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 it 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

Assumptions
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.

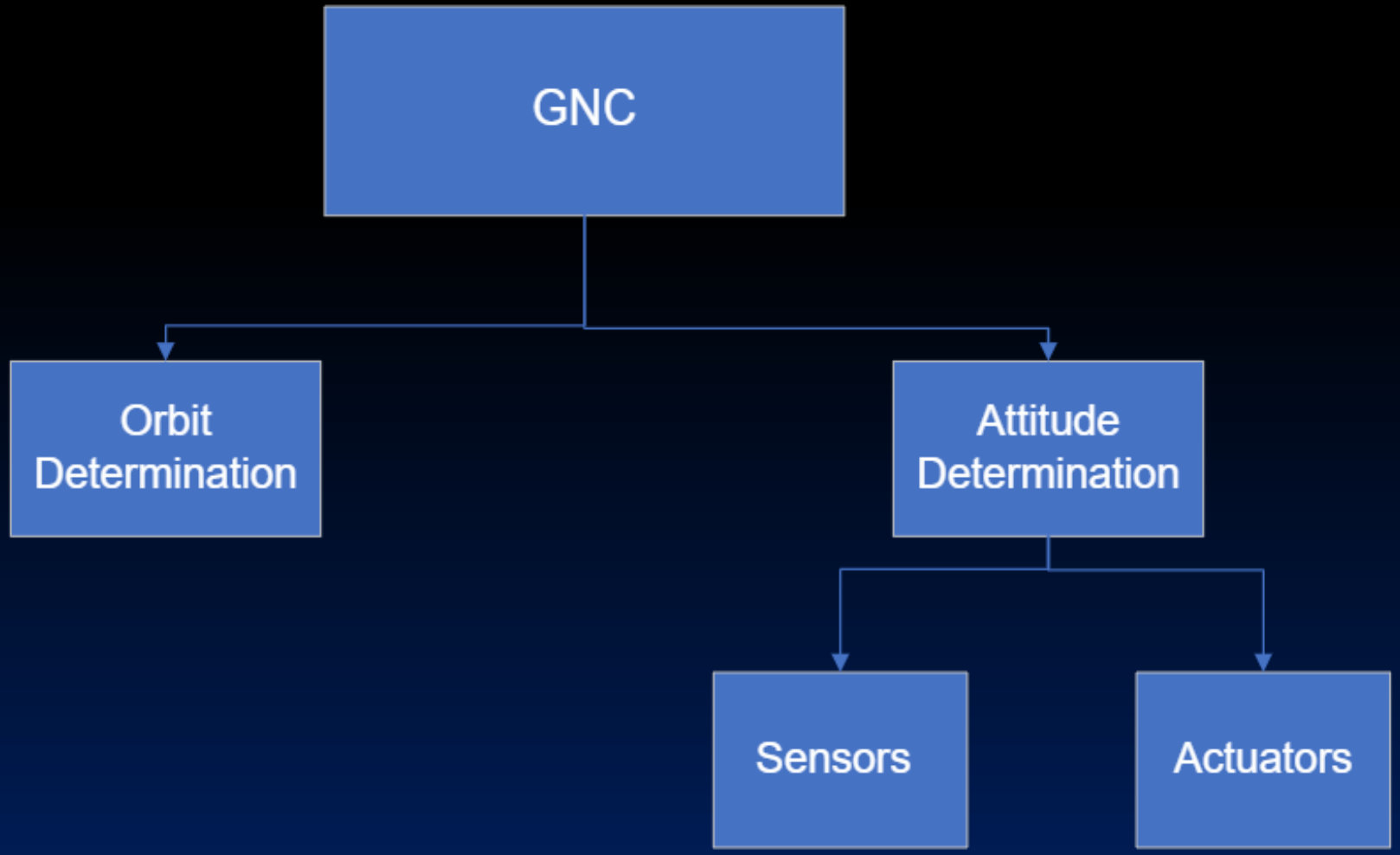
Requirements

Requirement #:	Derived From:	Requirement:
GNC - 13	SAT - 1, SAT - 11	Magnetorquers shall provide a magnetic moment of at least 0.089 Am^2.
GNC - 15	GNC - 5	Magnetometers shall be capable of reading geomagnetic field measurements of at least ±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.

