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Lunar Orbit CubeSat Injector - LOCI

Mission Idea Contest IV

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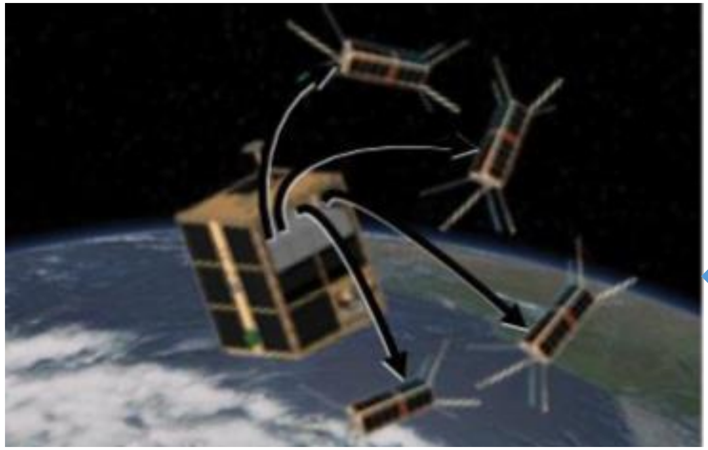
LOCI – *the Idea*

- It is a **great challenge to independently get CubeSats to the Moon** on their own.
- LOCI aims at **injecting four 2U CubeSats in Moon's orbit** to overcome inherent propulsion drawbacks.
- **Provide considerable shielding** from prolonged radiation exposure.
- Deployment of ***<u>multiple</u>*** CubeSats for ***<u>multiple</u>*** tasks beyond LEO.
- Performance matching of CubeSats to larger satellites at lower cost and shorter development time.
- **Formation flying** will increase the potential functionality of CubeSats.

Introduction

- CubeSats limited partly by inability to maneuver themselves.
- Risk mitigation against Launch vehicle and Primary payload.
- ISRO, ISC. Kosmotras & Eurockot, SpaceX and JAMSS offer CubeSat launches however huge backlog still exists.



As Primary Payload deployment – Nanosail-D2, Space Launch System Exploration Mission-1 & MarCO A & B

ILS and Sea Launch do not launch CubeSats

Image sources: dynetics.com, sea-launch.com & ilslaunch.com

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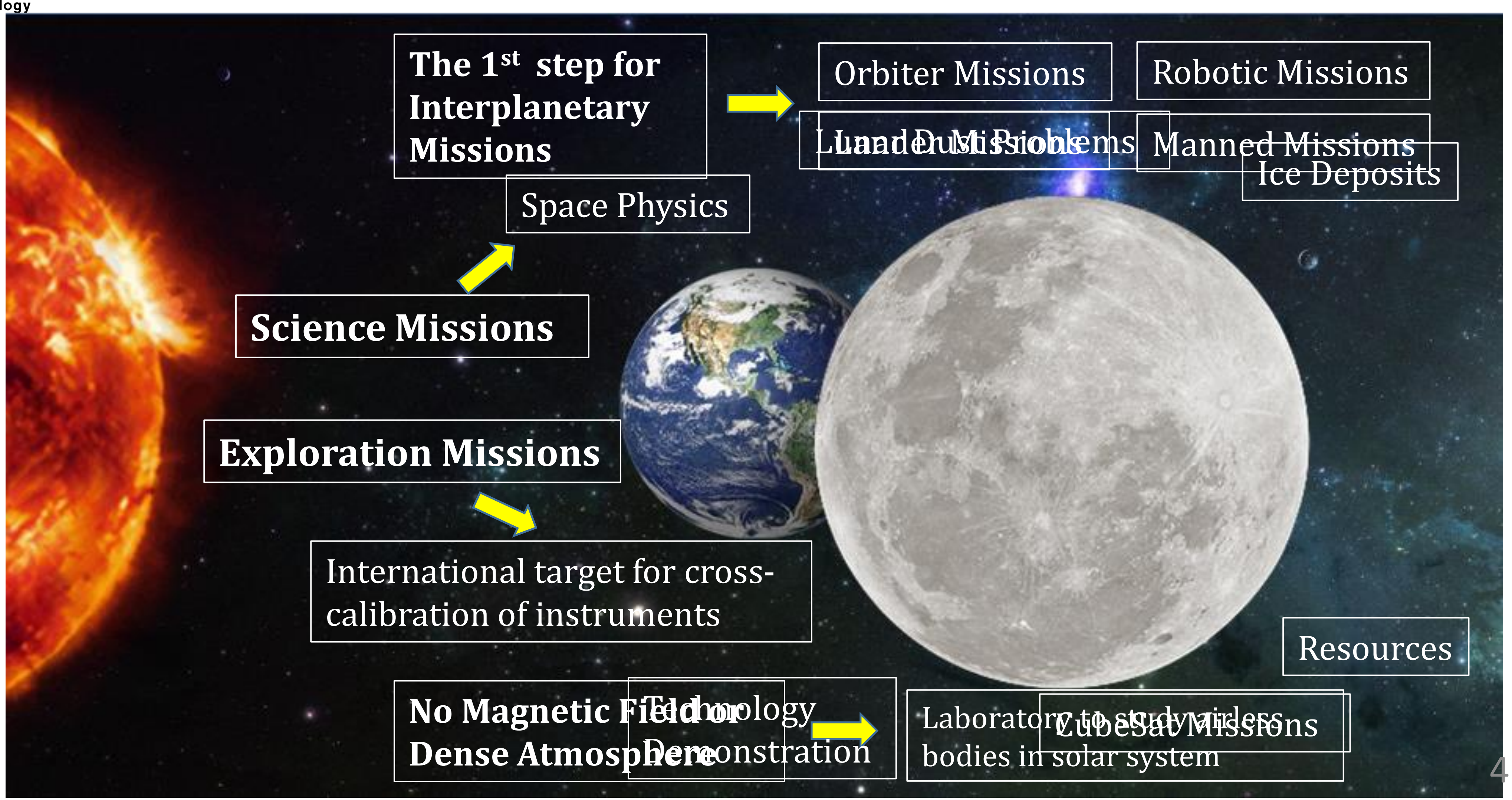
Why is the Moon our target?



