E.T.PACK-F

European Innovation Council

Operational Solutions and Validation of Critical Subsystems for Autonomous and Compact Deorbit Devices Based on Bare Electrodynamic Tethers

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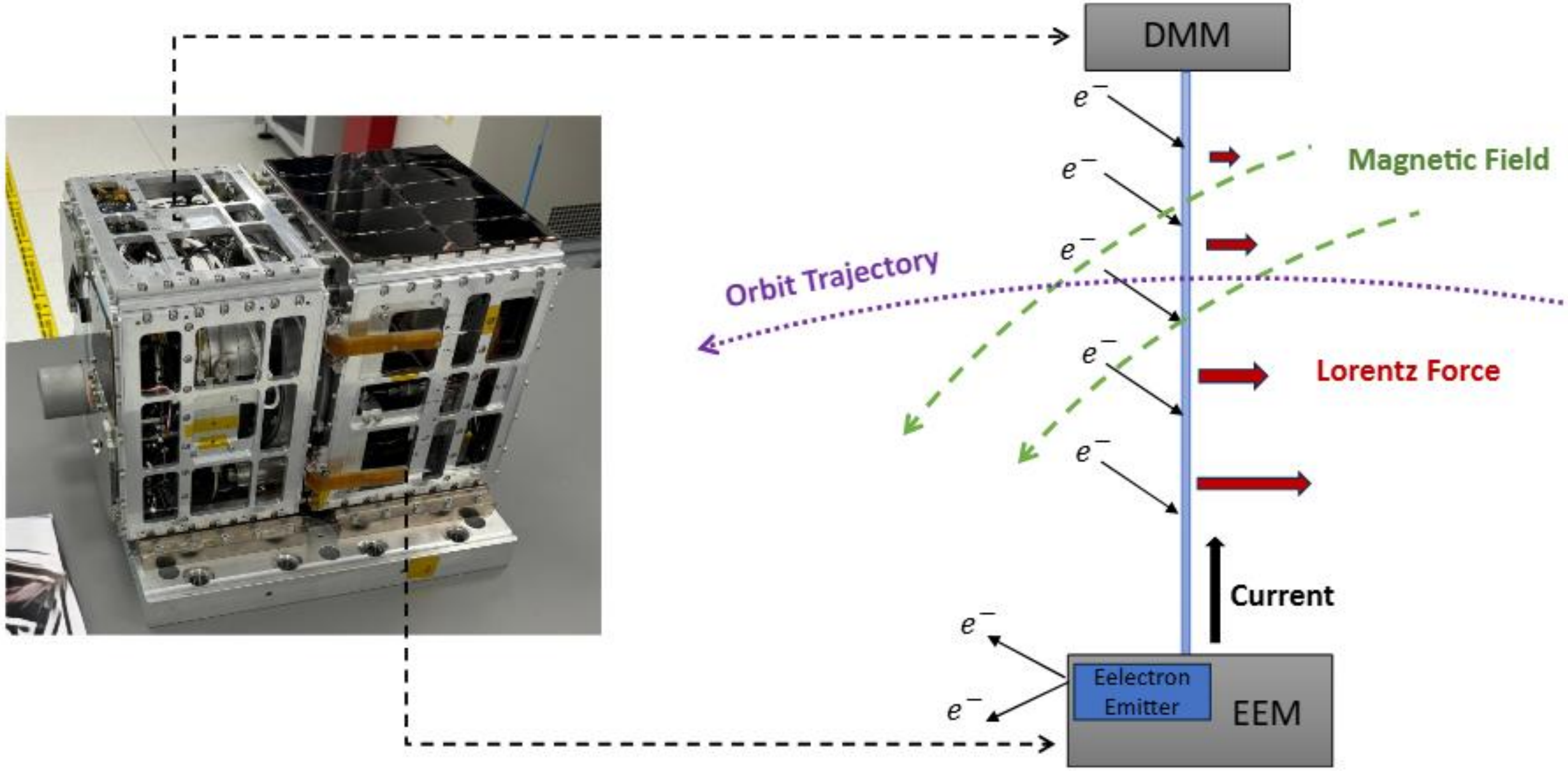
PhD Aerospace Engineering UC3M
Doctoral Meetings 2026
2nd and 3rd June 2026

Introduction

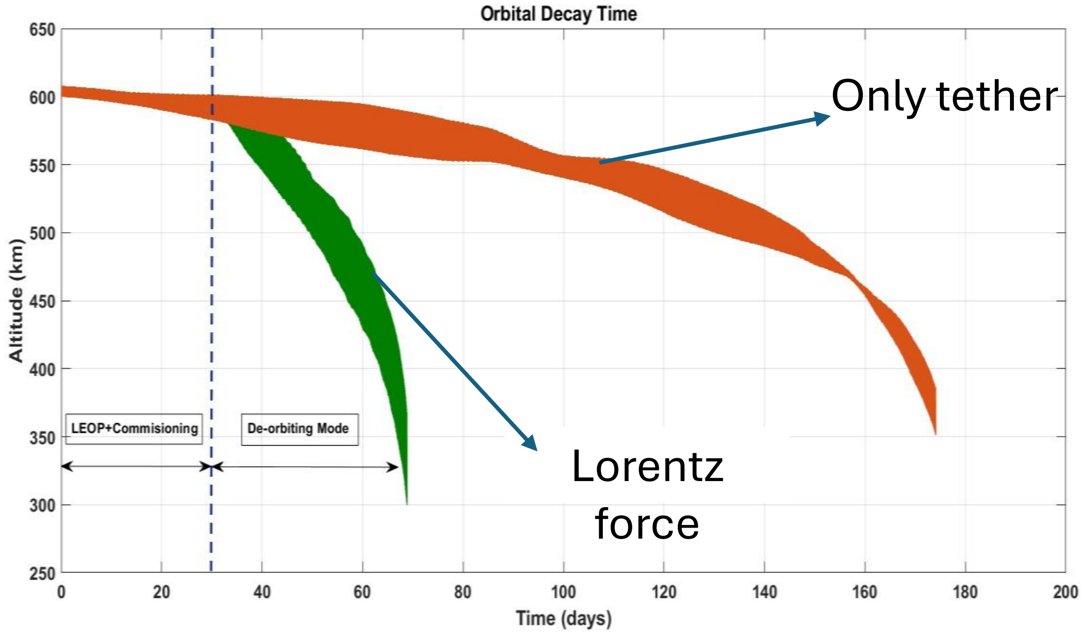
- ✓ Electrodynamic Tether systems are a promising solution for deorbiting space debris.
- ✓ E.T.PACK-F was a project aimed at developing a flight-ready deorbit device (TRL8).
- ✓ It includes two modules separated by a 420 m long tether.
- ✓ The propellant-less Lorentz force appears thanks to the action of the geomagnetic field on the tether current.

