THE POWER OF COLLABORATION

# COSMIC Capstone Challenge:
# Final Design Brief

## H2Probe, University of Pittsburgh: Geosynchronous Xenon Refueling Spacecraft (GXRS)

**Students:** Aidan Kleinhenz, Nathan Belculfine, Camden Smith, Arin Magesh, Rishi Manoj, and Mat Tannenbaum
**Advisor:** Dr. Matthew Barry
**Mentor:** Anjit Fageria

April 9, 2026

# Team Overview

*Geosynchronous Xenon Refueling Spacecraft*

Six-member team from the University of Pittsburgh.

- Aidan Kleinhenz – Program Director
- Nathan Belculfine – Refueling Lead
- Camden Smith – Docking Lead
- Rishi Manoj – System Analyst
- Arin Magesh – Chassis Lead
- Mat Tanenbaum – Electrical Sys. Lead

*Aidan Kleinhenz*

*Nathan Belculfine*

*Camden Smith*

*Mat Tannenbaum*

*Rishi Manoj*

*Arin Magesh*

# Executive Summary

*Geosynchronous Xenon Refueling Spacecraft*

- Spacecraft are often discarded once their fuel supply runs out, polluting highly-used orbits and wasting launch resources.

- Satellites should be designed to be refuellable, rather than relying on launching replacements or costly mission extension vehicles which can only service one client at a time.

- We propose an autonomous refueling spacecraft capable of supplying supercritical Xenon to satellites that utilize electric propulsion systems. The system will employ a custom tank interface designed by our team to enable docking and propellant transfer. Xenon will be stored as a supercritical fluid to eliminate active cooling and cryogenic complications while maximizing storage density.

# 2.4 Program Management Milestones

*Geosynchronous Xenon Refueling Spacecraft*

**AUG 2024** Project start

**SEP 2024** Program manager selected

**OCT 2024** Operations chosen

**NOV 2024** System requirements defined

**DEC 2024** System requirements review

**JAN 2025** Trade studies complete

**MAR 2025** Conceptual design finalized

**APR 2025** Path to PDR & project end

# 2.2 Storyboard of Complete Operation

*Entire Process From Launch -> Docking*

**Phase 1:**
**Launch and Deployment**
- Insertion into MEO
- Separation of Solar Array Deployment

**Phase 2:**
**MEO to GEO Transfer**
- Perform burn into client's GEO trajectory

**Phase 3:**
**Rendezvous**
- Rendezvous Proximity Operation with ingress burns to meet client satellite

**Phase 4:**
**Docking and Capture**
- Claw arms extend to full 97.7 mm radius
- grooves align and engage
- Hard capture initiated

**Phase 5:**
**Xenon Refueling**
- Induce client tank to nominal pressure
- Propellant valves open to allow for transfer

**Phase 6:**
**Undocking**
- Propellant line purged + sealed
- Servicer detaches and burns off

# Refueling System Introduction

*Refueling*

**Requirements:**

- Propellant must remain supercritical (above critical P and T) during storage and transfer
- Transfer system must drive propellant into client tank without active cooling
- Client tank pressure must be controlled to maximize propellant mass transferred

**Solution:**

- Gas pre-charged bellows accumulator to store and pressure-feed supercritical xenon
- Helium gas cylinder for client tank pressurization and venting control
- Pre-integrated interface on client satellite with dedicated gas and propellant feed ports

# Weighted Propellant Trade Study

*Refueling*

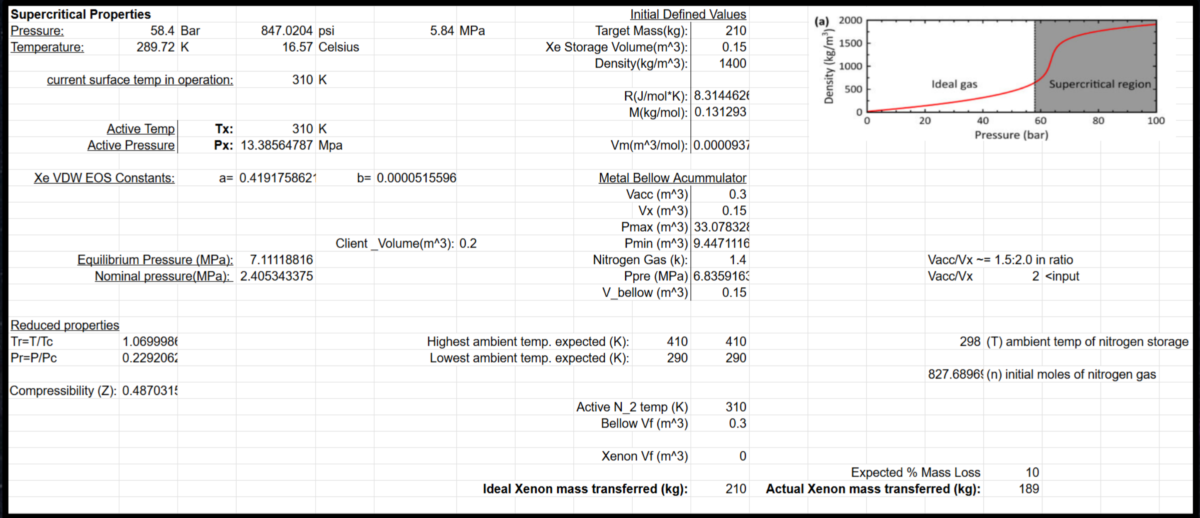
| | Maturity & Compatibility (0.30) | Storability & Transferability (0.30) | Cost & Availability (0.25) | Density (0.15) | Score: |
|---|---|---|---|---|---|
| **Xenon** | 10 | 9 | 1 | 3 | 6.40 |
| **Krypton** | 4 | 7 | 9 | 1 | 5.70 |
| **Iodine** | 1 | 2 | 10 | 10 | 4.90 |

# Propellant Storage and Transfer Analysis

## *Refueling*

- Initialized 0.3 m³ accumulator (2:1 volume ratio) and target mass of 210 kg to transfer
- Equated xenon pressure via VdW EOS
- Calculated bellows pre-charge pressure (6.84 MPa)
- Using arbitrary temp. of 310 K, inducing 13.4 MPa (Xe and N pressure):
  - Calculated a final equilibrium pressure of 7.11 MPa from full bellows expansion using ideal gas law
  - Determined client tank nominal pressure of 2.4 MPa using pressure equilibrium equation

## Excel Thermodynamic Tool



**Supercritical Properties** Initial Defined Values
Pressure: 58.4 Bar 847.0204 psi 5.84 MPa Target Mass(kg): 210
Temperature: 289.72 K 16.57 Celsius Xe Storage Volume(m^3): 0.15
Density(kg/m^3): 1400
current surface temp in operation: 310 K
R(J/mol*K): 8.314462
M(kg/mol): 0.131293
Active Temp **Tx:** 310 K
Active Pressure **Px:** 13.38564787 Mpa Vm(m^3/mol): 0.000093
Xe VDW EOS Constants: a= 0.419175862 b= 0.0000515596 Metal Bellow Acummulator
Vacc (m^3) 0.3
Vx (m^3) 0.15
Pmax (m^3) 33.07832
Client _Volume(m^3): 0.2 Pmin (m^3) 9.4471116
Equilibrium Pressure (MPa): 7.11118816 Nitrogen Gas (k): 1.4 Vacc/Vx ~= 1.5:2.0 in ratio
Nominal pressure(MPa): 2.405343375 Ppre (MPa) 6.835916 Vacc/Vx 2 <input
V_bellow (m^3) 0.15
Reduced properties
Tr=T/Tc 1.069998 Highest ambient temp. expected (K): 410 410 298 (T) ambient temp of nitrogen storage
Pr=P/Pc 0.229206 Lowest ambient temp. expected (K): 290 290
827.6896 (n) initial moles of nitrogen gas
Compressibility (Z): 0.487031
Active N_2 temp (K) 310
Bellow Vf (m^3) 0.3
Xenon Vf (m^3) 0
Expected % Mass Loss 10
**Ideal Xenon mass transferred (kg):** 210 **Actual Xenon mass transferred (kg):** 189

➢ **Eq. 1:** Xenon pressure via Van der Waals EOS

$$P = \frac{RT}{V_m - b} - \frac{a}{V_m^2}$$

$$a = \frac{27R^2T_c^2}{64P_c}$$

$$b = \frac{RT_c}{8P_c}$$

➢ **Eq. 2:** Bellows nitrogen gas pre-charge pressure

$$P_{pre} = P_{min} / [\frac{V_{acc}}{V_x}(1 - (\frac{P_{min}}{P_{max}})^{1/k})]^k$$