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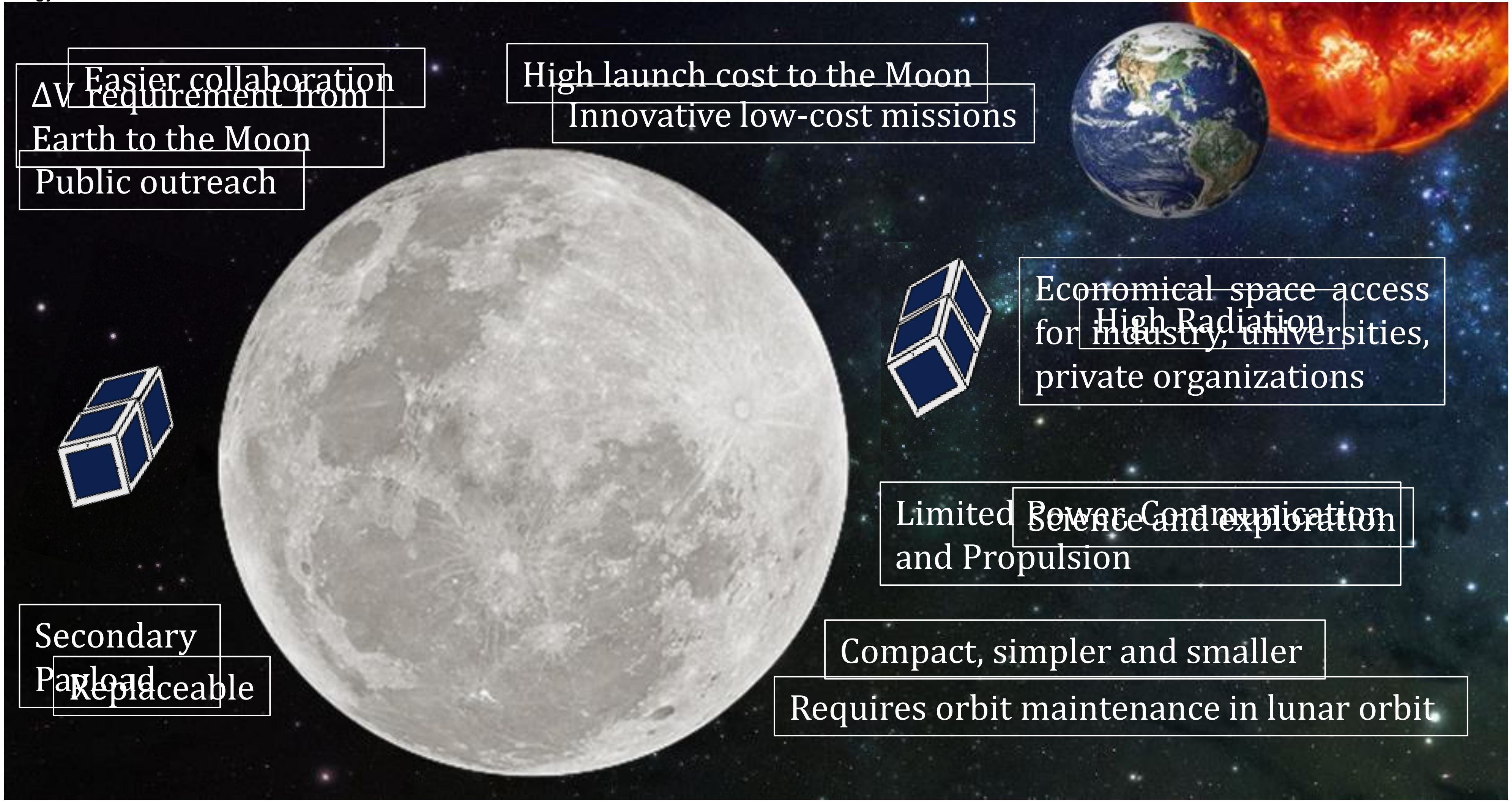
Why CubeSats for Deep Space?

