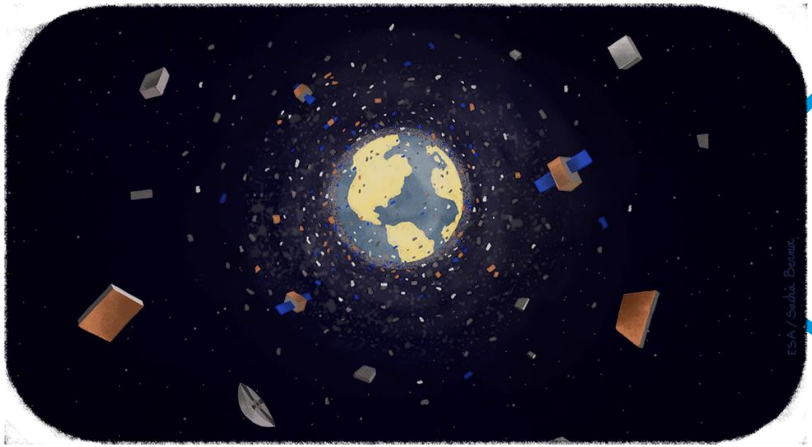
Design for Removal Activities Summary

Clean Space team

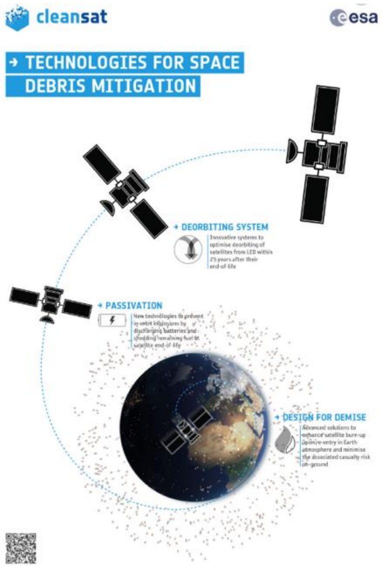
26/11/2020

Why?

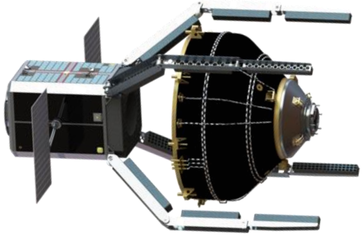
→ **Active Debris Removal** necessary for sustainable orbital environment

