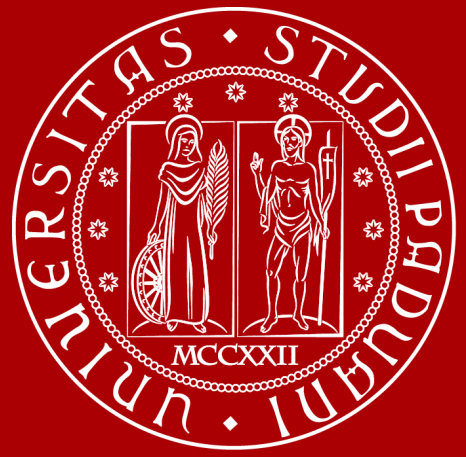

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Orbital debris management for a sustainable space environment

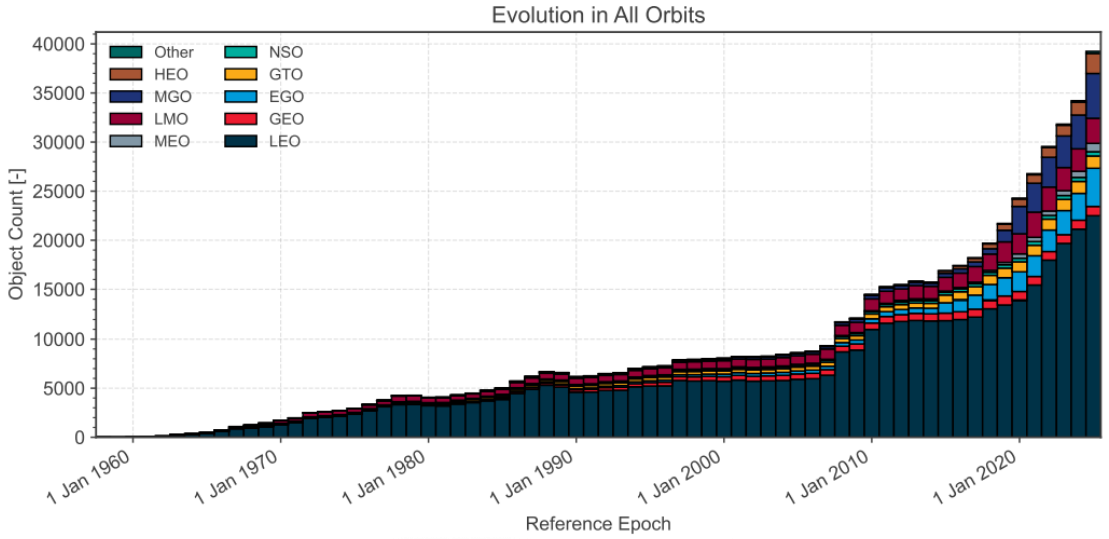
Alberto Abiti - 41th Cycle

