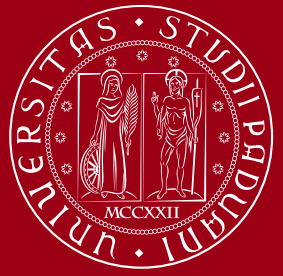

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Development of On Orbit Assembly technologies to enable spacecraft servicing

Federico Basana - 37^{th} Cycle

Supervisor: Dr. Francesco Branz

Meeting - 17/09/2024

Outline

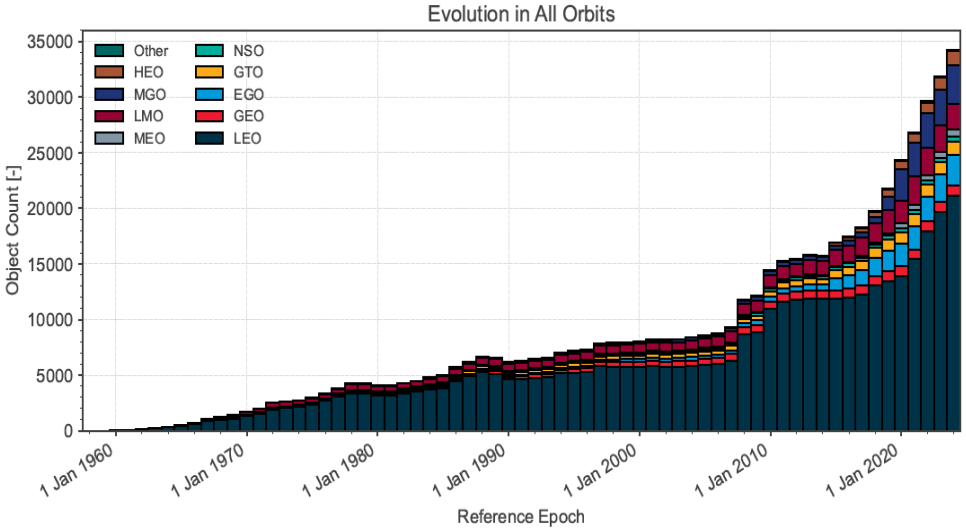
Space debris pose significant risks to functioning satellites

↓

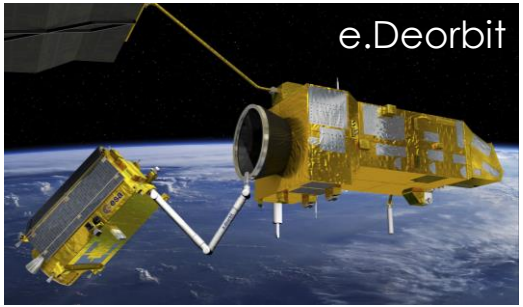
Their number is expected to grow in the next future

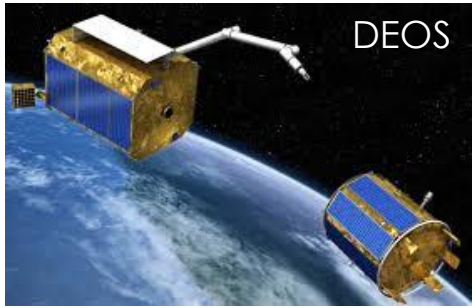
↓

Space Surveillance and Tracking
Space Situational Awareness
Collision Avoidance Manoeuvres

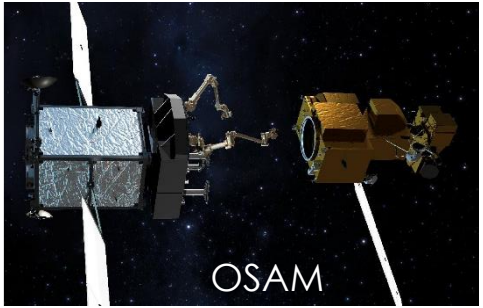


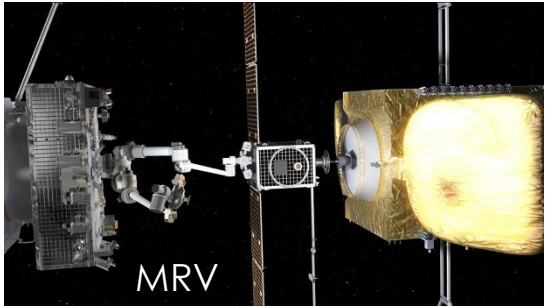
Why don't we remove them?