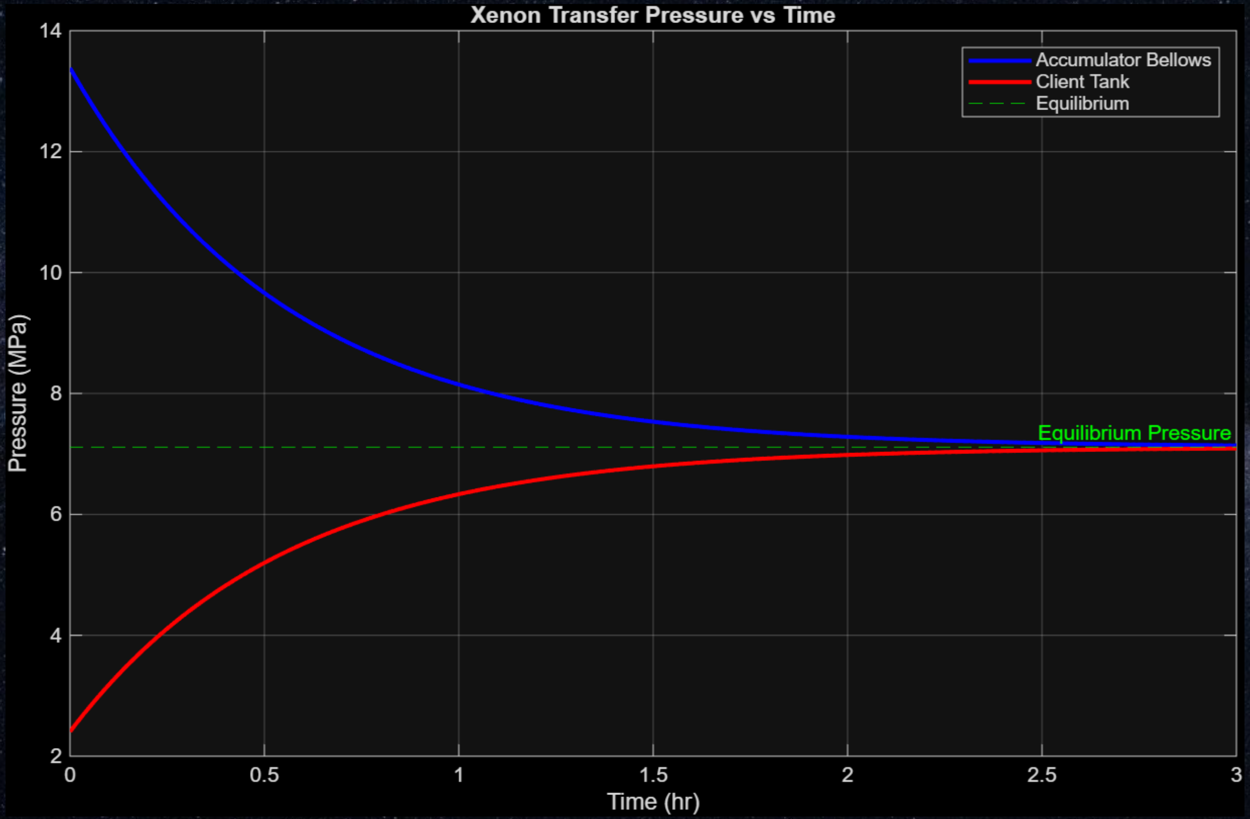
➢ **Eq. 3:** Client tank nominal pre-pressurization

$$P_C = \frac{P_f(V_b + V_C)}{V_C} - \frac{P_b V_b}{V_C}$$

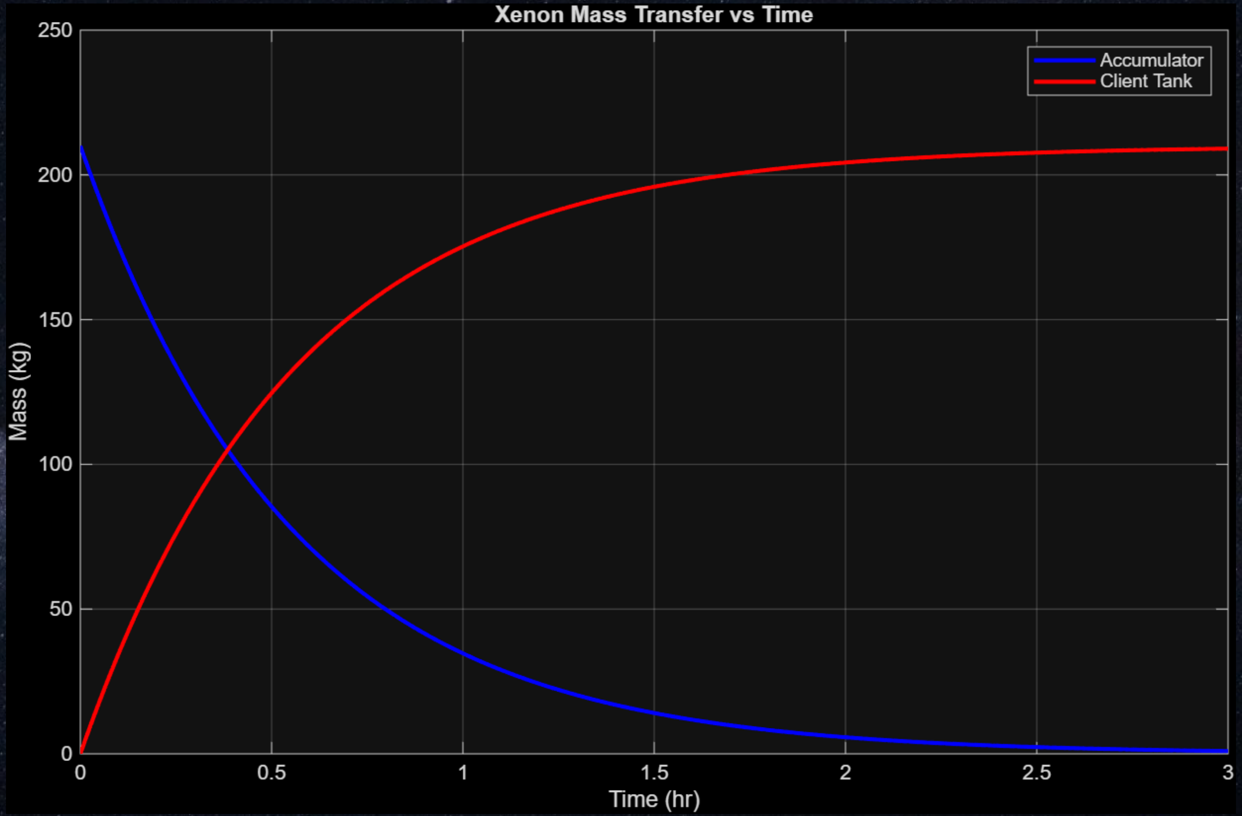
# MATLAB Transfer Simulation

*Refueling*

## Pressure vs Time



## Mass vs Time

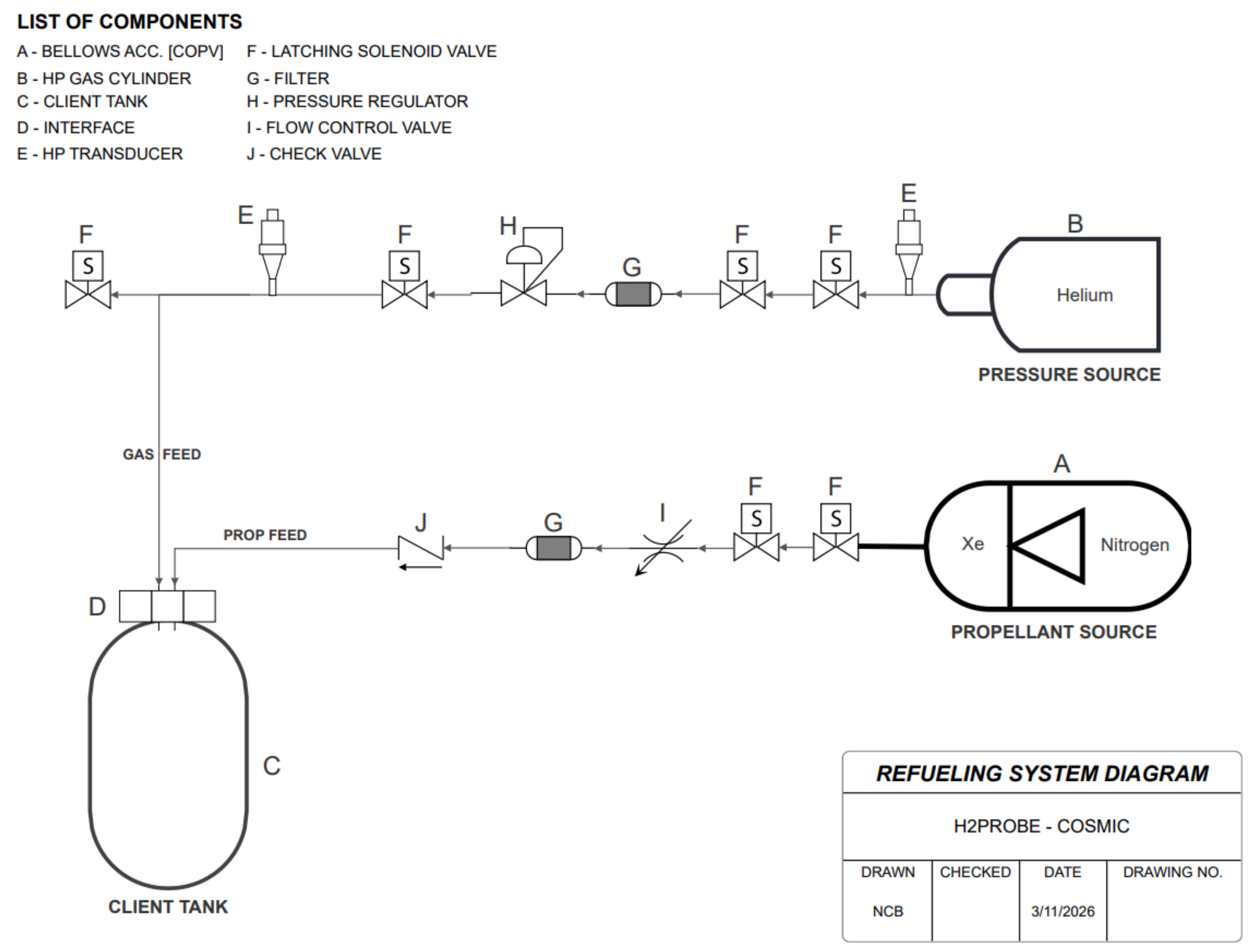


- First-order exponential decay response
- Client tank volume of 0.2 m³ for the example

# Docked Refueling P&ID System Diagram

*Refueling*

- Helium gas cylinder pressure source
- Metal bellows accumulator propellant driver
    - Nitrogen pre-charged bellows
    - Supercritical xenon propellant
- Gas pressurizing feed line (pressurize/vent capable)
- Propellant feed line



