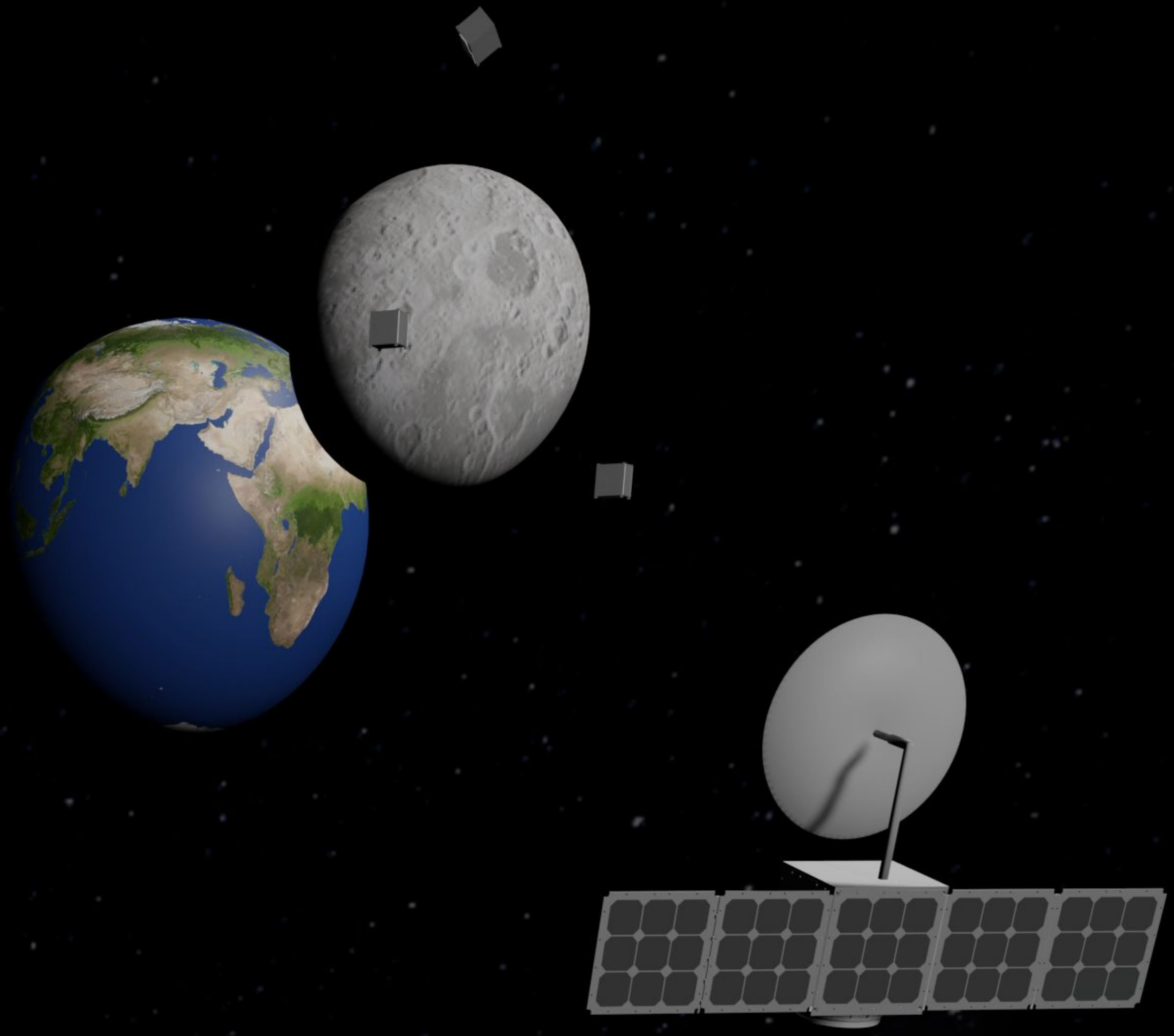

# *Lunar Far Side Tracking and Communication Relay System*


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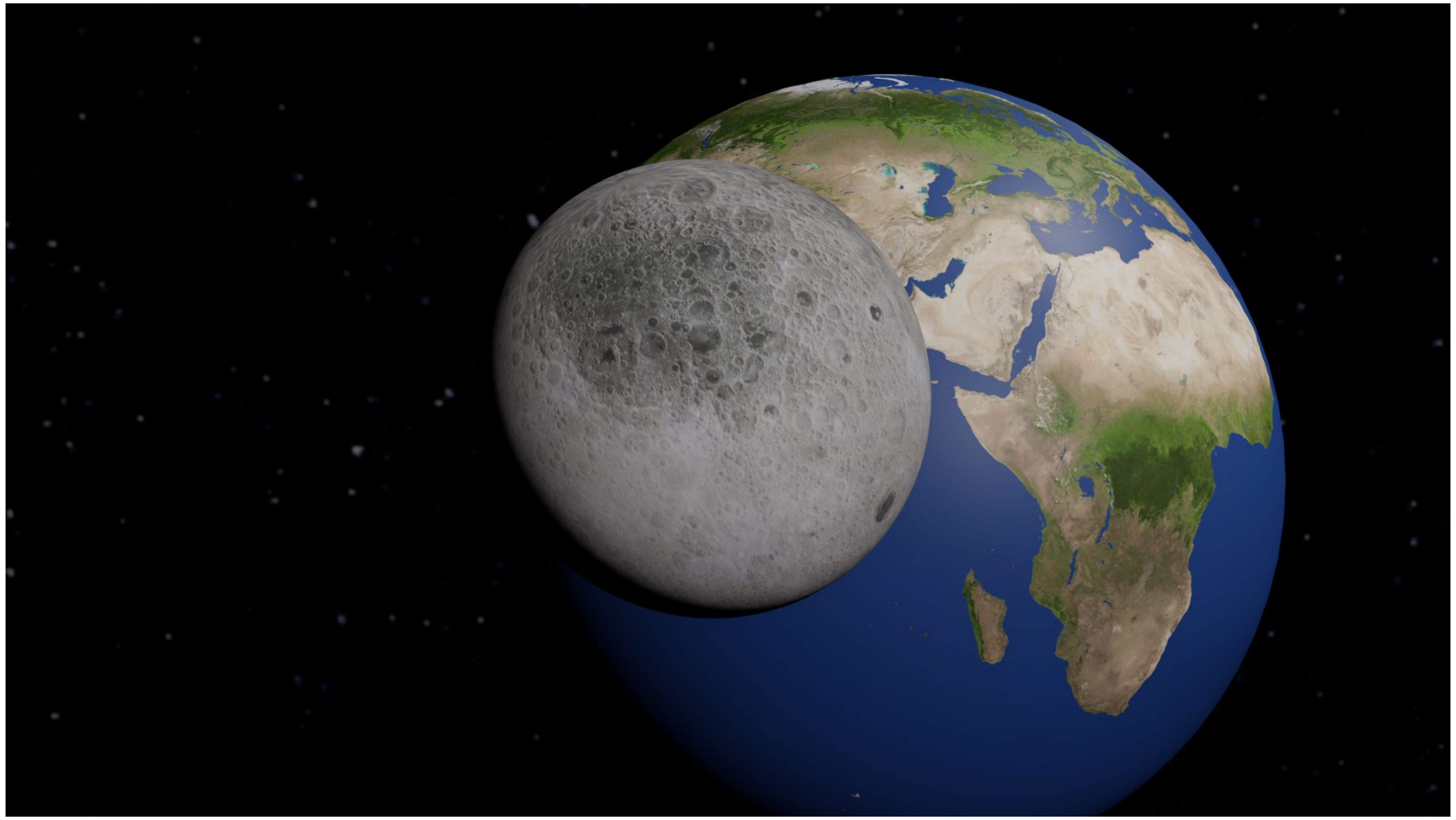
DHRUVA SPACE

# Mission Objective

**Need:**

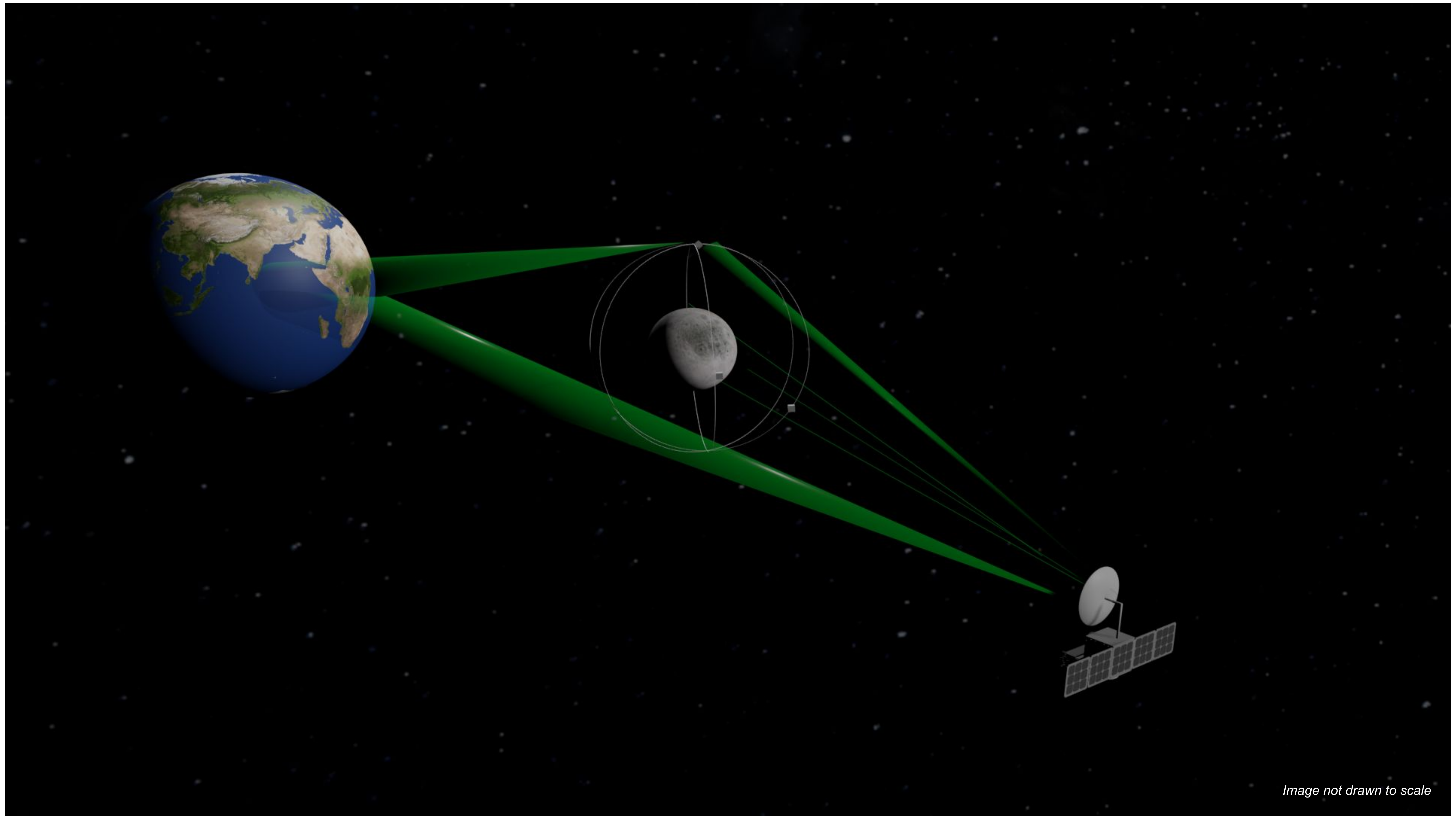
- Lunar Far side is inaccessible for Earth Based Ground Stations
- Space-based Communication relay system to transmit and receive data from systems (Landers, Rovers etc.) on the Lunar Far Side



