WORKSHOP “L’IMPEGNO ITALIANO NEL SETTORE DEI CUBESAT: TECNOLOGIE E MISSIONI FUTURE” – 2° EDIZIONE

2 - 4 July 2024, ASI, Roma

The INNOVATOR CubeSat Mission and the Development of its InterSatellite Link Transceiver

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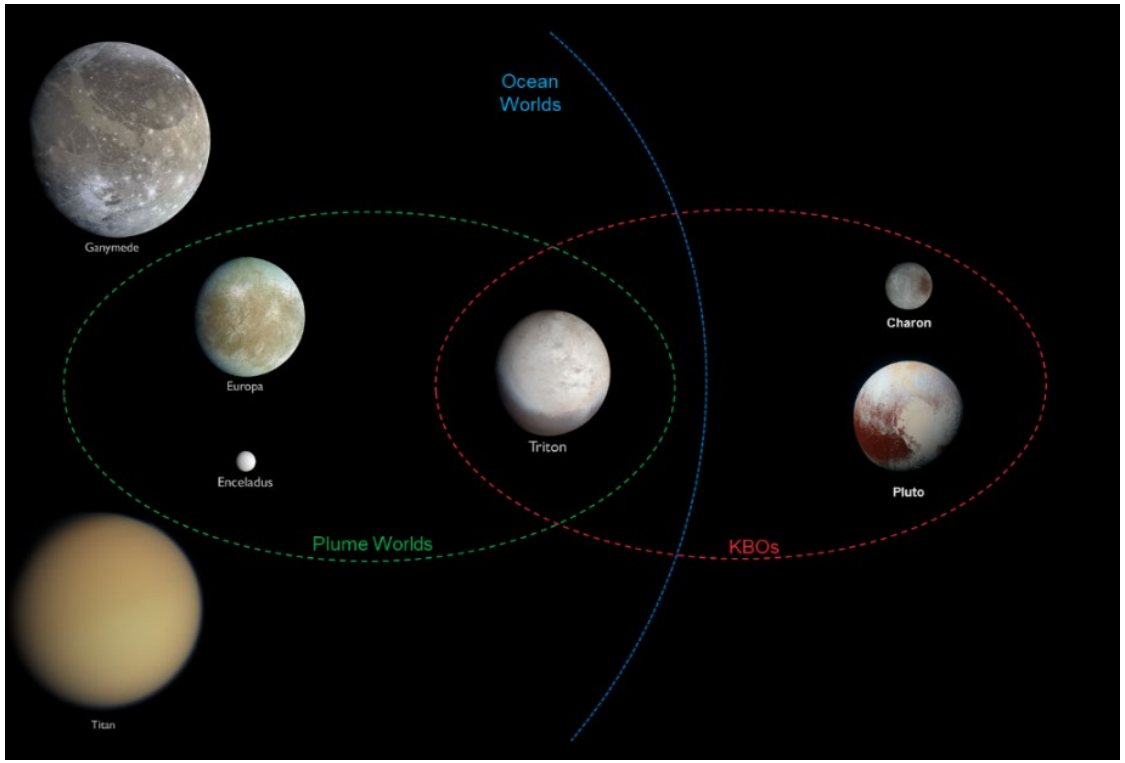
INNOVATOR

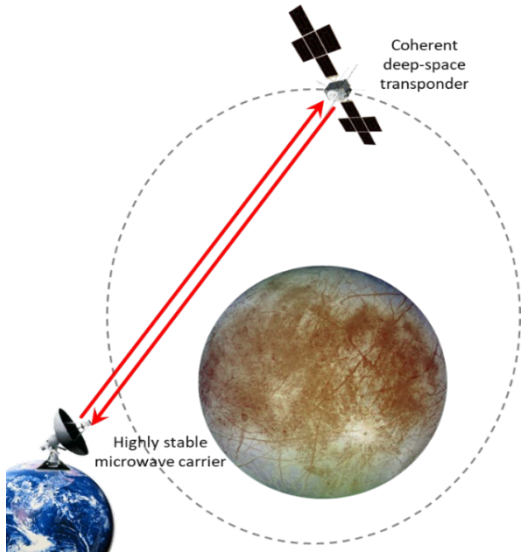
INtersatellite liNk fOr graVity and ATmOspheRic science

