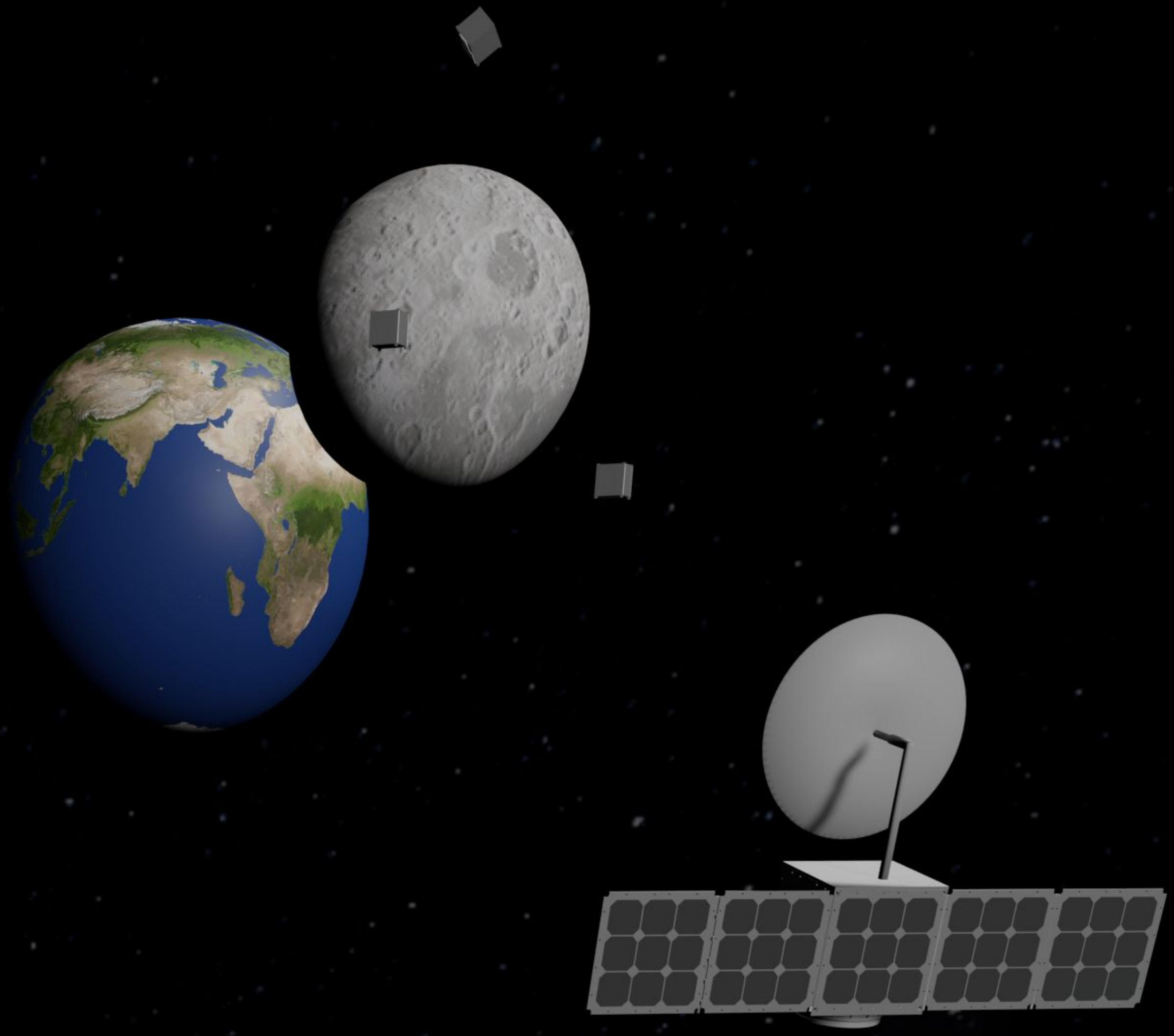

Lunar Far Side Tracking and Communication Relay System

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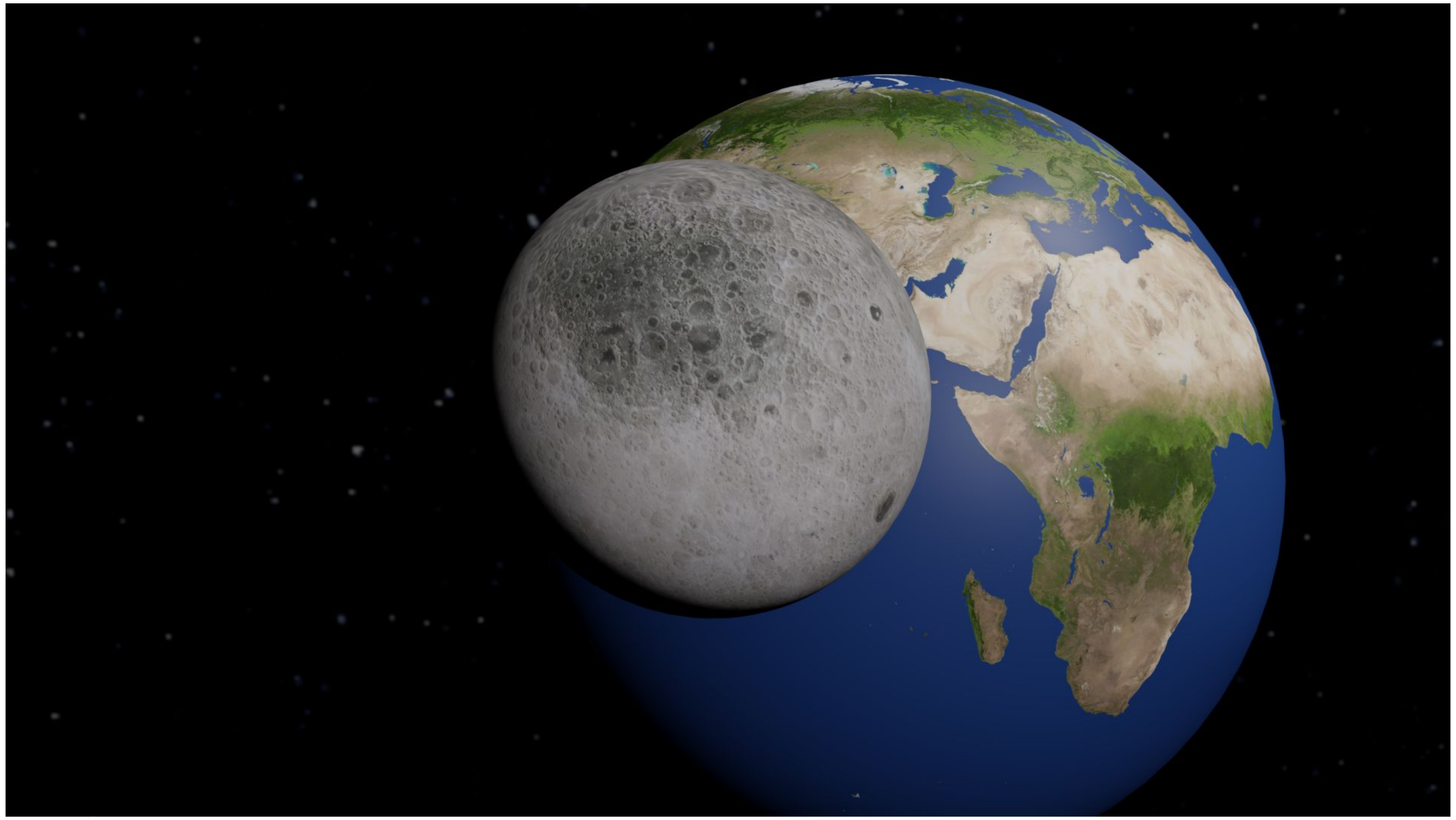
DHRUVA SPACE

Mission Objective

Need:

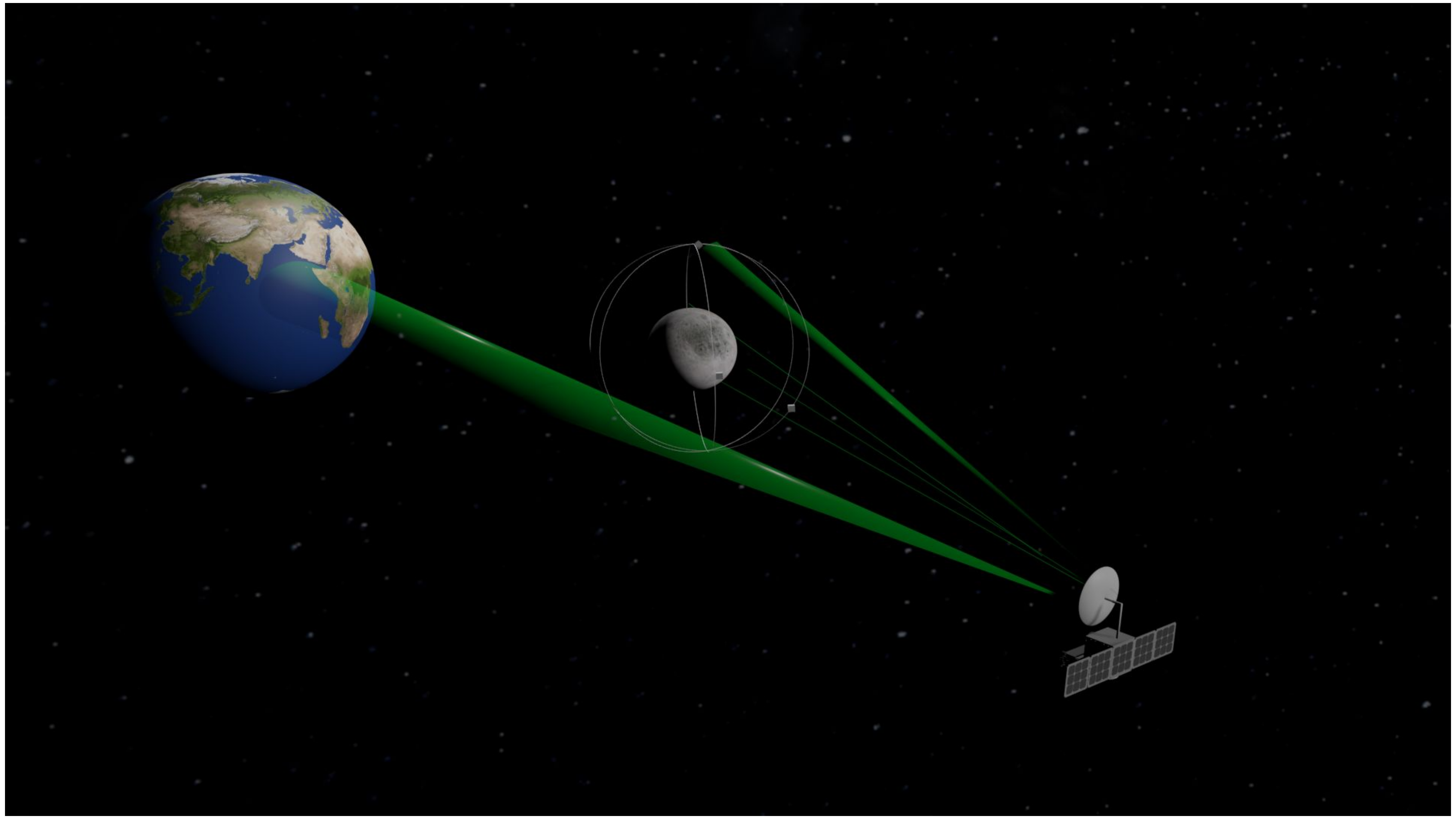
- Lunar Far side is inaccessible for Earth Based Ground Stations
- Space-based Communication relay system to transmit and receive data from systems (Landers, Rovers etc.) on the Lunar Far Side



Mission Objective

Solution:

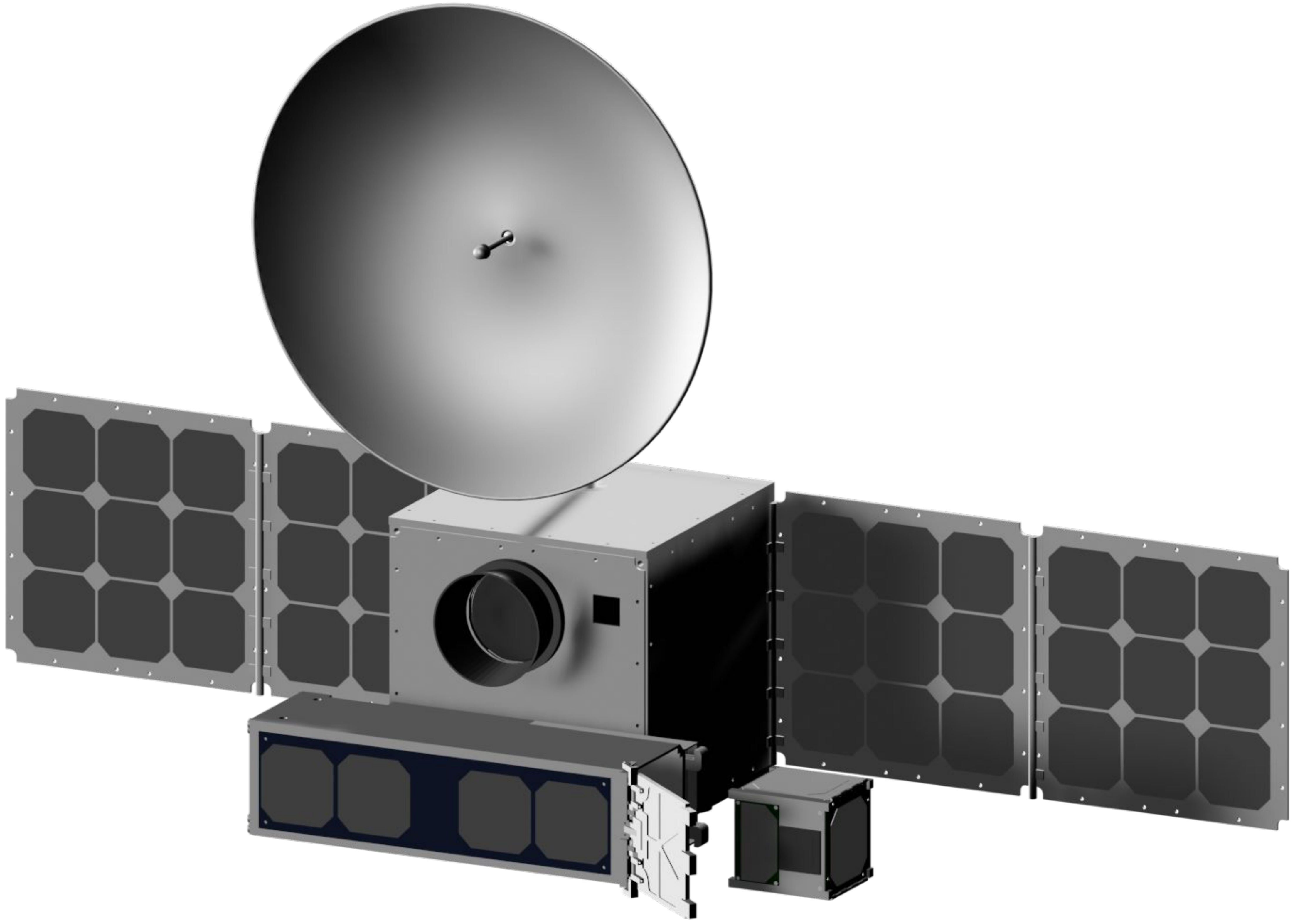
- Data relay spacecraft placed in the Earth-Moon L2 Lagrangian point along with spacecrafts in Lunar Orbits provides a near real-time communication access to the Lunar Far Side



Mission Profile

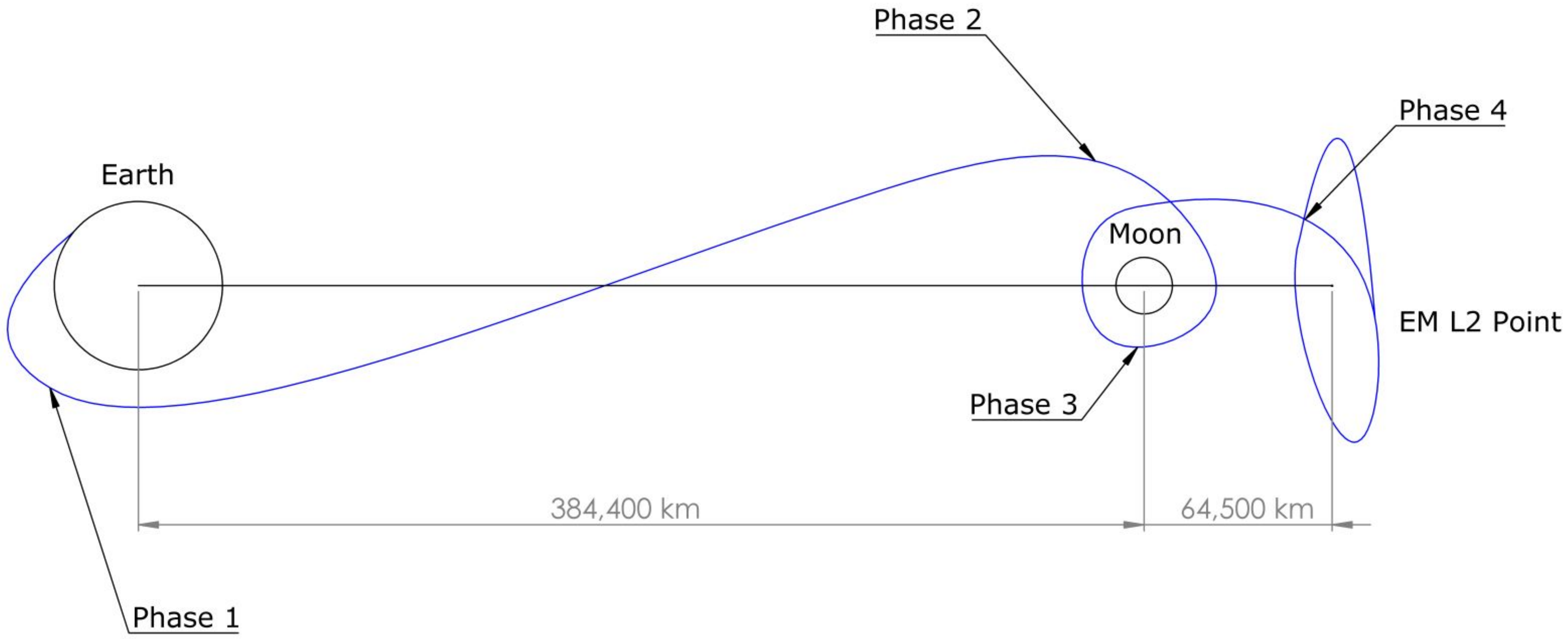
- **P30 - Parent Satellite**
  - serves as the primary spacecraft with IR imaging payload
  - stationed in L2 Halo Orbit
  - Deploy 1Us in Lunar Orbit

