UNIVERSITÀ
DEGLI STUDI
DI PADOVA

Analysis and modelling of spacecraft fragmentation in consequence of in-orbit collisions

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Introduction

Project description

State of art

Work plan

Gantt Chart and WBS

Main expected results

Conclusions

Introduction

- Increasing number of objects resident in Earth orbits
  - Growing **risk of impacts** and collisions
  - Potential **cascade effect** and reduced capability to access **polluted orbits**
- Need to understand the **physical processes involved in break-ups**
  - Consequences for the space environment
  - Potential risks and mitigation tecniques
- **Limited information** avilable on space fragmentation
  - Ground observations limited to **detectable objects (> 5 cm)**
  - Need to perform **numerical simulations** or **ground tests**

Project description

The project is divided into 3 main research lines

- Analysis of the fragmentation of **simple components**, aimed at characterizing the response of **new-generation materials** such as additive manufacturing components, composite materials, and polymers to hypervelocity impacts.

- Analysis of the fragmentation of **complex systems**, conducting **representative tests** of in-orbit fragmentation events resulting from explosions or accidental or deliberate kinetic collisions, gathering data from tests and literature, and improving the CSTS code.

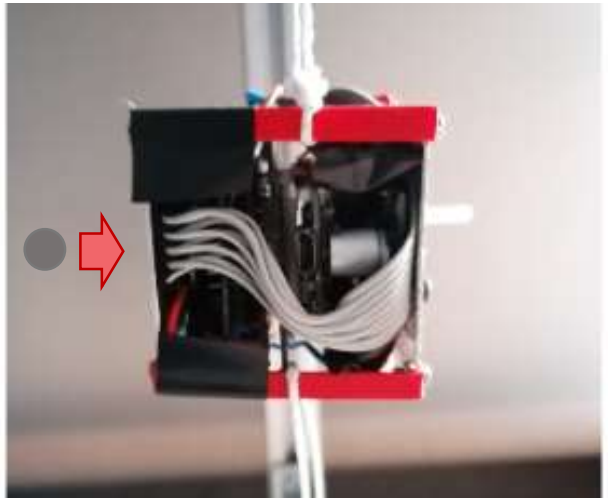
- **Development and testing** of a high reliability, high resolution, and low-cost **sensor** for the detection of millimeter-sized and submillimeter-sized debris in orbit.

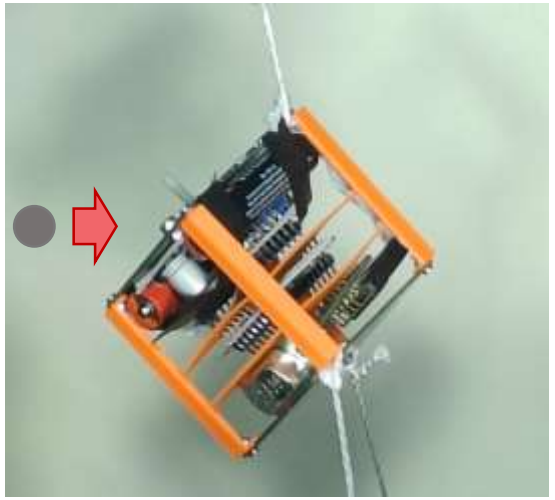
State of the art

- **Two stages Light Gas Gun (LGG)**: 100 mg projectiles up to 5.5 km/s
  - For aluminium and CFRP internal breakup models have been developed
  - Good correlation between calculated masses and actual fragment masses

