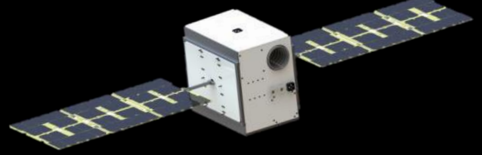
ASI CubeSat Workshop
2-4 July 2024
Roma, Italy

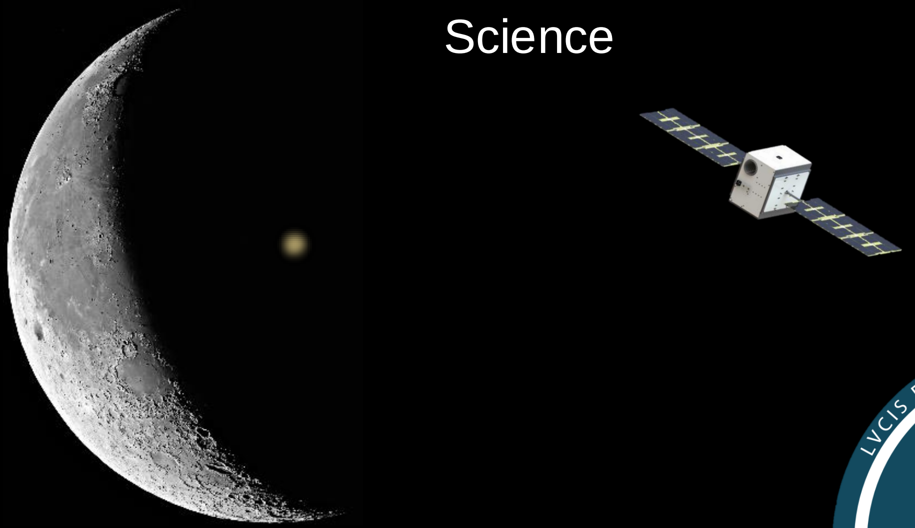


Phase B Design of LUMIO: A Lunar CubeSat Mission at Earth-Moon L2

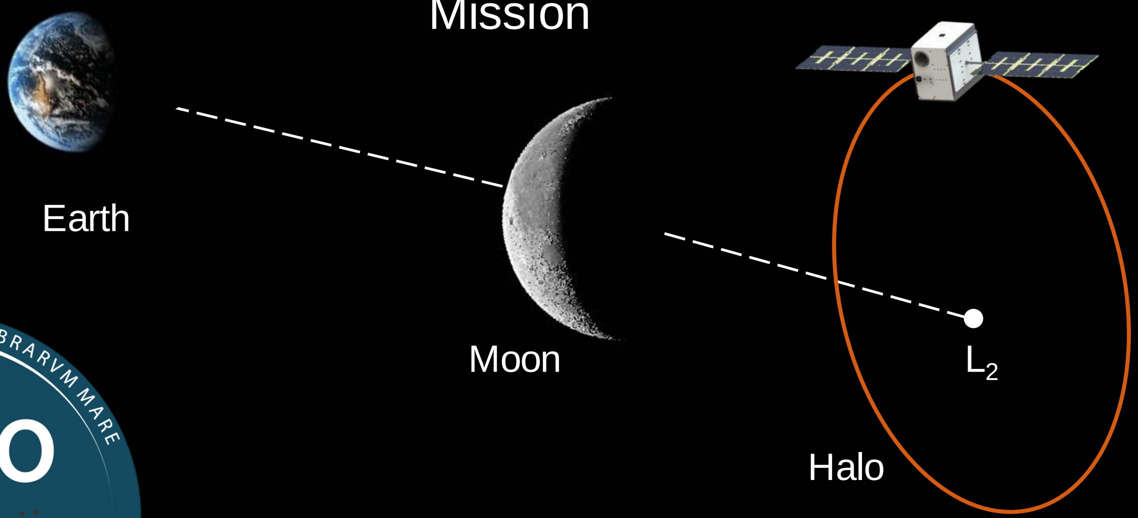
F. Topputo and the LUMIO Team

LUMIO in a nutshell

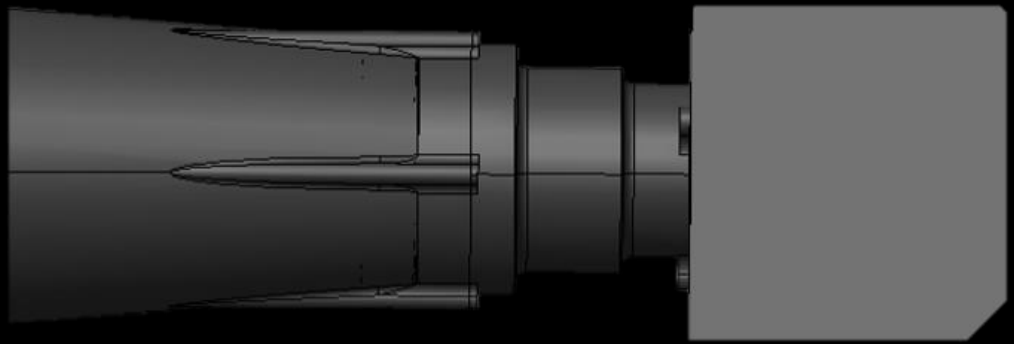
Science



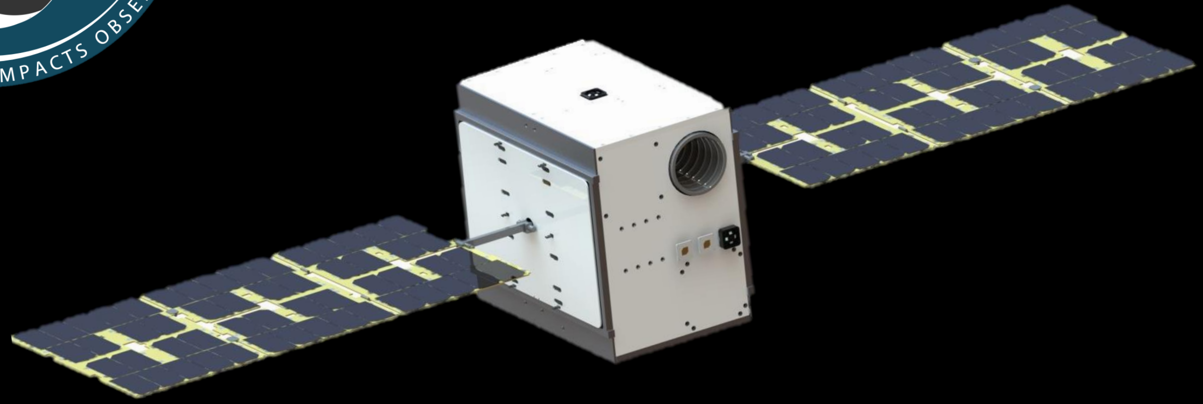
