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MBSE for Space Systems Design with Capella:

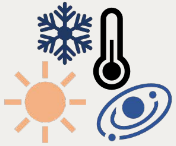
Design and Development of a PoC for a Modular Space Simulation Vacuum Chamber

Paula Andrea García Suárez

Why Simulation Facilities Matter?

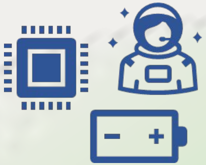
Why vacuum chambers are space systems

VC are essential for simulating space environments **on Earth**, including vacuum, thermal extremes, radiation.



Long-lived, reusable, multi-user infrastructure

They are used to test and validate components, materials, and systems **before** deployment.



Due to their complexity and cost, access is often limited (especially in Latin America).
Strengthening national infrastructure is critical to support local research.

Early design decisions define *everything*

Multidisciplinary complexity

Safety-critical

Cost and scalability constraints

Traditional document oriented design struggle with:

- Traceability
- Consistency
- Change impact

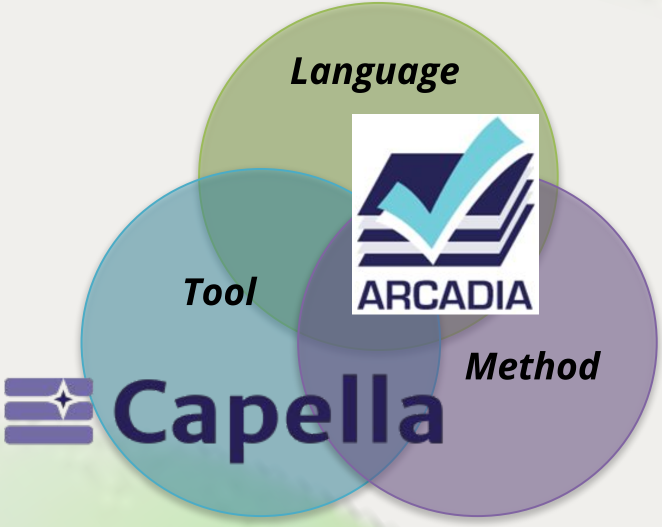
How can MBSE support early design decisions in complex space systems?

MBSE as a structuring framework

MBSE: structured reasoning, not just modeling

Capella + Arcadia:

- Clear architectural *layers*
- Strong separation of concerns
- Excellent for infrastructure systems



Project Overview

Vacuum Chamber Proof of Concept

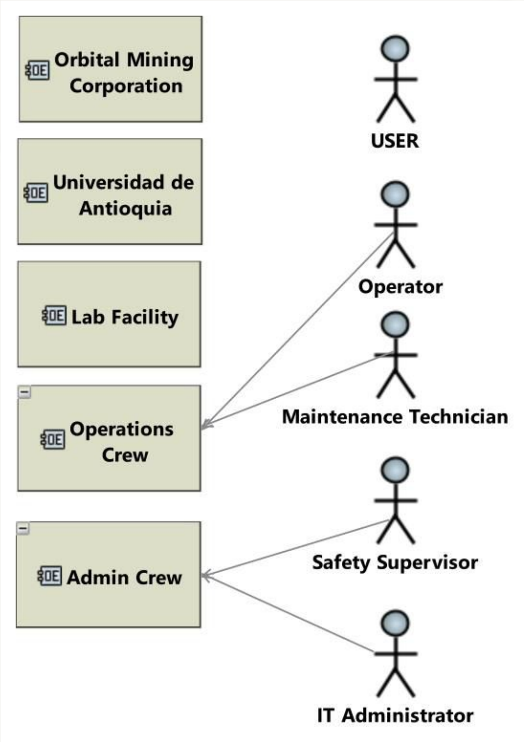
Mission: *Operate Vacuum Chamber and Space Simulation*

- Modular, scalable facility
- Target use case: lunar impactor simulations
- Outcome: complete system design (not construction)

Bridge into modeling...

Operational Architecture:

Structuring the Problem



Understanding the system before designing it

Before defining components, we clarified *who does what, when, and why*.

Operational Entity Breakdown Diagram

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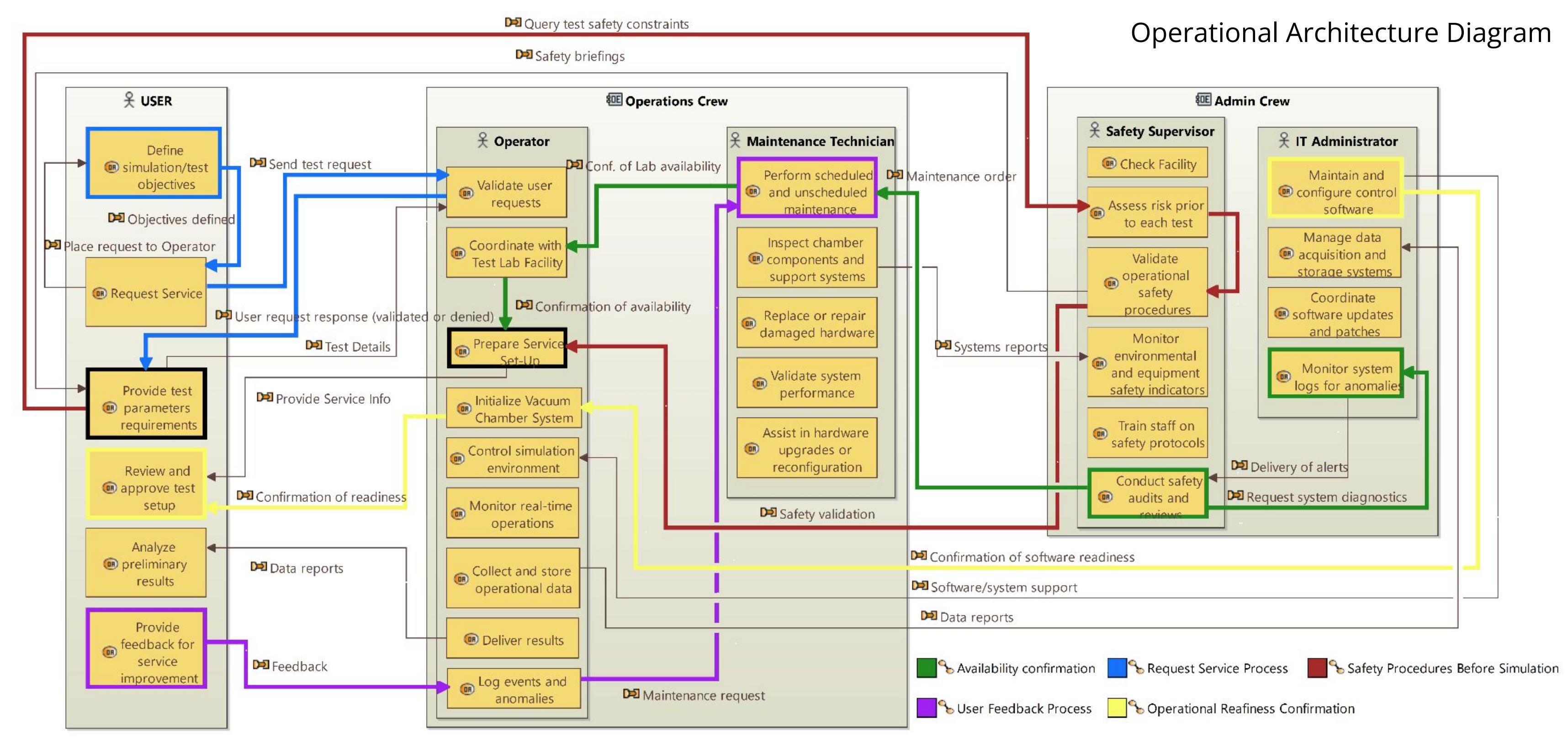
Operational Scenarios

Operational Architecture Diagram



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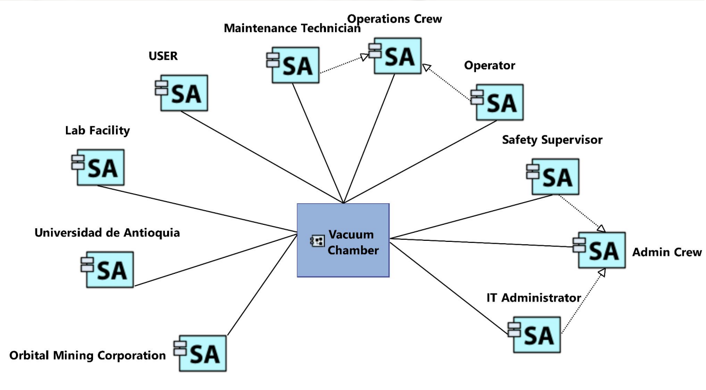
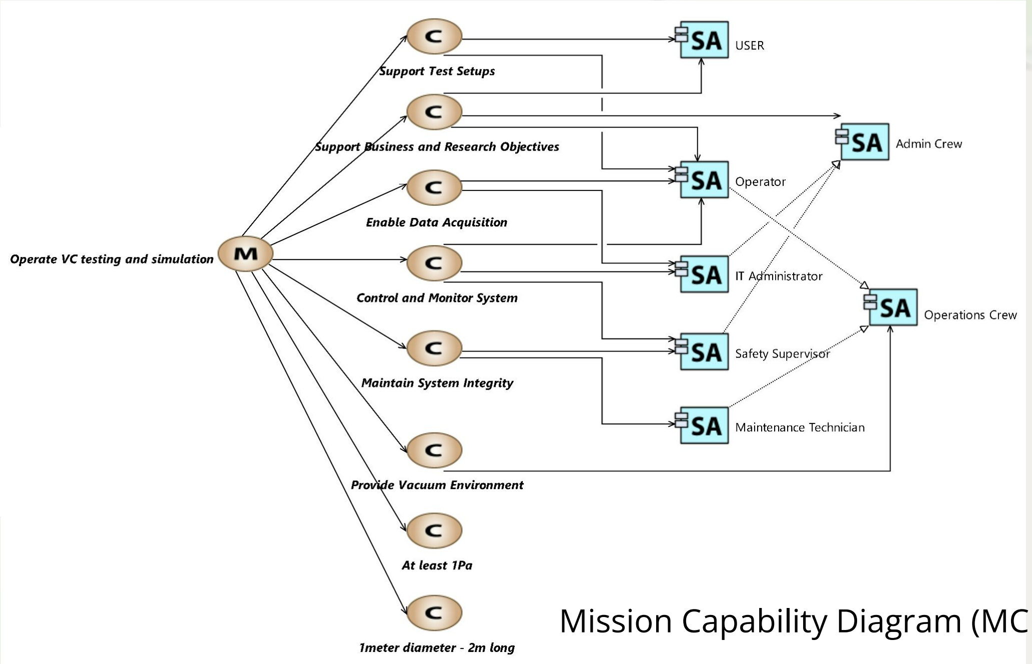
System Architecture