Consortium

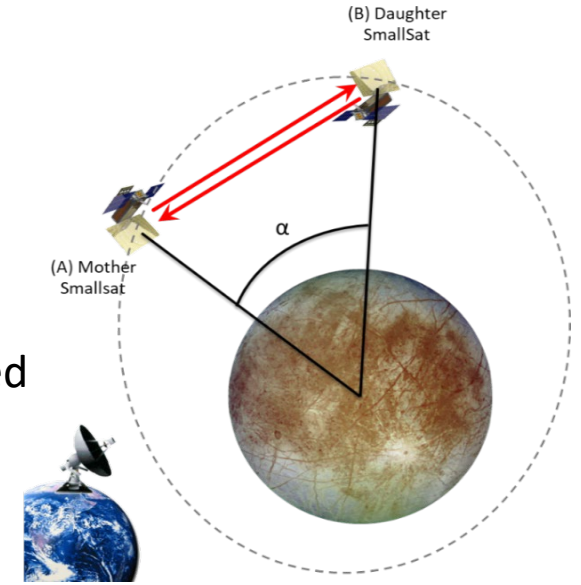
Distretto Tecnologico Aerospaziale (DTA) - Prime
IMT s.r.l.
Planetek Italia s.r.l.
Università di Bari
Politecnico di Bari (PoliBa)
Alma Mater Studiorum - Università di Bologna
Thales Alenia Space Italia s.p.a.

Motivations





Satellite-to-ground link based radio-tracking experiment



Satellite-to-satellite link based radio-tracking experiment

Mission Outline

INNOVATOR mission goal

To test in orbit an **innovative payload** for precise radio science observations in the fields of:

- **gravity science** (determination of planetary masses and gravity fields)
- **atmospheric science** (determination of the properties of neutral and ionized atmospheres)

➢ The mission is funded by the **Italian Space Agency**

Mission Highlights

1. **IOV of a novel, CubeSat class, Inter-satellite-link for radio-science investigations**
2. **2 6U CubeSats** deployed on the same **SSO** with variable phasing
3. Measuring **Gravity profiles** and **Atmospheric profiles** at high altitudes
4. Development time (**phases A-D**): **2 years** - Operational lifetime (**Phase E**) **> 1 year**

INNOVATOR | Mission Elements & Roles

IMT

2 x 6U XL CubeSats

Agenzia Spaziale Italiana

Funding and coordination

Project Management

DTA DISTRETTO TECNOLOGICO AEROSPAZIALE

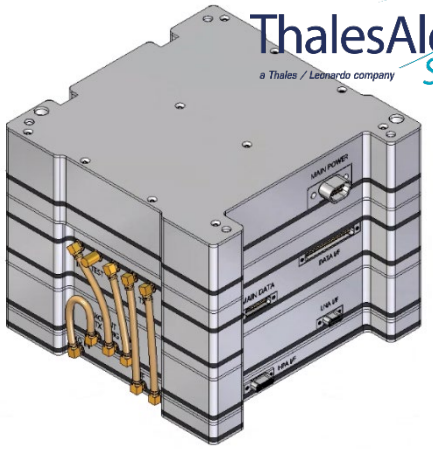
ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

