Space It Up!

Spoke 1

Firenze, 26/1/2026

AGENZIA SPAZIALE ITALIANA

MUR Ministero dell'Università e della Ricerca

The Space It Up! project is funded by the Italian Space Agency (ASI) and the Ministry of University and Research (MUR), under contract no. 2024-5-E.0 – CUP I53D24000060005.

Spoke 1

SPACE IT UP!

POLITECNICO MILANO 1863

UNIVERSITÀ DI PISA

Politecnico di Bari

Politecnico di Torino

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

UNIVERSITÀ DI TRENTO

ENEA
AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

Consiglio Nazionale delle Ricerche

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

CIRA
Centro Italiano Ricerche Aerospaziali

ThalesAlenia Space
a Thales / Leonardo company

TELESPAZIO
a LEONARDO and THALES company

SITAEL
AN ANGEL COMPANY

argotec
SPACE FOR AMBITIONS

Spoke 1: Enabling Technologies for Novel Near-Earth and Exploration Missions

Spoke Leader: F. Topputo (Polimi)

Mission Statement

Spoke 1 covers **research and development** activities at low TRL with the aim to promote a technological push that enables **novel missions** for the **protection** and the **sustainable development of the planet**, as well as for **planetary exploration** missions. Emphasis is on the development of enabling technologies to lower the satellite altitudes and to carry out space missions using distributed systems. These two concepts have the potential to produce enhanced Earth observation products and services.

Goals

- Develop enabling technologies that support the creation of enhanced Earth observation products and services.
- Develop solutions to allow Earth observation missions at low altitudes and/or with distributed systems.
- Develop enabling technologies to carry out deep space exploration with miniaturized systems.

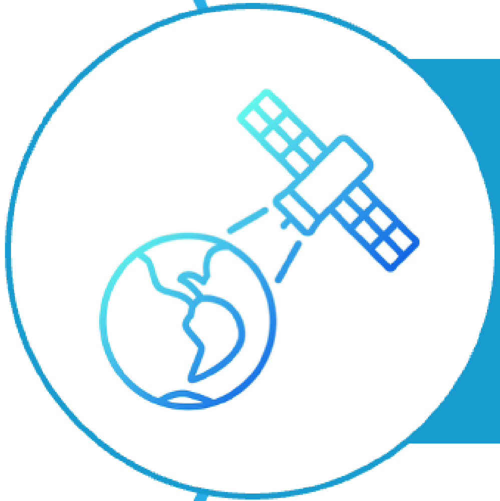
WP 1.2 - Very Low-Earth Orbit Platforms: Pushing the Envelope of Earth Observation

WP 1.2
Very Low-Earth Orbit Platforms: Pushing the Envelope of Earth Observation

Tasks

- Advanced materials for harsh environment *(TL: ENEA)*
- Air-breathing propulsion *(TL: Unipi)*
- System-environment interaction multi-disciplinary simulation and testing *(TL: Poliba)*
- Fine attitude and orbit optimal control systems *(TL: Polito)*

WP Leader: M. V. Salvetti (Unipi)



Goal:

To lower the satellite altitudes at which Earth observation can be carried out.

Task 1.2.1 – Advanced Materials for VLEO Spacecraft

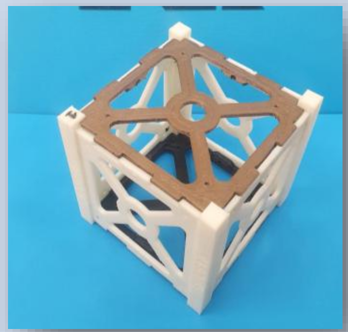
Development, modeling, and characterization of advanced materials and coatings for spacecraft in VLEO

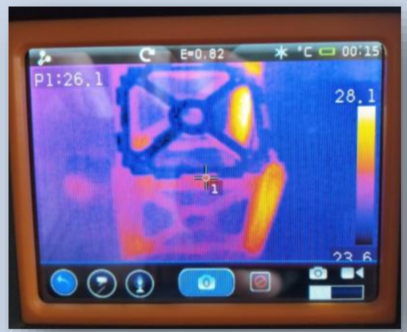
Development

- **High-Performance Thermoplastics**
  - Development of carbon fiber-reinforced PEEK substrates (ENEA)
- **High-Performance Thermosets**
  - Novel composites with protective coatings (Unipi, ENEA).
- **AO-Resistant Coatings**
  - Deposition of Kapton-based nanocomposite coatings using electrospraying (ENEA)
- **Ceramic Matrix Composites (CMC)**
  - High-temperature, AO-resistant composites; testing in plasma wind tunnels (CIRA)