- **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	Phase 2	Phase 3	Phase 4
Launch	Lunar Orbit Insertion	1U CubeSat Ejection	Halo Orbit Insertion



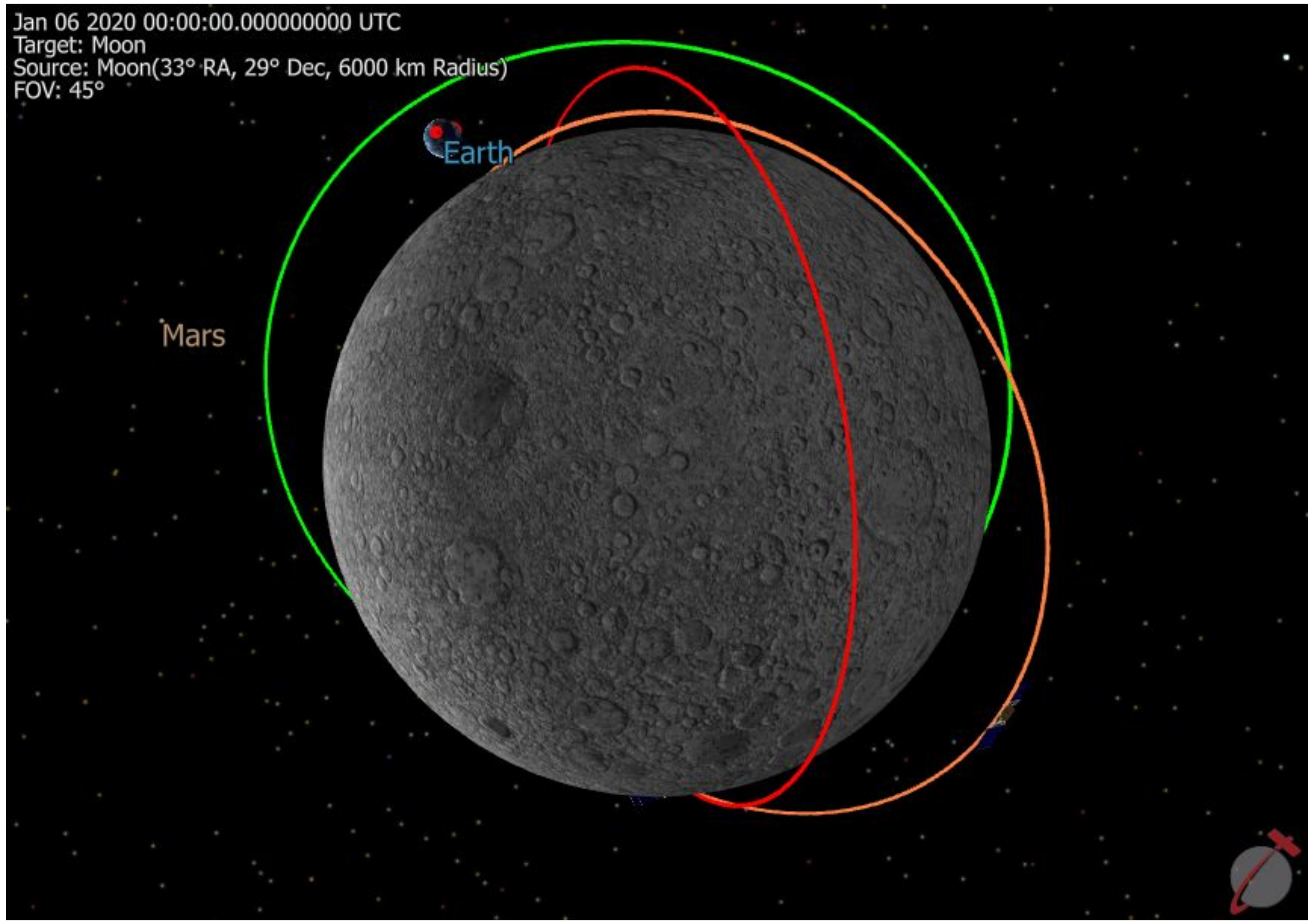
Orbit Phase	Delta-V Requirement
Lunar Orbit (40° inclined orbit) to L2 insertion	776 m/s
Stationkeeping in L2	132 m/s per year

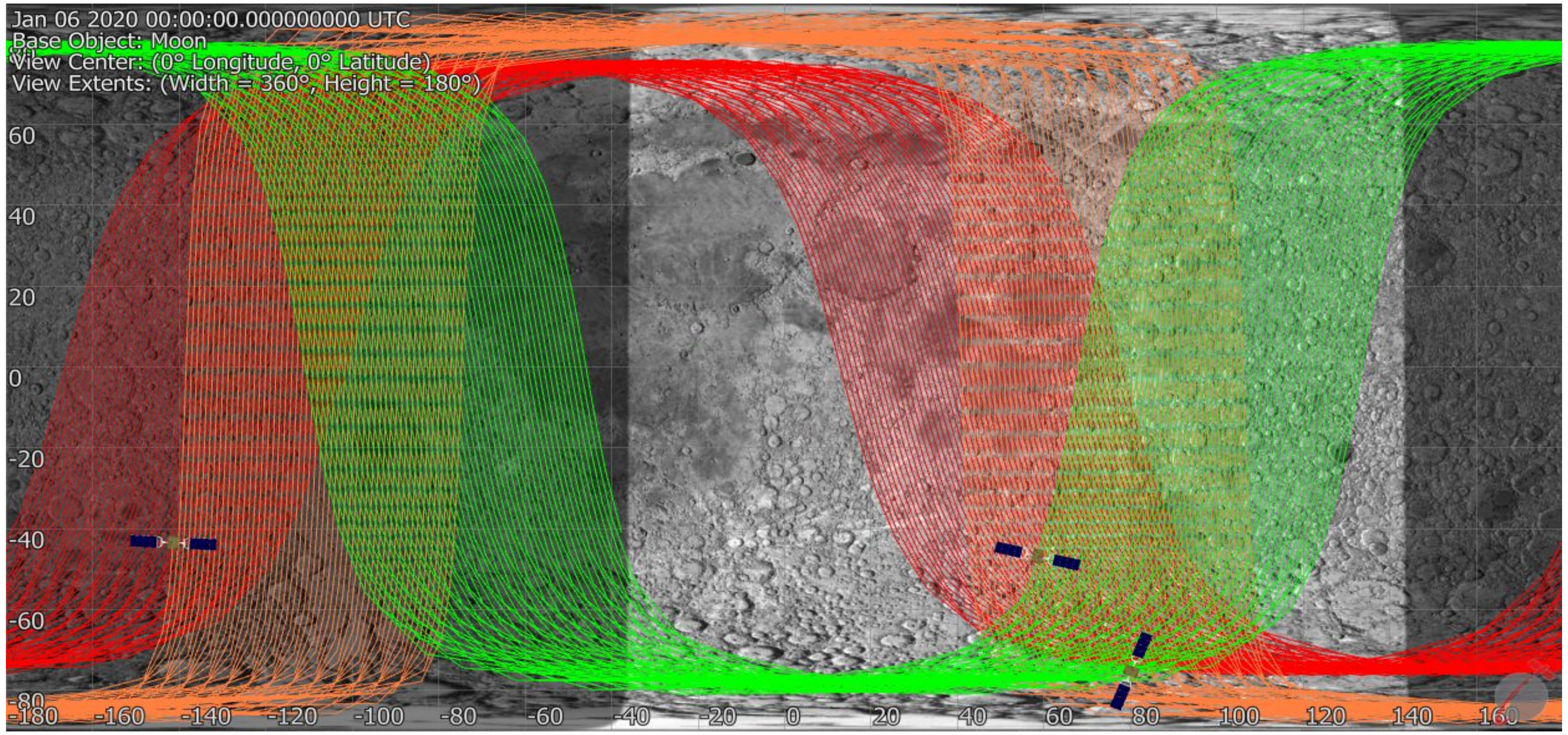
NASA:GSFC Technical Note TN-D-6365: The utilization of halo orbits in advanced lunar operations