From operations to system functions



The Contextual System Actor diagram (CSA) allows the definition of our system: **Vacuum Chamber.**



Mission Capability Diagram (MCB)

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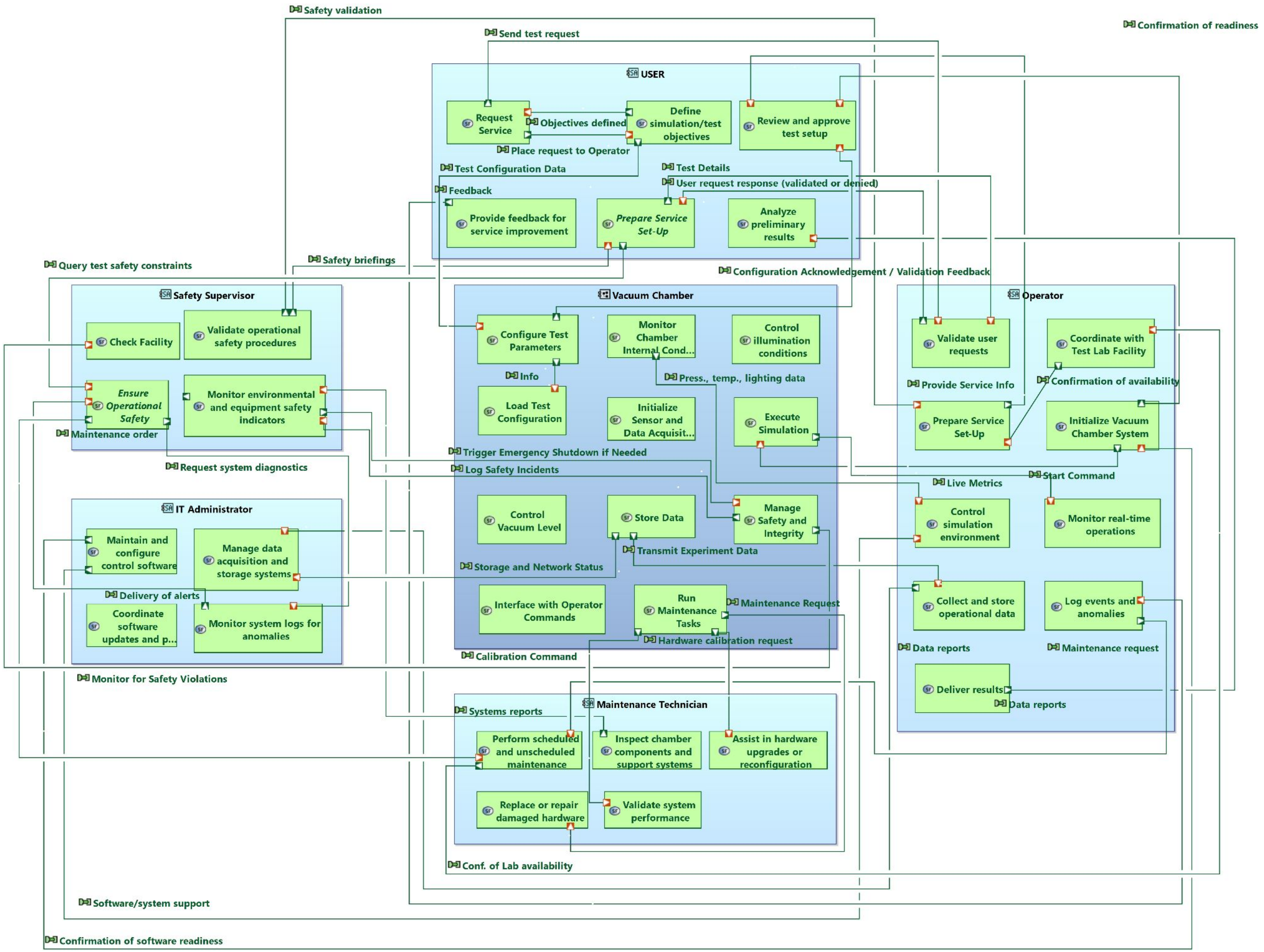
System Archtecture



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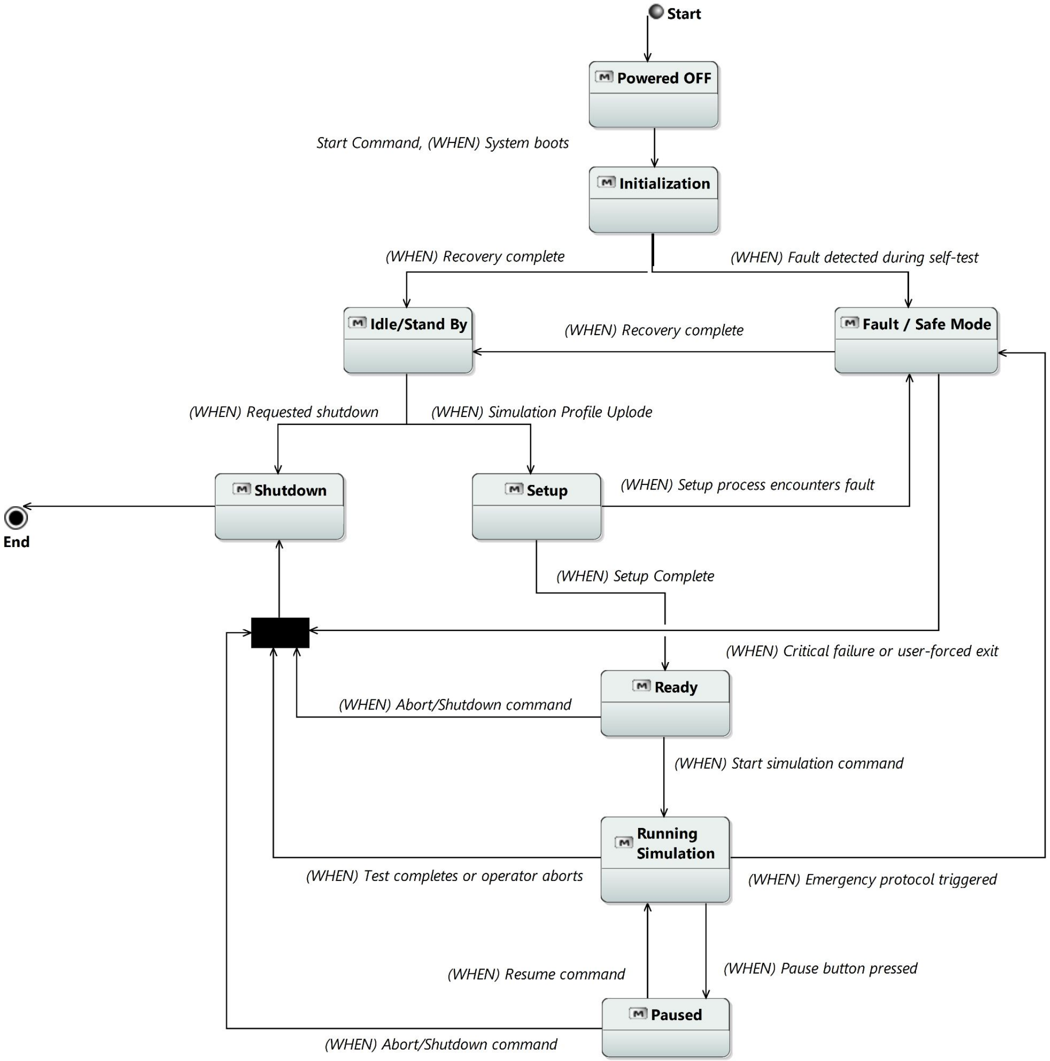
Mode-State Machine Diagram