Characterization

- **Advanced Optical Fiber Sensors**
  - Fiber sensors for structural health monitoring and environmental diagnostics (POLIBA)
- **Comprehensive Characterization**
  - Multiscale analysis with microscopy, spectroscopy, mechanical testing, and irradiation (ENEA, CNR, POLIBA)





Task 1.2.2 – Air-Breathing Propulsion

Breadboard development of air-breathing propulsion systems for VLEO, with a focus on cathode technology and system-level test facilities.

- **Cathode Technology**
  - Development and analysis of multiple cathode types
  - Test campaigns to verify cathode operation with air propellant
- **Vacuum Facility**
  - Design and procurement of a large vacuum chamber for cathode and thruster testing
  - Supports high vacuum, oxygen-rich propellant, and future upgrades
- **Numerical Modeling**
  - DSMC simulations for air inlet performance (PoliBA)
  - PIC-MCC simulations for air plasma dynamics in cathode and plume (CNR-ISTP)

- Operative pressure: 10^{-5} mbar
- Internal dimensions: ø 1m x 2m
- Turbomolecular pumping system
- Upgraded with a water-cooled beam dump foreseen
- All components delivered
- Currently being set up
- Upgrade of electrical power supply and cooling under way
- Operations to start Q1 2026

Task 1.2.3 – System-Environment Interaction Simulation & Testing

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Modeling, simulation, and experimental validation of system-environment interactions in VLEO, with a focus on aerothermodynamics, materials, and thermal management.

- **Constellation & Platform Design**
  - System-level analysis for VLEO constellations; focus on altitudes below 250 km (SITAEL)
- **Aerothermodynamics & Reentry**
  - Numerical simulations of 3U CubeSat a several VLEO altitudes (Poliba, Unina, CIRA)
  - Experimental validation in plasma wind tunnels (CIRA)
- **Material Degradation & Monitoring**
  - Study of main degradation mechanisms; Development of Health and Usage Monitoring Systems (Polimi)
- **Thermal Management**
  - Passive thermal control strategies for small satellites (Unipi)
  - Enhanced surfaces through innovative deposition techniques & advanced manufacturing (Unipi)

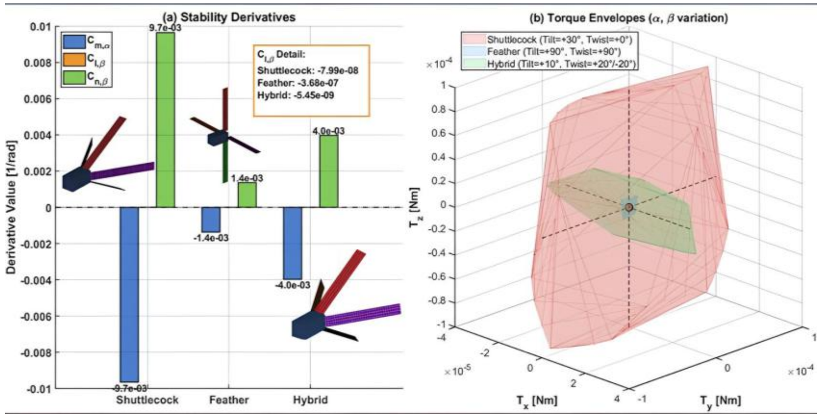
Task 1.2.4 – Fine Attitude and Orbit Optimal Control

Design, simulation, and hardware-in-the-loop testing of optimal control algorithms for attitude and orbit in VLEO, with application toconstellation management and platform design

- **Algorithm Development**
  - Classical, adaptive, robust, and AI-based control algorithms for attitude and orbit
  - Guidance algorithms for formation flight and payload-level stabilization

- **Platform & Sensor Design**
  - Design of a 16U CubeSat platform for VLEO, with detailed analysis of actuators and sensors
  - Distributed CAN-based sun sensor system

- **Simulation Environment**
  - Matlab/Simulink-based simulator for orbital propagation, image-plane motion, actuator dynamics, and control