Politecnico di Bari

Mission Design and Science Data Analysis

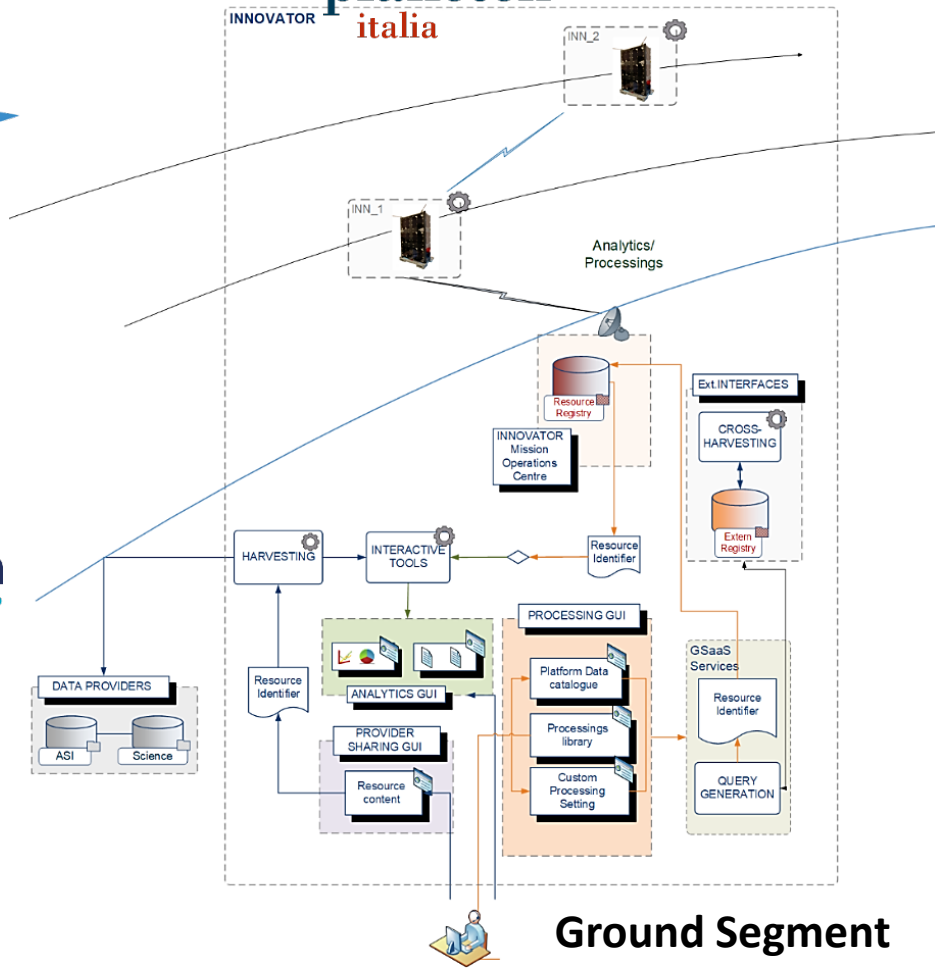
ThalesAlenia Space
a Thales / Leonardo company