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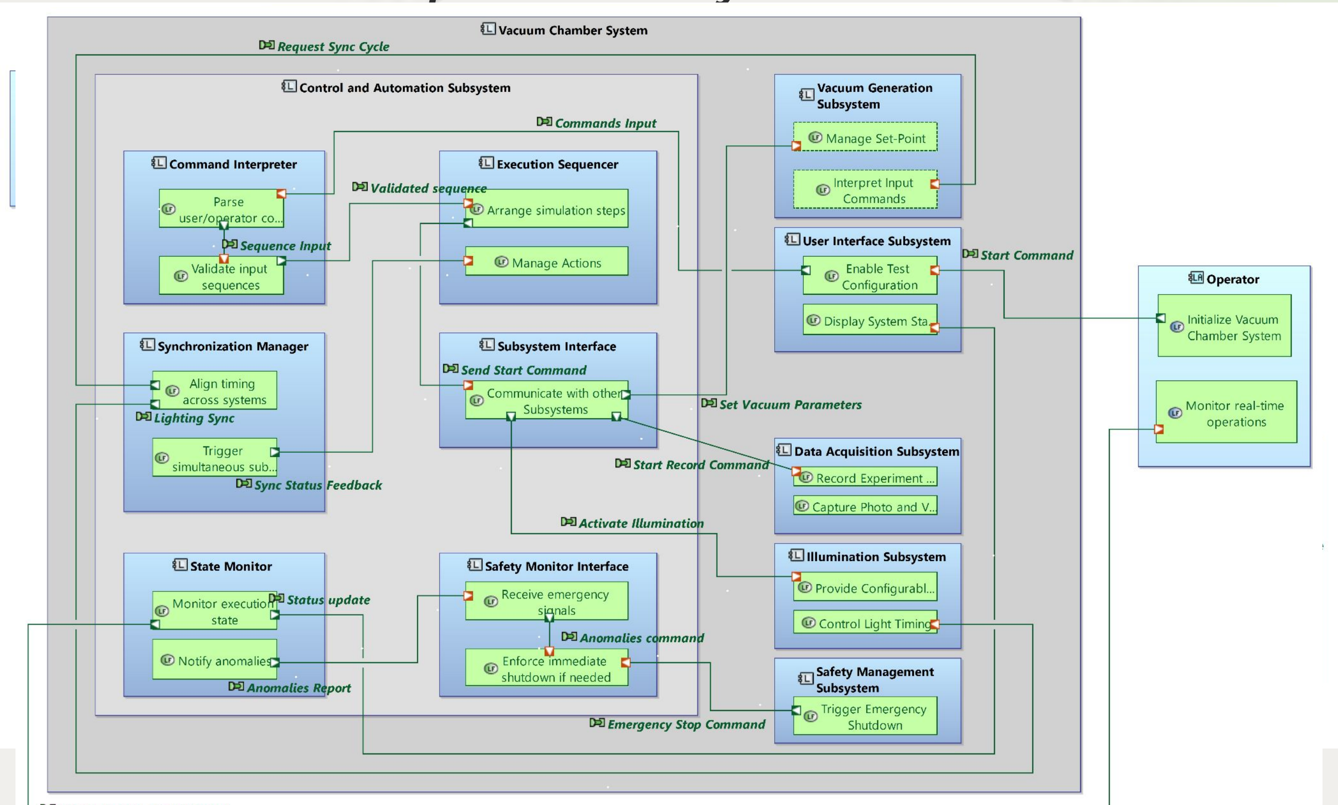
Logical Architecture

From operations to system functions



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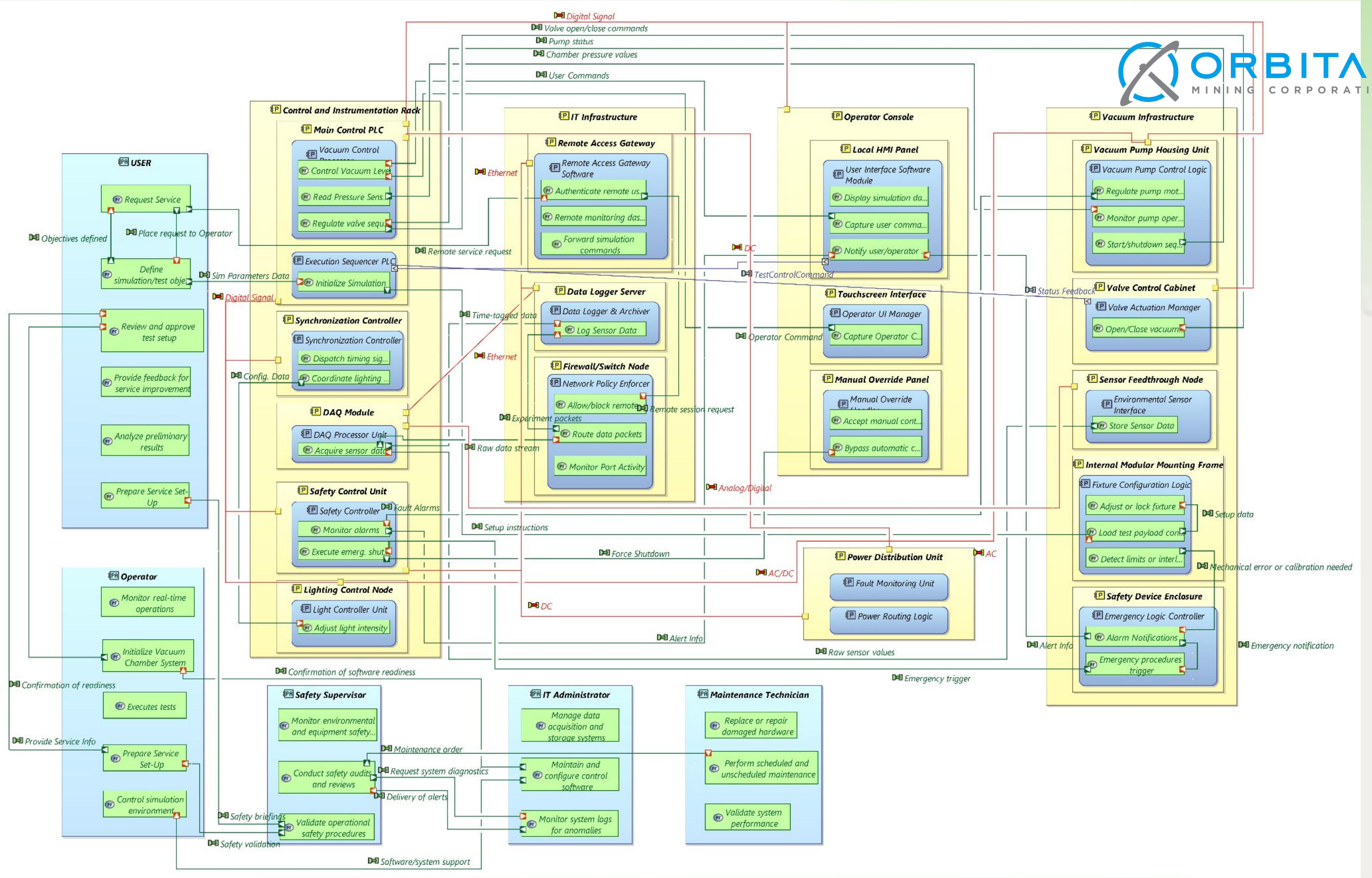

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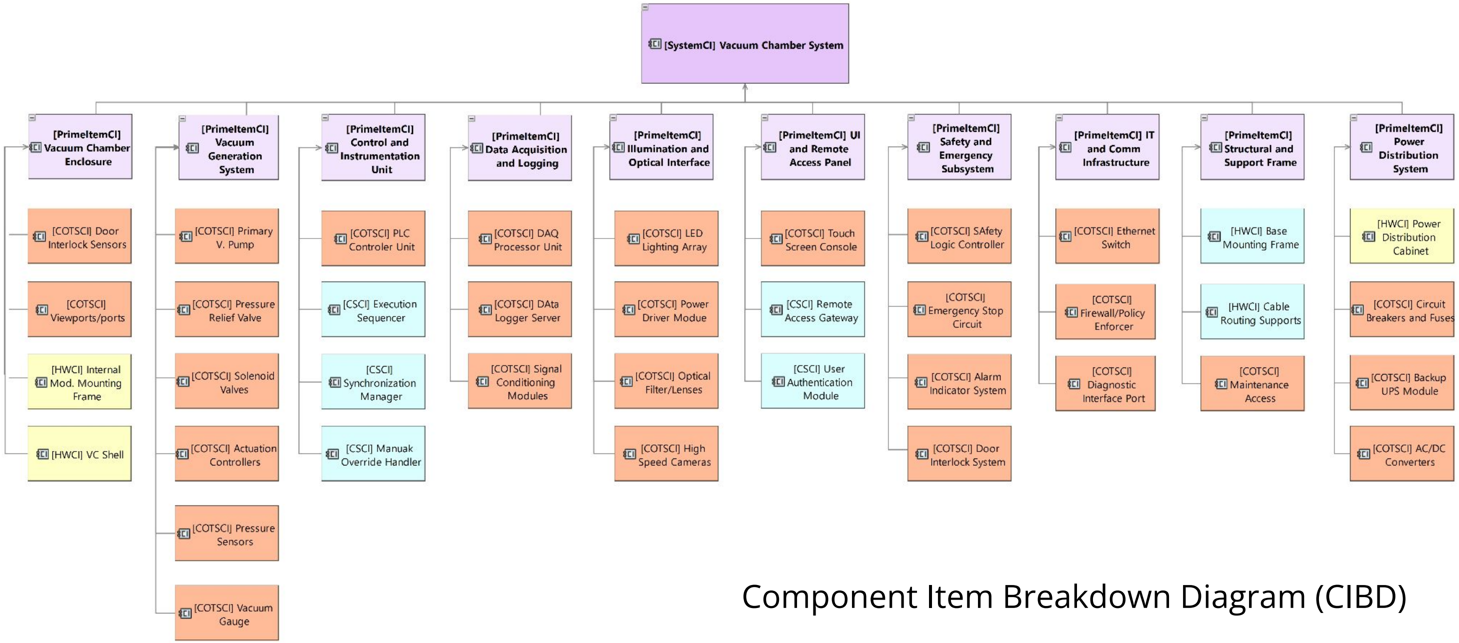
From Architecture to EPBS