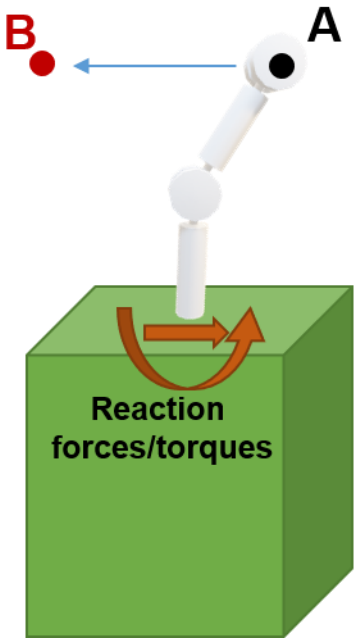


Why don't we repair them?



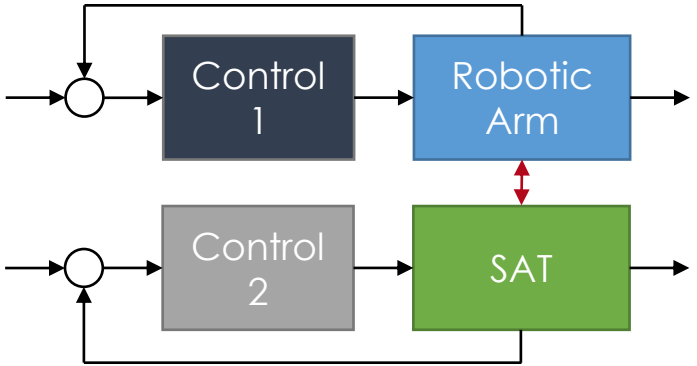


Space manipulators

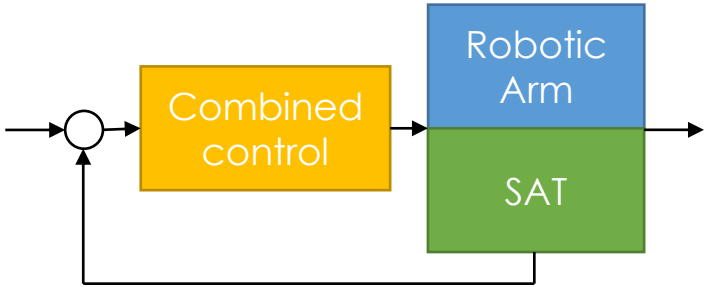


Free-Flying control

Decoupled control



Combined control



Minimum base reaction control & MKE

Strategies to reduce the base torque
IF redundant manipulators are used

↓

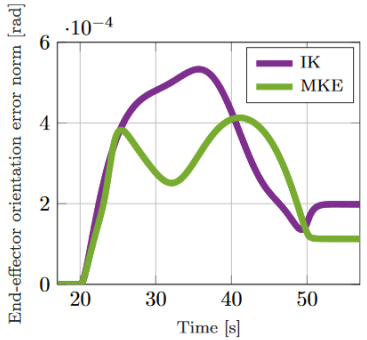
The MKE locally minimize the kinetic energy of the manipulator

↓

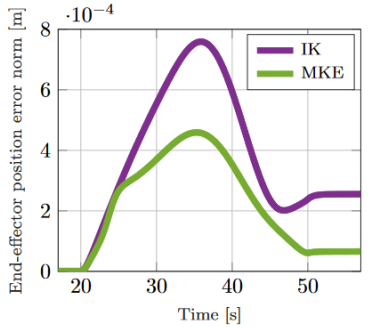
Comparison with classic Inverse Kinematics (IK) algorithm

↓

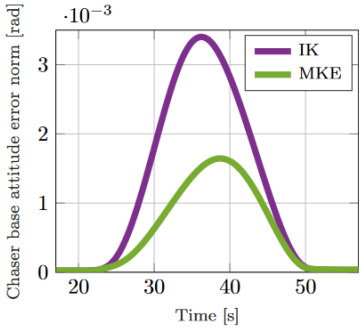
Case study: 7-DoF free-flying robotic arm performing different trajectories



