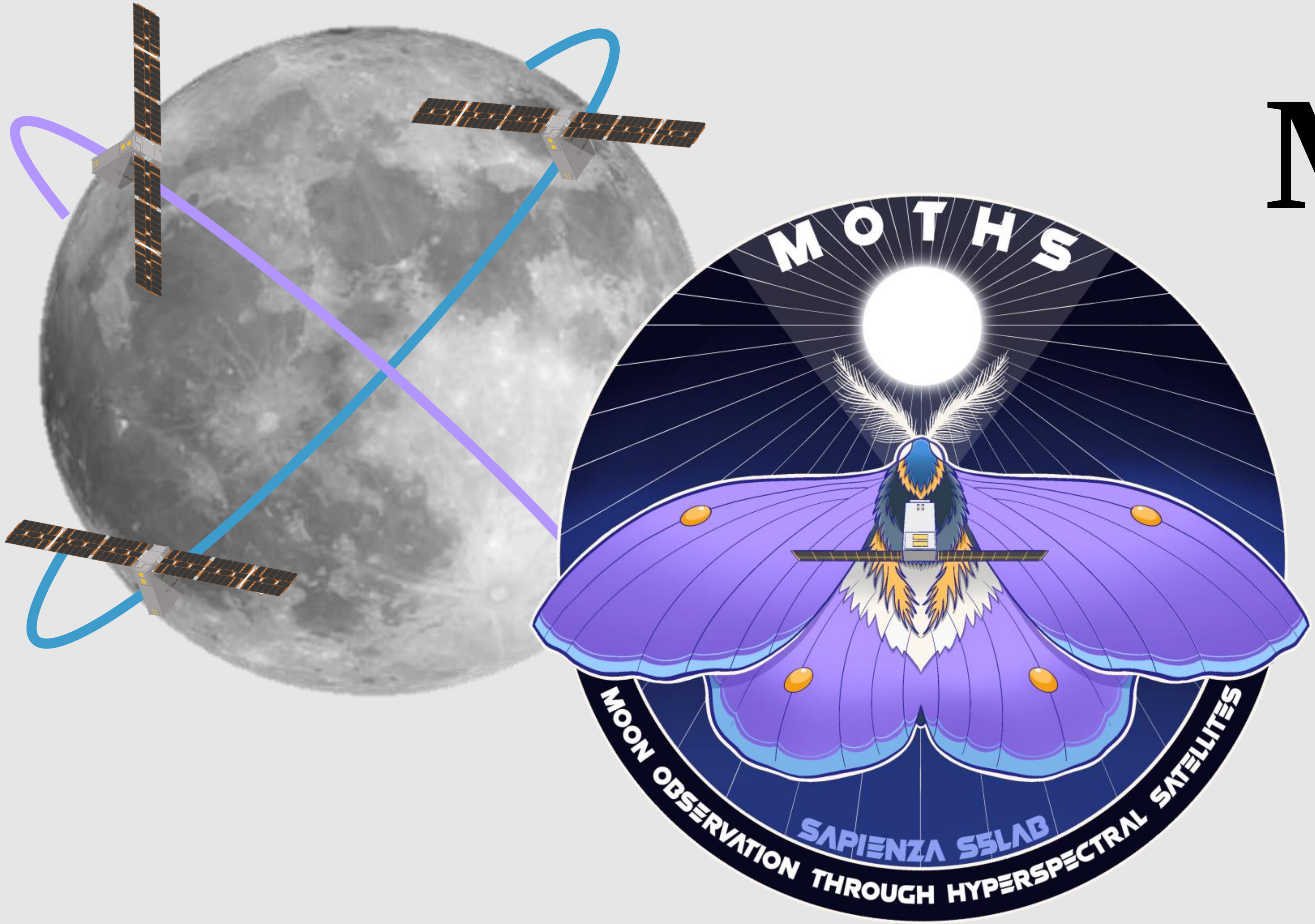
The 8° Mission Idea Contest
For Multiple Nano-satellites