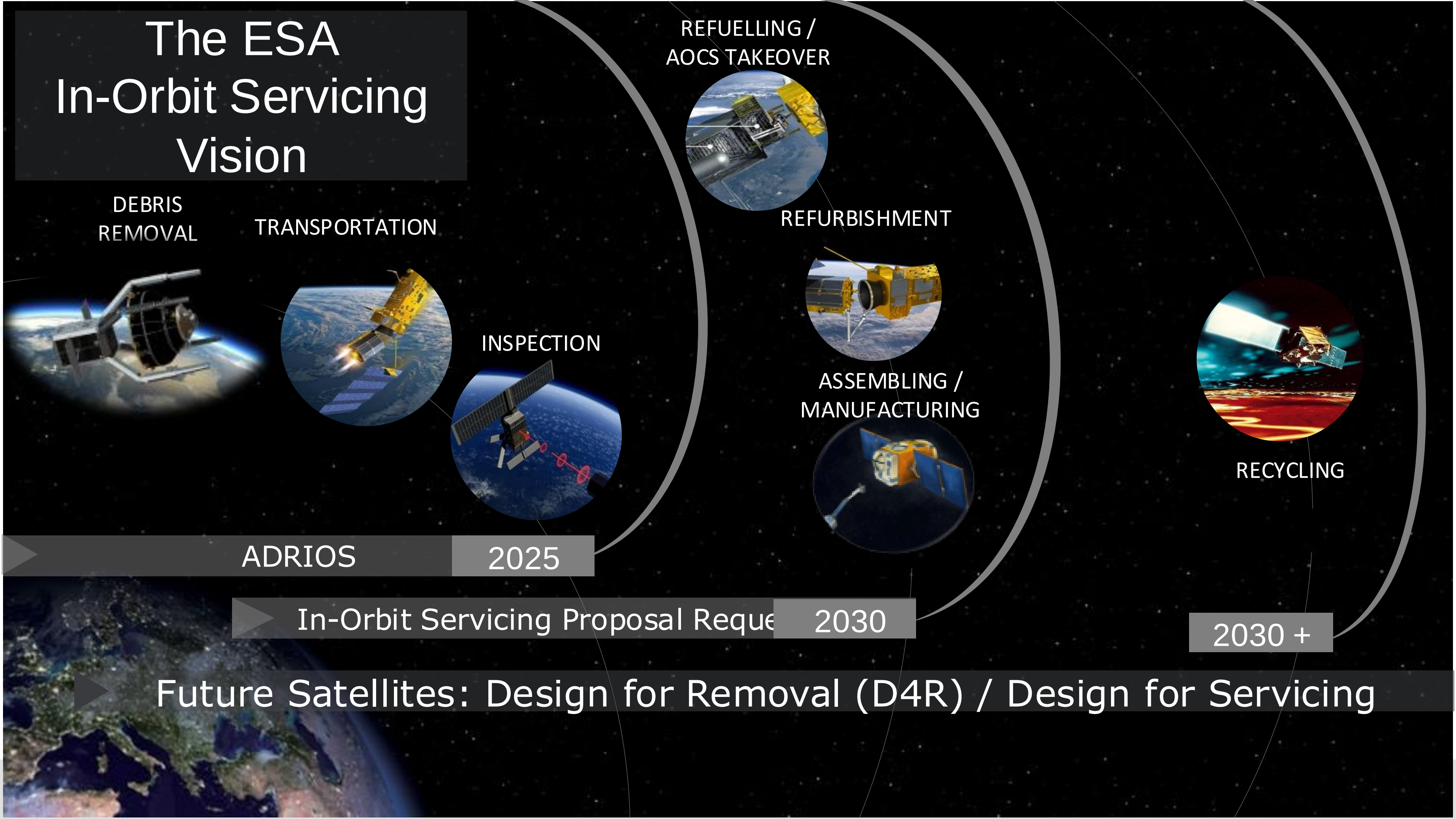


1. Design satellites to avoid debris generation



2. Remove objects currently in-orbit



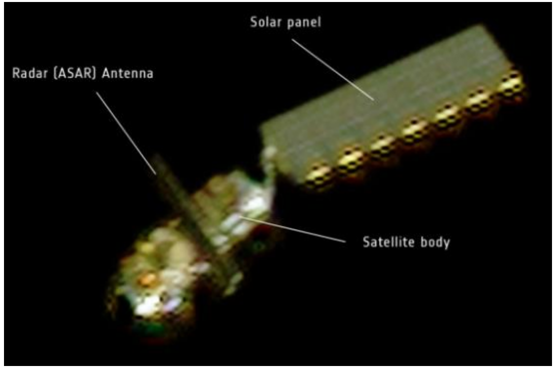


The ESA In-Orbit Servicing Vision
DEBRIS REMOVAL
TRANSPORTATION
INSPECTION
REFUELLING / AOCS TAKEOVER
REFURBISHMENT
ASSEMBLING / MANUFACTURING
RECYCLING
ADRIOS
2025
In-Orbit Servicing Proposal Reque
2030
2030 +
Future Satellites: Design for Removal (D4R) / Design for Servicing

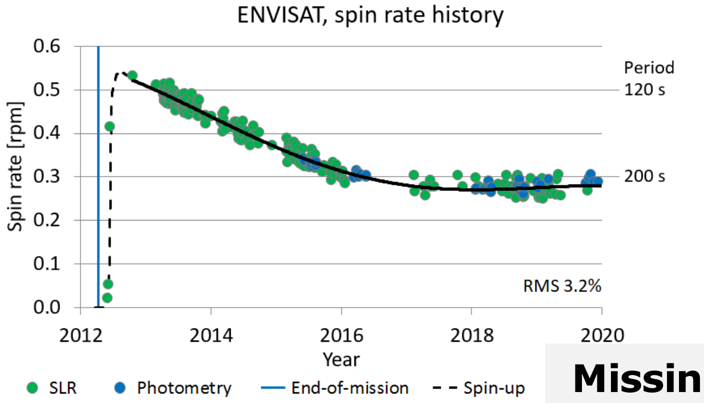
Why?