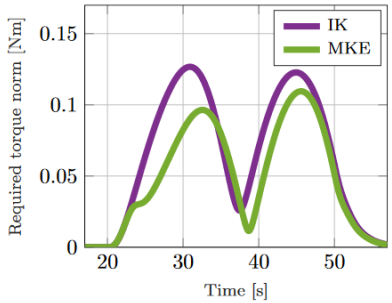
(a) End-Effector orientation error norm



(b) End-Effector position error norm



(c) Satellite attitude error norm



(d) Required torque norm

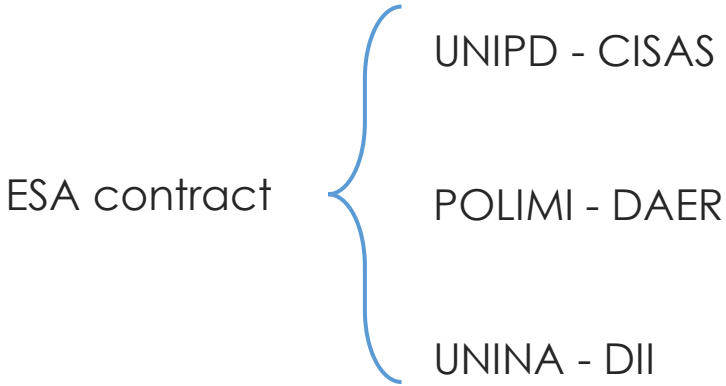
1. F. Basana, F. Branz, Simulation of robotic space operations with minimum base reaction manipulator, Journal of Space Safety Engineering (JSSE), 6/07/2022, https://doi.org/10.1016/j.jsse.2022.06.005
2. F. Basana, F. Branz, A simulation tool for robotic active debris removal with minimum reaction space manipulator, 72" International Astronautical Congress (IAC), Dubai, United Arab Emirates, 25-29 October 2021

Combined control – The GRACC study

Study for developing innovative GNC solutions for IOS/ADR missions

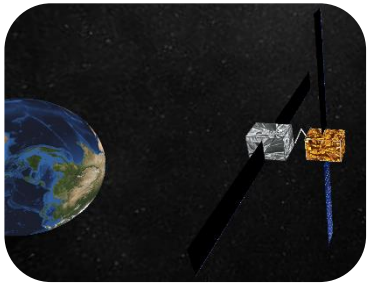
Adoption of:

- a multi–variable combined control approach;
- a fully autonomous navigation architecture based on active or passive EO sensors.



Combined control – The GRACC study

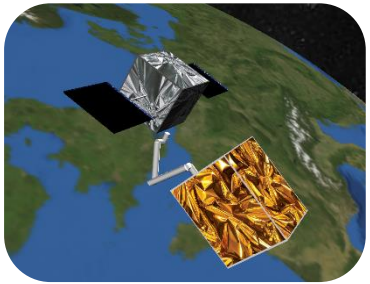
Scenario 1



The target (large telecom satellite) is:

- operative,
- controllable
- capable to receive a refuel/update/repair

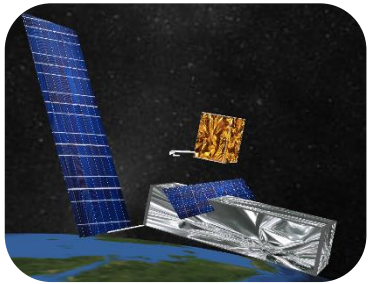
Scenario 2



The target (One web) is tumbling and is equipped with:

- a grapple fixture
- fiducial markers across the spacecraft body

Scenario 3



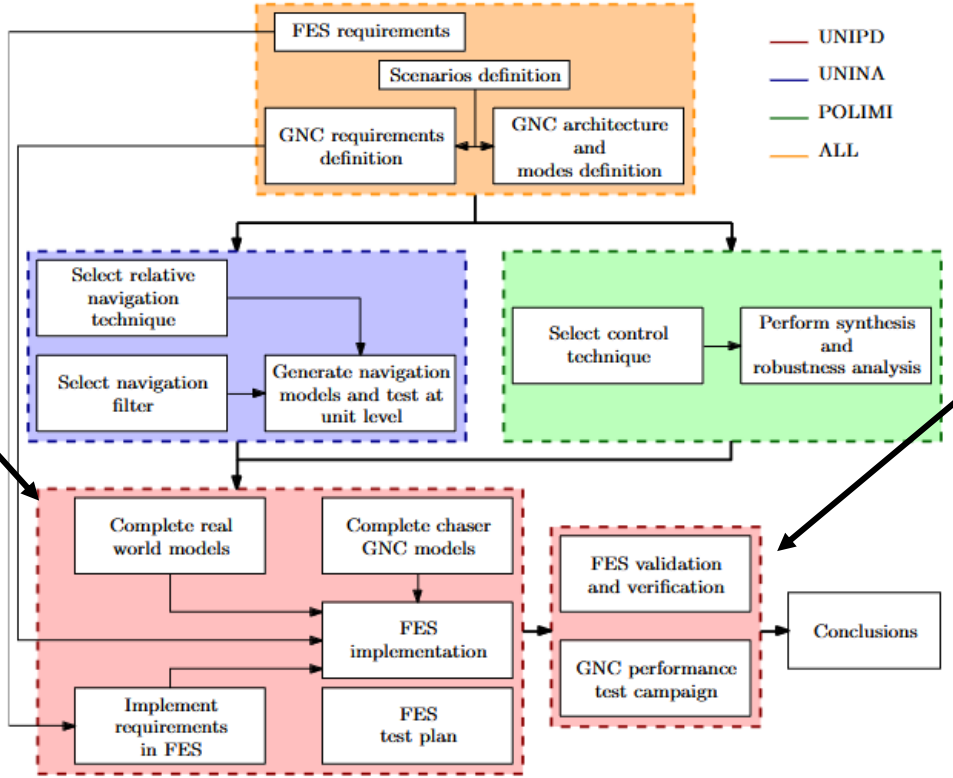
ENVISAT is captured. The chaser is synchronized with the motion of the non-cooperative target which is spinning at a rate of 5 deg/s.