Payload

Microsatellites and Space Microsystems - Laboratory -

planetek italia



Ground Segment

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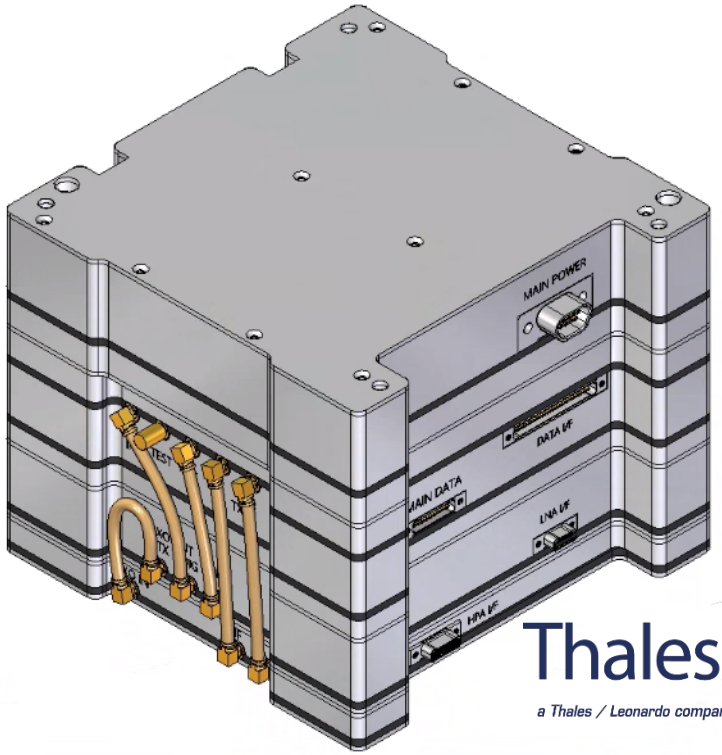
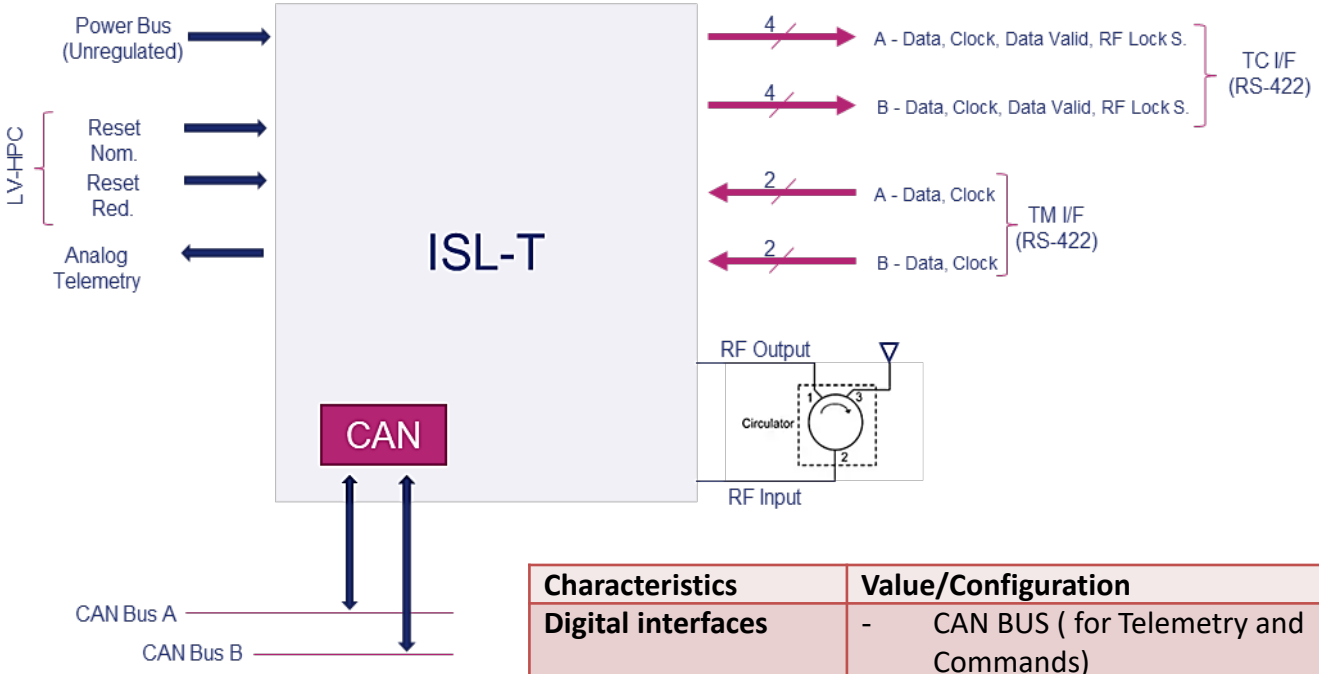
INNOVATOR | The Payload





Functions:

- TT&C
- Ranging measurements (< 10cm @ 1s int. time)
- Range-Rate measurements (< 50µm/s @60s int. time)