**LIST OF COMPONENTS**

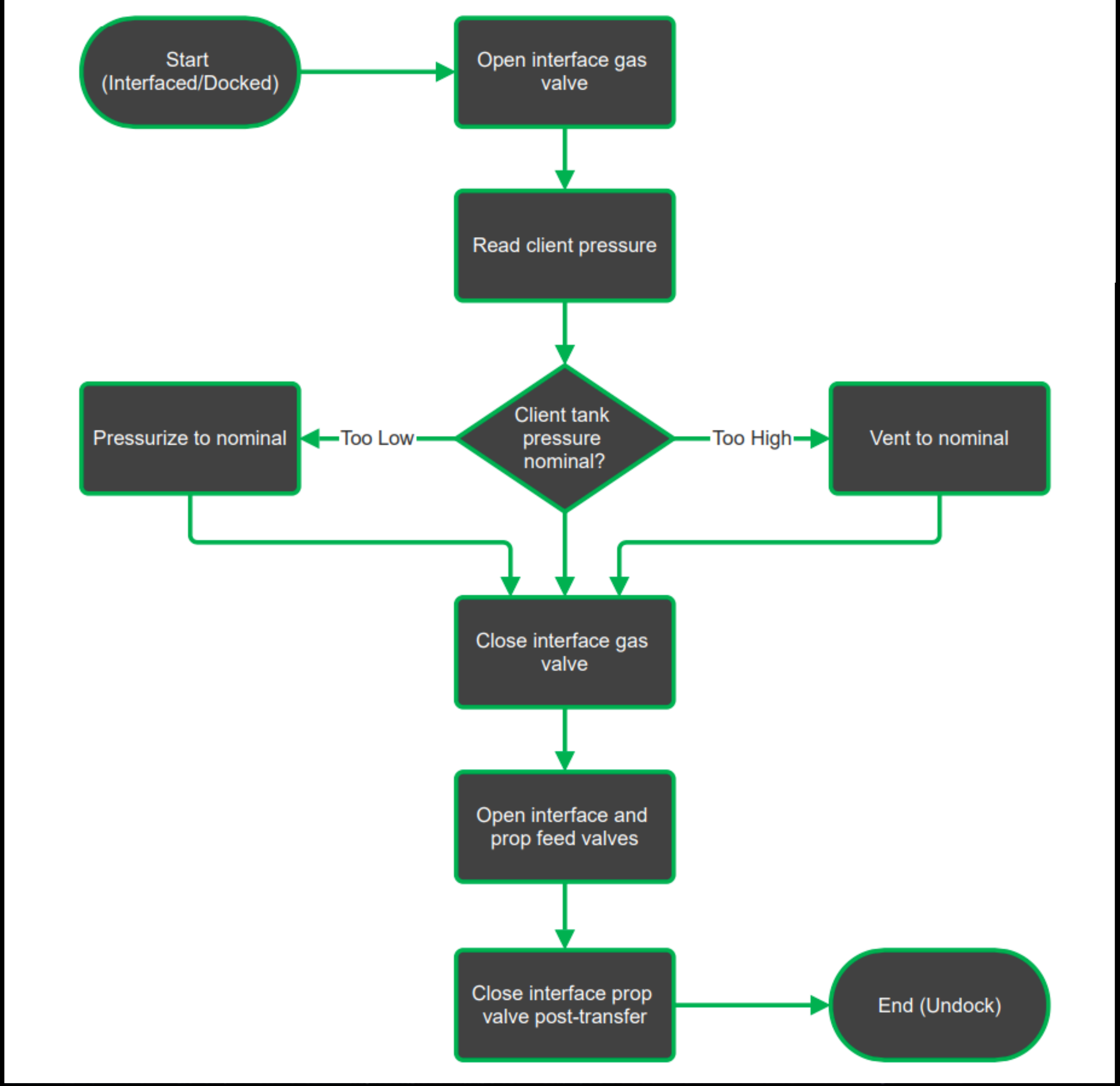
A - BELLOWS ACC. [COPV]
B - HP GAS CYLINDER
C - CLIENT TANK
D - INTERFACE
E - HP TRANSDUCER
F - LATCHING SOLENOID VALVE
G - FILTER
H - PRESSURE REGULATOR
I - FLOW CONTROL VALVE
J - CHECK VALVE

| REFUELING SYSTEM DIAGRAM | | | |
|---|---|---|---|
| H2PROBE - COSMIC | | | |
| DRAWN | CHECKED | DATE | DRAWING NO. |
| NCB | | 3/11/2026 | |

# Docked Refueling Operations Flow Diagram

*Refueling*

1. Reading if client pressure is nominal
    - Vent or pressurize
2. Close off gas feed
3. Release propellant feed
    - Allow bellows to expand and drive propellant transfer
4. Close propellant feed



Geosynchronous Xenon Refueling Spacecraft

# Projected Path

*Docking*

- Design 2-part soft-capture system (GXRS & Client Tank) which extends and retracts to guide and stabilize the target satellite. Once satellites are sufficiently aligned, the docking assembly performs a controlled “lunge,” allowing the soft-capture mechanism to engage and interlock with the corresponding ring on the client satellite.

- After the two soft-capture rings connect, an onboard fluid transfer mechanism extends and connects to the client’s fuel tank interface. This mechanism will be a large focus of the design, with both a Simulink and practical model likely.

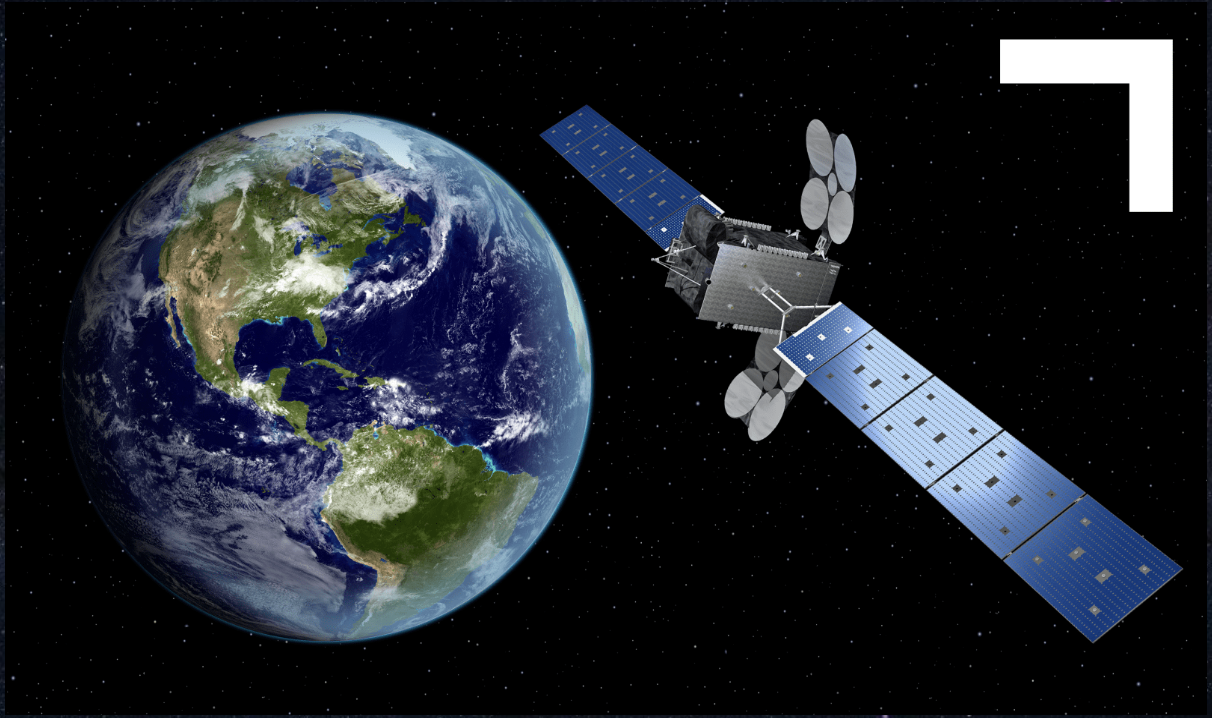
- A mockup of the chassis will be created, currently undergoing research into whether existing platforms could suit project needs. Stress and vibrational analysis will be performed to ensure systems are protected during launch and docking, and a CAD model to draft the placement of components like the refueling mechanism and power systems.

**Design interface and fuel system, then supporting chassis and fuel systems.**

# PMAD Architecture: Regulated vs. Unregulated Bus

*Electrical Systems*

- Regulated bus: voltage filtered out before reaching each subsystem; better fault tolerance and voltage stability, but it is heavier and less efficient.
- Unregulated bus: power routed directly from source, regulation handled at load level; lighter, more efficient, but noisier power levels.
- Scores were very nearly tied (75.5% vs 76%). Mission's RF comms payload demands low-noise stable power so regulated bus architecture is best.