In all the scenarios, the capture and the post-capture stiffening of the 7-DoF robotic arm phases are considered

Combined control – The GRACC study

FES implementation

- simplified models of the two satellites
- environmental disturbances
- propellant sloshing
- real actuators and sensors behaviour



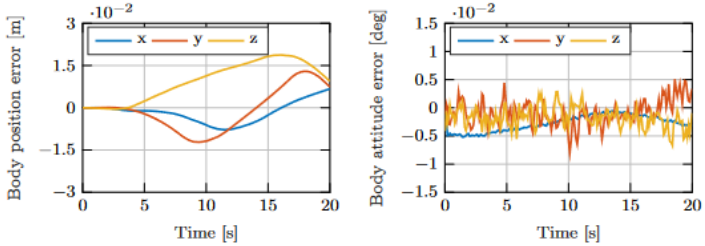
Test campaign

- FES validation and verification
- Nominal simulations
- Error budget analysis
- Monte-Carlo analysis

Combined control – The GRACC study

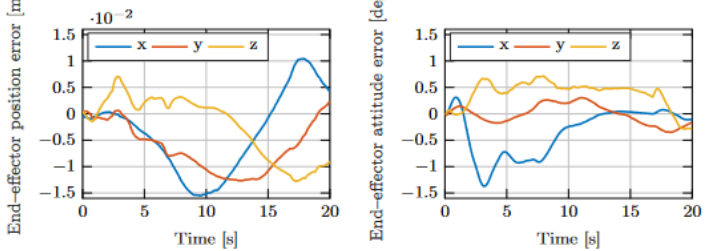
Examples of results – SC2

Phase A



(a) Chaser body position error.

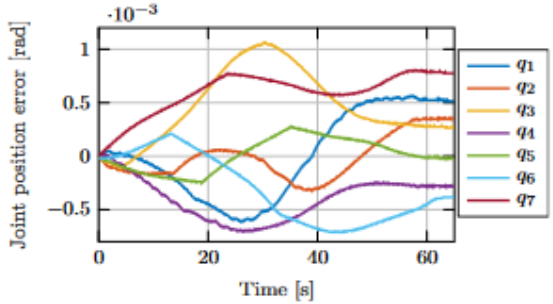
(b) Chaser body attitude error.

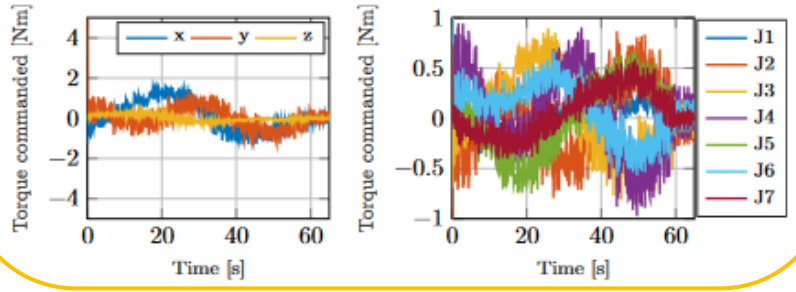


(c) End–effector position error.

(d) End–effector attitude error.

Phase B





F. Basana, Z. Pavanello, F. Branz, A. Francesconi, G. Borelli, D. Invernizzi, M. Massari, M. Lovera, A. Nocerino, R. Opromolla, I. Huertas Garcia, and P. Simplicio, Satellite and robotic arm combined control for spacecraft close-proximity operations, CEAS Space Journal, pp. 1–20, 2024, https://doi.org/10.1007/s12567-024-00560-0

Z. Pavanello, F. Branz, A. Francesconi, A. Cenedese, R. Antonello, F. Basana, P. Iob, D. Vertuani, M. Massari, C. Colombo, M. Lovera, D. Invernizzi, P. Ghignoni, L. Ticozzi, G. Borelli, R. Opromolla, M. Grassi, G. Fasano, A. Nocerino, C. Lombardi, C. Vela, I. Huertas Garcia, P. Simplicio, Combined control and navigation approach to the robotic capture of space vehicles, 72nd International Astronautical Congress (IAC), Dubai, United Arab Emirates, 25-29 October 2021