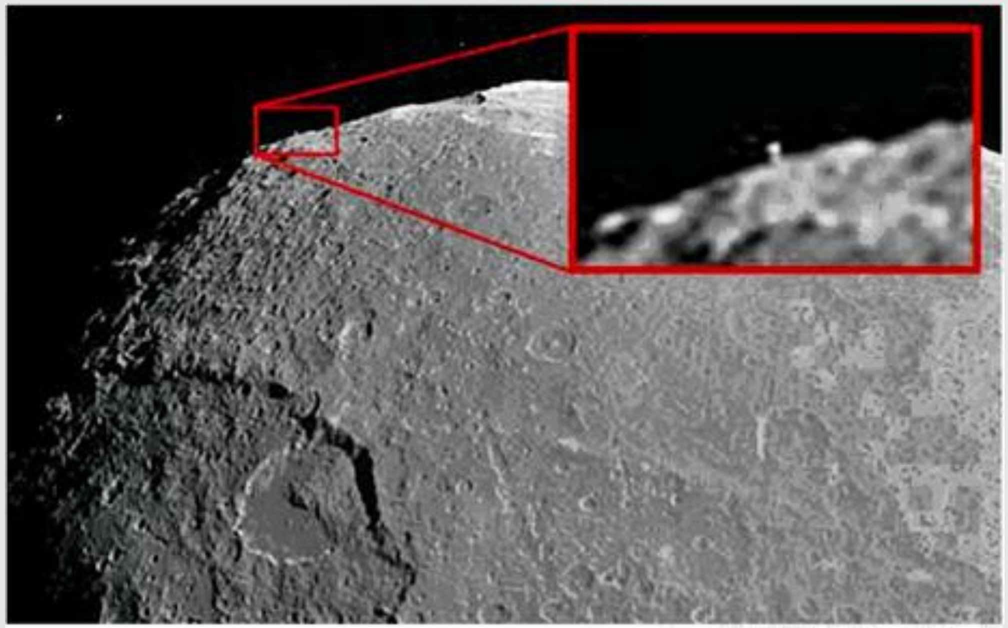



# MOTHS

**M**oon
**O**bservation
**T**hrough
**H**yperspectral
**S**atellites

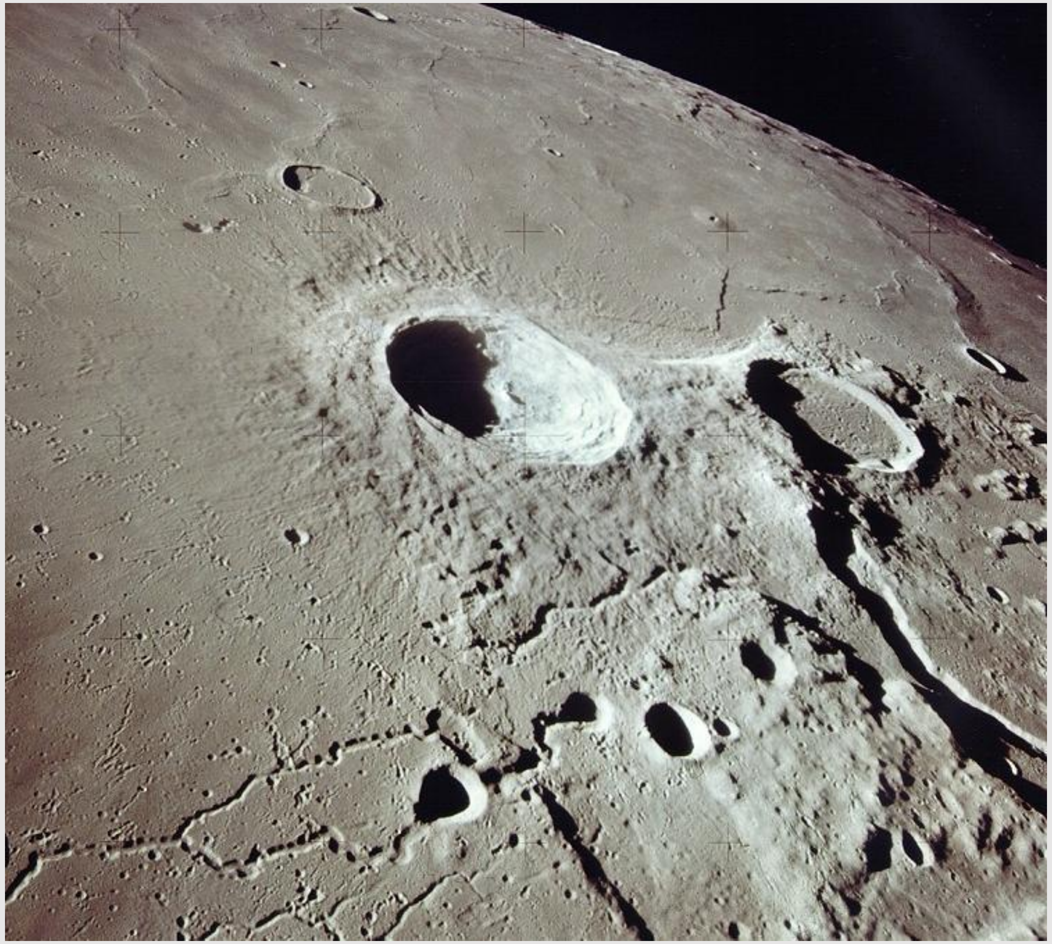
# TRANSIENT LUNAR PHENOMENA

Short-lived changes in light, colour or appearance on the surface of the Moon observed from Earth. These phenomena range from foggy patches to permanent changes in the lunar landscape.



- For future human lunar missions, to choose an appropriate Moon landing site and possible position for lunar settlement, it is necessary to analyse the phenomena of TLP.
- To understand the colour-changing effect due to this phenomenon, it is important to study the correlation between outgassing and moonquakes.

# MOTHS MISSION OBJECTIVES



1 **Detection of colour changes** on the surface of the Moon in optical wavelengths, to locate the main affected sites and to establish, if present, the correlation with outgassing of Argon, Radon and Polonium.

2 Investigate the **Argon outgassing** location as an indicator of seismic activity with the perspective of using this data as a basis to determine landing sites for future human missions.