Mission



Payload: VIS, NIR



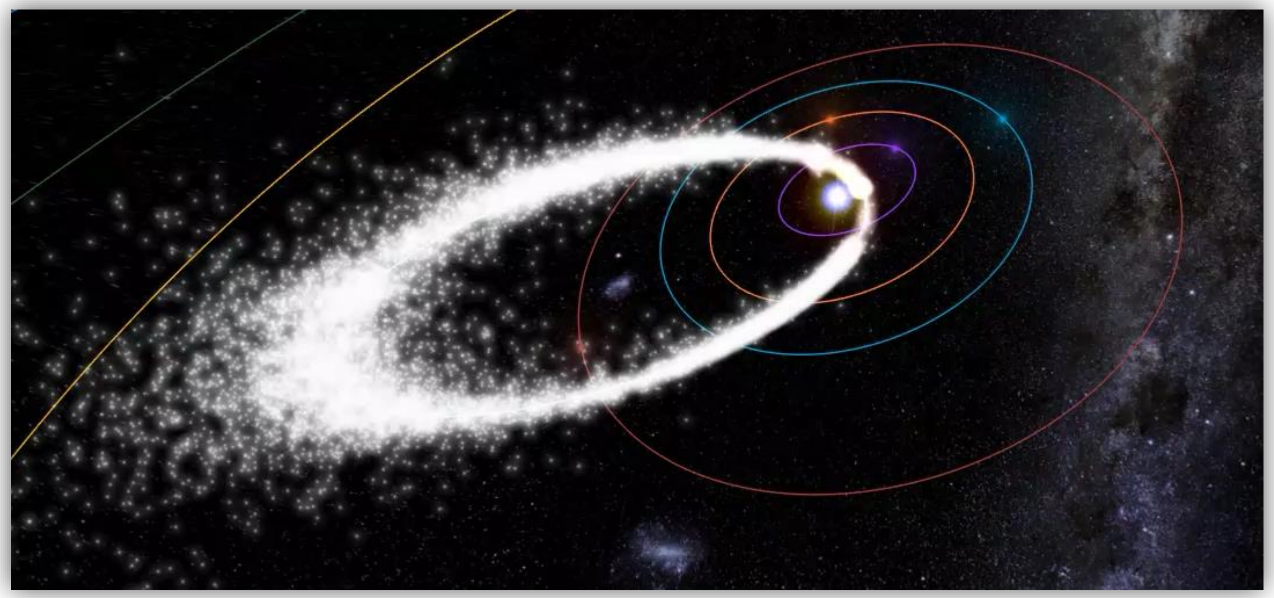
Platform: 12U-XL



LUMIO science

CubeSat mission to a halo orbit at Earth–Moon L_2 that shall observe, quantify, and characterise meteoroid impacts on the Lunar farside by detecting their impact flashes

Meteoroid impacts → Crater excavation | Seismic wave | Particles ejection | Radiation emission



