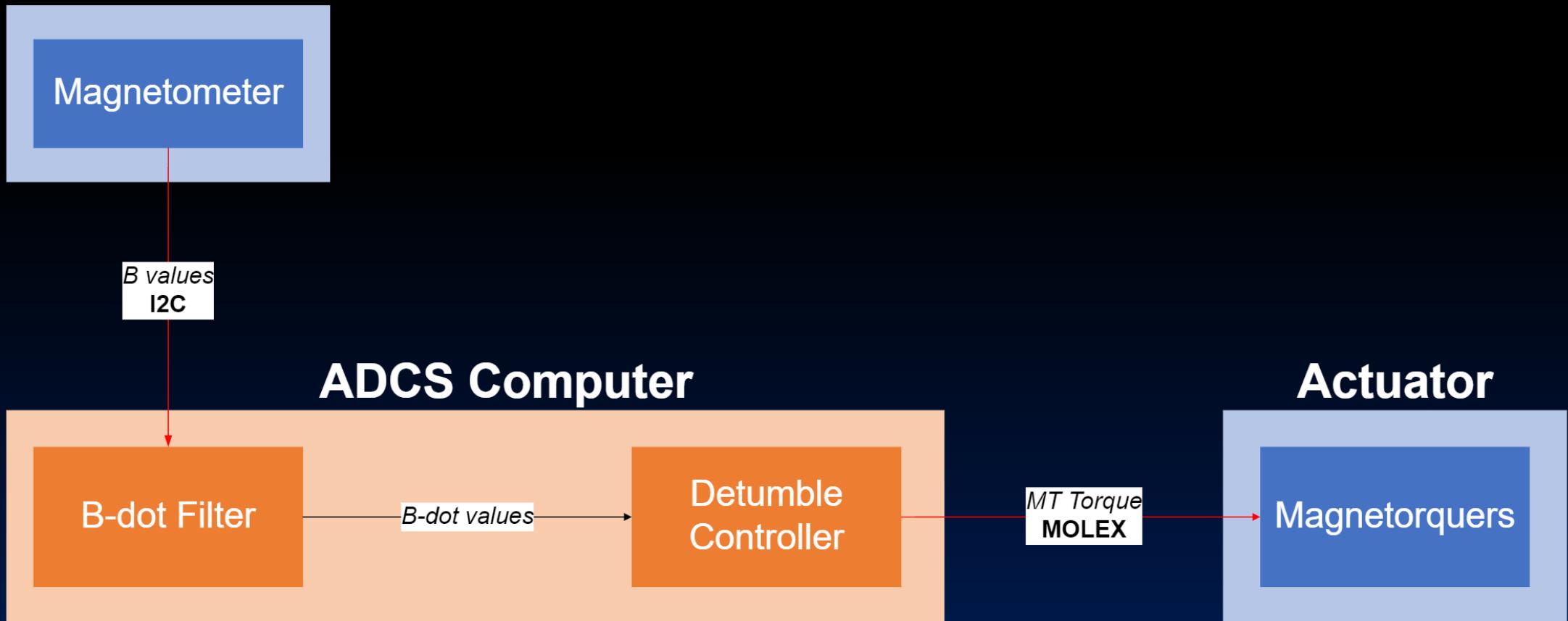


# Transmitting Mode – Ground Track



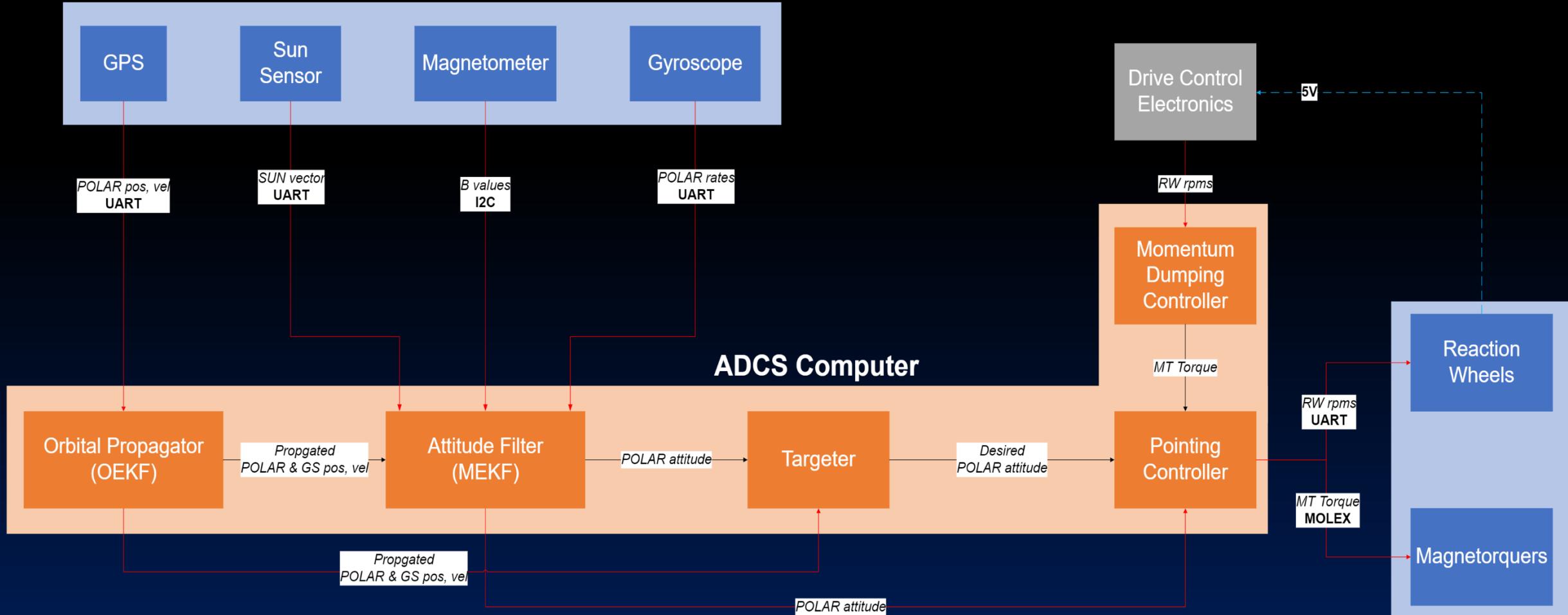


# Detumble Sensor



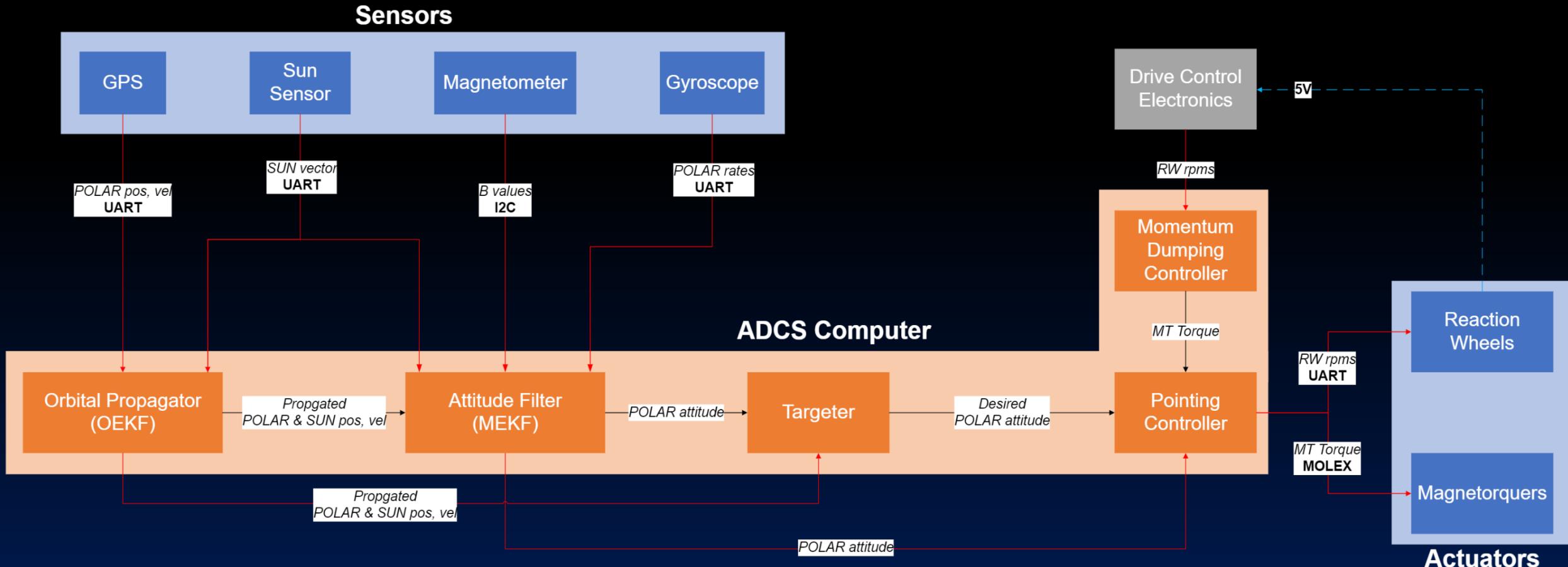


# Transmitting Mode



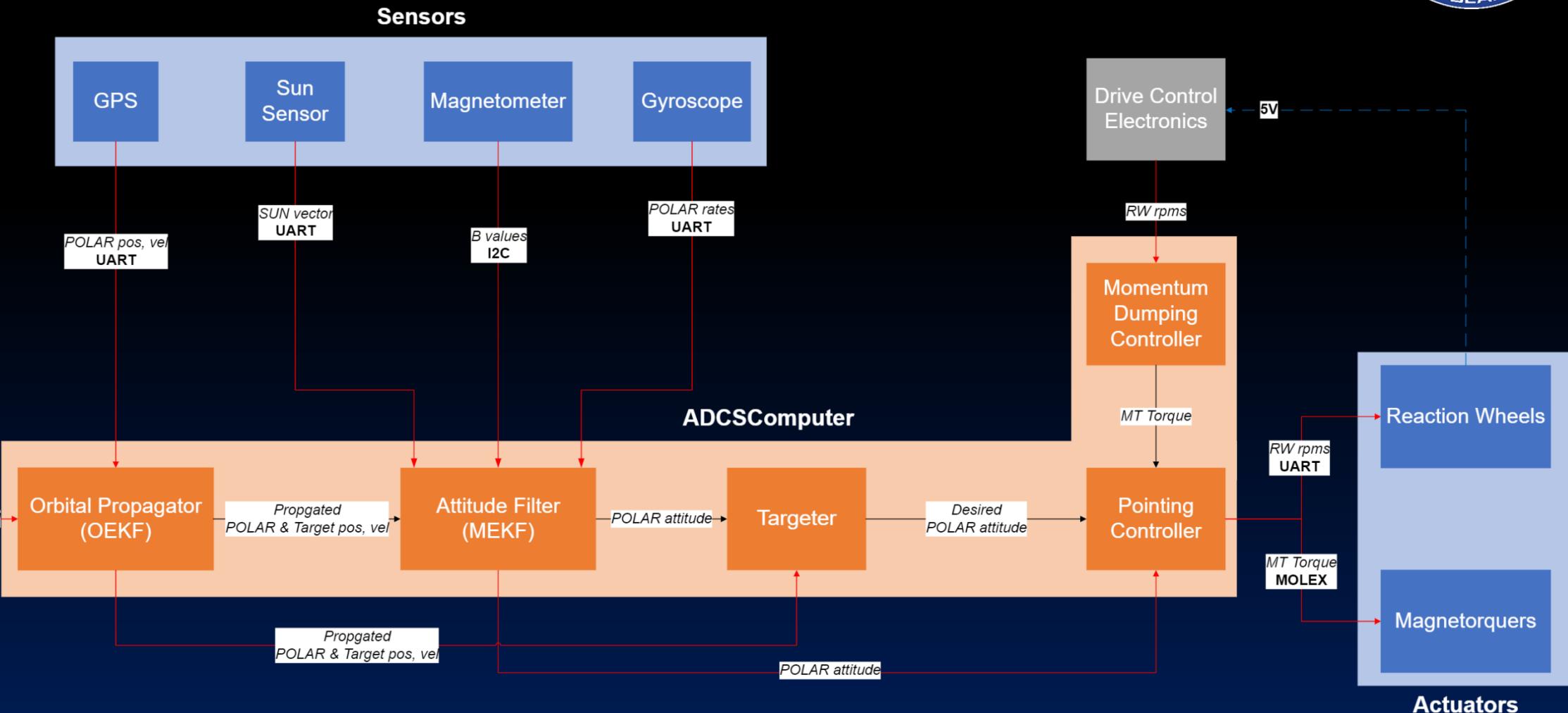