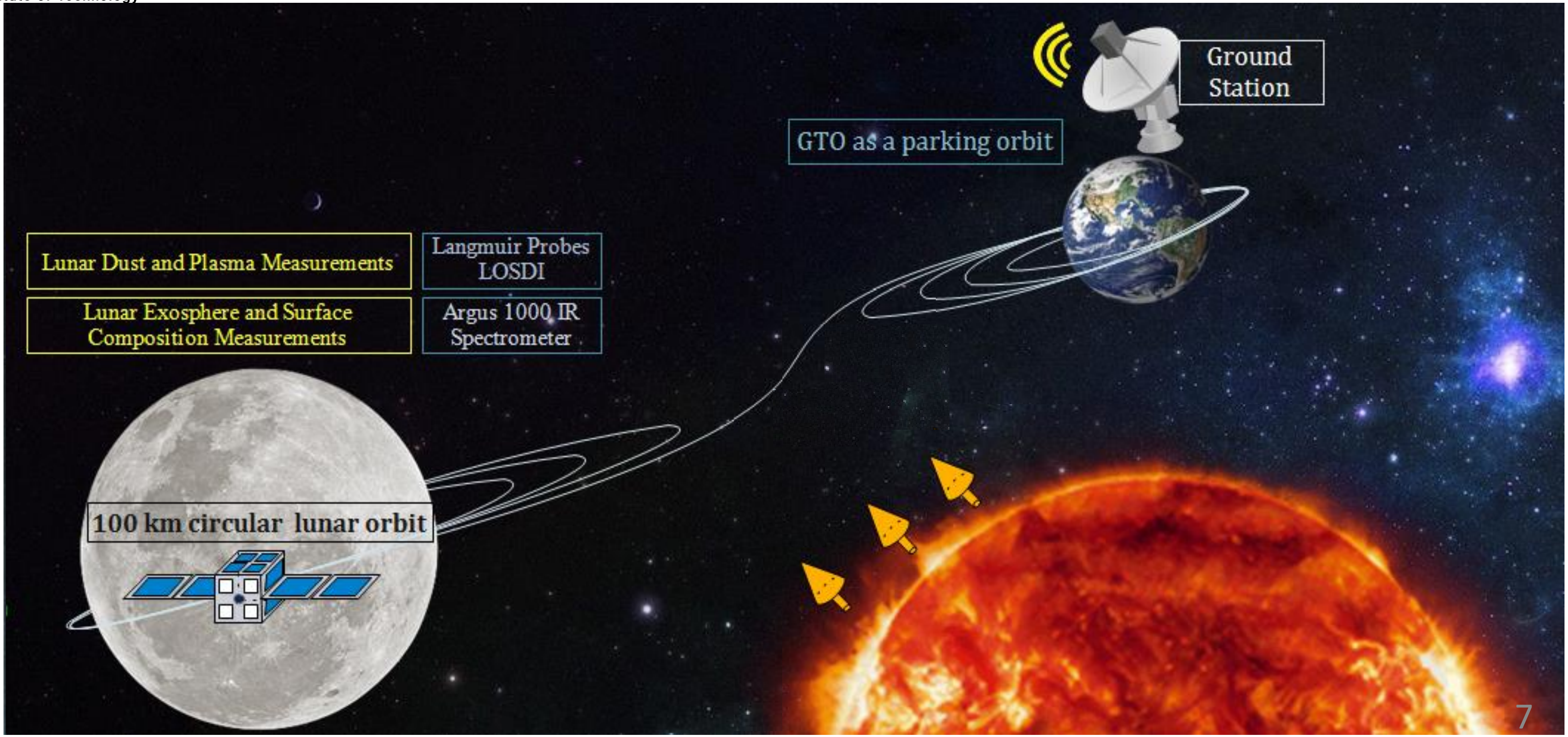
CubeSats Limitations for Deep Space



Mission Objectives

- To **deploy 3rd party four 2U-Cubesats** into different orbits whose orbital ephemeris will be compatible with the Nanosatellite lunar orbit insertion strategy.
- To develop a satellite structure that **ensures functional integrity of four 2U-Cubesats**.
- To **perform measurements** of plasma density, temperature potential around lunar orbit, & density variation of submicron dust grains.
- To **encourage collaboration** with international organizations for the achievement of mission objectives towards lunar mission