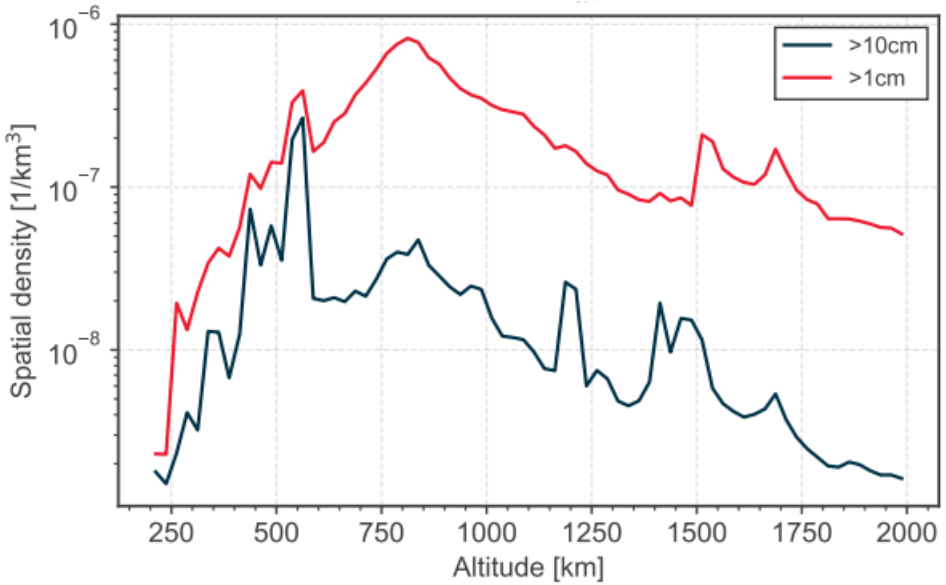
Meeting - 12/11/2025

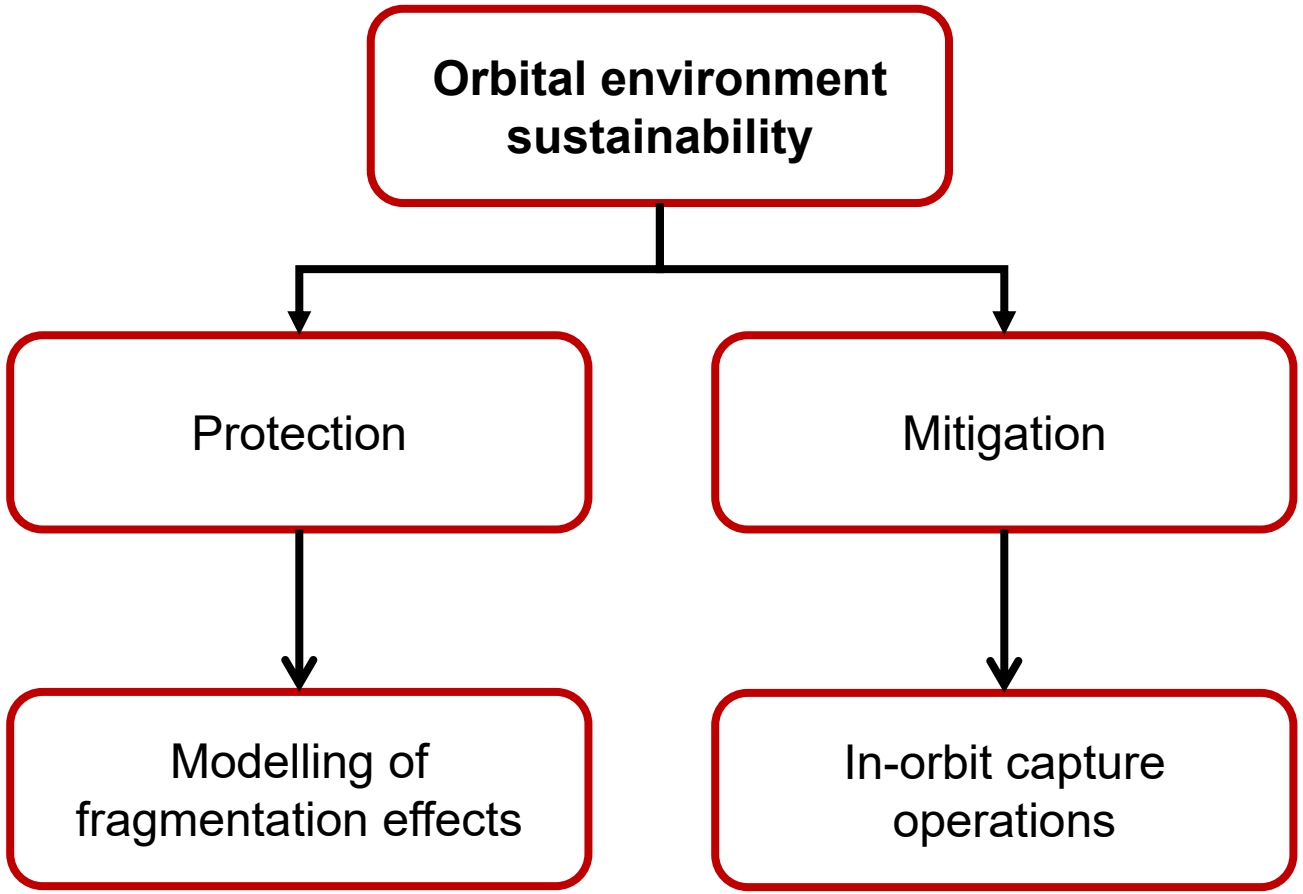
Outline

- Orbital environment sustainability
- Doctoral work objectives
- Project description
- Gantt chart
- Main expected results