Orbit - 1U constellation

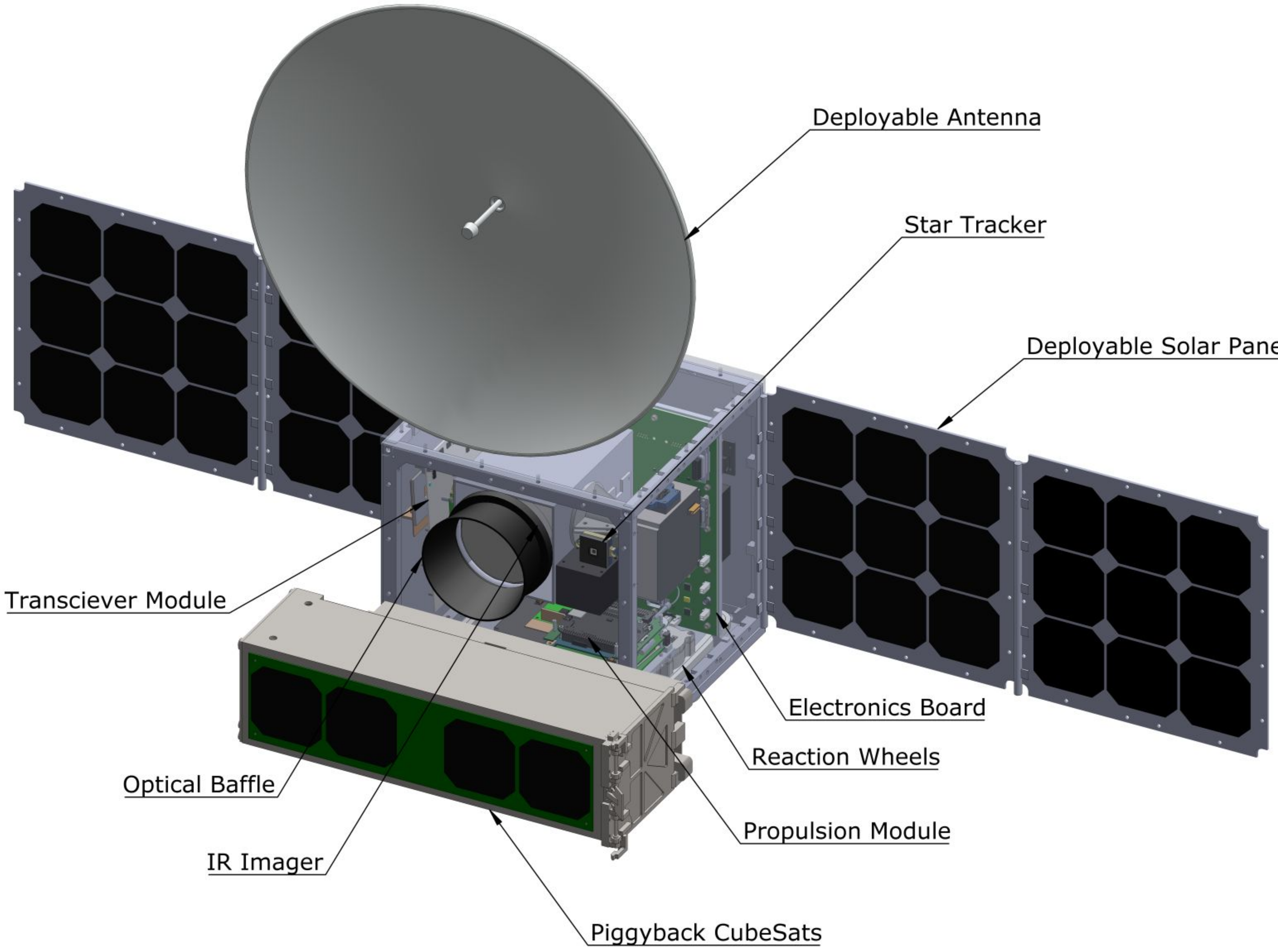
- CubeSat Constellation: 3x 1U Satellites
- Lunar Orbital parameters

  a = 2000km | i = 86 deg | RAAN: 60, 90, 120 deg
- The inclination is chosen based on stability of orbit and maximum coverage