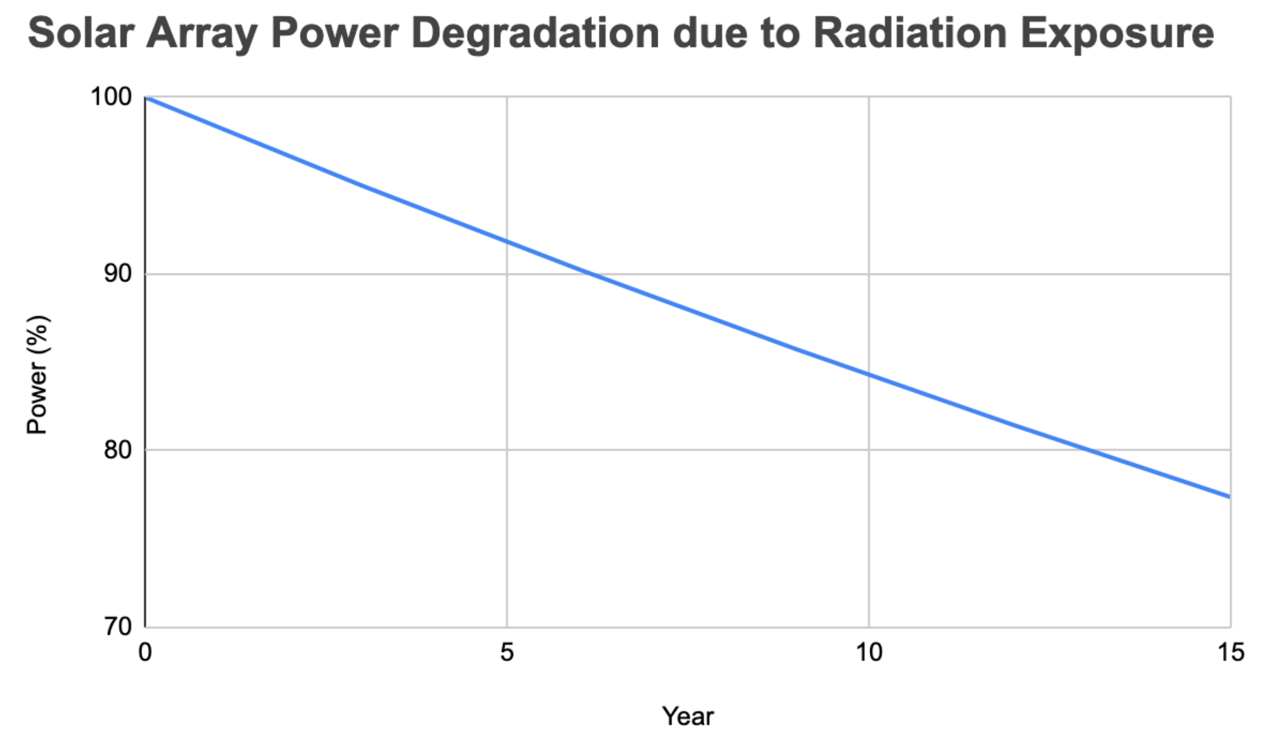


GEO-Star 2 created by Northrop Grumman also uses regulated power bus architecture in GEO.

# Solar Cell Technology: Triple-junction GaAs vs. Crystalline Silicon

*Electrical Systems*

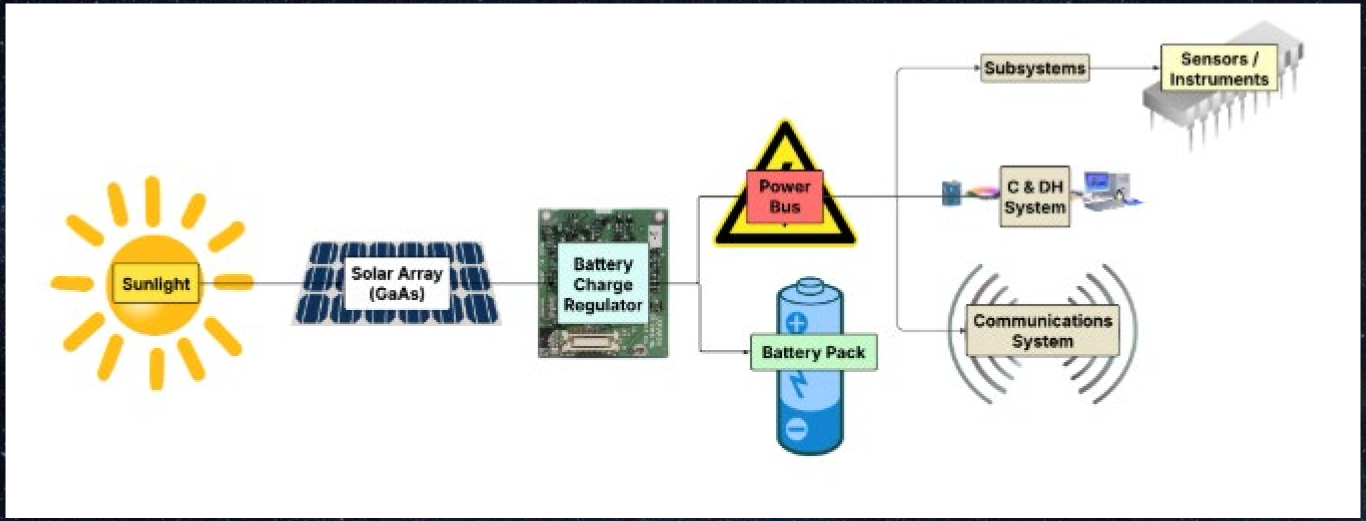
- Triple-junction GaAs: spectrum-splitting multi-layer design, radiation tolerant, high efficiency; purposely built for GEO.
- Crystalline silicon: cheaper and commercially dominant on Earth, but degrades much faster under constant GEO radiation exposure
- GaAs clearly wins here: 74% vs 51.5% across voltage output, radiation tolerance, thermal performance, and power-to-mass ratio.



Solar array power degradation due to radiation exposure over GEO mission lifetime, assuming ~5% degradation per year for triple-junction GaAs solar arrays.

# Electrical System Design & Power Modes

*Electrical Systems*



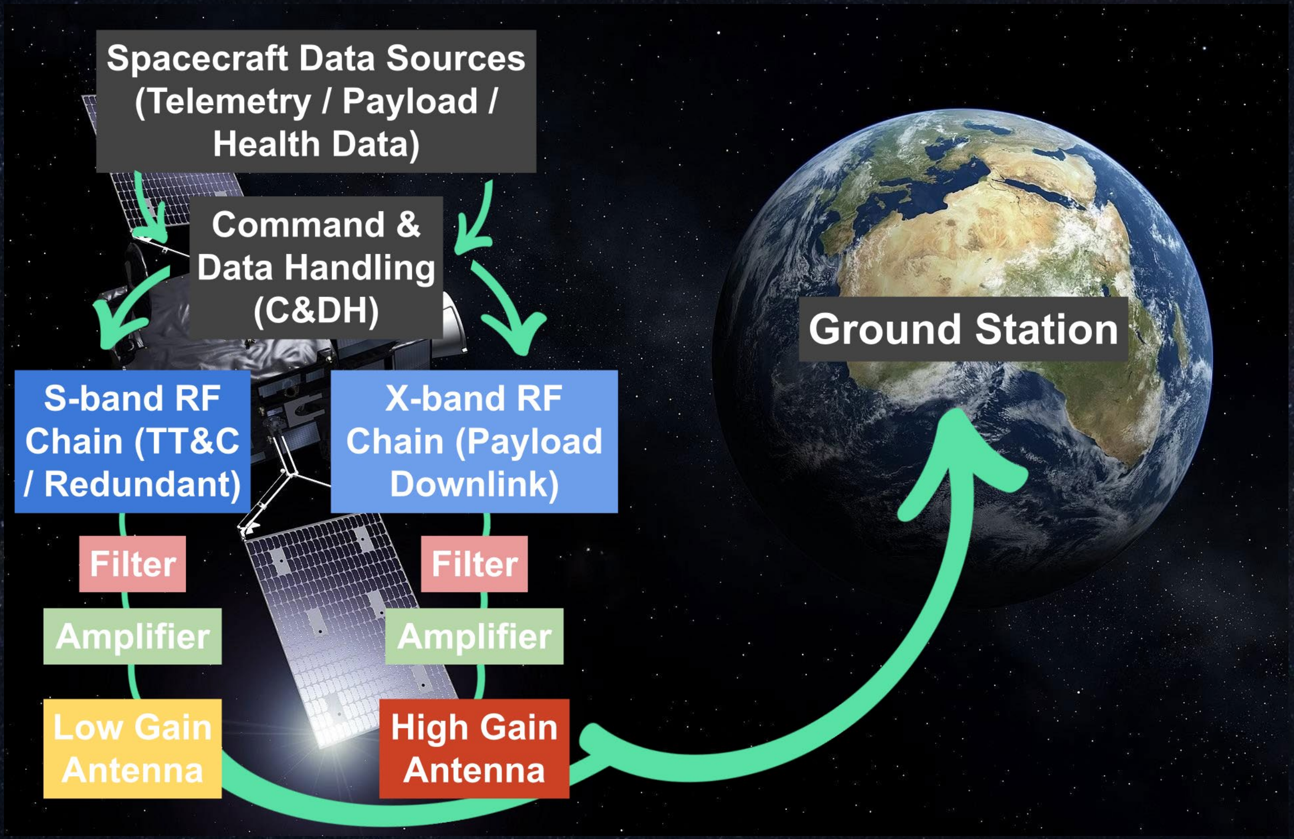
- 4 subsystem design: power generation (GaAs solar arrays) -> energy storage (batteries) -> PMAD (regulation/distribution) -> comms power interface (dedicated low-noise RF stage)
- Sunlight mode: arrays generate primary power, PMAD distributes to loads, excess power charges batteries.
- Eclipse mode: batteries take out full power, full operations sustained through up to ~70 mins of darkness.

Satellite power flow from solar arrays through regulation to spacecraft subsystems.

# Telecommunication System: Antenna & Freq.

*Electrical Systems*

- Antenna: HGA (high gain rate, precise pointing) vs. LGA (wide coverage, reliable low-rate, simpler) -> LGA wins due to reliability & power efficiency.
- Frequency trade: S-band (2-4 GHz, lower atmospheric effect, power-efficient) vs. X-band (8-12 GHz, higher data rate, more complex). -> S-band wins due to more efficiency.
- Final Decision: Dual architecture design: S-band LGA for telemetry/commanding, X-band HGA for high-rate payload data downlink. Allows redundancy for fault tolerance.



Spacecraft Data Sources (Telemetry / Payload / Health Data)

Command & Data Handling (C&DH)

S-band RF Chain (TT&C / Redundant)

X-band RF Chain (Payload Downlink)

Filter

Filter

Amplifier

Amplifier

Low Gain Antenna

High Gain Antenna

Ground Station

Dual-band communication architecture using S-band LGA for telemetry, tracking, and commanding, and X-band HGA for high data rate payload downlink.

