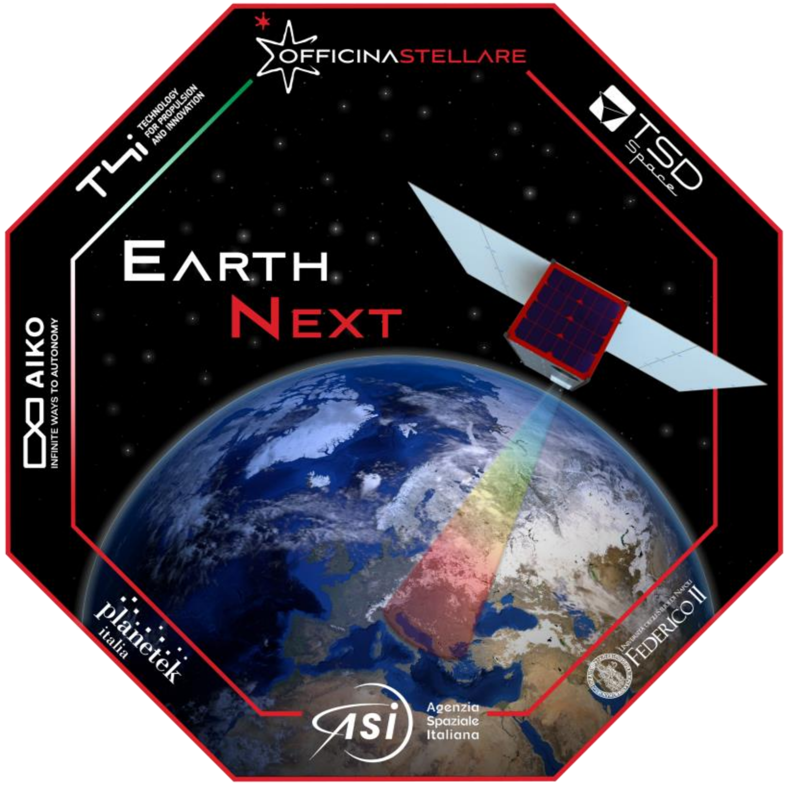


EarthNext: design preliminare di una piattaforma CubeSat italiana per Osservazione della Terra da orbita VLEO

L. Iannascoli, L. Cavicchiolo, E. Melozzi, A. Capanni, A. Turella, E. Piersanti – *Officina Stellare SpA*
G. Leccese, M. Rinaldi, A. Terraciano, M. Di Clemente, R. Luciani, S. Natalucci - *ASI Italian Space Agency*
M. Duzzi, F. Trezzolani – *T4I* - Technology for Propulsion and Innovation
G. Capuano, G. M. Capuano, P. Longobardi, E. Vecchio, F. Saggiomo – *TSD-Space*
M. D. Graziano, M. Grassi, T. A. La Marca – *University of Naples "Federico II"*
V. Fortunato, D. Chirulli, L. Pascali – *Planetek Italia*
C. Cardenio, A. La Rocca, F. Fontana – *AIKO Space*

EarthNext: Team and Project Status

- EarthNext funded up to PDR, **closeout meeting** held on **June 12th**
- **Five breadboarding models** of mission-**enabling technologies** were successfully designed, produced and **tested**

Officina Stellare (OS) is an innovative SME active in the design and production of telescopes, opto-mechanical and aerospace instrumentation for Ground and Space based applications.

Technology for Propulsion and Innovation (T4i) is an innovative SME focused on the development of innovative complete propulsion systems specifically designed to serve the micro and small satellite markets.

TSD Space is an innovative SME delivering high performing on board and ground electronic equipment for space applications including EO Payload Electronics, Camera FPA & Electronics.

AIKO S.r.l. delivers state of the art Artificial Intelligence solutions for flight and ground software with the goal of enabling autonomous space missions.

The team has got a long experience in the analysis and design of space missions and systems, with particular reference to missions in LEO for Earth Observation.

Planetek Italia S.r.l. provides solutions to exploit the value of geospatial data through all phases of data life cycle from acquisition, storage, management up to analysis and sharing.

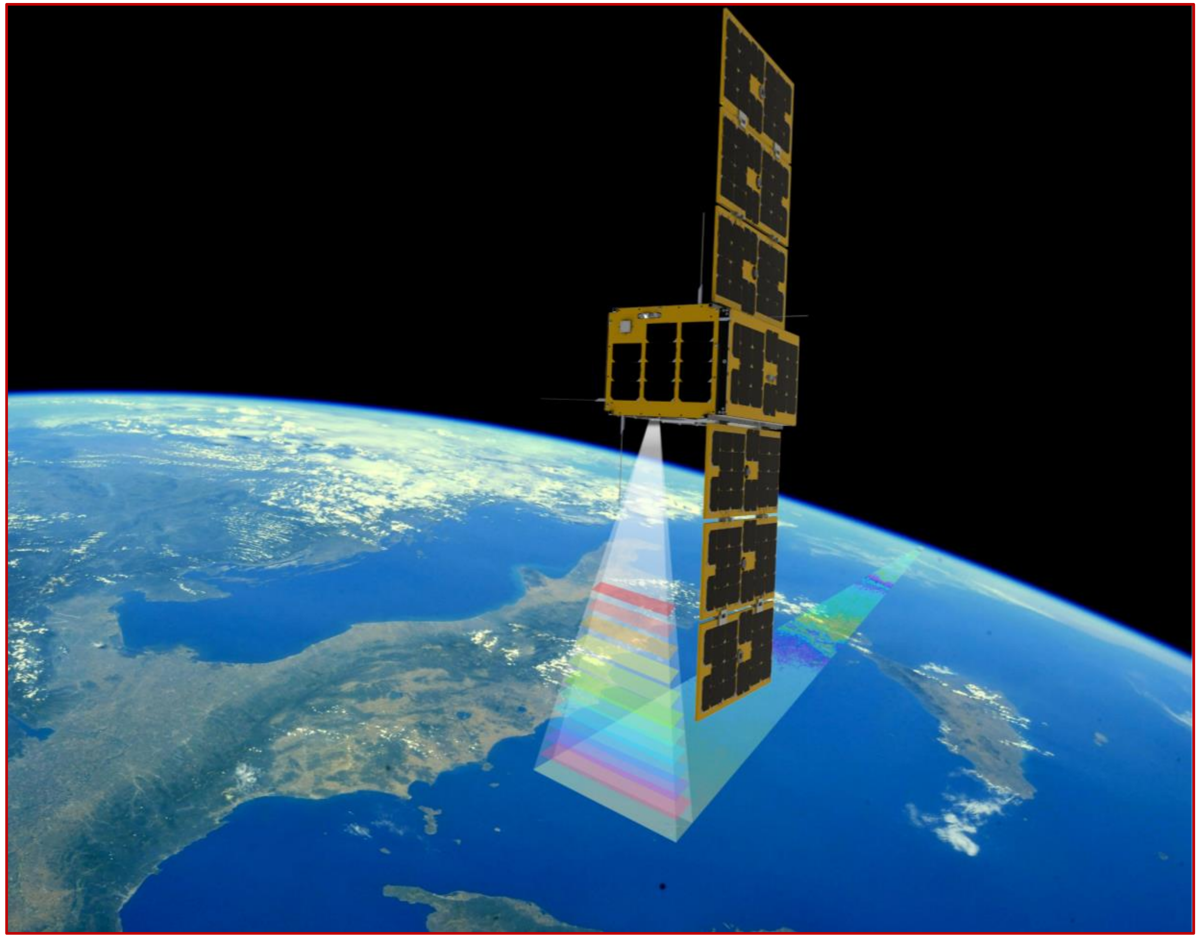
- **Milestone:**
  - ✓ KOM: September 2022
  - ✓ PRR: December 2022
  - ✓ SRR: March 2023
  - ✓ PDR: March 2024

EarthNext Project Objectives

EO Mission's main objective is twofold:

- Demonstrate **<u>CubeSat operations</u>** in **<u>VLEO</u>**, **<u>IOD/IOV</u>** of enabling technologies
  - on-board propulsion to <u>compensate demanding drag effects</u>
- Provide **<u>products and services</u>** in land/marine application
  - <u>high spatial resolution multispectral images</u>

<u>Augment other reference optical missions:</u> data fusion of EarthNext high spatial resolution with higher spectral resolution mission

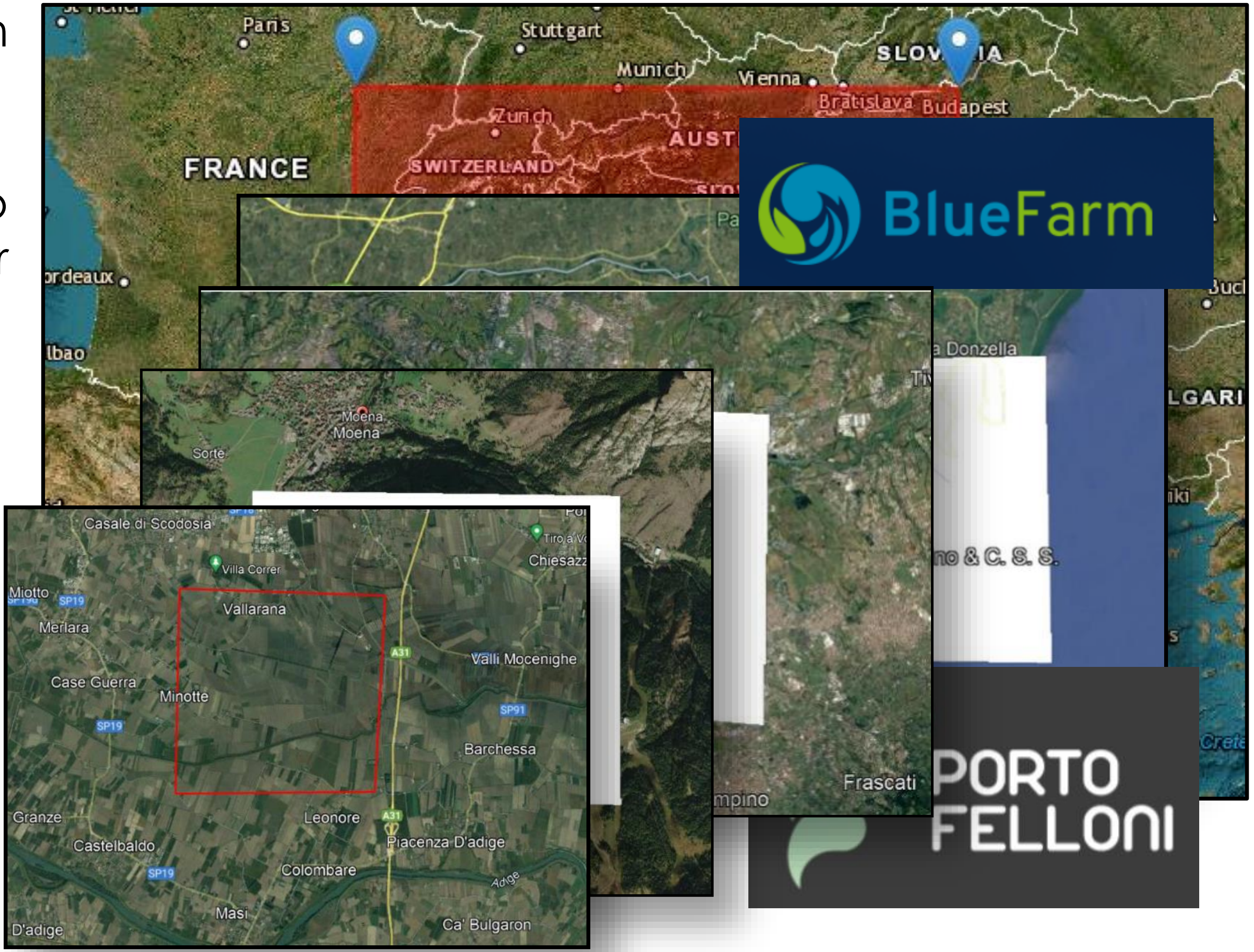


EarthNext Mission targets and AoI

- Users driven mission **targets:** collecting inputs from various potential users and about their pain points.