Concept of Operation

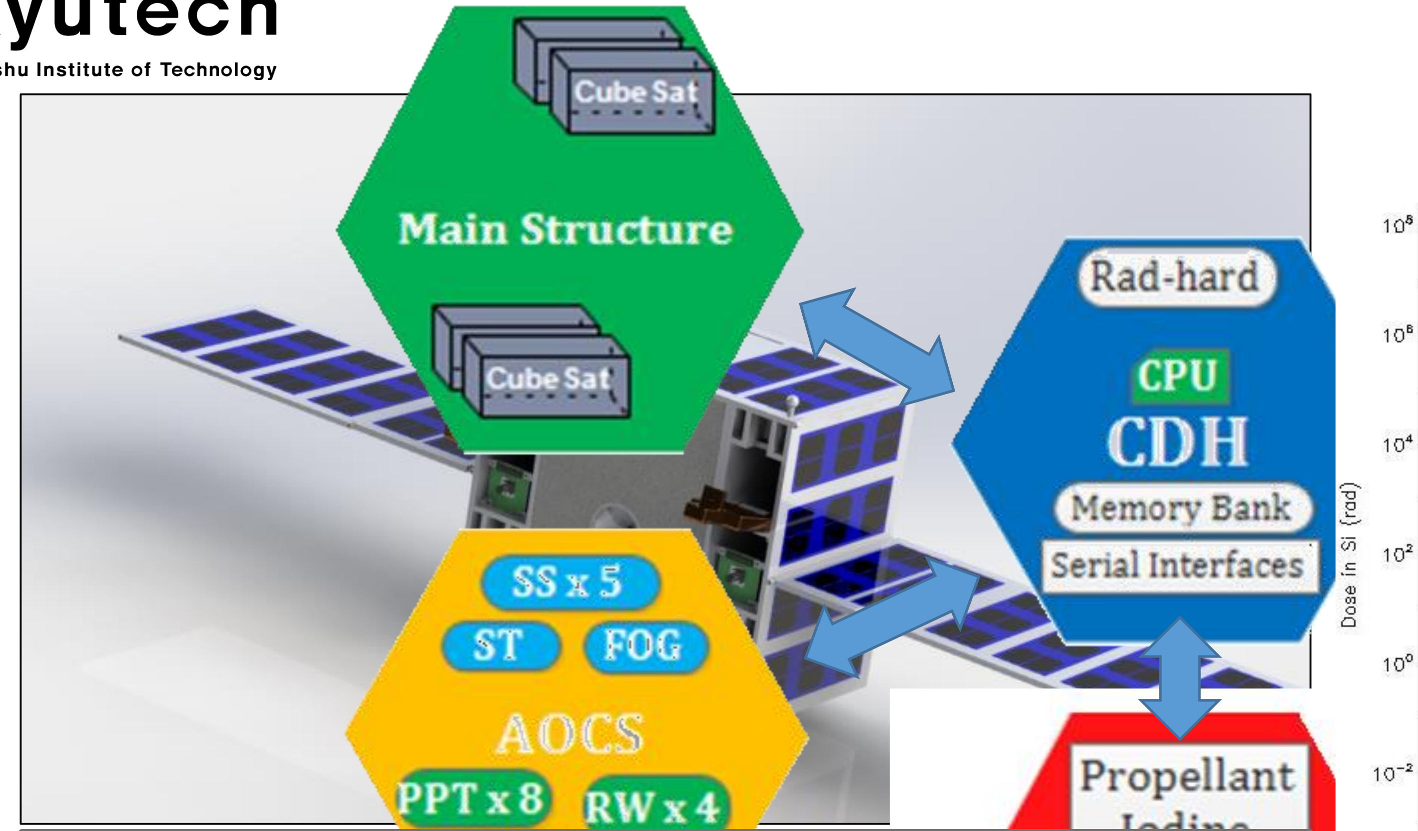


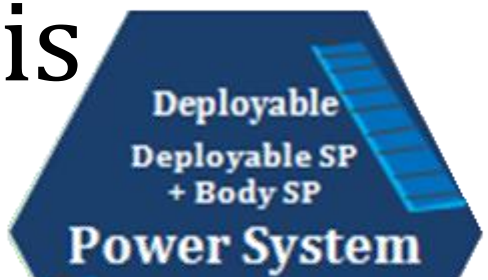
Key Performance Parameters

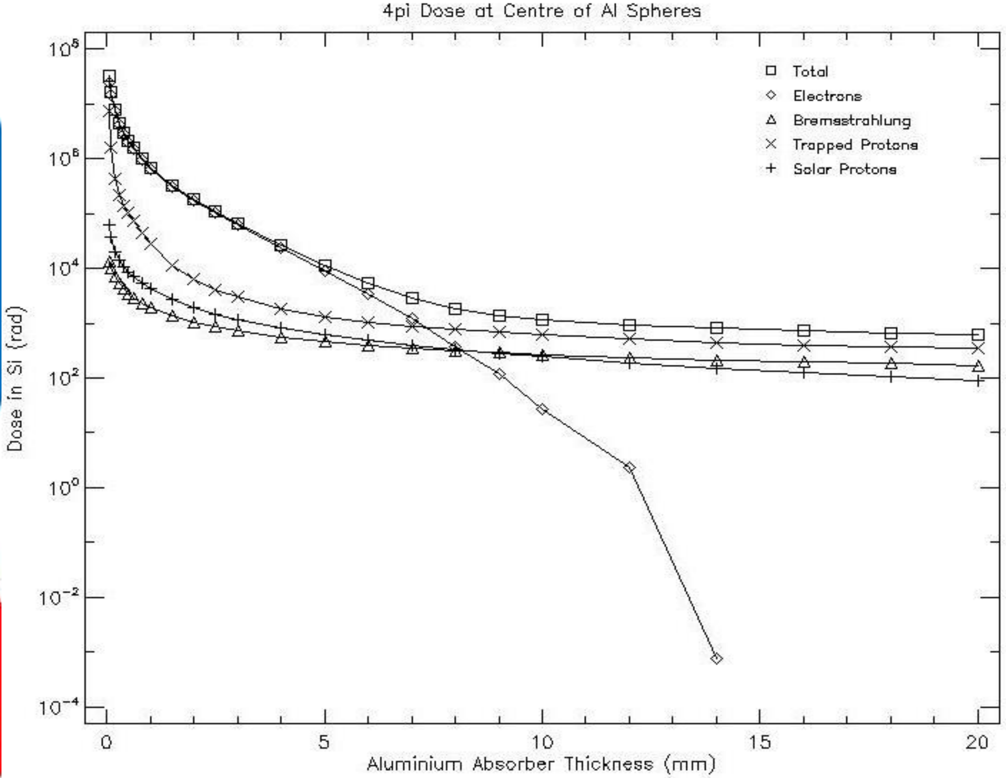
- **Successful deployment of four 2U CubeSat** into their requested orbit with a position accuracy of 10m.
- The **measurement of solar wind & magnetospheric plasma** properties with Langmuir probe & 3-axis magnetic field (< 2 nT).
- The **measurements of submicron dust grains** (<1 μm) will be performed by a Lunar Optical Scattering Dust Instrument.
- Adaptive exposure capability to **analyze lunar exosphere and surface composition** with approximately 6nm spectral resolution.

Radiation Analysis

Satellite Bus





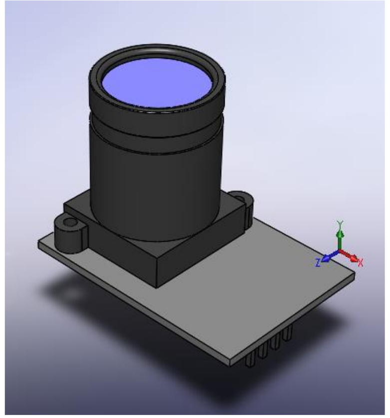


Shielding Material: Aluminum alloy 7075-T6
Shield Thickness: 1 cm (Radiation analysis SPENVIS)
Launch Adapter: Compatible with Arianne Rocket
Size: 60 cm x 60 cm x 34 cm (LxHxW)
Total Mass: 43 kg (35 kg of LOCI + 8 kg from CubeSats)

Secondary Mission – *Payload Operations*

Operation	Outcome	Exploration	Science
1. CubeSat Separation and Lunar Approach Imaging	Visual evidence of the mission success	✓	
2. Lunar Dust and Plasma Measurements	The relation of upstream plasma flow and high altitudes dust variation	✓	✓
3. Lunar Exosphere and Surface Composition Measurements	The composition of lunar surface and exospheric dust	✓	✓

1



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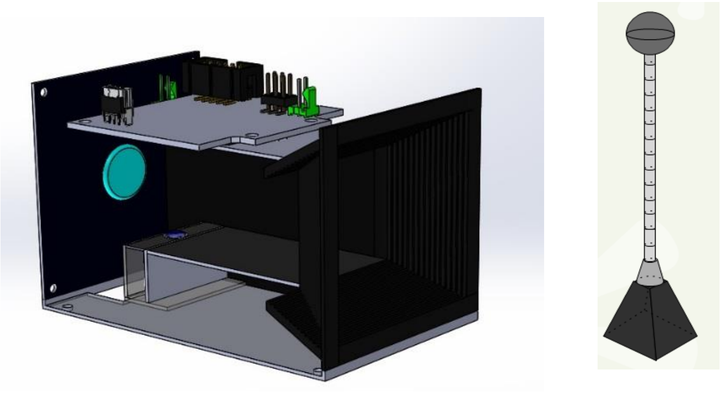

