ESA Interplanetary Small Spacecraft Missions: Pushing the Boundaries of Miniaturised Systems & Technologies

Simone Simonetti, European Space Agency (ESA)

27/05/2025

Outline

- Introduction to ESA Small Spacecraft Fleet
- ESA Small Spacecraft missions in implementation phase
    - Juventas & Milani: Piggy-back passengers of HERA
    - HENON: Stand-alone CubeSat for space weather forecasting
    - LUMIO: Observing Lunar Meteoroid Impacts
- ESA Small Spacecraft missions in definition phase
    - SATIS: Rapid Reconnaissance of NEOs
    - VMMO: Mapping Lunar Volatiles and Minerals
    - Small Missions for Lunar Exploration
    - LightShip: ESA new opportunities for communication & navigation around Mars
- Conclusion

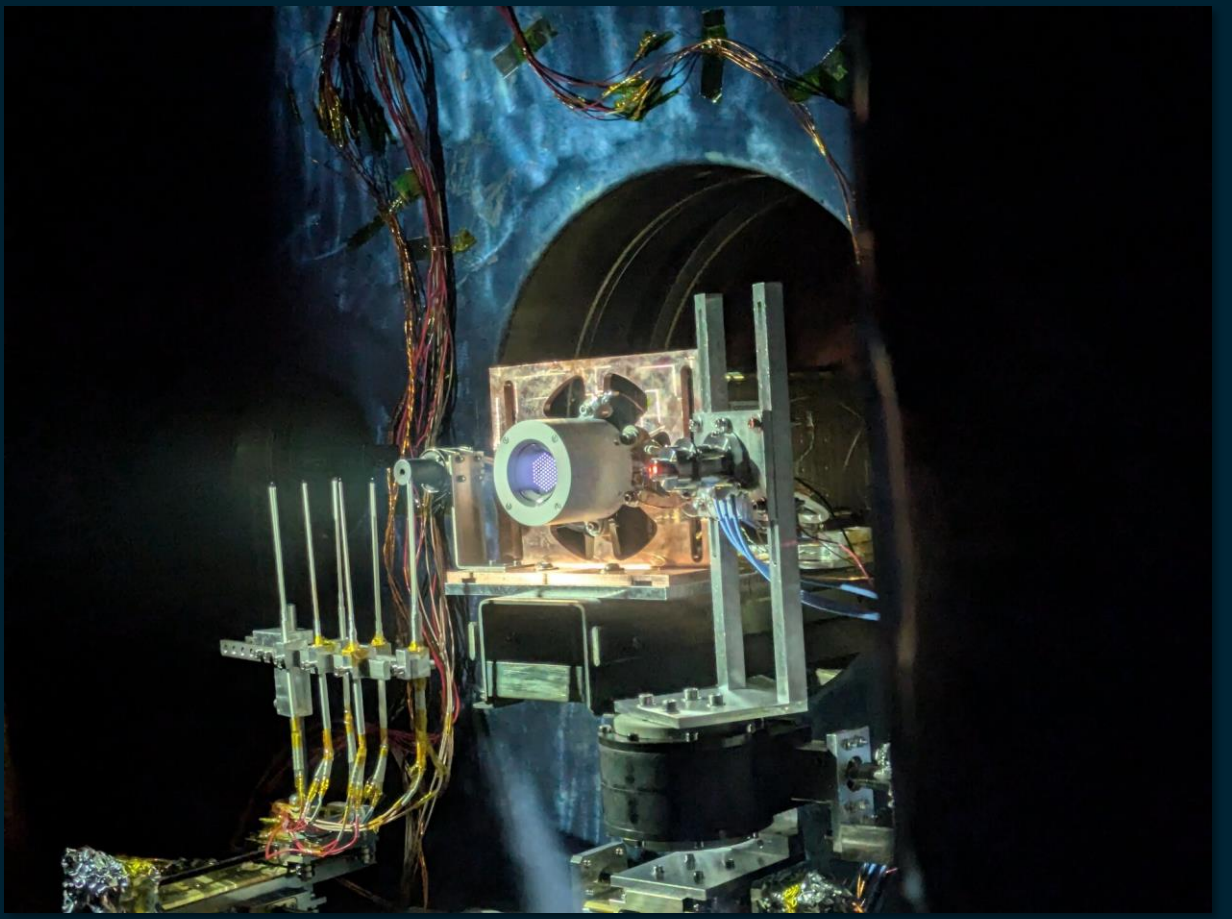
Recent Advancements in SmallSat Technology

Technological advancements are crucial for interplanetary mission success. ESA is at the forefront of developing enabling technologies for SmallSats:

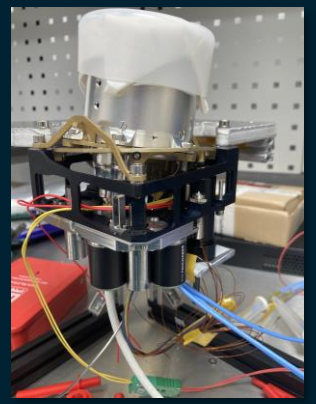
- **Improved Propulsion Systems**
  Recent developments in propulsion technology have enhanced the efficiency and agility of SmallSats, allowing for more ambitious missions.