A new approach for servicing satellites

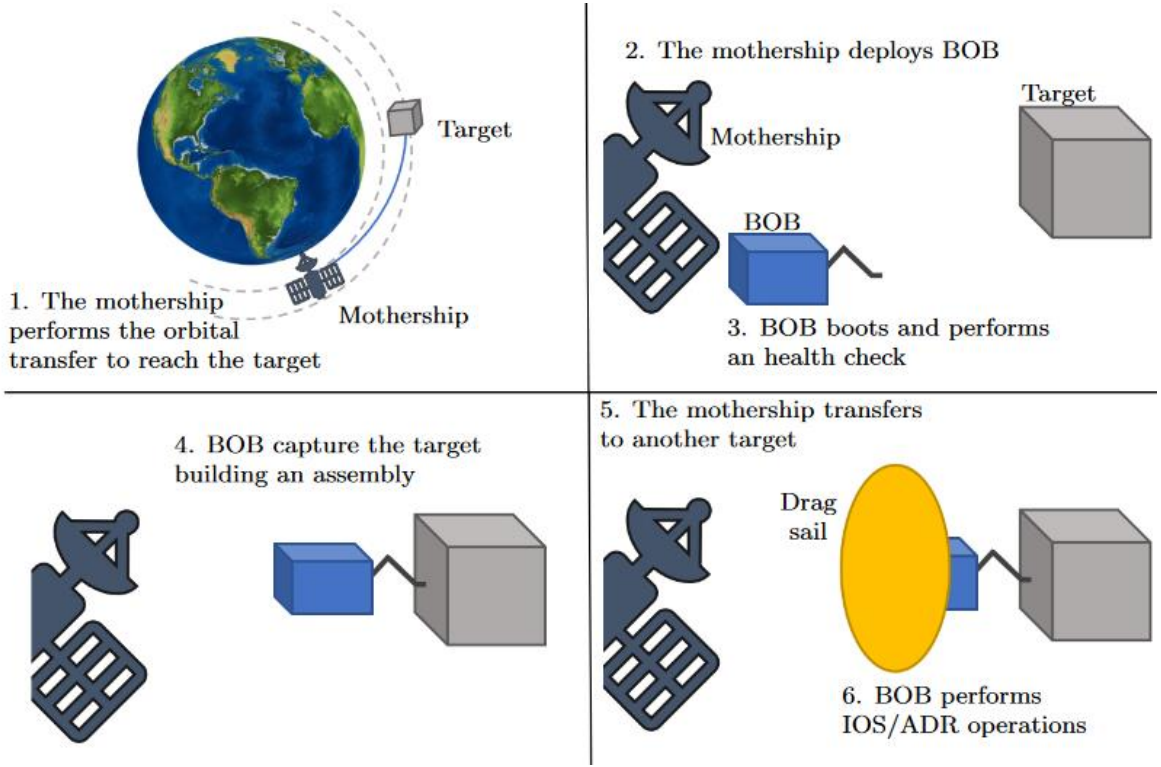
Main problems of IOS/ADR missions:

- Complexity
- Cost
- Collision risk

Employ a CubeSat-sized servicer equipped with a robotic arm

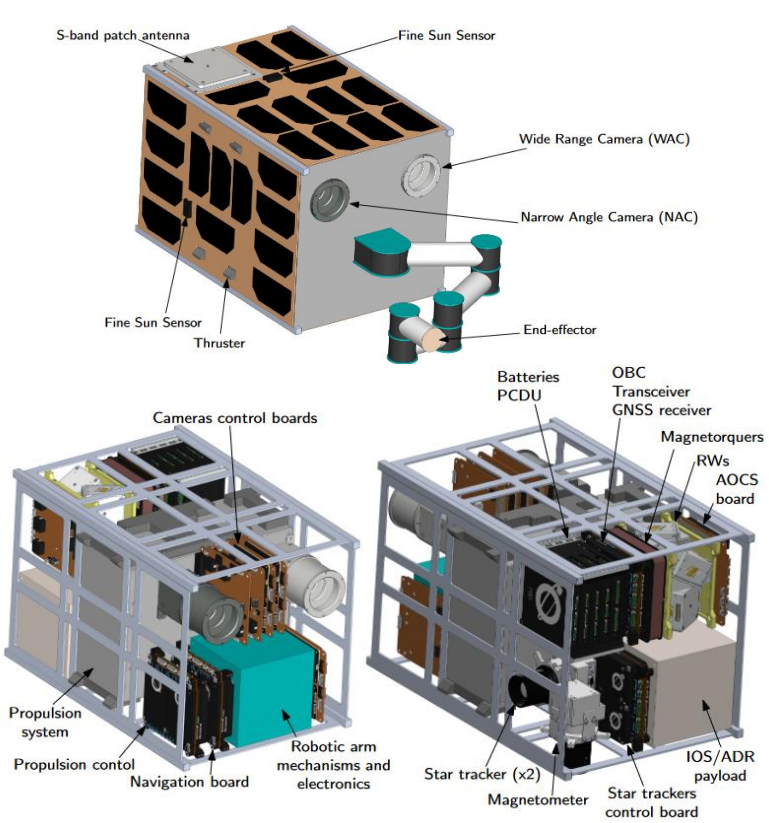
Advantages:

- Fast development
- Cheap
- Less severe effects in case of collision

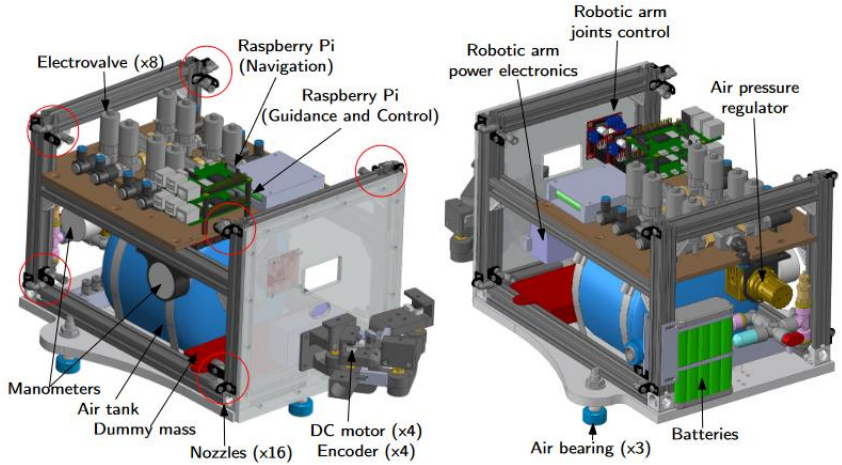


A new approach for servicing satellites

Space – Basic Orbital Butler (BOB)

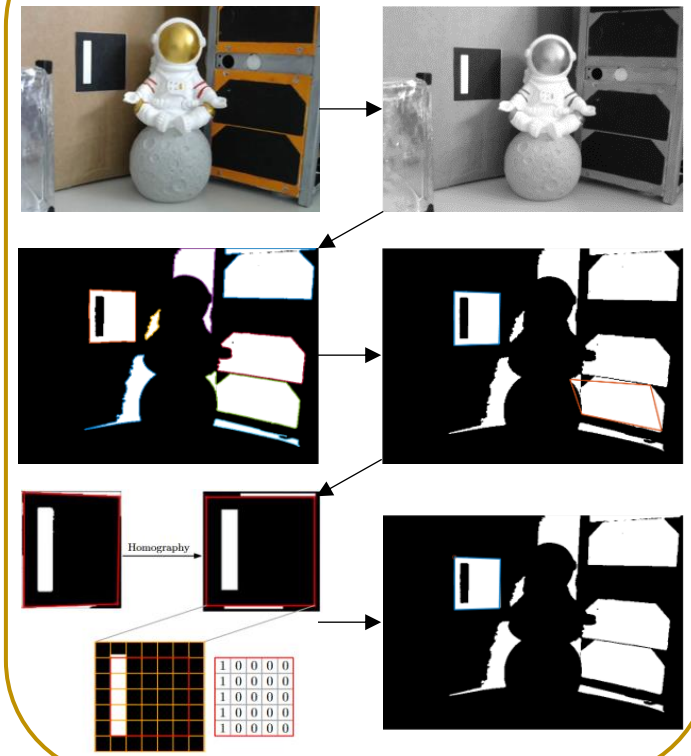


Space – BOB mock-up (mcBOB)