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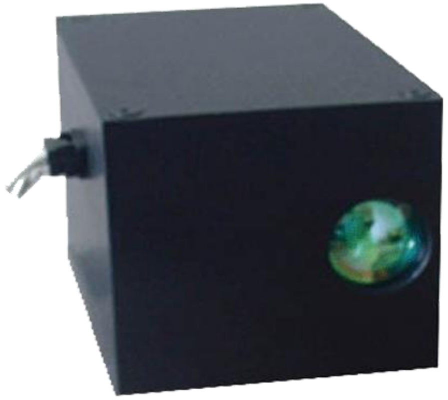
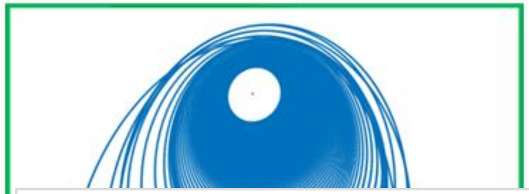


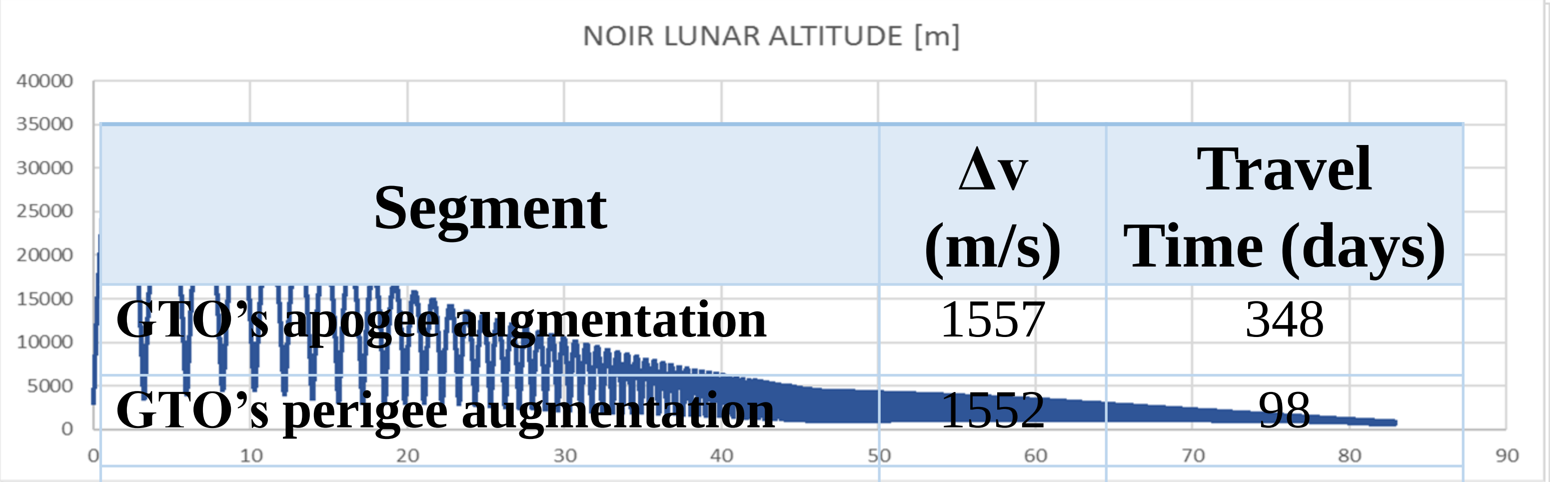
https://www.cubesatshop.com/product/argus-1000-infrared-spectrometer/

Orbit Transfers

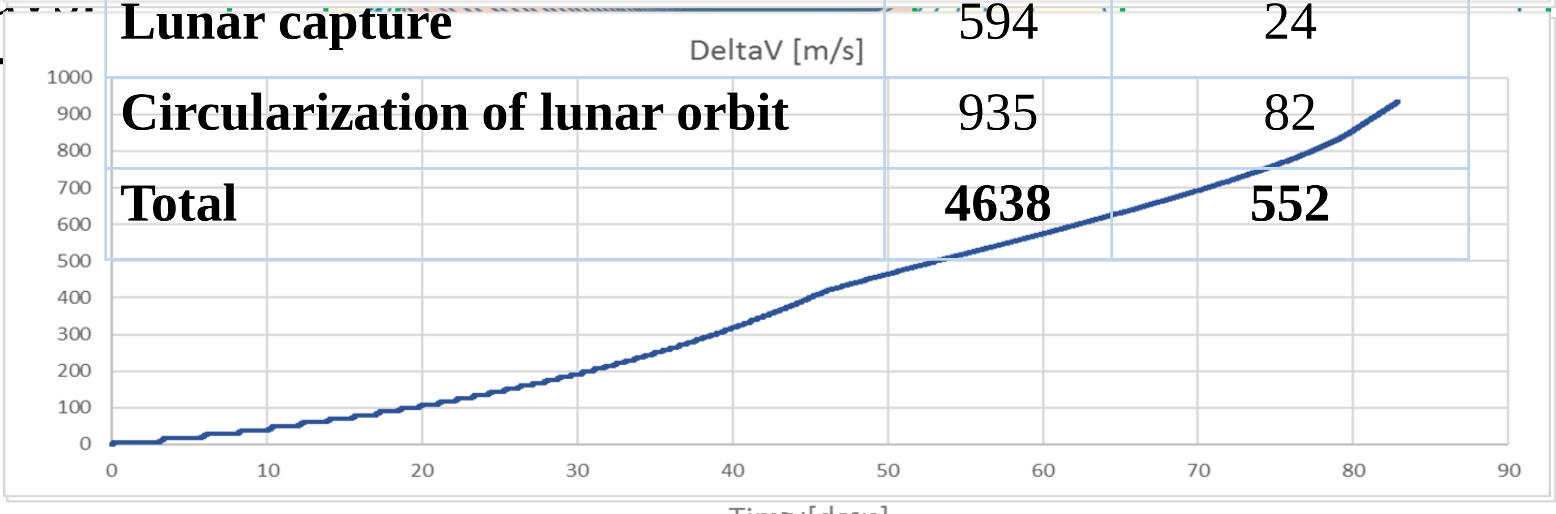
1. Thrust firing at perigee GTO – raise apogee.
2. Thrust firing at apogee. Lunar capture expected at 310,000 km and 90,000km relative to Earth and Moon.
3. Thruster burns stabilizes the Lunar orbit.
4. Circularize and decrease orbit to 100 km altitude.