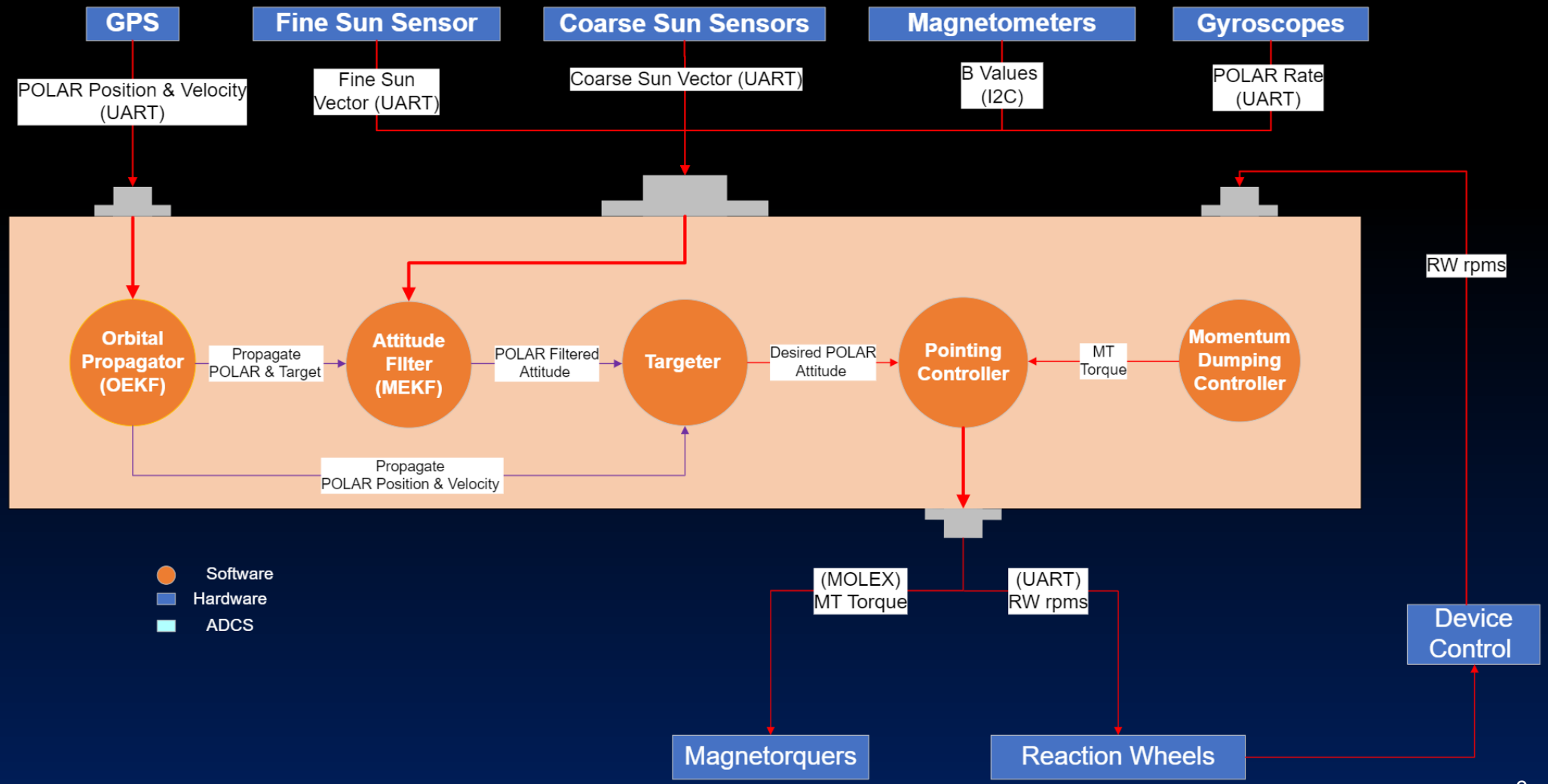
Constraints

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

Subsystem Architecture

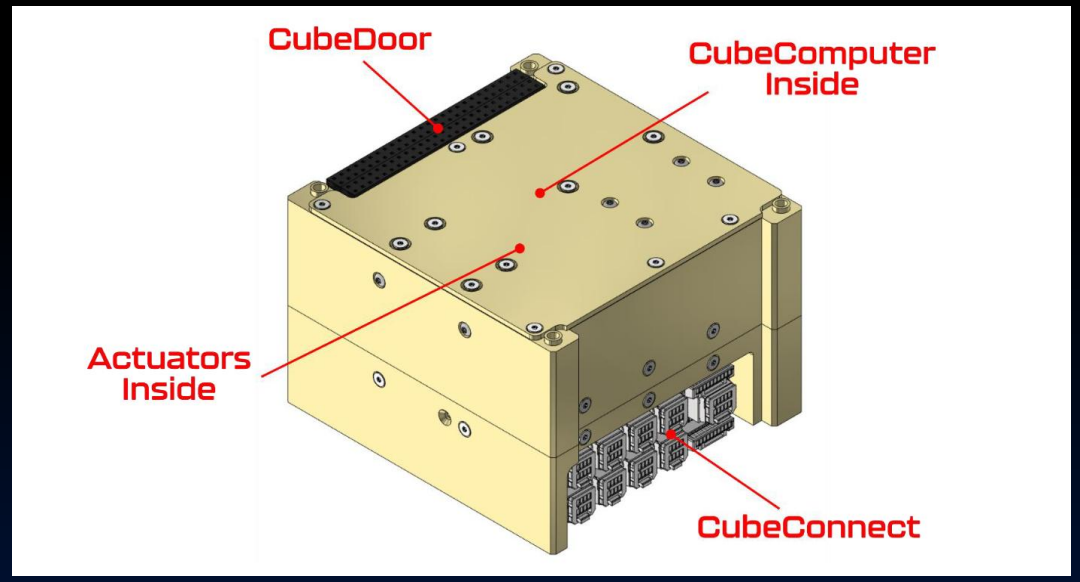


GNC ICD Schematic Interface



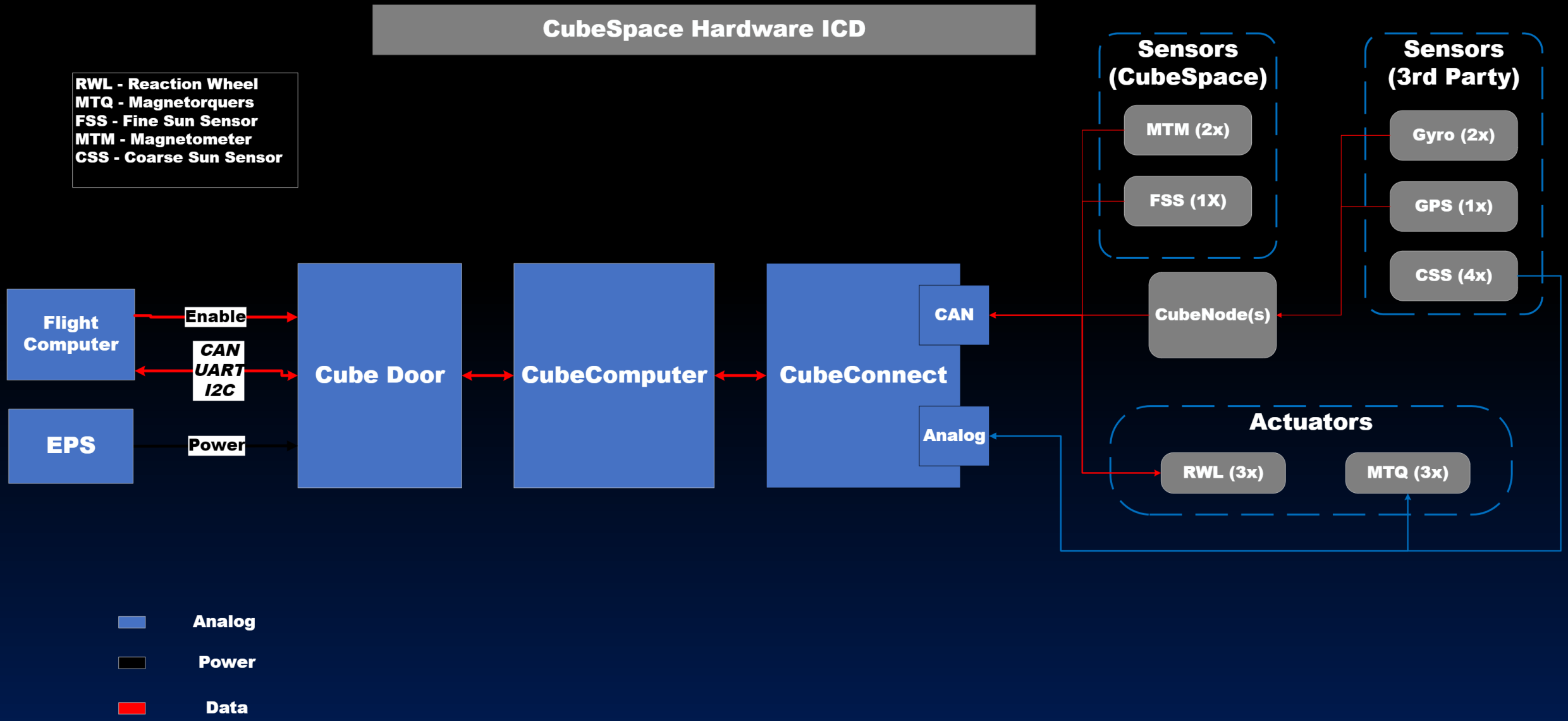
Integrated System Update

CUBESPACE



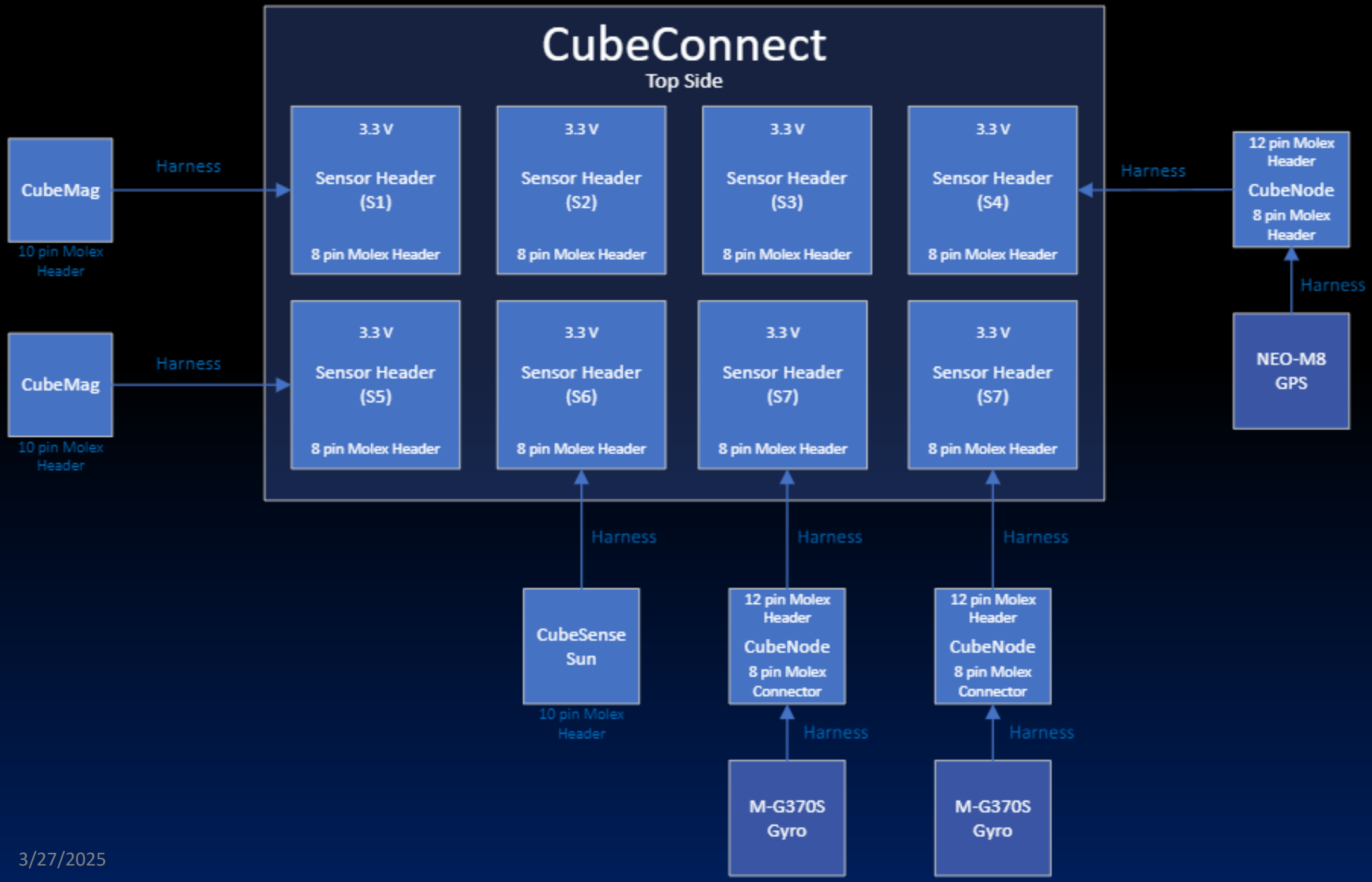
CubeSpace - Gen 2 ADCS

CubeSpace Hardware ICD

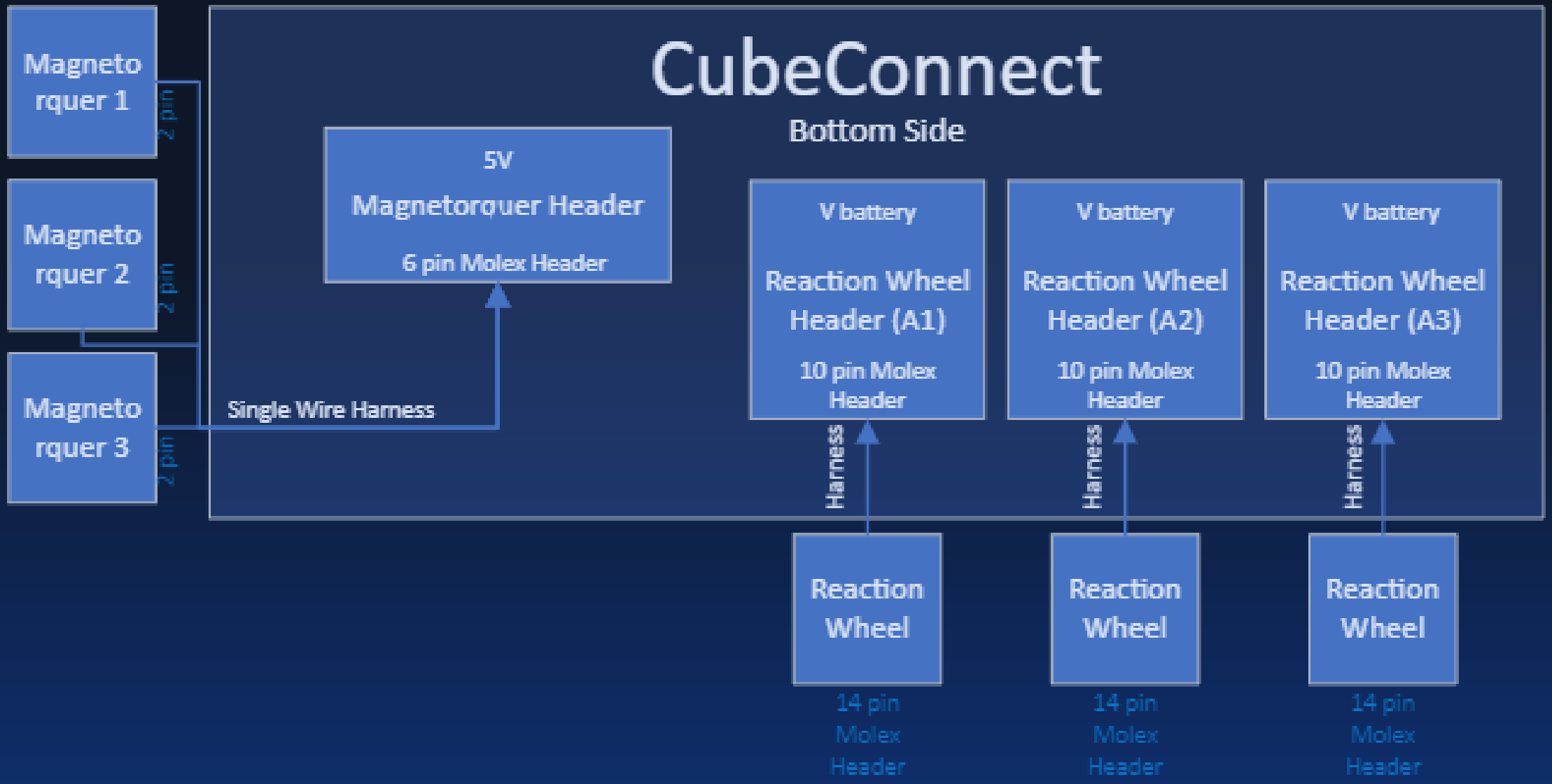


Component Selection

- 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


CubeConnect
Top Side
3.3 V
Sensor Header (S1)
8 pin Molex Header
3.3 V
Sensor Header (S2)
8 pin Molex Header
3.3 V
Sensor Header (S3)
8 pin Molex Header
3.3 V
Sensor Header (S4)
8 pin Molex Header
3.3 V
Sensor Header (S5)
8 pin Molex Header
3.3 V
Sensor Header (S6)
8 pin Molex Header
3.3 V
Sensor Header (S7)
8 pin Molex Header
3.3 V
Sensor Header (S7)
8 pin Molex Header
CubeMag
10 pin Molex Header
Harness
CubeMag
10 pin Molex Header
Harness
Harness
12 pin Molex Header
CubeNode
8 pin Molex Header
Harness
NEO-M8 GPS
Harness
CubeSense Sun
10 pin Molex Header
Harness
12 pin Molex Header
CubeNode
8 pin Molex Connector
Harness
M-G370S Gyro
Harness
12 pin Molex Header
CubeNode
8 pin Molex Connector
Harness
M-G370S Gyro
Harness