System model to product structure



Component Item Breakdown Diagram (CIBD)

The model becomes directly actionable

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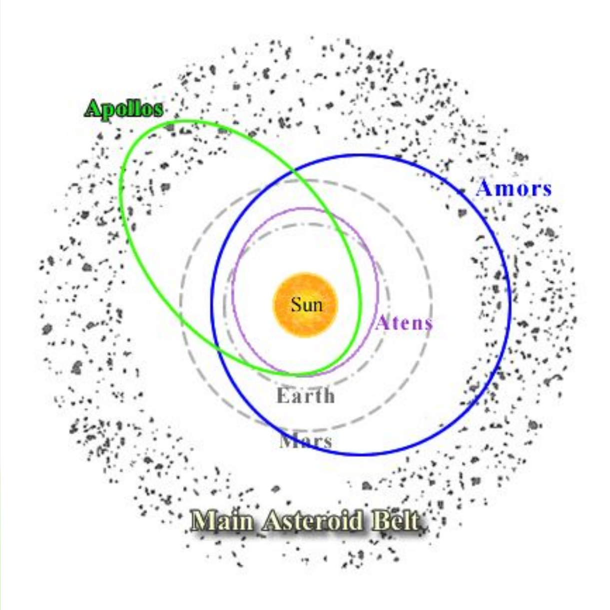
MBSE for Space Systems Design with Capella:

A MBSE Approach to the Development of a Space-Based Observatory for NEO Detection

Juan Felipe Ríos Orozco

Problem Context

A **NEO (Near-Earth Object)** is an asteroid or comet with a perihelion distance < 1.3 AU.



The Alarming Fact:

- Asteroids larger than 140 m can cause regional damage.
- Only ~40% have been detected so far.

Problem Context

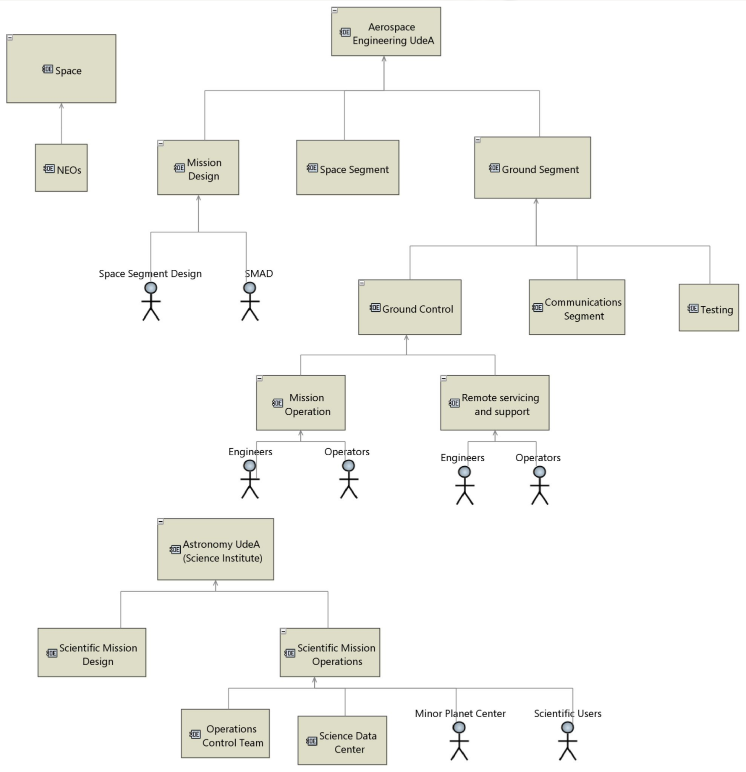
Limitations of Ground-based Observations:

- Atmospheric interference.
- Reduced field of view.
- Undetectability of NEOs from the Sun's direction.

Space-Based Observatory Benefits:

- Increased coverage.
- Absence of atmospheric interference.
- Continuous operation.
- Access to other spectral regions.
- Capability to observe areas close to the Sun.

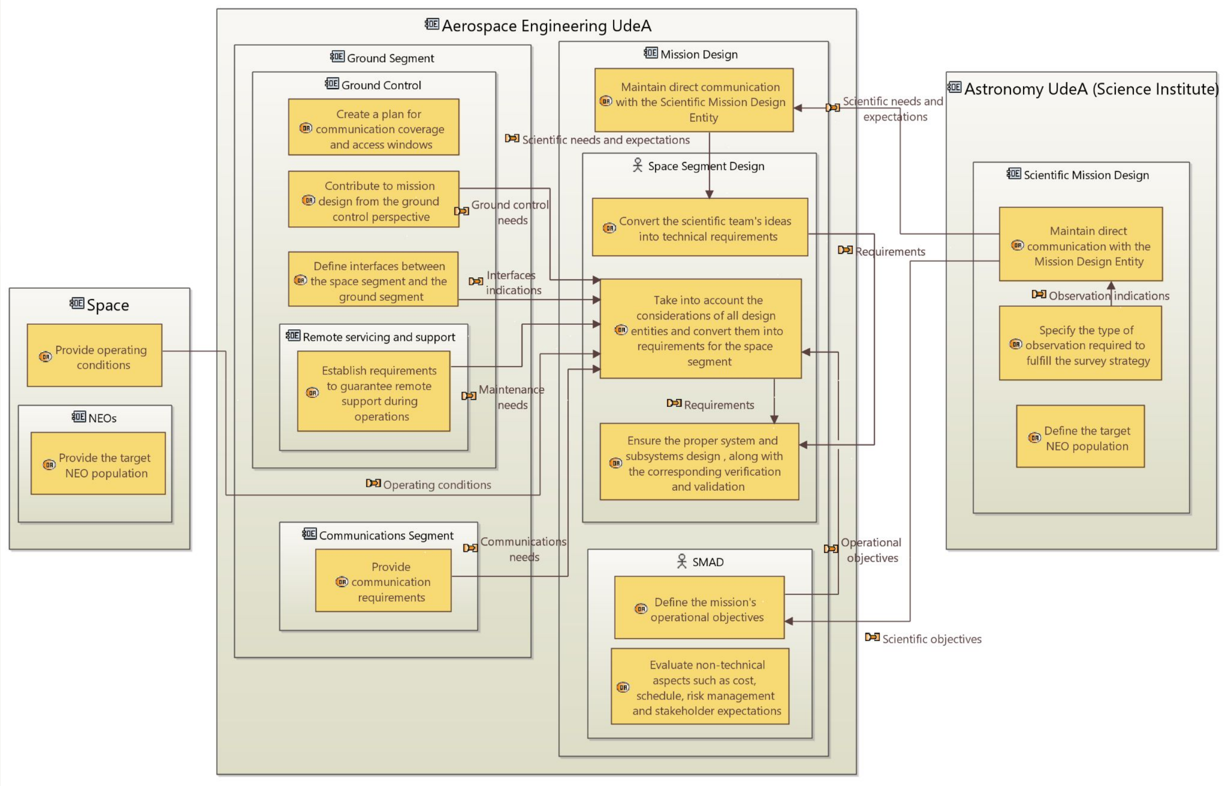
Operational Analysis



Two main entities:

- Engineering Entity
- Science Institute

Operational Analysis



Operational Architecture - Mission Design

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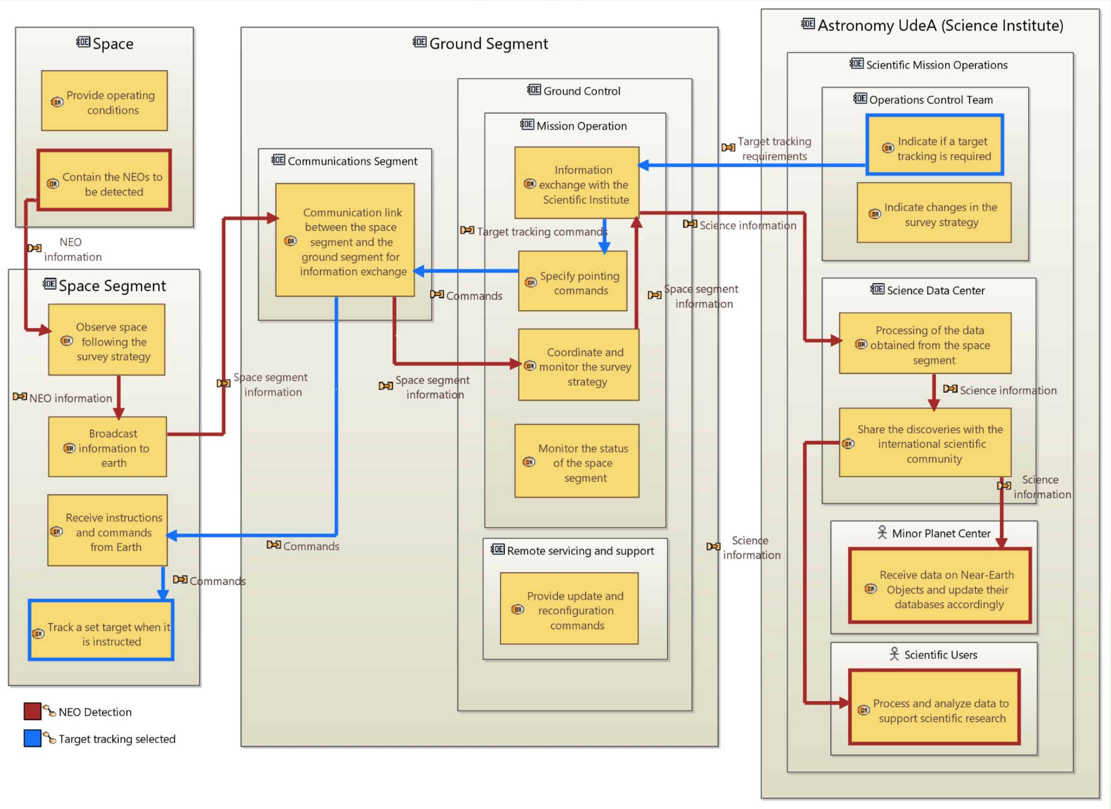
Operational Analysis