WP 1.3 - Distributed Space Systems: A Novel Paradigm for Earth Observation

WP 1.3
Distributed Space Systems: A Novel Paradigm for Earth Observation

Tasks

- Design and testing of low-TRL GNC solutions for distributed platforms
  (TL: Unina)
- Enabling technologies for in-orbit assets servicing and protection
  (TL: Unibo)
- On-board and on-ground processing and applications
  (TL: Unipi)
- Enabling technologies for near-Earth satellites
  (TL: Unitn)

WP Leader: P. Di Lizia (Polimi)

Goal:

To implement novel near-Earth missions with distributed platforms

Task 1.3.1 – Design and Testing of Low-TRL GNC Solutions for Distributed Platform

Development and testing of advanced GNC techniques and architectures for distributed space platforms, including constellations, formation flying, in-orbit assembly, servicing, and inspection

- **GNC for Distributed Platforms**
  - Centralized and decentralized control strategies for multi-satellite coordination
  - Focus on limited control authority scenarios, hybrid control schemes, and distributed GNC solutions
- **Constellation Modeling & Optimization**
  - Development of models for large constellations in LEO, enabling fast simulation and optimization
  - Heuristic optimization algorithms for coverage and revisit time analysis
- **Relative Navigation & Proximity Operations**
  - Relative navigation techniques using monocular cameras, LiDAR, and multi-sensor fusion
  - Hardware-in-the-loop testbeds for GNSS-based navigation and formation flying
- **Onboard Automation & Communication**
  - Advanced onboard processing, inter-satellite links, and communication for distributed systems
  - Use cases for advanced routing, automation, and digital twin environments
- **Radiation Protection & Testing**
  - Use of COTS with risk mitigation strategies for reliability in distributed architectures

Task 1.3.2 – Technology for Distributed Systems

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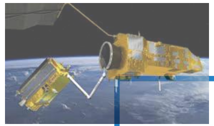
Development of enabling technologies for autonomous in-orbit servicing and protection, including GNC for proximity operations and SSA for collision avoidance, with a focus on sensors, navigation, and AI



ASSETS SERVICING
GNC for Proximity & Very close proximity operations

- **Algorithms** for proximity GNC
- **Sensors** for relative navigation
- **Collision Avoidance** (close-range)
- **Testing** & TRL assessment

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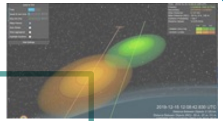
ThalesAlenia Space

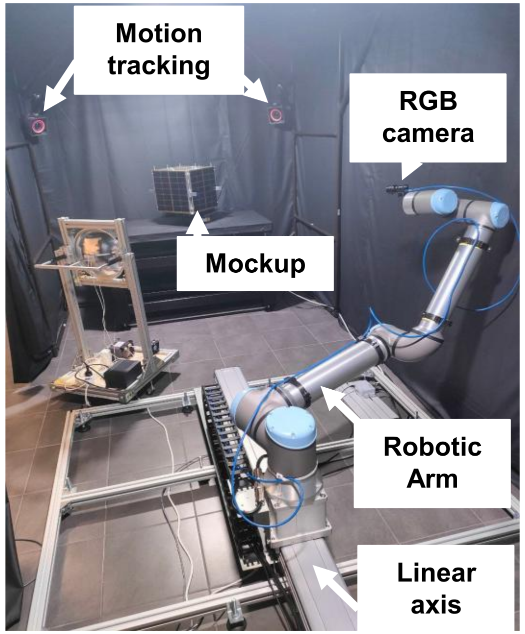
Inter-satellites range

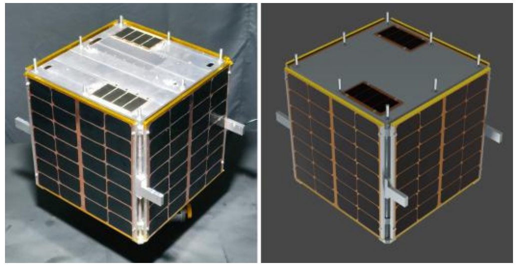
CLOSE → **FAR**



ASSETS PROTECTION
Situational Awareness & Collision Avoidance

- **Algorithms** for threat/debris detection, cataloguing & tracking
- **Sensors** for threat identification, tracking & μ-impacts detection
- **Collision Avoidance** (far-range)
- **Testing** & TRL assessment