- Mission-wide **Area-of-interest (AoI)** setup to cover **Italy**. Specific AoIs are defined to cover also a cluster of users in function of *pilot cases*

- Portfolio of pilot cases and applications:
  - Agriculture/Marine:support precision farming & aquaculture:
    (*Users*: ***Società Agricola Porto Felloni*** & ***BlueFarm s.rl***)
  - Urban dynamics: changes detection
  - Forestry: local forest mapping
  - Common Agricultura Policy Monitoring: NDVI



Operating in VLEO: opportunities

Outstanding recurrent costs reduction

Smaller **aperture diameter** for a fixed GSD

Lower sensitivity to space debris

Satellite **natural re-entry** at mission end

High **EO resolutions at lower costs** in a small **form factor** spacecraft

Improved GSD for a fixed aperture diameter

Overall **architecture simplification**

Atmosphere contribution to radiation shielding

Operating in VLEO: challenges

Operating in a *Very Low Earth Orbit Environment* with a CubeSat involves many demanding tasks, the so-called **Project Challenging Points (PCP)**.

Atmospheric Drag	Fast Track Speed	Limited Envelope	Atomic Oxigen

What are the PCP solutions identified by the EarthNext project team?

EP propulsion	FMC maneuver	TMA telescope	Material selection

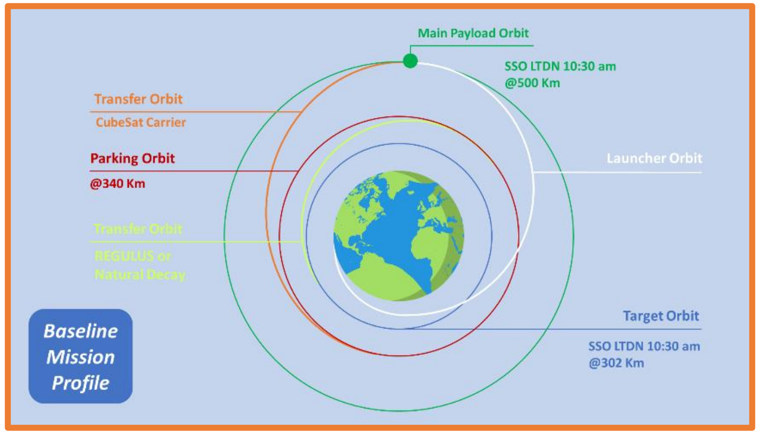
Launch Segment and Orbit design

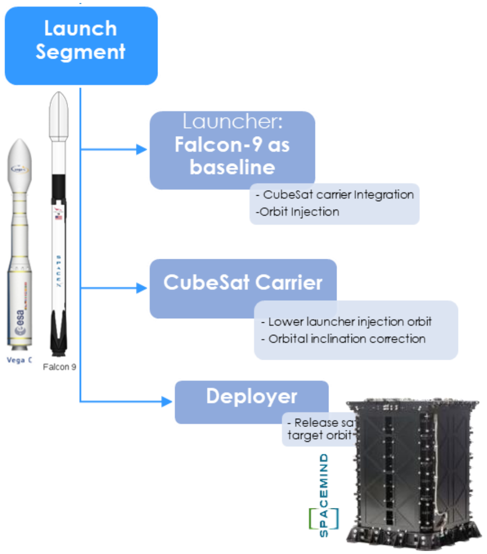
- A **Sun-Synchronous Orbit 10:30 LTDN** with mean altitude of **302 km** has been designed:
  - Meet users' **observability requirements**
  - Enable **mission side objective** (Sentinel-2, PRISMA, EAGLET & others);

- The designed orbit:
  - Avoids **morning haze**
  - Has **less cloud coverage** over the AoI
  - Suitable for land & marine application.

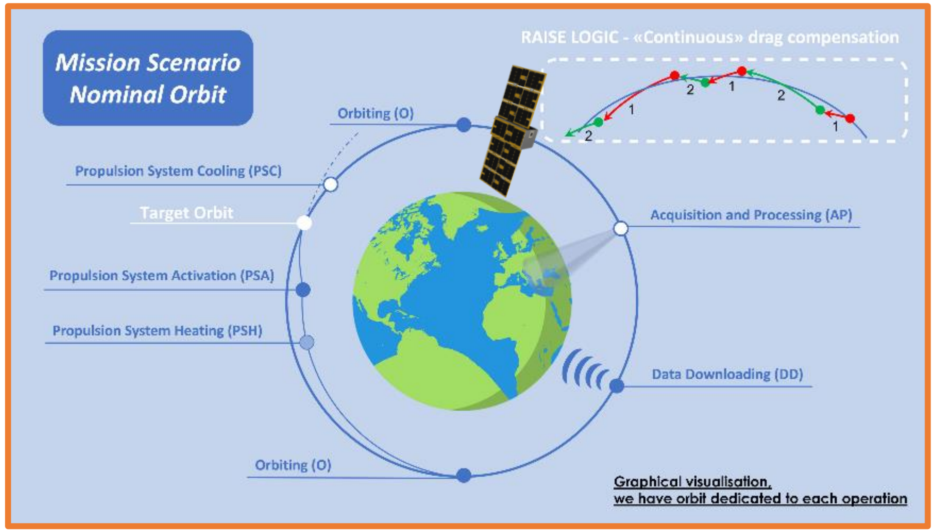
Reference : Wilfried, L.; Wittmann, K. Remote Sensing Satellite. In Handbook of Space Technology; J. Wiley and Sons: Hoboken
Reference: Murugan, P.; Pathak, N. Deriving Primary Specifications of Optical Remote Sensing Satellite from User Requirements.

- The Orbital Parameters have been selected:
  - To **"naturally" counteract** the **LTDN/inc drift**
  - Assuming a launch window in 2027