# Charging Mode

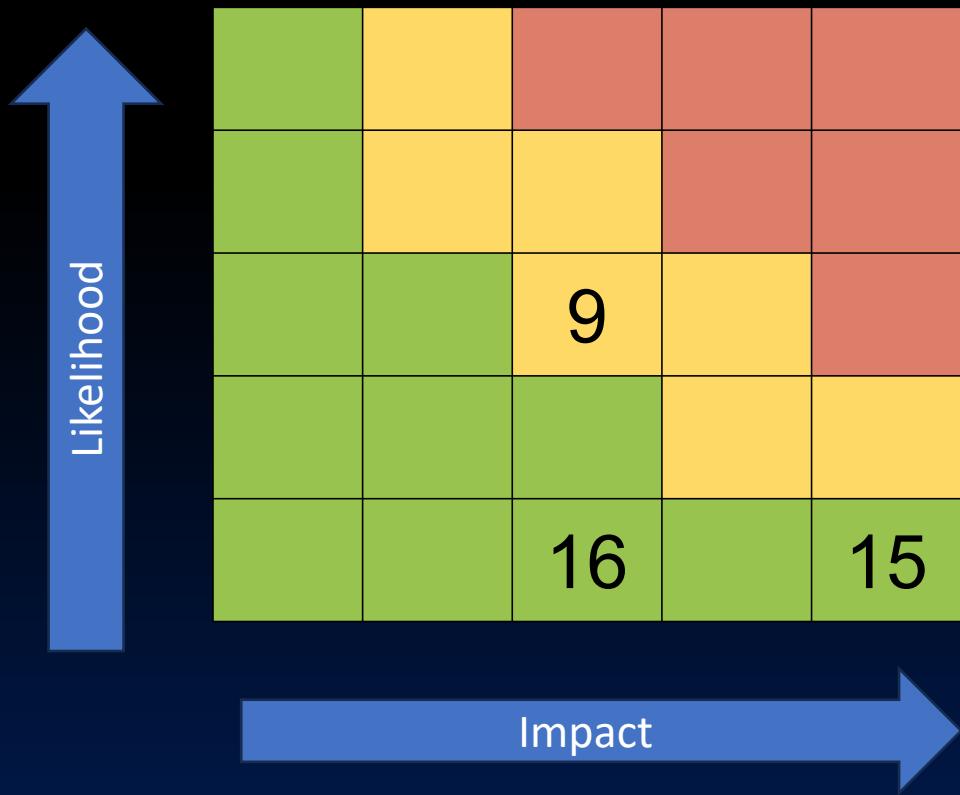




# Mission Mode



# Risks



ID	Risk	Mitigation
9	GPS Error	GNC will derive a pointing budget that allows for L-Band patch antenna to view the Iridium constellation often enough for accurate GPS data
15	Reaction Wheel Failure	Redundancy will be implemented to prevent damage to POLAR's pointing ability
16	GNC Sensor Aging	Redundancy will be implemented to prevent damage to POLAR's pointing ability