# 3.3 Data Handling and Comms

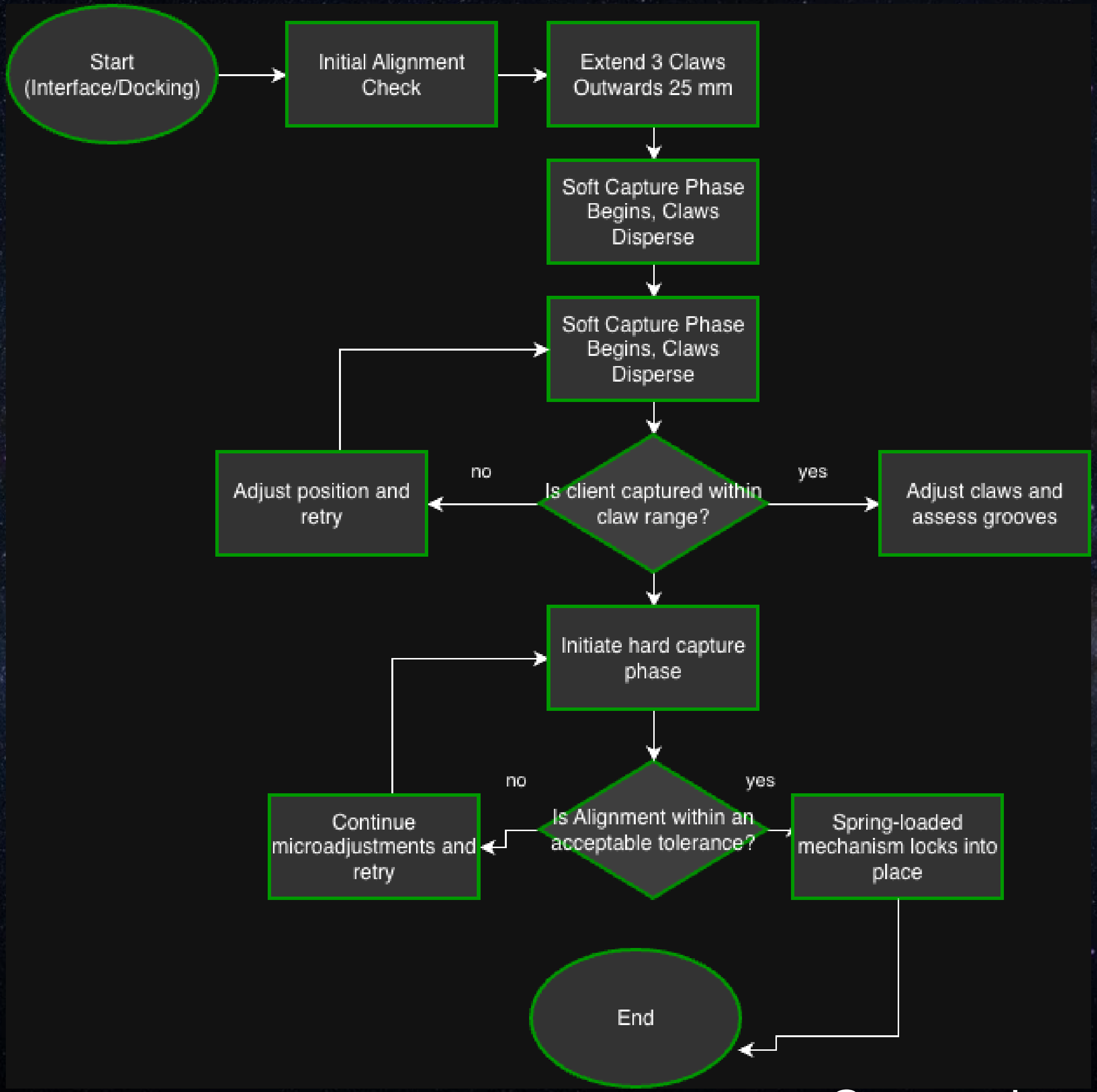
*Electrical Systems*

- Telecommunication System Requirements:
  - Low-latency hardware (transponders, amplifiers, steerable antennas)
  - Robust architecture: radiation-tolerant electronics, able to handle high thermal loads
  - Compliance with ITU standards
  - Mitigate Doppler effects on data signals
  - 24/7 Active ground station, autonomous data handling for real-time downlink (operator needed for commanding/uplink)

- Bitrate Requirements:
  - S-band (LGA - Telemetry, tracking, commanding): 10 Kbps - 10Mbps
  - X-band (HGA - Payload downlink, data comms): 100 Mbps - 2 Gbps

# Docking System Steps Flow Diagram

*Entire Docking Process*



# Weighted Autonomous Refueling Docking System Trade Study

*Docking*

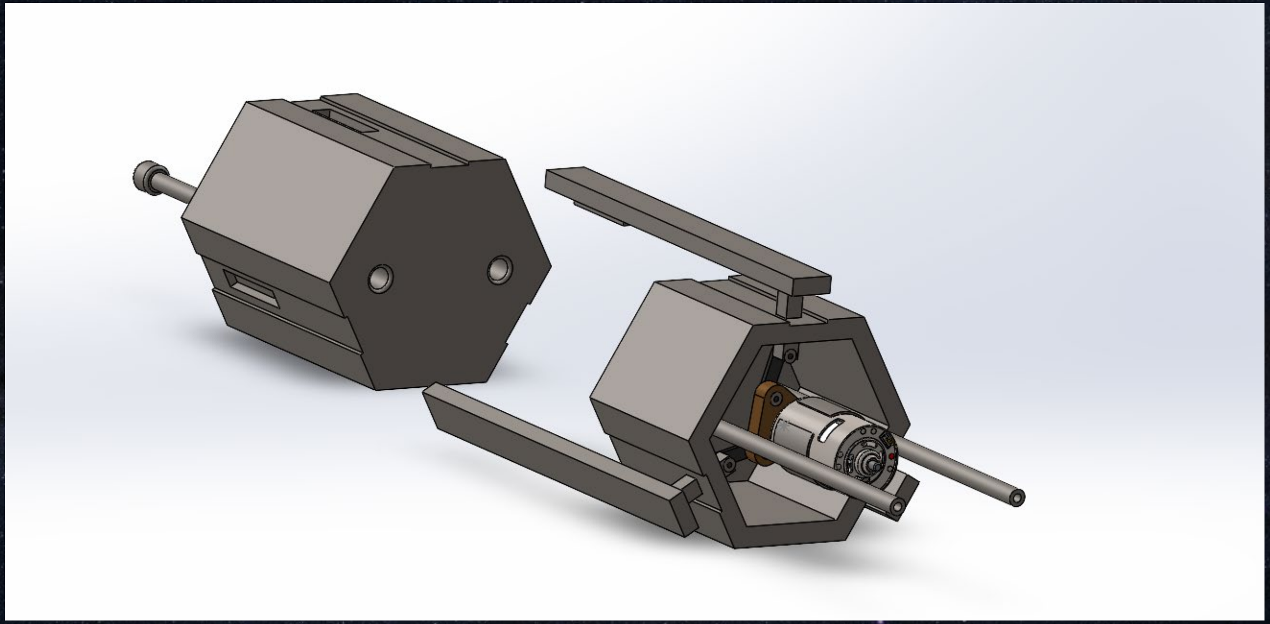
- Docking trade study considered four criteria: displacement tolerance, compatibility, energy absorption, cost
- Compatibility and Cost are equally weighted
- Each design was compared and assigned values from 1-10
- Our design had the most points after weighting

| Trade study | Displacement Tolerance (.10) | Compatibility (.35) | Energy Absorption (.20) | Cost (.35) | Results |
|---|---|---|---|---|---|
| NASA (NDS) | 10.0 | 2.00 | 8.00 | 5.00 | 5.05 |
| Our Design | 7.50 | 10.0 | 7.00 | 10.0 | 9.15 |
| Orbitfab’s RAFTI | 7.00 | 8.00 | 7.00 | 9.50 | 8.30 |

# 2.1 Docking System Design Stages

*Design Steps*

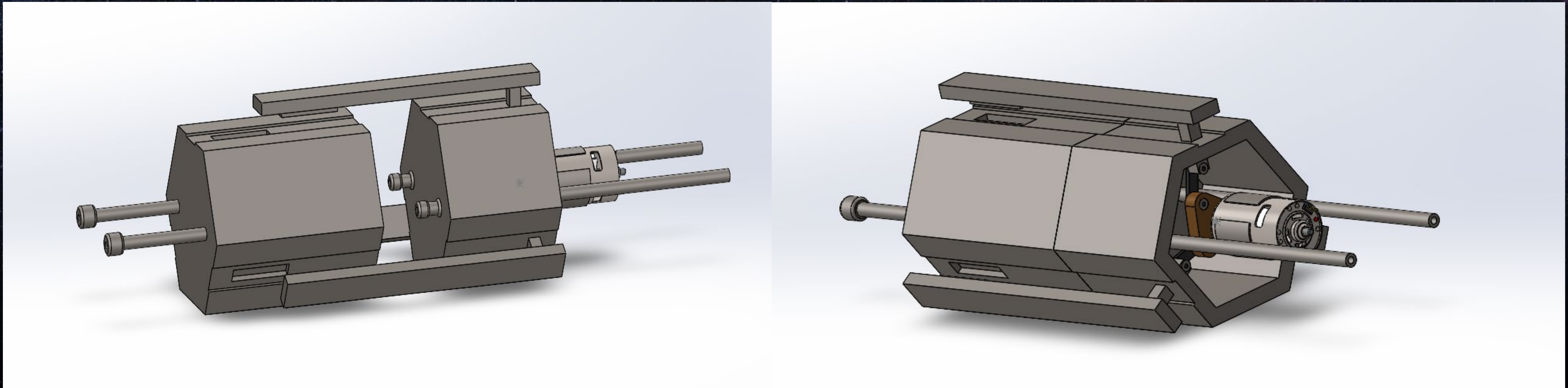
- Initial idea saw a socket like docking system with triangular claws to latch onto the client interface
- Idea changed as the design process went on, as the initial idea was both too small and overly complicated
- Design shifted towards a hexagonal base, given complexity of the original shape on the right
- Spring-loaded locking mechanism was added for extra security during the final phases of capture