- Initial injection or
- Escape Van-Allen b
- Travel time 552 da



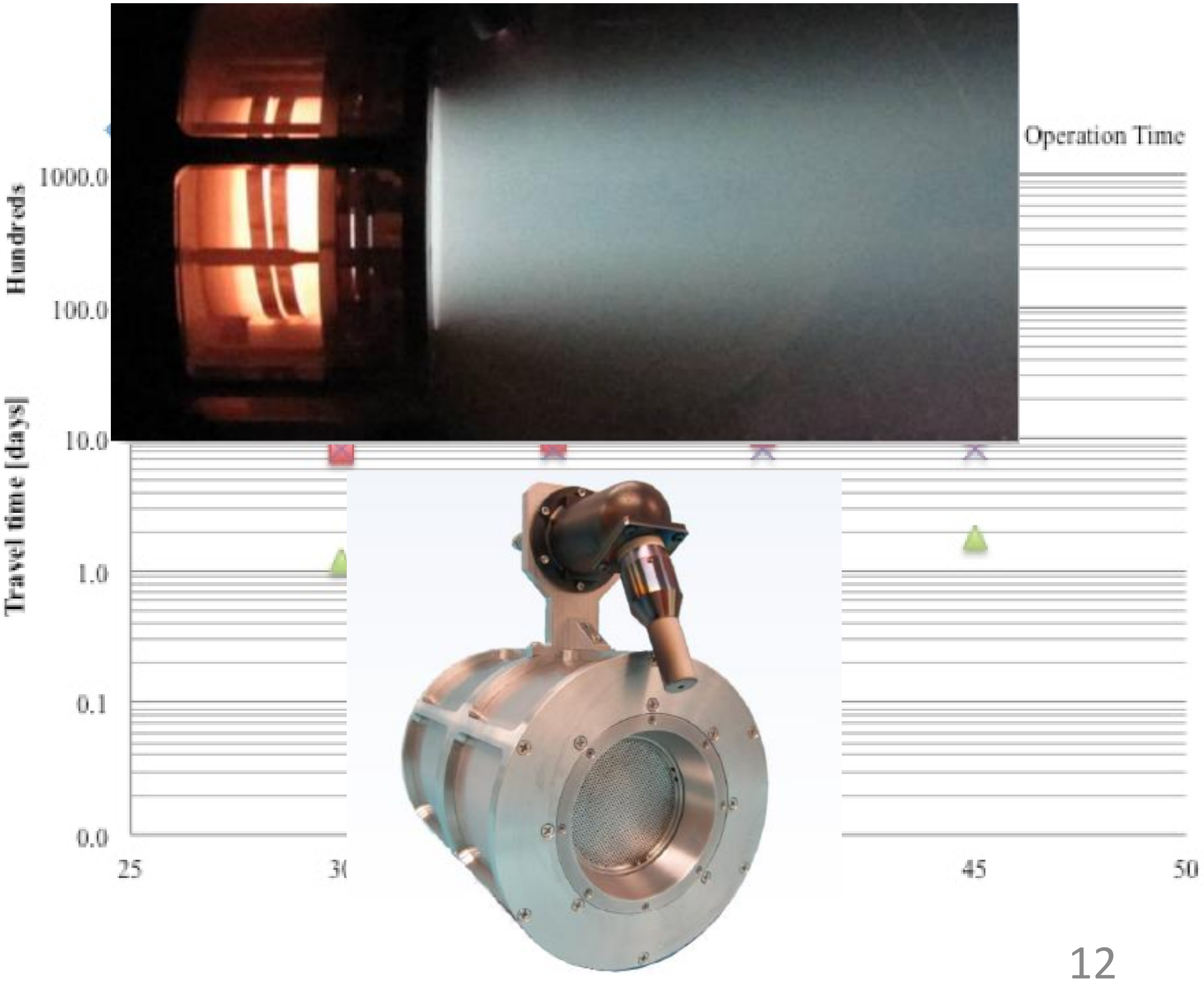


Segment	Δv (m/s)	Travel Time (days)
GTO's apogee augmentation	1557	348
GTO's perigee augmentation	1552	98
Lunar capture	594	24
Circularization of lunar orbit	935	82
Total	**4638**	**552**