# Mission Objective

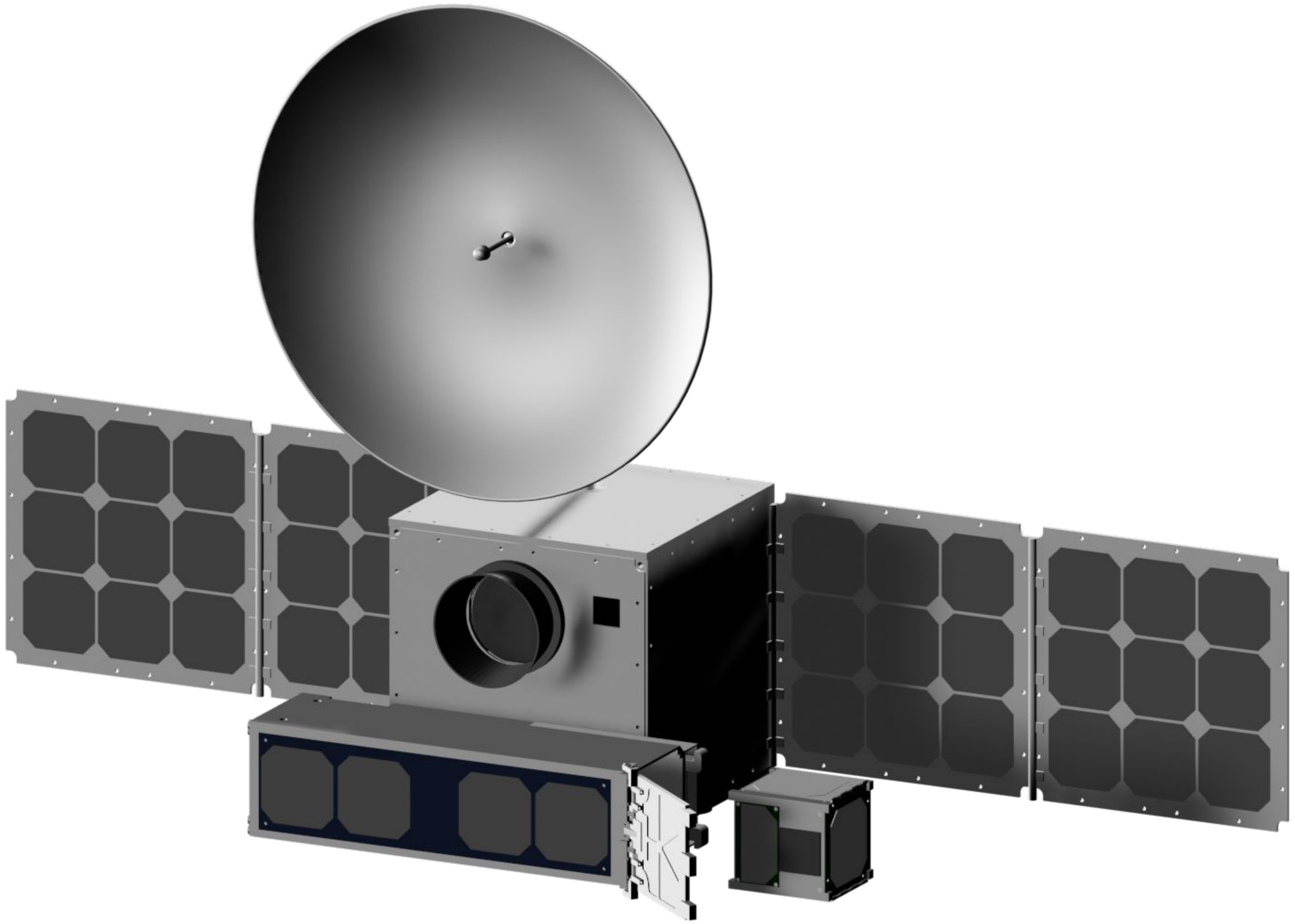
**Solution:**

- Data relay spacecraft placed in the Earth-Moon L2 Lagrangian point along with spacecrafts in Lunar Orbits provides a near real-time communication access to the Lunar Far Side



# Mission Profile

- Establish Lunar Far Side Tracking and Communication Capabilities
- **System:**
  - P30 platform
  - Piggyback of 3x 1U CubeSats
  - Inter Satellite Link built on Delay Tolerant Network (DTN) architecture
- **P30 - Parent Satellite**
  - serves as the primary spacecraft with IR imaging payload
  - stationed in L2 Halo Orbit
  - Deploy 1Us in Lunar Orbit
- **1U - Child Satellites**
  - forms a constellation in the lunar orbit - enable communication between Lunar surface assets, the Earth and P30