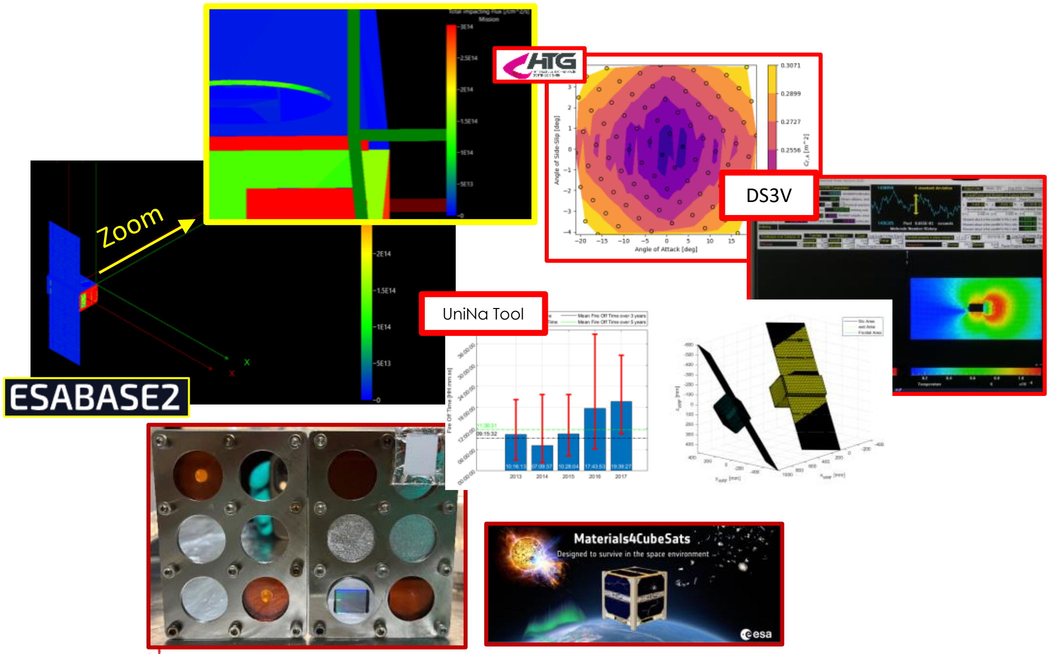


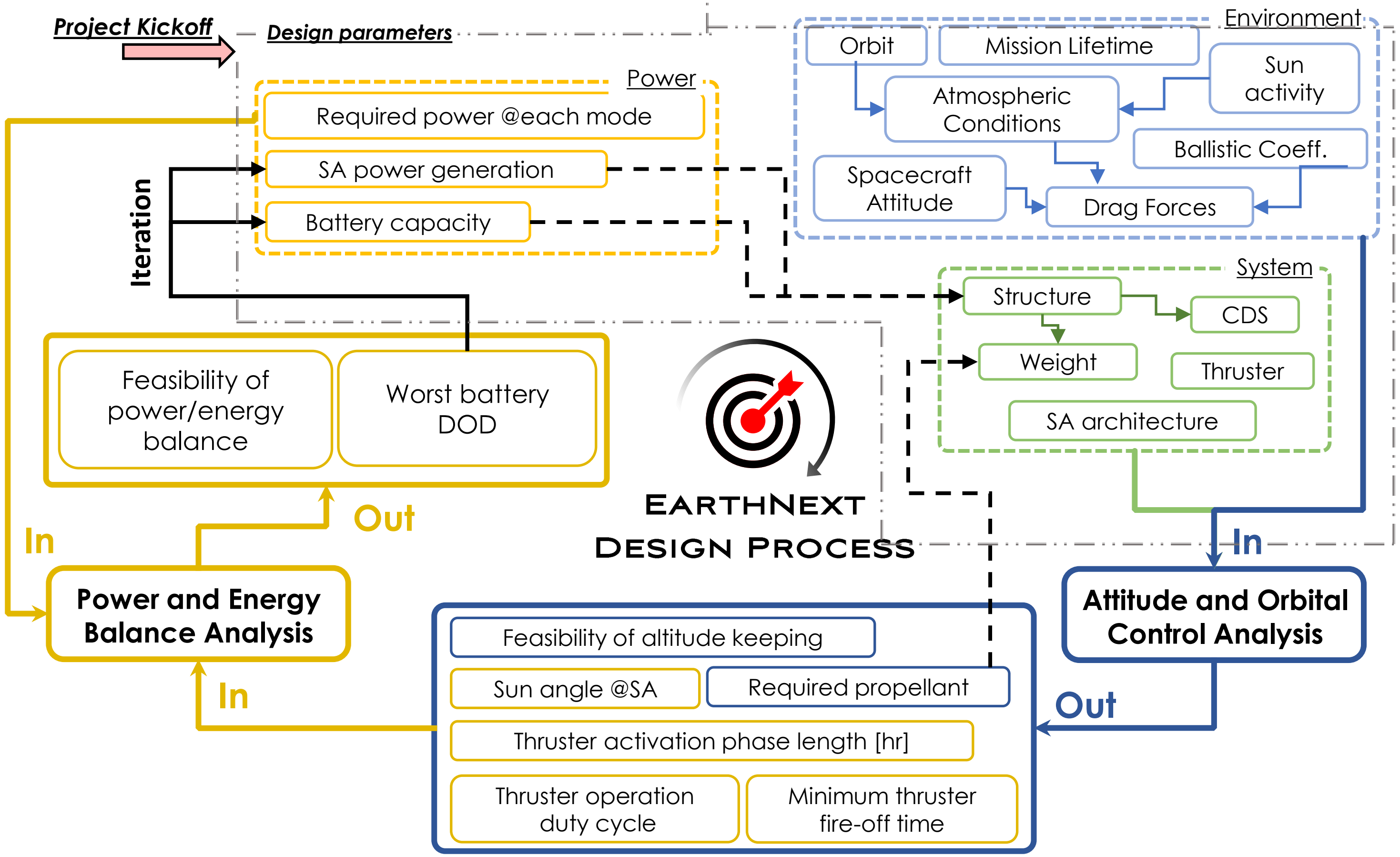
SMPOD16-C 1X Configuration



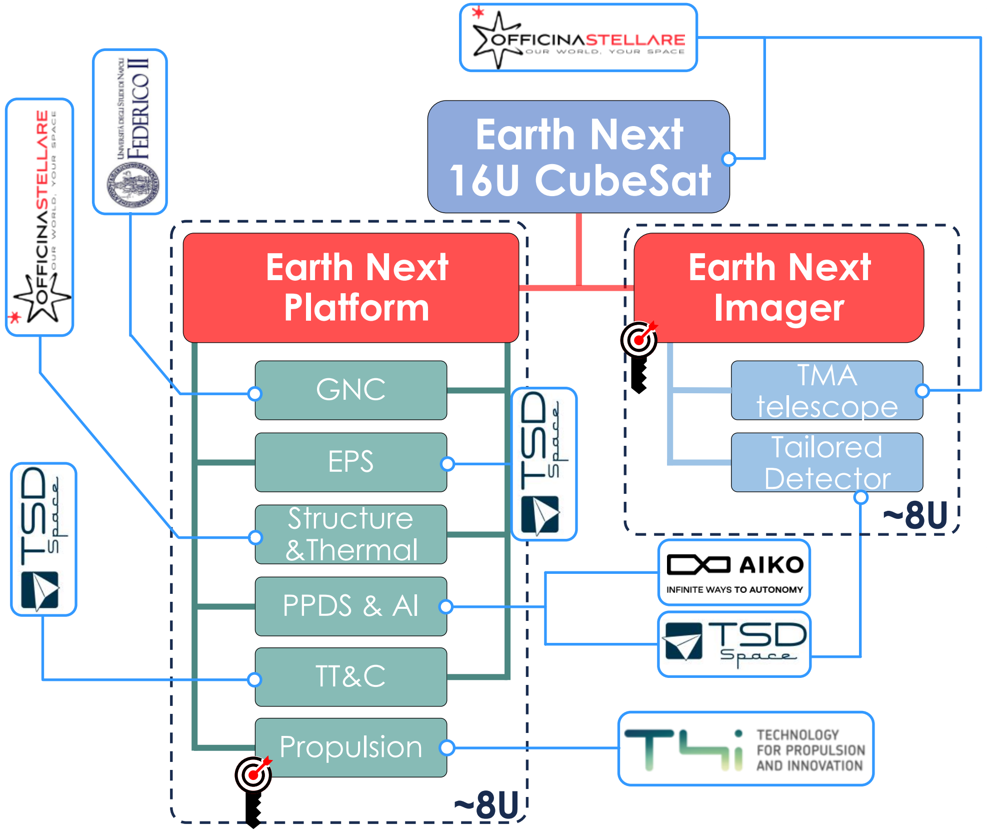
Space Segment Design Process

- **Most challenging** design points:
  - Feasibility of altitude and attitude control against drag forces
  - Hardly predictable environment
  - Power availability optimization for EP



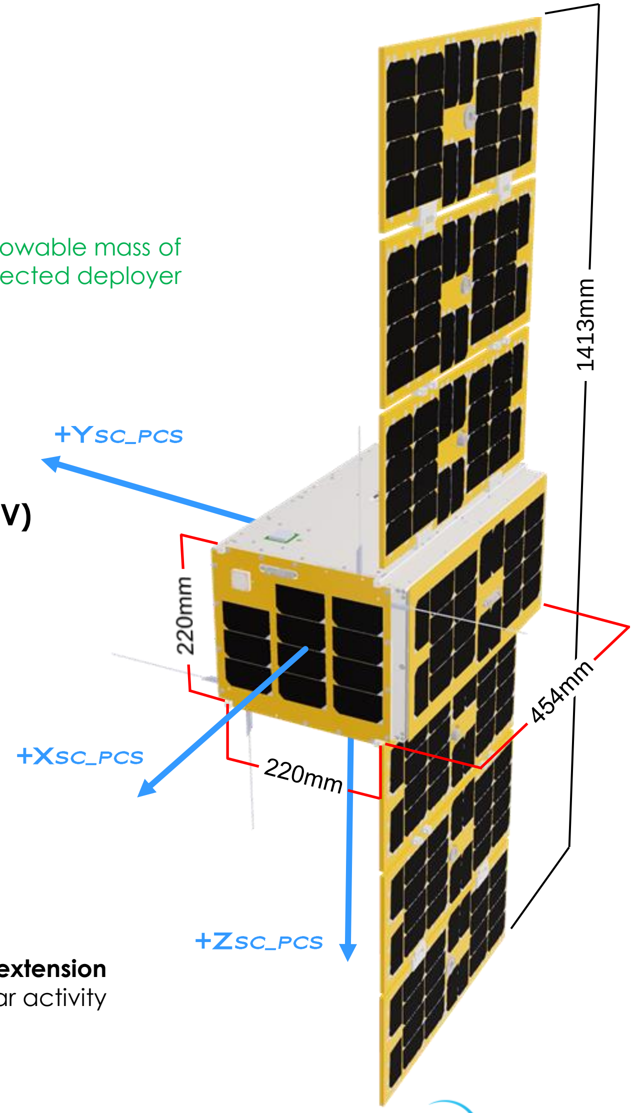


Space Segment Architecture



KEY ENABLING TECHNOLOGIES

- **Main design features:**
  - ✓ Volume: **16U**
  - ✓ Mass: **~35.5 Kg w/ PDR margin** < MAX allowable mass of selected deployer
  - ✓ Stabilization Type: **3-axis**
  - ✓ Peak power demand: **83W**
  - ✓ Power bus: **unregulated (11.8-16.8V)**
- **Main design performance:**
  - GSD @nadir **2.5 – 12 m**
  - Swath ACT **> 16Km**
  - Revisit time **3 -10 days**
  - Mission lifetime **3 years** **up to +2 yrs. extension** subject to solar activity

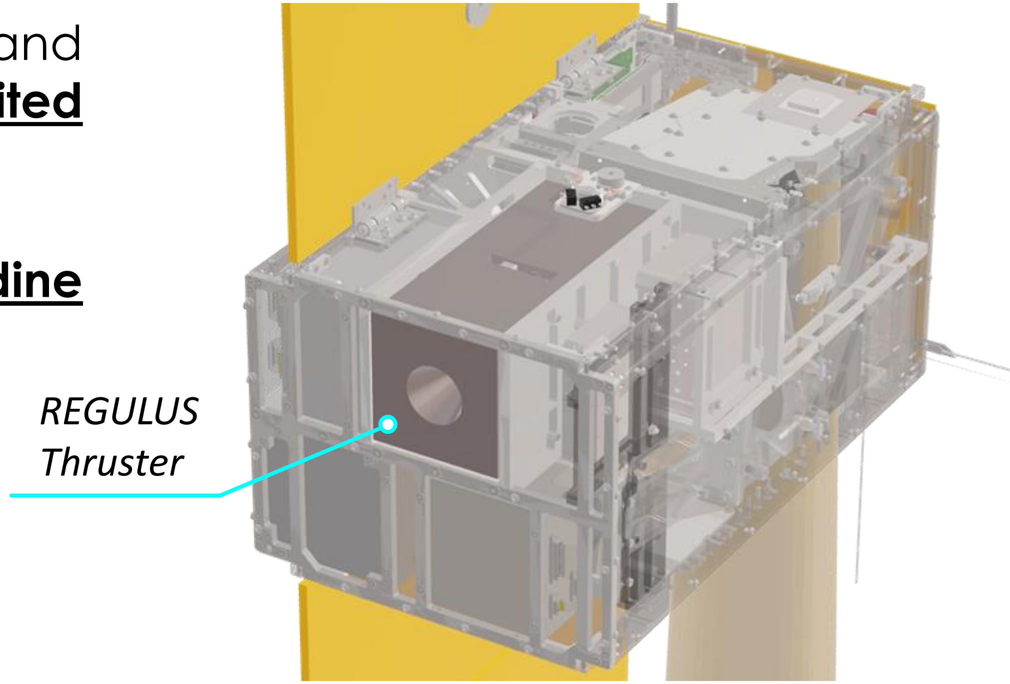


REGULUS-50-I2 Large: Features

- REGULUS is a **<u>MEPT thruster</u>**: is a relatively **new technology**, and thanks to its simple design and geometry it is **<u>particularly suited for MiniSAT propulsion solutions</u>**