# 2.1 Docking System Design Stages

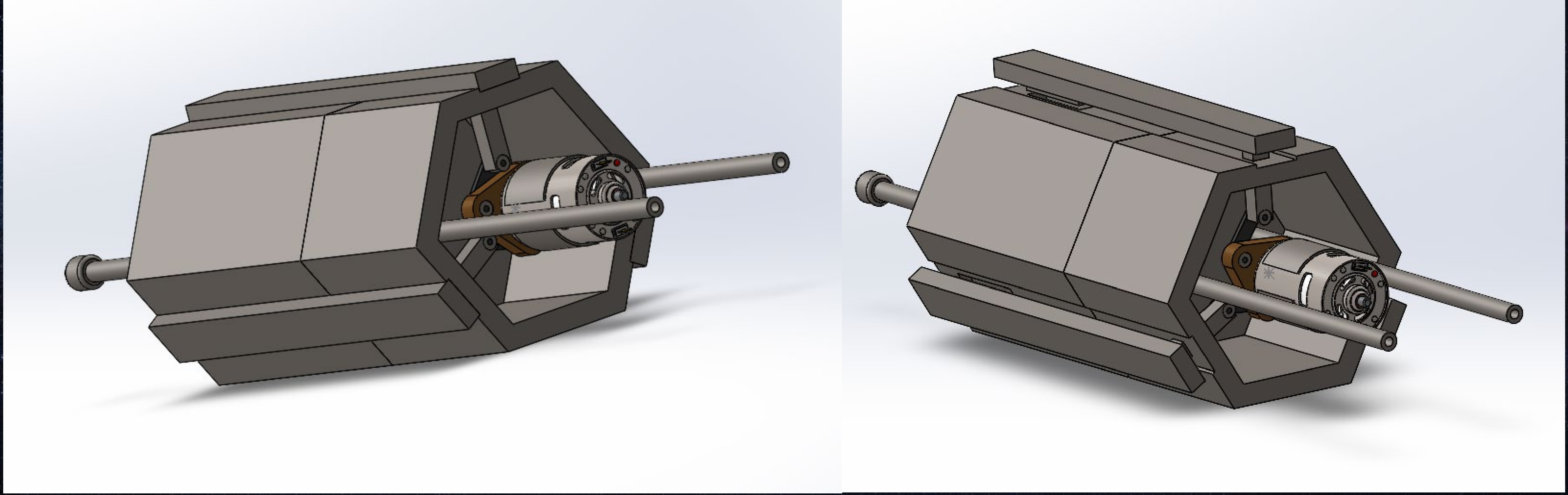
*Initial Docking Design Changes*

- As the docking system reaches the client, arms extend out ready to grab onto client satellite
- Autonomous control pushes the SM design closer to client
- Square grooves are filled in to prevent alignment changes
- Spring-loaded locking mechanisms released as each claw sinks into client



# 2.1 Docking System Design Stages

*Hard Capture Procedure*



# Mission Environment Background

*Chassis*

## Risks

- On its mission to the GEO, the satellite will traverse through:
  - Harsh thermal extremes (-150*C to 150*C)
  - Radiation Exposure (10^8 protons/cm^2*s)
  - Material degradation risk from long term exposure in space

## Chassis Requirements

- Must have high stiffness & be durable
- Must handle the thermal & radiative environment
- Interface must allow for docking ease

# Structural Analysis

*Chassis*

Analyzed three different structural options commonly used in smallsats and industry examples:

- Central Load-Bearing Spine – Northrop Grumman MEV
- Monocoque Shell - ESA ATV Pressurized Module
- Truss Structure - NASA Hubble Space Telescope

Evaluated on the following criteria:

- Structural Efficiency & Stiffness/Alignment
- Docking Load Path Clarity
- Replaceability & Manufacturability
- Reliability

All trade studies scores were scaled using the following equation:

$$\text{Score} = 10 \times \frac{Value}{Max\,Value}$$

# Material Analysis

*Chassis*

Analyzed four materials commonly used materials:

- Al-6061-T6
- Al-7075-T6
- CFRP
- Ti-6Al-4V

Evaluated on the following criteria:

- Strength/Weight & Stability
- Thermal Spreading
- Radiation Shielding

Evaluated using the following equations:

$$R = \frac{\sigma_y}{\rho}$$

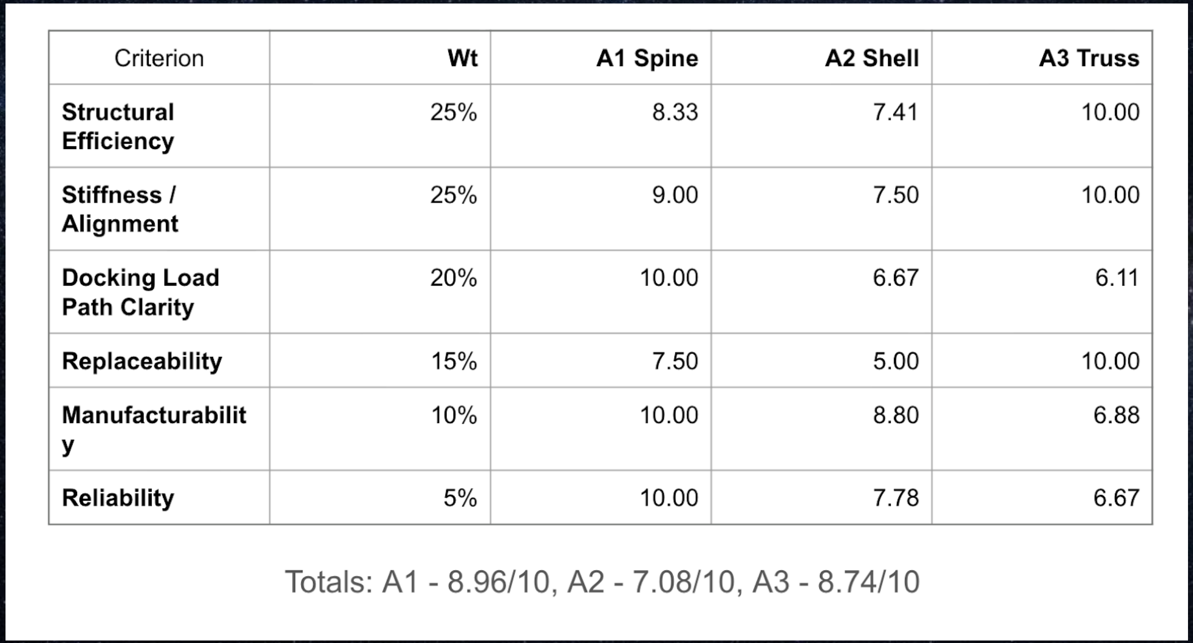
$$\alpha = \frac{\Delta L}{L \Delta T}$$

$$k = \frac{-q}{\nabla T}$$

# Trade Studies

*Chassis*

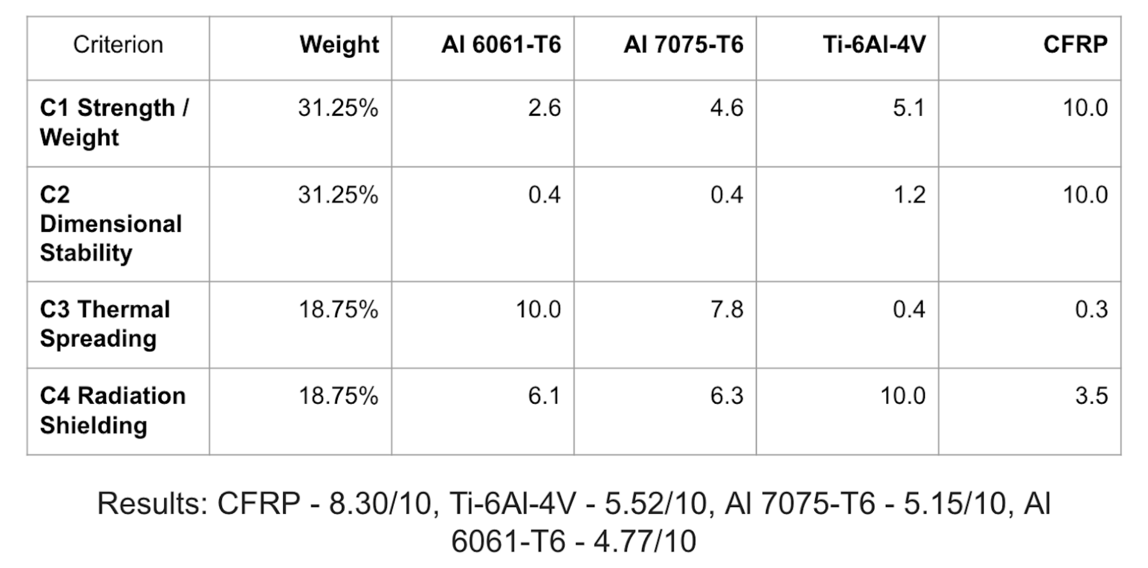
## Structures Trade Study



| Criterion | Wt | A1 Spine | A2 Shell | A3 Truss |
|---|---|---|---|---|
| **Structural Efficiency** | 25% | 8.33 | 7.41 | 10.00 |
| **Stiffness / Alignment** | 25% | 9.00 | 7.50 | 10.00 |
| **Docking Load Path Clarity** | 20% | 10.00 | 6.67 | 6.11 |
| **Replaceability** | 15% | 7.50 | 5.00 | 10.00 |
| **Manufacturability** | 10% | 10.00 | 8.80 | 6.88 |
| **Reliability** | 5% | 10.00 | 7.78 | 6.67 |