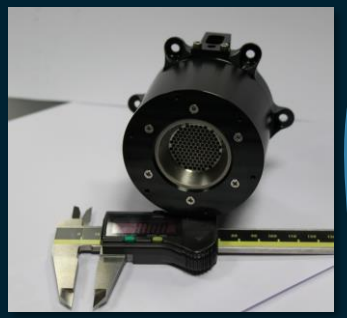
- **Enhanced Communication Capabilities**
  Advancements in communication tech have improved data transfer rates and reliability for SmallSats, leading to better mission results.

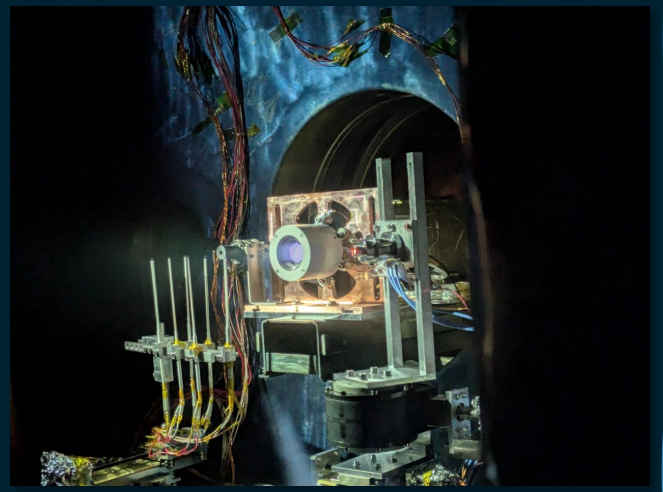
- **Miniaturized Instrumentation**
  Smaller instruments have increased the capabilities of SmallSats, significantly boosting their functionality.