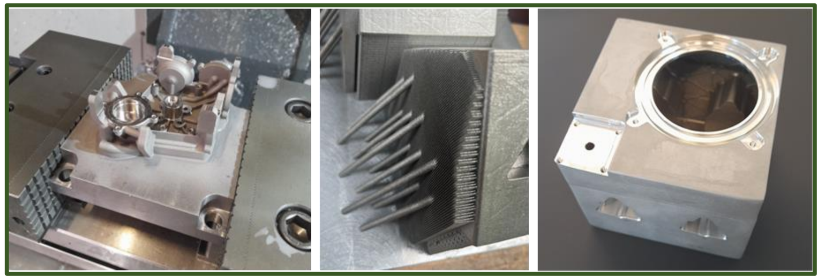
- REGULUS-50-I2 Large is a **<u>“Plug & Play”</u> EP system** fed with **<u>iodine propellant</u>**

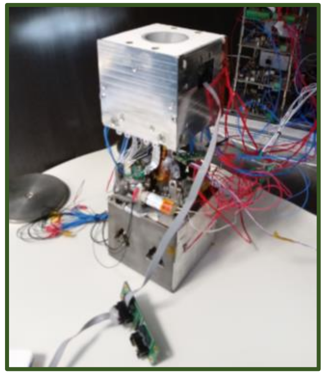
- **Key features:**
  - ***<u>No electrodes</u>*** (no cathodes-anodes exposed to plasma)
  - ***<u>No neutralizer and grids</u>***
  - ***<u>Delta V limited only by size of the reservoir</u>***
  - Standard interfaces with the satellite platform
  - **<u>Compensate the drag action</u>** for 3 to 5 years
  - Sized for the globally **<u>worst-case scenario</u>** drag compensation of the triennium 2000-2002)

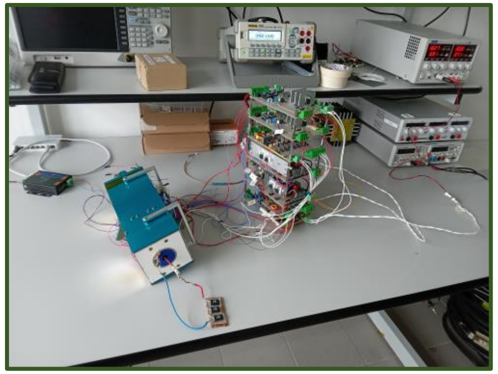


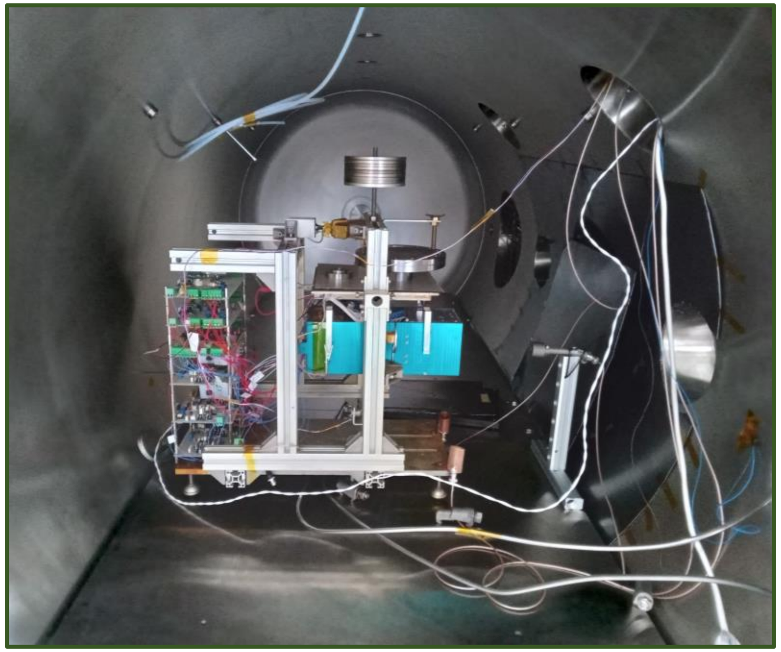
Main Features	Value
Thrust	0.1 – 0.5 mN (0.5 mN @ 50 W nominal)
Specific Impulse	Up to 550 s (@ 50 W)
Required power	30 – 50 W (50 W nominal)
Mass flow	0.1 mg/s
Propellant	Iodine (I2)
Volume	2.2 U (10 x 10 x 22 cm)
Weight (wet)	~6 kg (with 2.5 kg of solid Iodine loaded)
Electrical interfaces	CAN BUS, i2C with CSP protocol

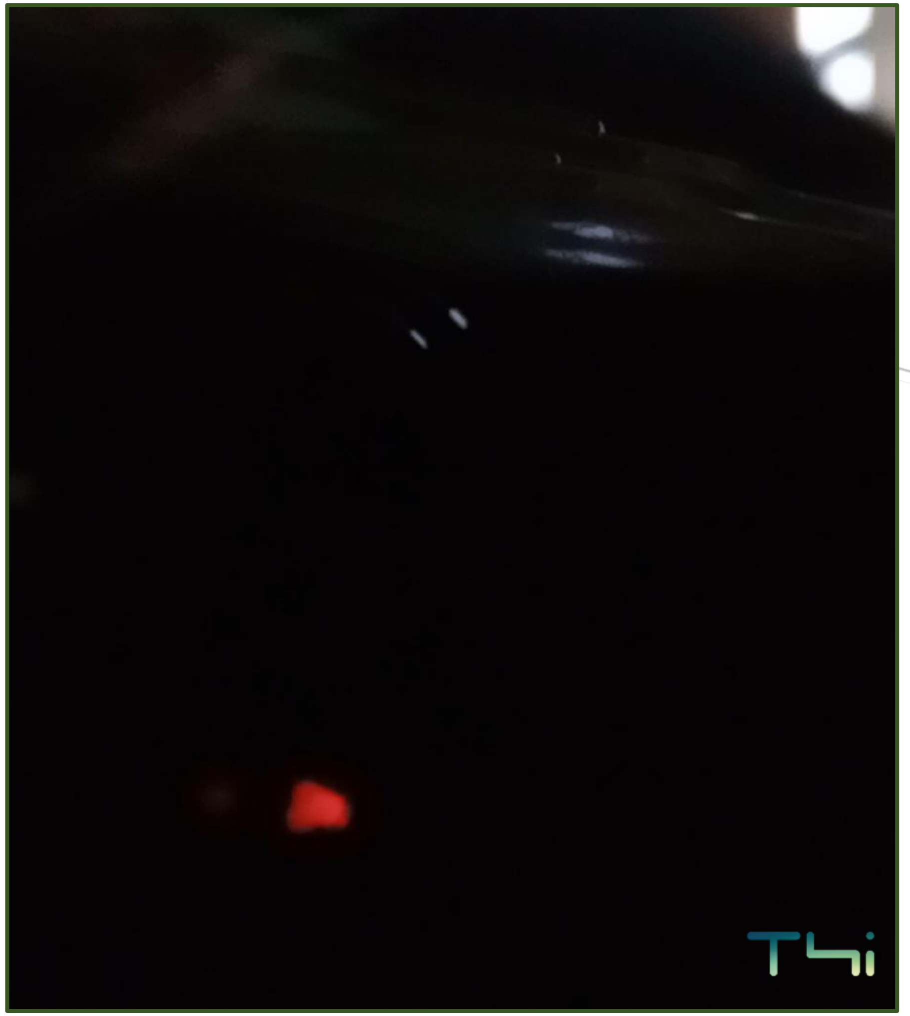
REGULUS-50-I2L BB: Test results







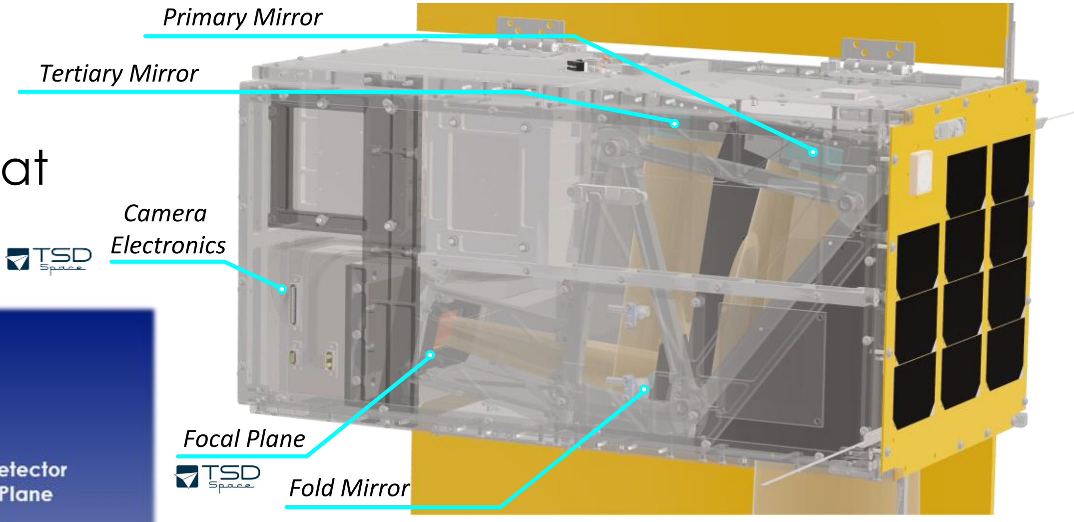




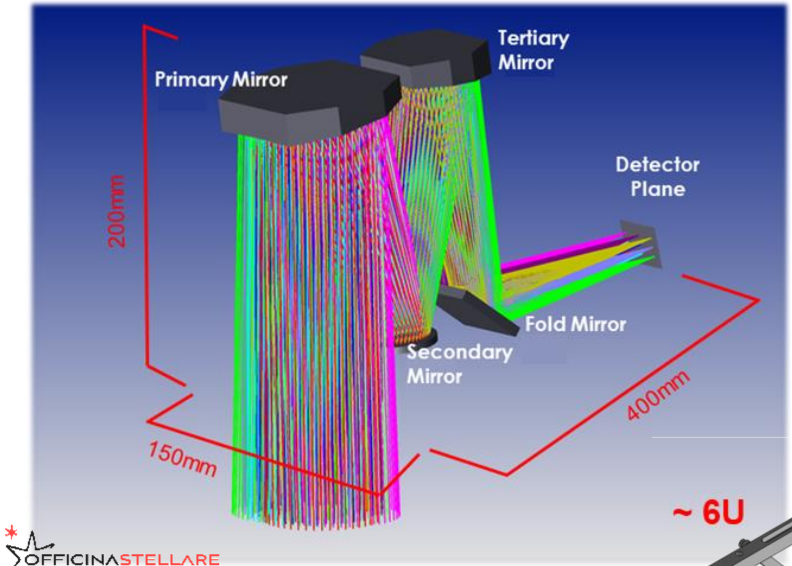
- **<u>Breadboard Model</u>** for the PDR review:
  - ✓ **<u>Increased</u>** total impulse
  - ✓ **<u>Updated fluidic</u>** to avoid performance transient
  - ✓ **<u>Unregulated</u>** input voltage