Orbital environment sustainability





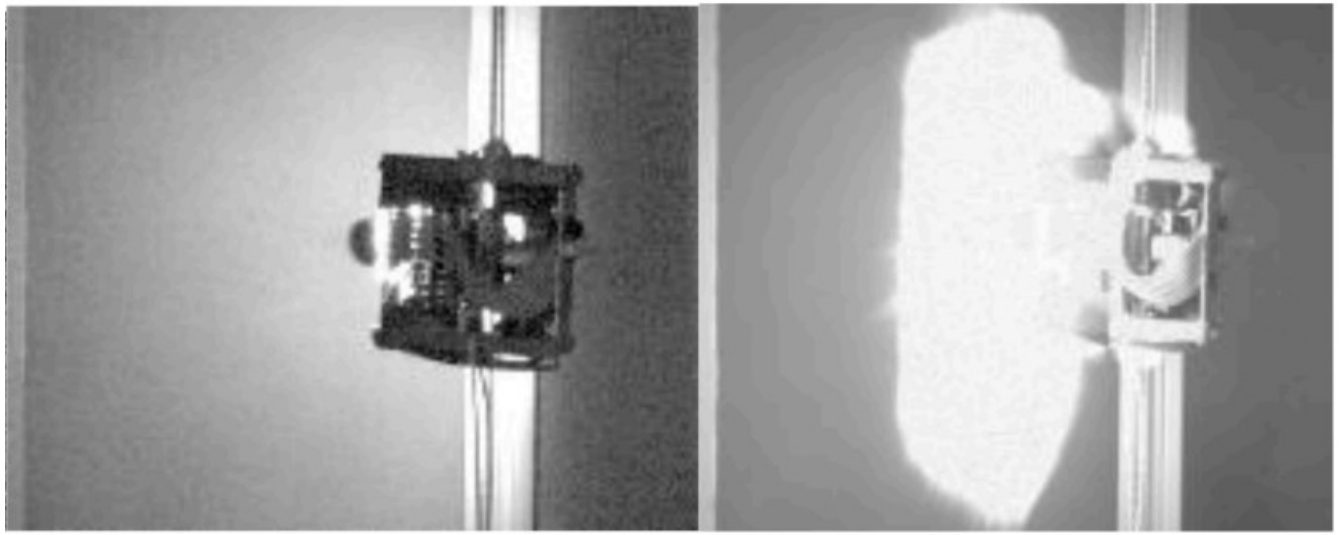


Orbital environment sustainability

Modelling fragmentation events

- Study of fragmentation models
  - Hypervelocity collision testing
  - Materials fragmentation models
  - Simulation
  - Complex structures models