# Subsystem Progress - PDR

Sensor Models, Calibration

Active Members: 6-7

Orbit Determination

Master Sim

Pointing Mode Sims

Attitude Determination

Unit-Level Test Procedures

Pointing Budget

Component Trade Analyses

Block Diagrams

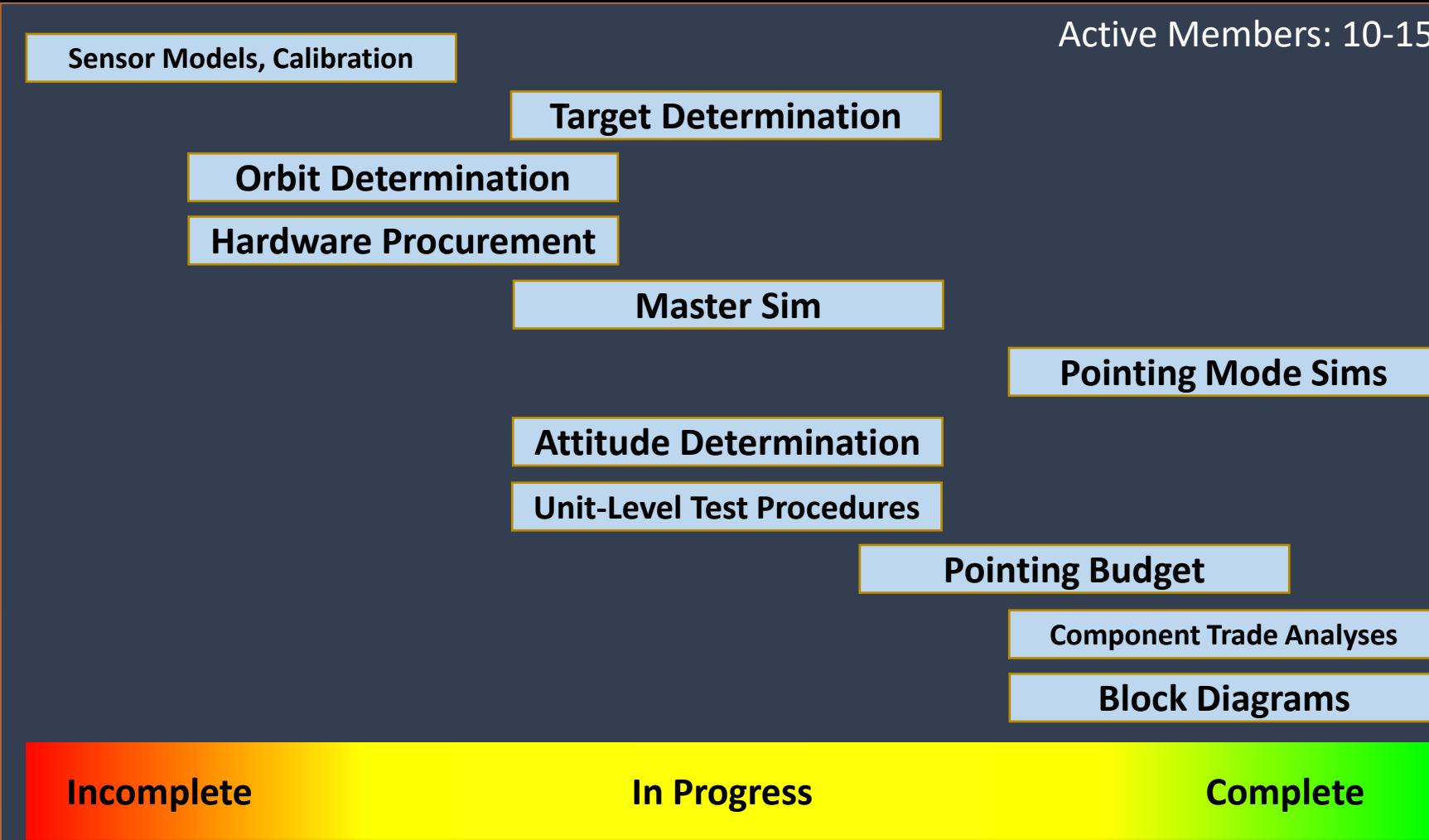
Incomplete

In Progress

Complete