Telescope BB: design and challenges

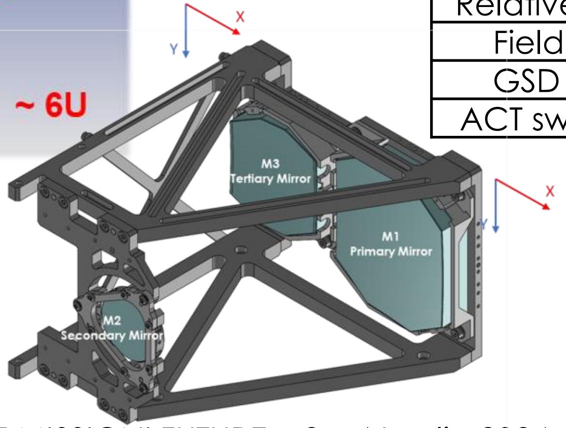
- **<u>Three Mirror Anastigmatic (TMA)</u>** architecture selected
- **Main driver:** very **<u>small envelope</u>** available on CubeSat platform led to mirror based solution
- **<u>Unobscured solution</u>** to **<u>maximize optical Modulation Transfer Function</u>** (MTF is related to resolution and image quality)
- **<u>Technical challenges</u>**:
  - To **<u>manufacture</u>** the mirror with correct shape
  - To integrate the mirrors
  - To **<u>finely tune mirror relative positions and directions</u>** to achieve the expected WFE "**<u>TMA alignment</u>**"



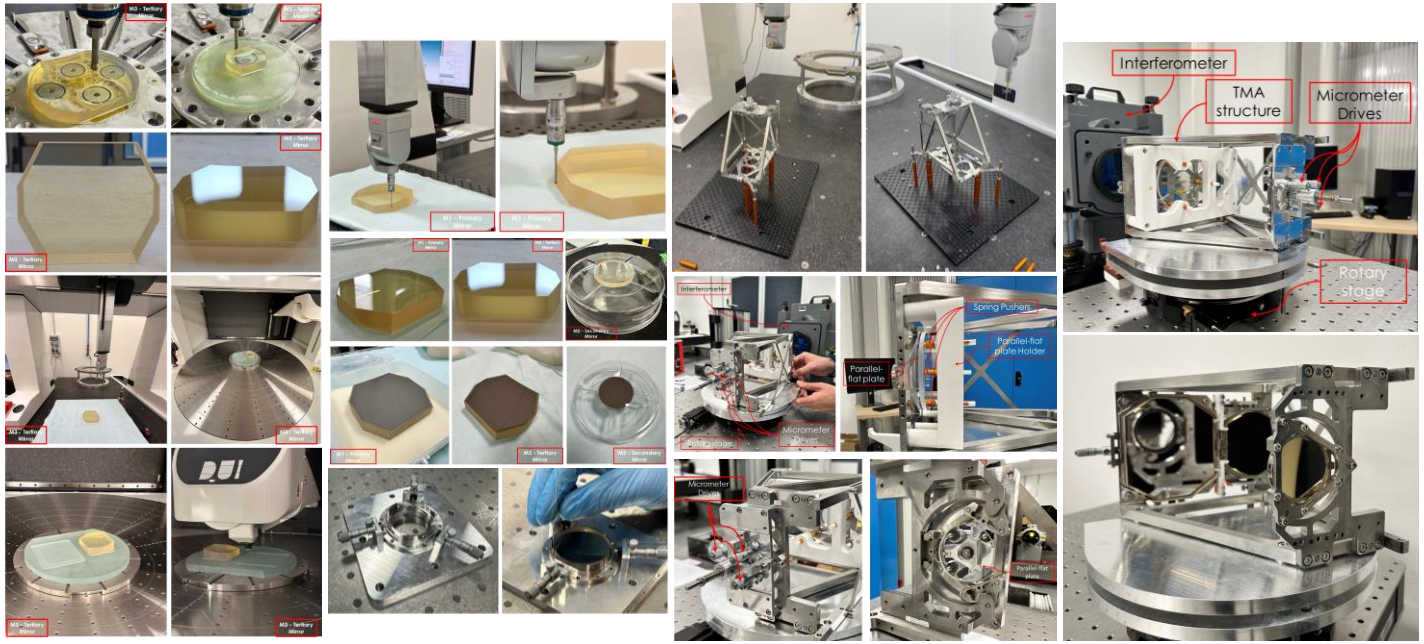
*Secondary Mirror not showed here



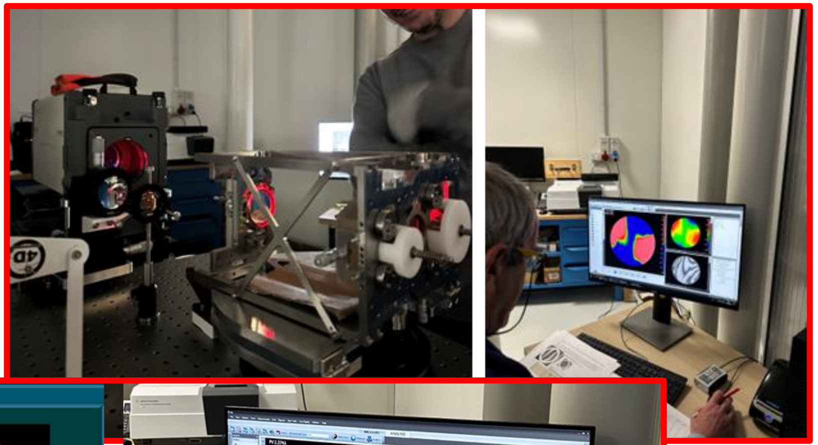
Parameters	Design results
Focal length	500 mm
Relative aperture	F/ 6.3
Field of view	3 x 1.5 deg
GSD @ nadir	3.9 m
ACT swath width	17 km

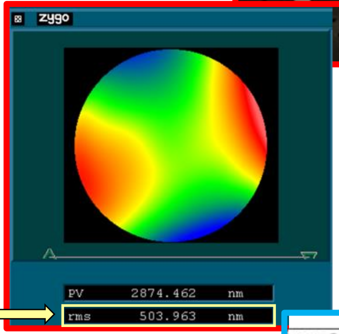


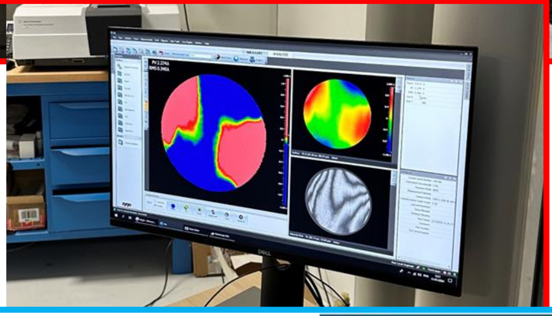
Telescope BB: Test results

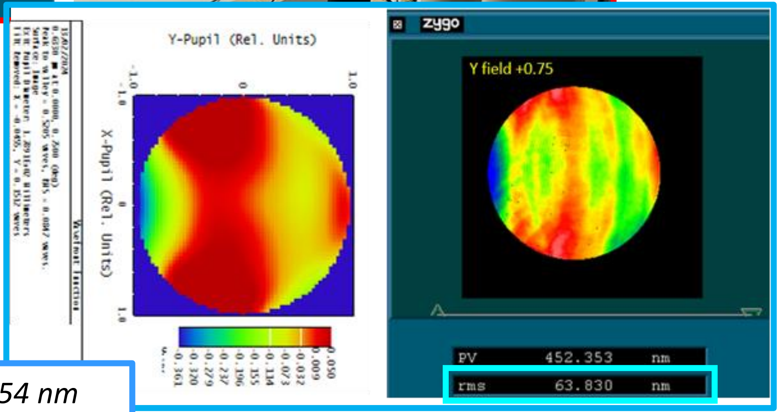


Start of the alignment process







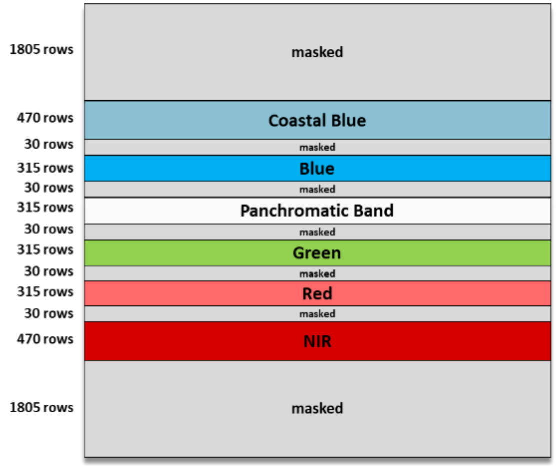


54 nm

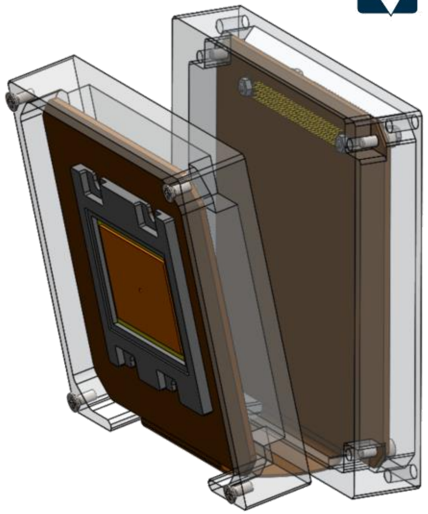
- ❑ **<u>Breadboard Model</u>** for the PDR review:
  - ✓ **<u>Mirrors manufacturing and integration</u>**
  - ✓ **<u>TMA alignment:</u>** WFE lower than stated pass/fail criteria at worst case scenario (+0.75 deg in Y direction)
    - ✓ **measured** TWFE equal to **64nm RMS** (<76nm RMS)