Operational Architecture - Operation

Operational Analysis

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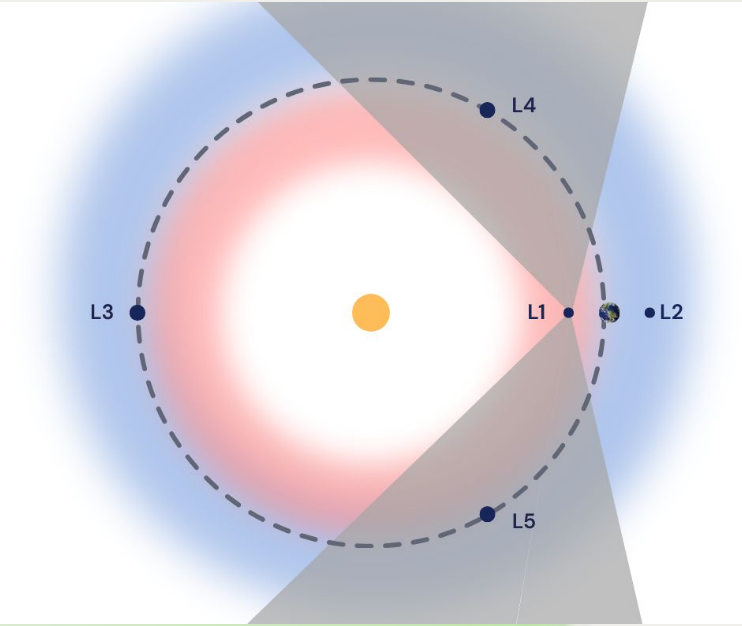
Operational Orbit: Halo orbit around Sun-Earth L1

- Good observational coverage of NEOs approaching from the Sun’s direction.
- Favorable phase angles.
- Easier communications compared to other options.
- Continuous coverage.

Spectral Range: Infrared



Operational Analysis

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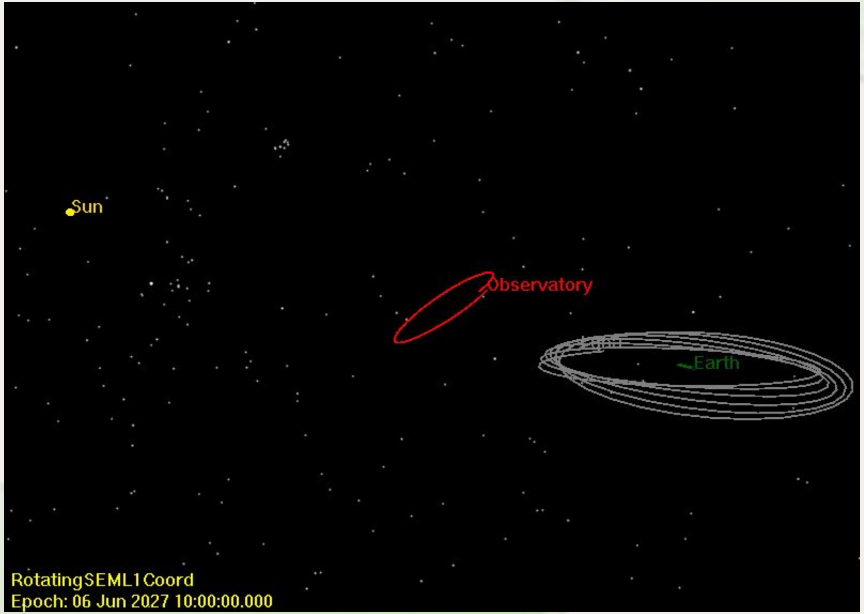

Spectral Range: Infrared

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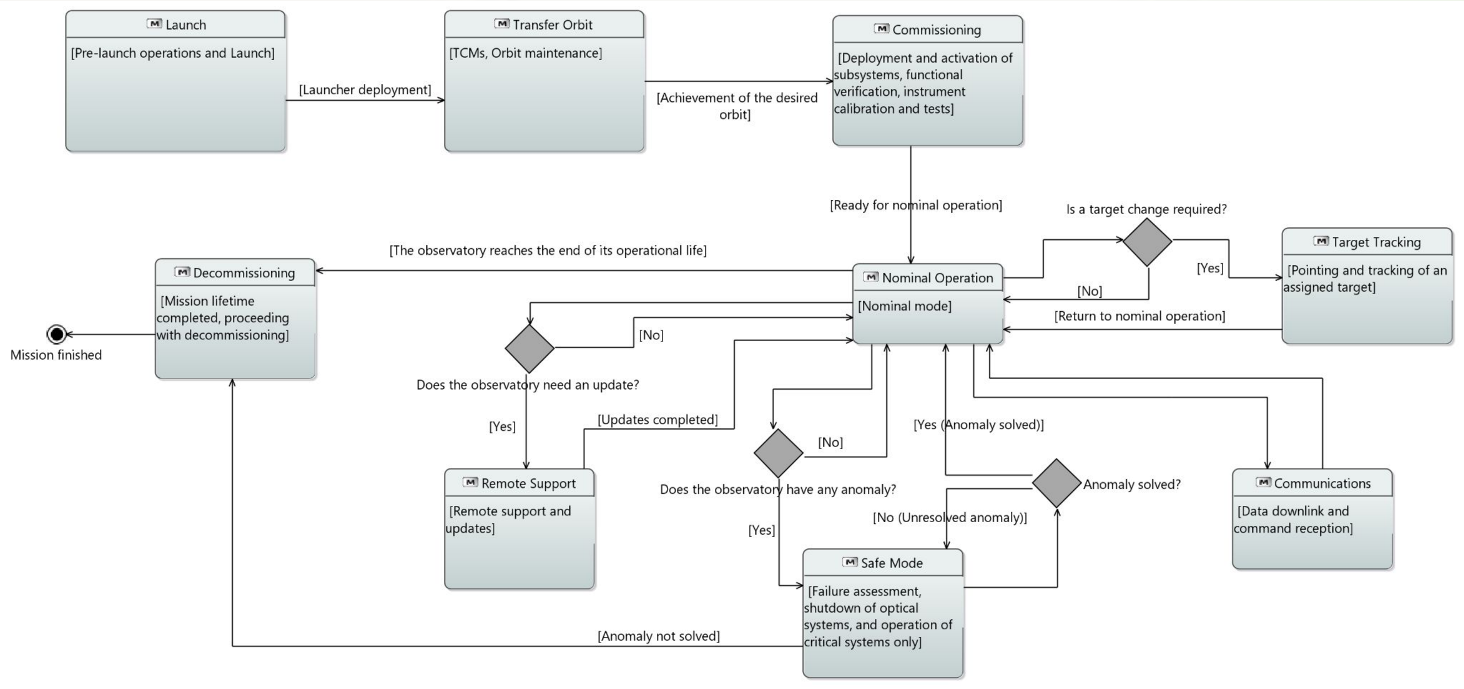
Modes of Operation



Mode-State Machine Diagram

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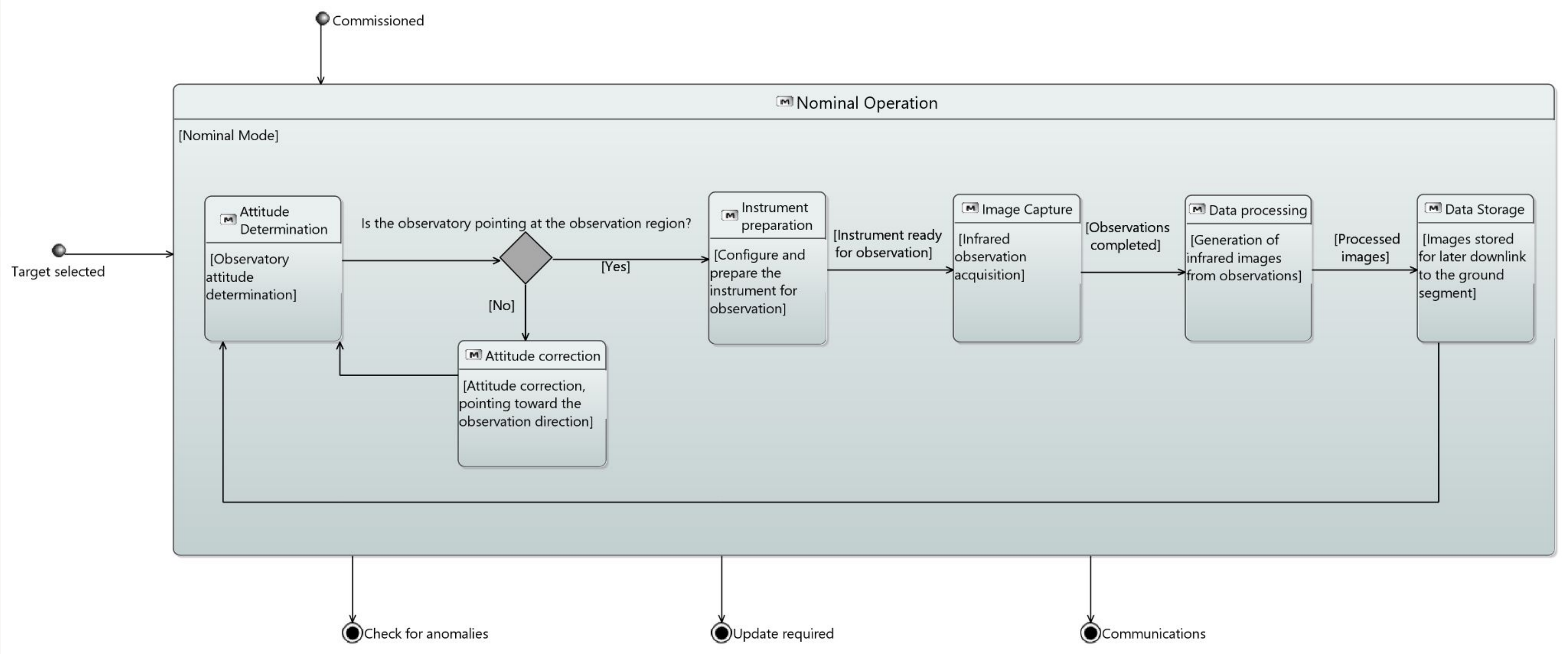
Modes of Operation