CubeADCS Stack



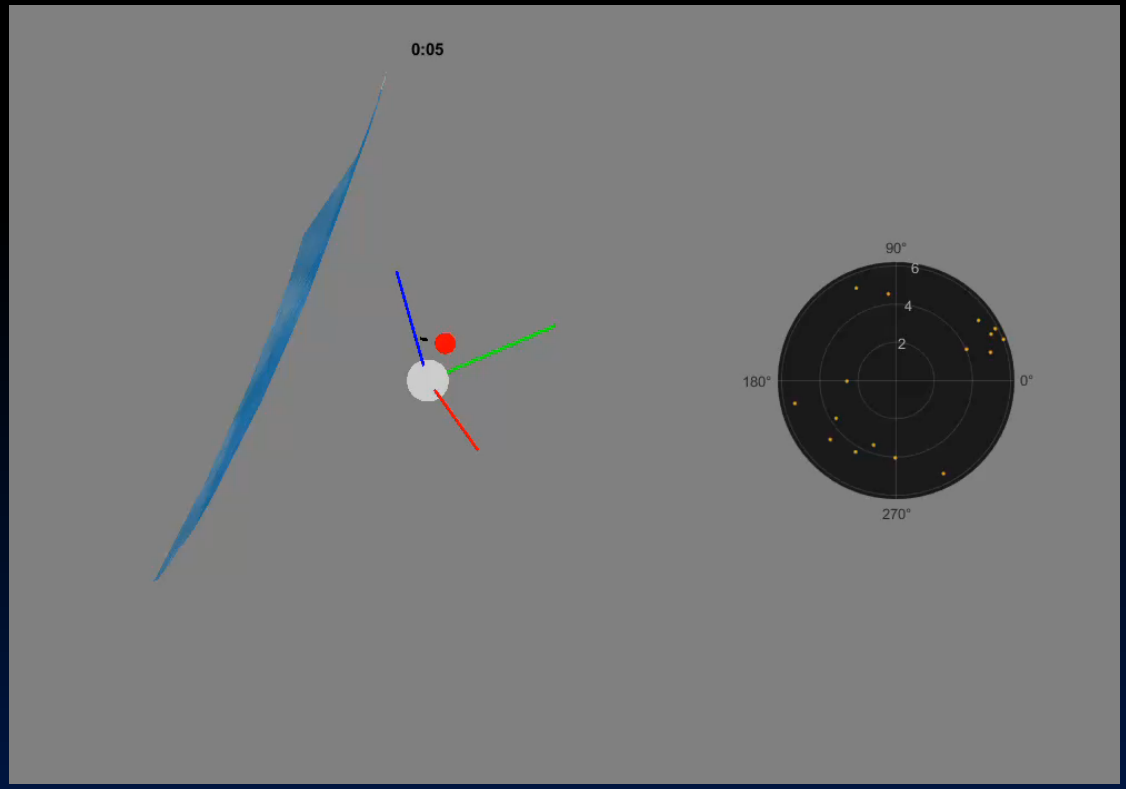
Pointing Simulation

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

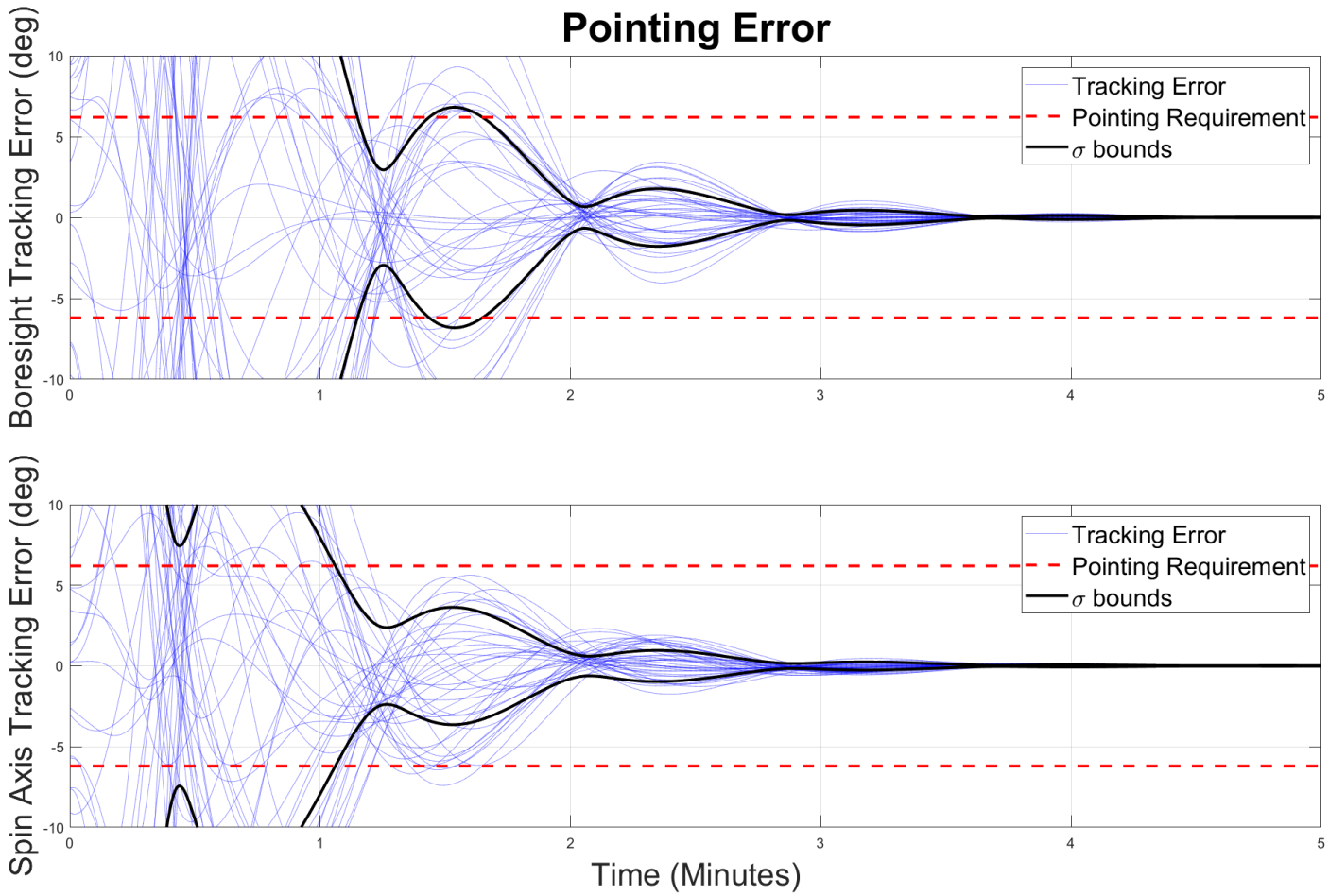
Future Development:

- 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

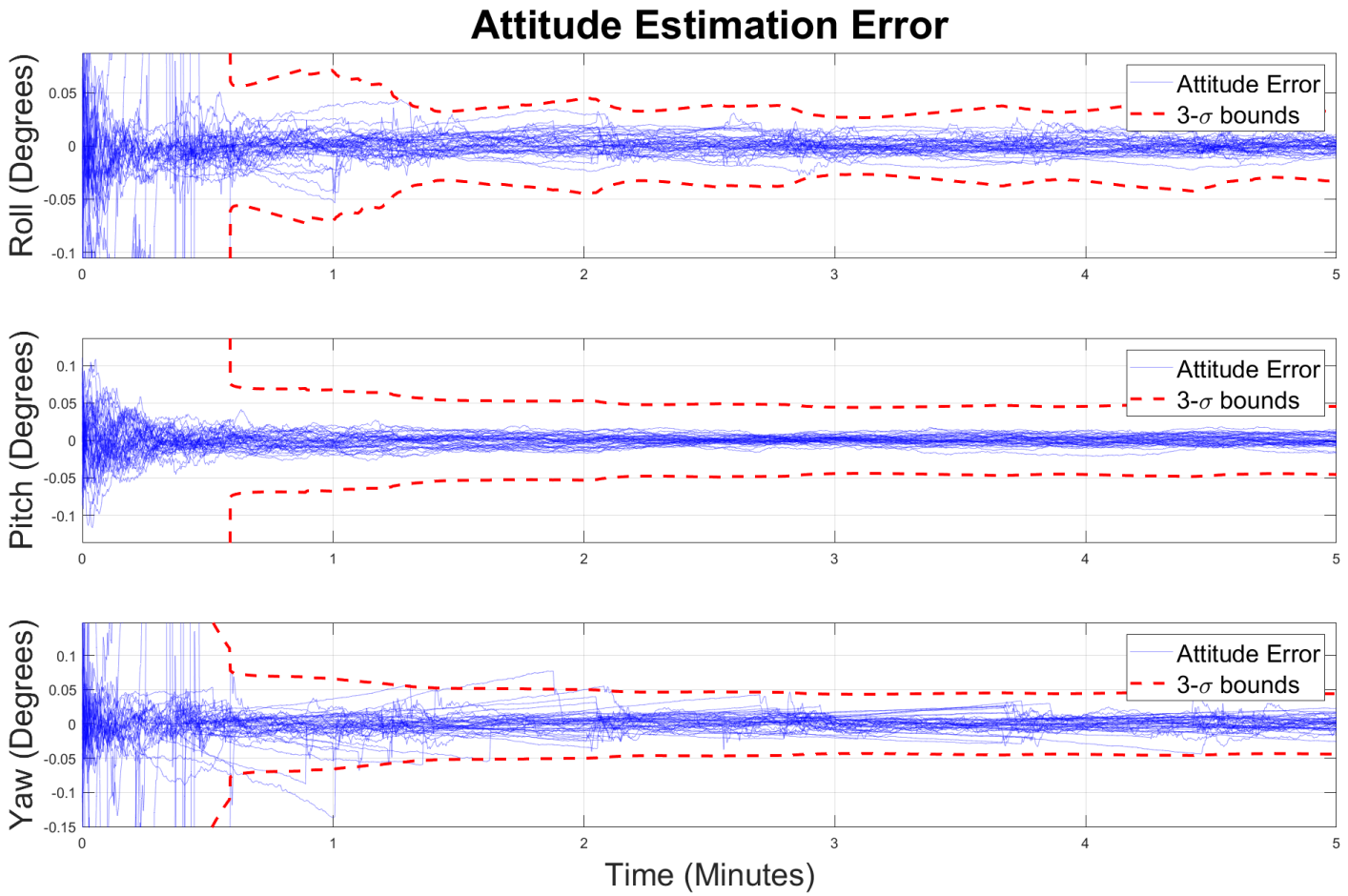


Mission Mode in Polar Mission Sim

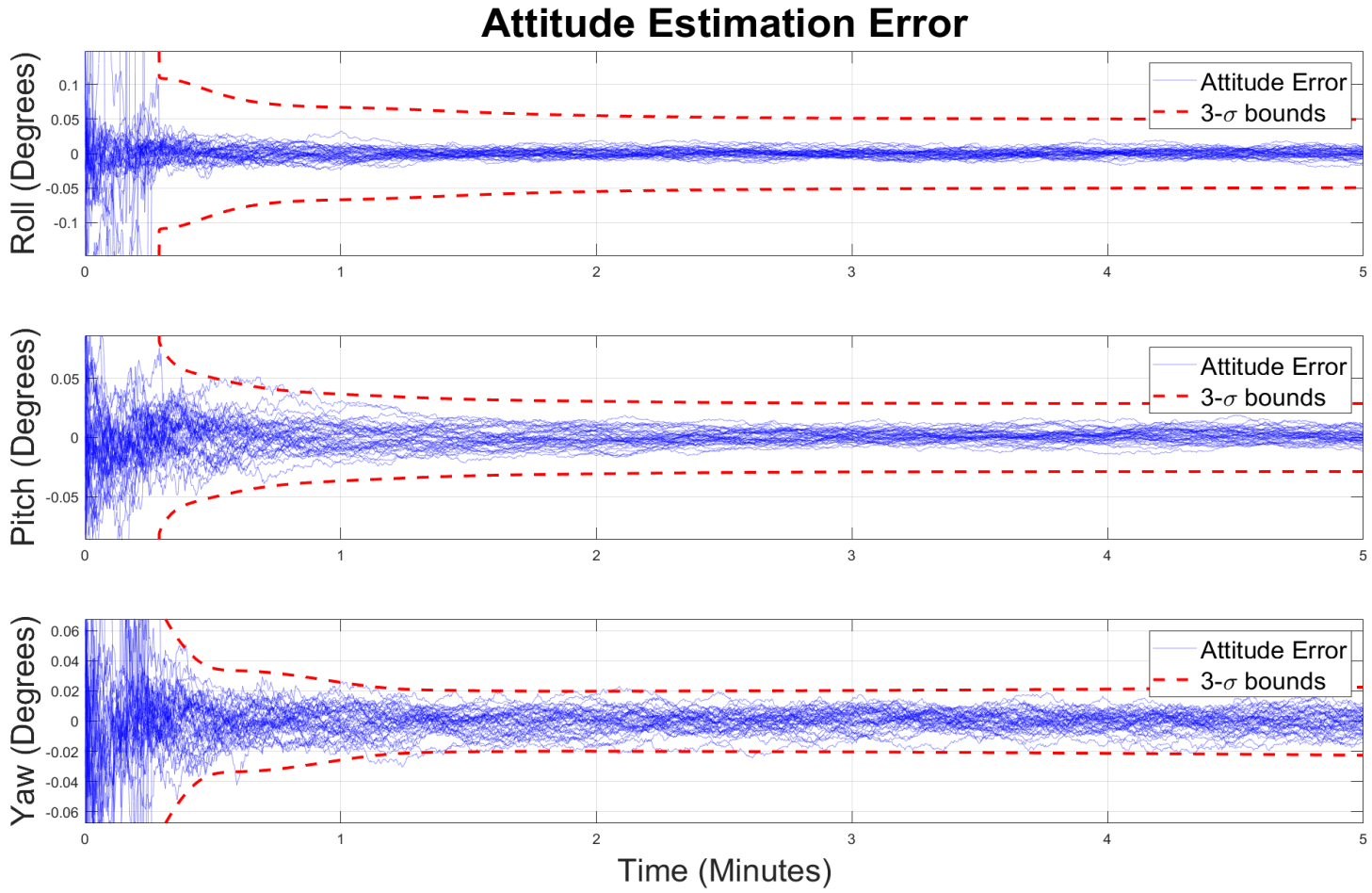
Charging Mode - Pointing



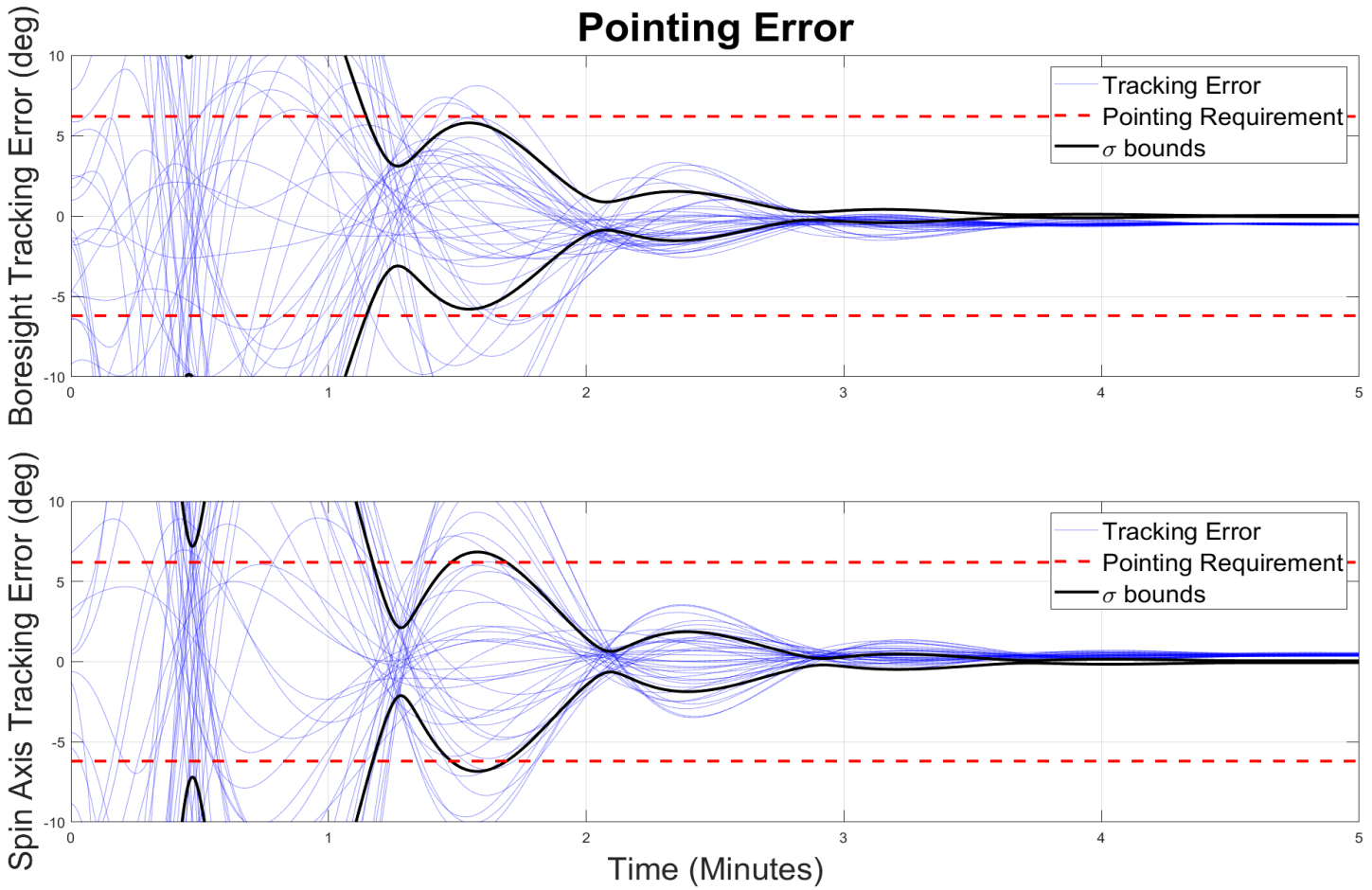
Charging Mode - Attitude



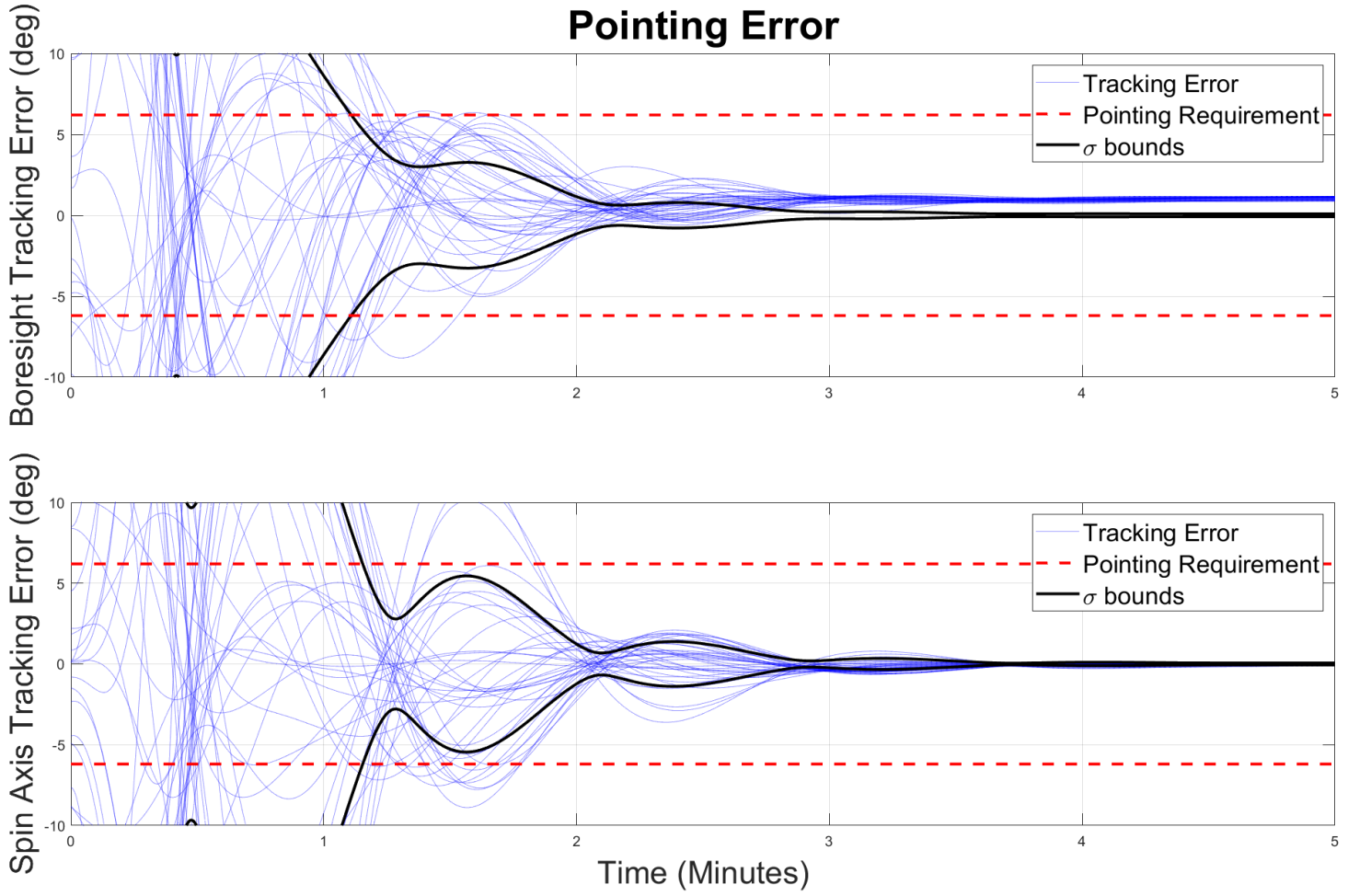
Mission Mode - Attitude



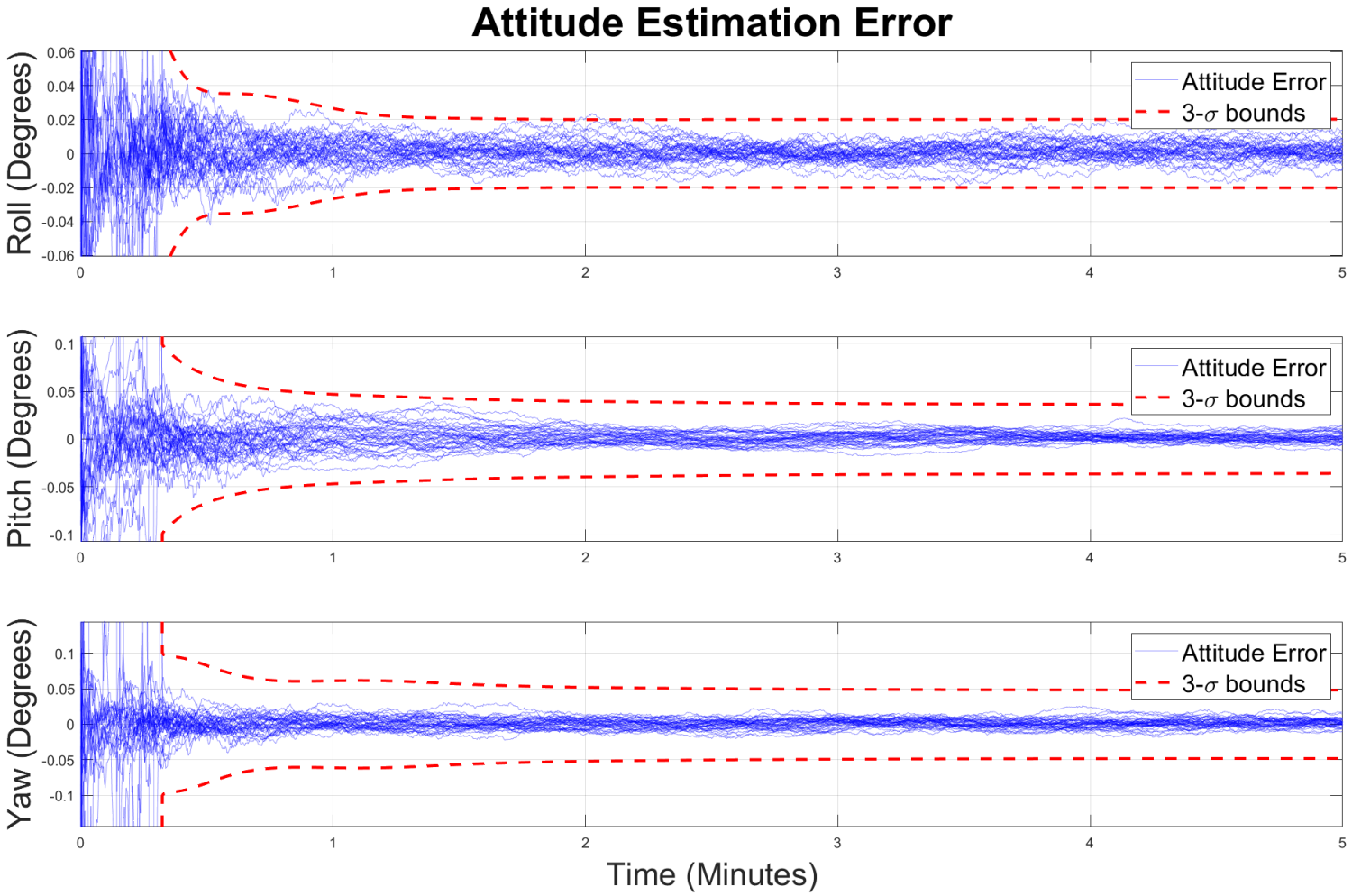
Mission Mode - Pointing