Qualification model of E.T.PACK-F deorbit device

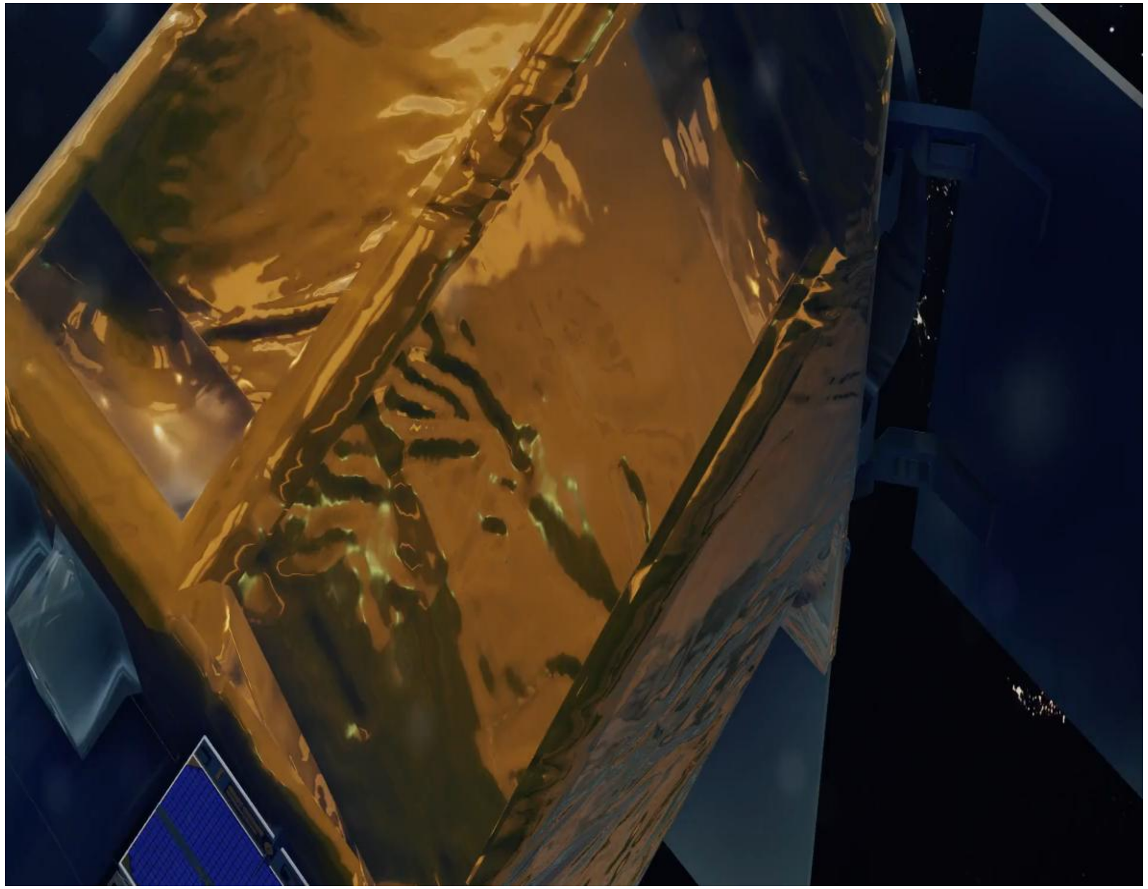


Introduction

EDT Performance



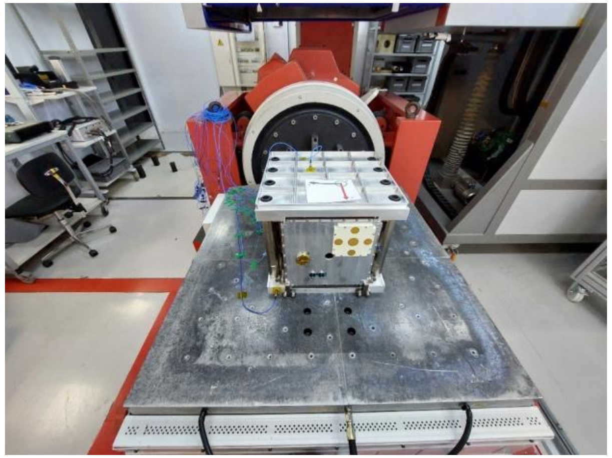
Satellite at 600 km: Without tether > more than 10 years
With tether < 3 months (Aerodynamic effect)
With EDT < 70 days

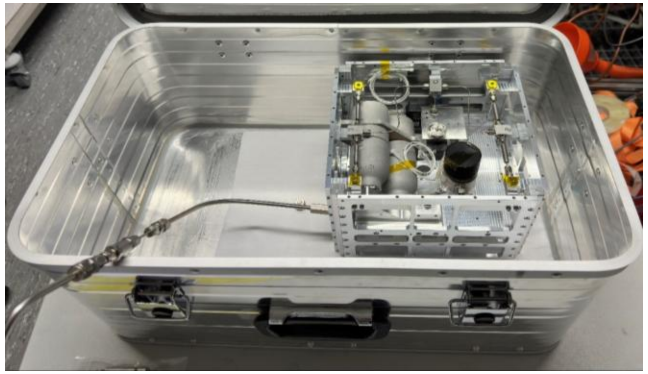


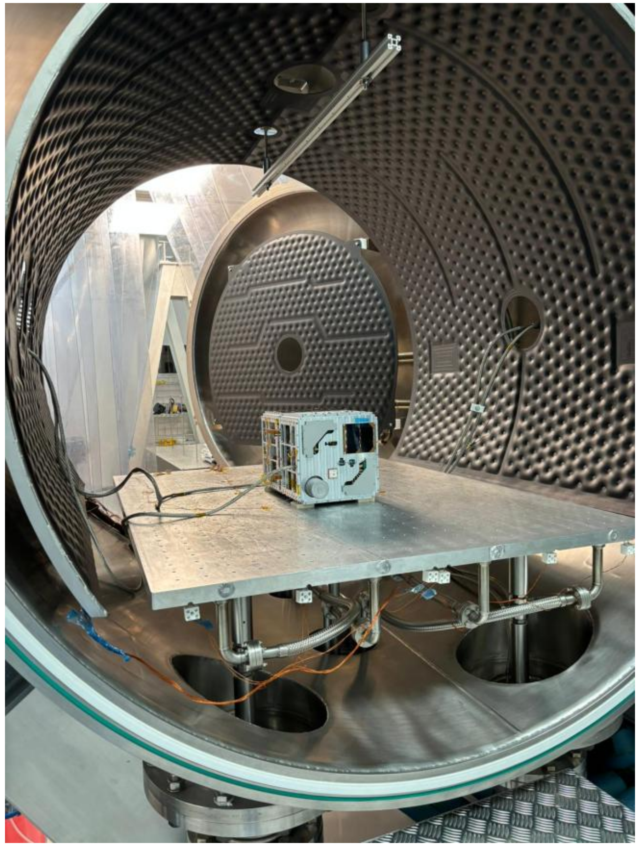
Video prepared in the E.T.PACK Project

Introduction

- Engineering qualification model (EQM) and flight model (FM) test campaign to reach **TRL8.**
- The mission, led by PERSEI SPACE, is expected to be launched in a Vega/C Rocket by AVIO in 2027.







PhD Thesis Objectives

- **Objective 1:**
  Validate the ADCS design, characterize its components, and verify the associated algorithms through hardware-in-the-loop testing

- **Objective 2:**
  Characterize the magnetic interference of the deorbit device (**DD**) by designing and developing a dedicated measurement setup, and to propose operational mitigation strategies based on the measured level of interference.