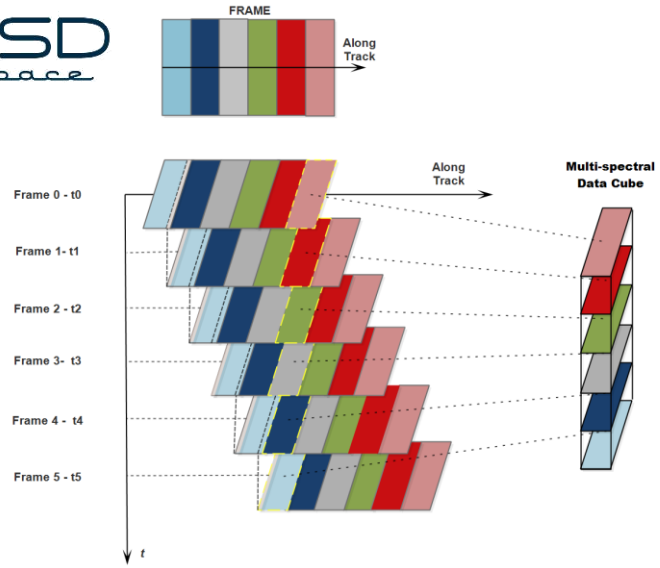
FPA & Proximity Electronics BB

- Electro-optical payload rely on a **custom multispectral filter** array implementing **“Spatio-Spectral Scanning”** acquisition mode:
  - **Multi-spectral data cube**: adoption of a multispectral filter array, in combination with relative motion of the imager with respect to Earth
  - Acquired 2D image contains a **full spatial resolution image**, comprised of a number of spectral stripes



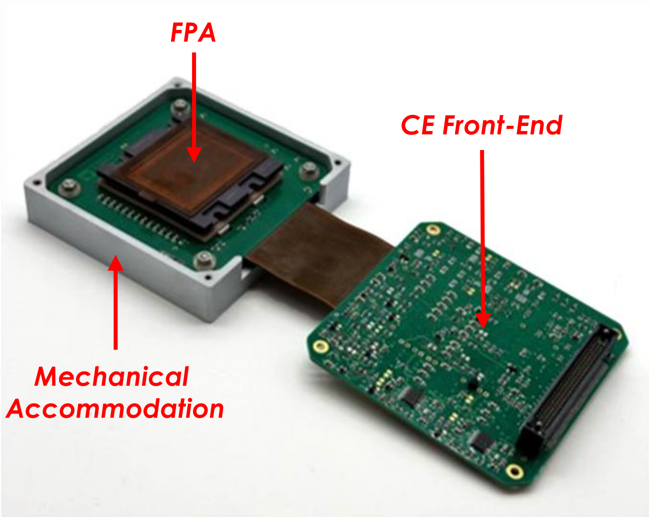
- The FPA B/B is developed as an engineering model, to solve any possible criticality in Phase B and reduce significantly any risks in Phase C/D
  - Demonstrate the **scalability** of FPA electronics to **fit CubeSat sizes**
  - Demonstrate the **viability to integrate** the optical filters directly on the large area imager
  - Carry out **preliminary functional tests**

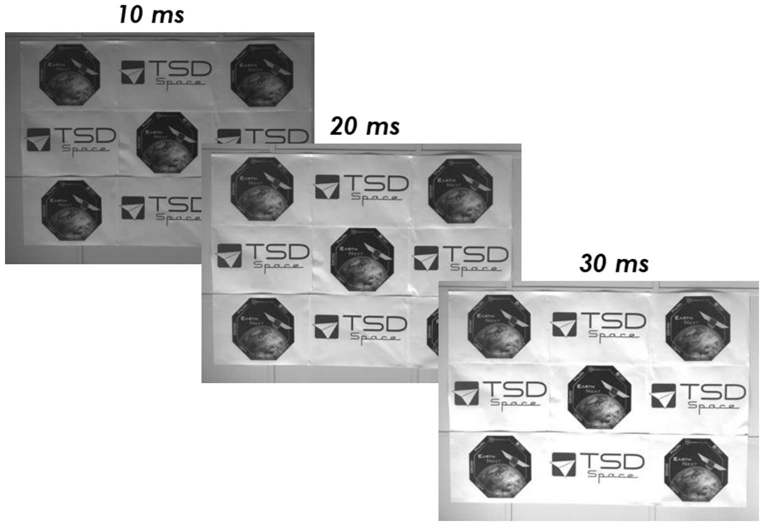


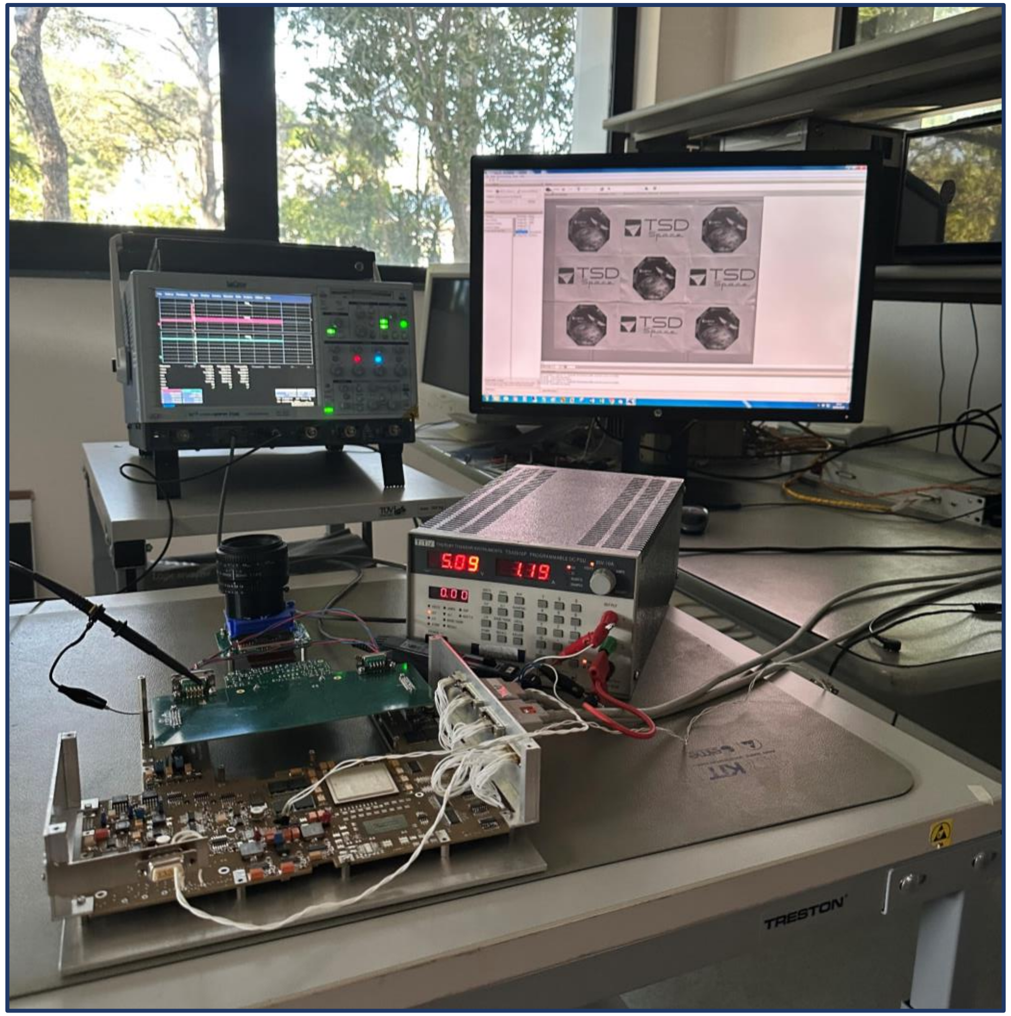


FPA & Camera Electronics BB

- ❑ FPA BB consists of **two innovative rigid PCBs** connected through a flexible PCB
- ✓ Electronics **has been downscaled** as targeted
- ✓ Demonstrated the **viability to integrate** the optical filters
- ✓ **Functional** tests have been carried out **successfully**
  - Achieved frame rate @ full-frame: **8,07fps**
  - Required exposure time normal mode @ 302km: **105us**

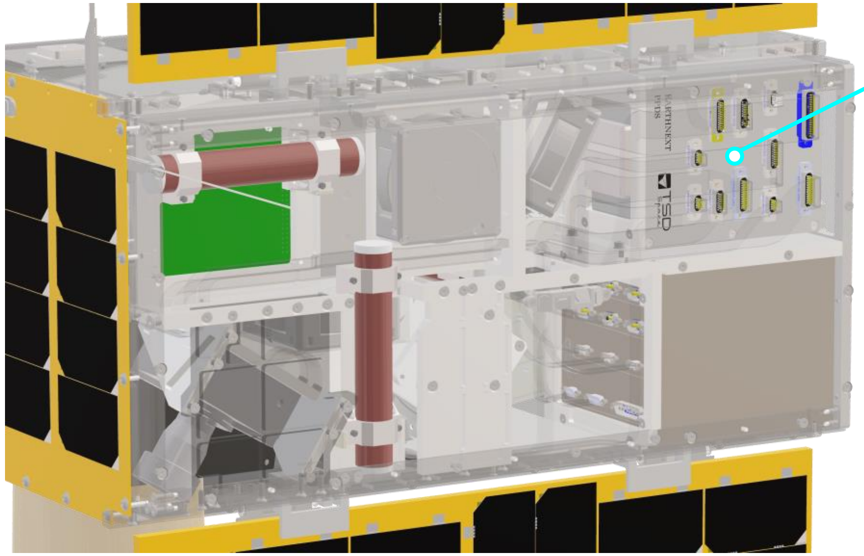






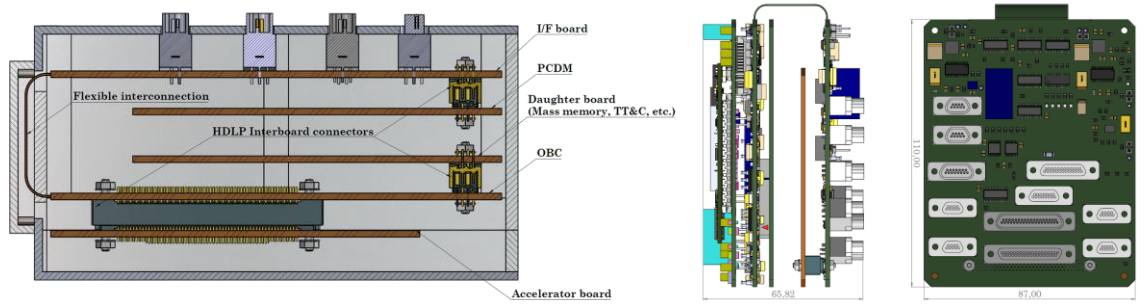
Platform & Payload Data System

- The PPDS is an **integrated data system**, able to support both the platform and the payload data handling and processing
  - PCDM, MMU, TT&C, Central Data Handling & Processing (**CDH&P**) and Processing Hardware Accelerator (**PHA**), **I/F board (implemented in the OBC BB)**
- **Technical challenges**:
  - Demonstrate the **scalability** to fit CubeSat sizes
  - **Upgrade** the relevant OBC **computational capabilities** to enable the **implementation of AI algorithms**