- Study of vulnerability
  - Models depending on precise geometry

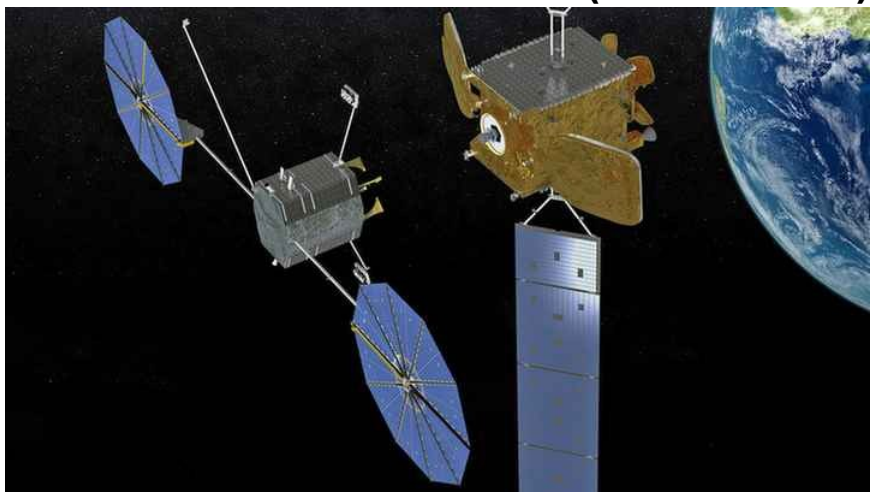


Orbital environment sustainability

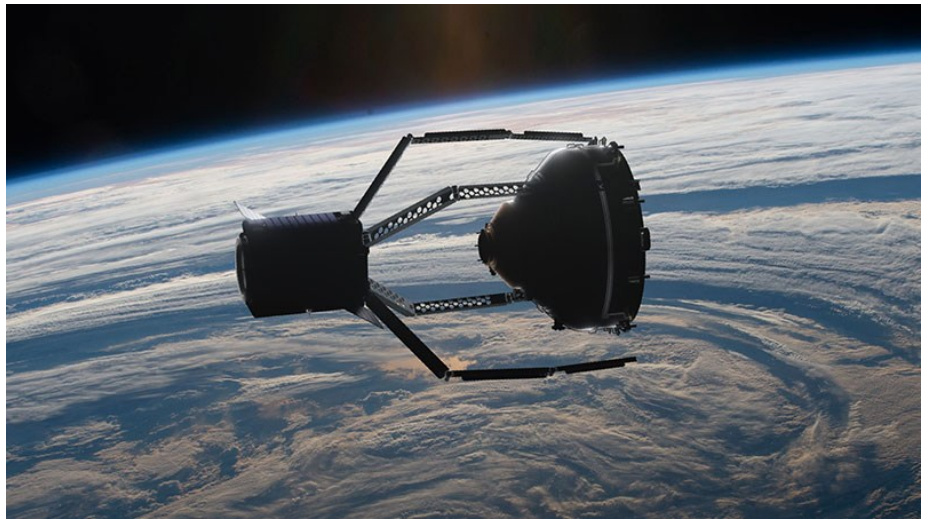
In-orbit capture operations

- In orbit servicing (IOS)
  - Orbit maintenance or modification
  - Refuelling
  - Repairing
  - Assembling
- Active Debris Removal (ADR)

MEV-1 & MEV-2 missions (2020 - 2021)



ClearSpace-1 mission (2028)



Doctoral work objectives

Modelling of fragmentation effects

- Study of local fragmentation models
- Numerical modelling of complex structures
- Consequences and vulnerability model

Identification of critical targets

Mitigation efforts

- Technology for removal: Trade off
- Simulation of in-orbit capture scenarios with a robotic arm
- Validation of in-orbit capture operations and facility development

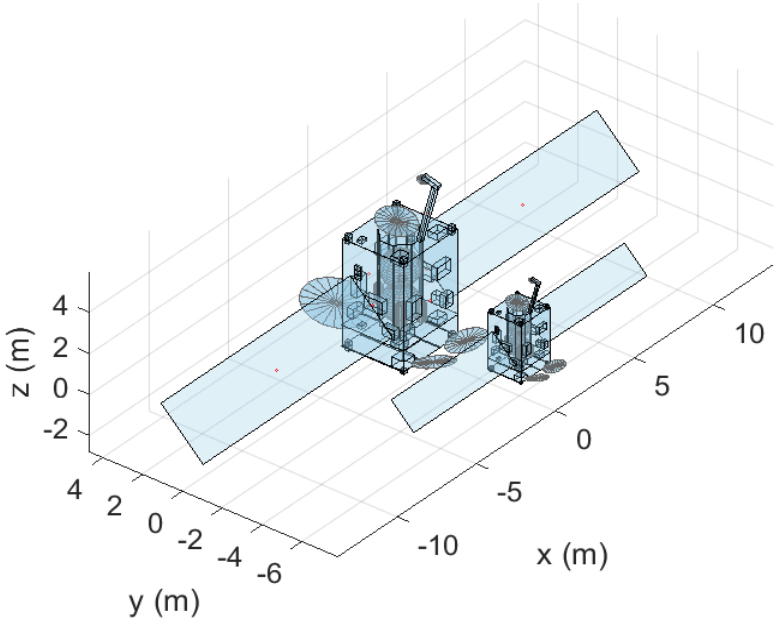
Project description

Study of the local and global fragmentation effects

- **Experimental** activities to study HVI fragmentation.
- Study of **local** fragmentation models and integration in **CSTS.**
- Study of **global** fragmentation behaviour of complex structures.