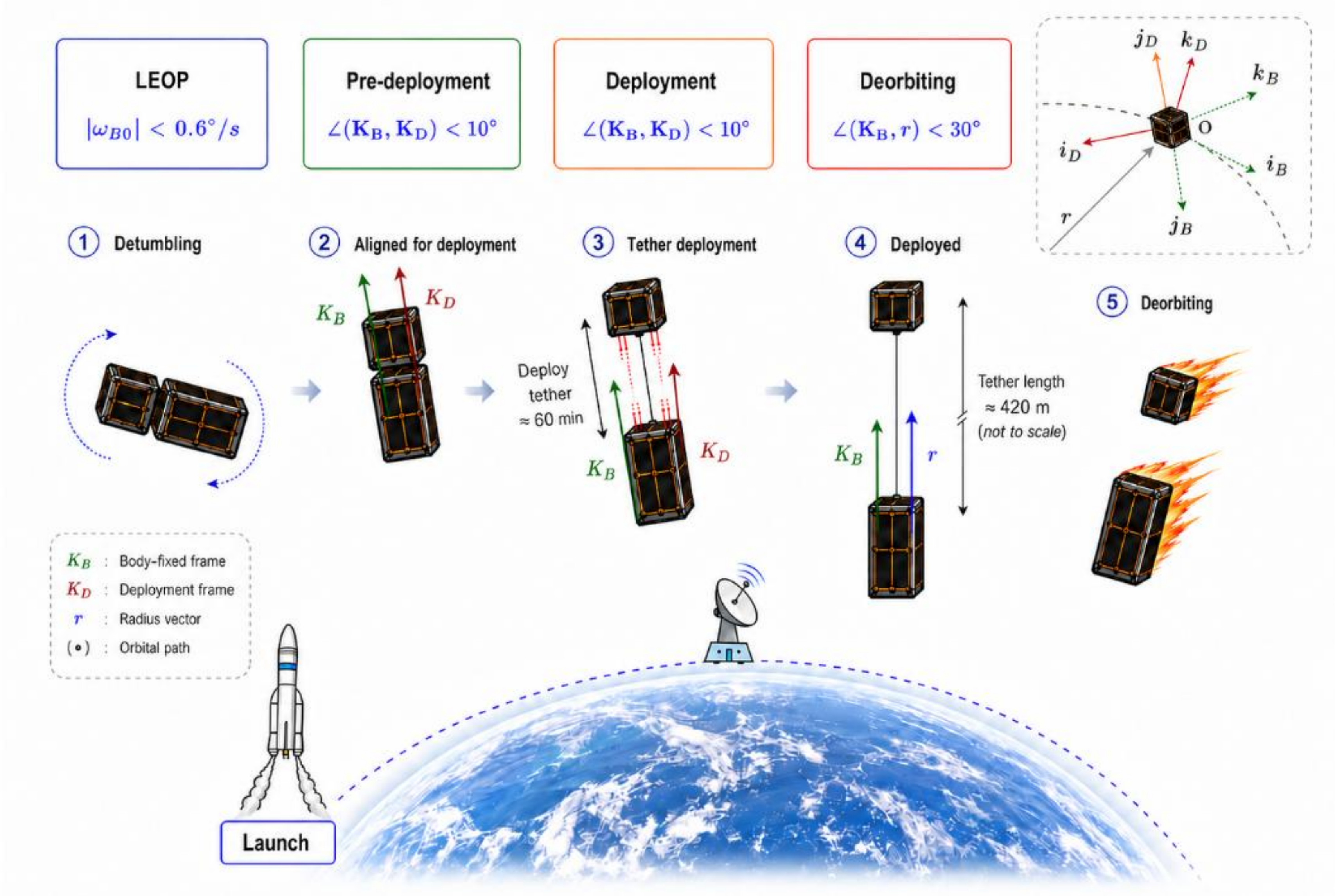
- **Objective 3:**
  Propose and analyze practical and efficient strategies to command the ignition time of the hollow cathode during the deorbit phase.

  ← Presented in 2024

- **Objective 4:**
  Design the dedicated ground segment and validate the complete ground-segment chain before launch. Include telecommunication subsystem and mission operation tasks for monitoring and operating satellite during the mission.