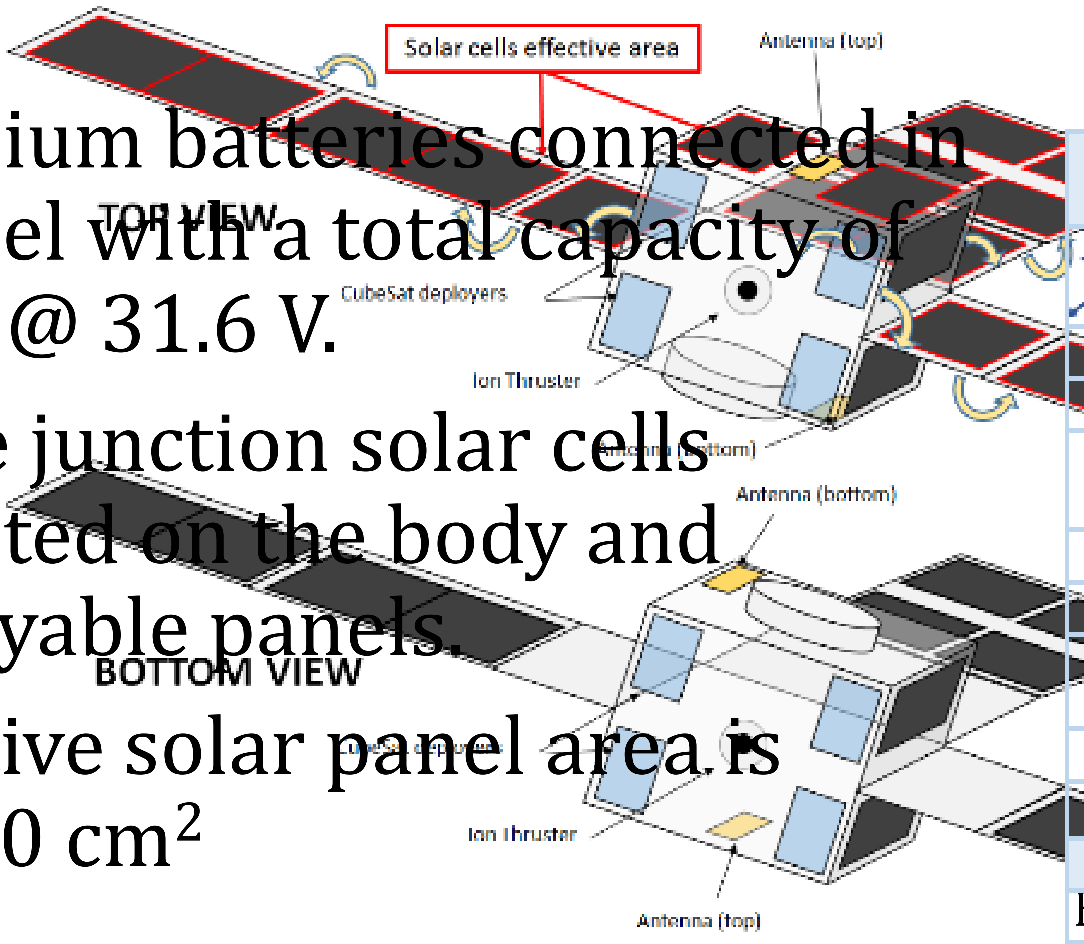
Propulsion System

- Propulsion system is required to deliver 4600m/s.
- Wet mass of LOCI is ≈50kg
- Constant thrust of 0.004N.
- BIT-7 Ion thrusters was selected
- Available total thrust power of 360Watts
- I_{sp} of up to 3500s
- Max. Available thrust 0.011N.
- LOCI wet/dry mass 1.07



Electrical Power System

- 9 Lithium batteries connected in parallel with a total capacity of 30Ah @ 31.6 V.
- Triple junction solar cells mounted on the body and deployable panels.
- Effective solar panel area is 16,260 cm^2



MODES OF OPERATION AND CRITICAL SUBSYSTEMS	
Transfer orbit mode (AOCS, Thruster, Comm, Thermal, C&DH)	
Nominal Power [W]	256
Maximum Power [W]	480
CubeSat release mode (AOCS, Comm, Thermal, Camera, C&DH)	
Nominal Power [W]	72
Maximum Power [W]	110
Secondary mission (AOCS, Comm, Thermal, Payload, C&DH)	
Nominal Power [W]	56
Maximum Power [W]	120
Electrical Power System	
Battery Capacity [Wh]	950 @ 32V
Solar cells power [W]	630