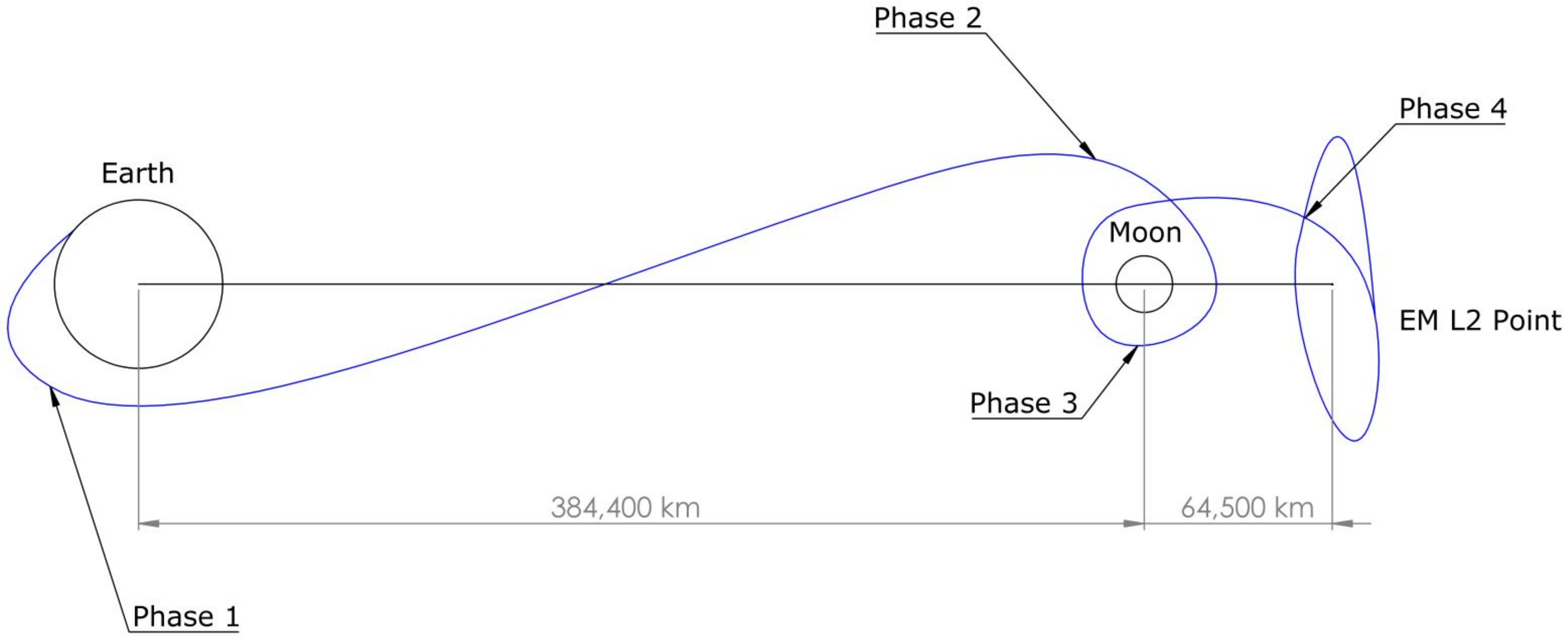
# Orbit - P30 Parent

**Phase 1** — **Launch**

**Phase 2** — **Lunar Orbit Insertion**

**Phase 3** — **1U CubeSat Ejection**

**Phase 4** — **Halo Orbit Insertion**



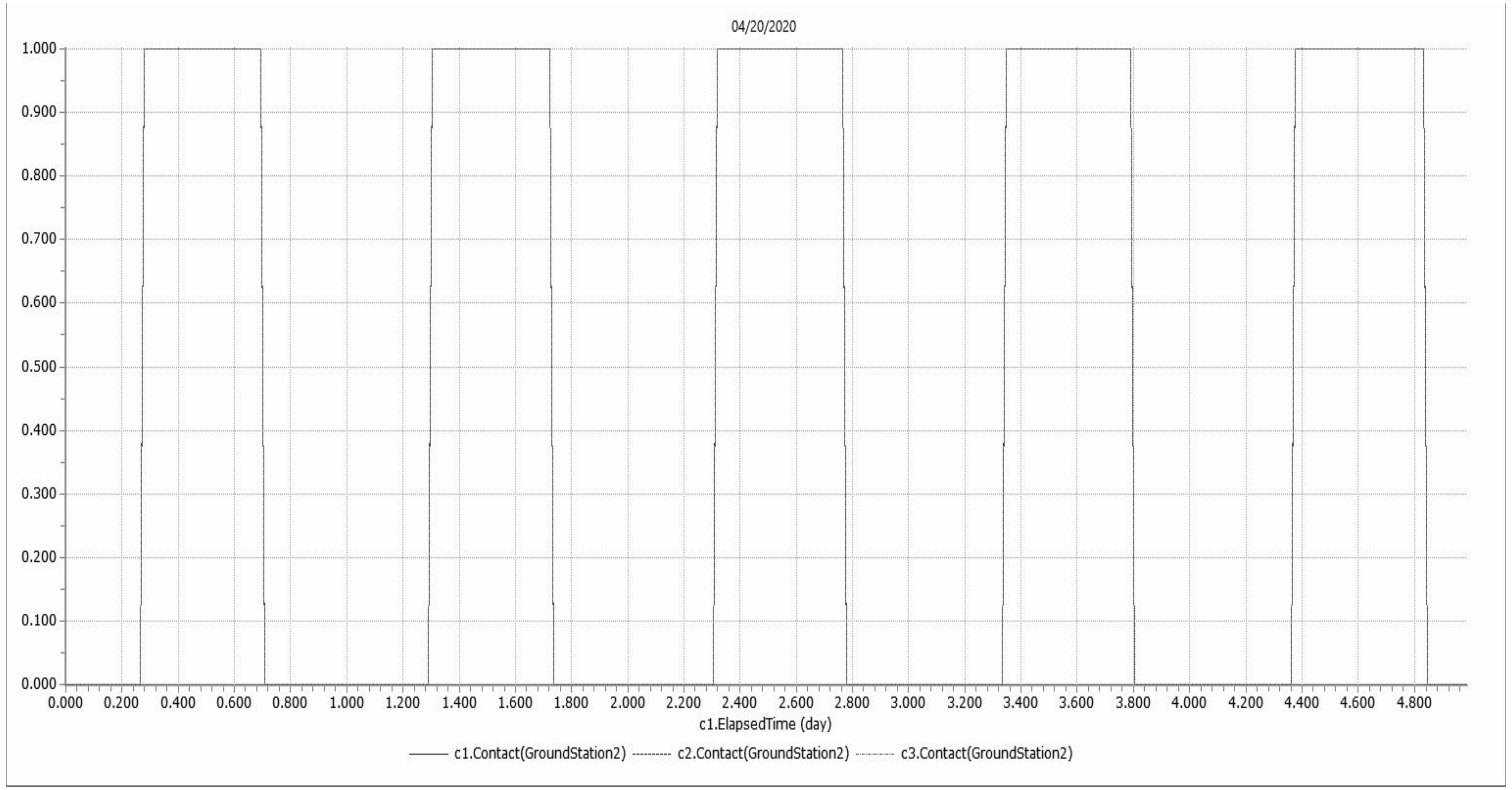

| Orbit Phase | Delta-V Requirement |
|---|---|
| Lunar Orbit (40° inclined orbit) to L2 insertion | 776 m/s |
| Stationkeeping in L2 | 132 m/s per year |

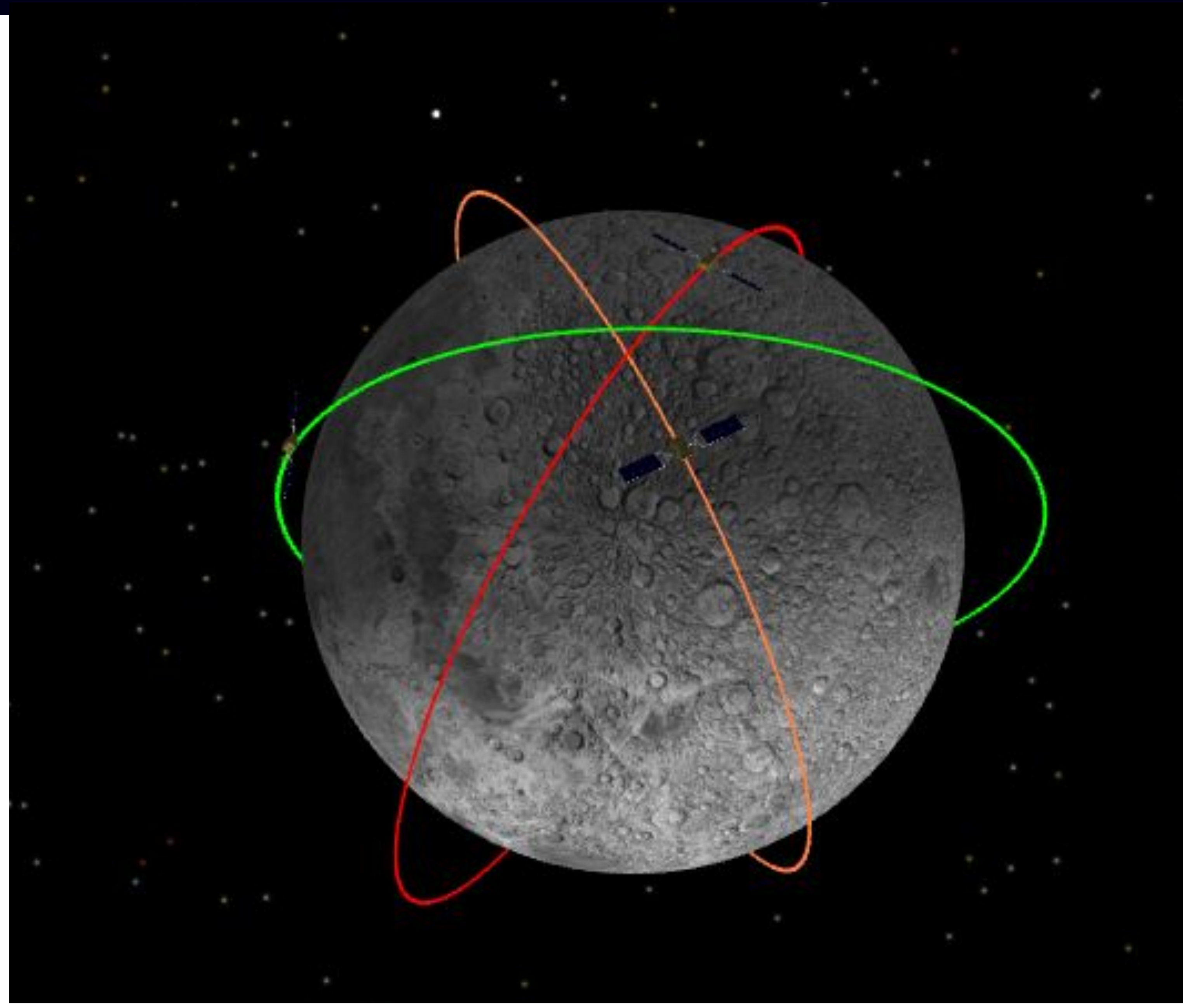
- The deltaV depends on amplitude of orbit, can be considered as worst case
- Halo orbit can have amplitude much higher than radius of moon, so that moon doesn't block the sc-Earth
- It may take up to several weeks to achieve the required delta V and reach the Halo Orbit

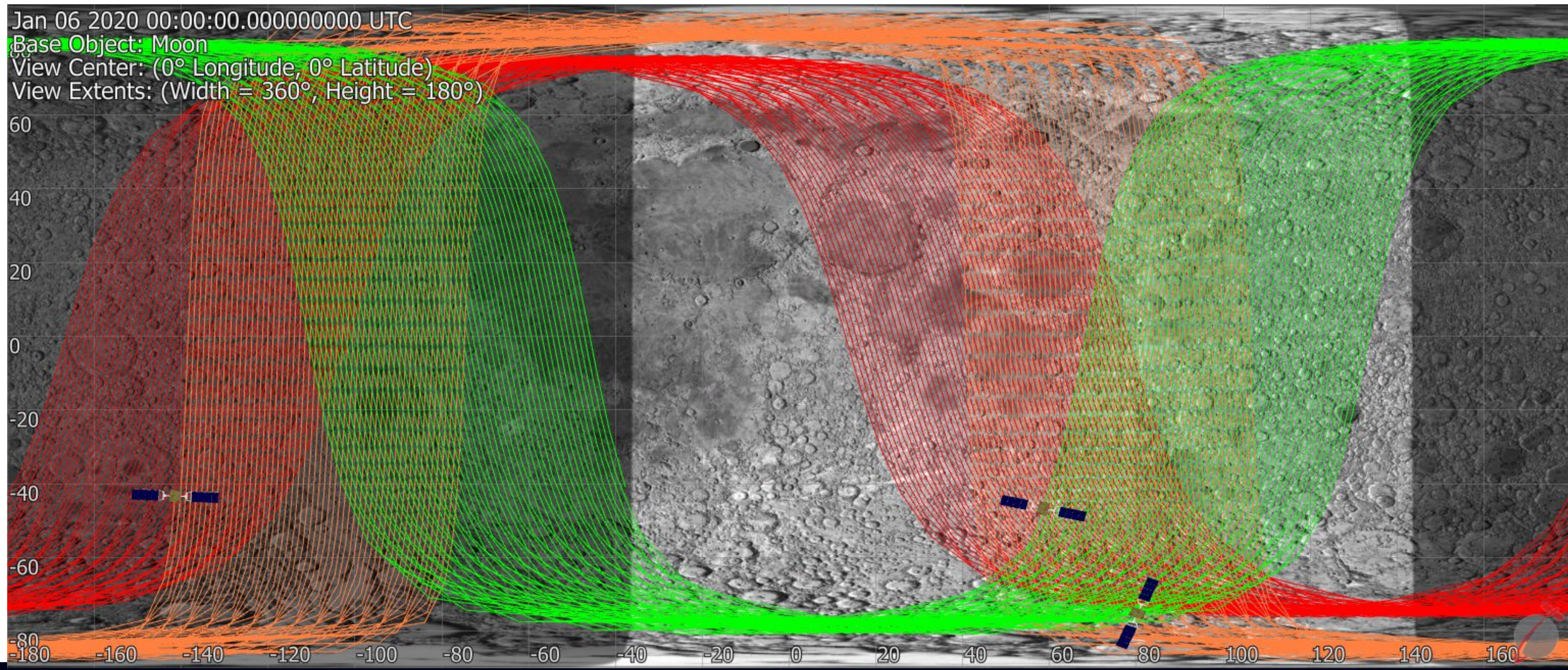
*NASA:GSFC Technical Note TN-D-6365: The utilization of halo orbits in advanced lunar operations*