# Subsystem Progress - CDR





# Next Steps

Develop  
Mission Sim

Implement live  
TLE data of  
candidate  
satellites

Submit CMO to  
CubeSpace

Complete  
Testing  
Procedures

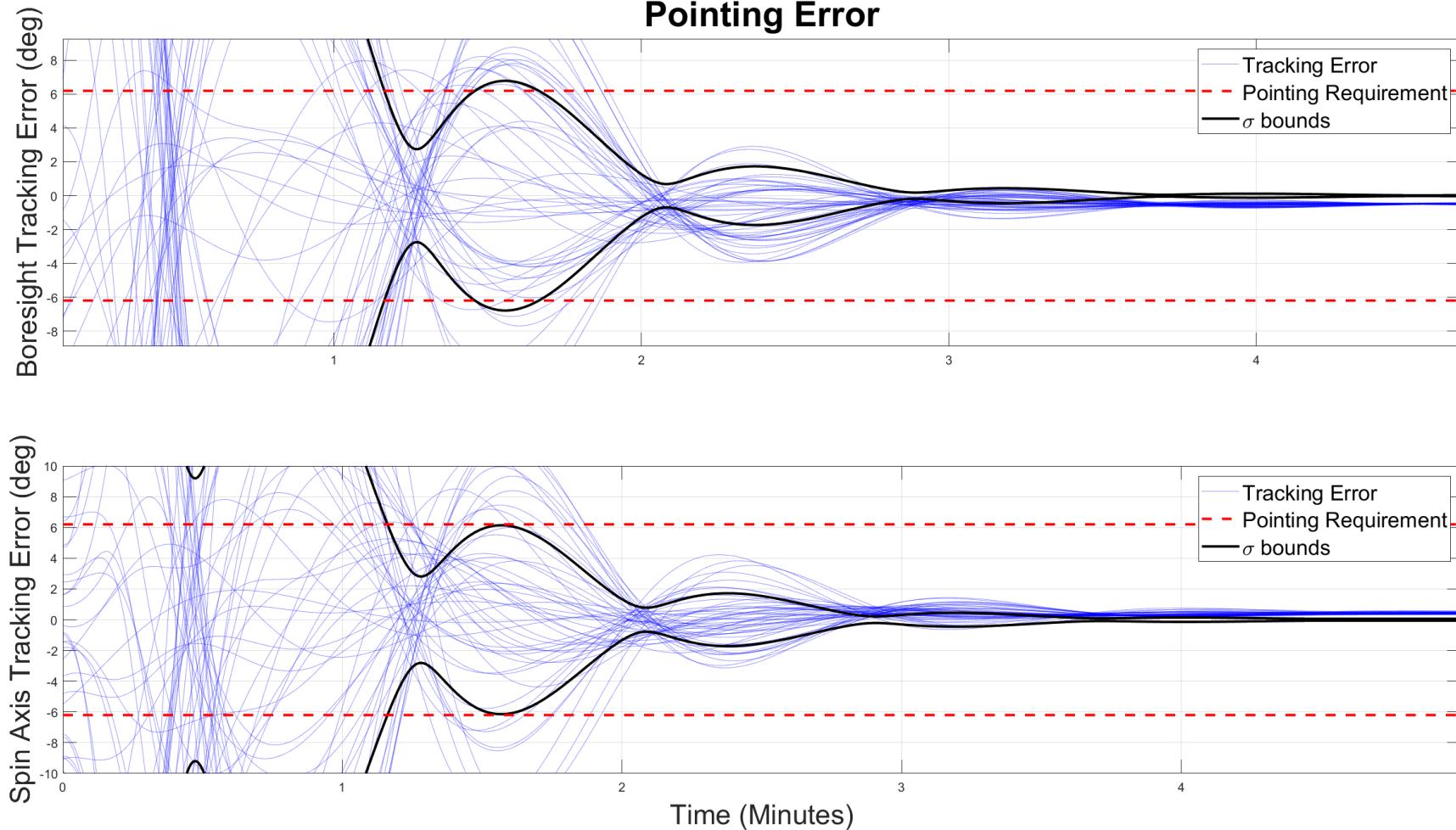
- Run a full mission Phase with different modes
- Integrate pBDRF material analysis algorithm