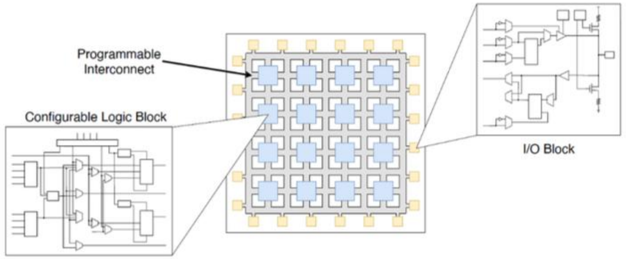
Testbeds for validation of multi-sensor navigation techniques. 1) Point clouds acquisition for LiDAR-based relative navigation; 2) Monocular-vision deep-learning-based navigation; 3) Photorealistic satellite mock-ups

Task 1.3.3 – On-Board and On-Ground Applications

UNIVERSITÀ DI PISA

On-board RF processing, AI-based telemetry, Earth observation data processing, and autonomous structural monitoring, with a focus on hardware accelerators and photonic technologies

- **RF Signal Processing & AI**
  - Classical and AI-based RF signal detection, modulation classification, and interference detection
- **AI Hardware Accelerators**
  - Review of ASICs, FPGAs, GPUs, TPUs, and photonic processors for space applications
- **Structural Monitoring & Explainable AI**
  - Integration of AI and explainable AI (XAI) for on-board and on-ground data processing, including health monitoring, FDIR and anomaly detection; emphasis on transparency, reliability, and compliance
- **Photonic Technologies**
  - Development of photonic Fast Fourier Transform Processors (FFTP) for onboard SAR data processing



Ongoing activities

- Definition of RF use-case scenarios and AI-based algorithms for implementation on FPGA-based on-board signal processing

Hardware equipment

- FPGA POLARFIRE SOC ICICLE
- ALPHA DATA KINTEX ULTRASCALE DEV KIT

Task 1.3.4 – Enabling Technologies for Near-Earth Satellites

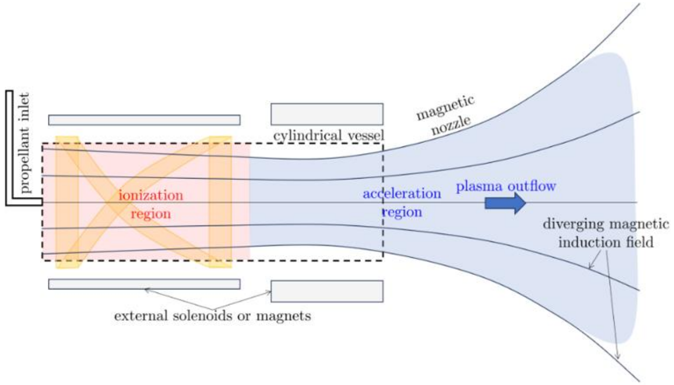
Research and development on advanced propulsion, on-board systems, and high-efficiency perovskite solar cells for near-Earth and deep-space miniaturized platforms.

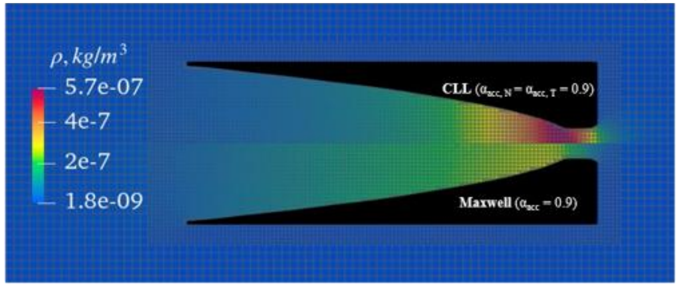
- **Laser Ablation Propulsion**
  - Modeling and experiments on confined laser ablation, composite polymers,
    and aerogels for impulse generation (UniTn)

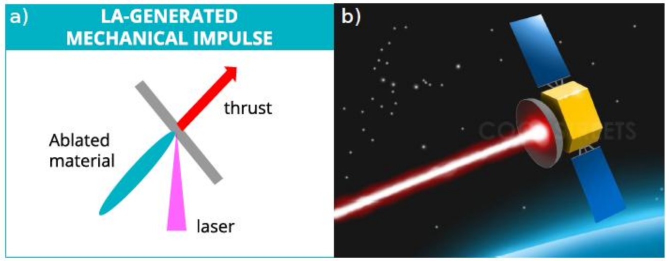
- **Green Chemical & Electric Propulsion**
  - Development and testing of hybrid rocket engines and air-breathing electric propulsion; CFD and DSMC of intake and combustion chamber (UniNa)