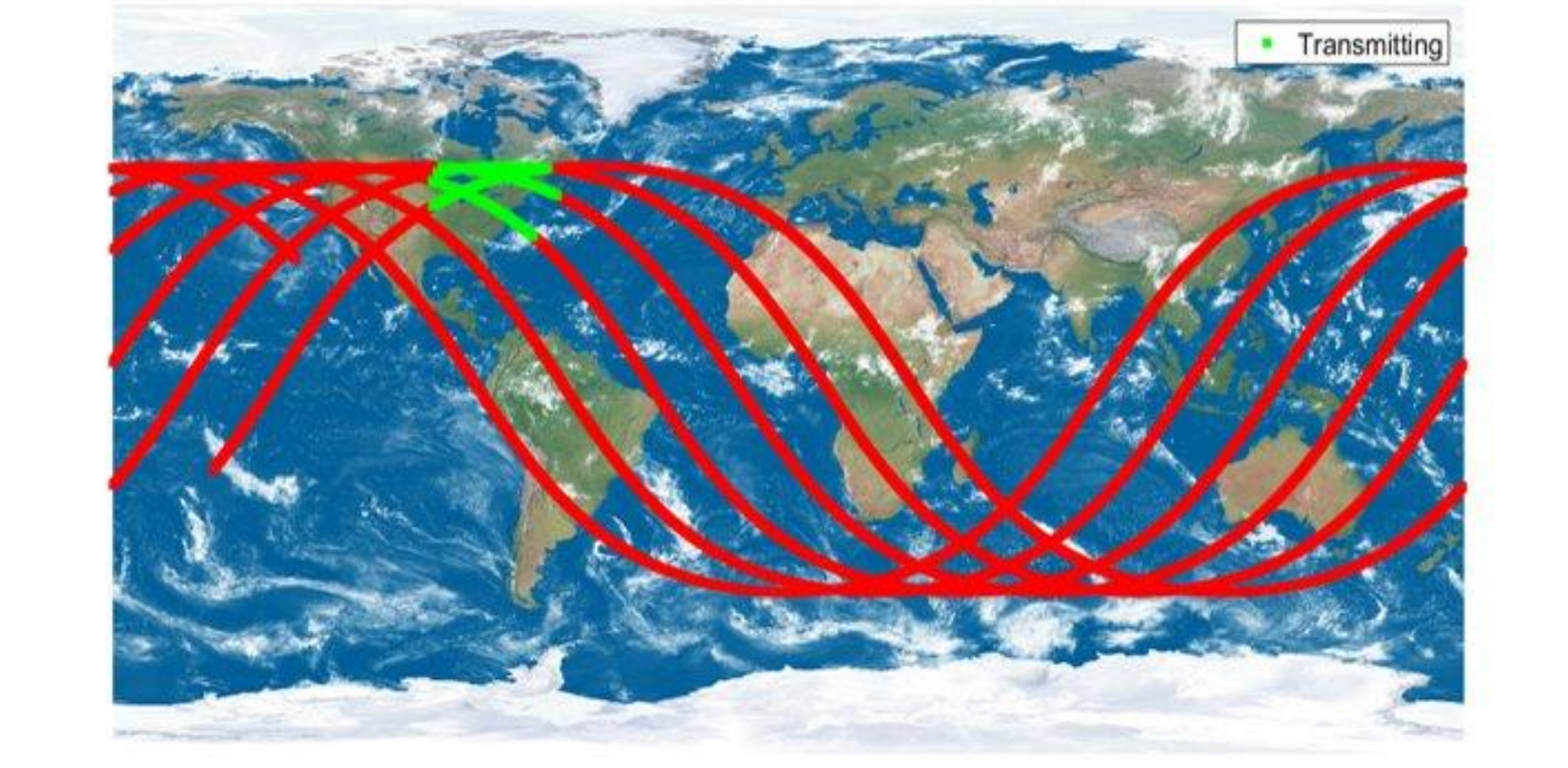
Transmitting Mode - Pointing



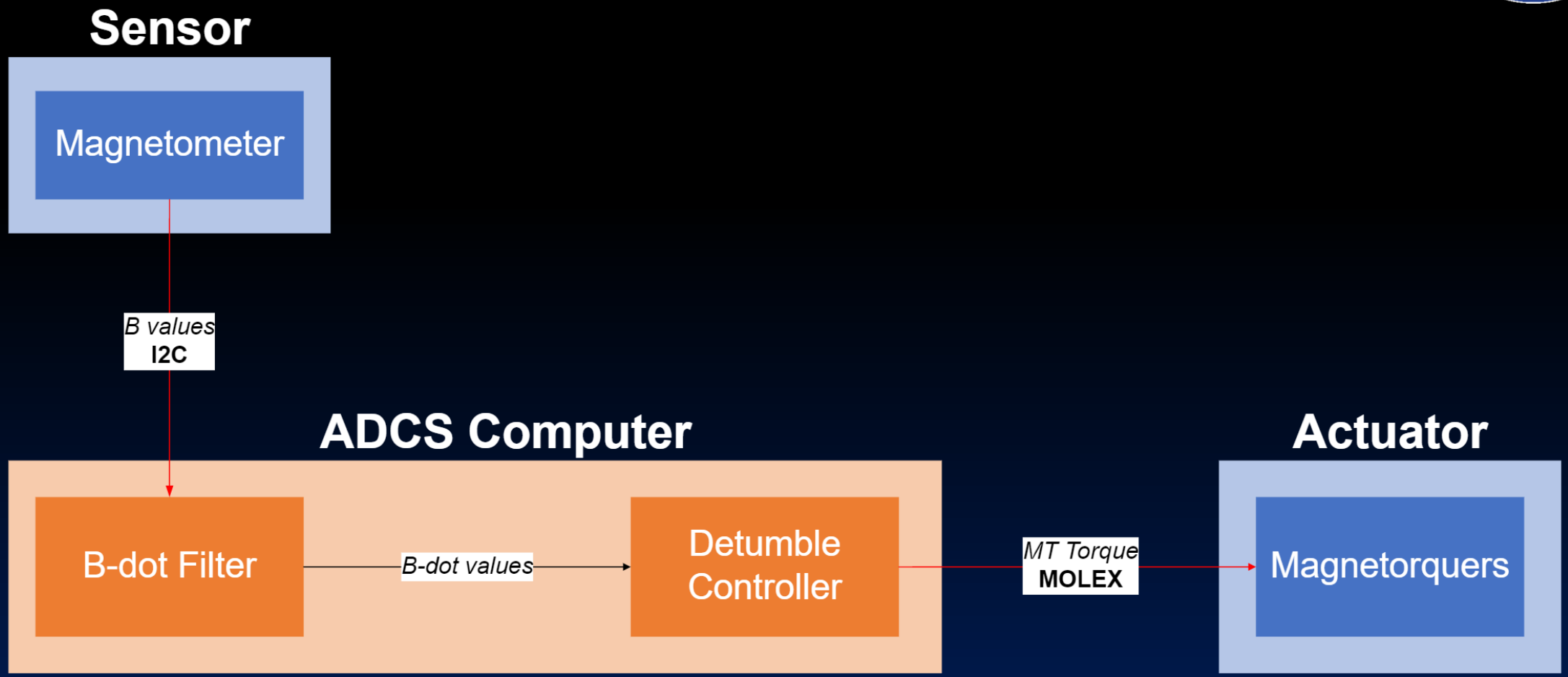
Transmitting Mode - Attitude



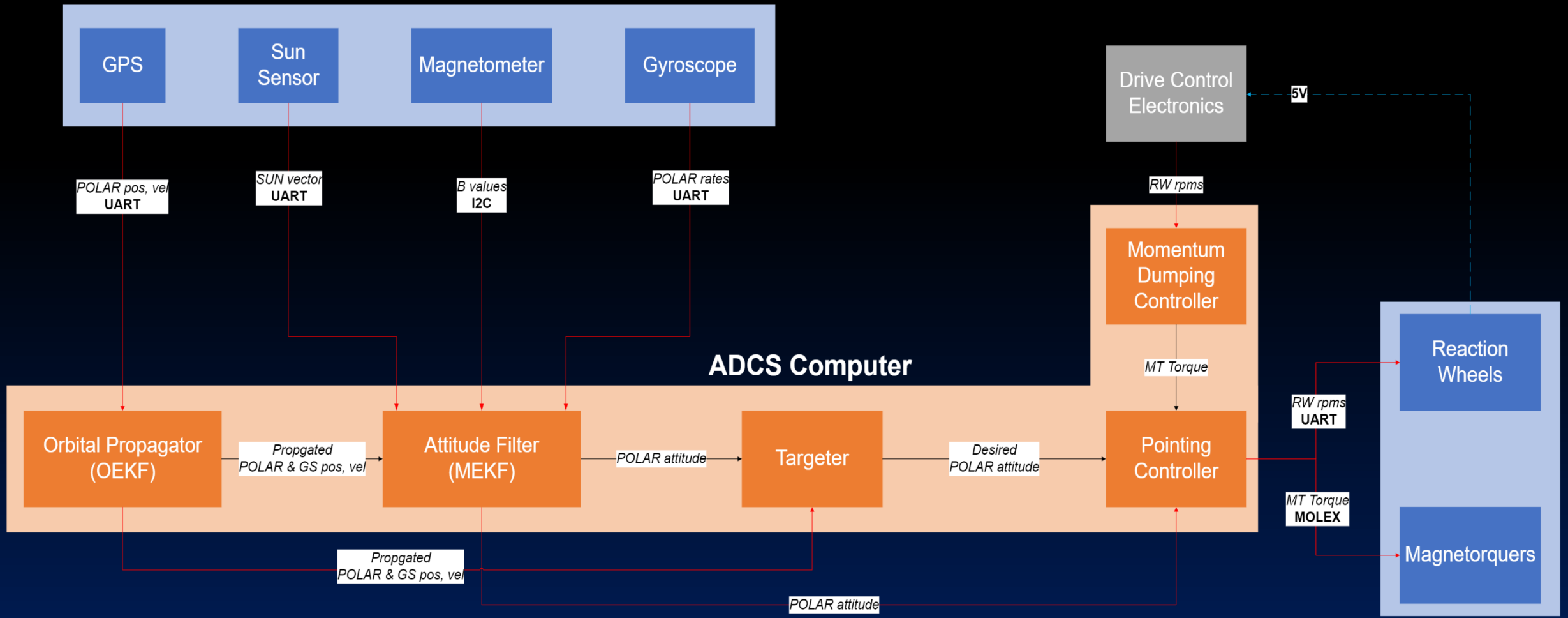
Transmitting Mode – Ground Track



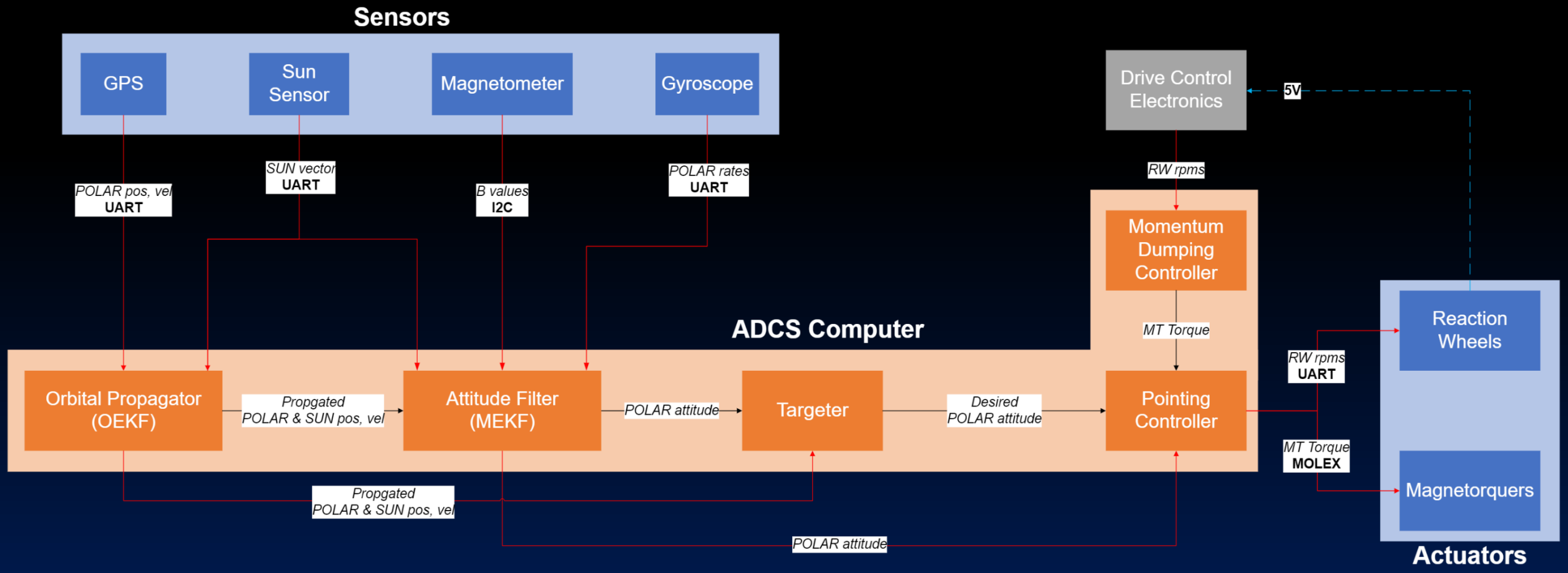
Detumble


Sensor
Magnetometer
B values
I2C
ADCS Computer
B-dot Filter
B-dot values
Detumble Controller
MT Torque
MOLEX
Actuator
Magnetorquers