- Integrating a CelesTrack scraper
- Use observation selection from Operations

- Verify Hardware Selection with CubeSpace
- Order ADCS hardware



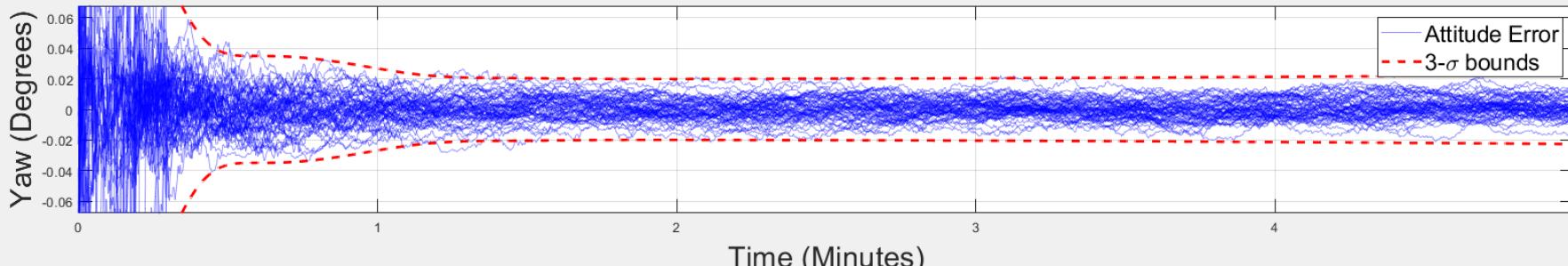
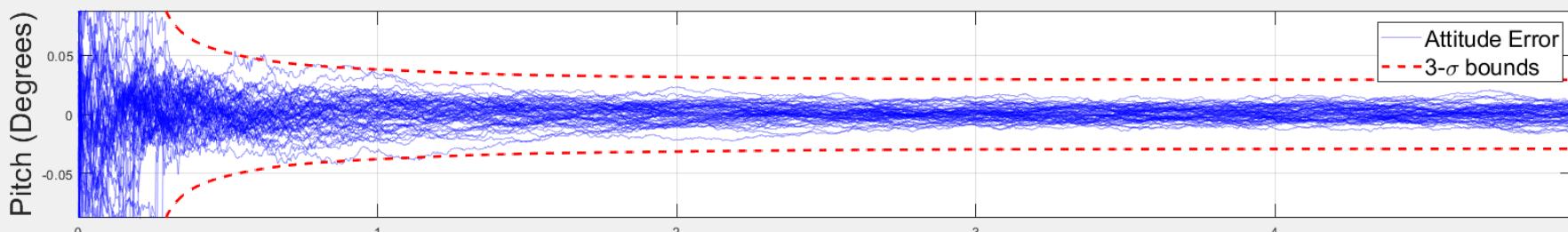
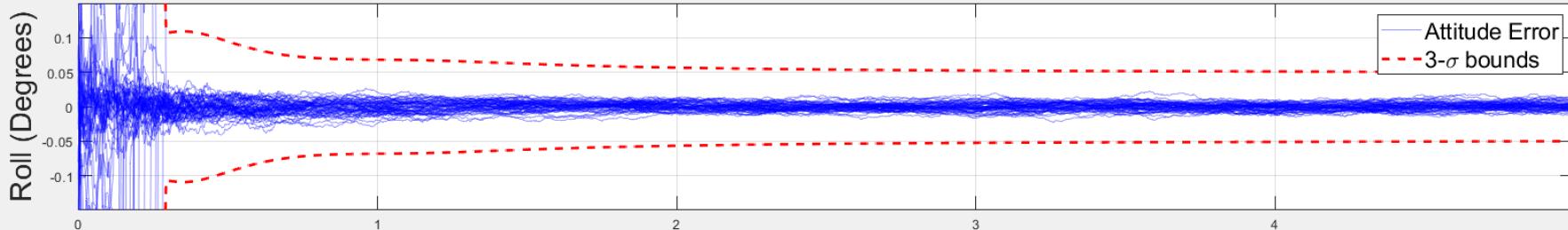
# Mission Mode - Pointing