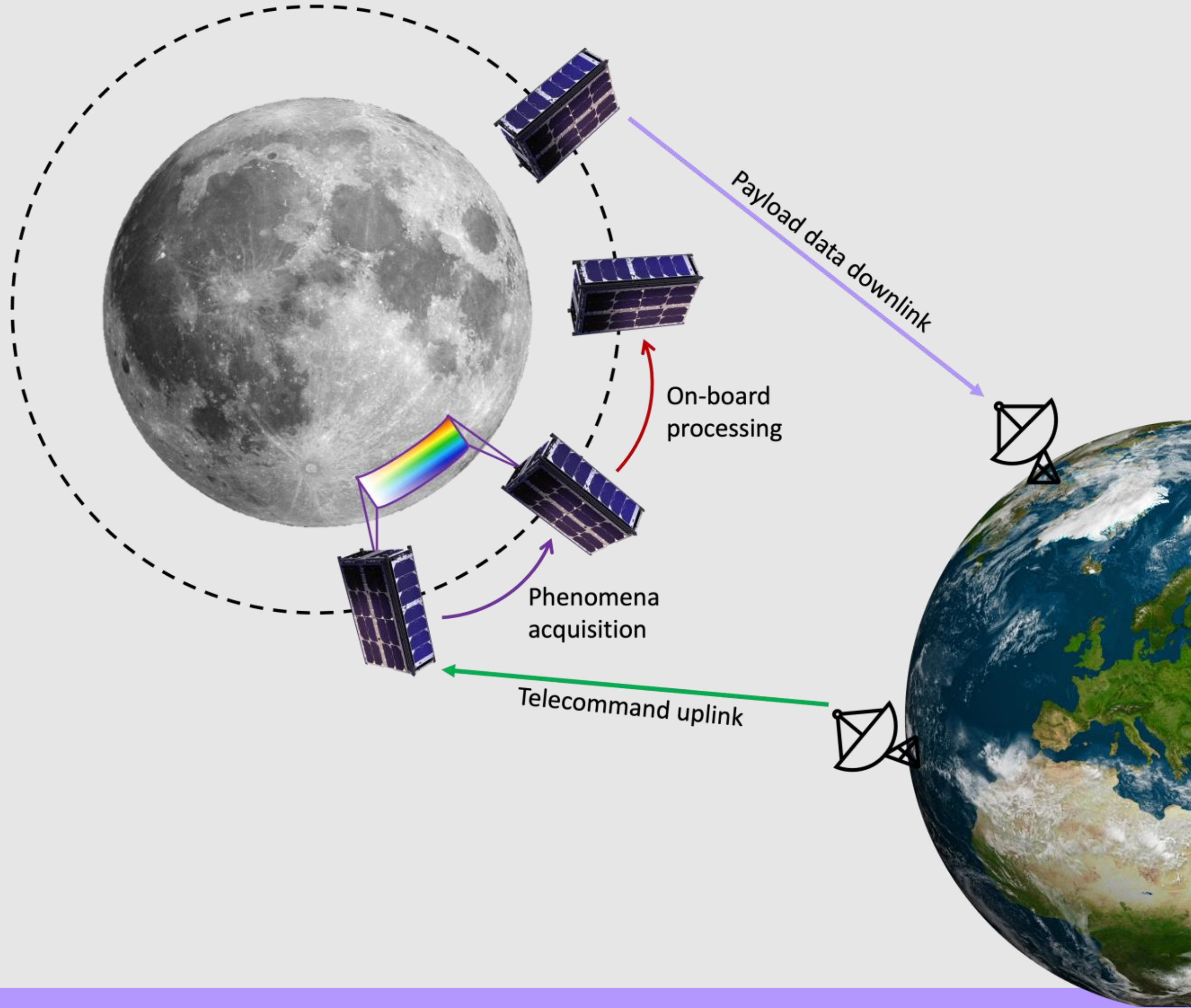
3 **Verify** if the **TLP observations conducted from Earth's surface** are affected by the atmosphere comparing, for the same event, the data acquired from lunar orbit and from Earth.

# CONCEPT OF OPERATIONS

**PHASE 1 – Acquisition Phase**
Scientific data acquisition phase, which lasts for **2 minutes and 30 seconds**
Total of **4 acquisitions**: 2 dark side & 2 visible part

on-board processing of the data

**PHASE 2 – Download Phase**
Downlink phase with a period of **1 hour and 30 minutes** per acquired data set.



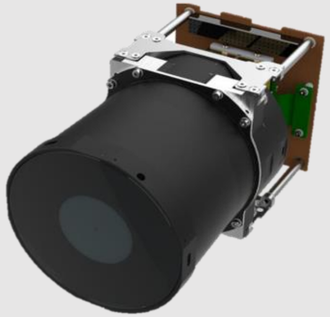
# PERFORMANCE PARAMETERS

- To ensure TLPs detection the spatial resolution shall be below 20 m, considering that the phenomena has an extension between a few kilometers, up to 100 km.
- To have a spectral characterization of the TLPs, the spectral band to be investigated shall be at least in the blue and red spectral region.
- The GNSS receiver shall acquire, as a minimum set, the L1 GPS band and the E1 GALILEO band from Earth GNSS constellations.

# PRIMARY PAYLOAD

*Sensor*
**Hyperscape100** from Simera Sense

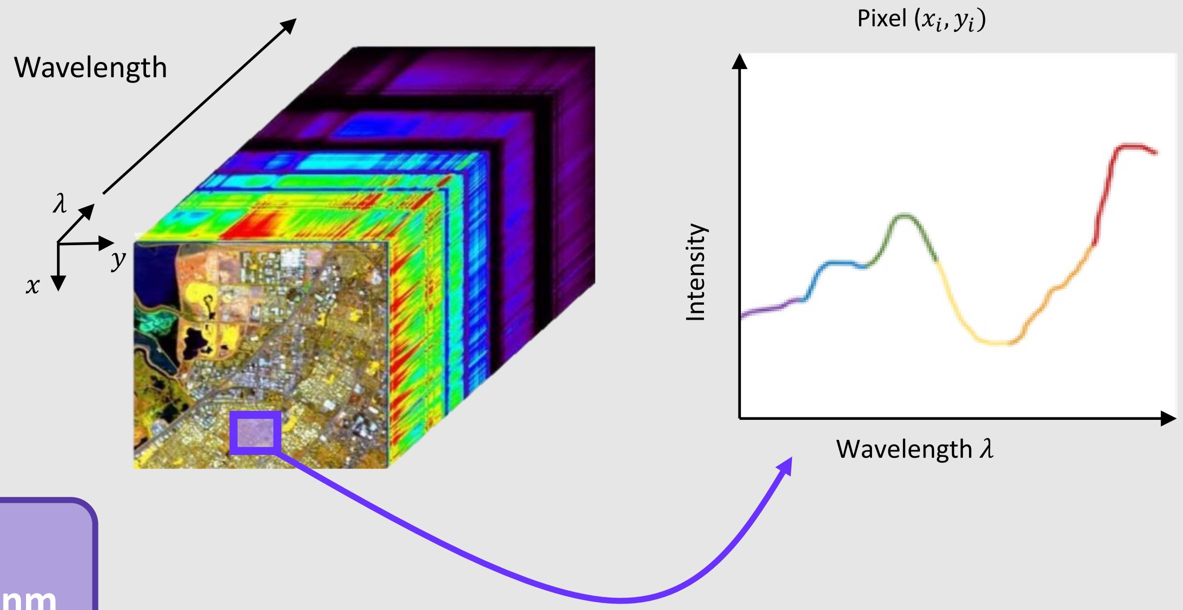
*Acquisition Mode*
Hyperspectral Push-broom Imager



| *Hyperscape Specifications* | | |
|---|---|---|
| **GSD @ (750 km)** | **SWATH @ (750km)** | **Data Rate @(32 bands)** |
| 7 m | 27 km | 0.4 GB/s |