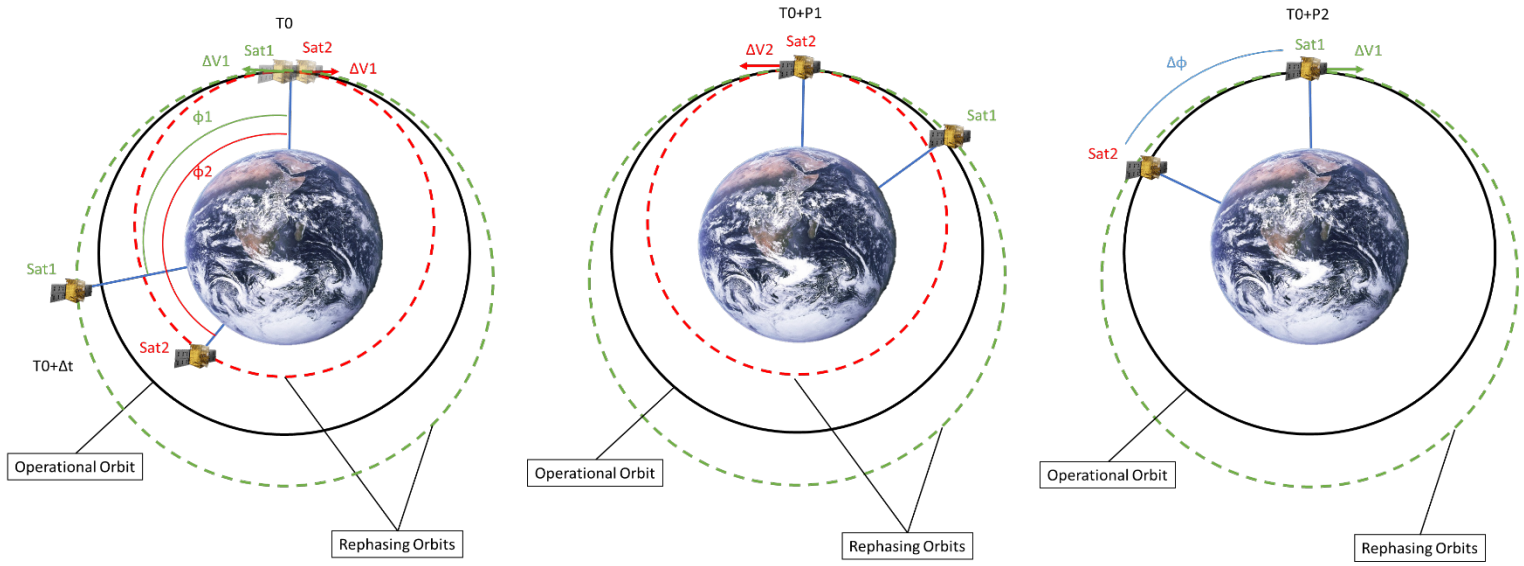
Characteristics	Value/Configuration
Digital interfaces	- CAN BUS (for Telemetry and Commands) - RS422 (for Payload data)
Power supply voltage	(12V-16.8V) or (24V-33.6V)
Uplink	2025 – 2110 MHz or 2200 – 2290 MHz
Downlink	2200 – 2290 MHz or 2025 – 2110 MHz
TX output power	Up to 1.5 W
Compatibility	Form factor PC 104-compatible
Power consumption in typical condition	- RX Only : 12,5 W - Rx + TX : 25 W
Total mass	Less than 978 g
ISL-T Size	1U