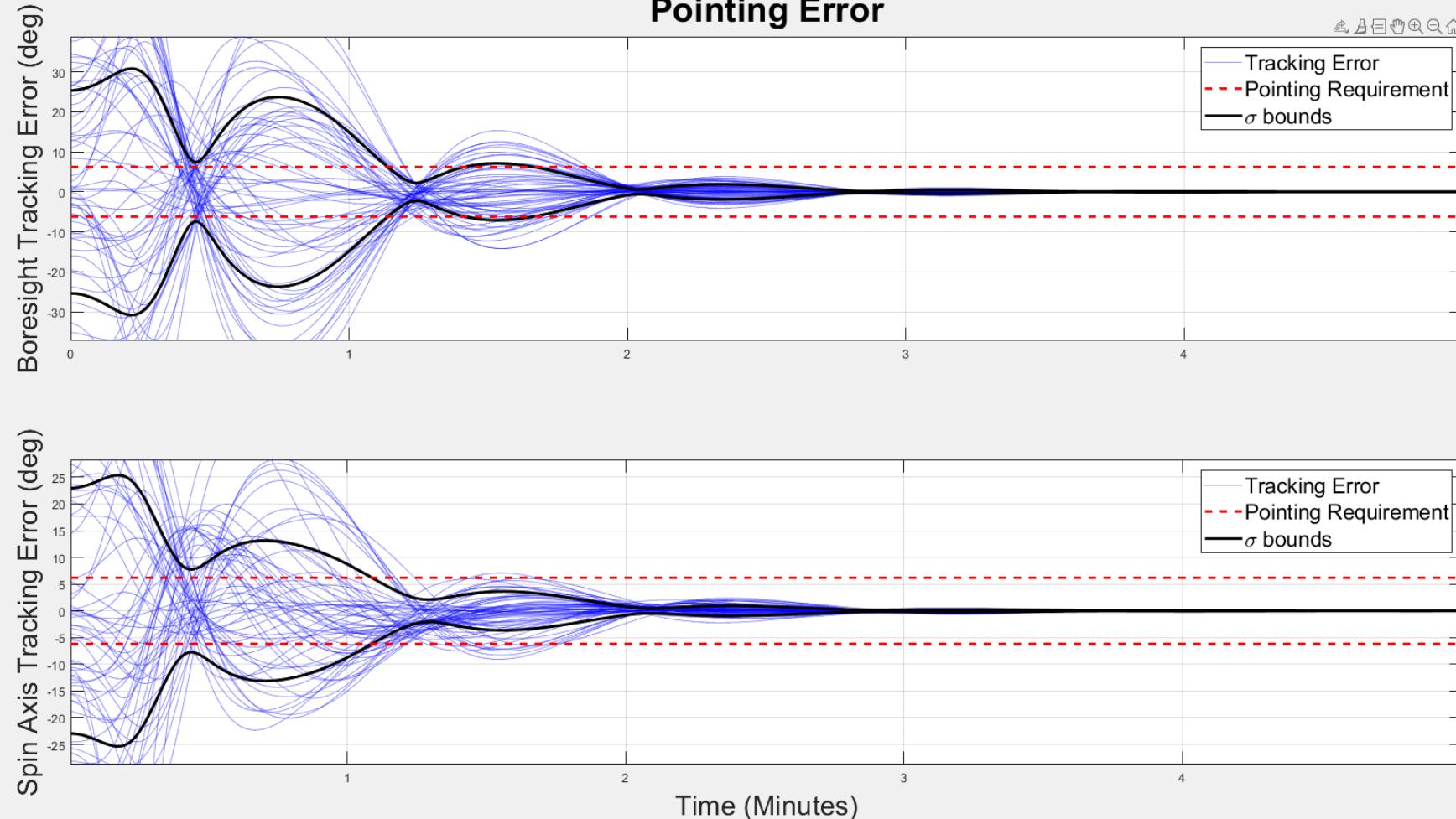
# Mission Mode – Attitude

Attitude Estimation Error



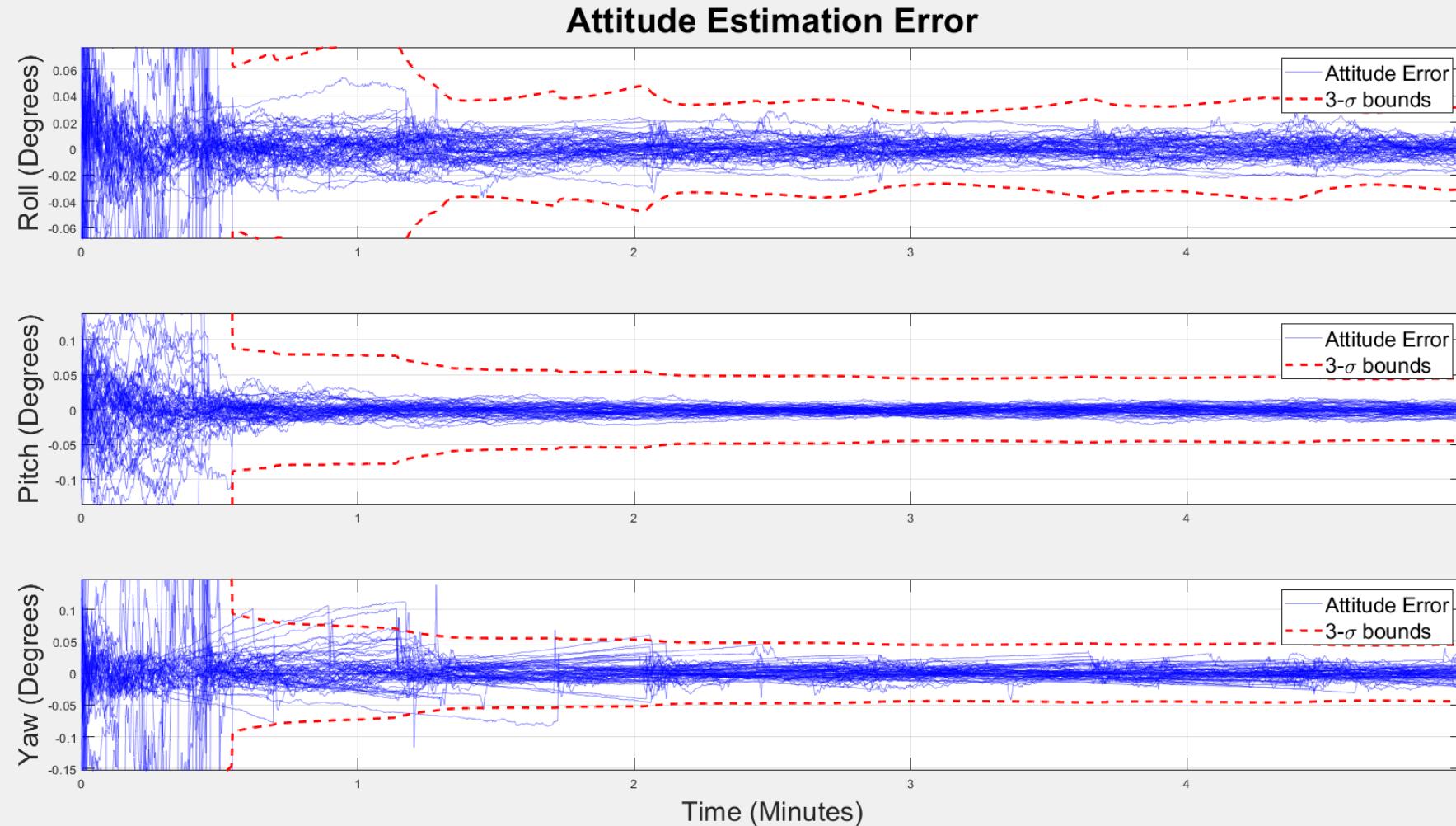