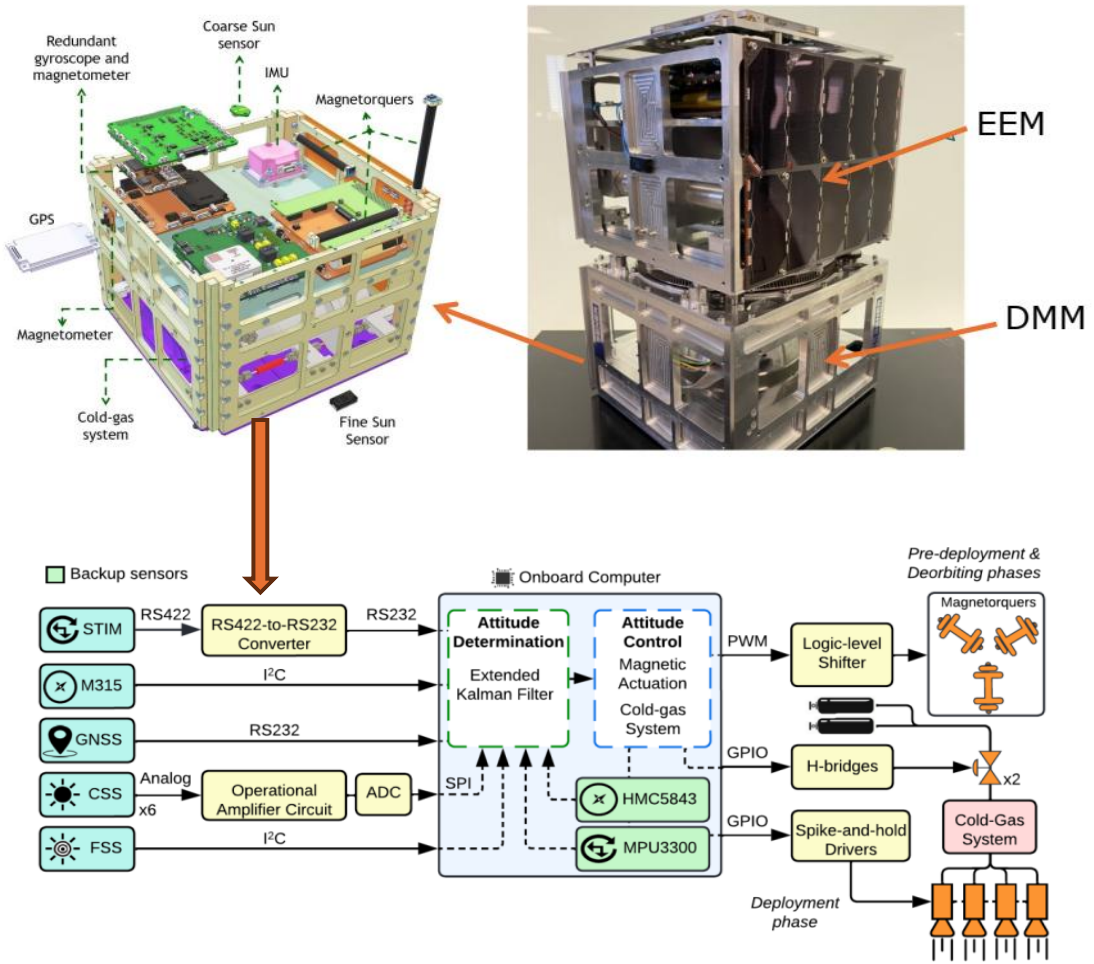
  ← Presented in 2025

Objective 1: Attitude Determination and Control



Objective 1: Attitude Determination and Control

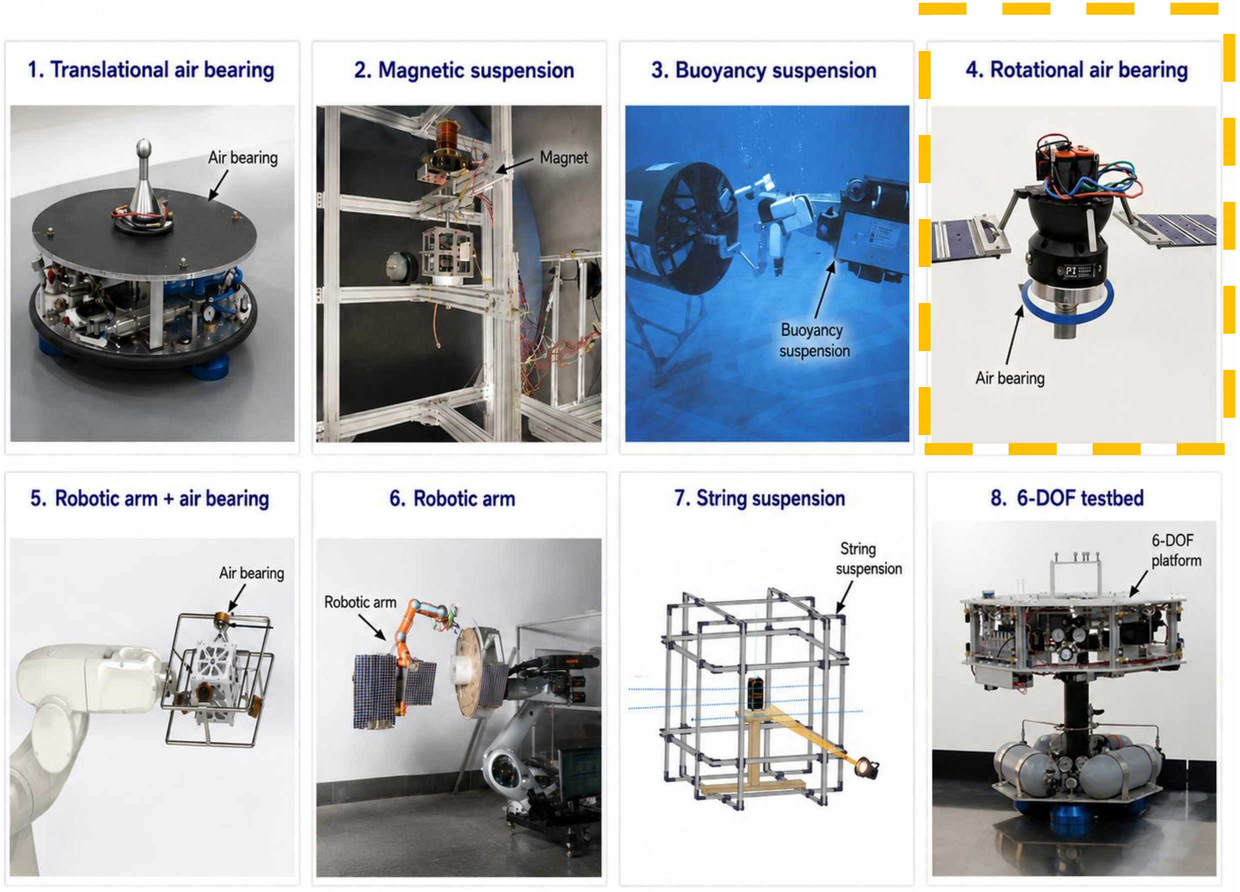
- ❑ Modules are fully independent in terms of ADCS.
- ❑ Both modules rely on the same sensors.
  - 3-axis gyroscopes: Main (STIM300) , Backup (MPU3300)
  - Magnetometers : Main (M315), Backup (HMC5843)
  - Sun sensors: Main (digital sun sensor), Backup (set of six analog Sun sensors)
  - A GNSS receiver
- ❑ The attitude determination method uses an EKF that combines sensor data to estimate attitude during the mission duration.
- ❑ Different control strategies for each mode, were designed.
- ❑ Magnetorquers are employed in pre-deployment and deorbiting phases
- ❑ Cold-gas system is used only during the deployment phase
- ❑ ADCS parameters are possible to modified during the mission by uplink commands.



Objective 1: Attitude Determination and Control

- ADCS is the most possible failure subsystem in satellite. HIL testing is needed to validate the design, algorithms and performance before launch to decrease the mission risk.
- First, an experimental setup should be developed.
- HIL requirements for the ADCS:
  - 3 degrees of freedom of rotation
  - Less magnetic interference
  - Low friction
  - Compatible with the size and mass of the satellite

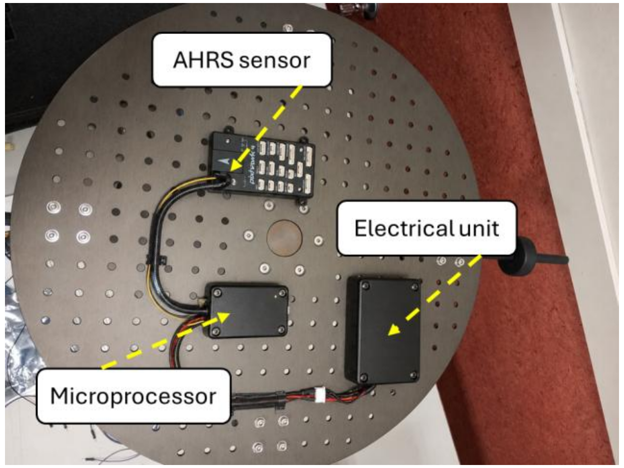
State-of-the-art :

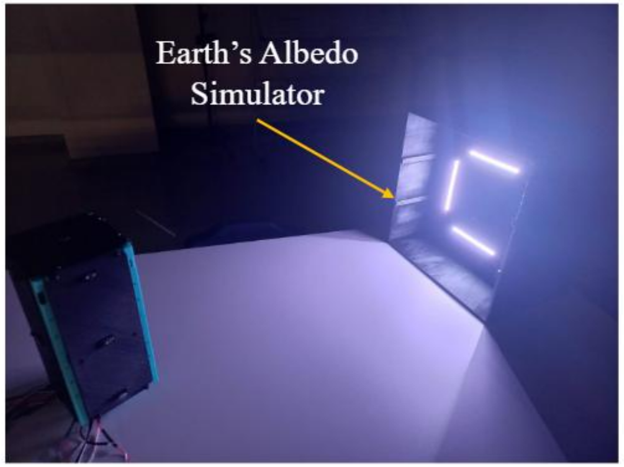


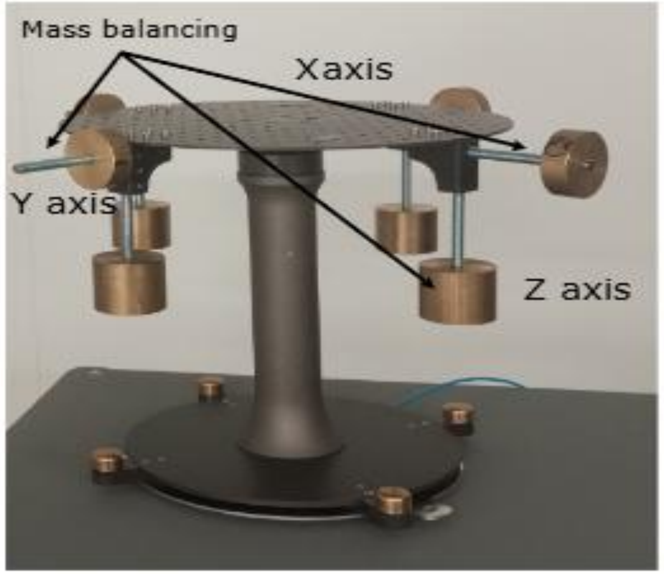
Objective 1: Attitude Determination and Control

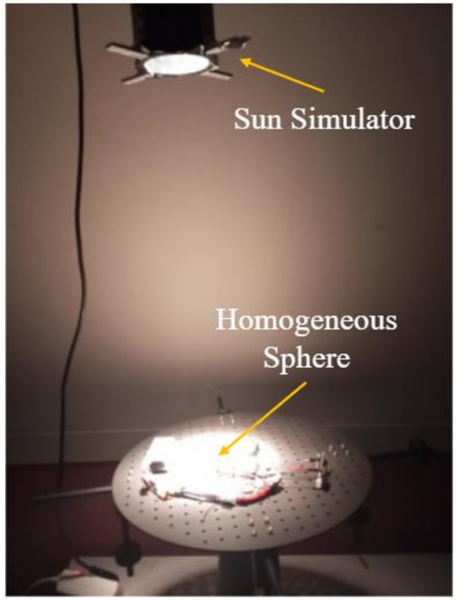
Experimental Setup:

- ❑ Nano satellite simulator for free 3 axes floating
- ❑ Compatible with satellite up to 16 U
- ❑ Balancing system for removing gravity torque
- ❑ Sun simulator to mimic sunlit and eclipse
- ❑ Earth Albedo light to simulate light reflected from Earth
- ❑ Ground station for monitoring and commanding
- ❑ Electrical and sensors unit