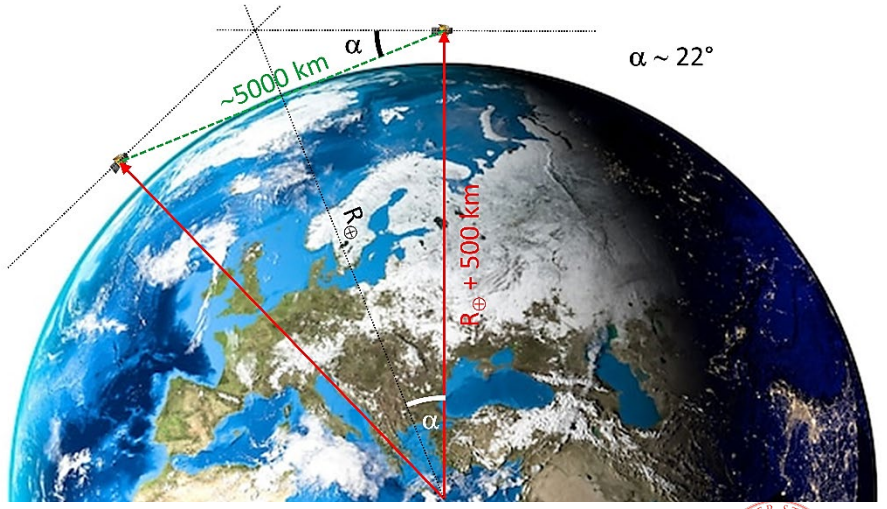
INNOVATOR | CONOPS

OPERATIONAL ORBIT: 500km Dawn-Dusk SSO (LTAN 06:00)

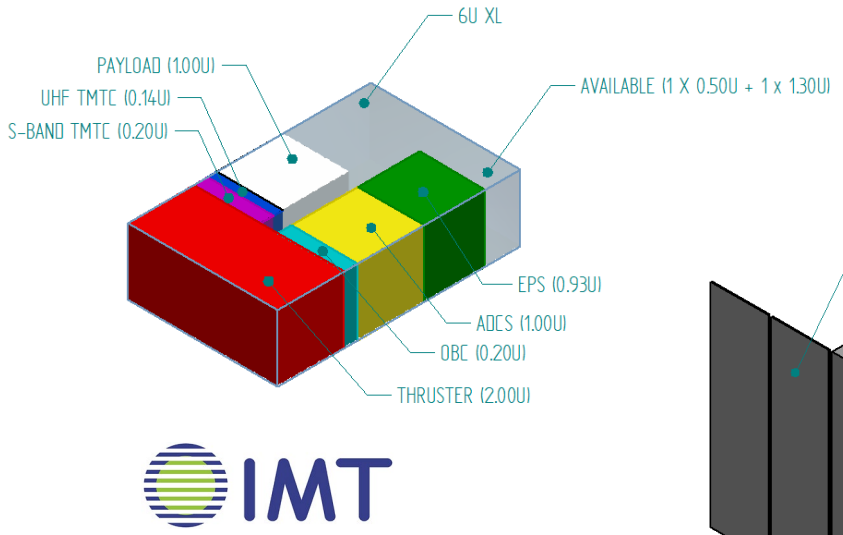
2 main mission phases

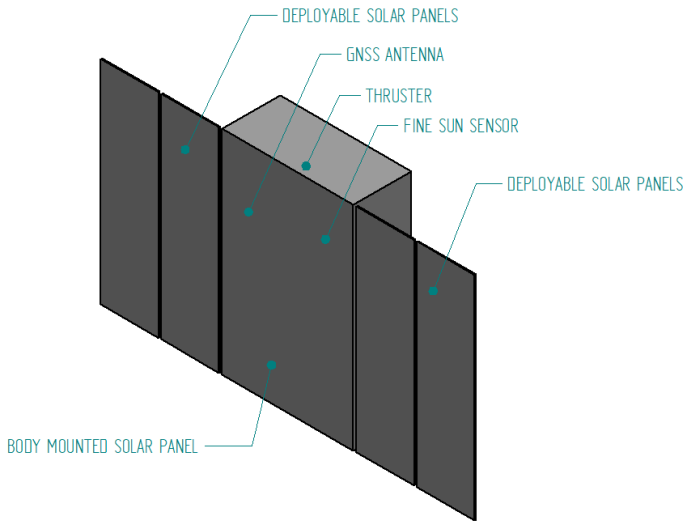
1. **Gravity Science Experiments (~ 6 months)**
   - Following a CubeSats rephasing maneuver - nominal inter-sat distance: ~20 km
2. **Atmospheric occultations (~ 6 months)**
   - Following a drifting manoeuvre from ~20 km to ~5000 km