# Charging Mode - Pointing



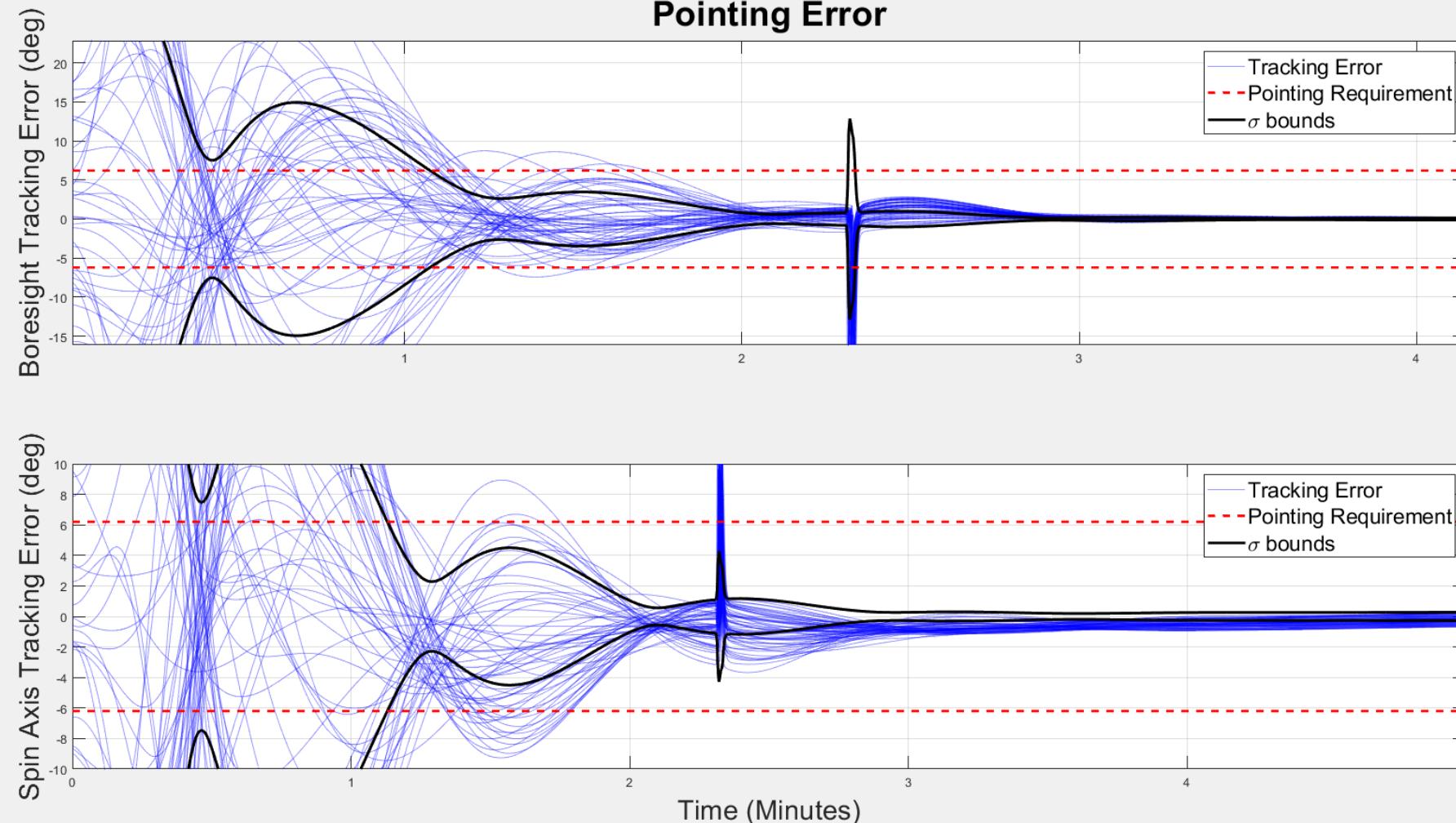


# Charging Mode – Attitude





# Transmitting Mode - Pointing





# Transmitting Mode – Attitude