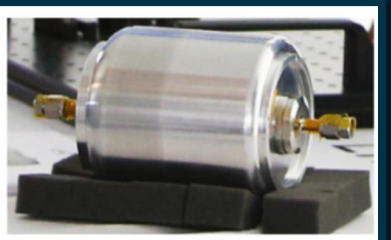
Technologies Under Development in ESA

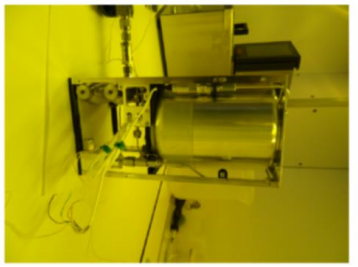




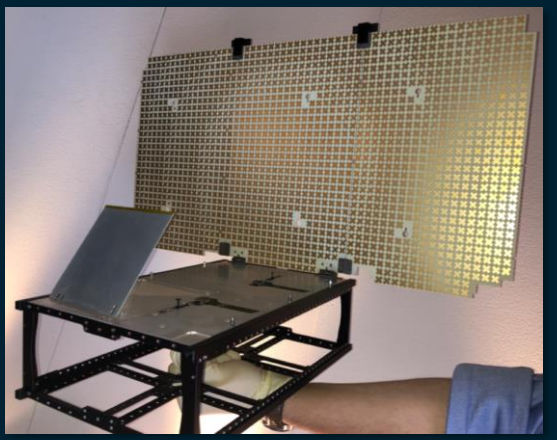


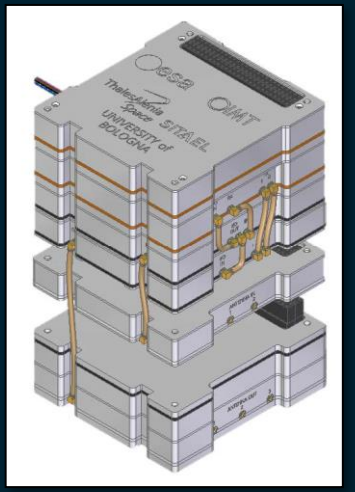
Electric Propulsion



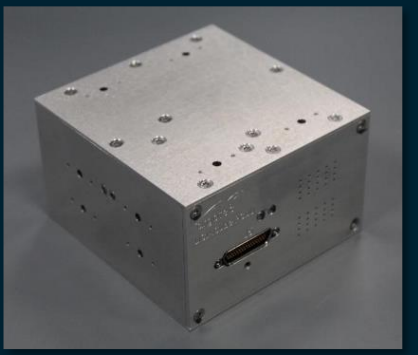


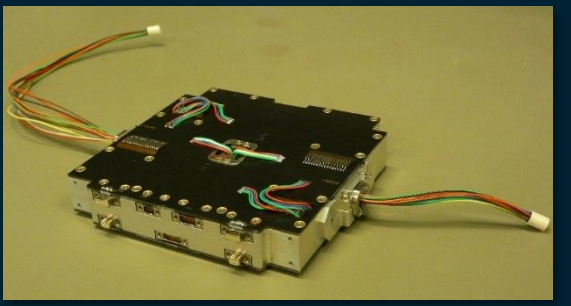
Chemical Propulsion





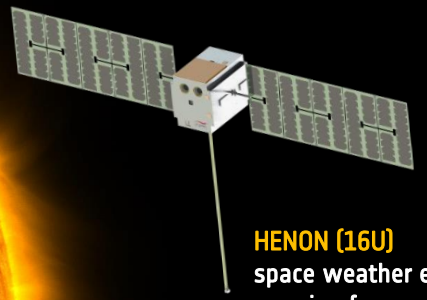
Communication





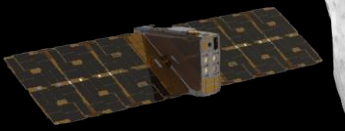
Power Subsystem

Definition
Implementation
Launched

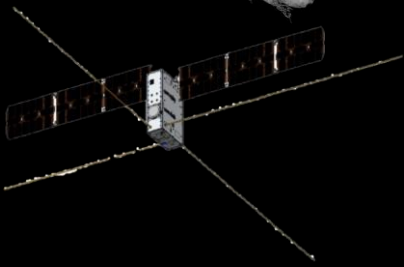


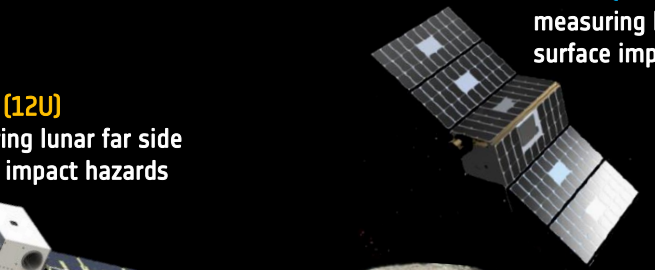
HENON (16U)
space weather early warning from Distant Retrograde Orbit

LightShip
propulsive tug spacecraft up to 12 passenger spacecraft to Mars



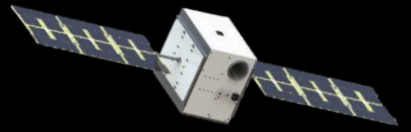
Juventas & Milani (2x6U)
observing asteroid deflection assessment with Hera

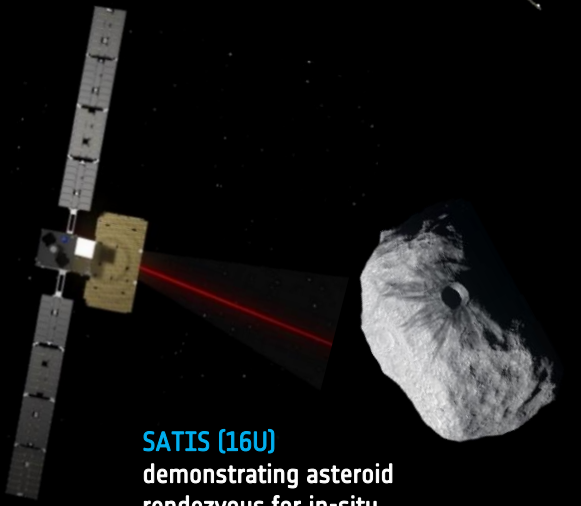




VMMO (16U)
measuring lunar far side surface impact hazards

LUMIO (12U)
measuring lunar far side surface impact hazards





SATIS (16U)
demonstrating asteroid rendezvous for in-situ exploration & planetary defence

Space Safety Programme

Deep Space Deployer (umbilical & low-vel. deployment)

S-band ISL

Hera

Dimorphos

S-band ISL

Juventas
Low frequency radar
Gravimeter
GOMSPACE

Milani
Hyperspectral imager (VTT Finland)
Volatile analyser
Tyvak International
A Terran Orbital Corporation

Launched on the Hera mission in Oct. 2024

HENON: Stand-Alone CubeSat for Space Weather Forecasting

Space Weather Forecasting

HENON aims to monitor the solar wind to predict solar storms, enhancing alert times from 3 to 6 hours.