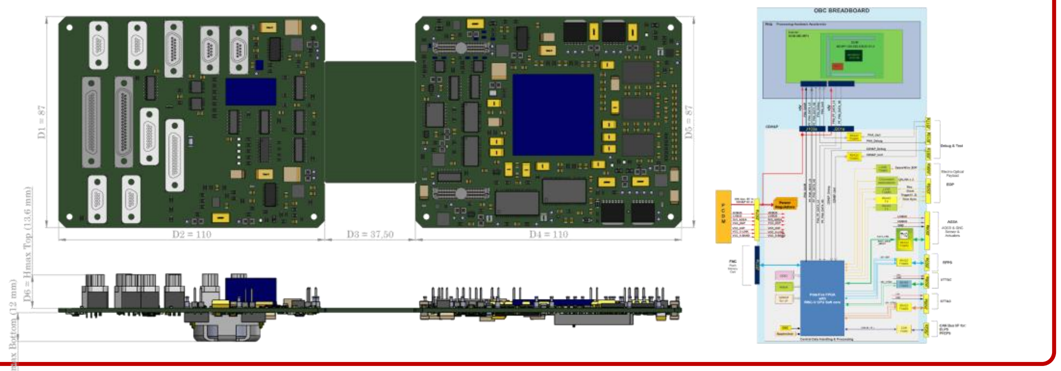


Platform & Payload Data System

PPDS EM



OBC BB

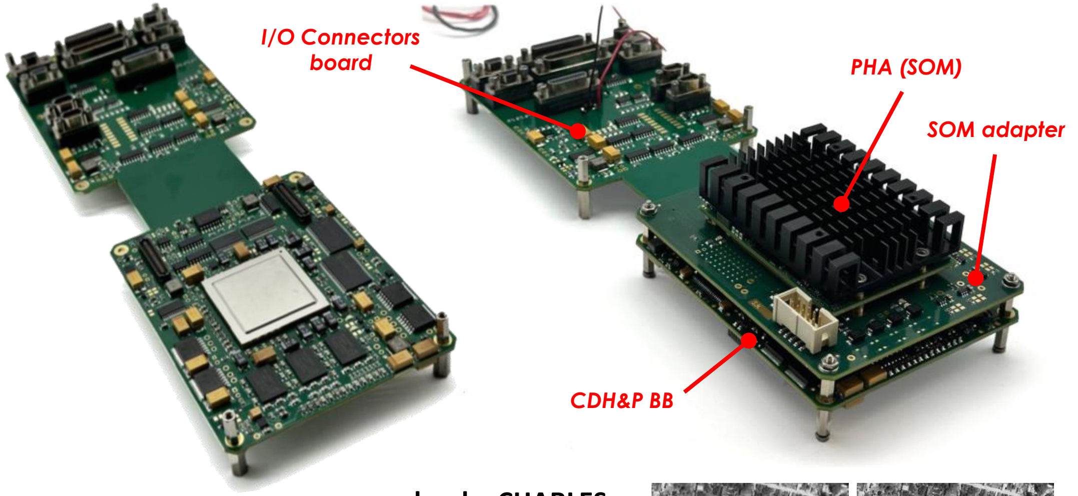


OBC&SW BBs: Manufacturing and AIT

✓ Electronics **<u>has been downscaled</u>** as targeted

✓ **<u>Functional</u>** tests have been carried out **<u>successfully</u>**

- to validate the proper functionality of the HW/SW configurations adopted for the PolarFire FPGA of the OBC BB and for the PolarFire SoC of the PHA BB **(AI Algorithms)**



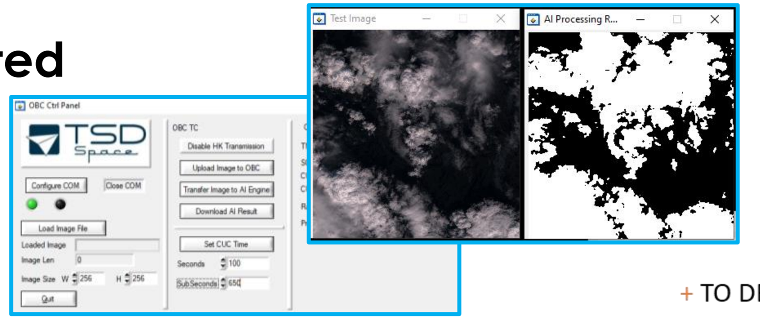
On-board AI and Deep Learning

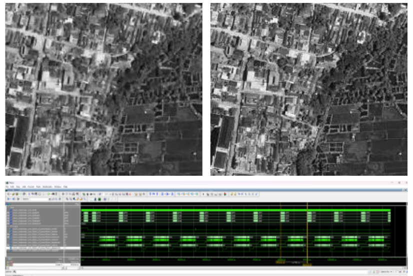
❑ Process acquired images **extracting customer-selected features**

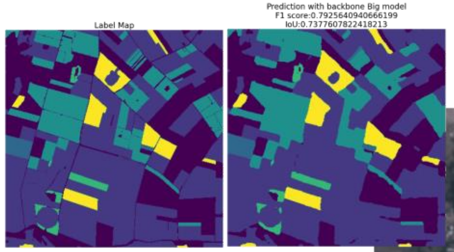
❑ Enabling **on-board autonomous decision-making** features

✓ **<u>BB models developed</u>**

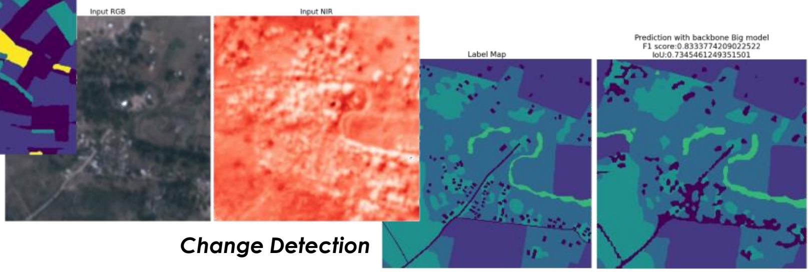
cloudy_CHARLES



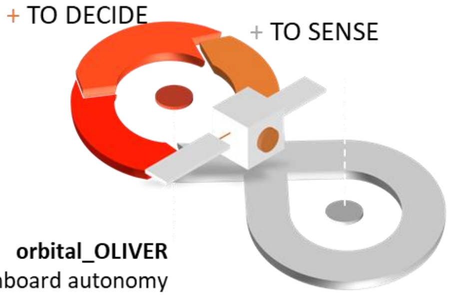




Precision Agricolture



Change Detection

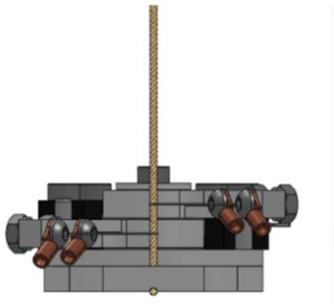


orbital_OLIVER
onboard autonomy

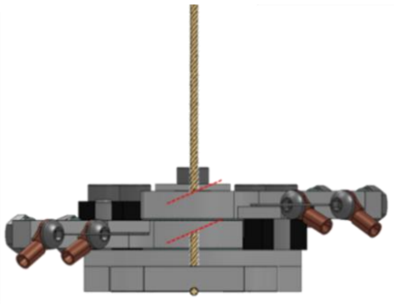
Solar Panels Deployment Mechanism

- The Solar Panels Deployment Mechanism BB is based on **a burn wire approach** (vast heritage, low cost and complexity, polymer wire can be pre-loaded to avoid gapping)
- **Driving design requirements:**
  - shall include a driving system which ensures that the resistor completely passes through the polymer wire
  - **shall be fail-safe**, i.e. shall include two independently powered initiator as to make it redundant.
- **Different combinations** of initiator/rope materials tested (Nichrome60, Kanthal A1/ Vectran, Dyneema)
- **Objective:** demonstrate SPDM is able to **fully trim** the hold-down rope

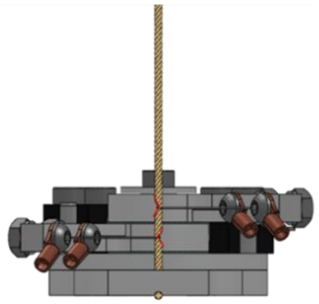
Criteria	Weight	HDRM design		
		Burn wire	SMA	Magnets
Reliability	5	8	8	9
Cost	3	10	6	5
Mass	4	8	9	5
Development	4	8	6	5
Low shock	5	9	8	10
Flexibility	4	9	7	8
Weighted score		**86%**	74,4%	72,8%



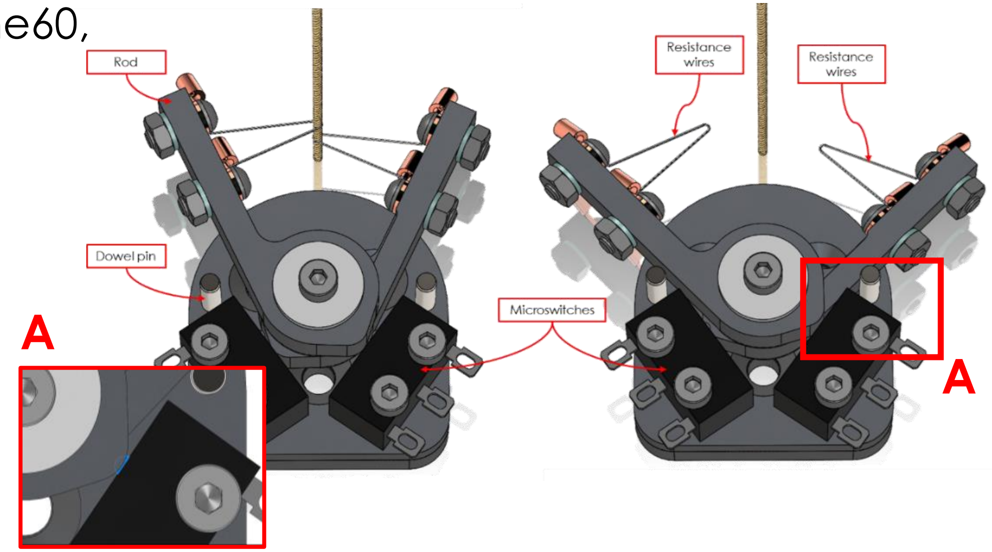
T0 before engaging the SPDM



T0 + n [s] after engaging the SPDM (fully trimmed)