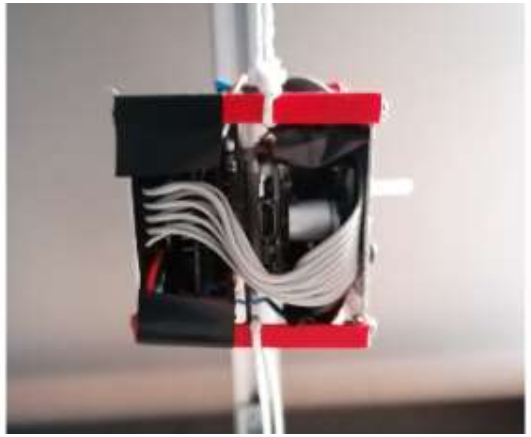
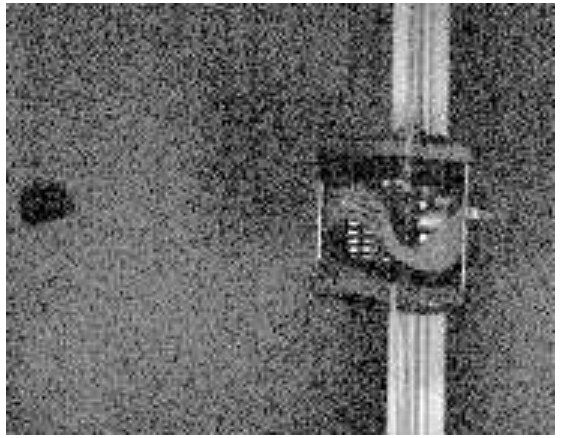
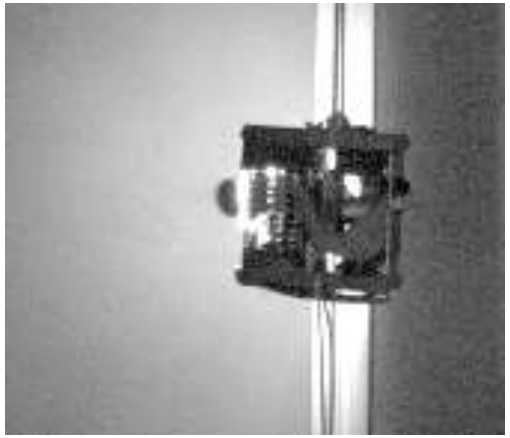
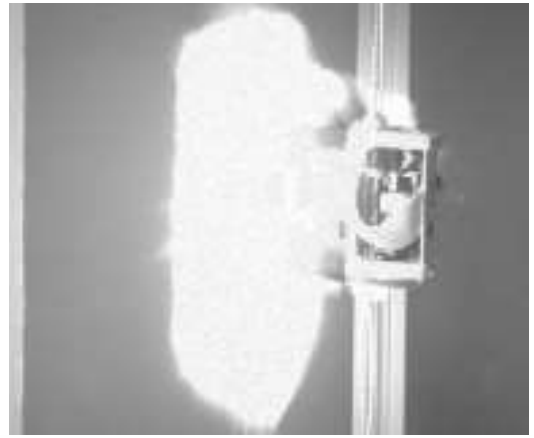
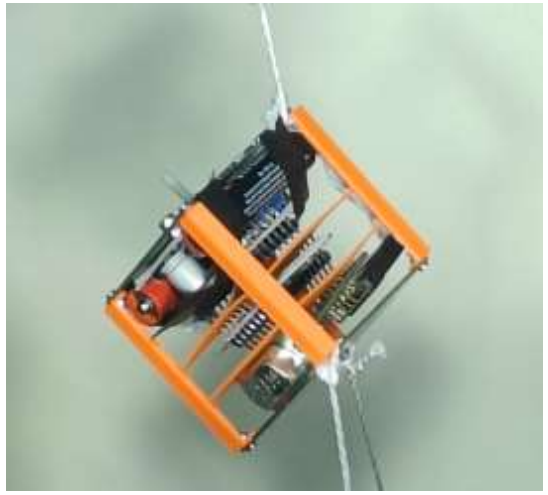
State of the art

- **Impact tests** recently performed on a **picosatellite mockup.**
- Projectile material and velocity kept constant to study the **correlation** between **generated debris population** and **impact geometry.**