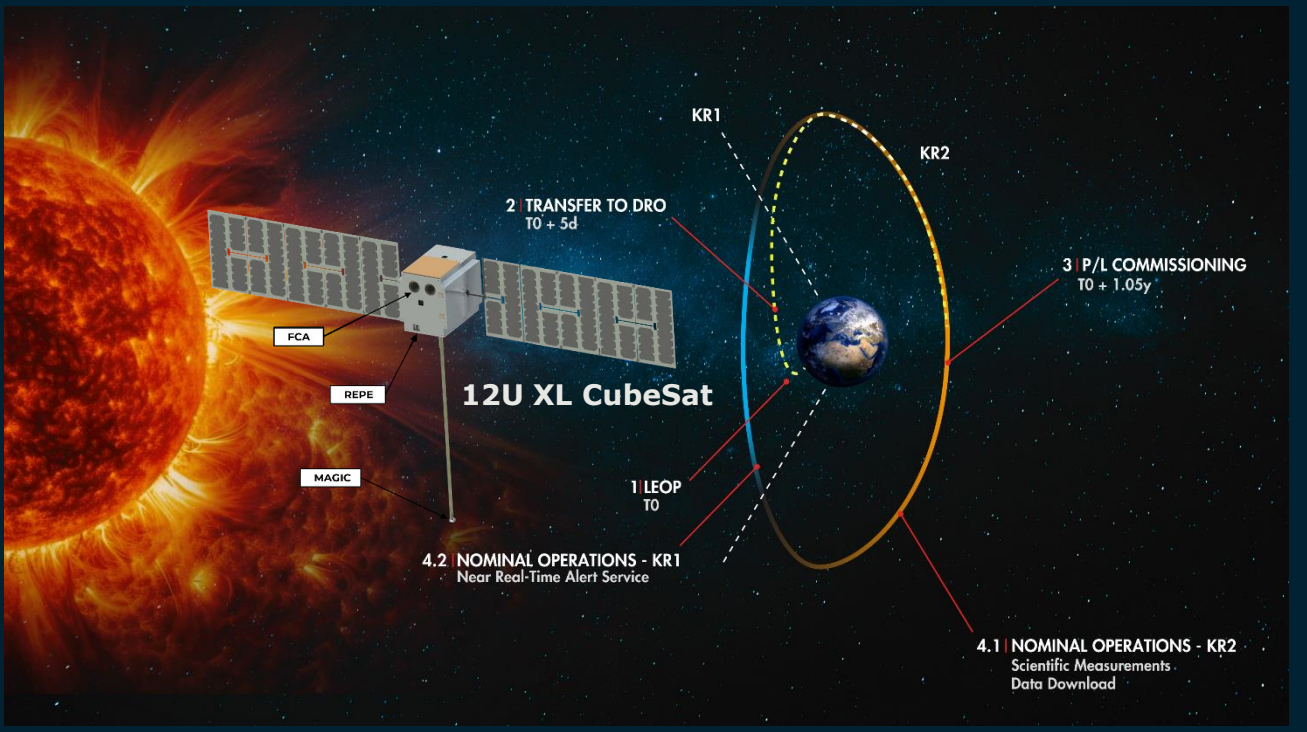
Payloads

FCA (Faraday Cup Analyzer), REPE (radiation monitoring payload), MAGIC (resistor magnetometer)

Mission Profile

The launch is planned for December 2026, with the CDR scheduled for August 2025.

The CubeSat will be set into a Sun-Earth Lagrange trajectory and will use its propulsion system to achieve a distant retrograde orbit after a year of transfer.



LUMIO: Observing Lunar Meteoroid Impacts

Observing Lunar Meteoroid Impacts

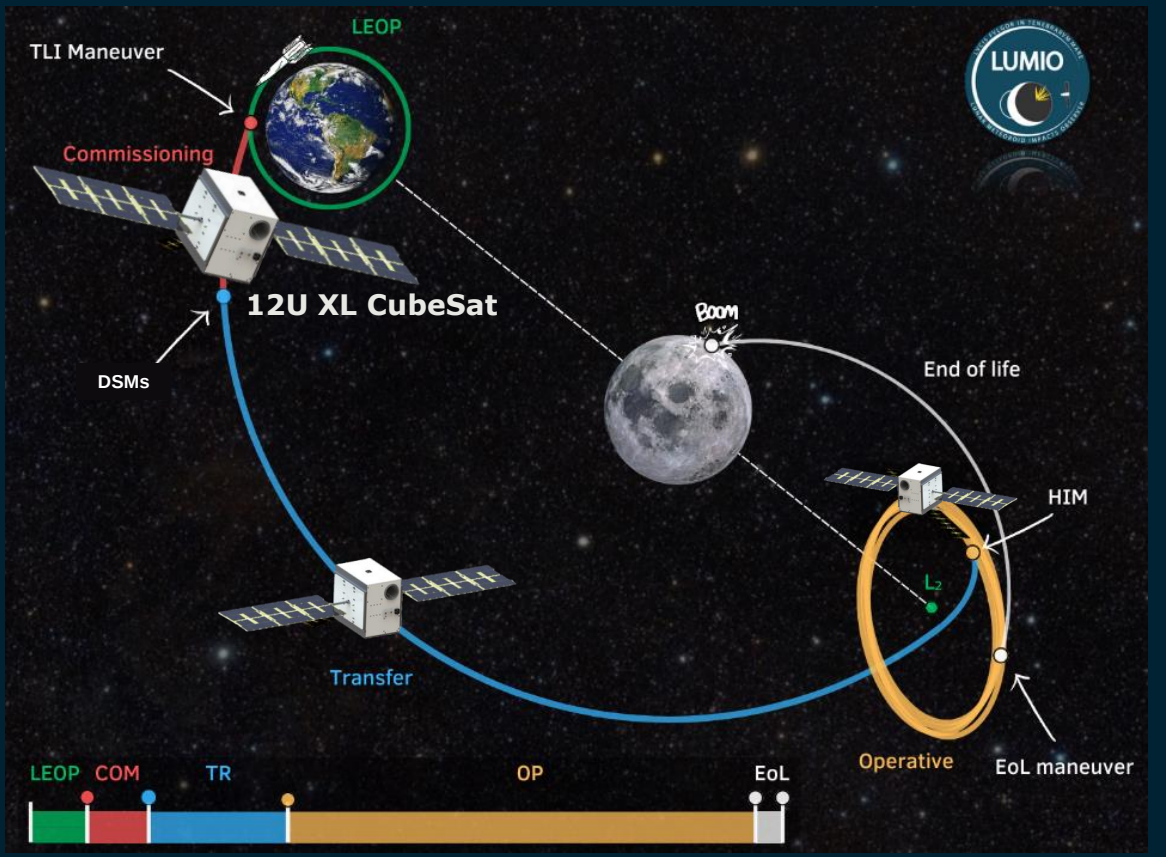
LUMIO aims to observe and analyze meteoroid impacts on the moon's far side.

Payloads

LUMIO-Cam, an optical camera operating in VIS and NIR.