*Type of Spectral Data*
**Hypercube** which is constituted by a large number of contiguous and narrow spectral bands

*Data Processing*
**Optical Images** and **spectral signatures** for each wavelength of the emission and absorbance phenomena




*Full Spectrum Characterization*
**32 bands** in a range of **442-884 nm** with a **spectral resolution of 0.2 nm**

# SECONDARY PAYLOAD

***GNSS receiver SGR LIGO***

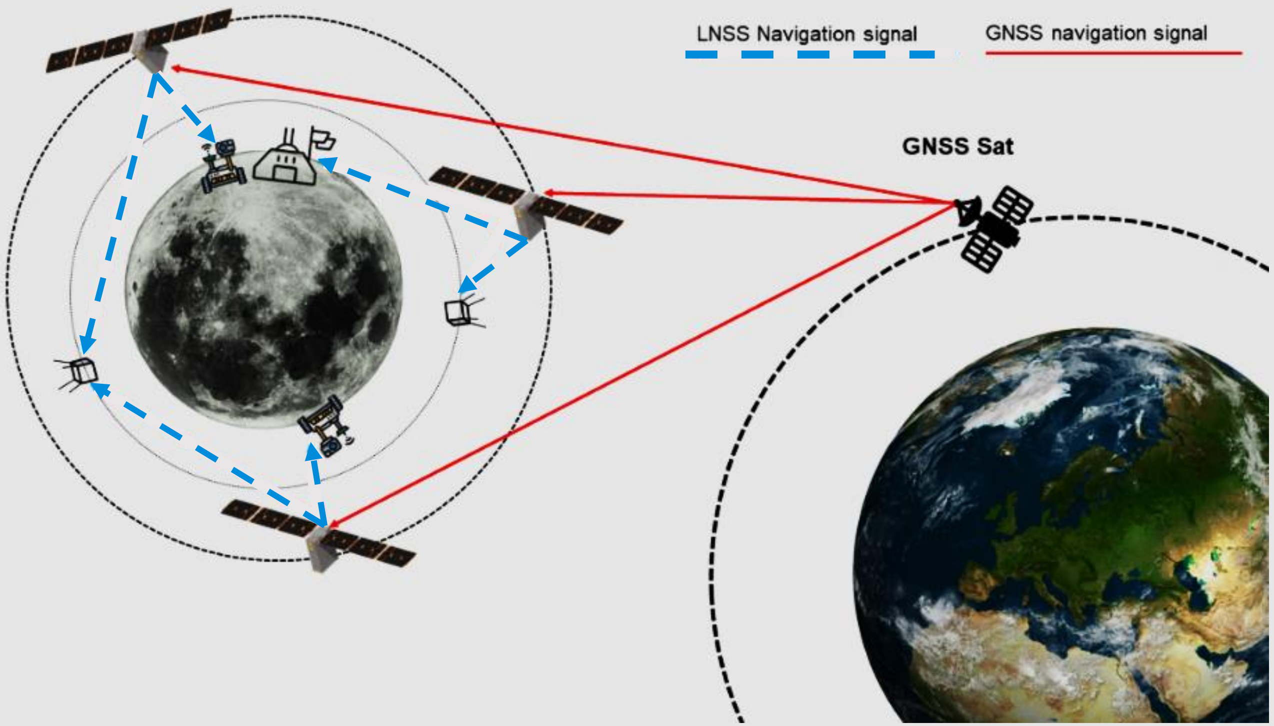
It will operate at the GPS L1 band (C/A code), GALILEO E1 band, and GLONASS G1 band

***LNSS receiver***

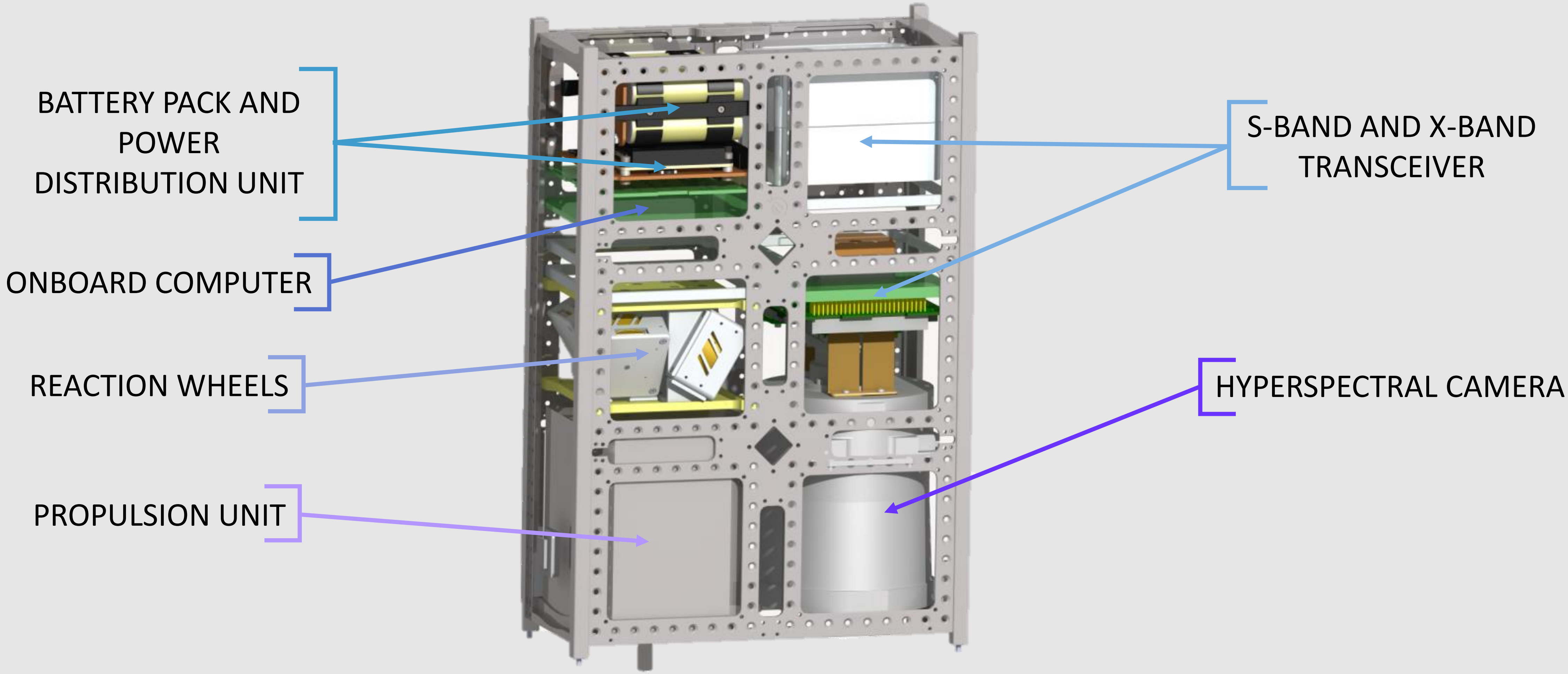
Support for future Lunar Navigation and Safety Systems (LNSS)