Totals: A1 - 8.96/10, A2 - 7.08/10, A3 - 8.74/10

## Materials Trade Study



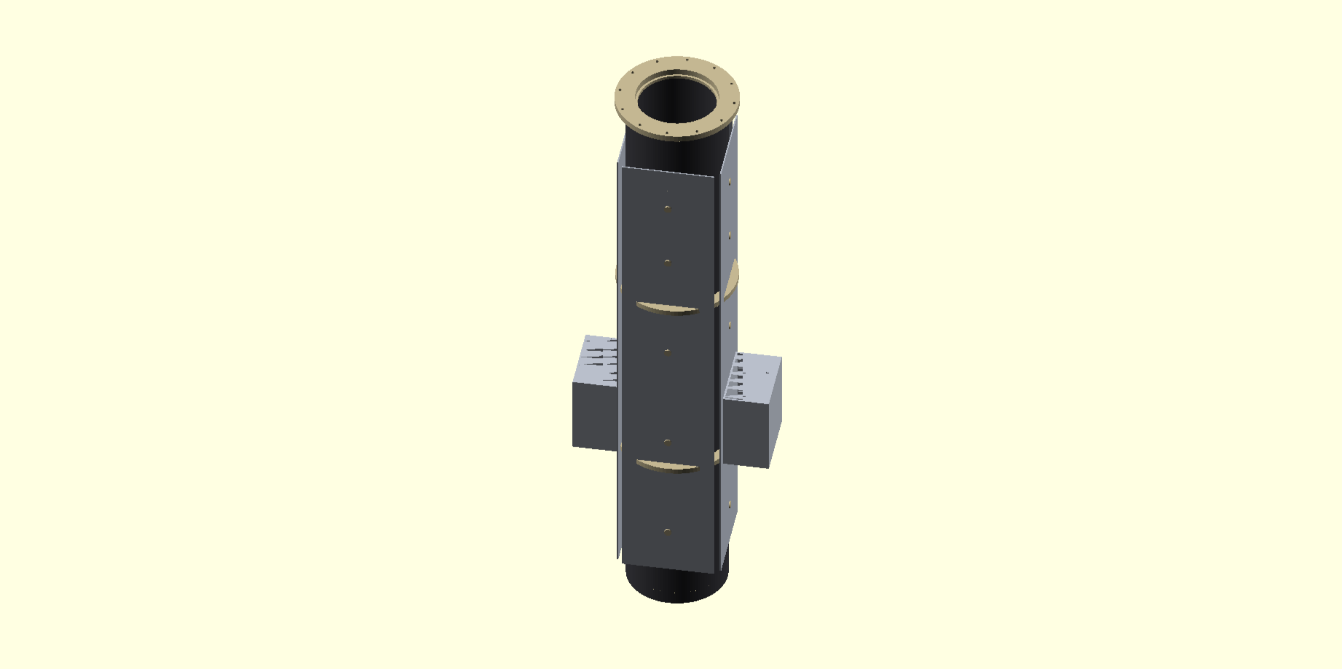
| Criterion | Weight | Al 6061-T6 | Al 7075-T6 | Ti-6Al-4V | CFRP |
|---|---|---|---|---|---|
| **C1 Strength / Weight** | 31.25% | 2.6 | 4.6 | 5.1 | 10.0 |
| **C2 Dimensional Stability** | 31.25% | 0.4 | 0.4 | 1.2 | 10.0 |
| **C3 Thermal Spreading** | 18.75% | 10.0 | 7.8 | 0.4 | 0.3 |
| **C4 Radiation Shielding** | 18.75% | 6.1 | 6.3 | 10.0 | 3.5 |

Results: CFRP - 8.30/10, Ti-6Al-4V - 5.52/10, Al 7075-T6 - 5.15/10, Al 6061-T6 - 4.77/10

# Final Structural Configuration

*Chassis*

- CFRP central spine
- Titanium docking bulkhead
- Internal ring frames (CFRP)
- Aluminum equipment panels + enclosures
- Titanium hardpoints & inserts
- External MLI wrap



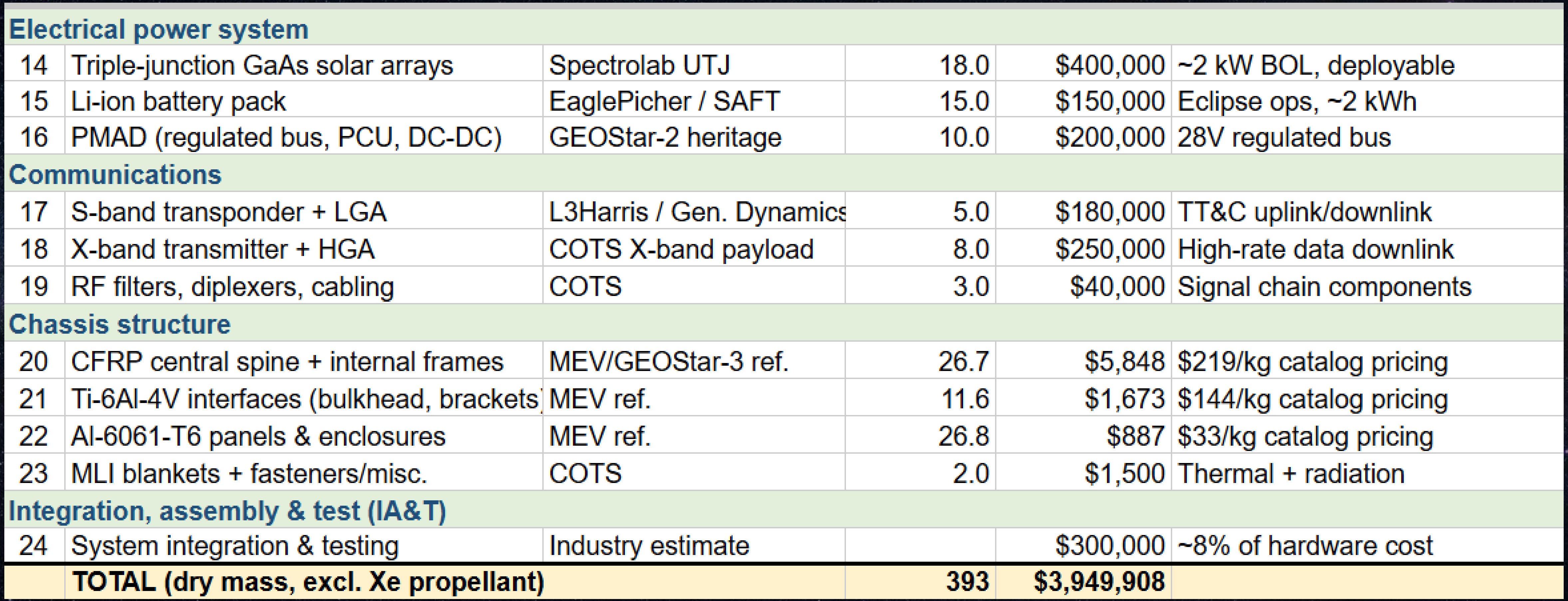
# Part 1 Bill of Materials Summary

*BOM Summary*

| # | Component | Basis / COTS reference | Mass (kg) | Est. cost ($) | Notes |
|---|---|---|---|---|---|
| **Refueling system** | | | | | |
| 1 | Xenon accumulator (COPV, 0.3 m³) | ESA L-XTA heritage | 22.0 | $180,000 | Ti liner + CFRP overwrap |
| 2 | Xenon propellant (210 kg) | Propulsion-grade Xe | 210.0 | $630,000 | ~$3,000/kg market rate |
| 3 | High-pressure He cylinder | COTS COPV | 8.0 | $45,000 | Client tank pressurization |
| 4 | Valves, regulators, feed lines | Moog / Vacco heritage | 6.5 | $120,000 | Solenoid, check, relief valves |
| 5 | Pressure & temp instrumentation | COTS transducers | 1.5 | $25,000 | PTs, thermocouples, flow sensor |
| 6 | Docking interface (client-side) | SM design, machined | 3.0 | $15,000 | Pre-launch install on client |
| **Docking system** | | | | | |
| 7 | SM hexagonal mechanism | Custom (Orbit Fab ref.) | 12.0 | $250,000 | 3 claws + spring locks |
| 8 | Docking sensors (LIDAR + camera) | COTS prox. sensors | 4.0 | $180,000 | RPO sensor suite |
| **GNC & propulsion** | | | | | |
| 9 | Hall-effect thruster | Busek BHT-600 | 8.0 | $350,000 | Includes PPU & cathode |
| 10 | Own-use Xe tank (50 kg cap.) | COTS COPV | 6.0 | $55,000 | MEO-to-GEO transfer fuel |
| 11 | Star trackers (x2, redundant) | Blue Canyon NST | 1.0 | $120,000 | Attitude determination |
| 12 | IMU + reaction wheels (x4) | Honeywell / NewSpace | 8.0 | $200,000 | 3-axis + 1 redundant |
| 13 | Flight computer (primary + backup) | RAD750 / LEON-class | 3.0 | $250,000 | Radiation-hardened |
| **Electrical power system** | | | | | |
| 14 | Triple-junction GaAs solar arrays | Spectrolab UTJ | 18.0 | $400,000 | ~2 kW BOL, deployable |
| 15 | Li-ion battery pack | EaglePicher / SAFT | 15.0 | $150,000 | Eclipse ops, ~2 kWh |
| 16 | PMAD (regulated bus, PCU, DC-DC) | GEOStar-2 heritage | 10.0 | $200,000 | 28V regulated bus |