Mission Profile

Scheduled launch in Q1 2028, with CDR in Q2 2026. It will launch towards the Moon and operate in an L2 Halo orbit.



SATIS: Rapid Reconnaissance of NEOs

Assessment of NEOs

SATIS is designed to quickly assess near-Earth objects (NEOs) to gather essential data about their characteristics.

Payloads

Hyperspectral imager VIS/NIR/SWIR, TIR imager, Laser altimeter, radio science experiment

Mission Profile

Launch NET 2030 to Earth escape trajectory and up to 2-year transfer with electric propulsion to rendezvous the target asteroid

SATIS: Rapid Reconnaissance of NEOs

Assessment of NEOs

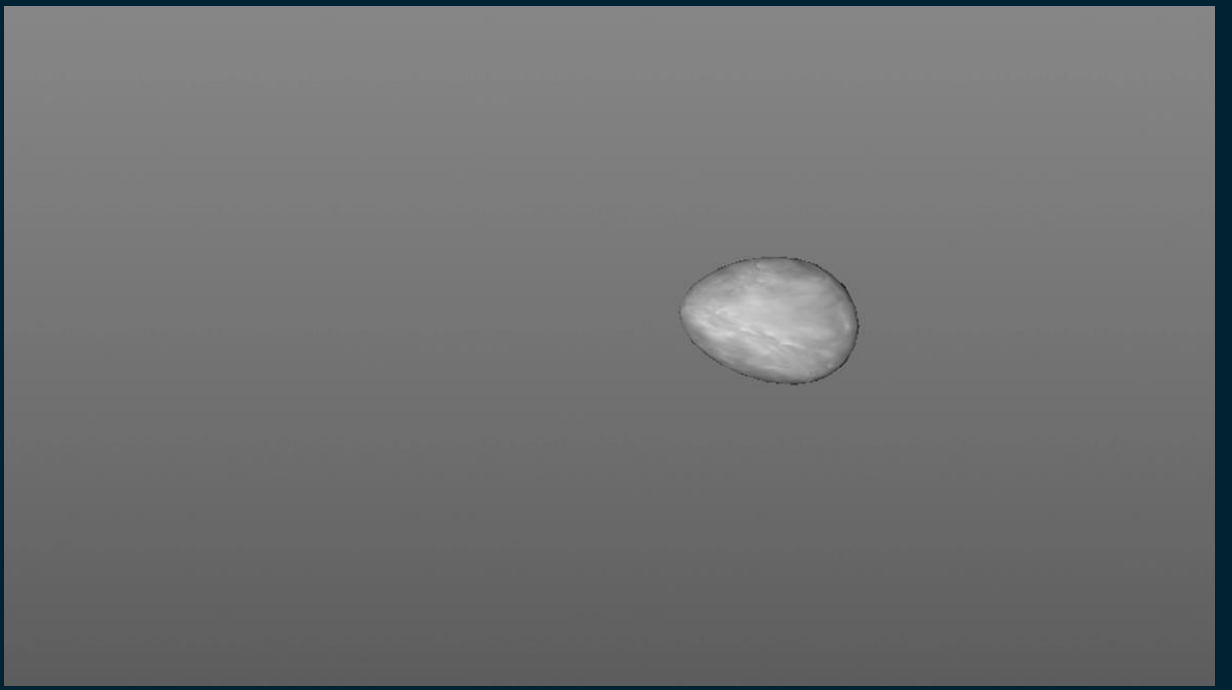
SATIS is designed to quickly assess near-Earth objects (NEOs) to gather essential data about their characteristics.

Payloads

Hyperspectral imager VIS/NIR/SWIR, TIR imager, Laser altimeter, radio science experiment

Mission Profile

Launch NET 2030 to Earth escape trajectory and up to 2-year transfer with electric propulsion to rendezvous the target asteroid



Small Missions for Moon Exploration: VMMO

Mapping Lunar Surface

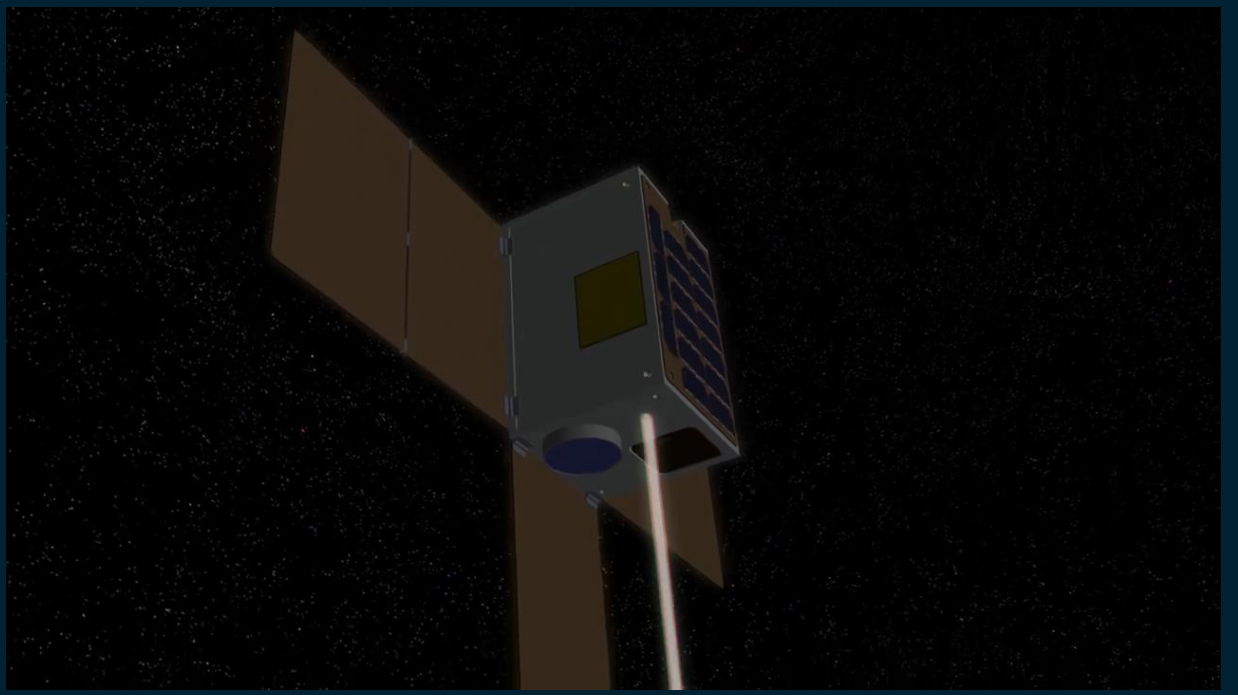
The mission aims to effectively map the distribution of volatiles and minerals on the Moon's surface.