***Patch antenna EXA GCA01***

It has a wide-band operation over GPS, GLONASS, Galileo, BeiDou systems from 1561MHz to 1606MHz



# SATELLITE DESIGN



# OBDH & ADCS

## OBDH

**Proton400KTM**

Multi-core Single Board Computer (SBC) built around an advanced 45nm dual-core NXP PowerPC

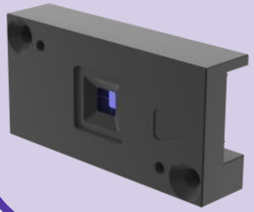
- The SBC is Radiation-hardened and can **endure an amount of Total Ionizing Dose up to 100 krads**
- NXP P2020 is a dual-core 1.2 GHz, 32-bit processor supporting DDR3 RAM up to 2 GB with Error Detection and Correction (EDAC) code
- **Storage capability of 256 GB**

## ADCS

### Determination


**IMU Sensor**
**STIM300**
**Accuracy** : 5°

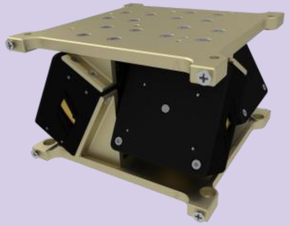
**NanoSense FSS**
**Fine sun sensor**
**Accuracy** :
- FOV<45°, +/-0.5°
- FOV<60°, +/-2.0°



**ST200 Star Tracker**
Accuracy:
- 30 arcsec
- 200 arcsec (roll)

### Control

**NanoTorque GSW-600**
Reaction wheels in pyramid configuration
**Characteristics**:
Max torque per wheel: 1,5 Nm



**VACCO ArgoMoon MiPS**
Propulsion system
**Characteristics**:
delta-V=56 m/s
central thuster: 100 mN
4 cold gas thrusters: 25 mN

# EPS

**BATTERIES**

Nano Power BPX

•Utilizes 18650 Li-Ion cells with a nominal cell capacity of 3000 mAh

•86 Wh capacity

**POWER DISTRIBUTION UNIT**

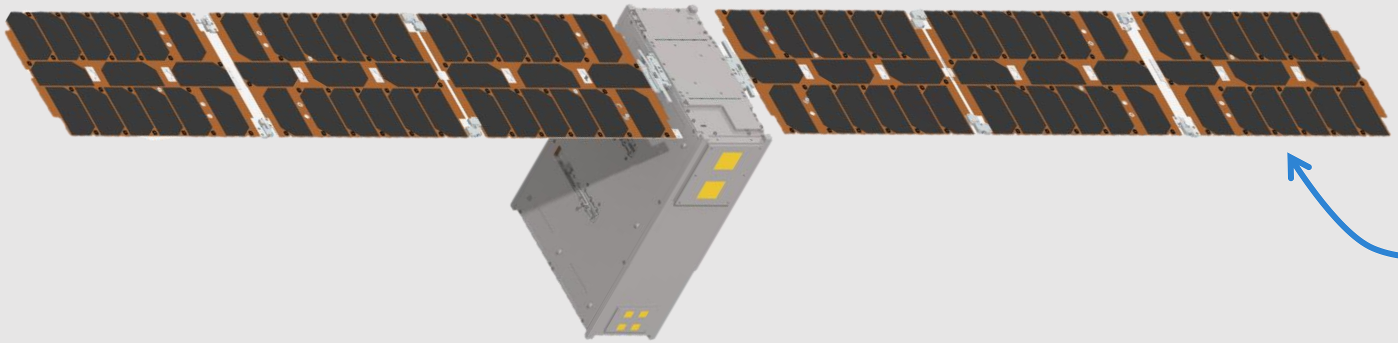
NANO Power P60 System

Composed o:

- P60 Dock motherboard
- Combination of an Array Conditioning Unit (ACU)
- Power Distribution Unit (PDU)


**POWER BUDGET**

| | Power [W] | Duty Cycle [min/orbit] | Power Consumption [Wh] |
|---|---|---|---|
| **Power Generation** | +55.00 | 140 | + 128.333 |
| **Total Request Components** | | | -107.554 |
| **Total Request Components + 10% of margin** | | | -118.309 |
| **Power Margin per Orbit** | | | **+10.0243** |
| **DOD** | | | 13.8 % |