# Orbit - 1U constellation

- CubeSat Constellation: 3x 1U Satellites
- Lunar Orbital parameters
  - a = 2000km | e = 0.1 | i = 86 deg | RAAN: 60, 90, 120 deg
- The inclination is chosen based on stability of orbit and maximum coverage



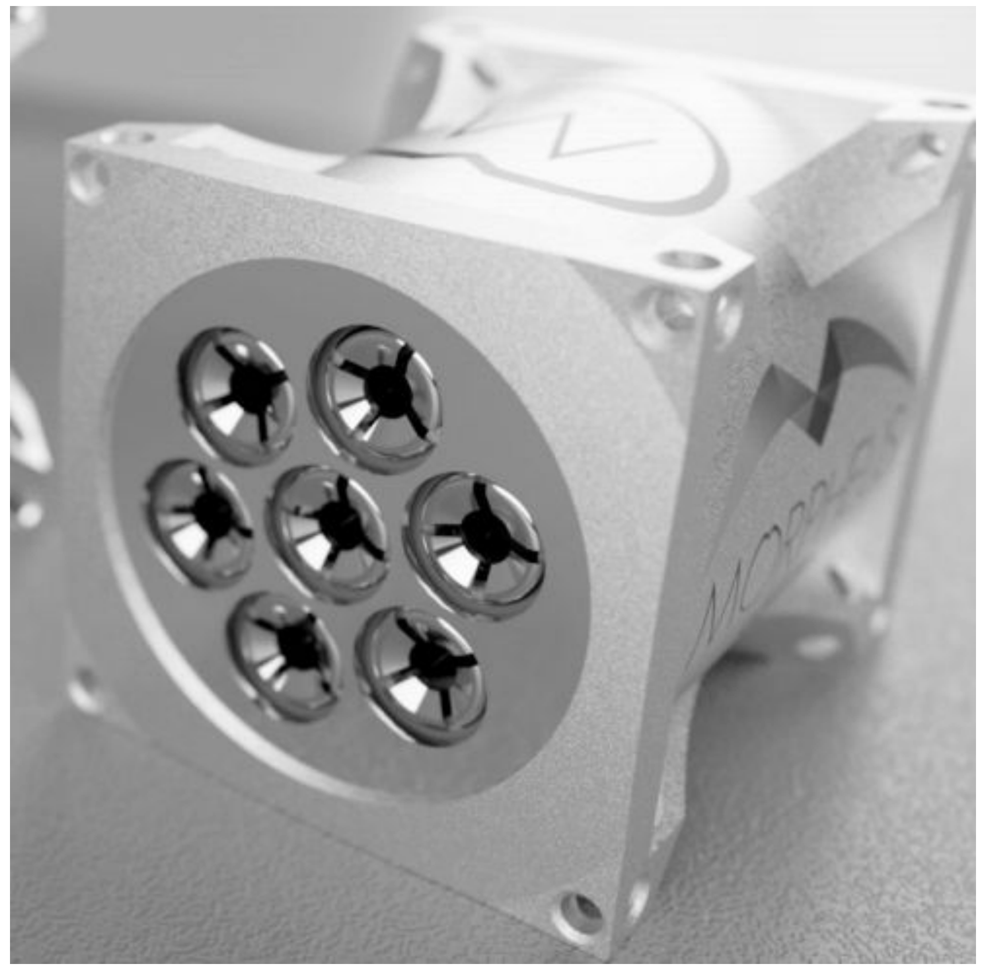





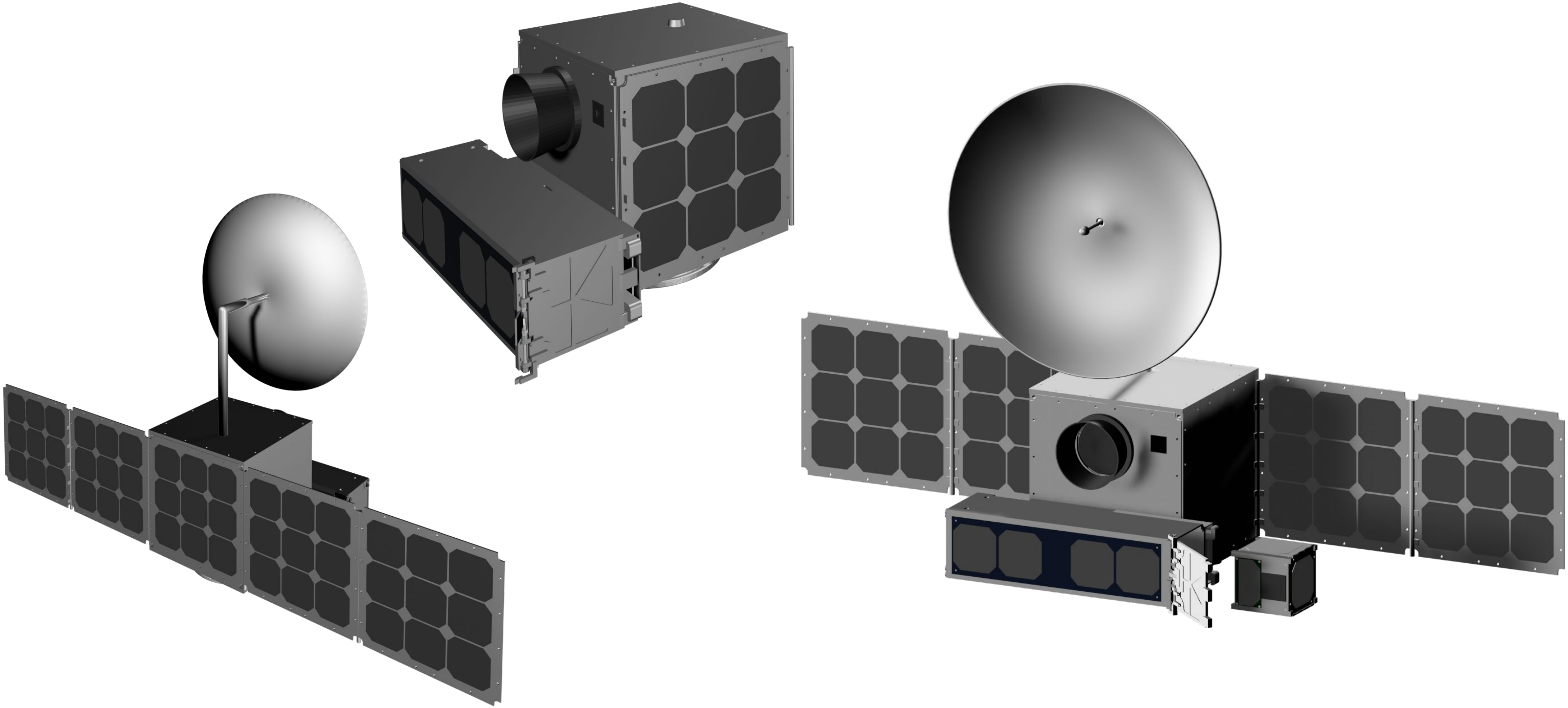
# P30 Platform - Parent

| SUBSYSTEM | DESCRIPTION |
|---|---|
| BUS | Clustered Small satellite Platform: In-house<br>Scalable and modular |
| Electrical Power System | Deployable Solar Panels: up to 90W of power production |
| Command and Data Handling | FPGA based OBC<br>S- / X- / Ka- band with deployable antennas<br>Data rates 10 - 100 Mbps<br>Tethers Unlimited / Syrlinks / Canopus: compatible with NASA Ground Networks |
| Attitude Control | Integrated 3-axis stabilization - CubeSpace<br>Star trackers, Gyroscopes, Reaction wheels |
| Orbit Control | Low power Field emission electric propulsion: Morpheus Space |
| Thermal Control | Multi-layer insulation using Carbon nanotube sheets, along with necessary surface coatings |
| Imager | Infrared Imaging of the Far Side of the Lunar Surface |