Nominal Mode

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System Analysis

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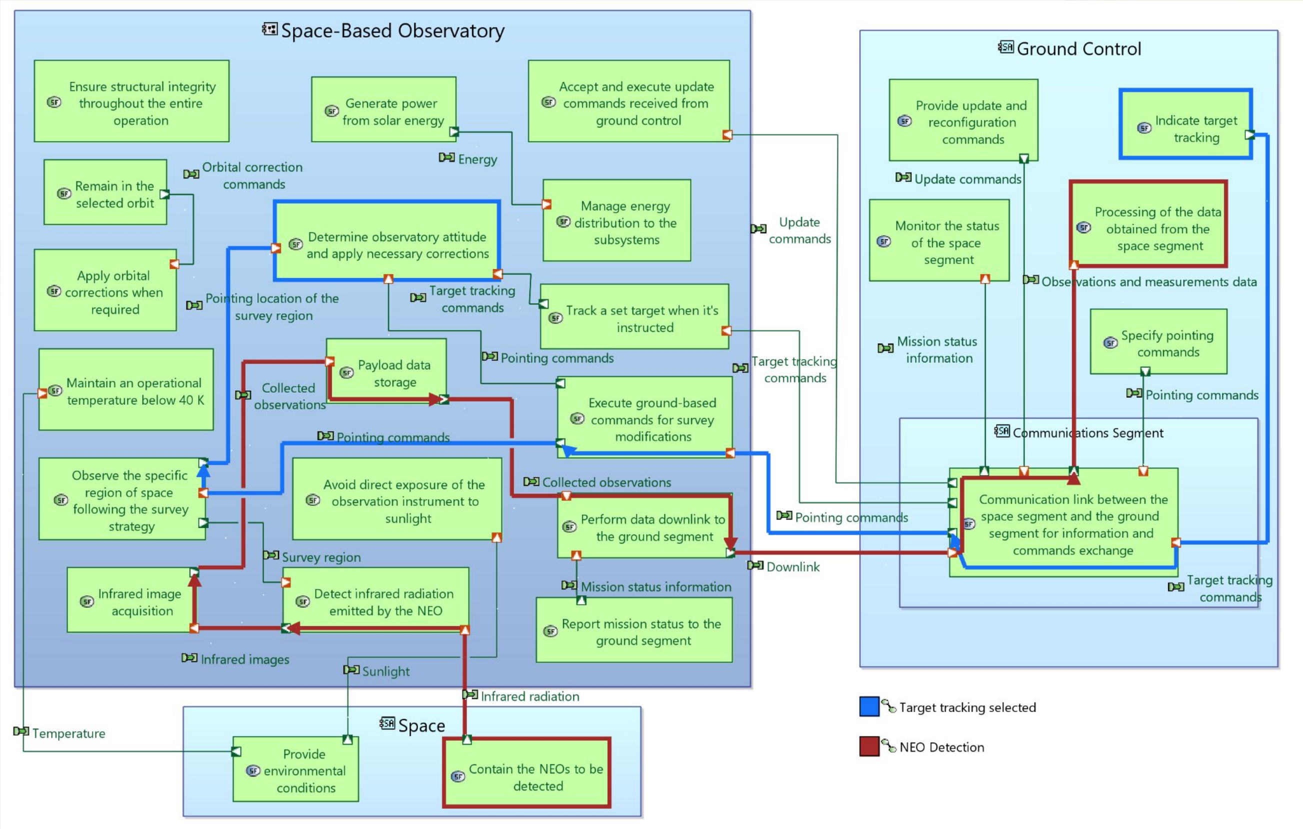

System Architecture

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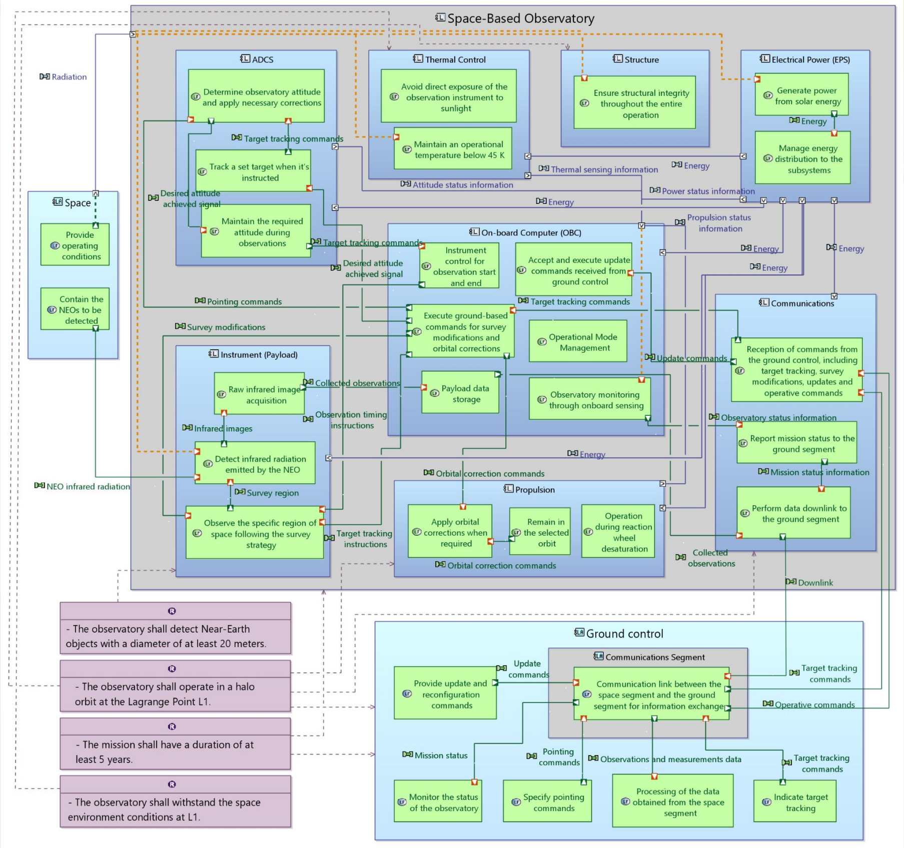
Logical Analysis

Subsystems:

- ADCS
- Thermal Control
- Electrical Power (EPS)
- On-board Computer (OBC)
- Infrared Instrument
- Propulsion
- Communications
- Structure



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Logical Analysis

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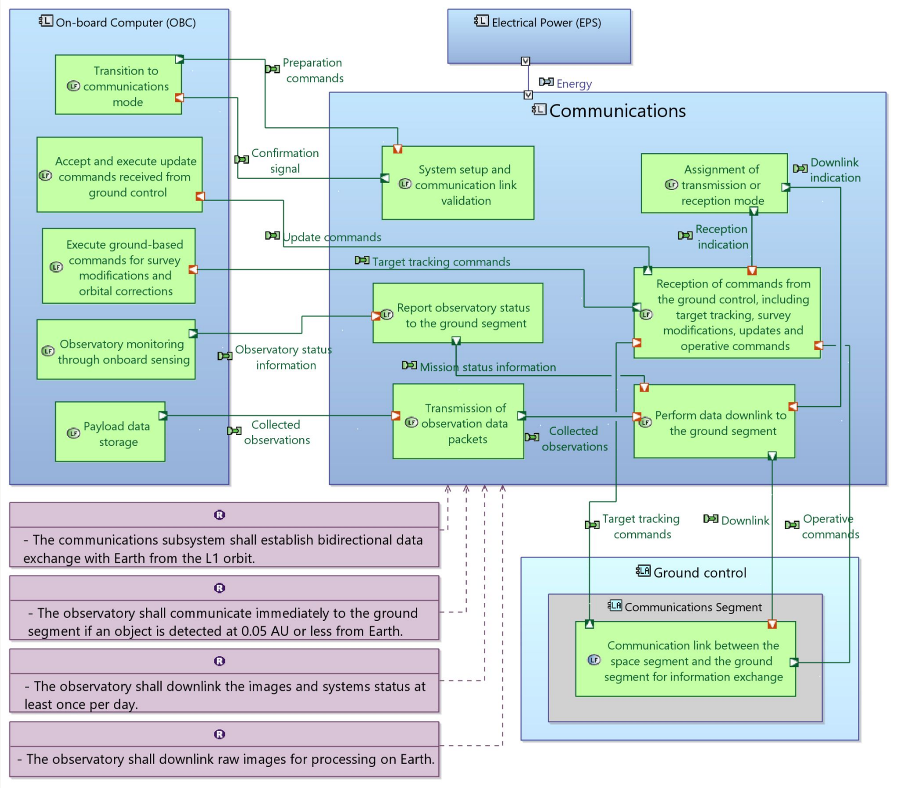