INNOVATOR | Platform





Parameter	Value
Platform Type	CubeSAT 6U XL
Communication	TX/RX UHF TX/RX S-BAND
ADCS pointing accuracy	< 2°
Propulsion	Electrothermal Propulsion
Propellant Type	Water
ΔV	~ 50 m/s
Solar Panels	2 x Deployable Solar Panels
Solar Panel Peak Power	45W @ BOL
Battery Pack Capacity	84 Wh
Platform Dry Mass	10.5 Kg
Platform Wet Mass	10.9 Kg

ΔV needs

a. Phasing manoeuvre at the beginning of Phase I

b. Handover between Phase I and Phase II, placing the two S/C in two circular orbits with a relative orbital speed of 4 m/s

c. Collision Avoidance

d. De-orbiting maneuver to comply with a 5 years re-entry guideline

INNOVATOR | Ground Segment

Based on the Ground Segment as a Service (GSaaS) concept

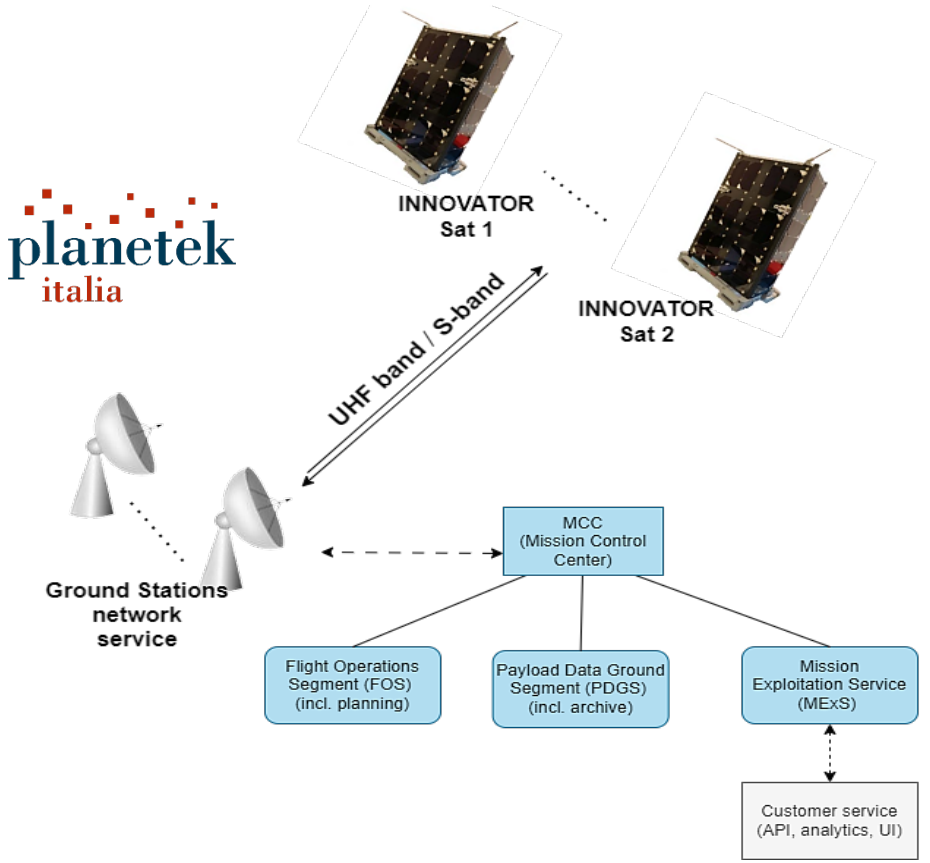
1. Ground Station Network with UHF and S-band link
2. Mission Control Center

Functions:

- Space2Ground and Ground2Space contacts
- Operations feasibility, scheduling, and execution
- Science data processing chain
- Mission exploitation and Data dissemination