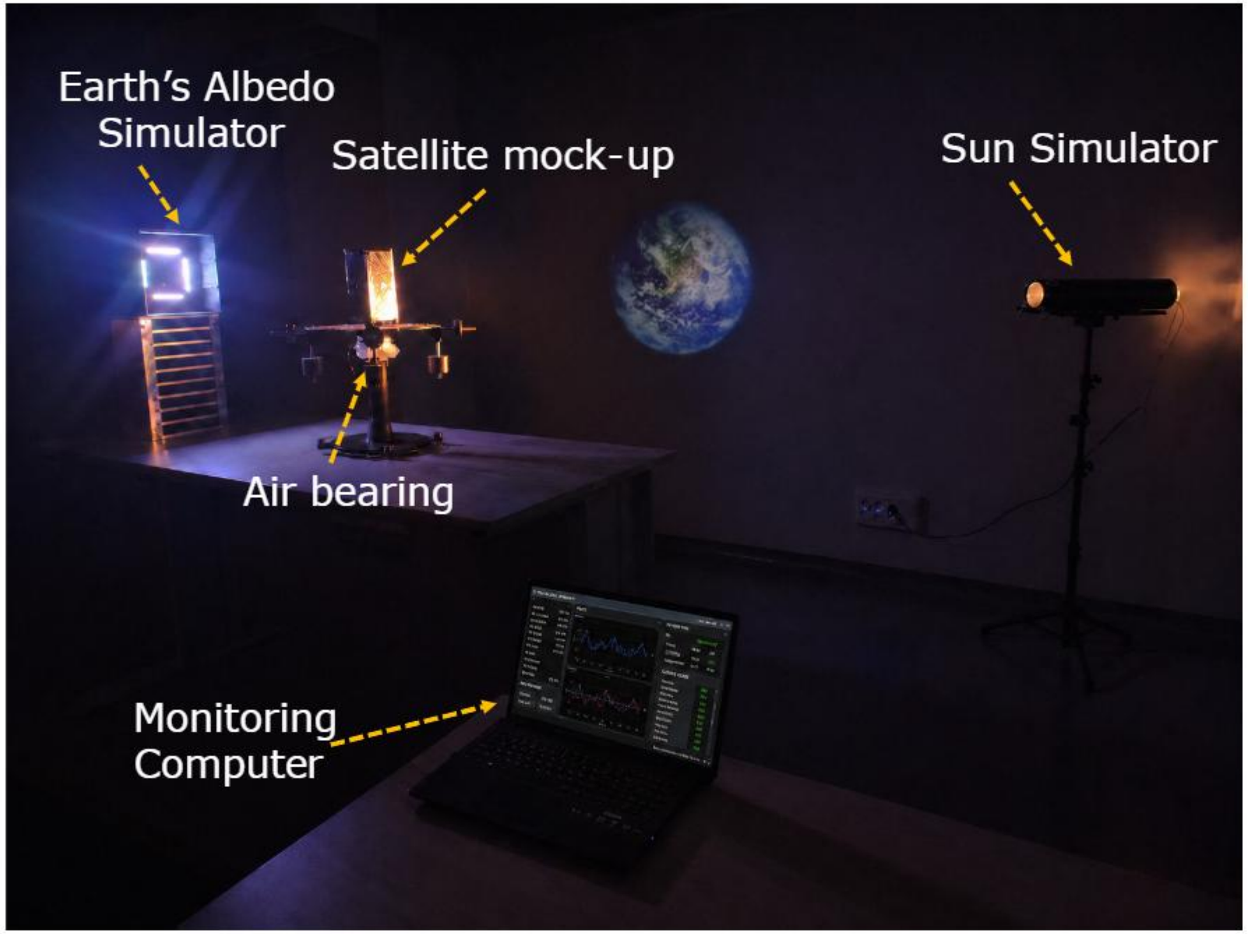




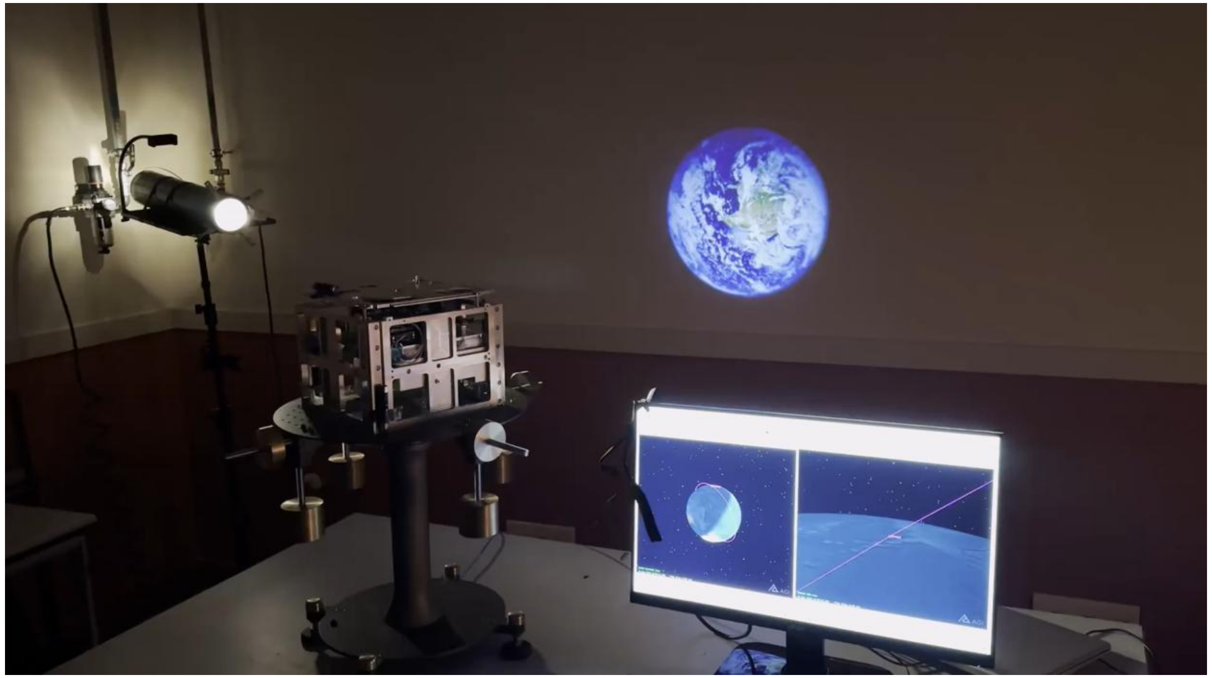




Objective 1: Attitude Determination and Control



Integrated Setup

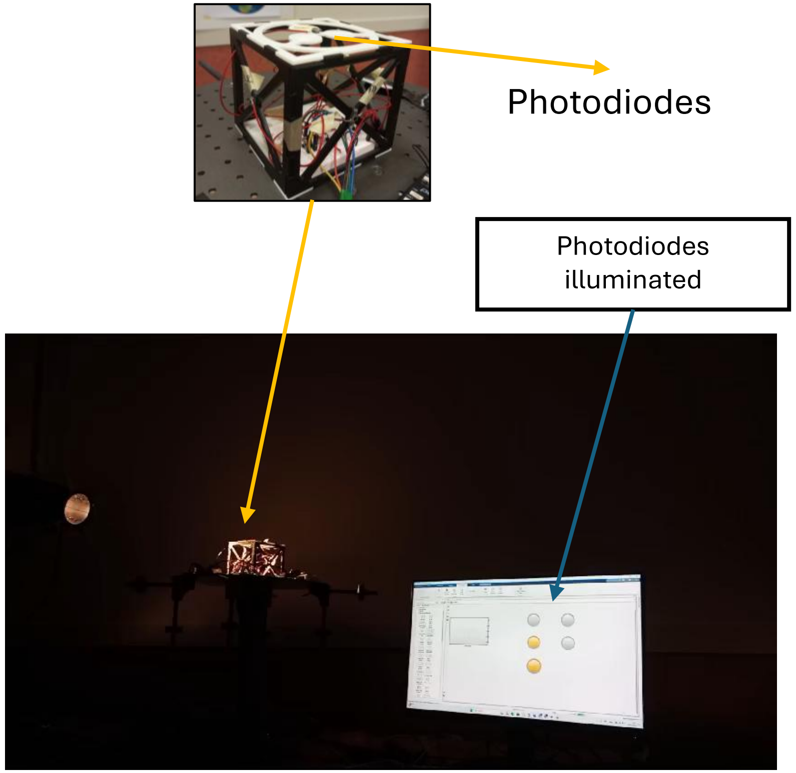


Setup under HIL test

Objective 1: Attitude Determination and Control

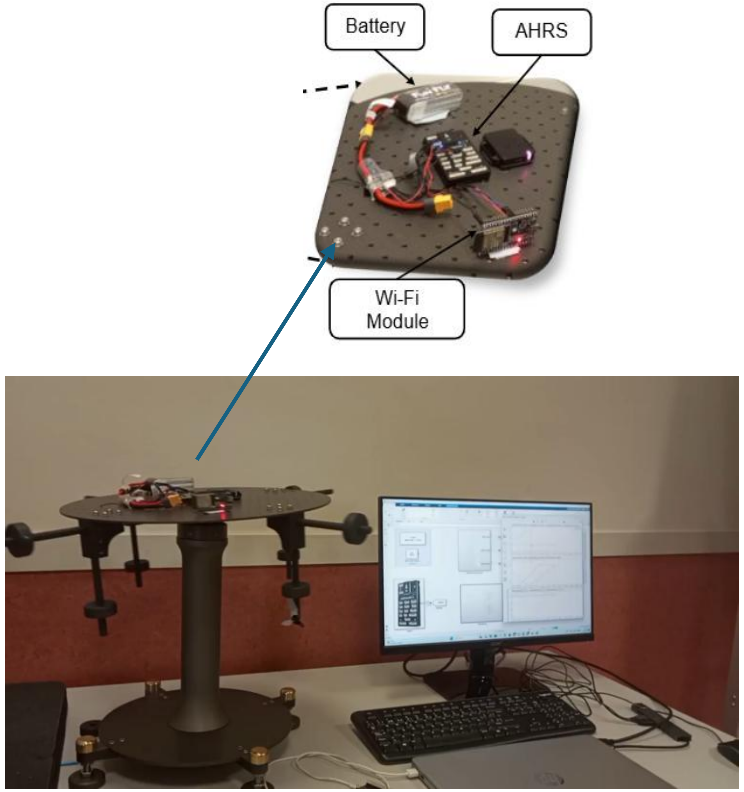
Sun sensor validation

Validation of photodiodes configuration and algorithm



Algorithm Validation

Validation of attitude determination algorithm



End to End Test

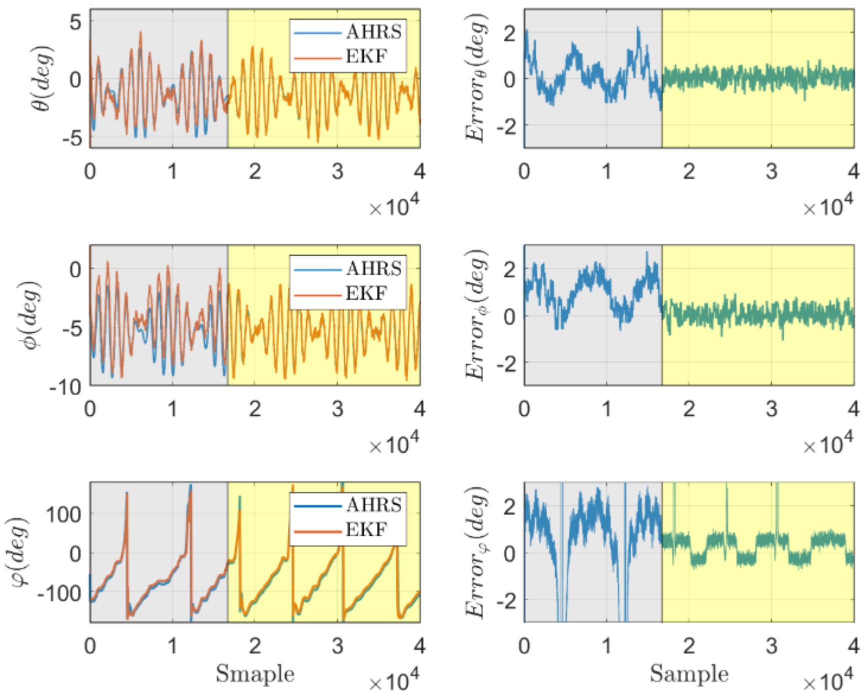
Validation of entire subsystem including sensors, algorithm, microcontroller

Objective 1: Attitude Determination and Control

Results of End-to-End attitude determination tests:

Required attitude determination accuracy < 5 deg error

	Sensors	Sunlight	Eclipse
Attitude determination validation	Main sensors	✓	✓
	Gyro: Backup Mag, SS: Main	✓	✓
	Mag: Backup SS, Gyro: Main	✓	✓
	SS: Backup Gyro, Mag: Main	✓	✓