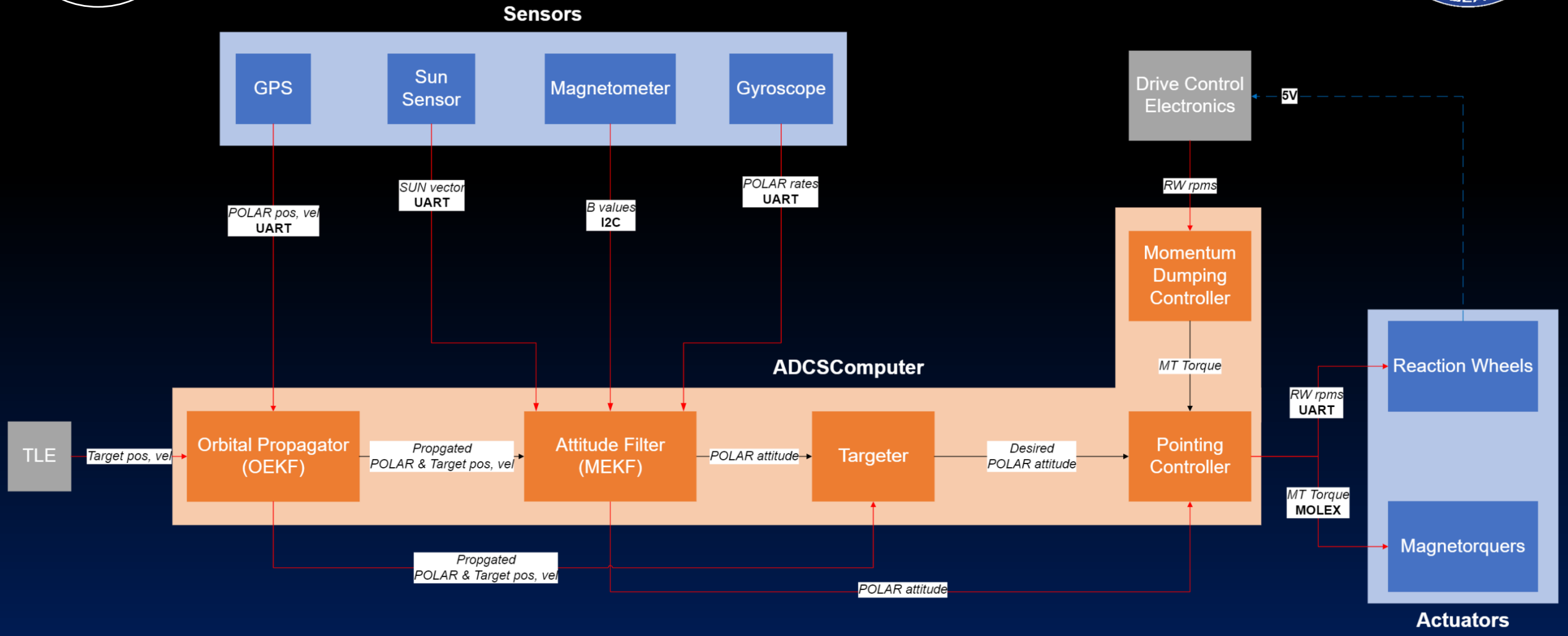
Transmitting Mode



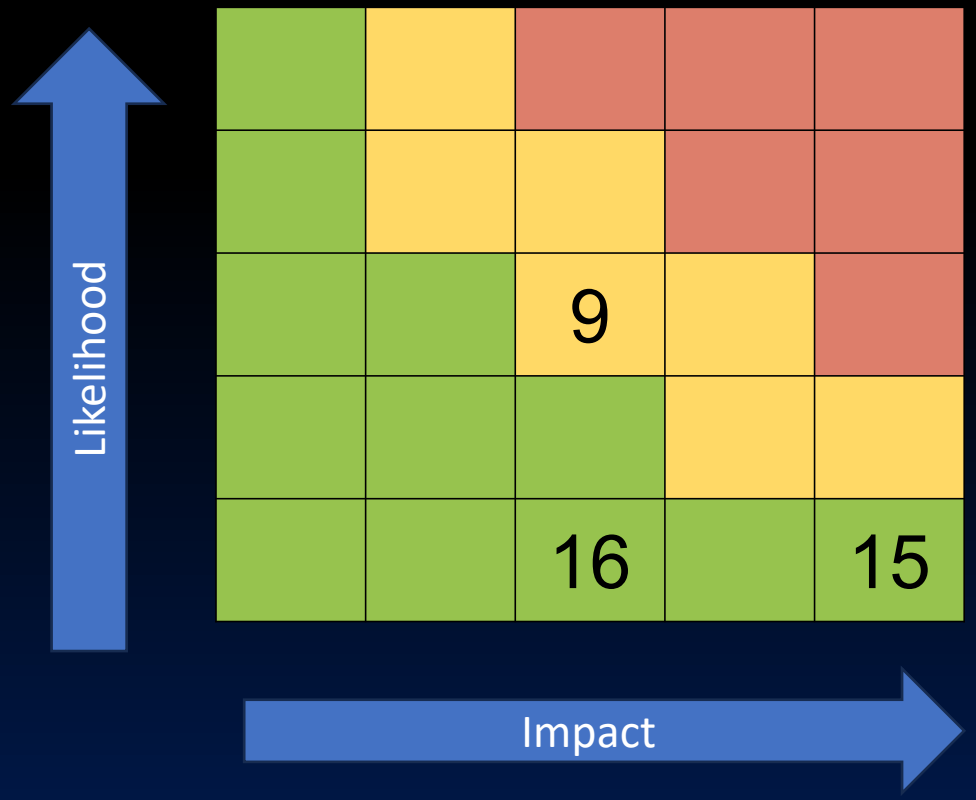
Charging Mode



Mission Mode

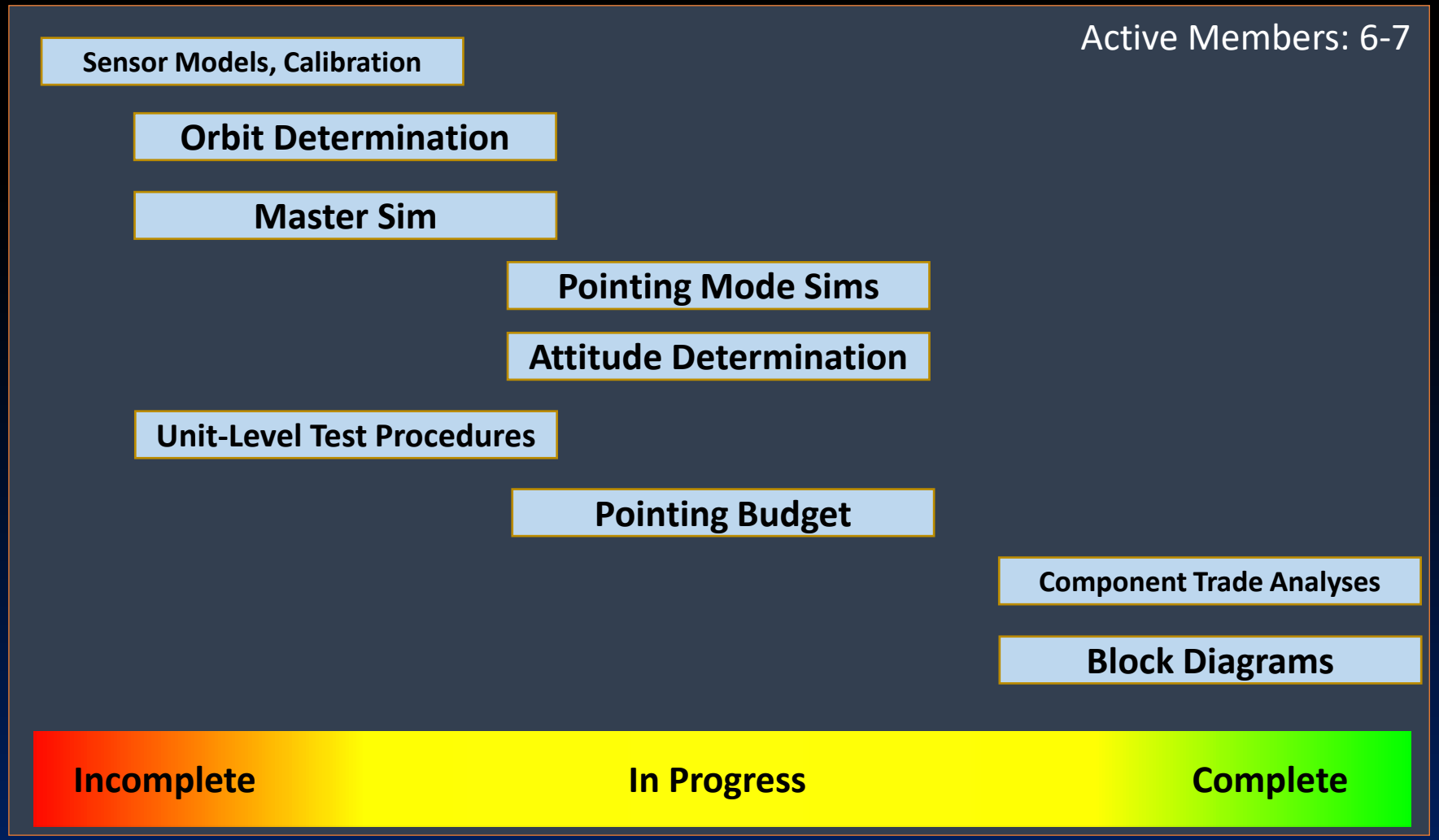


Risks

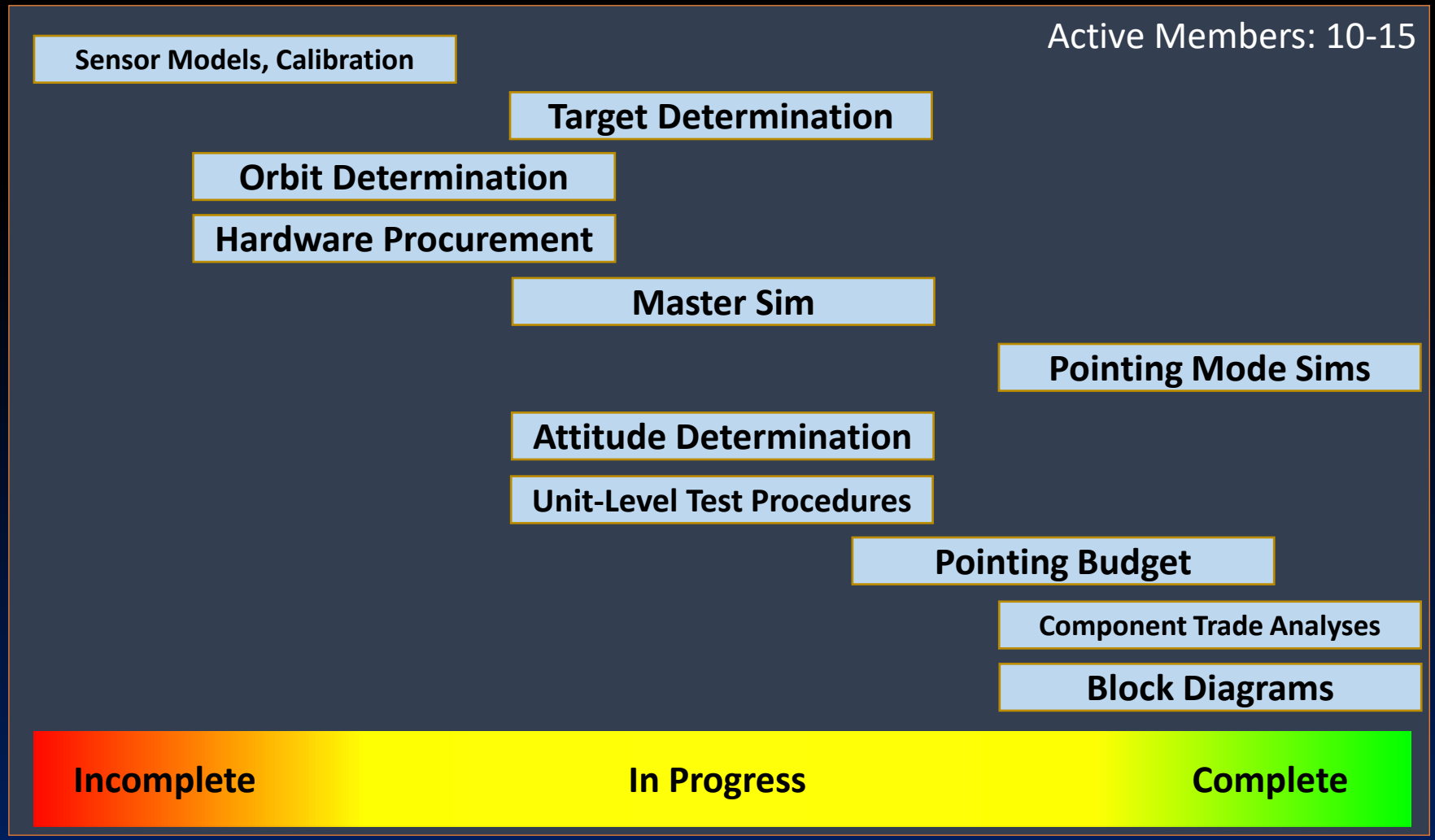


ID	Risk	Mitigation
9	GPS Error	GNC will derive a pointing budget that allows for L-Band patch antenna to view the Iridium constellation often enough for accurate GPS data
15	Reaction Wheel Failure	Redundancy will be implemented to prevent damage to POLAR's pointing ability