Scientific Data Products

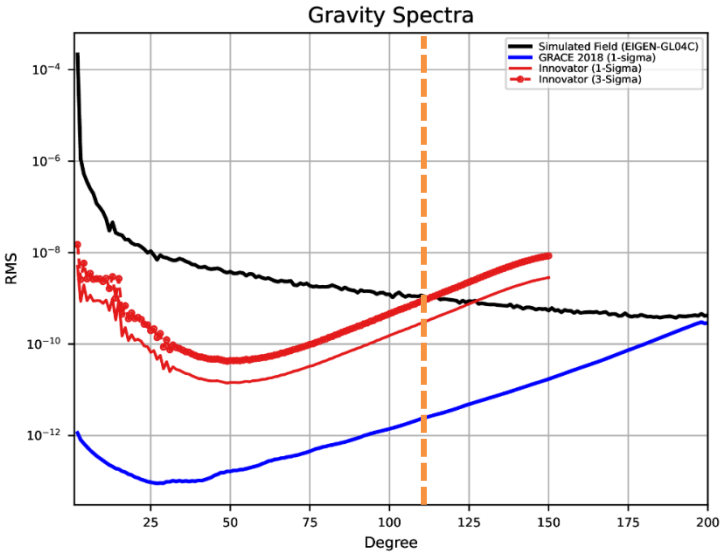
- Level 0: raw housekeeping and instrument data
- Level 1: calibrated data converted to engineering units
- Scientific Level: harmonic gravity coefficients, atmospheric refractivity, Total Electron Content (TEC)



INNOVATOR | Scientific Operations

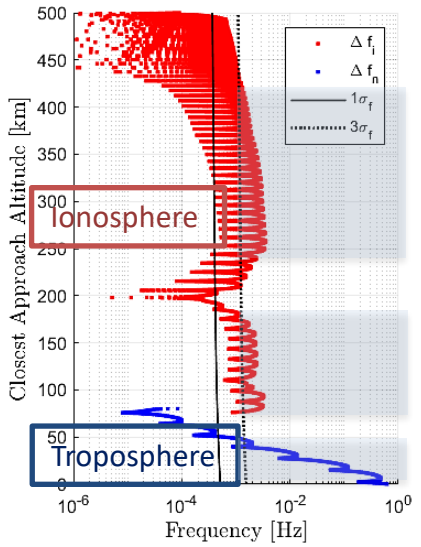
Gravity Science Experiment

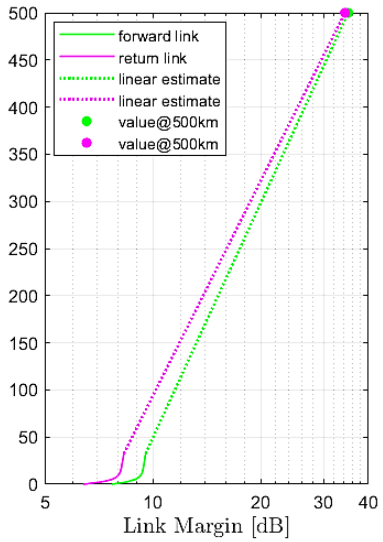
- Constant satellite phasing (≈ 20km inter-sat distance)
- Earth gravity field can be estimated through the joint OD of the 2 CubeSats
- Observability up to degree 110 is expected



Atmosphere Radio-occultation Experiment

- Satellites phase-drifting at ≈ 4 m/s
- Retrieval of the *neutral* atmosphere and *ionosphere density* profiles from the refractivity-induced ISL frequency shift
- Observability in three altitude regimes:
  - Low Troposphere (< 50 km)
  - Low ionosphere (80-180 km)
  - High ionosphere (200-430 km)





Conclusions and Next Steps

- Demonstration of feasibility of a CubeSat IOV mission hosting an ISL-T payload for radio science experiments in the field of gravity and atmospheric science
- A Concept of Operations was developed to fulfil the scientific requirements and payload validation objectives
- Initial evaluation conducted for the ΔV, mass, power, and link budgets to ensure mission feasibility within the 6U XL platform constraints.
- A detailed study of orbital geometry for both mission phases, especially Phase II, where CubeSats will be drifting at 5000 km apart to achieve an Earth-grazing RF beam, was conducted to maximize the scientific return.
- Follow-up - Phase B study where deeper analysis will consolidate the promising outcomes obtained so far.

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Thank you!

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