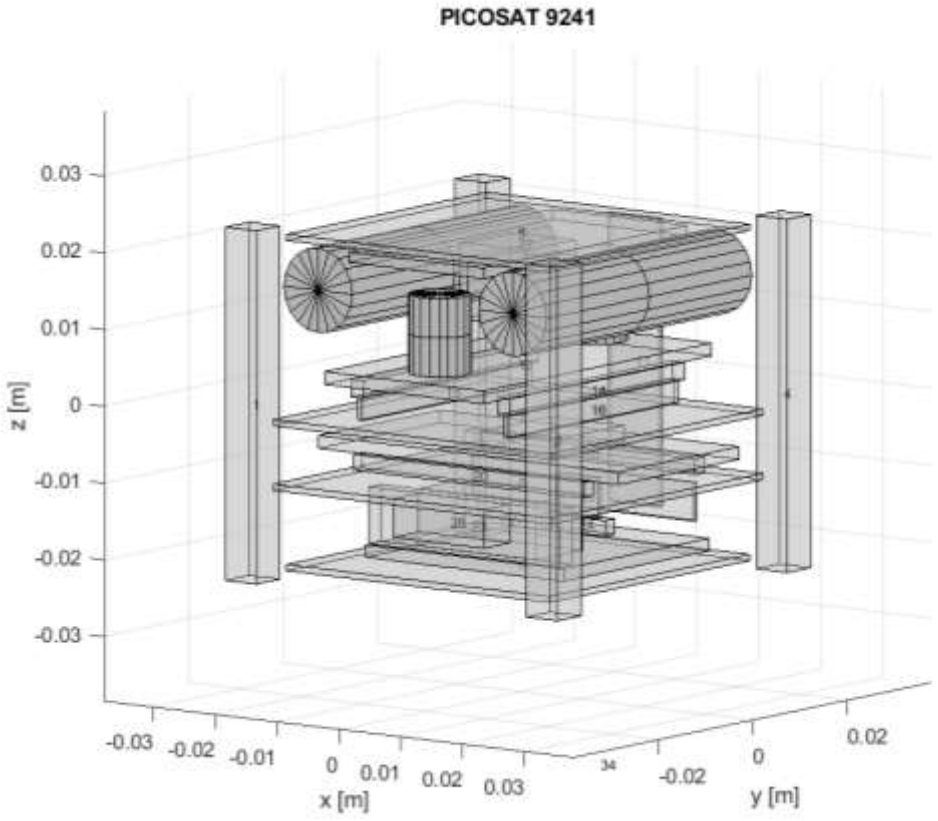


State of the art

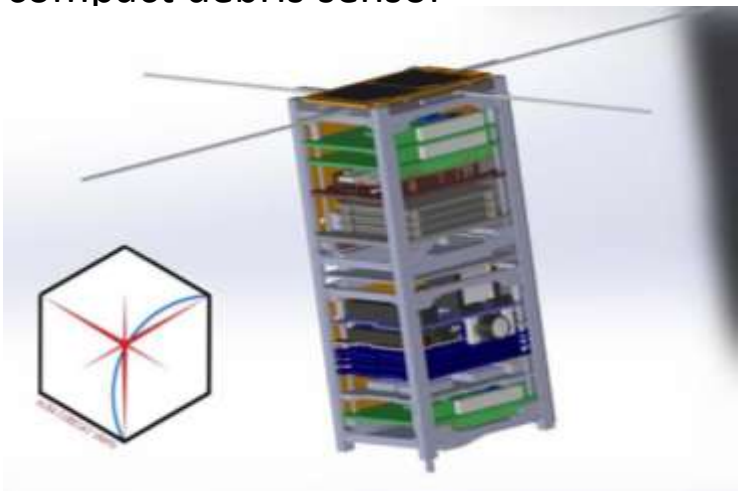

State of the art

- Codes developed **semi-empirically** are used to perform simulations of fragmentation events in orbit
- Impacts between **very different or very large geometries** are particularly challenging
- Function that **correlates crater** shape and size **with impact geometry** is not currently implemented



State of the art

- Numerous **in-situ impact detectors** have been used or are under development with different baseline technologies
- In Padova, **the student team Alba Cubesat** has realized the **preliminary design** of an extremely lightweight and compact debris sensor