Vulnerability model and candidate spacecraft identification

- **Statistical fragmentation analysis** of a satellite model varying impactor parameters.
- Generalization of the **vulnerability model** to relate vulnerability level to simple-to-obtain parameters.
- Identification of **potential candidates** for ADR and IOS.

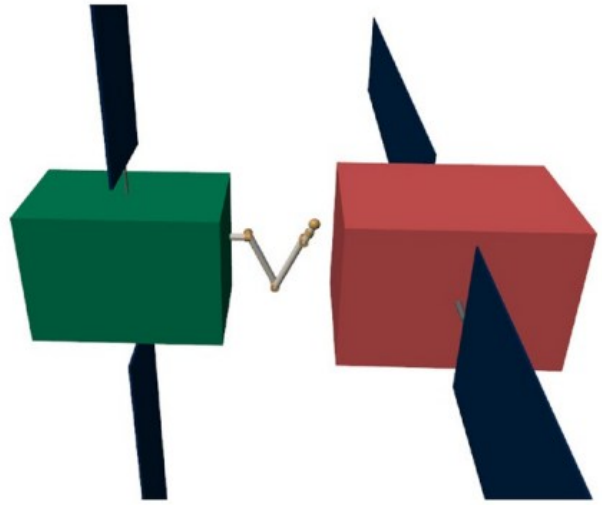


Project description

Simulation of capture scenarios

- Study of the **kinematics**, **dynamics** and **control** of the capture operation, considering the influence of disturbances, forces during the contact and the possible deformation of flexible structures.

- **Simulation** of selected **capture scenarios** using a GNC software implementing a combined-control approach.



Experimental validation of capture scenarios

- **Development** and **optimization** of the laboratory **facility** to reproduce close-proximity operations and capture with a robotic arm in a downgraded environment.

- **Experimental validation** of the simulated capture scenarios.

Outline

PHD STUDENT	Alberto Abiti	DATE	10/11/2025
PHD THESIS	Orbital debris managment for a sustainable space	ADMISSION TO	First year

WBS NUMBER	TASK TITLE	% OF TASK COMPLETE	FIRST YEAR												SECOND YEAR												THIRD YEAR											
			T1			T2			T3			T4			T1			T2			T3			T4			T1			T2			T3			T4		
			O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
1	Study of the state of art																																					
1.1	Study of the state of art	0%																																				
2	Study of the local and global fragmentation effect																																					
2.1	Fragmentation experimental activities	0%																																				
2.2	Local fragmentation models study	0%																																				
2.3	Global fragmentation models study	0%																																				
2	Vulnerability model and candidate spacecraft identification																																					
2.2	Statistical fragmentation analysis	0%																																				
2.3	Study of a vulnerability model	0%																																				
2.4	Identification of critical targets	0%																																				
3	Simulation of capture scenarios																																					
3.2	Study of the control and dynamics of the manipulator	0%																																				
3.2	Simulation of capture scenarios	0%																																				
4	Experimental validation of capture scenarios																																					
4.1	Development, integration and optimization of laboratory facility	0%																																				
4.2	Validation test campaign	0%																																				
5	Doctoral thesis and documentation																																					
5.1	Academic studies and documentation preparation	0%																																				
5.2	Congress partecipation and paper writing	0%																																				
5.3	Thesis writing	0%																																				

Main expected results

Modelling of fragmentation effects:

- Extend the knowledge about **local** and **global fragmentation** behaviour after a hypervelocity collision.
- Development of a **model** that can relate the **vulnerability** level of a satellite to observable and **simple** to obtain parameters.

In-orbit capture operations:

- Experimental **validation** of an innovative **GNC software** for describing in-orbit capture scenarios with a robotic arm.
- **Development** of the close-proximity operations **facility.**

Thanks for the attention

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