Supporting Future Exploration

This mapping will support future exploration missions, guiding astronauts and robots in resource utilization.

Resource Utilization Efforts

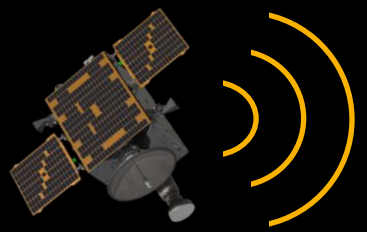
The data gathered will assist in identifying resources that can be utilized for sustaining human activities on the Moon.



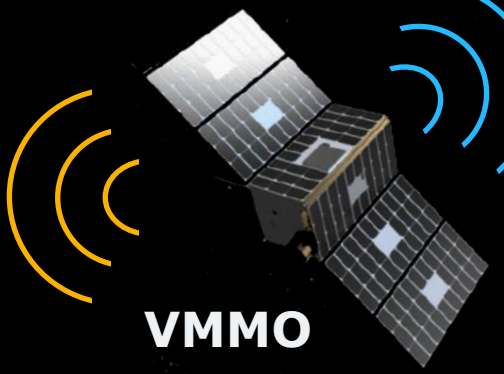
Small Missions for Moon Exploration: VMMO

DTE X-band

Lunar Pathfinder



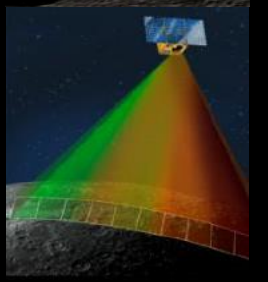
S-band



VMMO

VMMO Passive Mode:
Ilmenite in-situ
Resource and mineralogy
mapping at 300, 532, 690,
1064, 1350, 1560 and
1650 nm

VMMO Active Mode:
Water-Ice Mapping
at 532, 1064 and
1560 nm



Small Missions for Moon Exploration: Pre-Phase A Studies

Identifying Requirements

Pre-phase A studies focus on identifying the scientific and engineering requirements necessary for lunar missions.

Shaping Mission Concepts

These studies play a critical role in shaping mission concepts that align with identified requirements for future lunar exploration.

Ensuring Feasibility

Pre-phase A studies ensure the feasibility of lunar missions by evaluating technical, scientific, and operational aspects.

LightShip Propulsive Tug

Facilitating Affordable Mars Missions

LightShip intends to carry up to 12 passenger spacecraft to Mars while providing communication and navigation services. LightShip-1 will be the first of potentially 6 missions, offering a unique chance for network science.