**SOLAR PANELS**

NANO Power Tracking Solar 2030-3P

- Deployable Solar Panels
- SADA-50 gearbox mechanism
- 45 W per wing

# TT&C DTE

## Direct-to-Earth (DTE) communication – X band prioritized

### GROUND STATION

- Goldstone Deep Space Communications Complex (GDSCC) by NASA, California **Specifications**: 34m diameter with G = 68.2 dBi in downlink
- Malindi station, Kenya **Specifications** 10m diameter with G/T = 17.7 dB/K (in clear sky conditions) and G = 55.5 dBi
- Sapienza University of Rome, Italy (in progress)

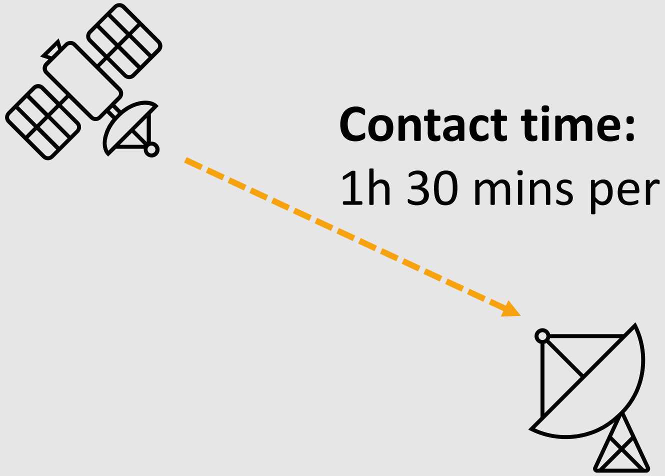
### INSTRUMENTATION

| INSTRUMENTATION | |
|---|---|
| **X-BAND ANTENNA** | |
| Operation frequency | 8.025-8.400 GHz |
| RF power input | <2W |
| Gain | 10 dBi |
| Type | Patch antenna |
| Linear RF output power | Up to +33dBm |
| **X-BAND TRANSCEIVER** | |
| X band Tx operation | 8.025-8.400 GHz |
| X band Rx operation | 7.145-7.250 GHz |
| Data rate Sat2Ground | 2 kbps -200 Mbps |
| Data rate Ground2Sat | 56 kbps+ |

# TT&C – DTE

| LINK BUDGET | | | |
|---|---|---|---|
| Feature | Unit | Downlink | Uplink |
| Distance | km | 384400 | 384400 |
| Frequency | Hz | 8400 | 8400 |
| Total losses | dB | 231,7 | 231,7 |
| Eb/N0 | dB | 21,65 | 60,9 |
| Eb/N0 required | dB | 18 | 18 |
| **Link Margin** | **dB** | **3,6** | **42,9** |

## PASSAGE DATA DOWNLOAD



**Contact time:**
1h 30 mins per orbit

## DOWNLOADED DATA

**Data rate:** 200Mbps → **Data transmitted**: 108000Mb (135GB)

**STORAGE EMPTIED IN 2 PASSAGES**

# TT&C – ISL

## Inter-Satellite-Link (ISL) communication (S-Band)

Used in case of **failure of the DTE** communication possible with **Lunar Gateway** by NASA (launch in 2024) and **Lunar Pathfinder** by SSTL (launch in 2024)

| LINK BUDGET | | | |
|---|---|---|---|
| Feature | Unit | Downlink | Uplink |
| Distance | km | 14000 | 14000 |
| Frequency | Hz | 2200 | 2200 |
| Total losses | dB | 189,3 | 189,3 |
| Eb/N0 | dB | 37,6 | 59,2 |
| Eb/N0 required | dB | 18 | 18 |
| **Link Margin** | **dB** | **19,6** | **41,2** |

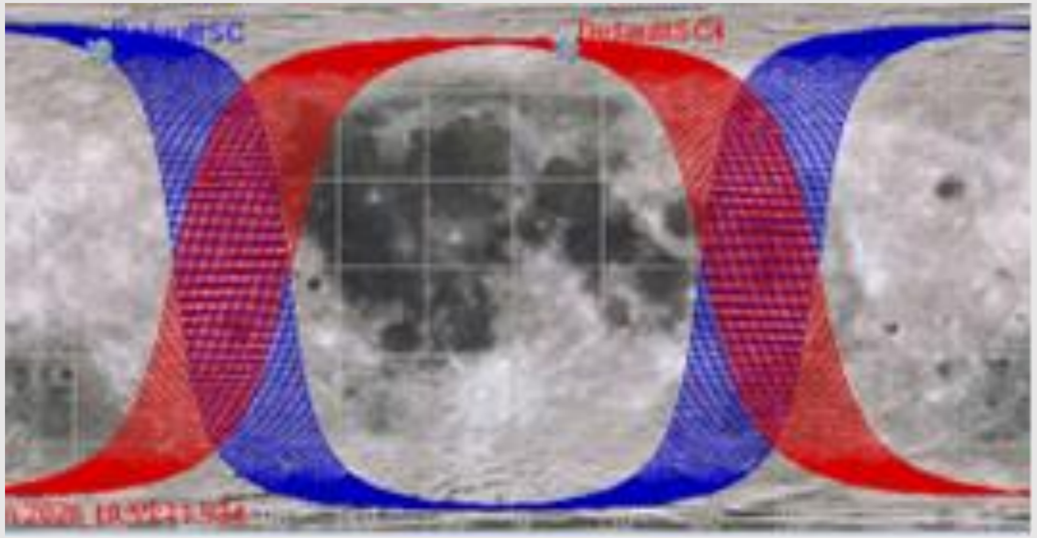
| INSTRUMENTATION | |
|---|---|
| **S-BAND ANTENNA** | |
| Operation frequency | 1.980-2.500 GHz |
| RF power input | 50MHz |
| Gain | 6-11dBi |
| Type | Dual patch antenna |
| Linear RF output power | Up to+33 dBm |
| **S-BAND TRANSCEIVER** | |
| X band Tx operation | 2.200 – 2.290 GHz |
| X band Rx operation | 2.025-2.110 GHz |
| Data rate Sat2Ground | 2 kbps … 200 Mbps |
| Data rate Ground2Sat | 56 kbps+ |
| Linear RF output power | up to +33 dBm |