16	GNC Sensor Aging	Redundancy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

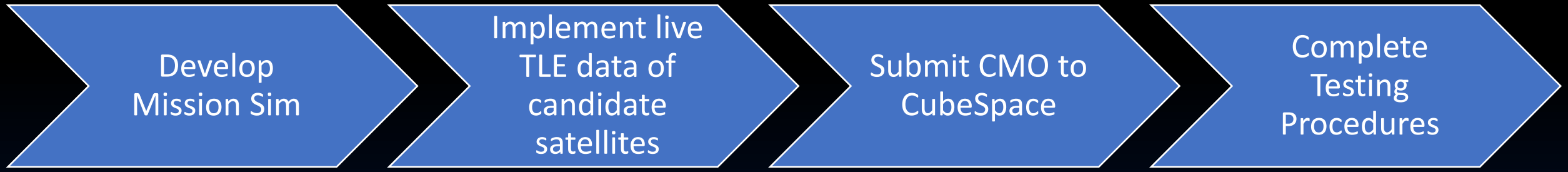
Subsystem Progress - PDR



Subsystem Progress - CDR



Next Steps

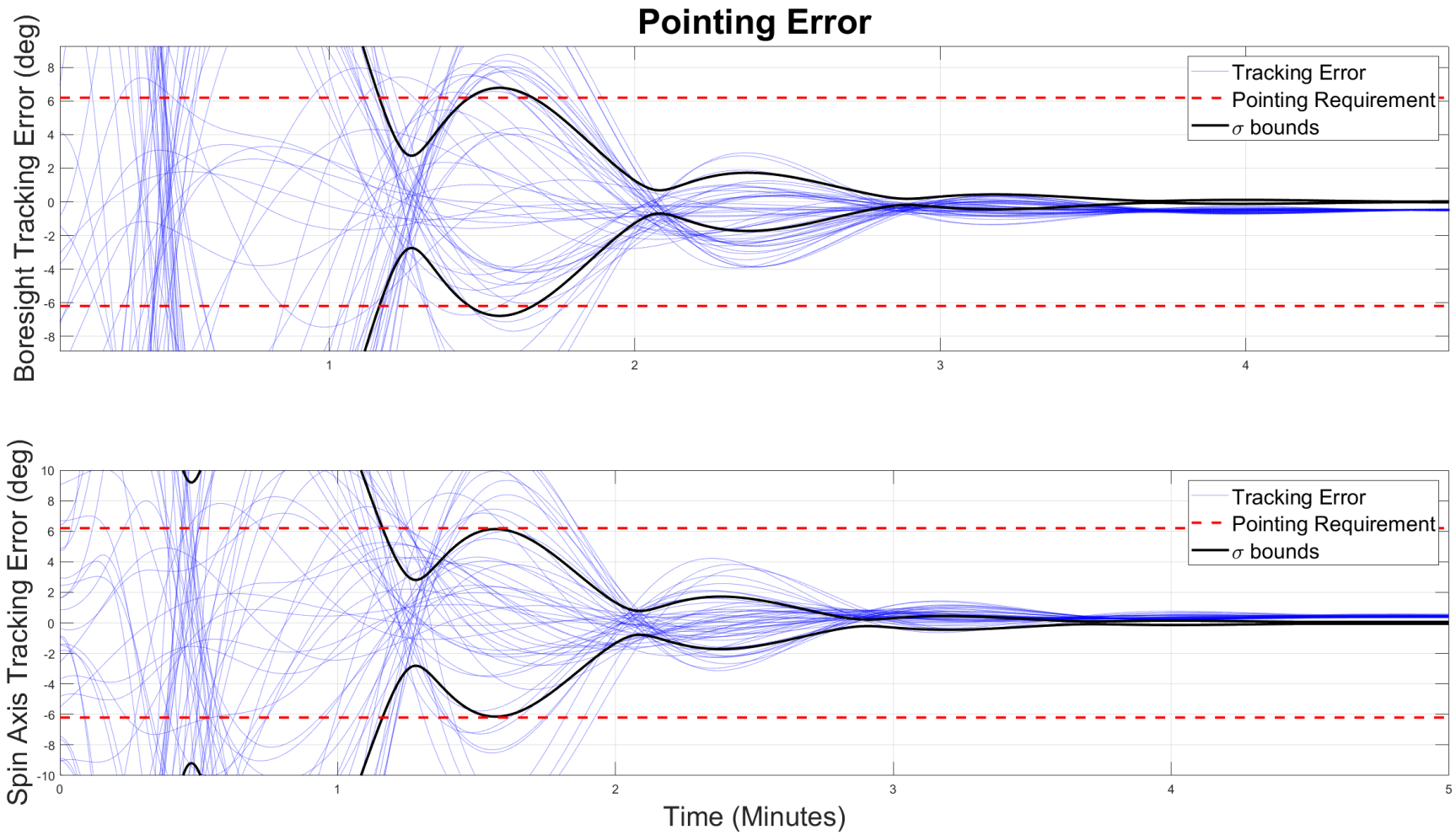


- Run a full mission Phase with different modes
- Integrate pBDRF material analysis algorithm

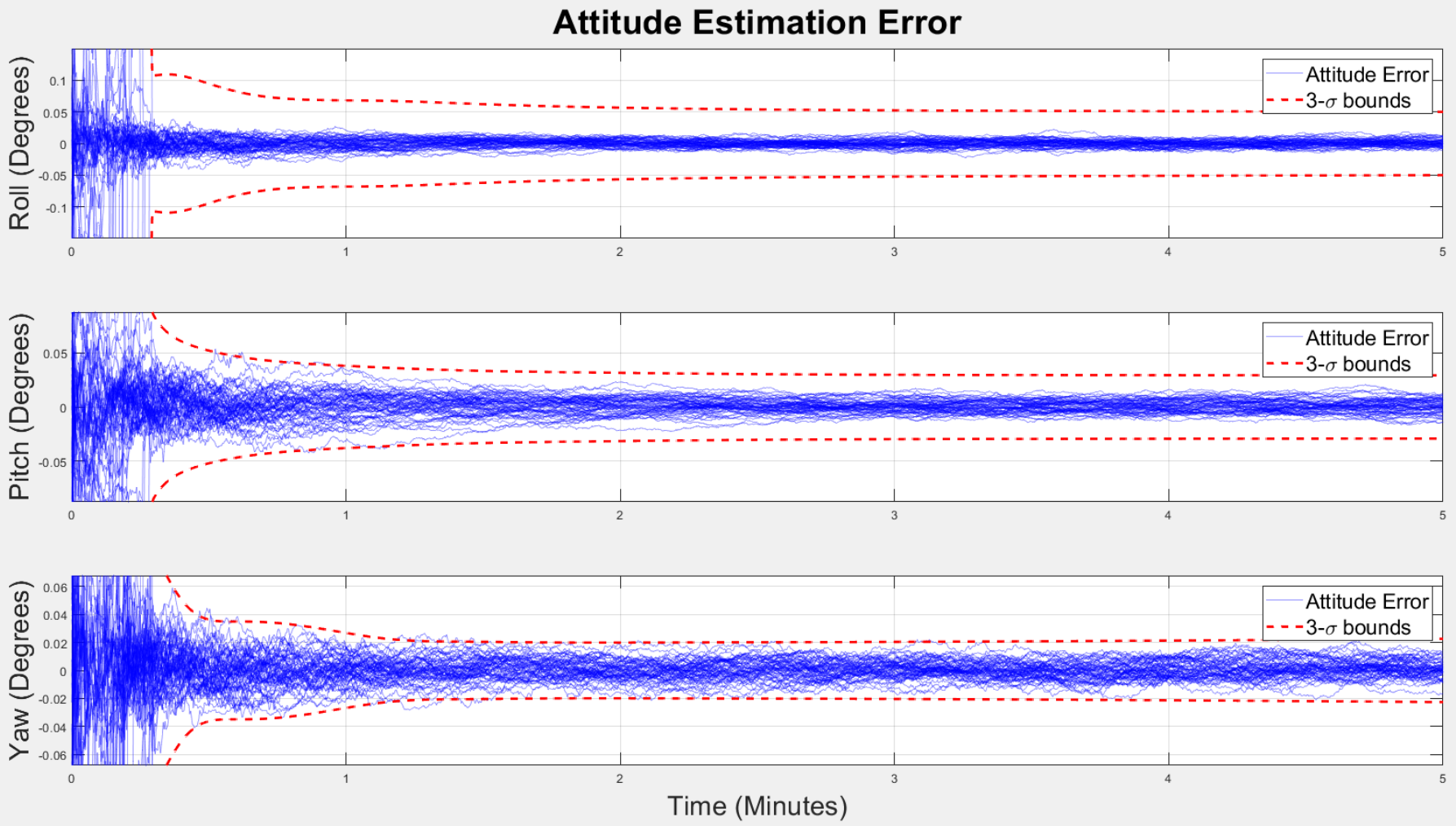
- Integrating a CelesTrack scraper
- Use observation selection from Operations