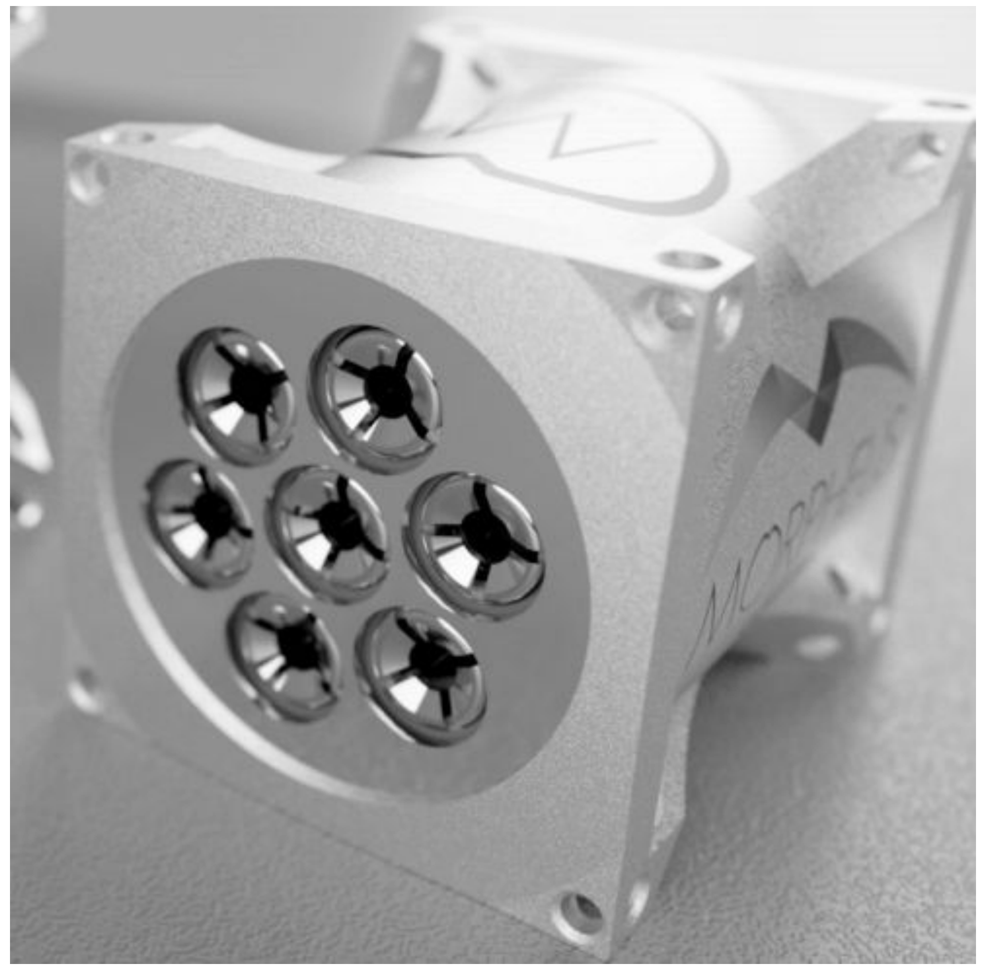
P30 Internal Configuration



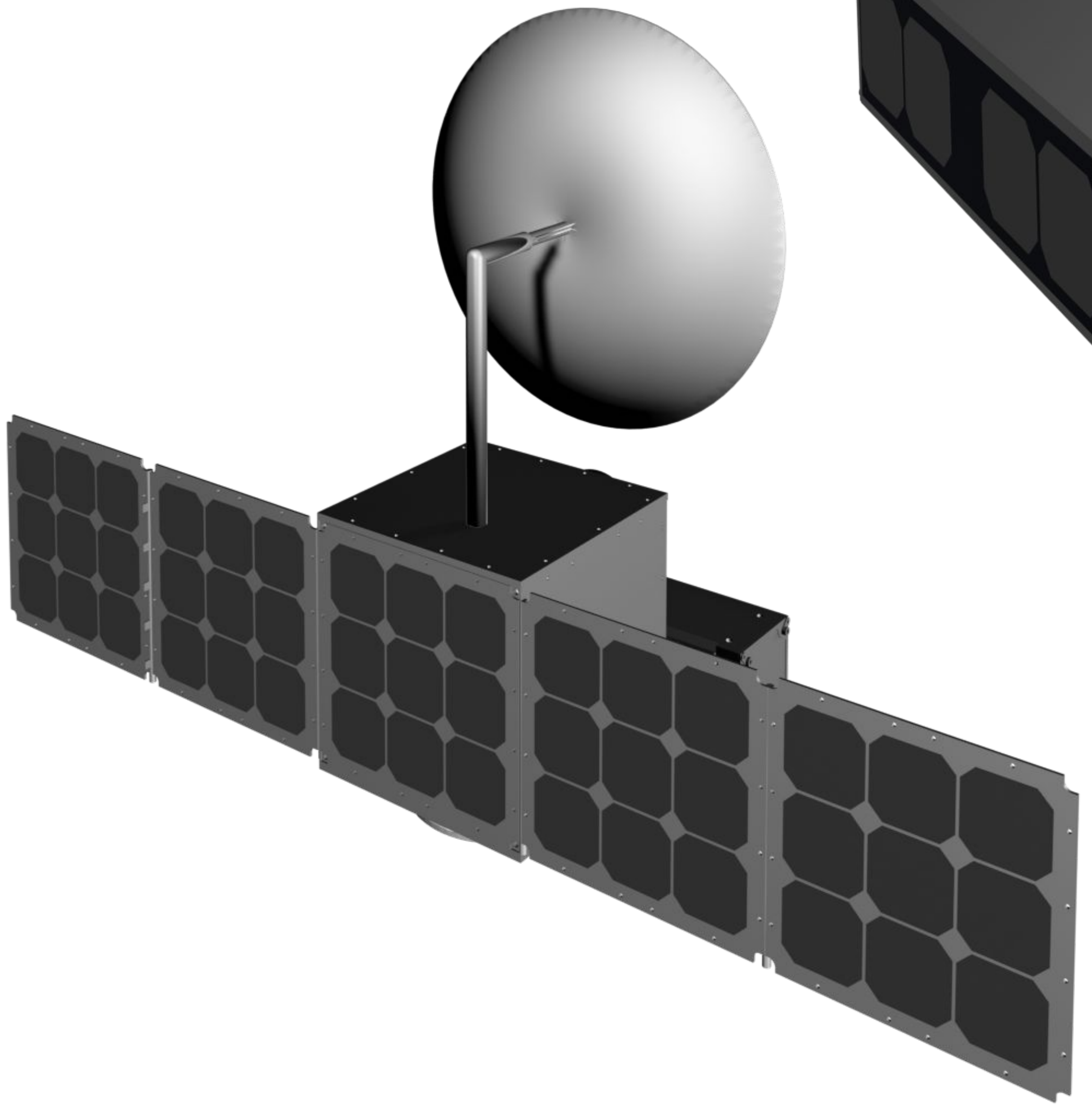
P30 Platform - Parent

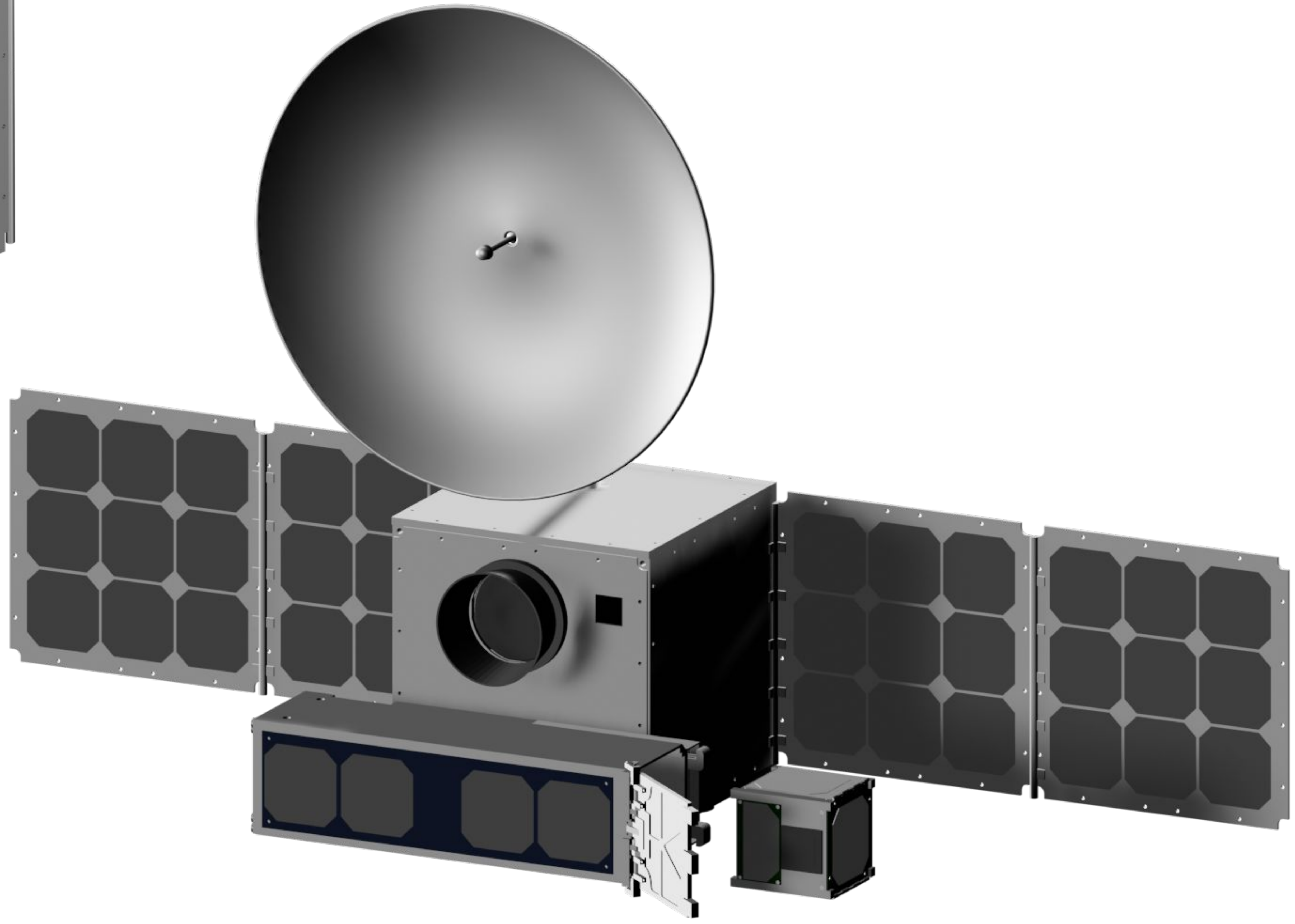
SUBSYSTEM	DESCRIPTION
BUS	Clustered Small satellite Platform: In-house Scalable and modular
Electrical Power System	Deployable Solar Panels: up to 90W of power production
Command and Data Handling	FPGA based OBC S- / X- / Ka- band with deployable antennas Data rates 10 - 100 Mbps Tethers Unlimited / Syrlinks / Canopus: compatible with NASA Ground Networks
Attitude Control	Integrated 3-axis stabilization - CubeSpace 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