	Backup sensors	✓	✓



Sensors	Eclipse[deg]			Illumination[deg]		
	σ_{E_ϕ}	σ_{E_θ}	σ_{E_φ}	σ_{E_ϕ}	σ_{E_θ}	σ_{E_φ}
STIM, M315, FSS	0.82	0.63	0.87	0.38	0.41	0.45
STIM, HMC, FSS	0.89	0.85	0.92	0.59	0.65	0.58
MPU, M315, FSS	1.86	1.92	1.52	0.96	1.09	1.16
MPU, HMC, FSS	1.91	2.24	2.37	1.24	1.17	1.42

Objective 2: Magnetic Interference

Problem Overview

E.T.PACK-F was designed to be **compact**, therefore its performance can be affected by magnetic interface.

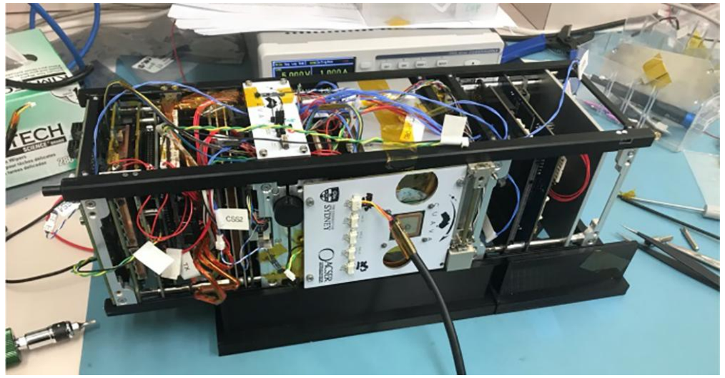
- ❑ **Residual magnetic dipole**
  - Electrical components, Wiring, Ferromagnetic materials

Interaction of the residual dipole with the ambient magnetic field generates **disturbance torque** $T = m \times B$

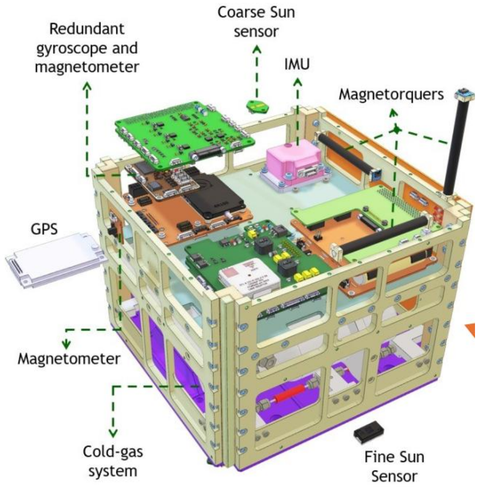
And two main sources of inferences

- ❑ **Cold Gas system**
- ❑ **Deployment Mechanism**

That can degrade the performance of mission, therefore need to be characterized.