Attitude & Orbit Control System

SS x 5

ST

FOG

RW x 4

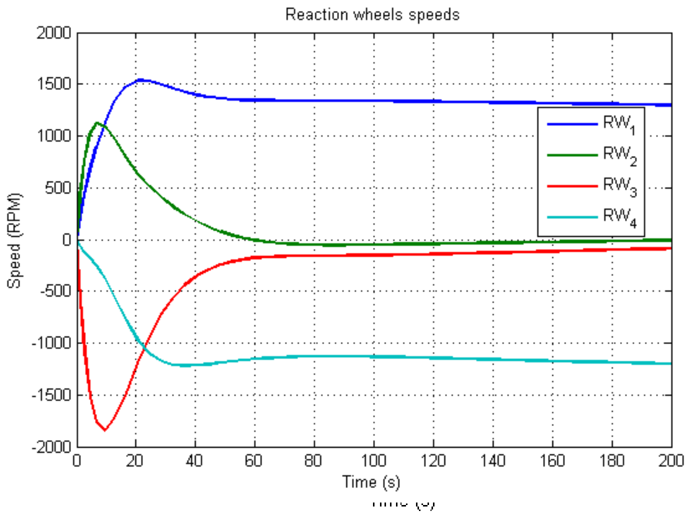
PPT x 8

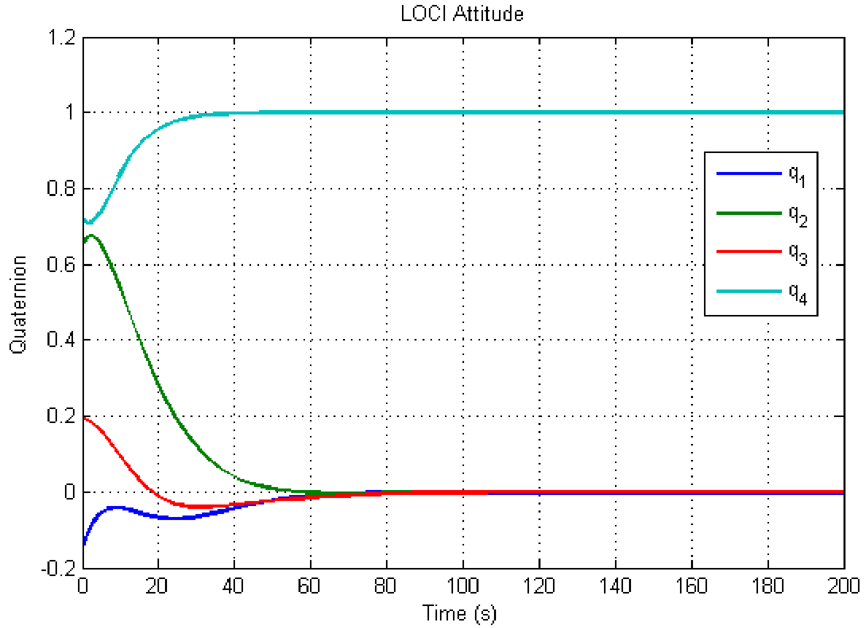
Pointing knowledge:
10 arcsec

Pointing accuracy:
36 arcsec

Control modes
Detumbling
Inertial pointing

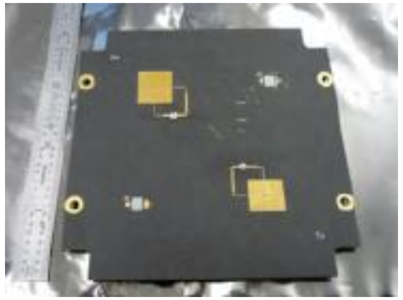
- **High accurate attitude control is required.**





Communication Subsystem

- The communication system is a commercial off-the-shelf Iris V2 CubeSat Deep Space Transponder developed by the NASA's Jet Propulsion Laboratory JPL.
- X-band frequencies operable with NASA's DSN
- One patch array Medium Gain Antenna (MGA)
  - Requires pointing
- Two low gain omni-directional antennas (LGA)
  - Mounted in opposite directions for communication with the Earth stations during the early transfer phase and when the MGA is not Earth pointing.



LGA — Single Tx & Rx patches on 10x10 cm face

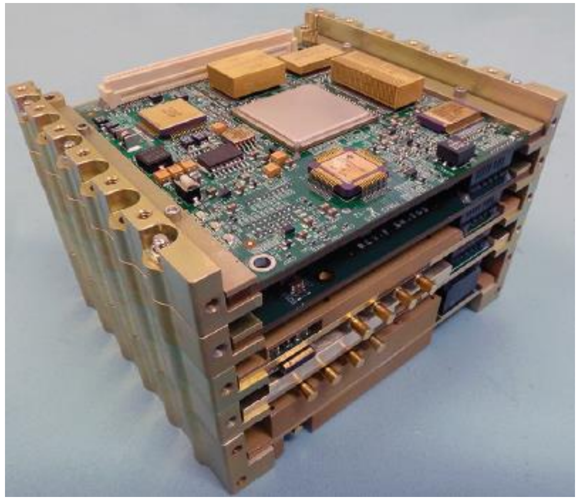
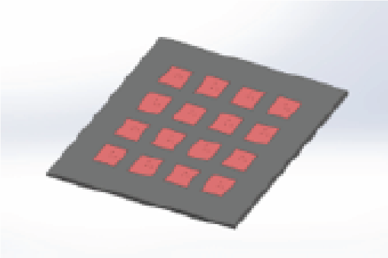


Image source: Iris V2 CubeSat Deep Space Transponder datasheet. Retrieved March 1, 2016 from deepspace.jpl.nasa.gov



MGA — 4x4 Tx patch array

Communication System Specification	
Uplink Frequency	7.2 GHz
Downlink Frequency	8.4 GHz
Variable Downlink Data Rate	1k-512kbps

….. More Subsystems

Command & Data Handling

- **Command and data handling** (C & DH) consist of a single board SCS750 radiation hardened with heritage.
- **Threat Response Processing** architecture to increase error free processing.
- **Serial communication** based on Low Voltage Differential Signaling.

Thermal Module

- **Active thermal control** to ensure strict temperature compliance.
- **External surface & protruding components** will be covered with **MLI blankets**
- Relative positions of components, their sizes, geometry, and orientation will be given adequate consideration.

Implementation plan

LOCI Project

Main satellite

Design

Development

Testing

Interested participants

Call for lunar mission based on 2U CubeSats x4

Ground Station Network

Provided by a prospective organization

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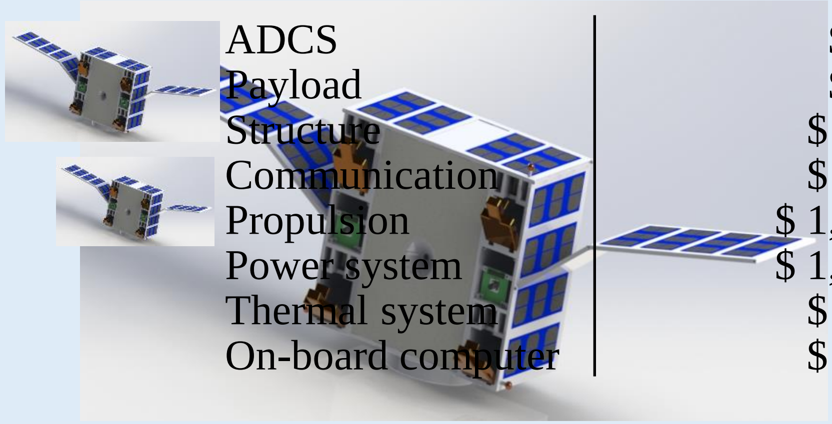
Implementation plan

LOCI Project budget

Project management, Integration and Test
USD$ 2,000,000

Engineering Model	**USD$ 4,965,000**
Flight Model	**USD$ 4,965,000**



ADCS	$ 70,000
Payload	$ 65,000
Structure	$ 500,000
Communication	$ 400,000
Propulsion	$ 1,000,000
Power system	$ 1,950,000
Thermal system	$ 400,000
On-board computer	$ 580,000

Launch
(as piggyback)

~ USD$ 400,000

Financial retrieval from CubeSats

~ USD$ 200,000
+
~ USD$ 200,000
+
~ USD$ 200,000
+
~ USD$ 200,000

Total Cost + 25% Margin **USD$ 15,412,500**

Implementation plan

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LOCI Project

Main Risks

Availability of launchers

Availability of a DNS

Communication limitations for orbit determination

AOCS loss of precision and orbit maneuvers limitation

Loss of solar panels due to debris or unexpected perturbation

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On behalf of LOCI team members,

Thank you!