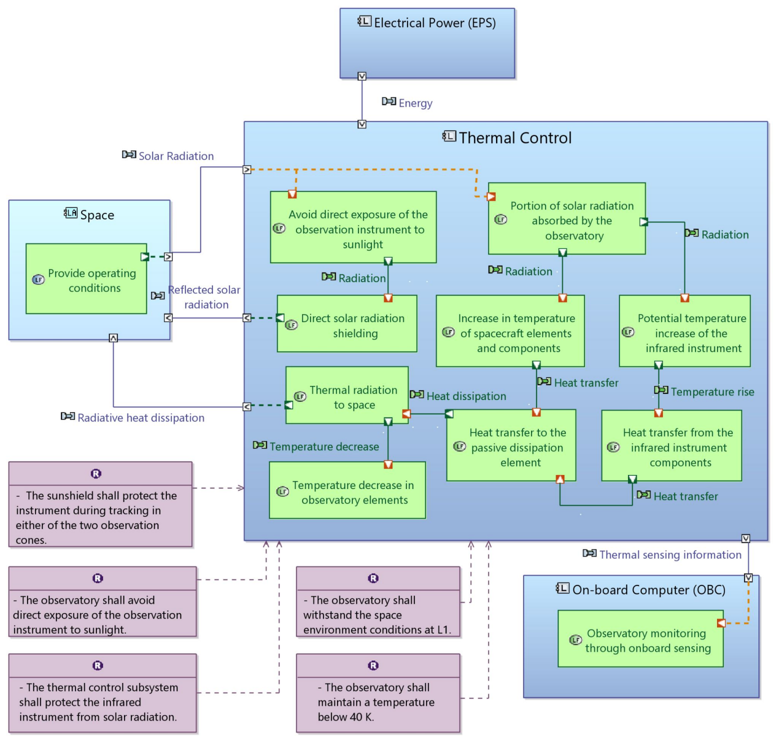

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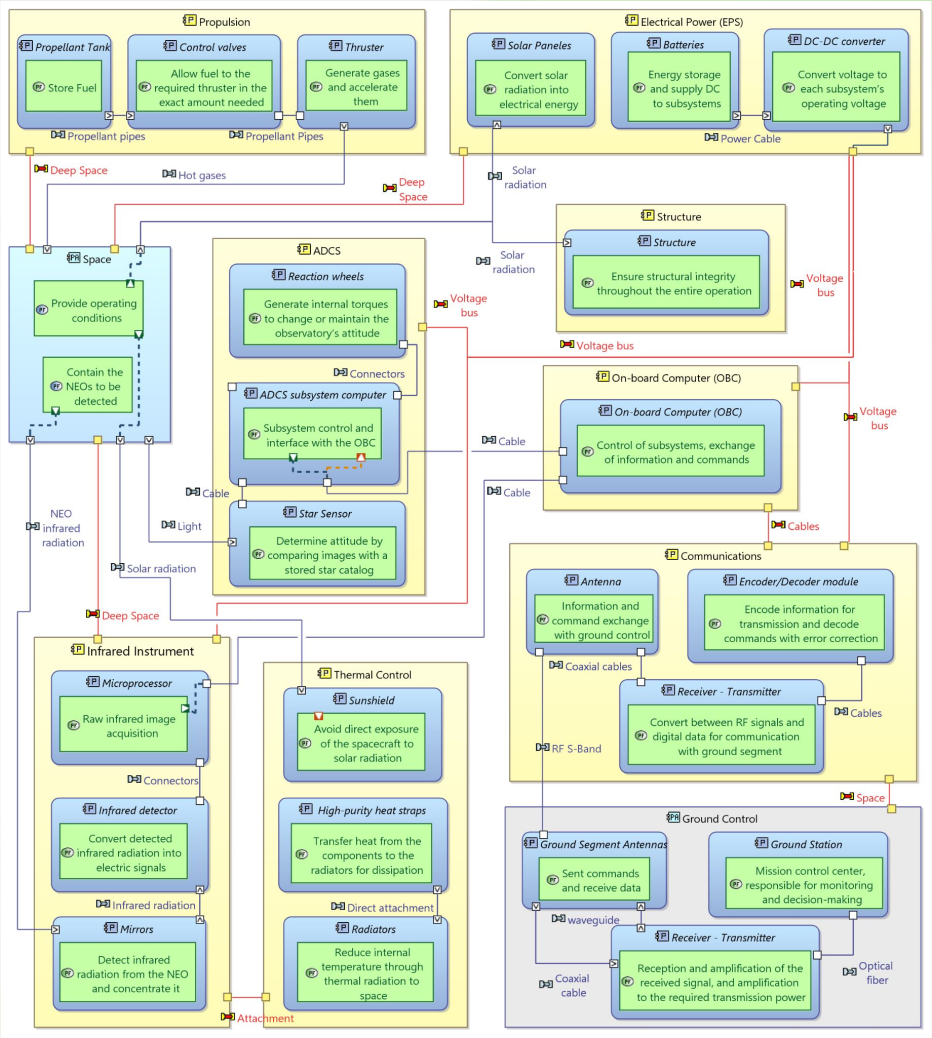
Physical Analysis



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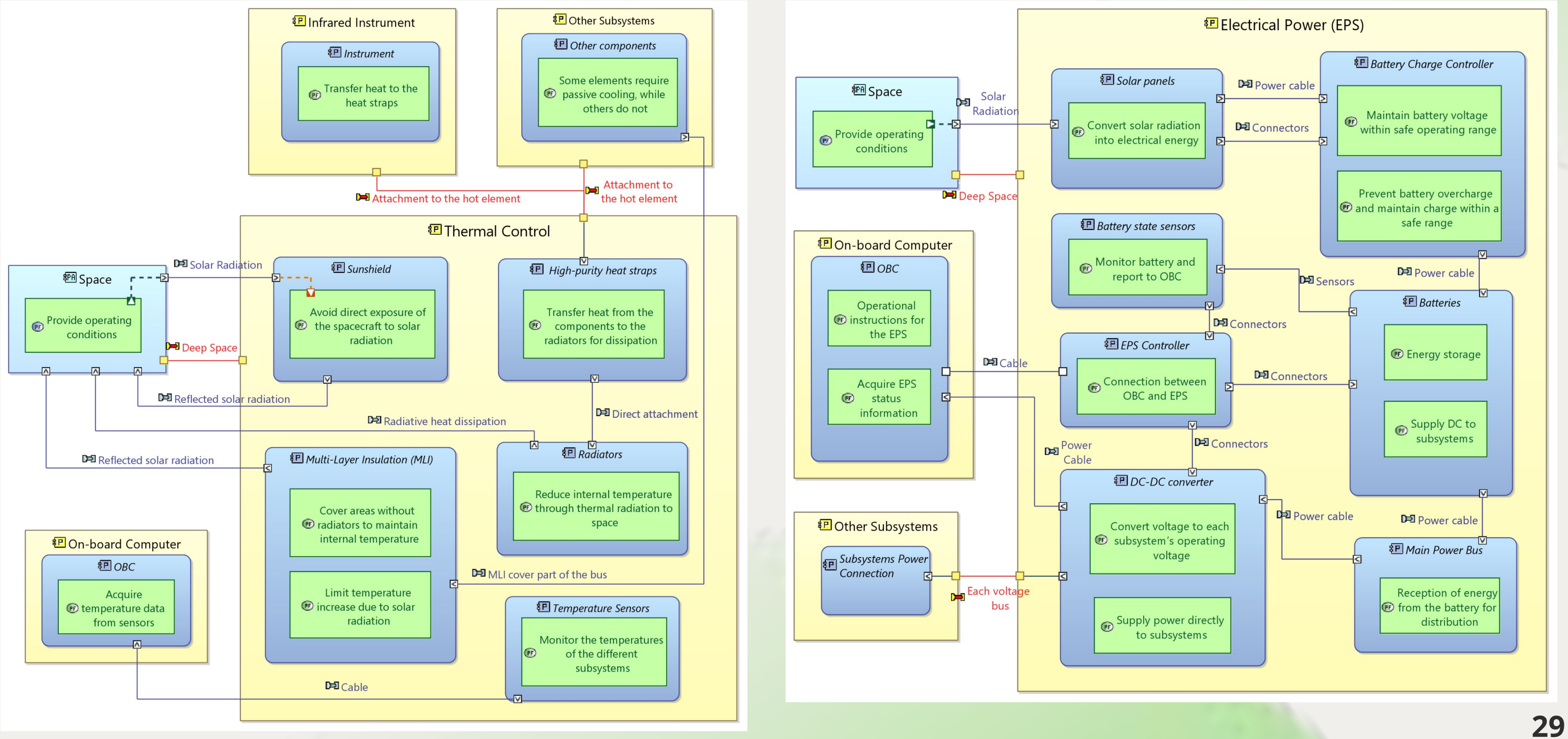
Physical Analysis