# ORBIT/CONSTELLATION DESCRIPTION

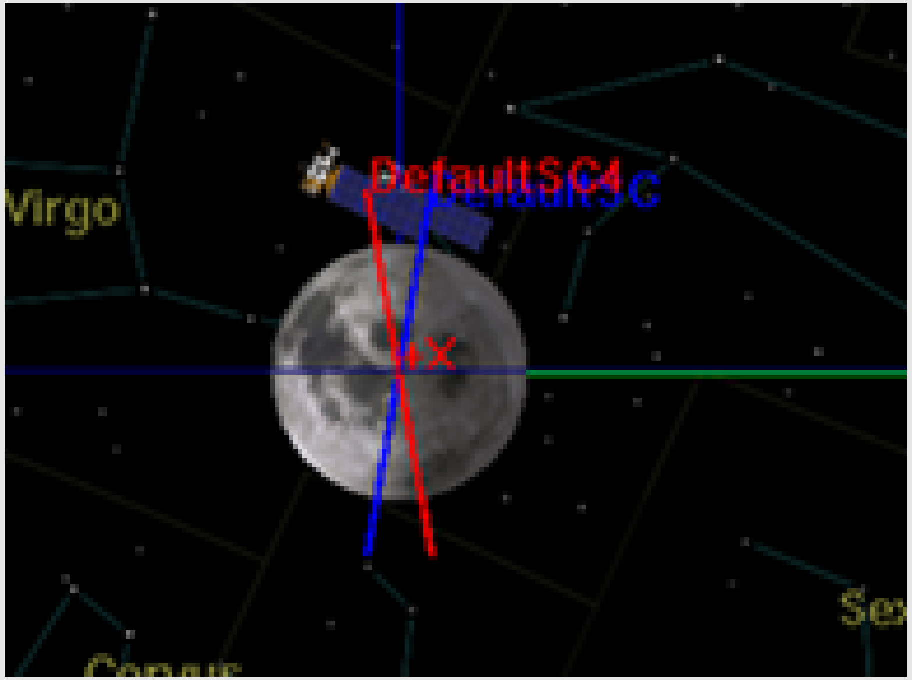
Six 6U CubeSat → two different orbital planes spaced at 180° RAAN

**ORBITAL PARAMETERS**

| e | a | i | ω | Ω | ν |
|---|---|---|---|---|---|
| 0 | 28474 $km$ | 80° | 0° | 0° | 0° |



*Ground Track of the two planes*




*Orbit 3D view*

# ORBIT/CONSTELLATION DESCRIPTION

CubeSats on the planes are spaced from the first of respectively 60° and 120° in True Anomaly to not overlie the sensors' swaths and consequently increase the total coverage

Simultaneous observations on the moon's far side and the side visible from Earth

Daily coverage percentage of 2.69% compared to the 0.45% of a single satellite

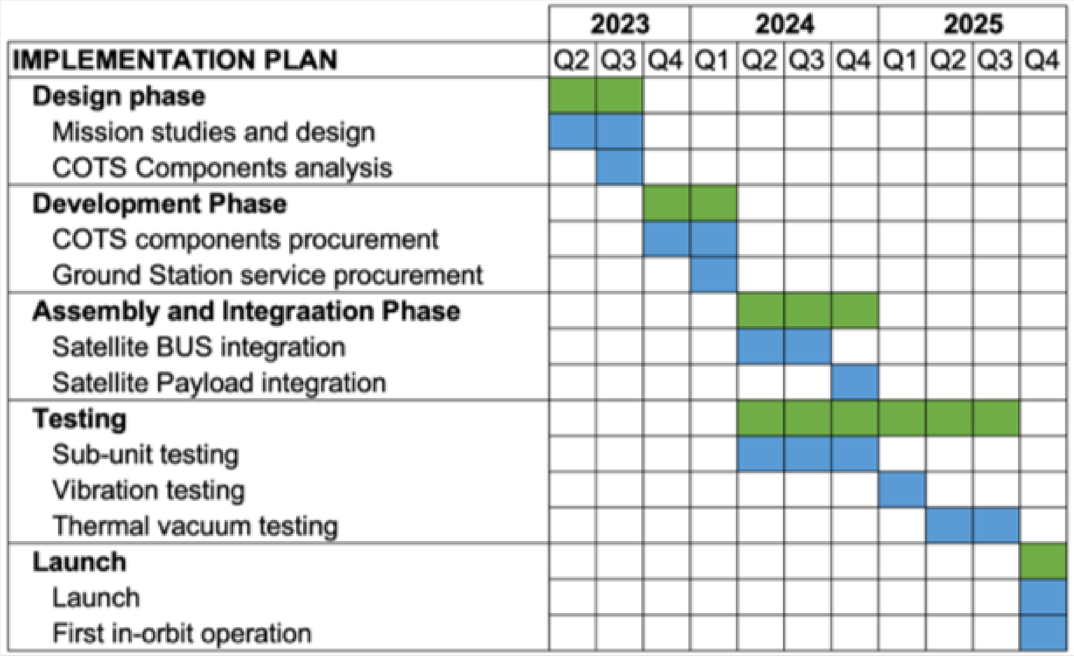
Complete lunar surface coverage in 37 days. Monthly revisit time enables mapping  the areas most affected by the long-term phenomenon associated with outgassing

**Earth to Moon transfer**

1. Electron launcher from Rocket Lab
2. Space Launch System (SLS) rocket
3. Falcon 9 Block 5 by SpaceX

# IMPLEMENTATION PLAN

The **MOTHS team** comprises **22 students**, studying for Master's and Bachelor's degrees in Aerospace engineering