# Part 2 Bill of Materials Summary

*BOM Summary*

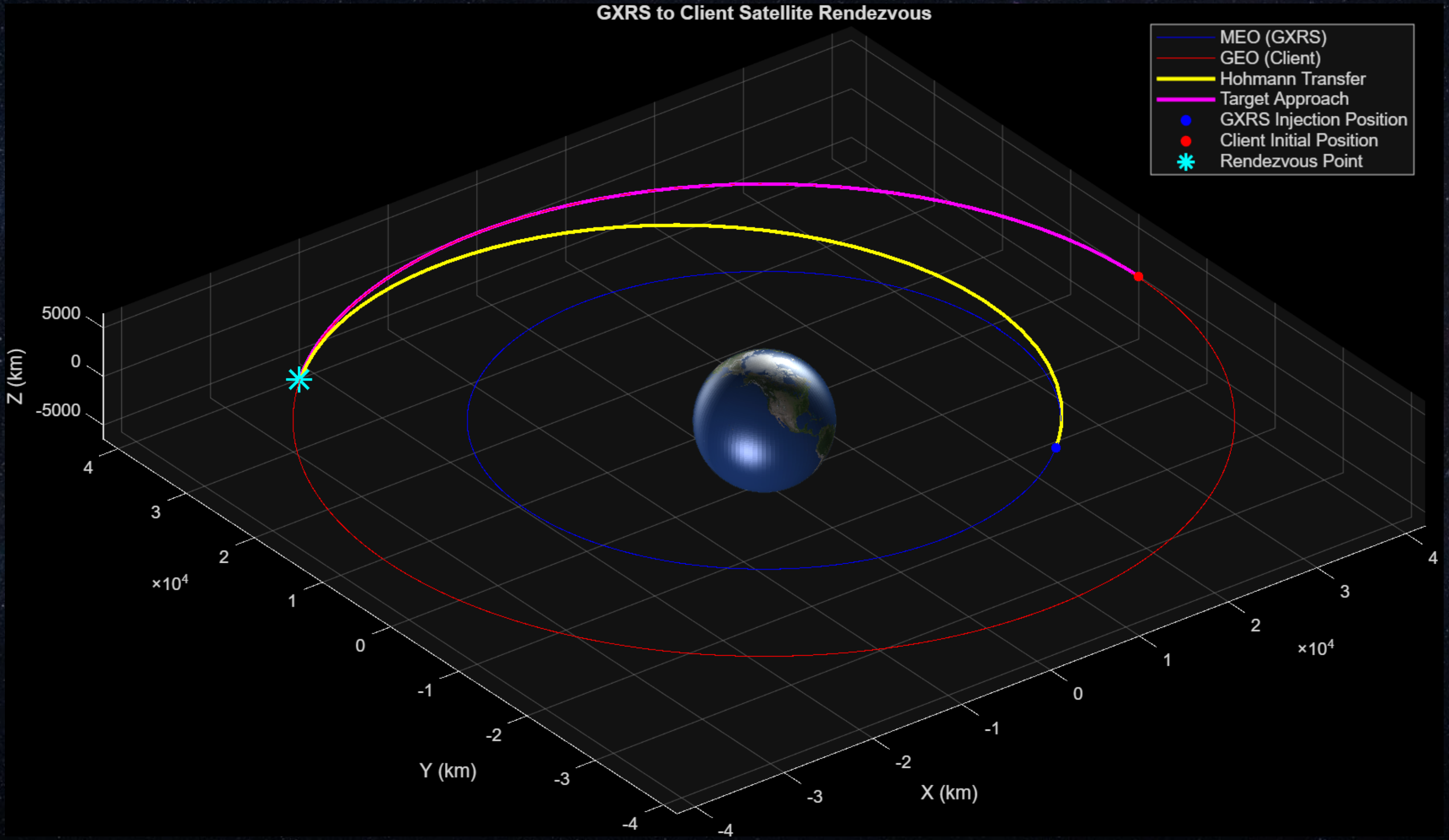


| | | | | | |
|---|---|---|---|---|---|
| **Electrical power system** | | | | | |
| 14 | Triple-junction GaAs solar arrays | Spectrolab UTJ | 18.0 | $400,000 | ~2 kW BOL, deployable |
| 15 | Li-ion battery pack | EaglePicher / SAFT | 15.0 | $150,000 | Eclipse ops, ~2 kWh |
| 16 | PMAD (regulated bus, PCU, DC-DC) | GEOStar-2 heritage | 10.0 | $200,000 | 28V regulated bus |
| **Communications** | | | | | |
| 17 | S-band transponder + LGA | L3Harris / Gen. Dynamics | 5.0 | $180,000 | TT&C uplink/downlink |
| 18 | X-band transmitter + HGA | COTS X-band payload | 8.0 | $250,000 | High-rate data downlink |
| 19 | RF filters, diplexers, cabling | COTS | 3.0 | $40,000 | Signal chain components |
| **Chassis structure** | | | | | |
| 20 | CFRP central spine + internal frames | MEV/GEOStar-3 ref. | 26.7 | $5,848 | $219/kg catalog pricing |
| 21 | Ti-6Al-4V interfaces (bulkhead, brackets | MEV ref. | 11.6 | $1,673 | $144/kg catalog pricing |
| 22 | Al-6061-T6 panels & enclosures | MEV ref. | 26.8 | $887 | $33/kg catalog pricing |
| 23 | MLI blankets + fasteners/misc. | COTS | 2.0 | $1,500 | Thermal + radiation |
| **Integration, assembly & test (IA&T)** | | | | | |
| 24 | System integration & testing | Industry estimate | | $300,000 | ~8% of hardware cost |
| | **TOTAL (dry mass, excl. Xe propellant)** | | **393** | **$3,949,908** | |

# MATLAB Rendezvous Simulation

*GNC*

- Established MEO and GEO initial orbits
- Selected arbitrary position of client in GEO
- Utilized Hohmann transfer function to find transfer time and delta-V
- Propagated client's trajectory over Hohmann transfer time to determine rendezvous point
- Iteratively computed injection point to reach rendezvous



# 1.4 Advancing High Value Missions

*How This Mission Contributes to In-Orbit*

- This mission advances key missions in-orbit in several critical ways:
  - COSMIC states that the value of refueling increases substantially with orbit altitude. By topping off rather than replacing these extremely high-value investments, the xenon refueling system directly addresses this need with a high-density propellant with an easily standardized docking apparatus.
  - The U.S. Space Force is shifting towards Dynamic Space Operations which require sustained maneuverability of spacecraft. Without refueling designs like the GXRP, defense satellites would be significantly less mobile with propellant-conservative restraints.
  - The technology required for the GXRP, including sensors for rendezvous, docking hardware, and propellant-transfer interfaces, exist at varying levels of maturity. Studies into systems like this directly address gaps in these technologies by proposing specific, analyzed solutions.

# 2.3 Path to PDR

*7 Steps Required*

- (1) Develop detailed interface control documents and a consolidated mass/power budget across all subsystems.
- (2) Conduct FEA thermal and structural analysis of the chassis under combined launch, transfer, and docking load cases.
- (3) Build and test a docking mechanism prototype to validate claw kinematics and spring-loaded locking engagement forces.
- (4) Develop a refueling system test plan using xenon simulant fluids under representative pressure conditions.
- (5) Expand the GNC simulation to include sensor noise models, realistic approach trajectories, and proximity operation control laws.
- (6) Complete a preliminary failure modes and effects analysis (FMEA) for all subsystems.
- (7) Refine the communications link budget for both S-band and X-band at GEO distance.

# 3.2 Risks

*Possible Risks and Solutions*

- Potential Risks
    - Docking mishaps
    - Thermal Distortion on Materials
    - Radiation Damage
    - Cold Welding
    - Hot spots leading to malfunction of electronics
- Potential Mitigation/Solutions:
    - CFRP as primary structure material - Reduces thermal distortion
    - MLI blanket – Reduces radiation exposure
    - Al-6061-T6 as Avionics enclosure material – Good thermal spreading capabilities, reduces likelihood of hotspots

# 4.1 Most Innovative Concepts Considered

*Most Innovative Concepts Chosen*

- (1) The spring-loaded ballpoint-pen-style locking mechanism for docking reduces fatigue compared to traditional springs and enables simple bidirectional docking/undocking via a single actuation mode.

- (2) The bellows-driven accumulator approach for propellant transfer avoids active pumping entirely, leveraging passive pressure equilibrium for a mechanically simple and reliable transfer.

- (3) The hybrid multi-material chassis strategy that assigns each material to its optimal structural zone—CFRP for weight-critical members, aluminum for thermal management, titanium for fatigue-critical joints—provides performance no single material could achieve.

# 4.2 Most Important Technology Gaps

*Technology Gaps and Solutions*

- A standardized/universal refueling part is needed, as current refueling systems must be equipped prior to launch.
  - Universal docking would help drastically, as it would be compatible with all potential clients.
- GNC system could be further expanded upon to increase precision and reduce micro-adjustments needed when docking
- Propellant leak detection is needed, as clean pressure transfer is assumed.
  - In-line mass flow leak detection technology would help increase confidence in the operation.

# 4.3 Biggest Challenges Encountered

*Three Biggest Challenges*

- First Challenge: Creating a simulation of the fluid transfer process.
  - Creating spreadsheets and simulation models of the propellant transfer took a significant amount of time and learning but led us to a much deeper understanding of the system we designed.
- Second Challenge: Selecting a propellant type to support.
  - Many different propellant types would have been possible to design for, but global supply issues and current "market share" in space were key factors to consider before the project even began.
- Third Challenge: Developing a docking mechanism compatible with many types of satellite.
  - Many existing satellite architectures exist, so a completely novel docking apparatus had to be developed in order to hard-capture a wide range of existing platforms.

# 5.2 Paper

*Technical Report Details*

Details of the technical report:

- Abstract length of 144 words.
- Paper length of 20 pages, including references.
- 38 references included.
- Currently, we are working with our school chapter of AIAA to publish our paper through the organization.

COSMIC Capstone Challenge:

# Final Design Brief

# Questions?