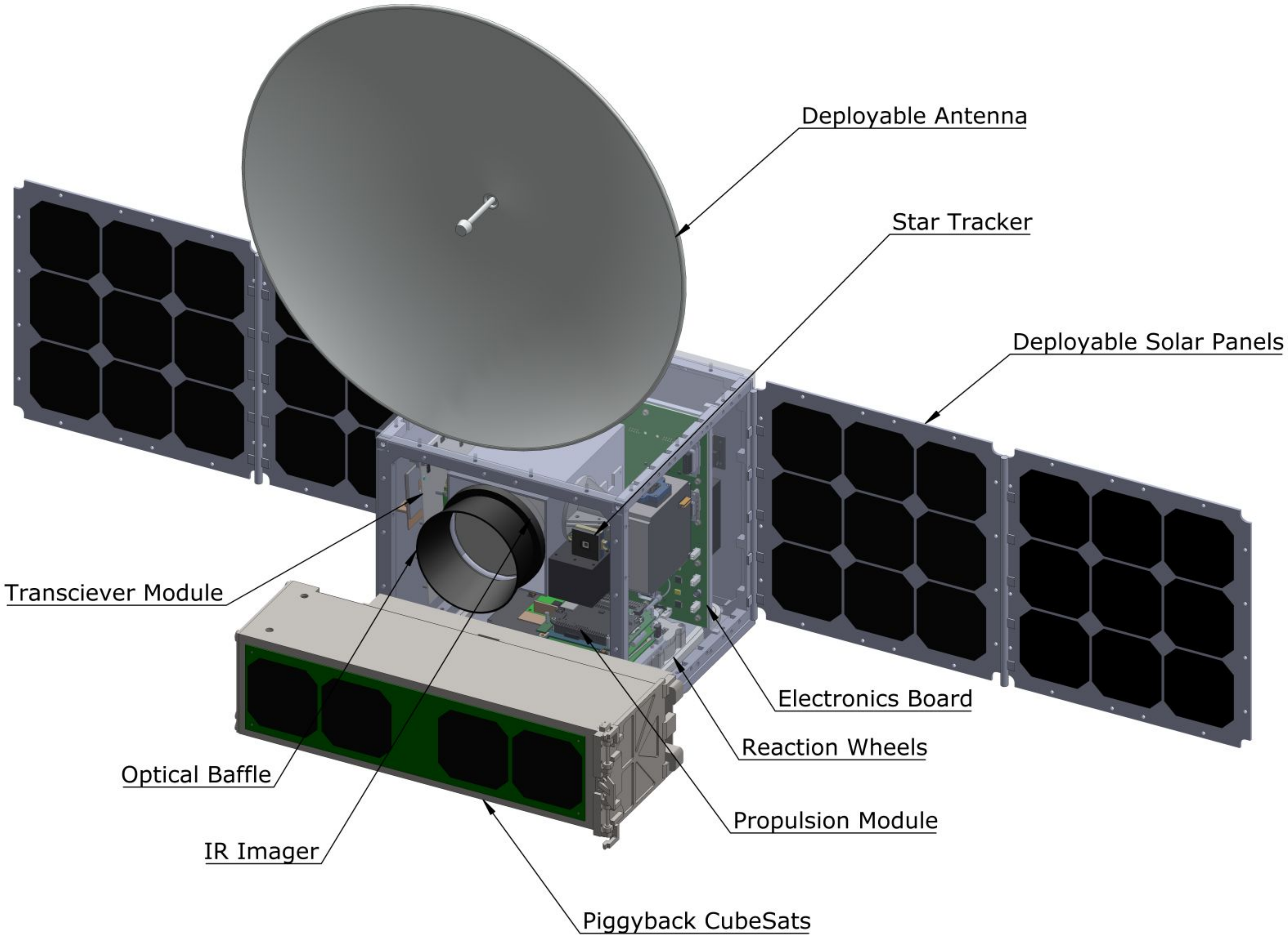
*nanoFEEP: Propulsion System*



# P30 Platform - Parent

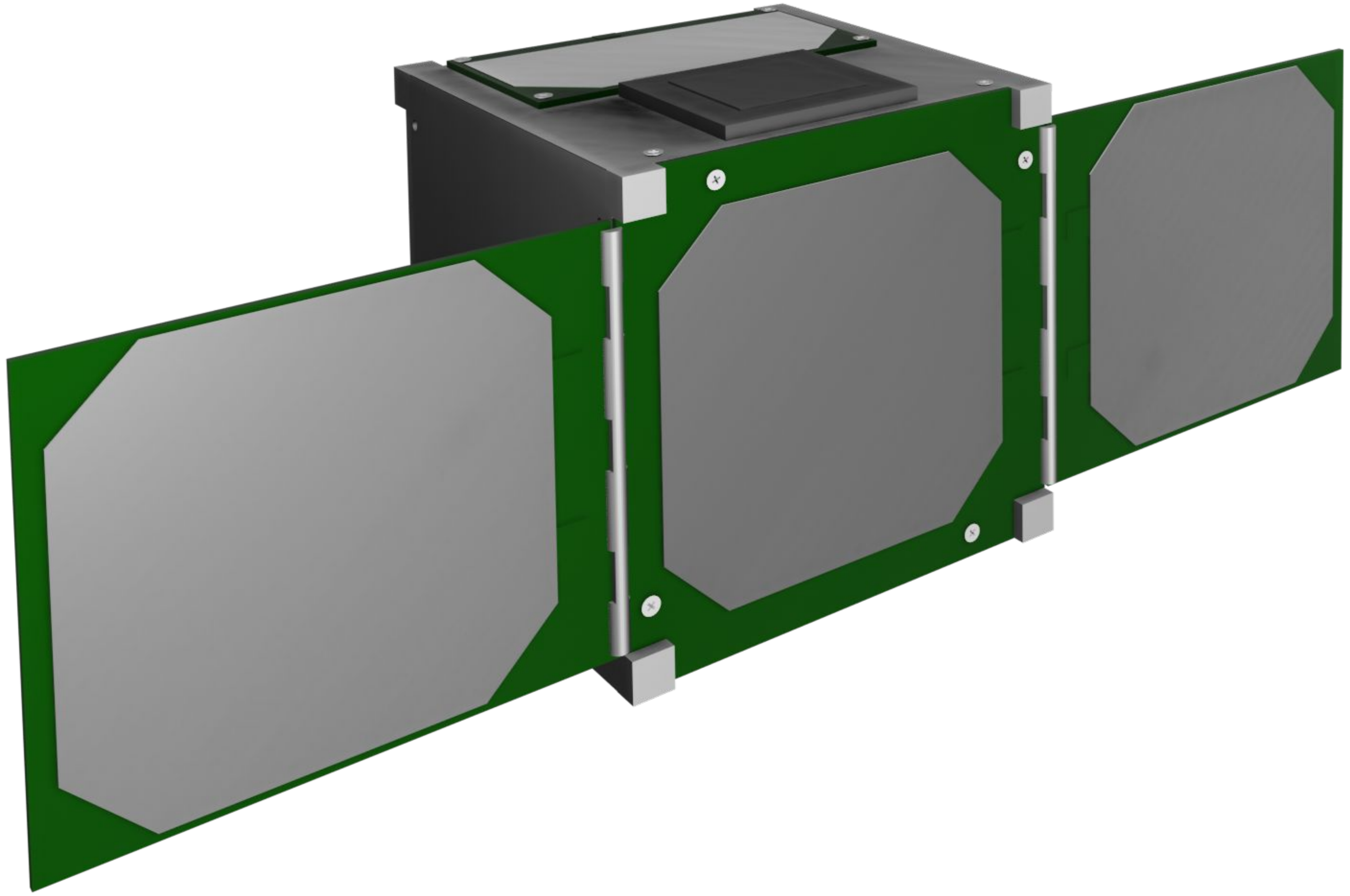


# P30 Internal Configuration



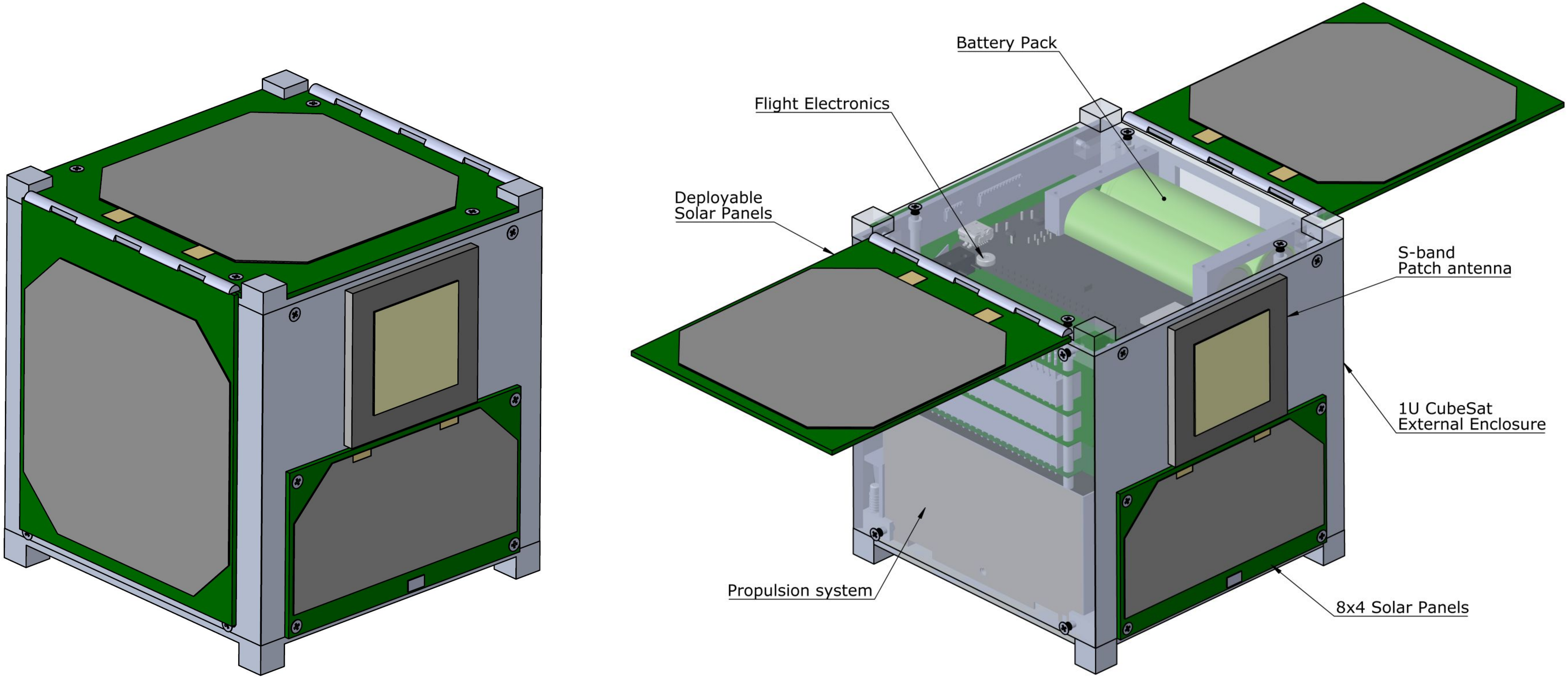
# 1U Platform - Child

| SUBSYSTEM | DESCRIPTION |
|---|---|
| **BUS** | 1U CubeSat Structure made with Aluminum 6061-T6 |
| **Electrical Power System** | Deployable Solar Panels: up to 8W of power production |
| **Command and Data Handling** | S- band with patch antennas<br>Data rates 10 Mbps<br>Tethers Unlimited / BDS |
| **Attitude Control** | Integrated 3-axis stabilization - CubeSpace<br>Star trackers, Gyroscopes, Reaction wheels |
| **Orbit Control** | Low power Field emission electric propulsion: Morpheus Space |
| **Thermal Control** | Multi Layer Insulation using carbon nanotubes sheets,<br>along with silicon-based thermal transfer substrate* |