Rendering of GEM Shower. Credits: www.meteorshowers.org

NELIOTA (ground). Credits: esa.int

Ground- vs space-based observations

Restrictions of Ground-Based Observations

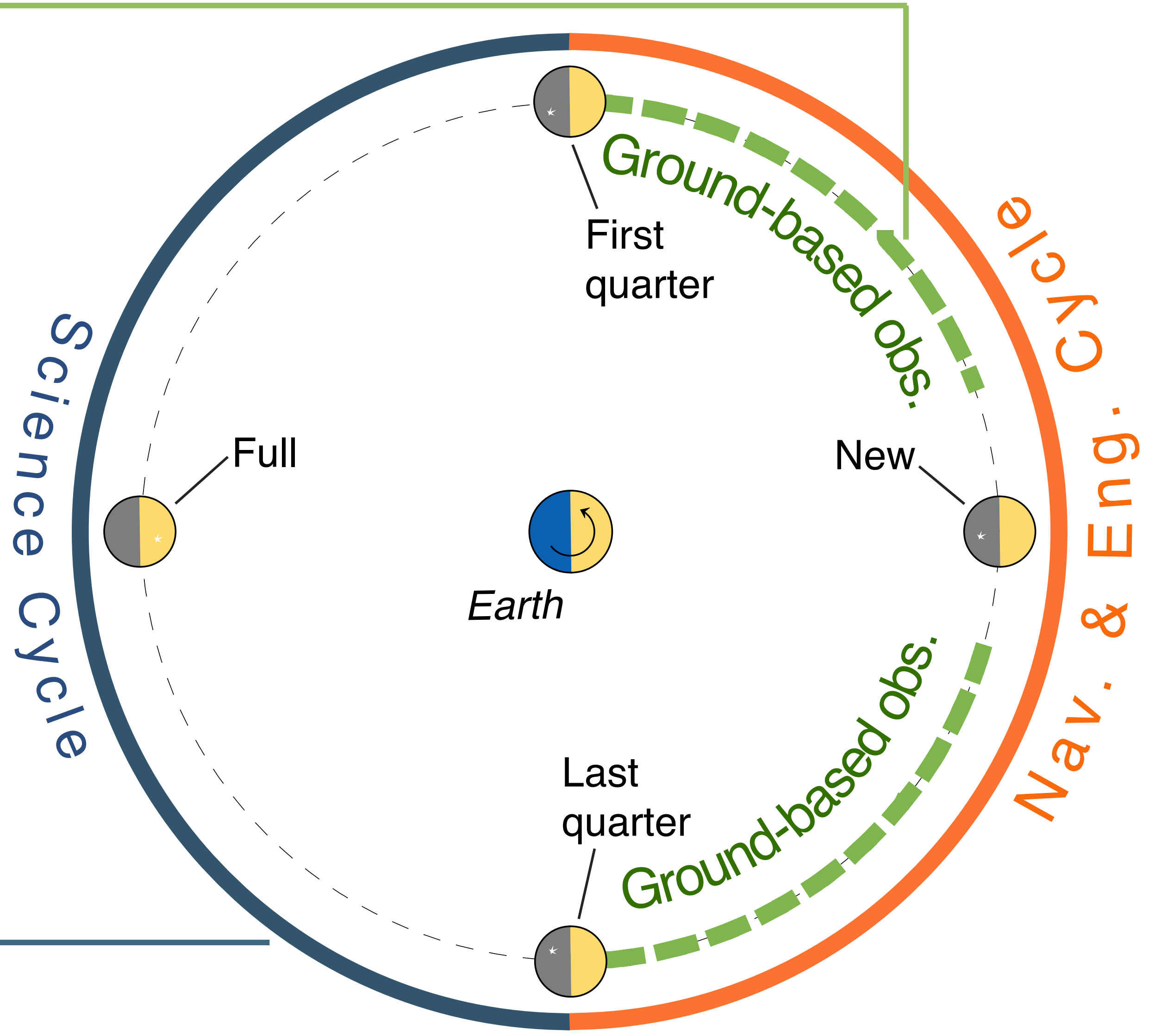
- Possible only during Earth's night
- Only with 10-50% illumination
- Only Apex, Antapex sources detectable
- No full disk possible (straylight)
- Affected by Earthshine
- Constrained by weather
- Signal attenuated by atmosphere

Advantages of Space-Based Observations

- Uninterrupted observations (~15 days)
- Anti-helion, toroidal sources detectable
- Possible simultaneous obs (space+ground)

Observation of lunar farside

√ No Earthshine, high-quality science products
√ Complement ground-based observations