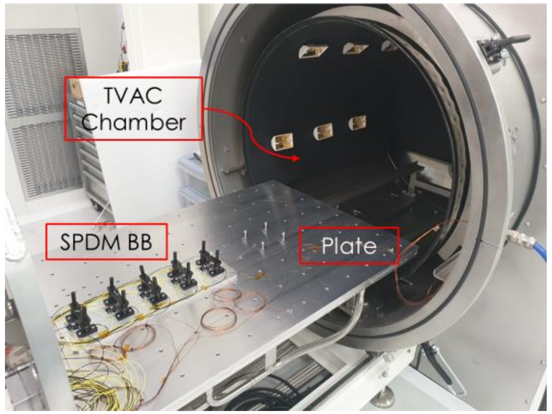
T0 + n [s] after engaging the SPDM (partially trimmed)

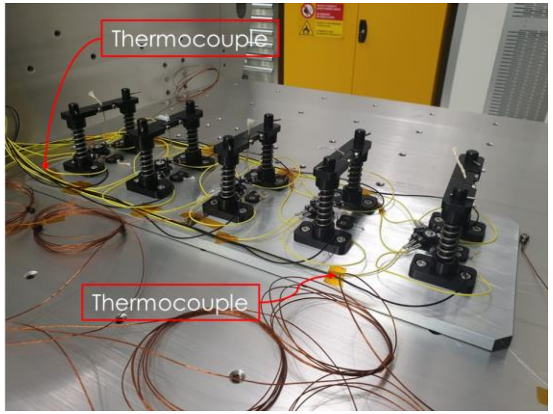


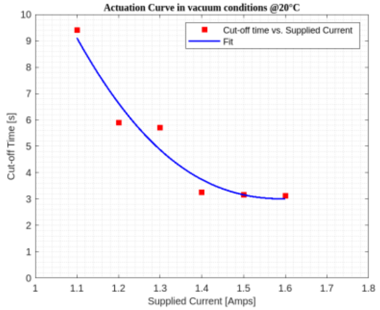
SPDM BB: Manufacturing and AIT

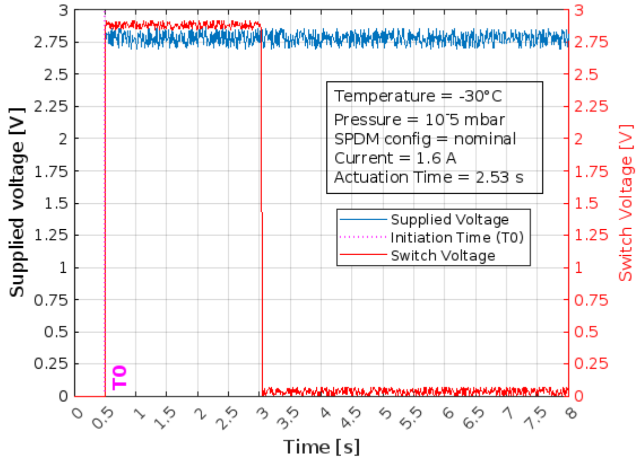
- SPDM BB mechanism have been **tested in TVAC** at:
  - Pressure: less or equal to 10^{-5}mbar
  - Temperature: Tstart +20°C, Cold Plateau **-30°C** Hot Plateau **+70°C**
  - Supplied current: 1.6 A
  - SPDM config.: nominal
- ✓ Refurbishment of SPDM BB mechanism has been performed
- ✓ **Fail safe configuration** have been tested: **loss of one resistor** and **off-nominal supplied current**
- ✓ The test setup with the five mechanisms was **fired five times** in vacuum: ***No failures were detected***
- Nichrome60 and Kanthal A1 resistors behave very similarly: **Vectran most suitable material** due to **mechanical properties** (no creep, no elongation under load, low CTE)

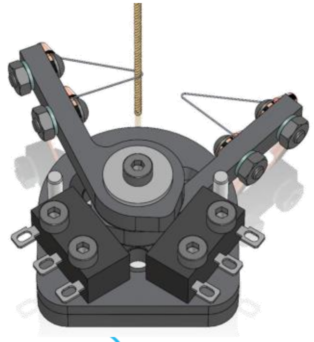
Initiator/rope	Average cut-off time
Nichrome60/Vectran	2.94 s
Nichrome60/Dyneema	2.53 s
Kanthal A1/Vectran	3.00 s
Kanthal A1/Dyneema	2.44 s







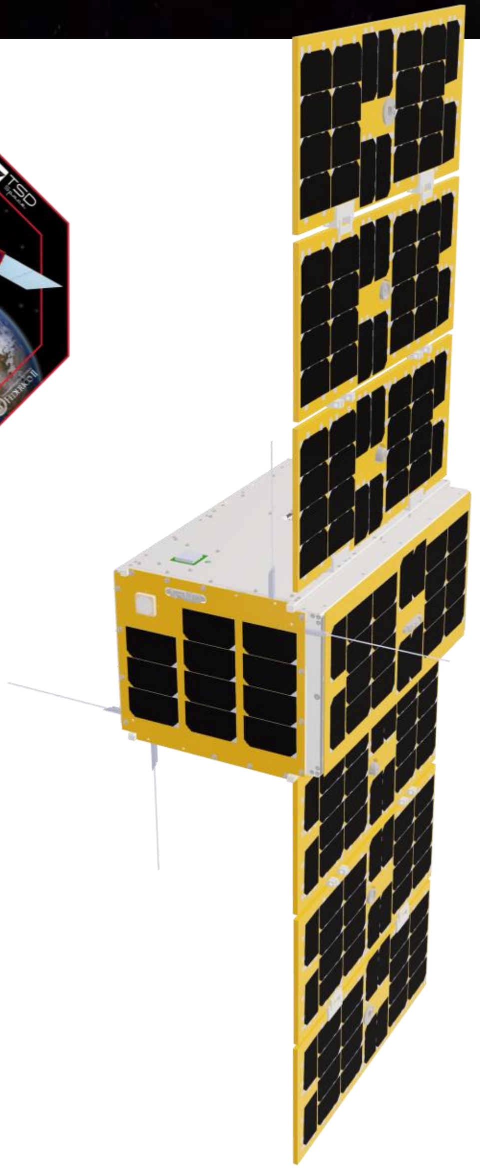




Future Perspectives

- **EarthNext project status:**
  - ✓ Phase C/D/E1 funds allocated
  - ✓ Phase C/D/E1 contract under preparation
  - ✓ CubeSat Structural and Thermal Model (STM)
  - ✓ CubeSat Engineering Model (EM)
  - ✓ CubeSat Proto-Flight Model (PFM)
  - ✓ Launch target for Q2/Q3 2027

EarthNext as the
<u>first Italian VLEO satellite</u>



OFFICINA STELLARE · TSD Space · T4i TECHNOLOGY FOR PROPULSION AND INNOVATION · AIKO INFINITE WAYS TO AUTONOMY · planetek italia · UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

EarthNext

Closer to the Earth
Next to the Future

Thank you for your attention!

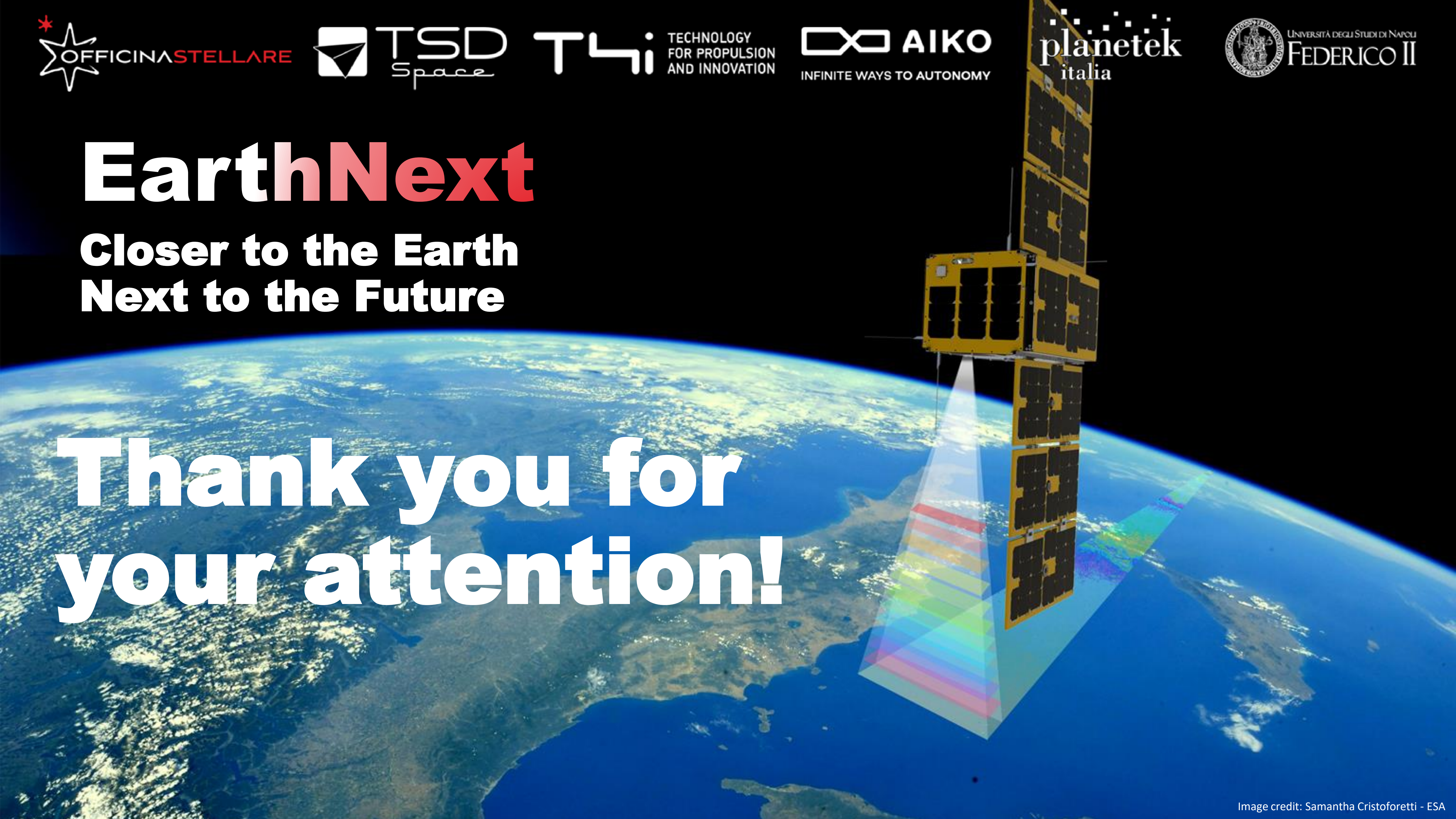


Image credit: Samantha Cristoforetti - ESA