** Ronnie Nader: Carbon Nanotubes Based Thermal Distribution And Transfer Bus System For 1U Cubesats And The Space Environment Attenuation Manifold Shield*

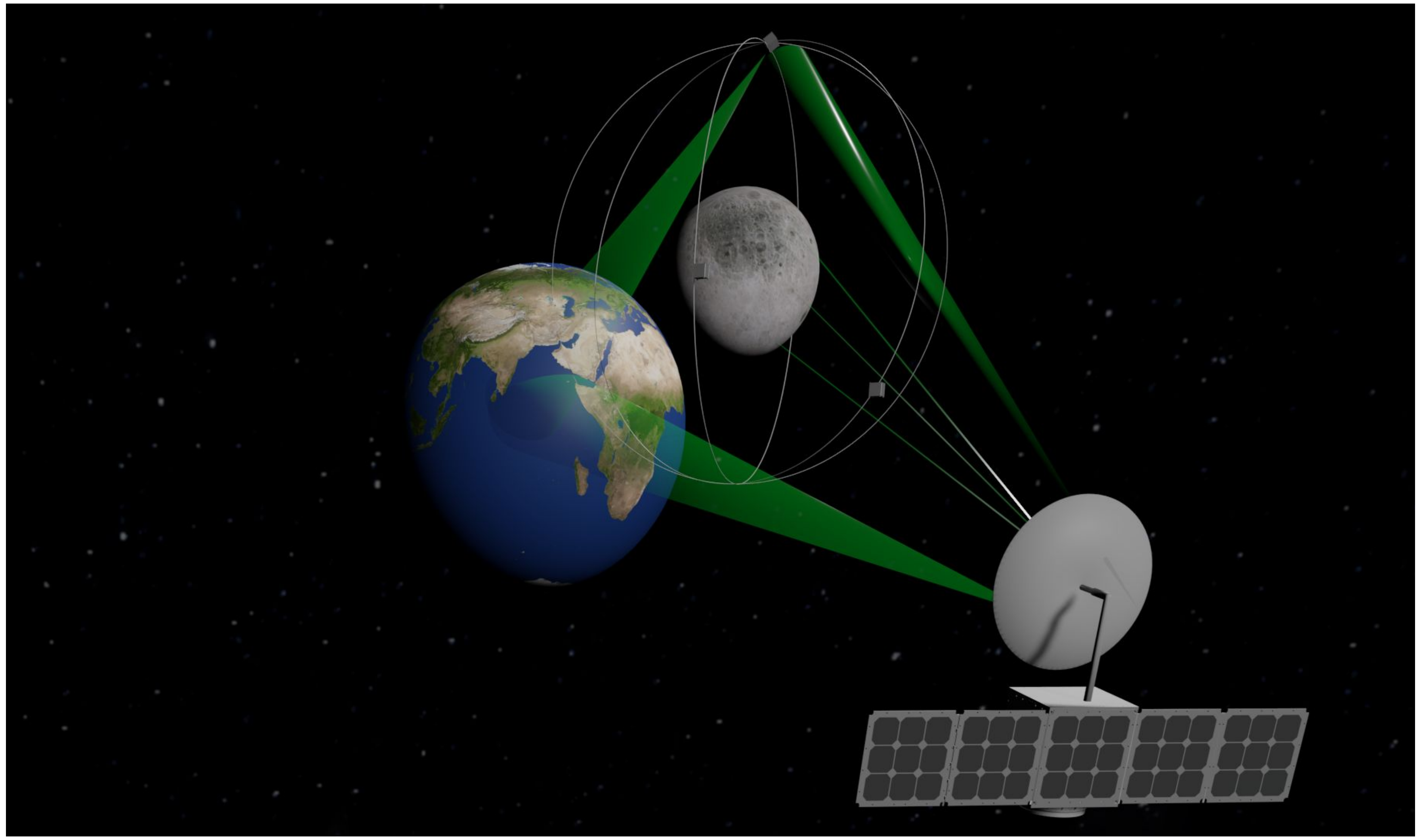
# 1U Internal Configuration



# Communication Architecture

**Ground Station: existing infrastructure**

- NASA NEN and SN are expanding to provide support to CubeSat Missions
  - Enhancing receivers on ground
  - Use of cryogenic LNAs
  - Testing ground capabilities with Artemis-1 (EM-1) and future missions



**P30 Parent Spacecraft**

NEN/ SN/ DSN compatible commercial transceivers

- S- Band: Tethers Unlimited SWIFT-SLX (upto 15 Mbps)
- Deployable antenna: BDS Phantom Works High Gain S-Band Antenna

*NEN: Near Earth Network*
*SN: Space Network*
*DSN: Deep Space Network*

*Schaire et al (2016): NASA Near Earth Network (NEN) and Space Network (SN) CubeSat Communications*

# Link studies

Link Study Model

- Telemetry Operation: an uncoded OQPSK signal
- Loss model
  - Free Space, Atmospheric, Rain and Ionospheric losses
  - Circuit and pointing losses
  - Lunar Flux Density Loss
- 34m ground antenna and 1.2m Lunar Orbiter antennas was considered

Table 1. High-speed downlink model.

| Classification | Unit | S band | X band | Ku band | Ka band |
|---|---|---|---|---|---|
| System bandwidth | MHz | 26 | 26 | 26 | 26 |
| Distance | km | 384,403 | 384,403 | 384,403 | 384,403 |
| Transmit frequency | MHz | 2,295 | 8,420 | 12,200 | 32,000 |
| Lunar orbiter | | | | | |
| Transmit power | W | 20.0 | 20.0 | 20.0 | 20.0 |
| | dBW | 13.0 | 13.0 | 13.0 | 13.0 |
| Antenna diameter | M | 1.2 | 1.2 | 1.2 | 1.2 |
| Antenna efficiency | | 0.7 | 0.7 | 0.7 | 0.7 |
| Antenna gain | dBi | 27.7 | 38.9 | 42.2 | 50.5 |
| Antenna circuit loss | dB | 0.6 | 0.4 | 0.3 | 0.25 |
| Antenna pointing loss | dB | $3.2 \times 10^{-6}$ | $4.4 \times 10^{-5}$ | $9.3 \times 10^{-5}$ | $6.4 \times 10^{-4}$ |
| Channel | | | | | |
| Free space loss | dB | 211 | 222 | 225.9 | 234.2 |
| Atmospheric attenuation | dB | 0.033 | 0.039 | 0.1 | 0.154 |
| Ionospheric loss | dB | 0.2 | 0.2 | 0.2 | 0.2 |
| Rain attenuation | dB | 0.0 | 1.0 | 4.7 | 19.2 |
| Lunar flux density loss | dB | 5.34 | 5.4 | 5.0 | 3.96 |
| Earth station | | | | | |
| Antenna diameter | M | 34.0 | 34.0 | 34.0 | 34.0 |
| Antenna efficiency | | 0.7 | 0.7 | 0.7 | 0.7 |
| Antenna gain | dBi | 56.7 | 68.0 | 71.2 | 79.6 |
| Antenna circuit loss | dB | 0.6 | 0.4 | 0.3 | 0.25 |
| Antenna pointing loss | dB | 0.003 | 0.044 | 0.150 | 0.639 |
| Noise temperature | K | 34.0 | 31.9 | 38.0 | 44.9 |