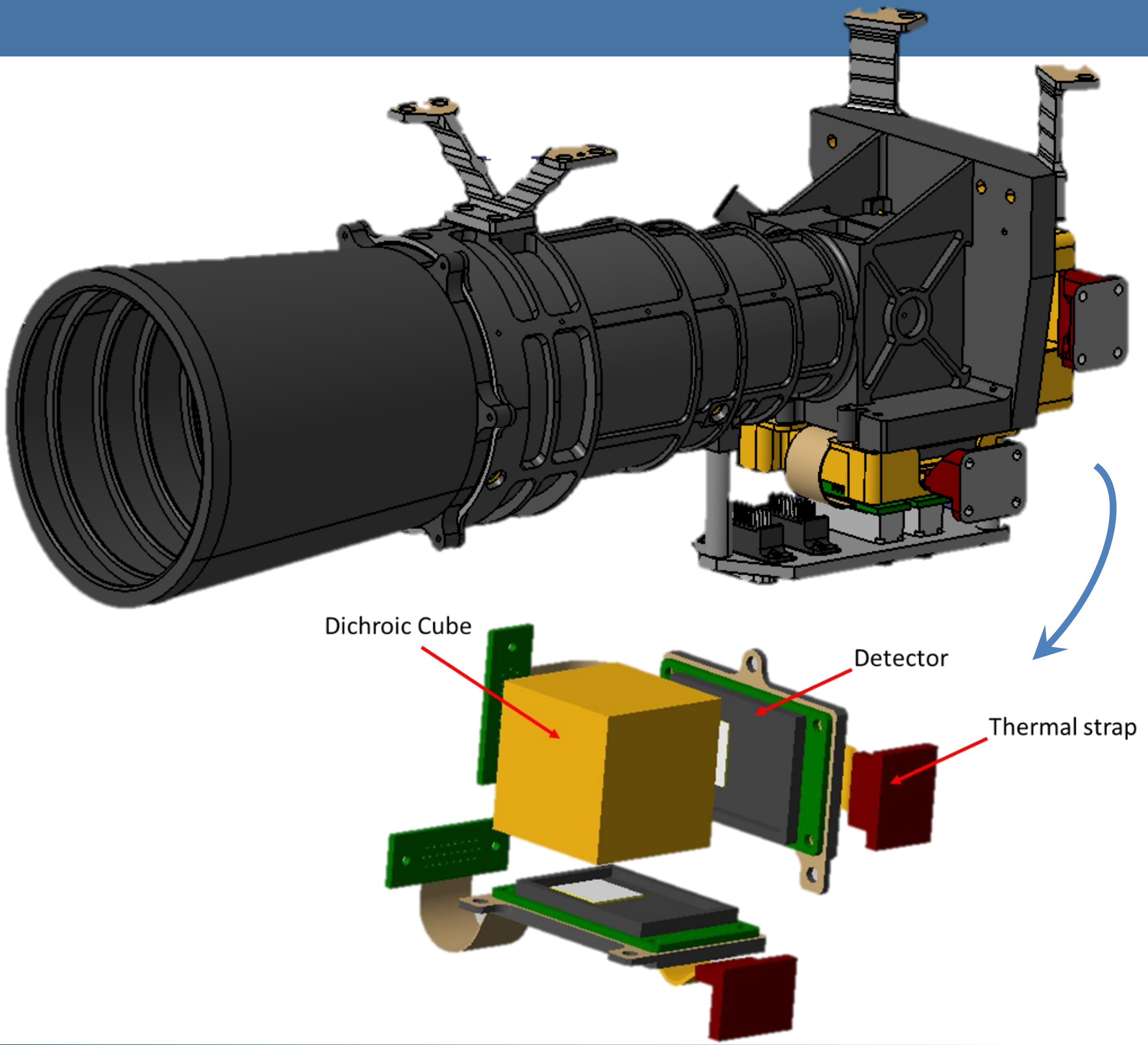
LUMIO-Cam

Main features

- Acquisitions in 450–950 nm (CCD)
- Beam splitter (450-800, 850-950 nm)
- High frame rate acquisition (15 fps)
- Synchronous acquisitions on two FPA
- 6 deg FOV, 127 mm focal length
- 100 mm baffle to avoid straylight
- Volume ~ 3U + PE of 1U (4 kg)
- Custom development

On board payload data processing

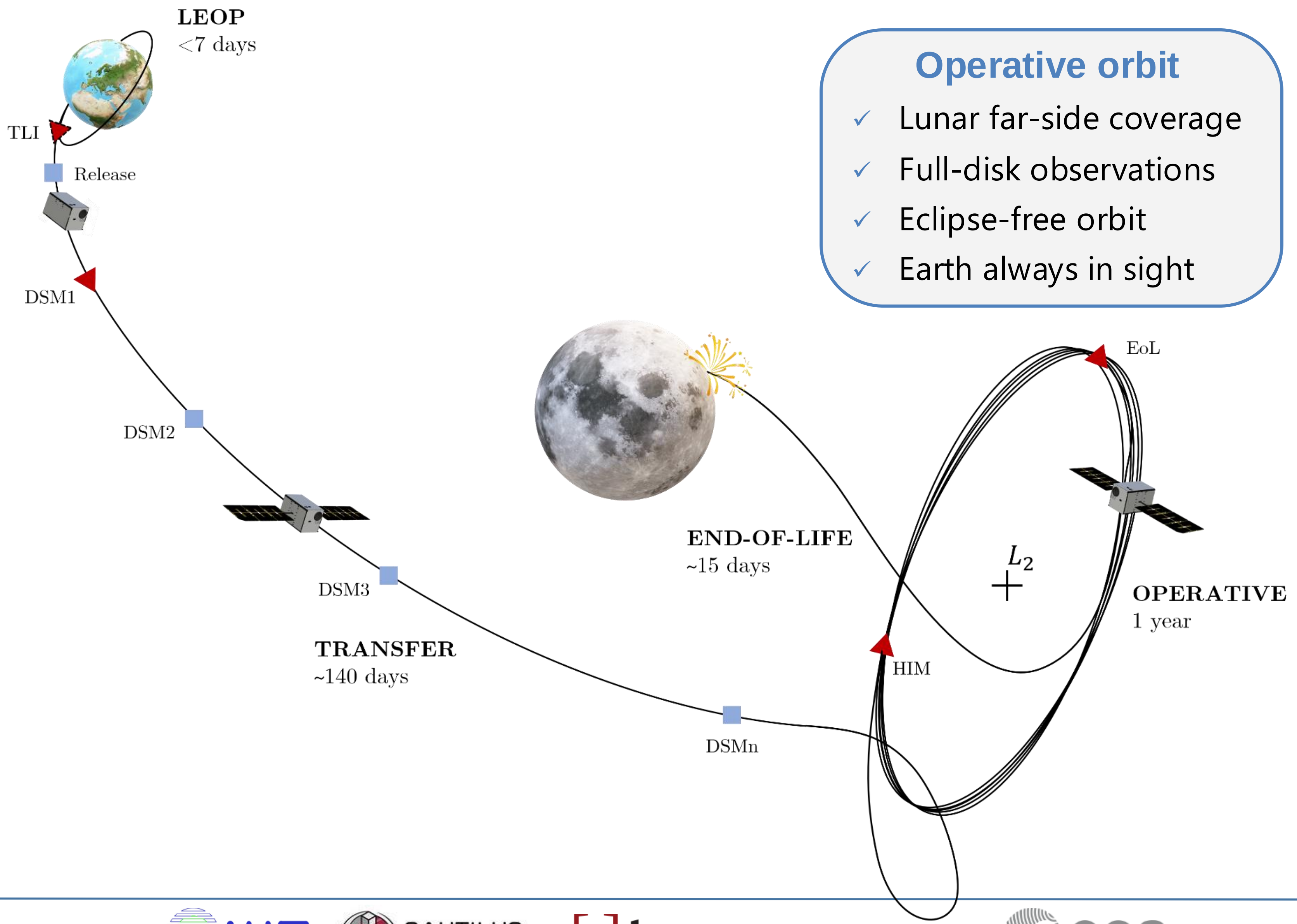
- On board validation of impacts
- Only main products retained