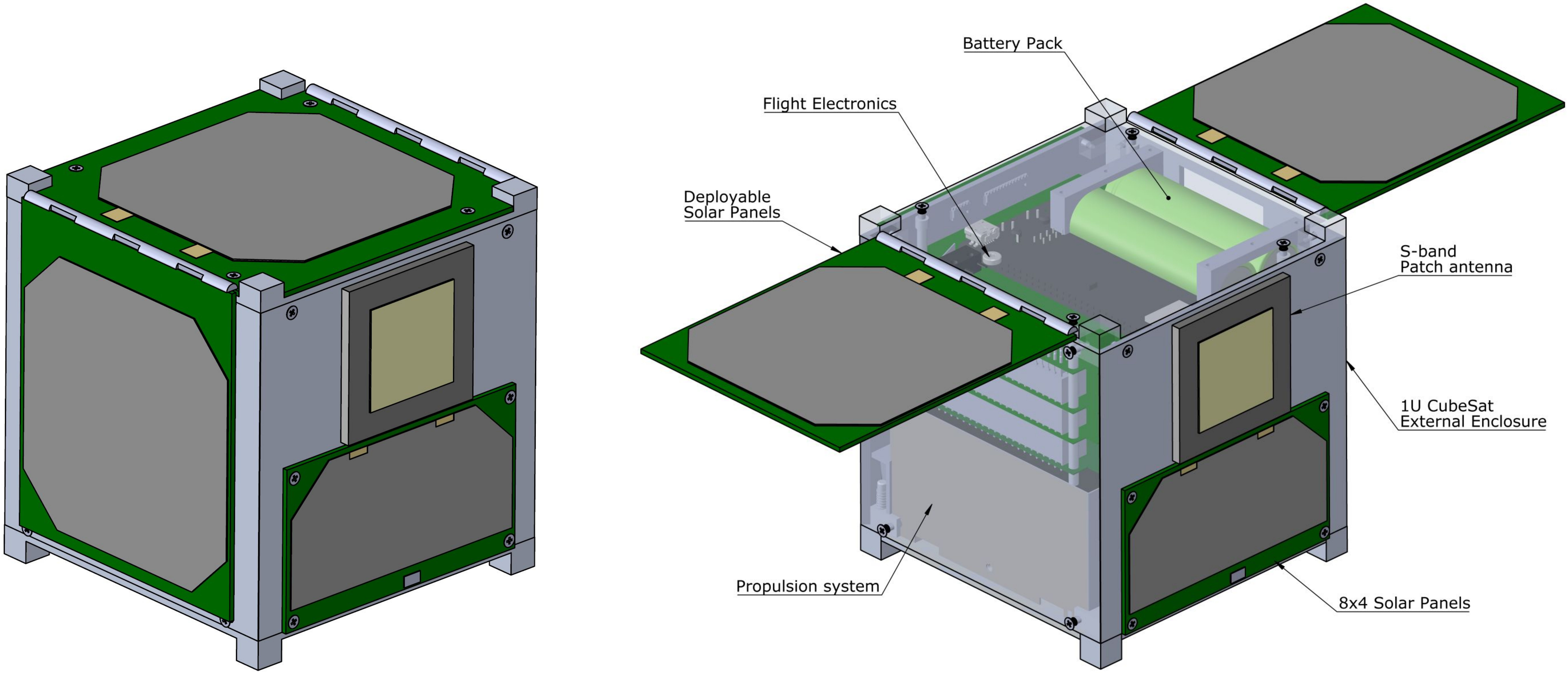


P30 Platform - Parent



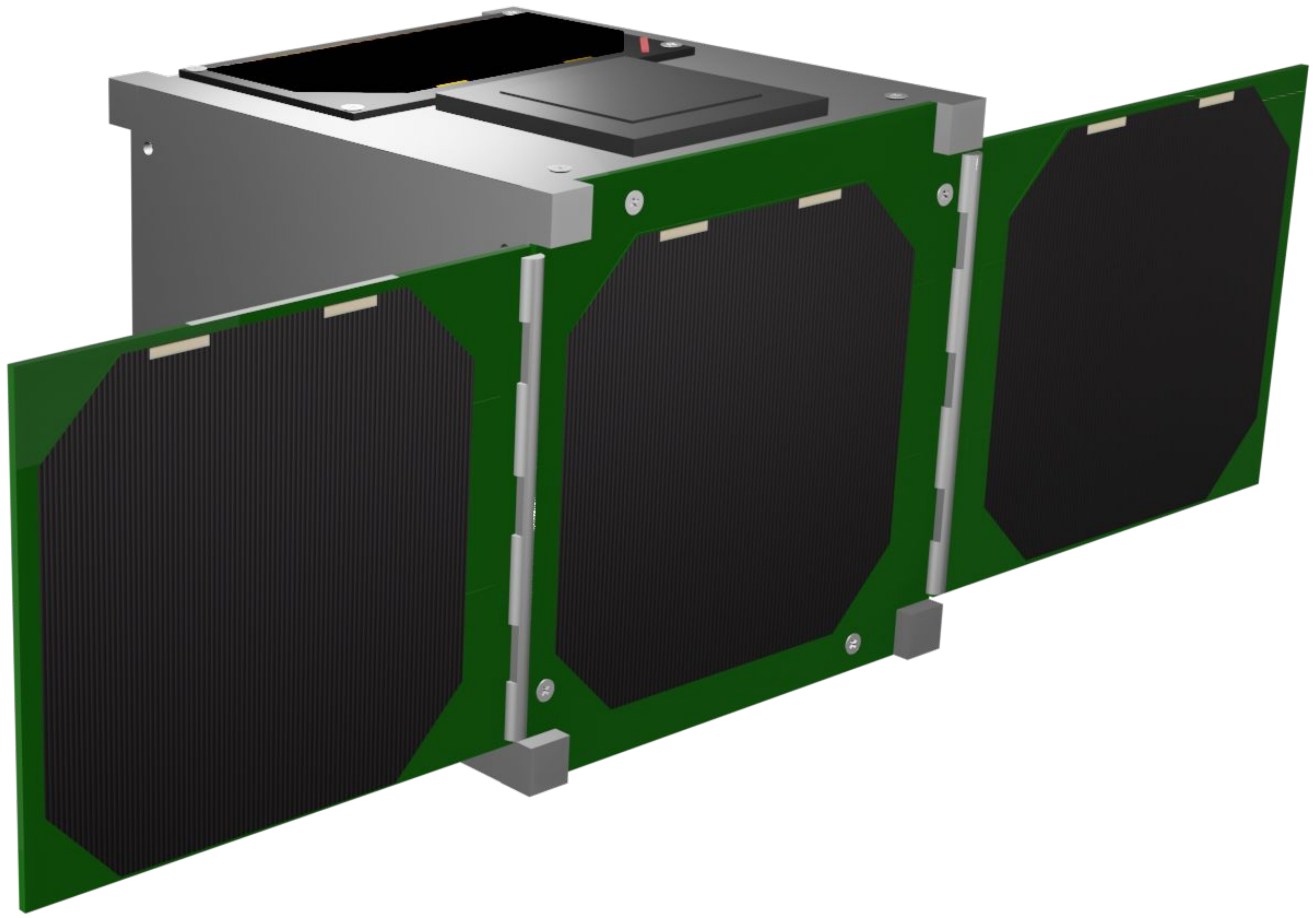


1U Internal Configuration



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 Data rates 10 Mbps
Attitude Control	Integrated 3-axis stabilization - CubeSpace Star trackers, Gyroscopes, Reaction wheels
Orbit Control	Low power Field emission electric propulsion: Morpheus Space
Thermal Control	Multi Layer Insulation using carbon nanotubes sheets, along with silicon-based thermal transfer substrate*

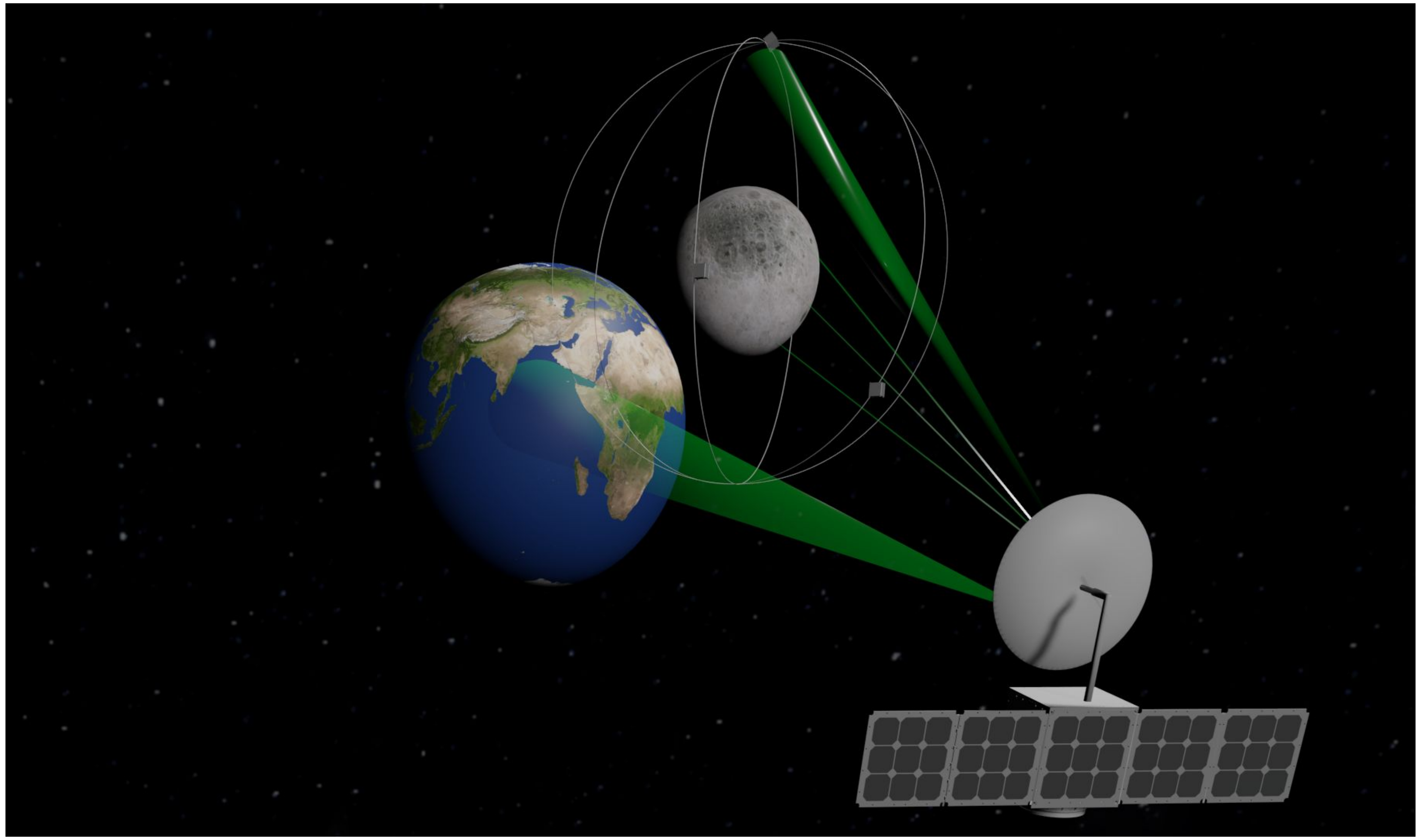


** Ronnie Nader: Carbon Nanotubes Based Thermal Distribution And Transfer Bus System For 1U Cubesats And The Space Environment Attenuation Manifold Shield*