Cuava1 satellite



CAD model of E.T.PACK-F

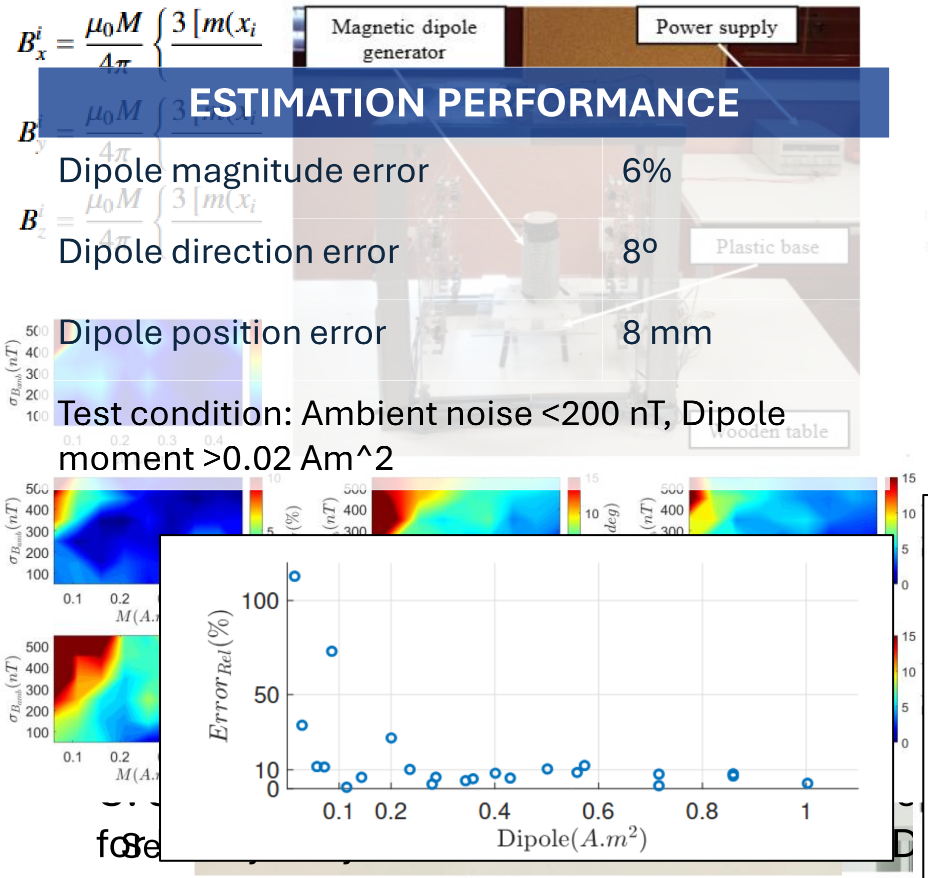
Objective 2: Magnetic Interference

- Software design
- 3D modeling
- Manufacturing
- Lab Validation
- Validation against other setups
- DD Dipole Estimation

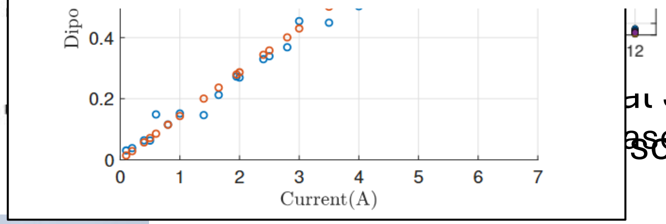
A setup is required to estimate the magnitude, direction, and location of the residual magnetic dipole.

ESTIMATION PERFORMANCE	
Dipole magnitude error	6%
Dipole direction error	8º
Dipole position error	8 mm

Test condition: Ambient noise <200 nT, Dipole moment >0.02 Am^2



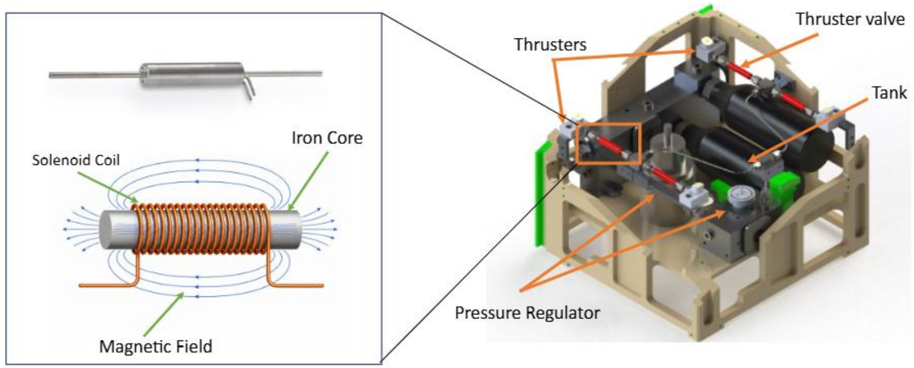
MADES		
Mode	$M_d^{est}(Am^2)$	u_d^{est}
0	0.0078	[0.12, -0.19, 0.96]
1	0.0214	[0.32, -0.28, 0.91]
2	Change undetectable	
3	0.0122	[0.14, -0.23, 0.95]
4	Change undetectable	
5	Change undetectable	
6	0.0136	[-0.08, -0.05, 0.97]
7	Change undetectable	



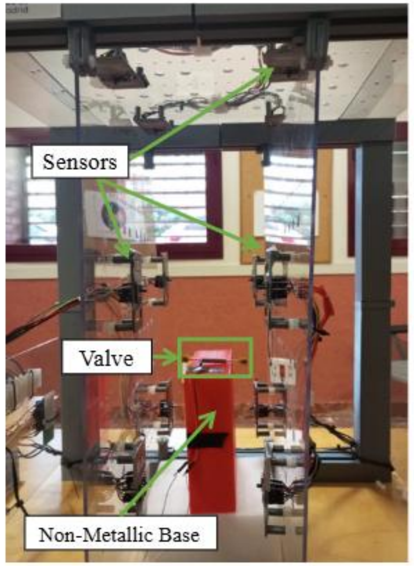
Journal, 2025

Objective 2: Magnetic Interference

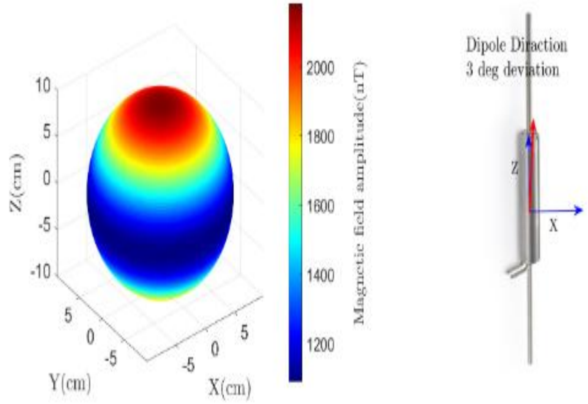
❖ Cold gas system and magnetic mapping approach



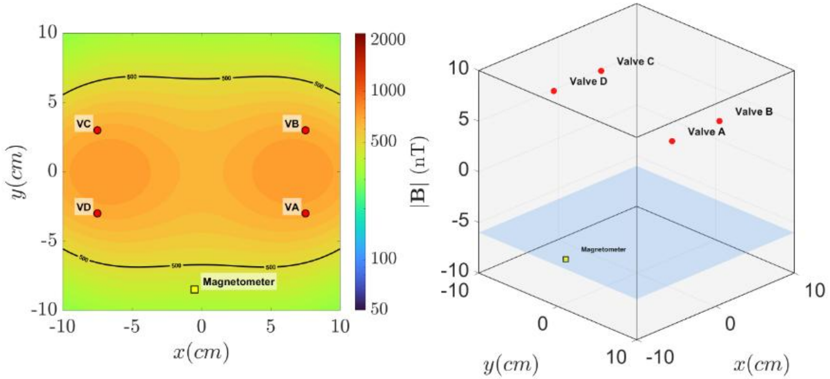
Dipole characterization



Magnetic effect



Mapping approach

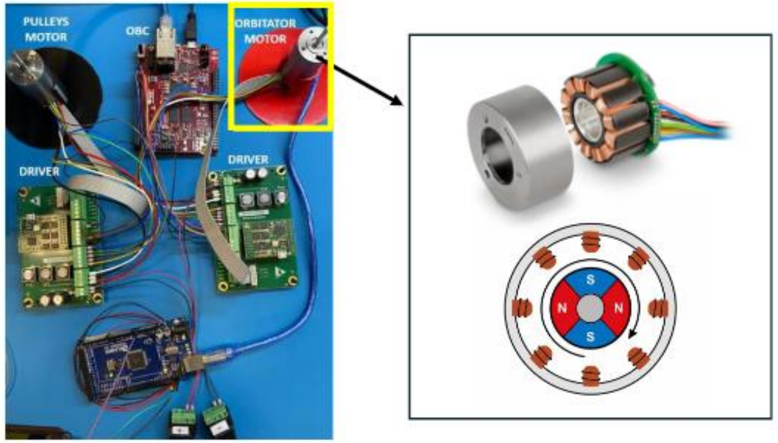


Magnetic effect on the proposed sensor location

Analysis Results:
Dipole of vale : 0,002 Am^2
Dipole direction: Almost along solenoid with 3 degrees deviation
Magnetic field direction error < 0.2 deg
Proposing magnetic mapping approach, to find a location for installing magnetometer with low interference.