LUMIO mission design

Main assumptions

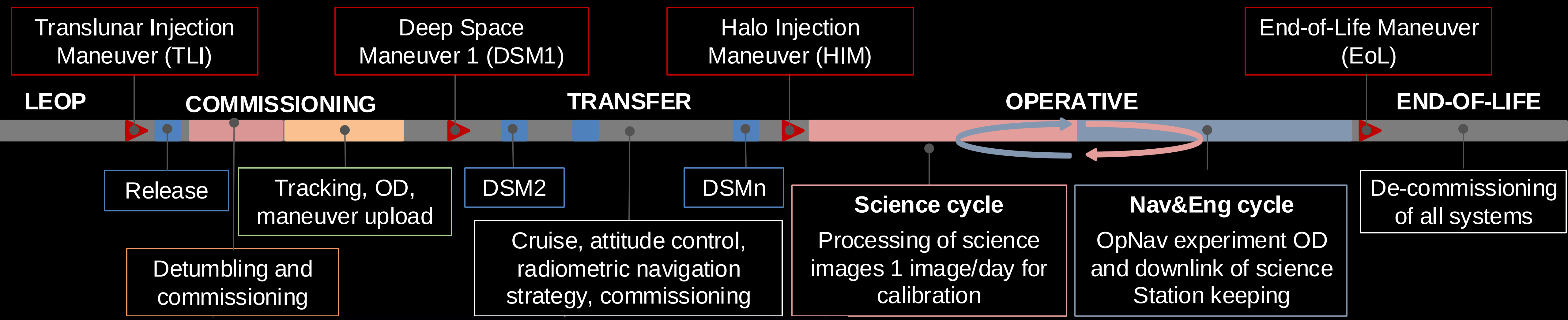
- Launched as piggy back of a CLPS mission using WSB lunar transfer
- Released from launcher/carrier after completion of the TLI
- Implements a transfer to the halo orbit using its own propulsion system

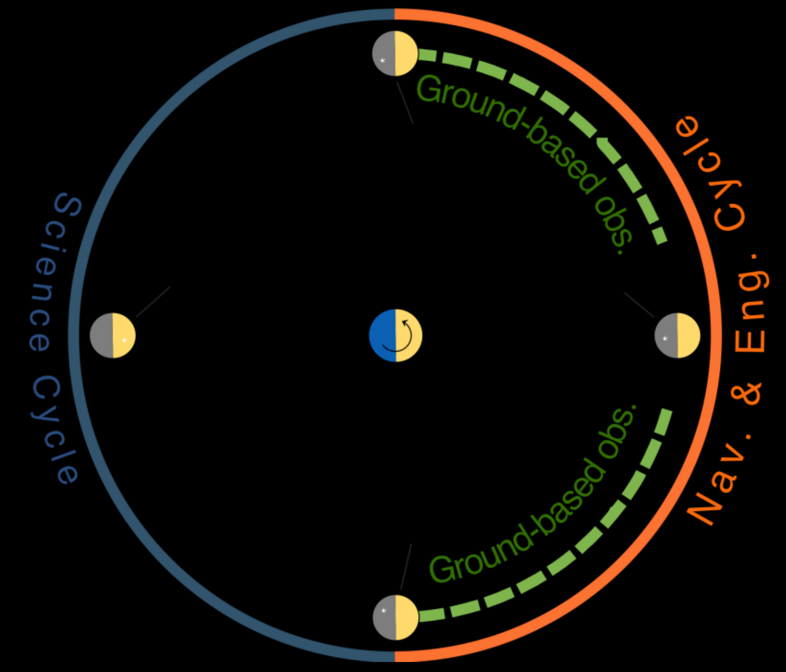


Operative orbit

- ✓ Lunar far-side coverage
- ✓ Full-disk observations
- ✓ Eclipse-free orbit
- ✓ Earth always in sight