Communication Architecture

Ground Station: Existing infrastructure

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



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

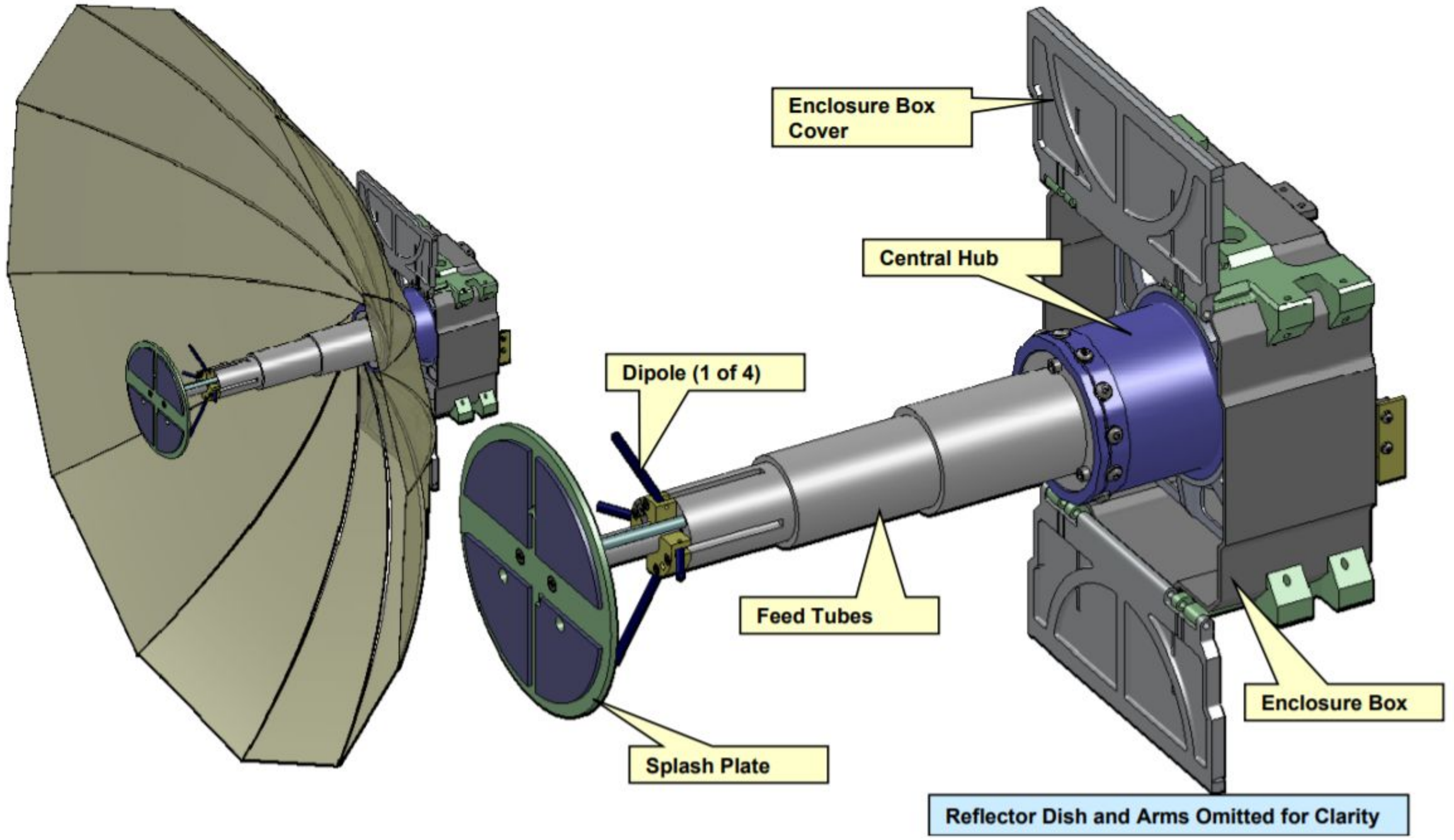
Communication Architecture

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

Source: *https://www.tethers.com/praesent-fringilla-eleifend-dui-sit-amet/*



Source: *BDS Phantom Works: Miniature Deployable High Gain Antenna for CubeSats (April 2011)*

Link studies

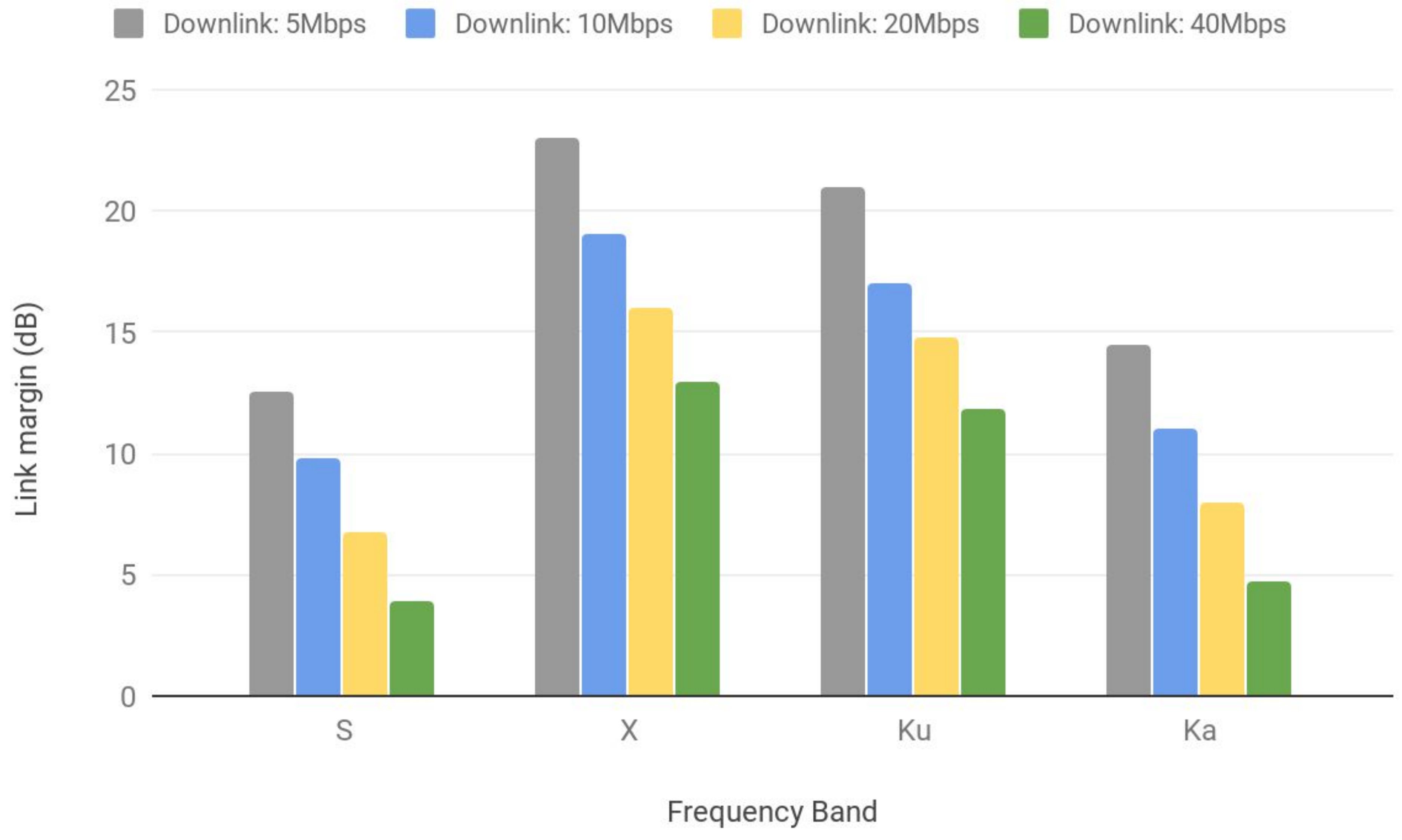
Link Study Model

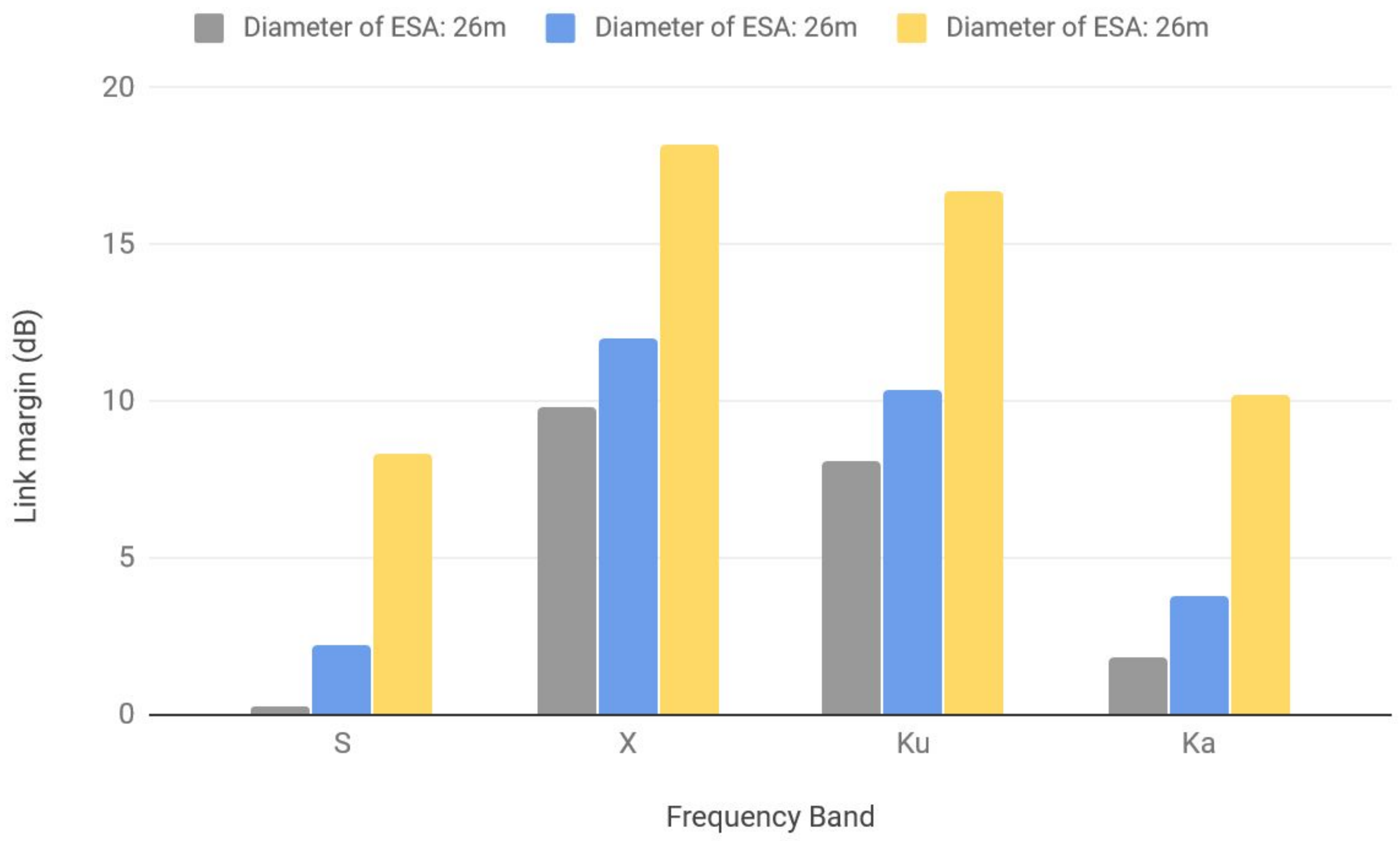
- Telemetry Operation: an uncoded OQPSK signal
- Loss model
  - Free Space, Atmospheric, Rain and Ionospheric losses
  - Circuit and pointing losses
  - Lunar Flux Density Loss
- 34m ground antenna and 1.2m Lunar Orbiter antennas was considered