- **Electric Plasma Thrusters**
  - Design and modeling of Helicon plasma thrusters with optimized magnetic topology and rotating magnetic field acceleration (ENEA)

- **On-Board Systems & Solar Cells**
  - Distributed electronic subsystems using microcontrollers and FPGAs for data acquisition, signal processing, and control







WP 1.4 - Deep-Space Exploration with Miniaturized Platforms: Democratizing the Outer Space

WP 1.4
Deep-Space Exploration with Miniaturized Platforms: Democratizing the Outer Space

Tasks

- Autonomous operations of miniaturized platforms in deep space
  (TL: Polimi)
- Technologies for resources extraction, manipulation, and utilization
  (TL: Polimi)
- Radiation-tolerant, miniaturized components
  (TL: Poliba)
- Enabling technologies for deep-space, miniaturized platform
  (TL: CNR)

WP Leader: C. Ciminelli (Poliba)

Goal:

To demonstrate the validity of miniaturized technologies for dee-space exploration.

D1.4.1 –Autonomous Operations of miniaturized platforms

Development and testing of software and hardware solutions to increase autonomy of miniaturized, deep-space probes, including scientific, engineering, and flight operations

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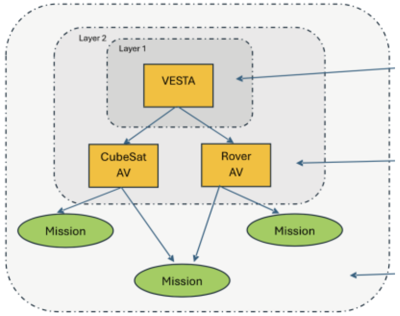
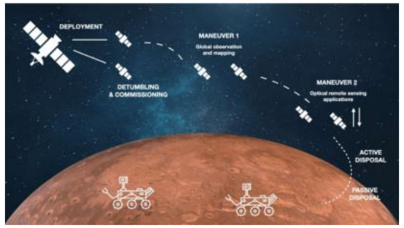
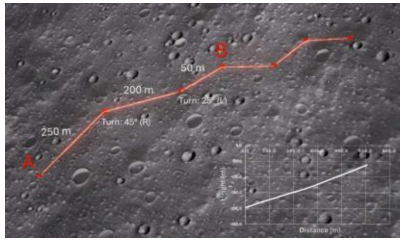
- **Autonomous Guidance**
  - Robust onboard guidance algorithms for deep-space trajectory planning (PoliMi)
- **Rad-Hard Avionics**
  - Modular, fault-tolerant avionics for CubeSats and rovers (PoliTo)
- **Onboard Autonomous Navigation**
  - Semi-autonomous GNSS-like constellations for Mars, using ISL (UniBo)
- **Automated Platform Design**
  - Autonomous optimization tool for platform architecture (TAS-I)
- **Digital Twin & Simulation**
  - End-to-end digital twin environments for mission simulation (TPZ)



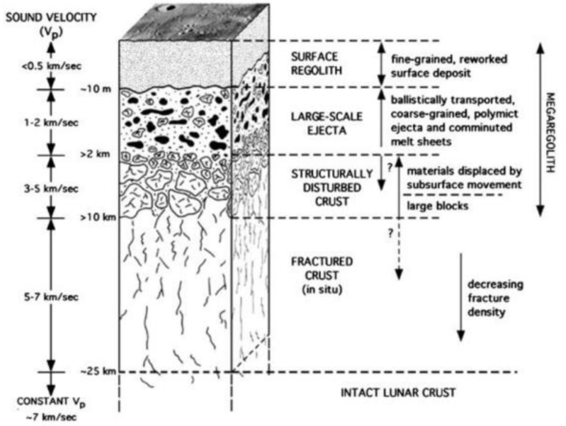


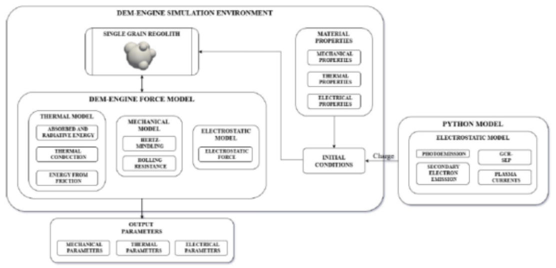


D1.4.2 – Technologies for Resources Extraction, Manipulation, and Utilization

Enabling technologies for planetary resources identification, extraction, manipulation, and utilization to support space exploration and future missions, with a primary focus on the Moon