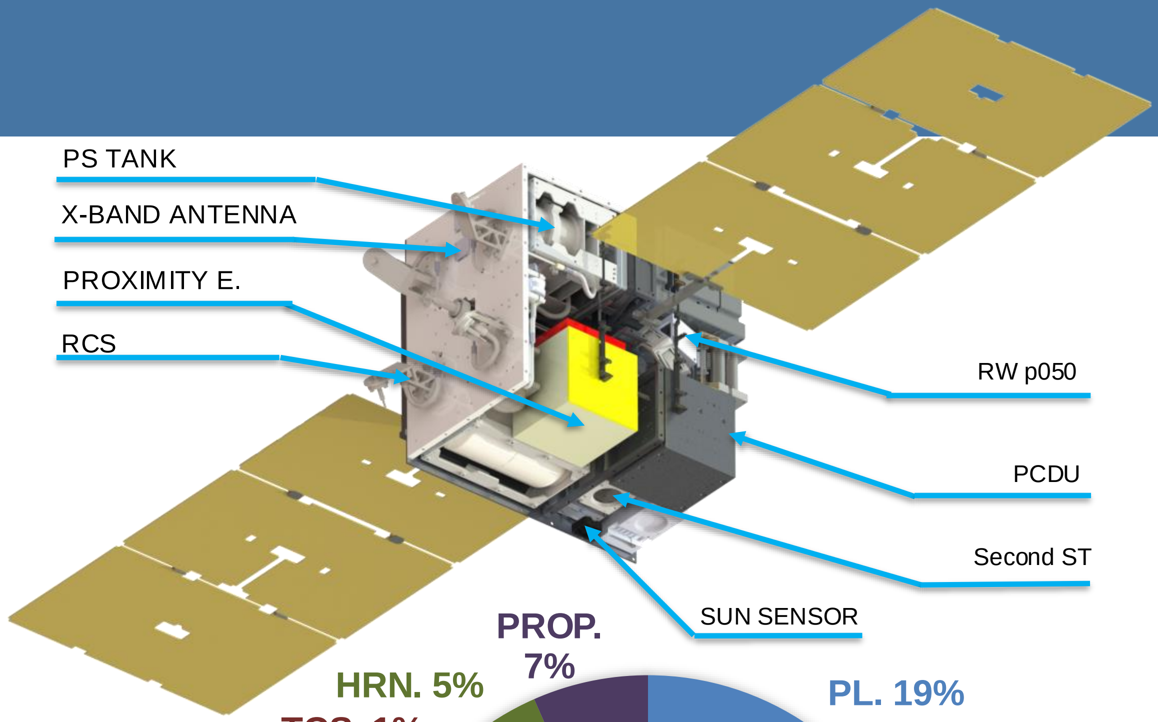
LUMIO mission phases

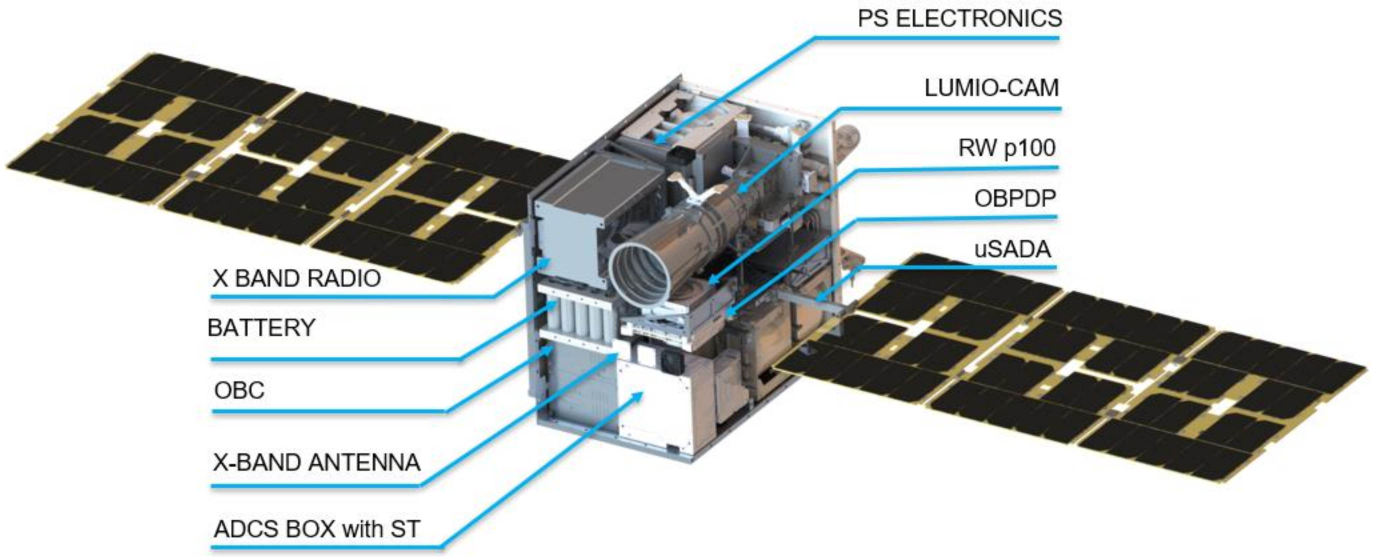


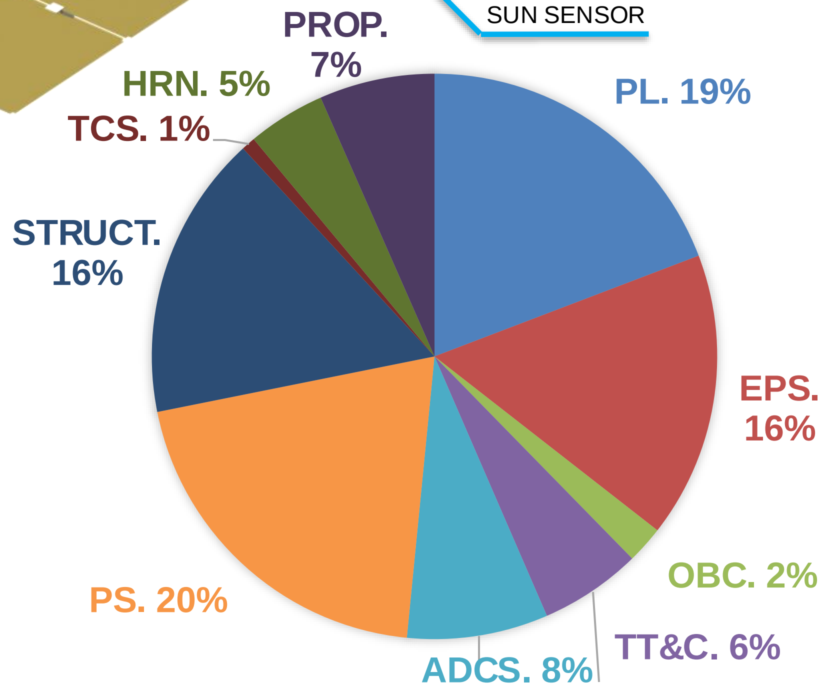


LUMIO platform

- 12U (XL) form factor, 2 deployable SA
- 1.5 years, >1 year in lunar environment
- Mass: <29 kg
- Power: ~110 W generation
- DTE link: X-band (radio nav, P/L data, T&C)

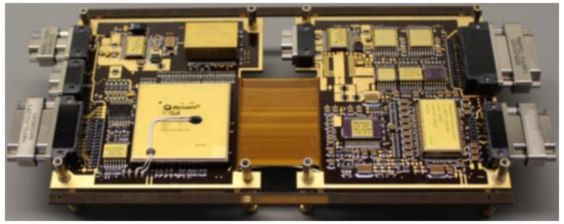






LUMIO key technologies

Fermi OBC & OSW

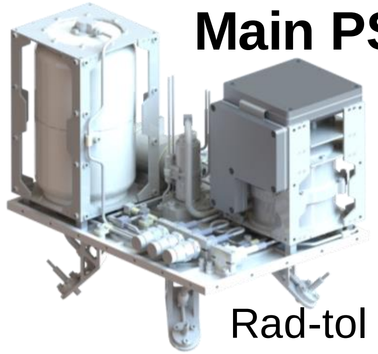


HW acceleration
Real time OS

Volta PCDU

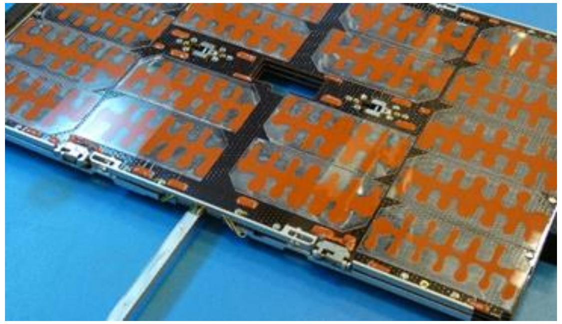
100+ W, SET/SEL-protection