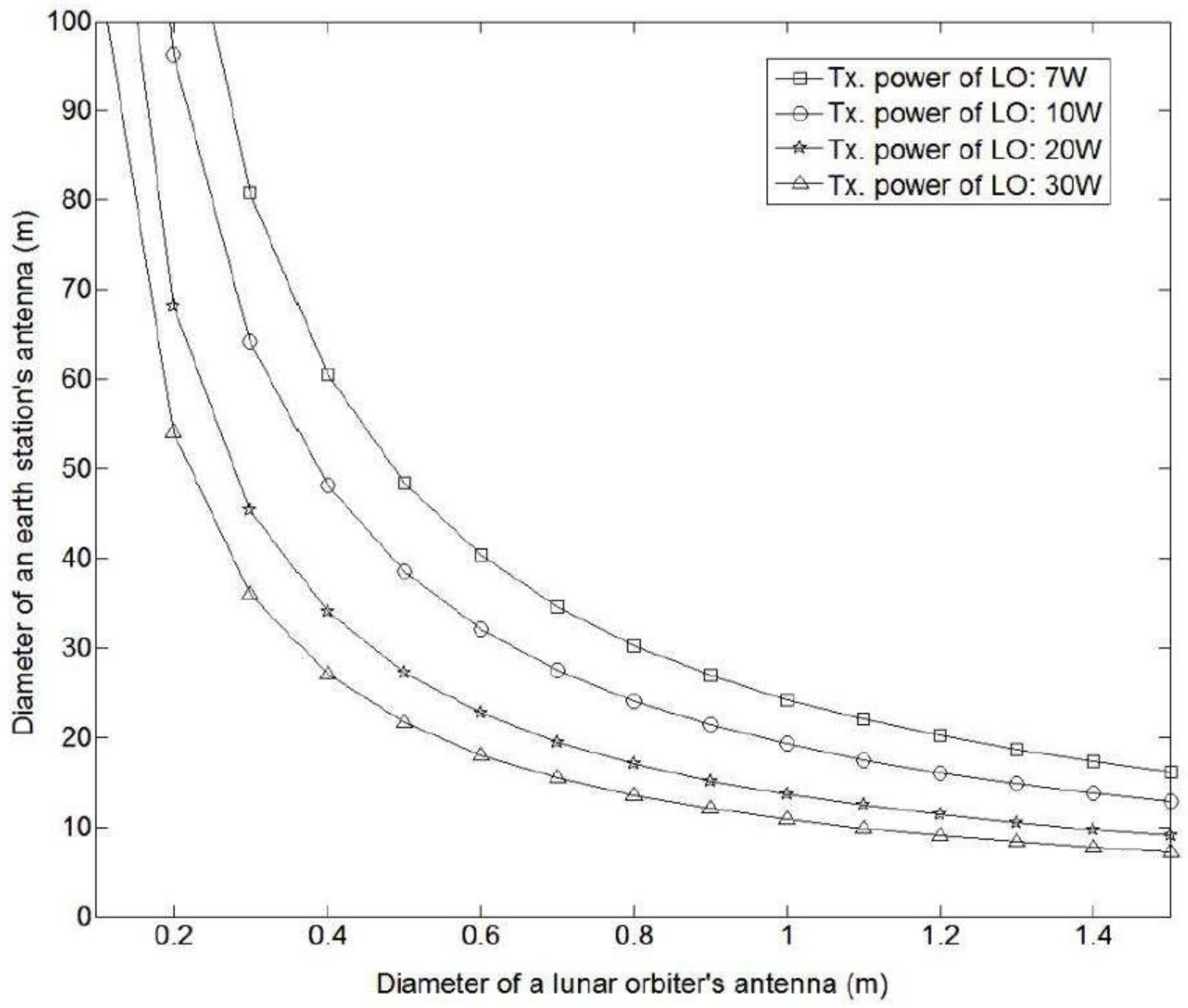
Classification	Unit	S Band	X Band	Ku Band	Ka Band
System Bandwidth	MHz	26	26	26	26
Distance	km	384,403	384,403	384,403	384,403
Transmit Frequency	MHz	2,295	8,420	12,220	32,000
Lunar Orbiter					
Transmit Power	W	20.0	20.0	20.0	20.0
	dBW	13.0	13.0	13.0	13.0
Antenna Diameter	M	1.2	1.2	1.2	1.2
Antenna Efficiency		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	0.3
Antenna pointing loss	dB	3.2 E-6	4.4 E-5	9.3 E-5	6.4 E-5
Channel					
Free space loss	dB	211.0	222.0	225.9	234.2
Atmospheric attenuation	dB	0.0	0.0	0.1	0.2
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	5.3	5.4	5.0	4.0
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	0.3
Antenna pointing loss	dB	0.0	0.0	0.2	0.6
Noise Temperature	K	34.0	31.9	38.0	44.9

Lee et al (2010): Design of Space Communication Systems for Lunar Exploration

Link studies







- Channel encoding can be implemented
- Adaptive modulation techniques / Spread Spectrum capabilities can be used
  - Power and bandwidth efficient signal techniques

Lee et al (2010): Design of Space Communication Systems for Lunar Exploration

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 Payload Downlink	Accommodate S- / X- / Ka- band transmitter with deployable / patch antennas Compatible with NEN, SN, DSN	Accommodate S- band transmitter with patch antennas 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	

Team Expertise

SANJAY
CEO

ABHAY
CTO

KRISHNA TEJA
COO

VISHAL
MISSION SPECIALIST

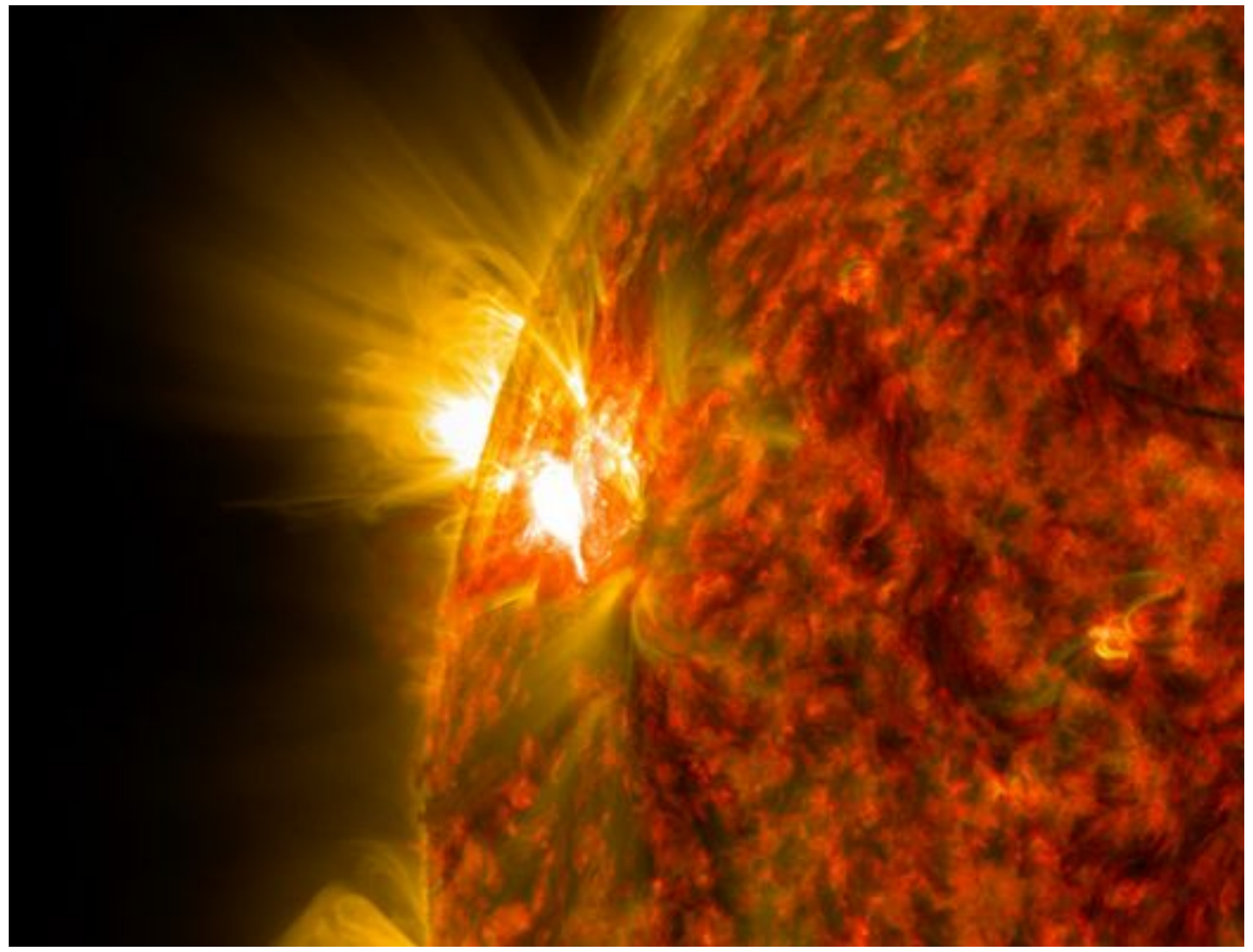
RAHUL
LEAD - SMG

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. Experts with multiple small satellite design and development experience
Communications	Experts with 3 decades of experience building ground stations, satellite communication modules at ISRO 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 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 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

Science Opportunities



Solar weather

Lunar environment

Radio Astronomy

Images: NASA, ESA archives

Image not drawn to scale

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Dhruva Space GmbH
Vienna, Austria

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