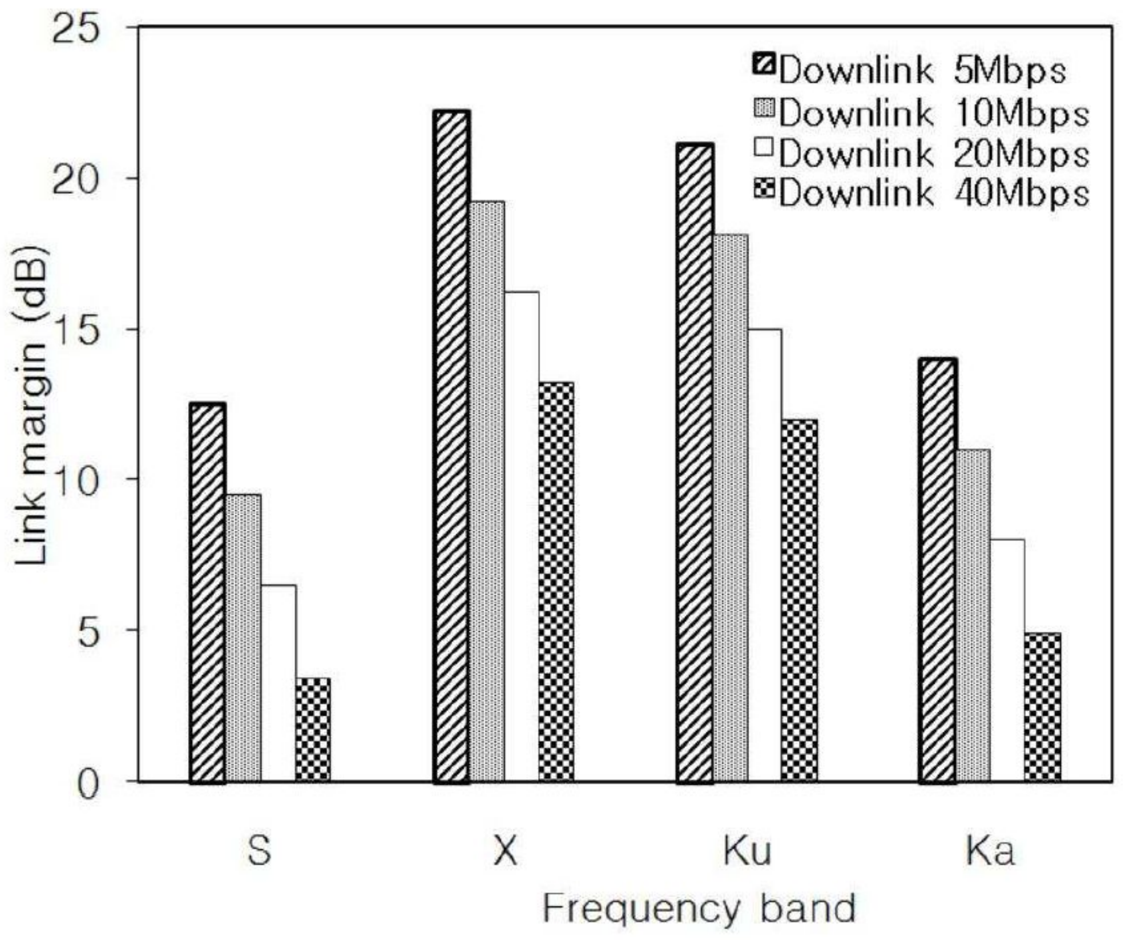



Figure 1. Link margins for the downlink data rates (under 52 Mbps).

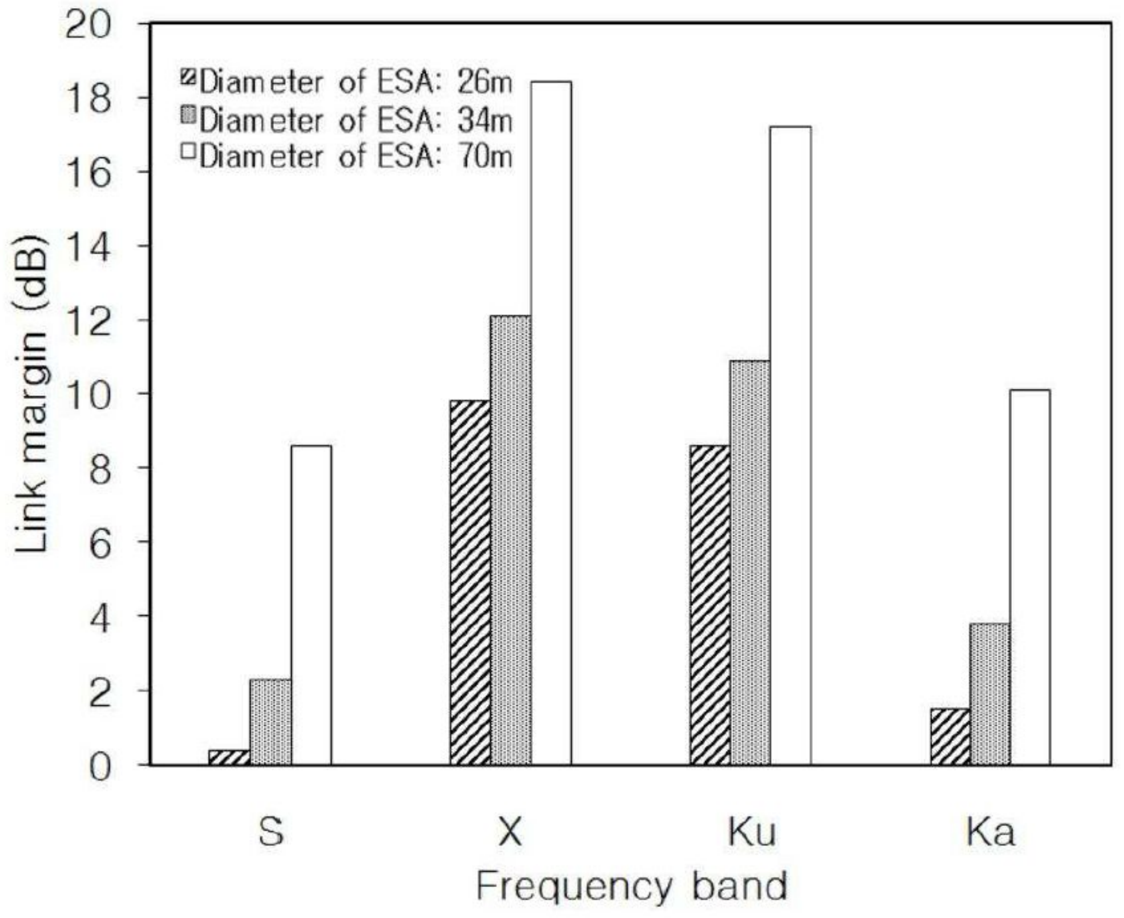
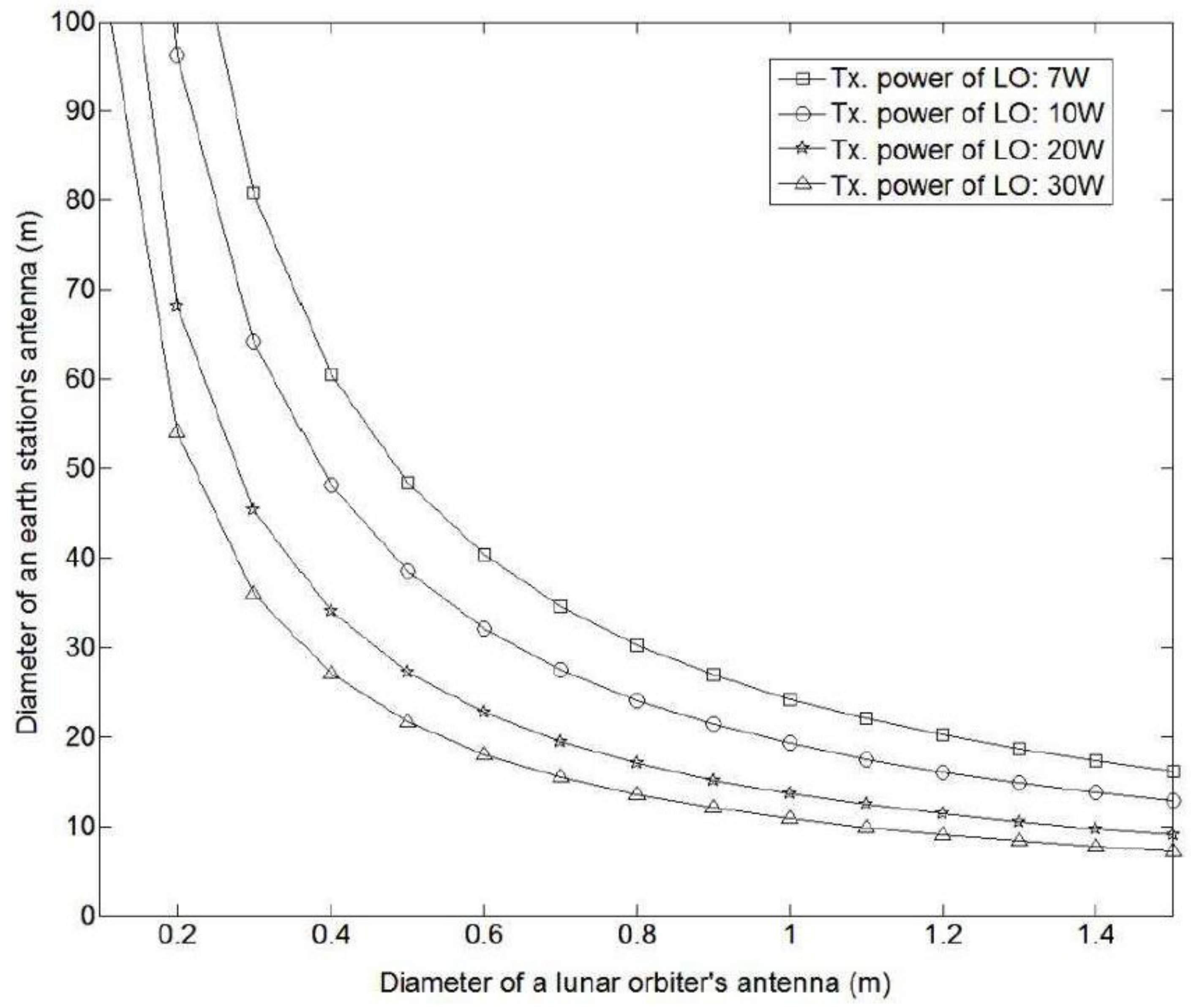



Figure 3. Link Performance for ESA diameters at the data rate 52 Mbps.