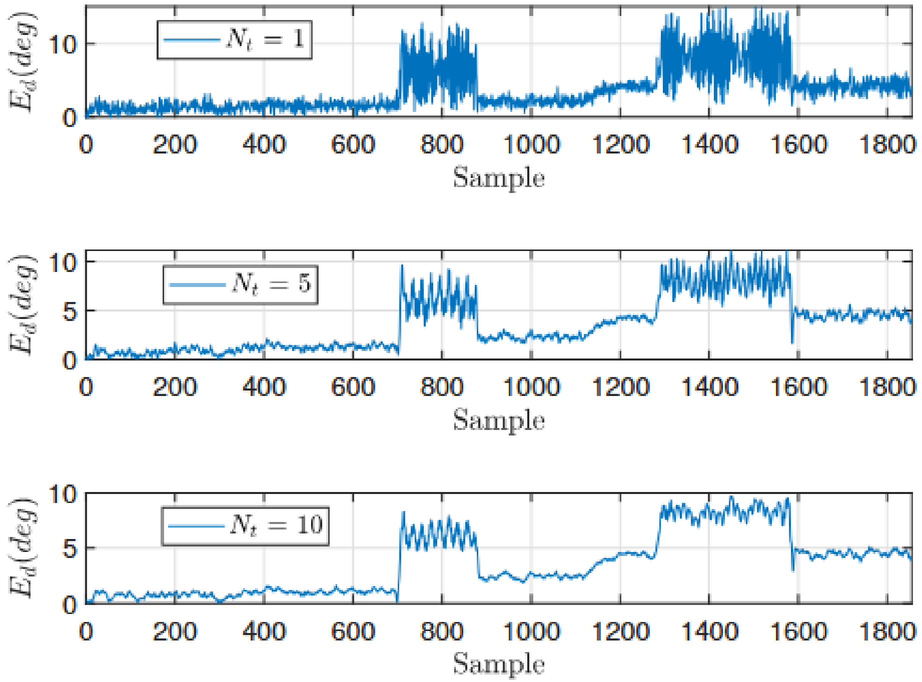
Objective 2: Magnetic Interference

Characterize the interference of the deployment mechanism

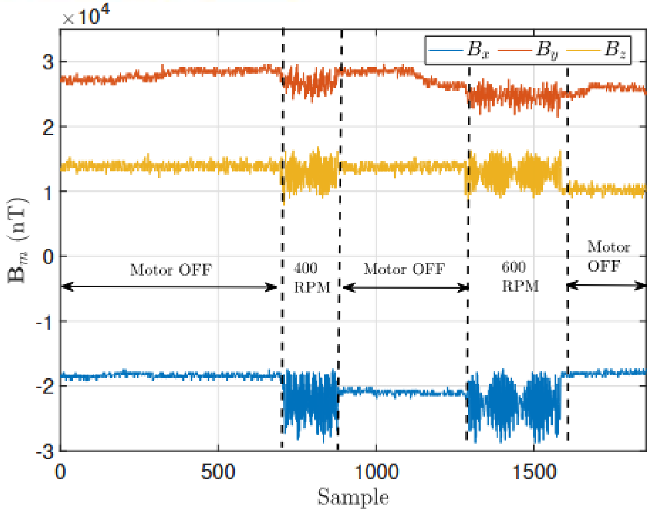


$$\langle \boldsymbol{B}_m^i \rangle = \frac{1}{N_t} \sum_{j=0}^{N_t-1} \boldsymbol{B}_m^{i-j}$$

$$E_d = \arccos\left(\frac{\langle \boldsymbol{B}_m^i \rangle \cdot \boldsymbol{B}_t}{|\langle \boldsymbol{B}_m^i \rangle|\,|\boldsymbol{B}_t|} \right)$$



Commanding motors



Conclusion:

- The HIL campaign confirmed that attitude determination algorithms, sensors combination and on-board processor can satisfy the mission accuracy requirements.
- Magnetic interference sources from residual magnetic dipole, cold gas and deployment mechanism characterized.
- Tests identified **several design revisions** that should be implemented to improve the robustness of the DD before flight.
  - ✓ **ground-based** activities like magnetometer calibration;
  - ✓ **in-orbit procedures** such as the estimation and removal of the gyroscope bias
  - ✓ **Algorithmic improvements**, such as the implementation of an EKF convergence indicator
  - ✓ **Onboard logic updates**, including sensor-switching strategies and the use of ground-station data to update relevant parameters during the mission

Achievements

Journals:

- G.Sharifi and G.Sánchez-Arriaga, Strategies for hollow cathode command in short electrodynamics tether-based deorbit devices, Acta Astronautica, 2024 https://doi.org/10.1016/j.actaastro.2024.04.039
- G.Sharifi , J. Gonzalez-Garcia, G.Sánchez-Arriaga, A Low-cost Experimental Setup for Determination of the Residual Magnetic Dipole of Small Satellites, IEEE Sensors Journal, 2025

Research Stay : Control, Robotics and Embodied AI

DTU Technical University of Denmark

Conferences:

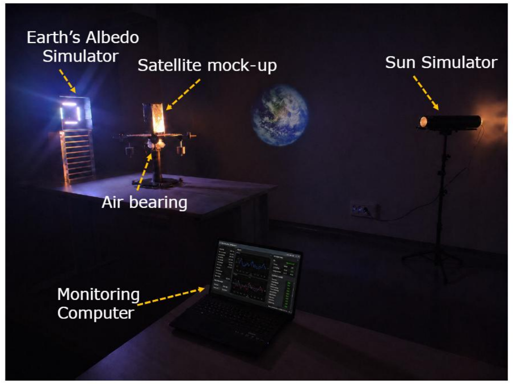
- Ghasem Sharifi, Diego Navarro-Tapia, Andrés Marcos, "Software and Hardware Validation of the Attitude Determination System of ST3LLARsat1 CubeSat MissionCEAS EuroGNC} conference, Madrid, 2026.
- G. Sharifi, S. Garcia, and G. Sanchez-Arriaga, "Validation of the Attitude Determination and Control System of a Deorbit Device Equipped with an Electrodynamic Tether Using Hardware in the Loop Testing", AIAA SCITECH, Orlando, FL, 2026.
- G. Sharifi, S. Garcia, D. Cruces, and G. Sanchez-Arriaga, "Hardware in the Loop Validation of the Attitude Determination and Control System of a Deorbit Device Equipped with an Electrodynamic Tether", 7th International Conference on Tethers in Space, Toronto, 2024
- G.Sharifi, S.Cuevas, L.Train, A.Hernández, A.Ponche, A.Marcos, UC3M's ST3LLARsat1 BOIRA: Baseline Design Review study and analyses for the ADCS and OBC subsystems, 13th European Cubesat Symposium, KU Leuven, Belgium , 2023
- Ghasem Sharifi, Andres Rabunal, Diego Navarro-Tapia, Andres Marcos, DEVELOPMENT OF AN ATTITUDE DETERMINATION AND CONTROL STRATEGY FOR THE ST3LLARSAT1 CUBESAT MISSION, The 4S Symposium 2024

Workshop: 2025 ESA Workshop on Aerospace EMC, Sevilla , 12-15 May, 2025

Achievements

Technology transfer and commercialization

- ❑ PhD-developed validation setups upgraded into commercial products.
- ❑ Products now available in the market through PERSEI Space.



Thank you!
Questions?

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