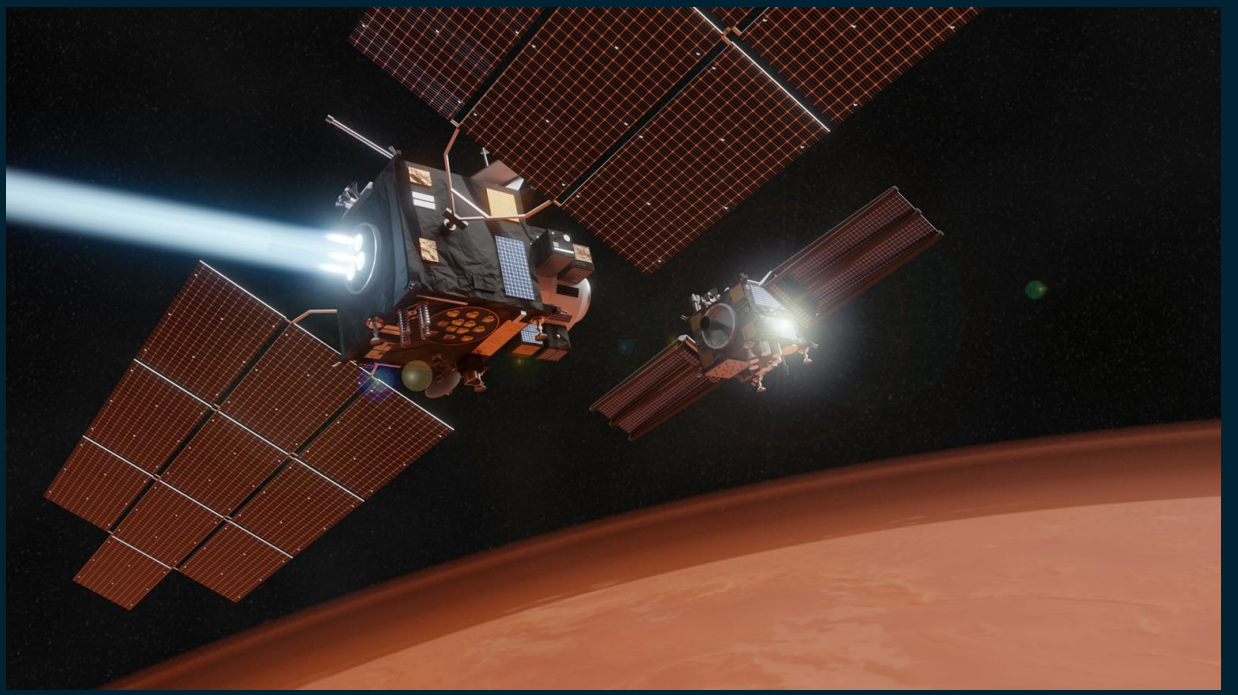
Scientific Objectives

The initial spacecraft, SpotLight, will create high-resolution maps of Mars from a low orbit around 300 km.