# Link studies

- Primary factors affecting successful link margin
  - Larger orbiter antenna - limited by power availability and launch costs
  - Larger ground antenna - limited by existing infrastructure and costs
    - 26, 34 and 70m currently
- Channel encoding can be implemented
- Adaptive modulation techniques / Spread Spectrum capabilities can be used
  - Power and bandwidth efficient signal techniques
- Possible use of patch antennas coupled with above changes needs to be explored

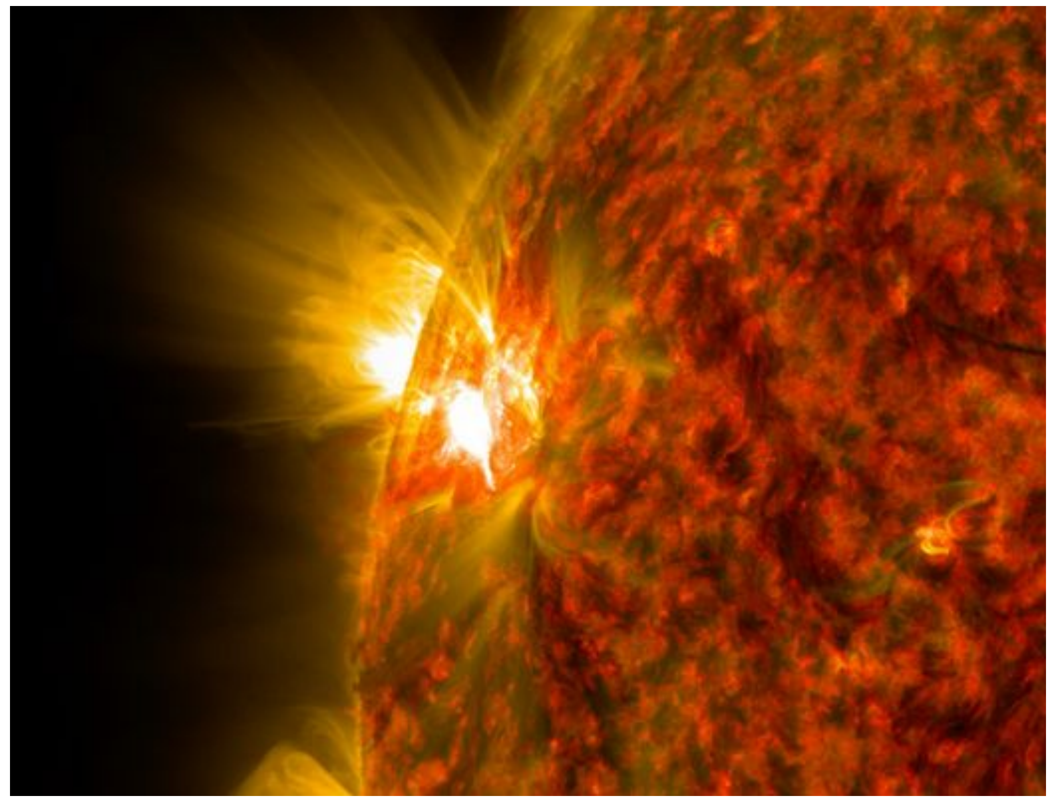



*Diameters of an Earth Station Antenna and a Lunar Orbiter Antennas for transmit powers of a Lunar Orbiter in the Ka band.*

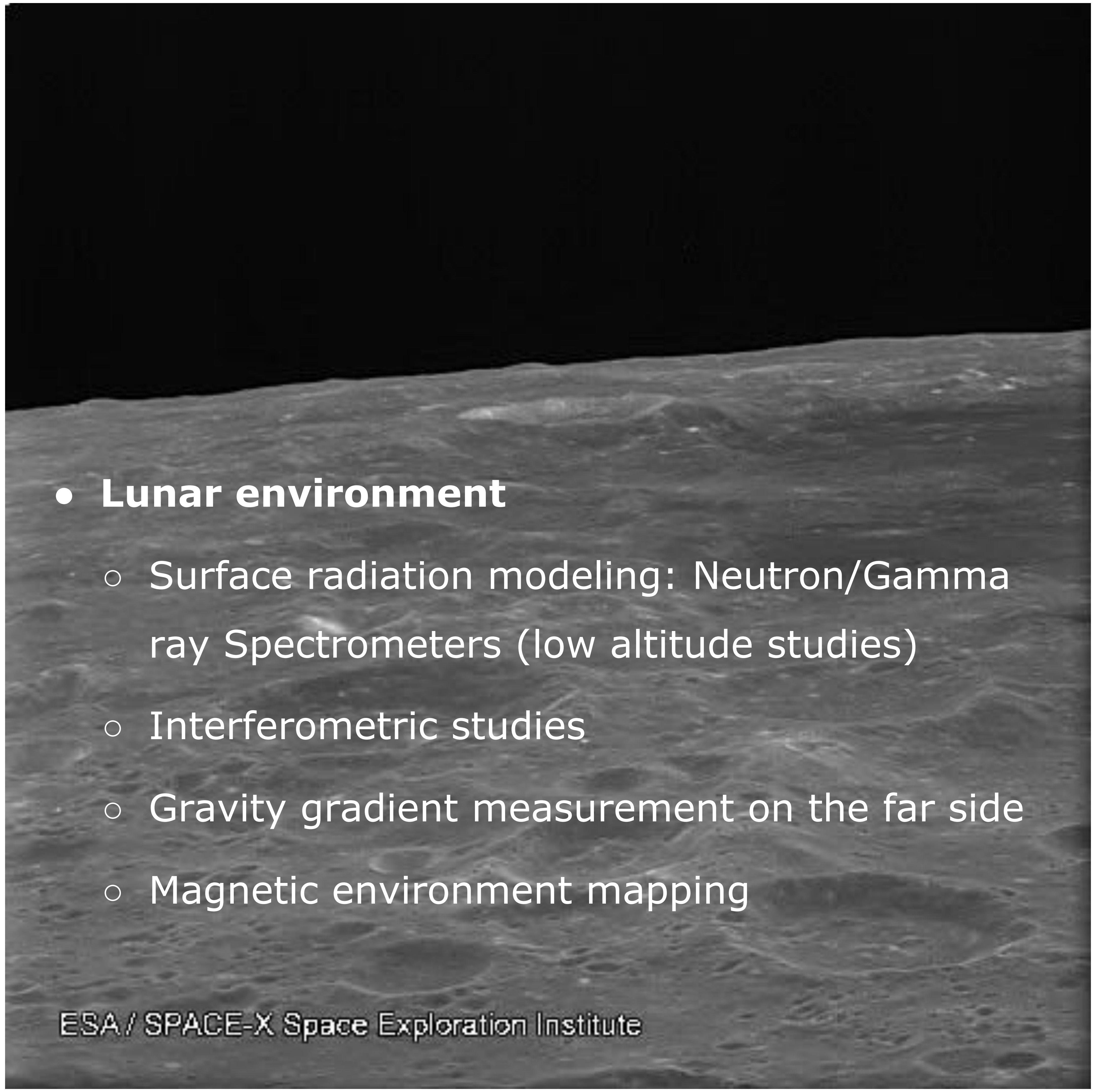
# Platform Capabilities

| | P30 | 1U |
|---|---|---|
| **System** | | |
| Mass | 10 kg (without Payload) | <2kg |
| Power | up to 90 W (deployable panels) | ~6-10 W (deployable panels) |
| Volume | 300 x 300 x 300 mm (stowed) | 100 x 100 x 113 mm |
| Mechanism | Compliant Mechanisms for robust reliable deployments | |
| **Key Platform Performance Characteristics** | | |
| Attitude Control System | Active Control System with Reaction Wheel Control | Active Control System with Reaction Wheel Control |
| Orbital Maneuvering | Electric Propulsion (higher delta V) | Electric propulsion |
| Pointing Knowledge, 3σ | <0.03 deg per axis | <0.1 deg per axis |
| Total pointing accuracy, 3σ | <0.07 deg per axis | <1 deg per axis |
| Telemetry and Telecommand<br>Payload Downlink | Accommodate S- / X- / Ka- band transmitter with deployable / patch antennas<br><br>Compatible with NEN, SN, DSN | Accommodate S- band transmitter with patch antennas<br><br>Compatible with NEN, SN, DSN |
| **Key Platform Interface Characteristics** | | |
| Standard Payload Data Bus | RS-422 | |
| Alternate Serial Bus Interface(s) | Ethernet, SPI, I2C, USB, CAN | |
| Internal data handling | Active analog, passive analog, discrete, serial (bidirectional serial bus), software 16 Bit / 32 Bit words, and memory dumps | |
| Power | | |
| Main Bus Voltage (Standard) | ~8V Regulated to 5V, 4.2V, 3.3V and 1.2V | |
| Thermal | | |
| Internal Temperature Environments | In-Orbit Temperature Range -10°C and +60°C (managed with thermal paints, MLI and use of carbon nanotube sheets | |

# Science Opportunities



- **Solar weather**
    - Monitoring SEP/CME (Solar Energy Particle/Coronal Mass Ejection) sites
    - Warning/alert system for SEP events




- **Lunar environment**
    - Surface radiation modeling: Neutron/Gamma ray Spectrometers (low altitude studies)
    - Interferometric studies
    - Gravity gradient measurement on the far side
    - Magnetic environment mapping

- **Radio Astronomy**
    - Low frequency Radio Telescopes

*Images: NASA, ESA archives*

# Team Expertise

**SANJAY**
CEO

**ABHAY**
CTO

**KRISHNA TEJA**
COO

**VISHAL**
MISSION SPECIALIST

**RAHUL**
LEAD - SMG

SPUTNIX
ams
CISCO
HYUNDAI
COM-SYS
Birla Institute of Technology & Science, Pilani
Massachusetts Institute of Technology
space master
Skoltech
Skolkovo Institute of Science and Technology
EMLYON business school
TU Delft
exseedspace

# Team Expertise

| DOMAIN | EXPERTISE |
| --- | --- |
| Structures and Mechanisms | Eminent scientists with 3 decades of experience in Computational Mechanics, Structural Dynamics.<br>Experts with multiple small satellite design and development experience |
| Communications | Experts with 3 decades of experience building ground stations, satellite communication modules at ISRO<br>Multiple RF experts who have worked on small satellite projects across the globe |
| On board computer (OBC) | Ex-ISRO expert with decades of experience in building OBCs for INSAT series of satellites<br>Hardware engineers with extensive experience in building ICs for commercial sensors |
| Electrical Power System (EPS) | Ex-ISRO Scientist with 2 decades of experience designing Power Systems for Spacecrafts |
| Electro Optical Systems | Distinguished Scientist from ISRO who has worked on development and qualification of star trackers, solid state fibre optic communications, interplanetary electro-optical payloads and high precision optical payloads for ISRO missions |
| Ground Segment | Outstanding scientist from ISRO who has worked on and managed communication systems including ground segments, antennas, RF and microwave systems for various Indian Space Programs<br>Has led multiple projects in developing space and ground communication systems |
| Networking and Protocols | Experts with years of experience working on setting up ground based networks with various protocols |

*Image not drawn to scale*

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Vienna, Austria

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