Isolated power rails (2.5V, 3.3V, 5V, 2x 12V)
FDIR, SPA & end-of-life management

Main PS & RCS



Rad-tol electronics
Green propellant & cold gas RCS
Main PS budget Δv= 80 m/s

Solar array wing assembly
Hold down release mechanism
Solar array drive unit.



µSADA

TM/TC, tracking, science data, ranging
Output RF power: 2 W

C-DST

2 strar trackers, 2 sun sensors
4 reaction wheels, 4 RCS thrusters
Gyroscopes, control board

ADCS

LUMIO timeframe

Lunar Meteoroid Impacts Observer

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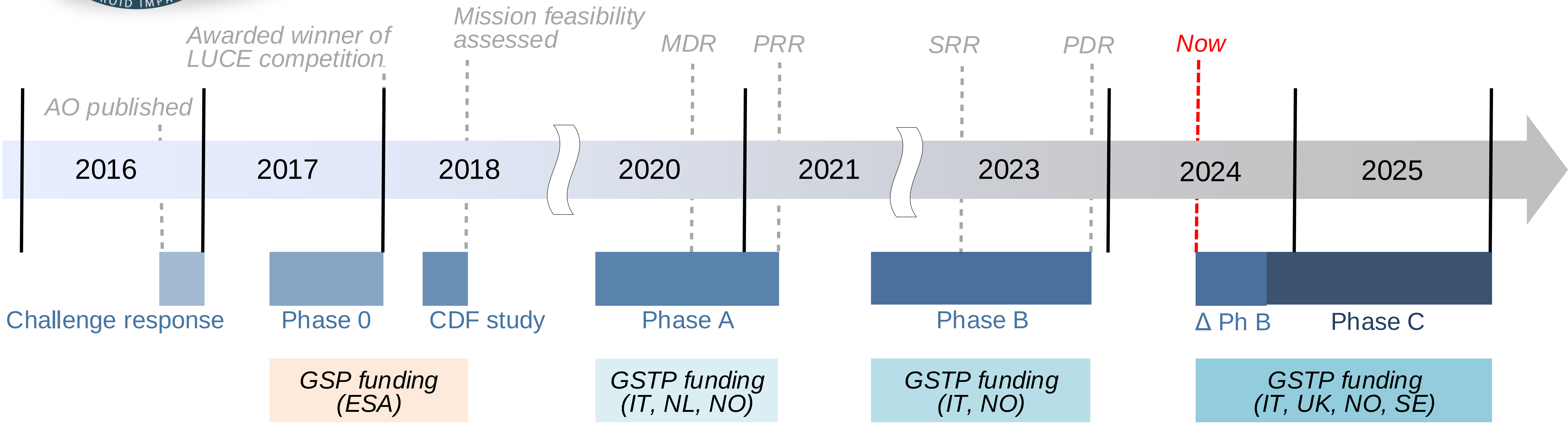