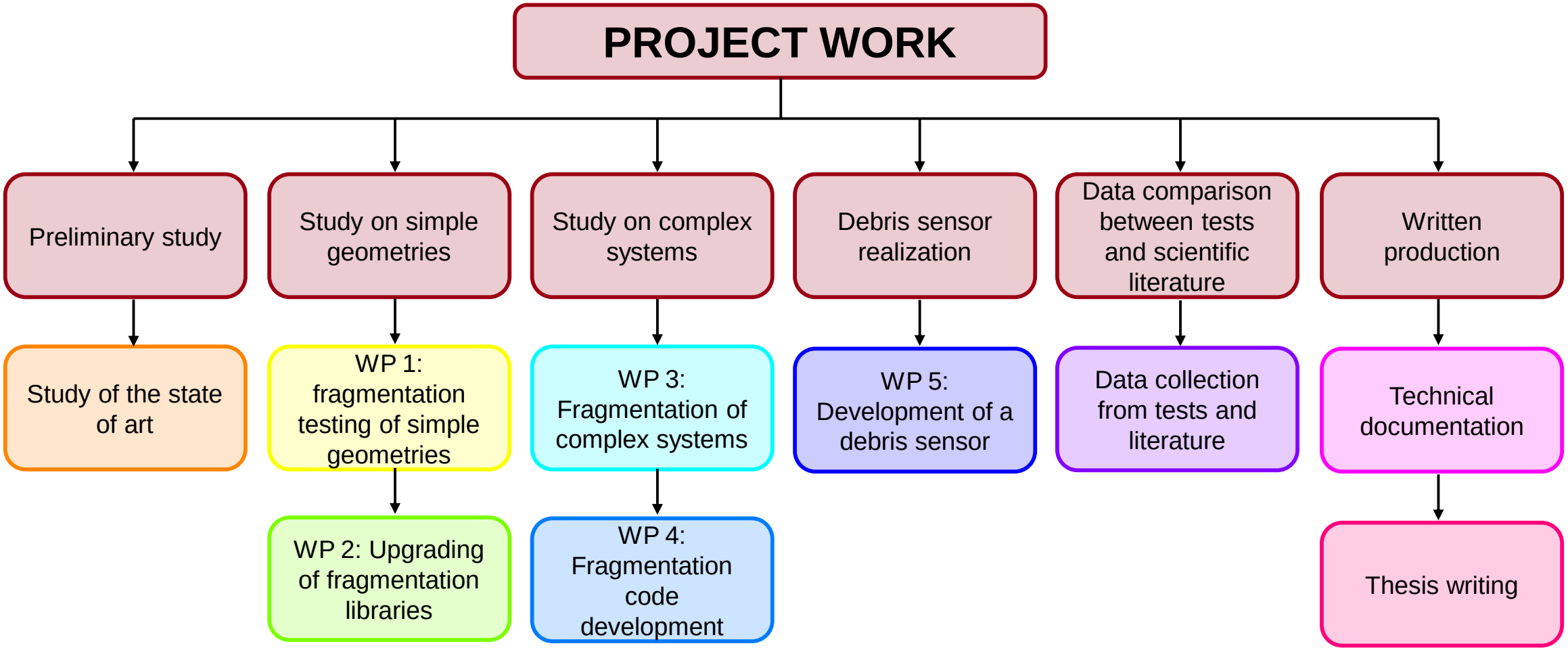


Work plan

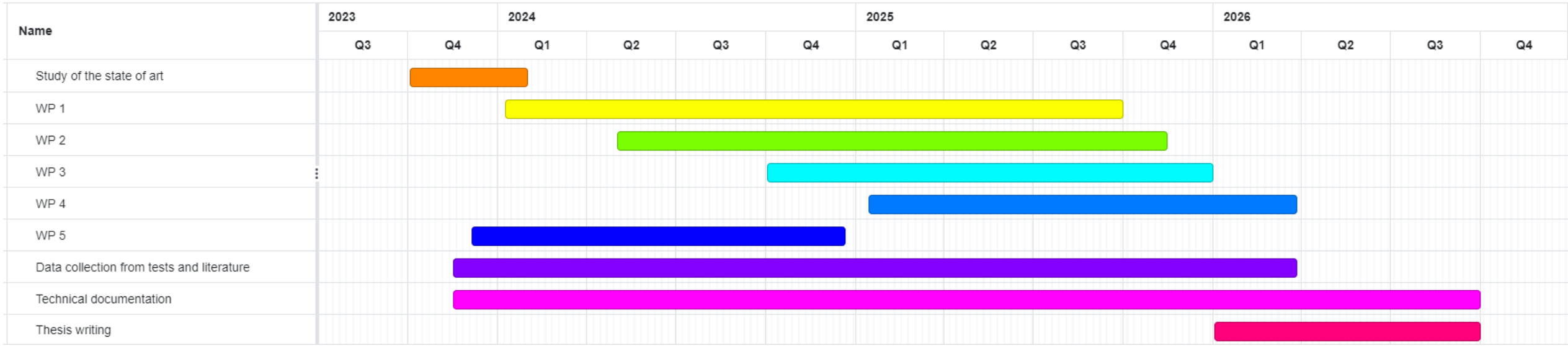
- This project is divided into 5 mutually independent work packages

WP 1: fragmentation testing of simple geometries	WP 2: Upgrading of fragmentation libraries	WP 3: Fragmentation of complex systems	WP 4: Fragmentation code development	WP 5: Development of a debris sensor
Study of fragmentation mechanisms of next-generation materials used on satellites such as composite materials, additive manufacturing technology, and polymeric materials.	Use of experimental data from tests to develop a more extensive materials library for the CSTS software developed by CISAS/UNIPD.	Performing hypervelocity impact tests for complex systems such as solar panels and mockups of small satellites and comparing with results in the literature.	Code implementation, running simulation of fragmentation events occurred in orbit and comparison with data from literature to improve models.	Supporting the Alba Cubesat student team with the goal of developing and testing an in situ sensor for millimeter and submillimeter debris. A 2.0 version is planned

Gantt Chart e WBS



Gantt Chart e WBS



Main expected results

- Better understanding of the phenomenon of fragmentation under hypervelocity impact conditions.
- Upgrading CSTS software by creating simplified fragmentation databases for innovative materials and improving the capability to simulate complex fragmentations.
- Acquiring test data and compare them with those in the literature.
- Develop a debris sensor to support data collection to reduce the uncertainty of submillimeter debris distribution models.
- Improving the ability to collaborate within interdisciplinary projects with other researchers. For this reason, it is planned to stay 6/18 months abroad. There are already contacts with research centers abroad (in particular with the Malta College of Arts, Science & Technology, MCAST) and with company (Thiot Ingénierie).

Thanks for your attention

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