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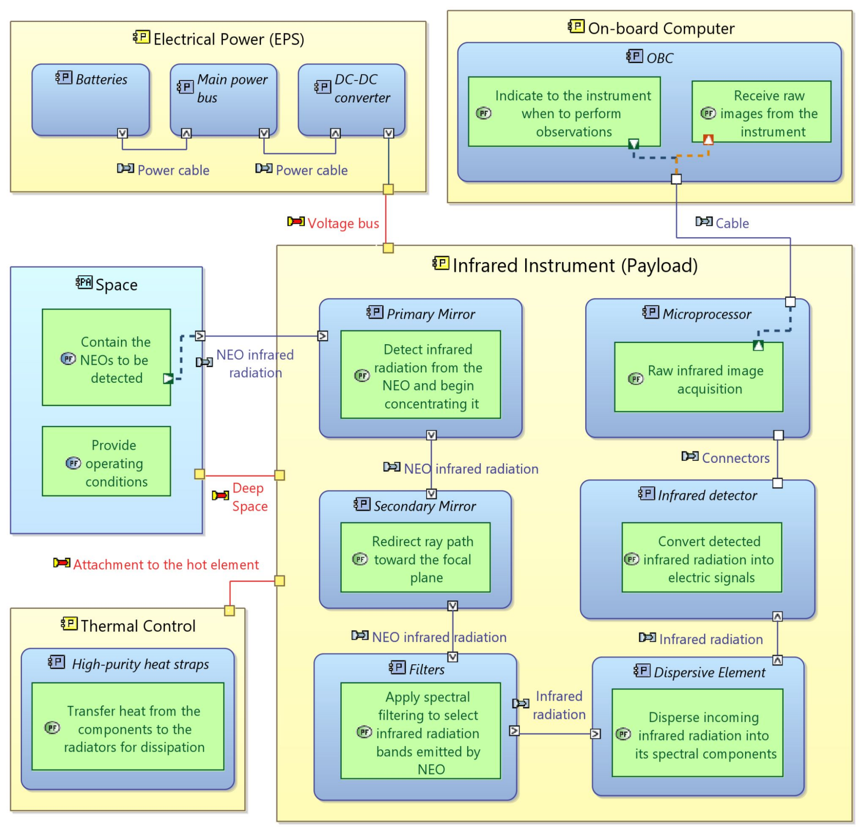
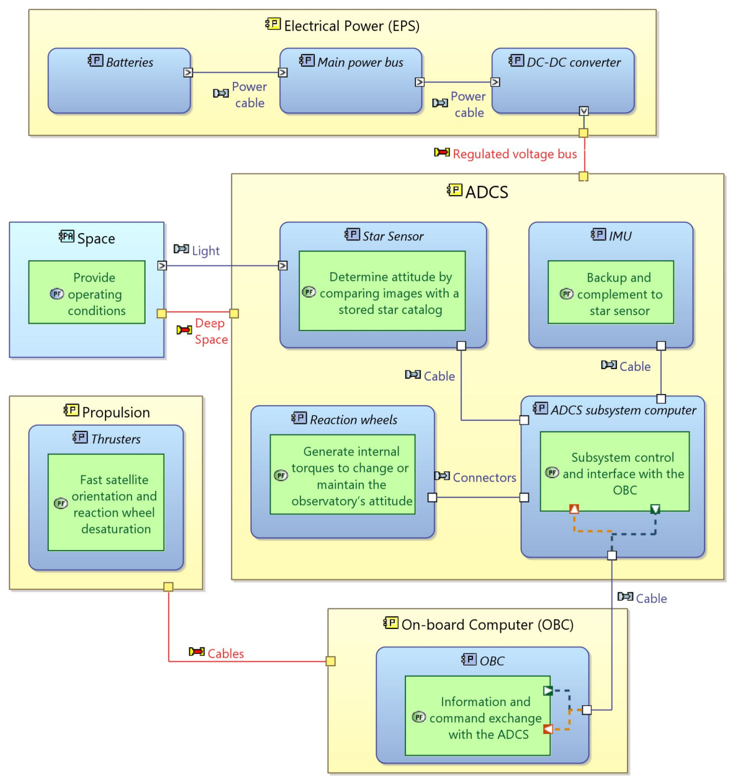
Physical Analysis





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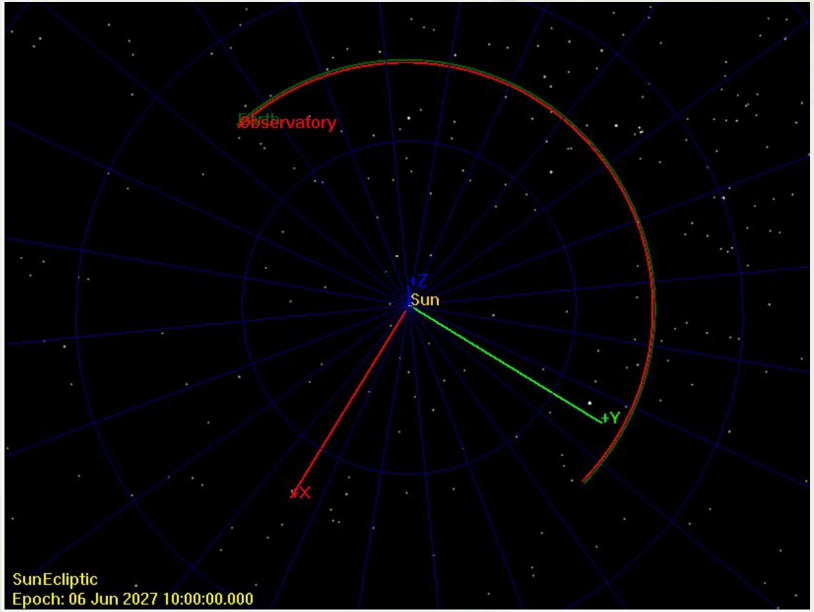
Validation & Verification



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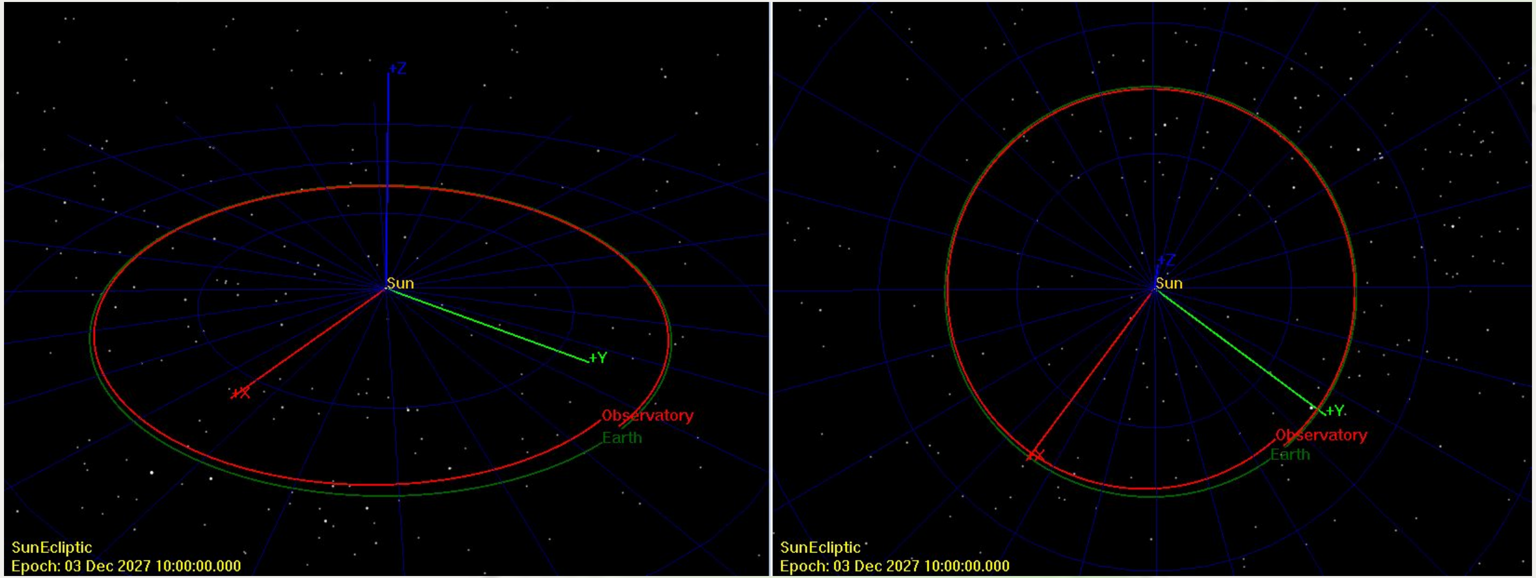
Validation & Verification



Validation & Verification

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10 Dec 2026 11:00:10.013	10 Dec 2026 21:39:13.437	38343.424613
11 Dec 2026 10:59:55.134	11 Dec 2026 21:39:03.713	38348.578923
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28 May 2027 10:48:34.125	28 May 2027 22:03:43.661	40509.536306
29 May 2027 10:47:26.351	29 May 2027 22:02:49.714	40523.363009
30 May 2027 10:46:23.023	30 May 2027 22:02:00.104	40537.081087
31 May 2027 10:45:24.143	31 May 2027 22:01:14.773	40550.630025
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05 Jun 2027 10:41:30.348	05 Jun 2027 21:58:23.902	40613.554142

Observation Window Times

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Validation & Verification

Facility	Start Time (UTC)	Stop Time (UTC)	Duration (s)
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	05 Feb 2027 15:11:53.234	06 Feb 2027 00:44:55.112	34381.878220
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	05 Feb 2027 11:47:20.569	05 Feb 2027 22:36:40.677	38960.108063

References

- García Suárez, P. “Design and Development of a Proof of Concept for a Modular Space Simulation Vacuum Chamber”, Bachelor’s degree project, Aerospace Engineering, Universidad de Antioquia, Carmen de Viboral,Antioquia,Colombia,2025.
- Ríos Orozco, J.F. “A Model-Based Systems Engineering Approach to the Development of a Space-Based Observatory for NEO Detection”, Bachelor’s degree project, Aerospace Engineering, Universidad de Antioquia, Carmen de Viboral, Antioquia, Colombia, 2025.

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Thanks!

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