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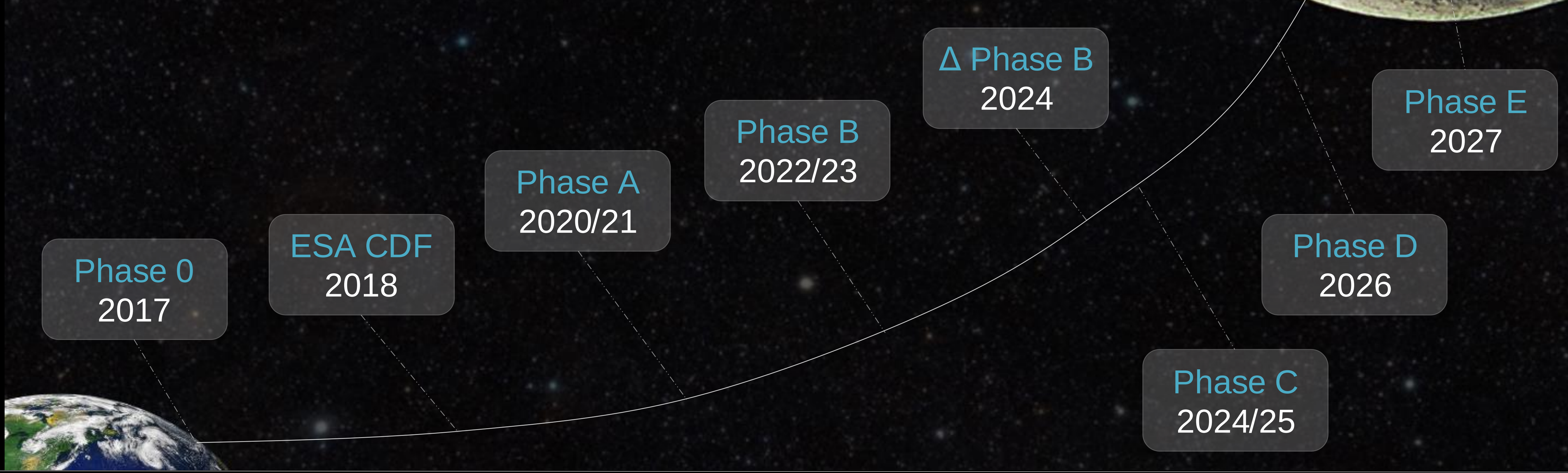
LUMIO roadmap

Objectives

- **Science**: To refine Lunar meteoroid environment model
- **Technology**: To demonstrate Lunar CubeSat technologies



LUMIO Phase B Consortium

ASI

Main funding body

Norsk Romsenter
Norwegian Space Agency

Funding body

esa

Project Coordination

LVCIS FVLGOR IN TENEBRARVM MARE
LUMIO
LUNAR METEOROID IMPACTS OBSERVER

POLITECNICO MILANO 1863	Prime Contractor Project Management Science, MA, AOCS/GNC
argotec	Platform Provider
LEONARDO	Payload Provider
IMT Ingegneria Marketing Tecnologia	X-band & SADA Provider
NAUTILUS NAVIGATION IN SPACE	Ground Segment Design Flight Dynamics Ops.
s[&]t	Onboard Payload Data Processing

LUMIO science team

Science Board

Principal Investigator
Francesco Topputo (PoliMi)
Science Lead
Fabio Ferrari (PoliMi)

Mission Advisors
Eleonora Ammannito (ASI)
Detlef Koschny (TUM)
Richard Moissl (ESA)

Funded by ASI

Working Groups (WGs)

- Meteoroid characterization
  Chair: Chrysa Avdellidou (UoL)
- Surface characterization
  Chair: Maurizio Pajola (INAF)
- Observation
  Chair: Hadrien Devillepoix (CU)
- Impact modelling
  Chair: Sabina Raducan (u^b)
- Lunar environment & engineering
  Chair: Pierluigi Di Lizia (PoliMi)
- Citizen science
  Chair: Tony Cook (Aber)

Core members (28)

Institutional partners (7)

Industrial team (6)

External collaborators (14)

Science Operation Center (SOC)

Coordination: Eloy Peña-Asensio (PoliMi)

Operations Planning

Payload Data System

60+ scientists involved

Lessons learnt (so far)

Mission

- Deep-space impulsive maneuvers are critical operations for lunar CubeSats
- Institutional flight dynamics great for large mission, not for lunar CubeSats

System

- Moving from LEO to lunar environment offers less COTS elements
- Some COTS elements are often “not as developed as advertised”
- There is a technological gap for mid-Δv-budget (40-80 m/s) propulsion systems
- There are few to none COTS Reaction Control Systems (RCS)
- A sophisticateed payload increases the complexity and cost of the mission

Project

- Injecting a CubeSat in a lunar transfer might be cheaper than thought
- For deep-space CubeSats, initial idea to flight can take a decade
- Implementing a mission under ESA’s GSTP is a political-technical puzzle

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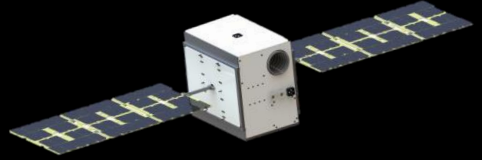

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