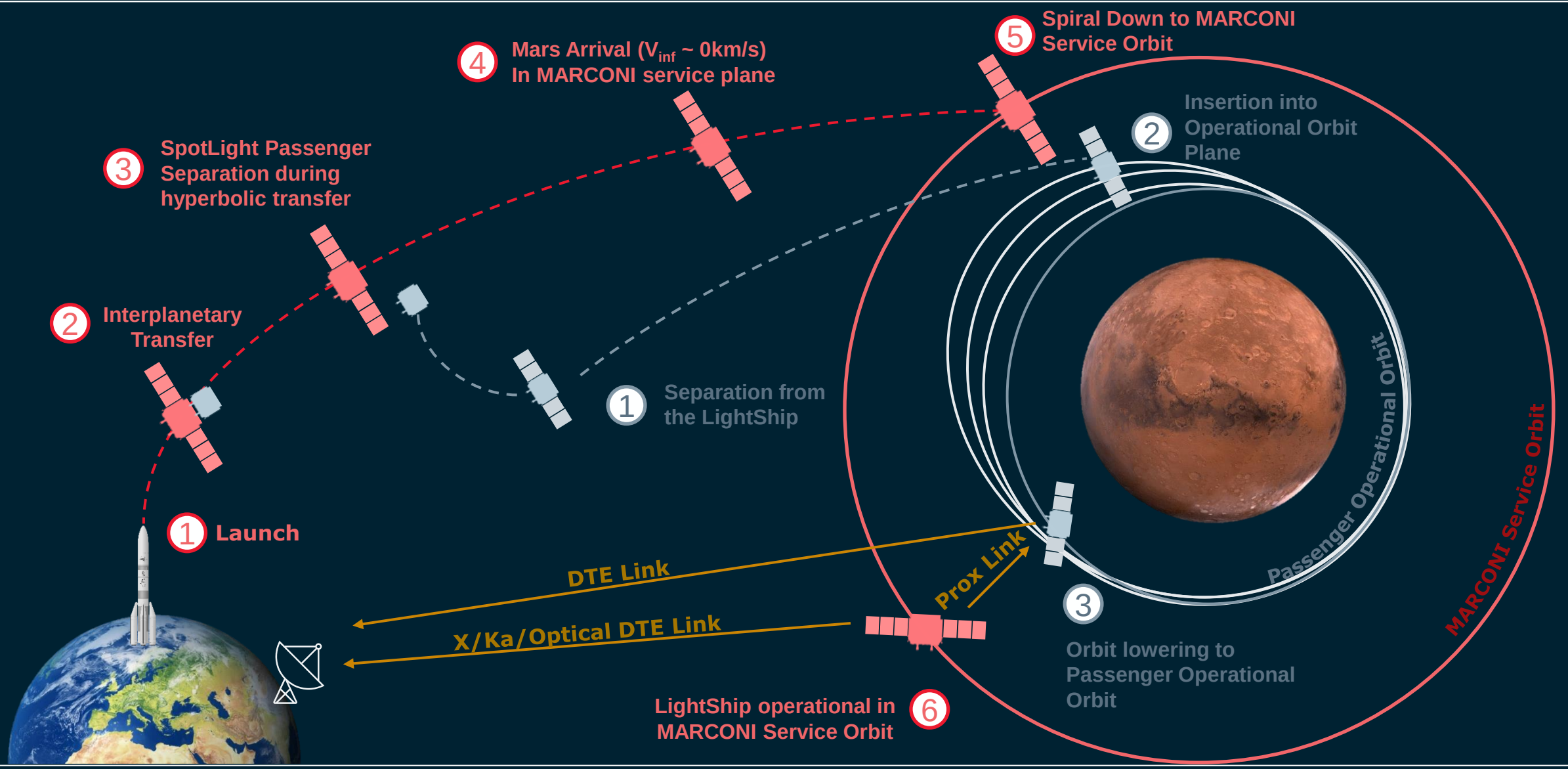
Current Progress

Industrial Phase A/B1 Study: Q4 2024 – Q2 2027

Expected launch readiness for LightShip-1: 2032



LightShip Mission Profile



Low-Cost Mars Platforms

Cost-Effective Mars Platforms Pre-Phase A Evaluations

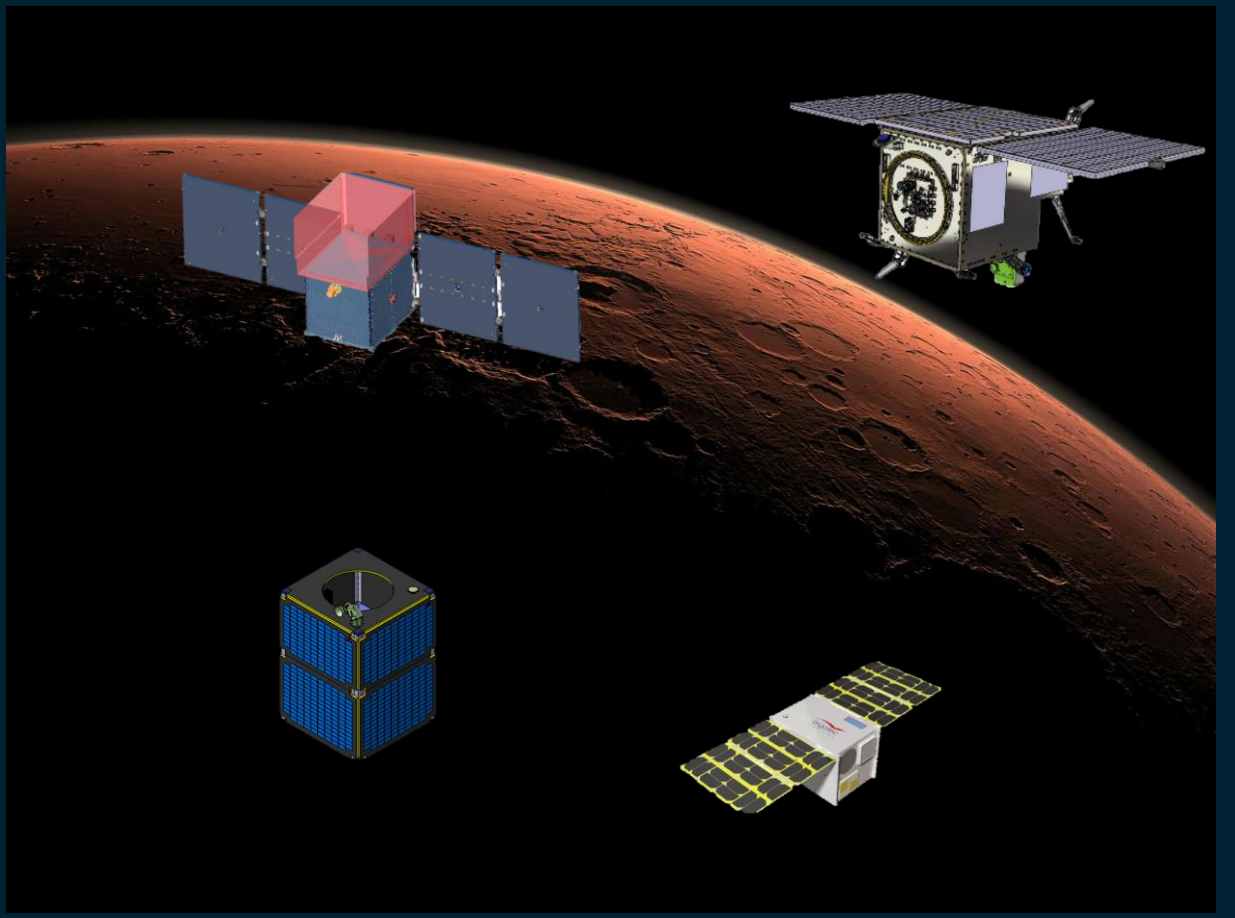
Currently, there are four contracts underway to assess the Technology Readiness Level (TRL) of the European SmallSat platform for LightShip and to identify any shortcomings.

Passenger Interactions with LightShip

A comprehensive analysis of the interfaces that passengers will engage with during their journey aboard LightShip.

Technological Gaps and Platform Functions

Recognize any technological gaps that need further development to facilitate a SmallSat mission around Mars, and assess the platform's capabilities and interfaces for carrying payloads to explore Mars.



Conclusions

Innovative SmallSat Missions

SmallSat missions are transforming the landscape of space exploration by utilizing budget-friendly approaches and cutting-edge technologies.

Advancing Planetary Science

SmallSats are showcasing their capability to conduct significant scientific studies, including the analysis of planetary atmospheres and monitoring space weather, which enhances our understanding of the solar system.

A New Chapter in Cosmic Exploration

The number of interplanetary SmallSat missions is expected to rise in the near future, driven by the collaborative efforts of international space agencies, private companies, and academic institutions. By pooling their resources and expertise, these entities aim to achieve ambitious exploration goals.