- Verify Hardware Selection with CubeSpace
- Order ADCS hardware

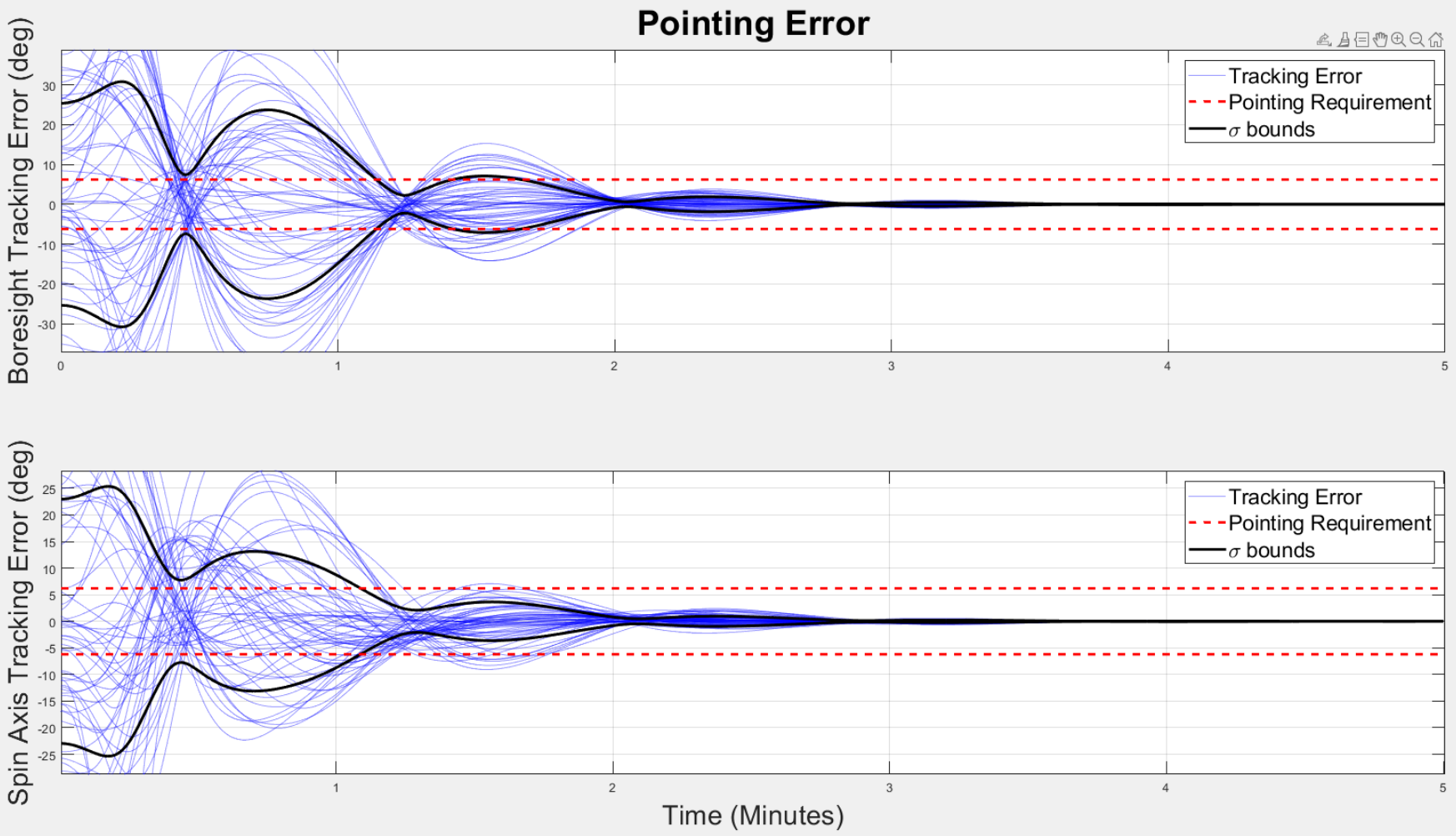
Mission Mode - Pointing



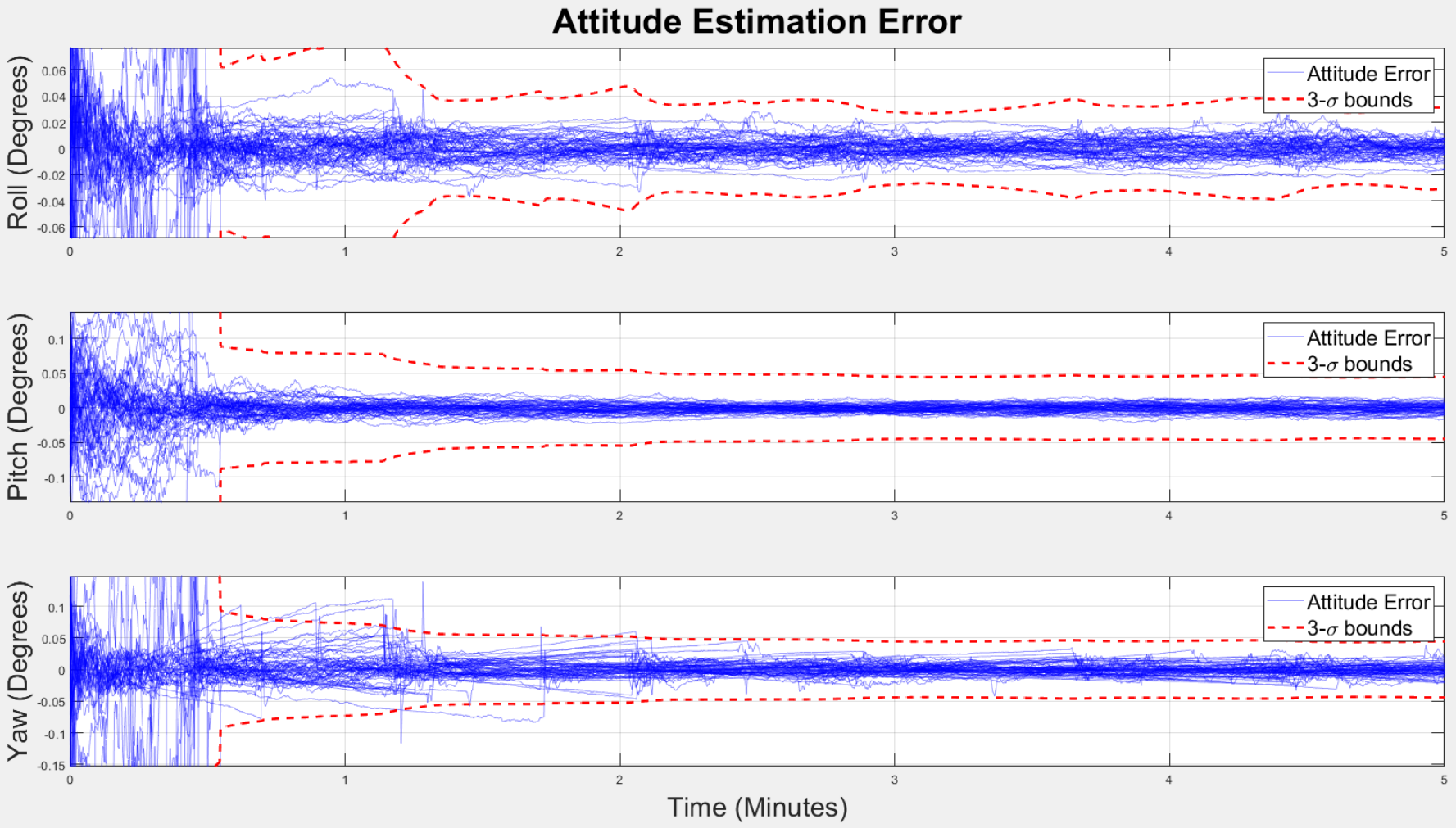
Mission Mode – Attitude



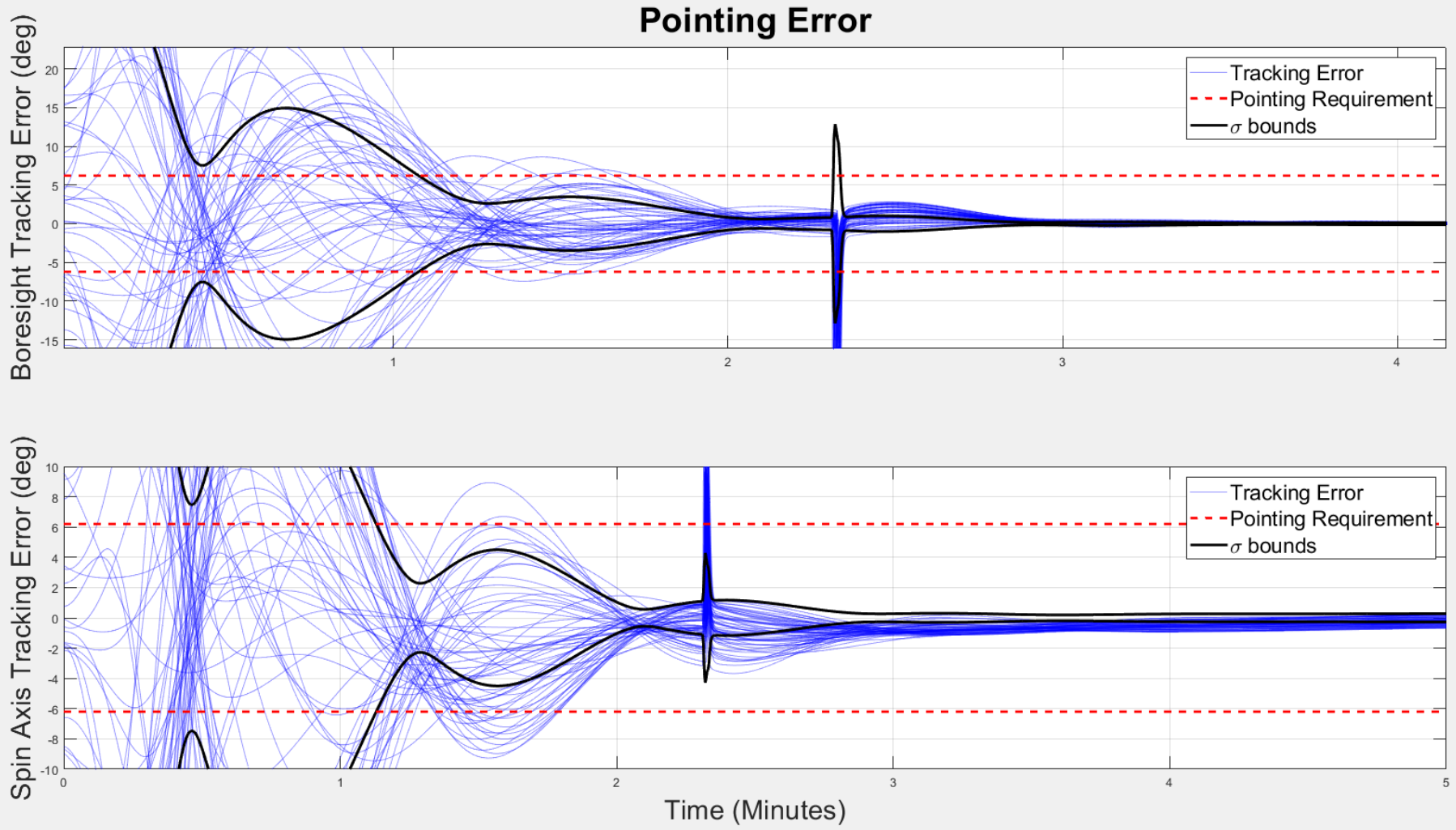
Charging Mode - Pointing



Charging Mode – Attitude



Transmitting Mode - Pointing



Transmitting Mode – Attitude