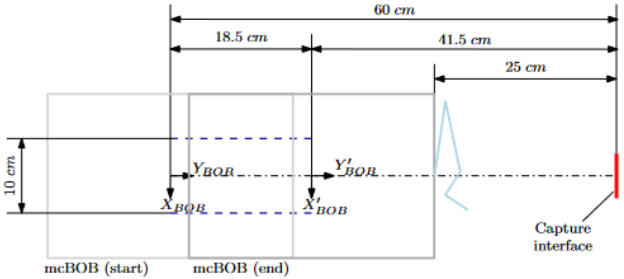


A new approach for servicing satellites

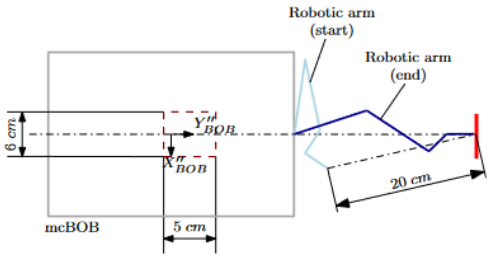
Navigation



Guidance

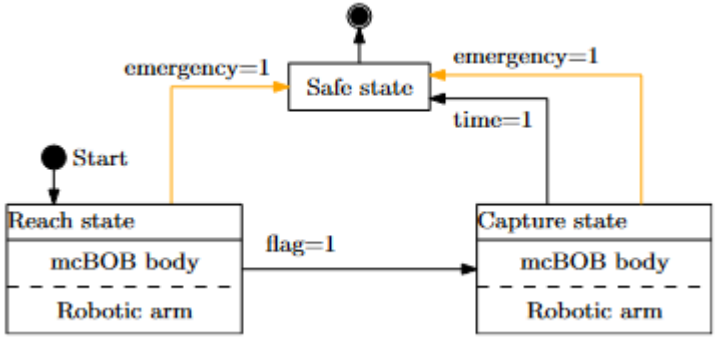


(a) Reaching Phase

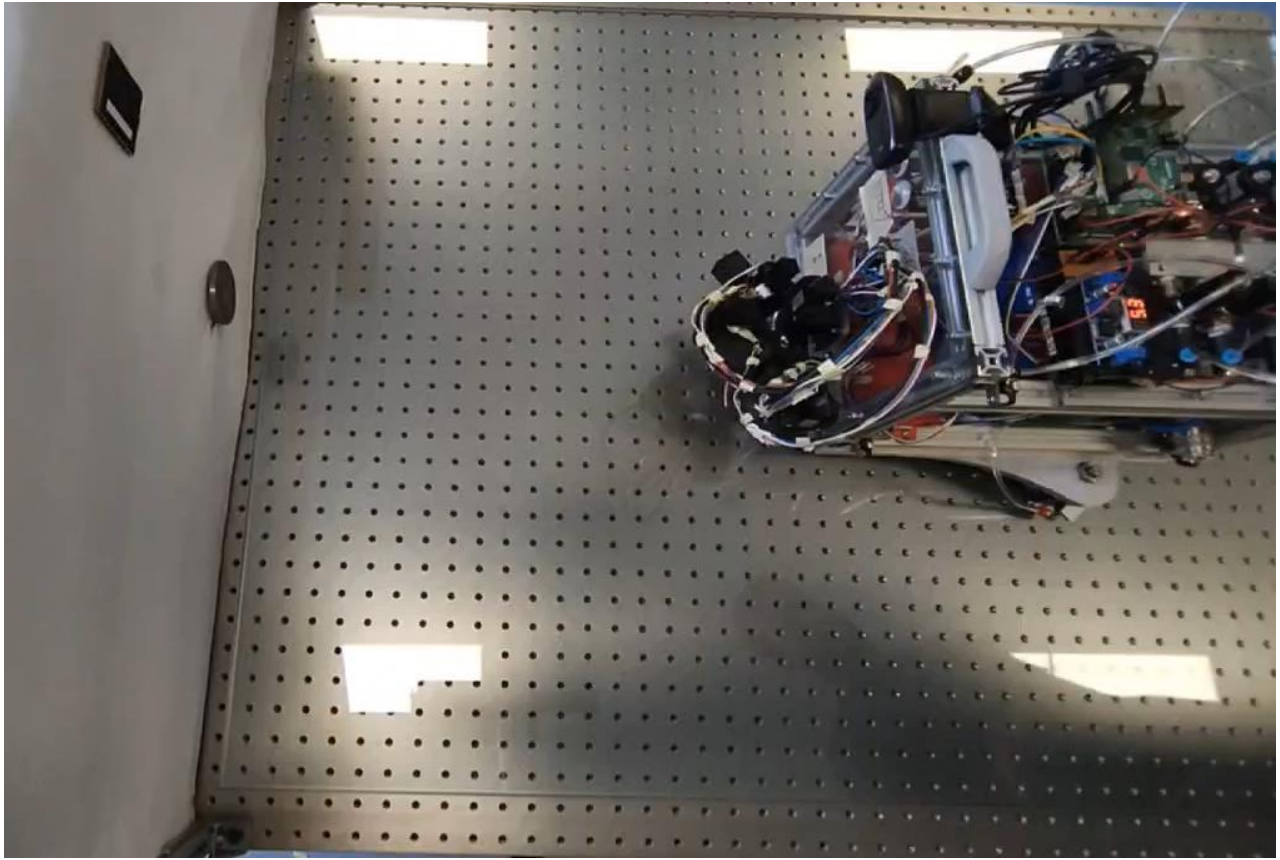


(b) Capture Phase

Control

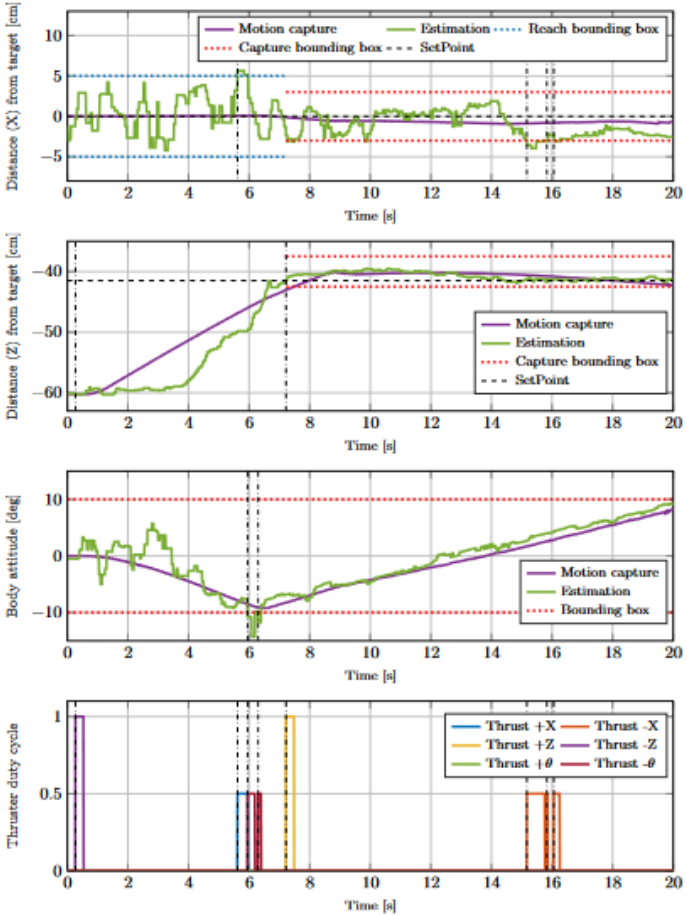


A new approach for servicing satellites

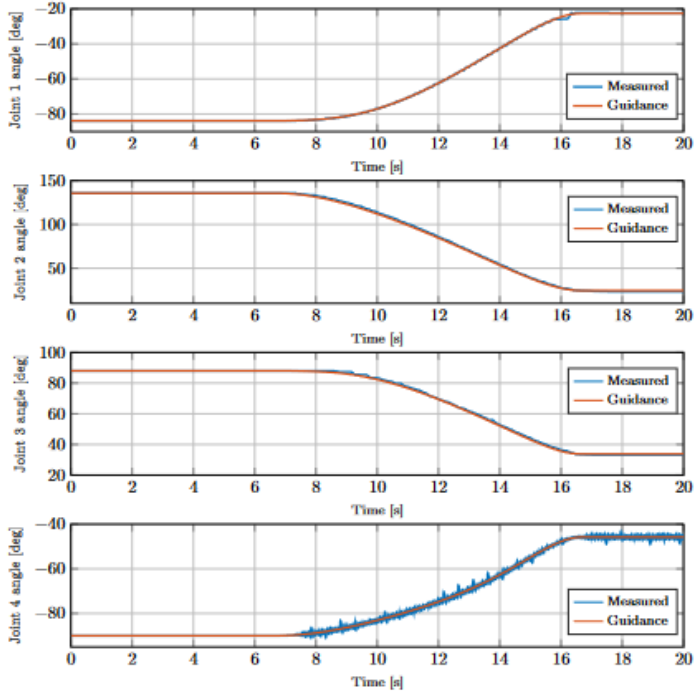


A new approach for servicing satellites

mcBOB body



mcBOB robotic arm



AlbaSat mission

AlbaSat is a **2U CubeSat** developed by a **student team** under the ESA's Fly Your Satellite! – Design Booster programme

esa

FLY YOUR SATELLITE!

Mission objectives:

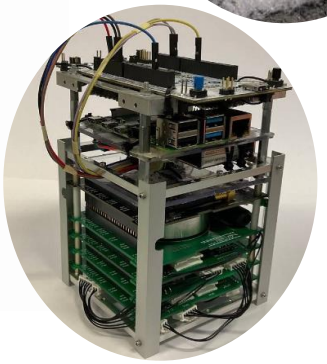
1. Collect in-situ measurements of the space debris environment
2. Study the micro-vibration environment on the satellite
3. Perform orbit determination through laser ranging
4. Investigate alternative systems for possible Satellite Quantum Communication applications on nanosatellites

AlbaSat successfully concluded the PDR and the FYS!-DB programme in May 2024

Four payloads:

1. Impact Sensor (IS)
2. Micro Vibration Sensor (MVS)
3. Corner Cube Retroreflectors (CCR)
4. QuantumFuture PayLoad (QPL)

AlbaSat mission



Conclusions

The work investigated new solutions for IOS/ADR missions.

- Investigations of methods for decoupling robotic arm motion from satellite body
- Development of a fully representative simulator for CPOs
- V&V and test of GNC combined control strategy with EO sensors
- Proposal and validation of a new approach for servicing satellites

- Improvement of existing technology
- Enhance performance and robustness of IOS/ADR missions
- Increase of mission safety

Thank for the attention

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