- **Planetary Surface Modeling**
  - Development of engineering models for regolith and surface materials
  - Synthetic image data generation for planetary landing using multispectral imaging
- **Soil Processing Technologies**
  - Breadboarding and lab testing; Modeling of granular regolith behavior
  - Modeling and simulation of non-cohesive multiphysics soil high fidelity representation to
- **Data Fusion for Soil Analysis**
  - Design, breadboarding and testing of miniaturized conveyor for non-cohesive material transportation on low gravity bodies
- **Operational Environment Modeling**
  - Breadboarding and testing of solution for low gravity bodies anchoring





D1.4.3 – Radiation-tolerant, miniaturized Components

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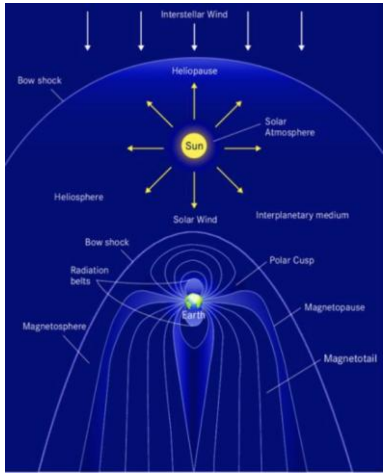
Assessment of the state-of-the-art in radiation-hardened components and circuits, and strategies to improve radiation tolerance for deep-space missions.

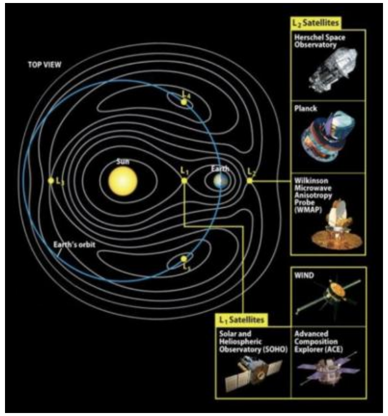
- **COTS in Deep Space**
  - Use of COTS for deep-space: advantages and challenges
  - Analysis of different mitigation strategies

- **Environmental Modeling**
  - Modeling of the radiation environments at Sun-Earth collinear Lagrange points

- **Radiation Shielding Materials**
  - Survey and experimental validation of advanced materials
  - Experimental validation and Monte Carlo simulations of advanced materials vs aluminium

- **Standardization & Future Trends**
  - Push toward unified qualification standards, shared databases, and modular qualification
  - Low-power integrated technologies, heterogeneous integration, onboard AI for FDIR





D1.4.4 – Enabling technologies for deep-space, miniaturized platform

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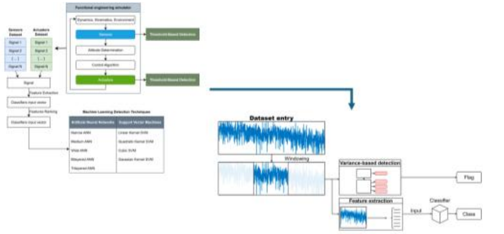
Consolidation and advancement of enabling technologies for deep-space exploration using miniaturized platforms

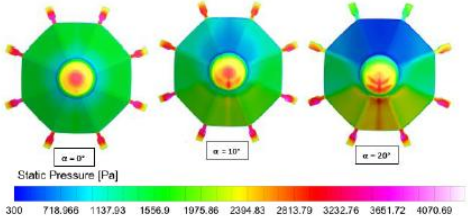


PoliMI — **AI-based tools for autonomous space missions**

AI-driven fault detection and diagnosis approach for spacecraft subsystems. A high-fidelity digital twin enables controlled signal generation, fault injection, and consistent benchmarking of alternative FDIR architectures.

UniNa — **Chemical green rocket propulsion based on hydrogen peroxide & Devices for aerobraking and planetary atmospheric entry**

Development and testing of green monopropellant and hybrid chemical rockets based on hydrogen peroxide for satellite applications. The study involves characterizing the performance of different catalysts used for hydrogen peroxide decomposition and deriving regression laws for various fuels.



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