- For the first satellite, an Engineering Model (EM) and a Flight Model (FM) will be produced
- EM will be used for satellite testing and verification

## COST BUDGET

| Activity | Cost |
|---|---|
| **Subsystem components** | 200000 € |
| **AIV and Testing*** | 0 € |
| **Launch** | 5 million € |
| **Operation and disposal** | 1 million € per year |
| **Payload** | 80000 € |
| **TOTAL (two years of operation)** | ~7 million € |

*considering facility at the University and Student participation in AIV activities

- governmental endorsement should be considered
- including manpower for the AIV and testing activities almost 45% of the total costs
- resulting total of around 11 million euros

# RISK ANALYSIS

| Risk description | Risk level | Mitigation action |
|---|---|---|
| Saturation of storage capacity due to incorrect processing and compression of data | Low | Telecommand from Earth to reschedule the acquisition and downlink strategy |
| Impossibility to send commands or receive data to/from the CubeSat in X band | Low | S band antenna and transceiver have been added in order to guarantee telecommunications |
| Impossibility to desaturate the wheels due to thruster malfunctions | Low | The thruster will be tested fully tested on the ground to guarantee its correct function before the launch |
| Development complexity of the mission for a student team | Medium | Finding space agencies collaboration for technical support |
| Insufficient funding for the development of the mission | Medium | Finding governmental project or space agencies collaborations for funding opportunities |

# CONCLUSIONS

**MOTHS** mission (Moon Observation Through Hyperspectral Satellites) consists of a **constellation of six 6U CubeSats** distributed on two orbital planes

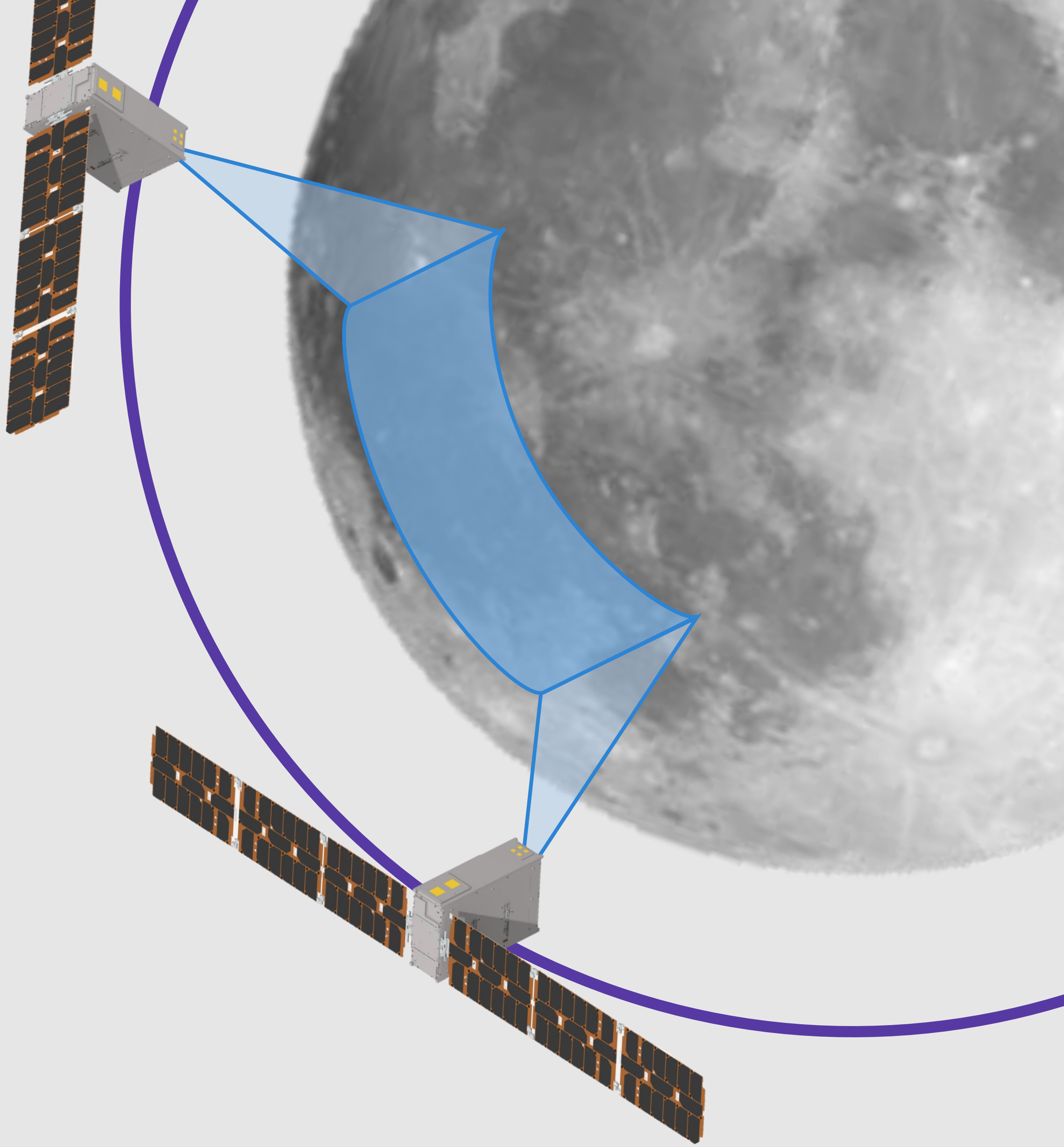
**MOTHS payload** consists of an **Hyperspectral camera** based on a CMOS sensor to detect Transient Lunar Phenomena and a **GNSS receiver** to support the future Lunar Navigation and Safety Systems (LNSS)

MOTHS constellation allows to obtain a complete **lunar surface coverage** within **37 days**

MOTH mission allows to **understand lunar phenomena** and lay the groundwork for **lunar exploration and colonization**

# Thanks for your attention!

MOTHS TEAM



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SAPIENZA
UNIVERSITÀ DI ROMA