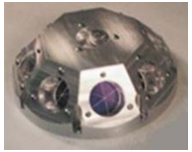
➔ Active debris removal with **unprepared** target is very challenging…

Debris are not designed for capture



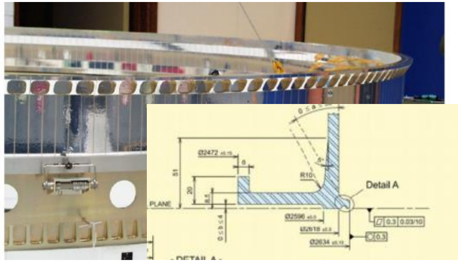
Debris objects spin





ENVISAT Retroreflector

Missing Capture interfaces

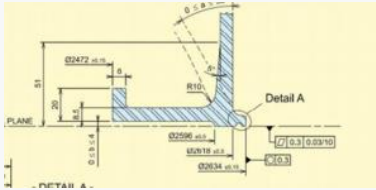


If not prepared, each satellite ADR solution would be different

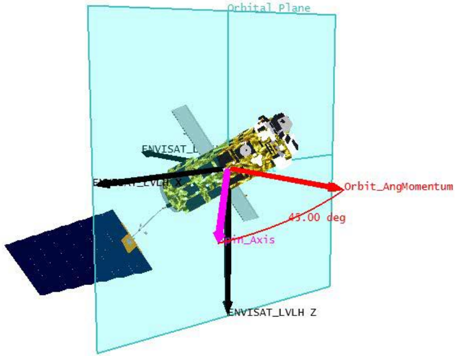
Why?

e.Deorbit / ENVISAT as a Case Study

Capture Interface



- Launch Adapter Ring selected for Capture
- Orientation of solar array constrains the approach direction
- Challenging geometry/profile for 'capture before contact'.



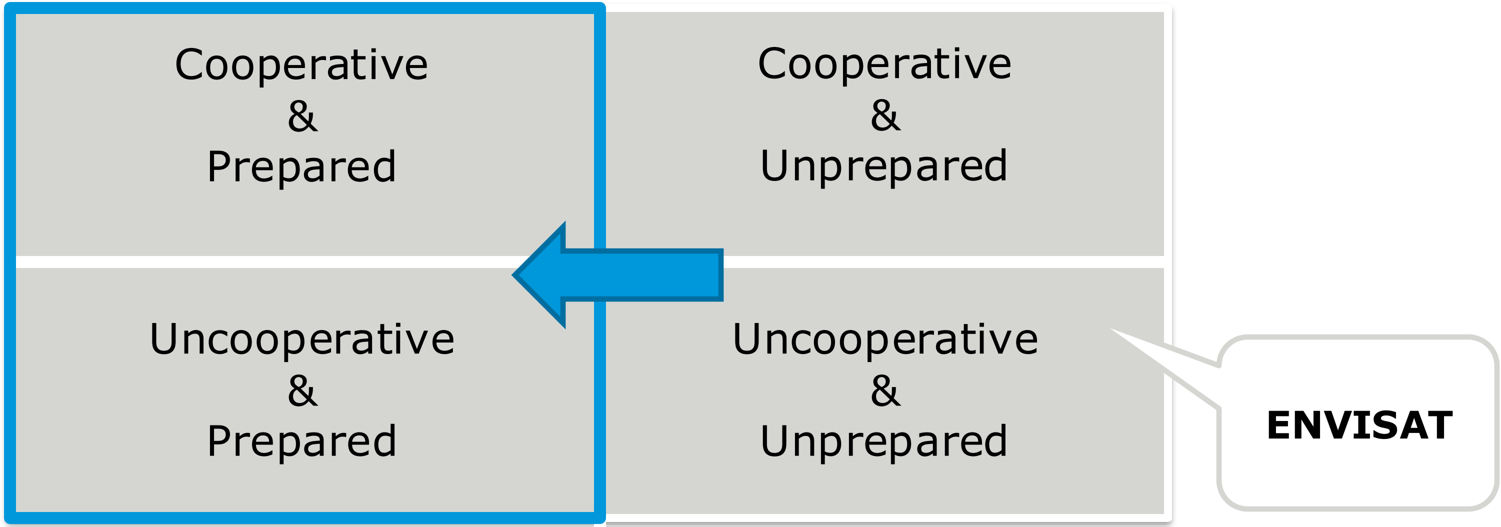
ENVISAT Tumbling Motion

Driving constraints for e.Deorbit:

- Synchronised motion with high tumbling rates → RCS thrusters sizing
- Large uncertainty box → Long robotic arm needed
- Sizing for torques of robotic interface
- Complex trajectory planning to avoid appendages
- Complex CAM planning
- RdV cameras + scanning LIDAR → No-markers for relative navigation

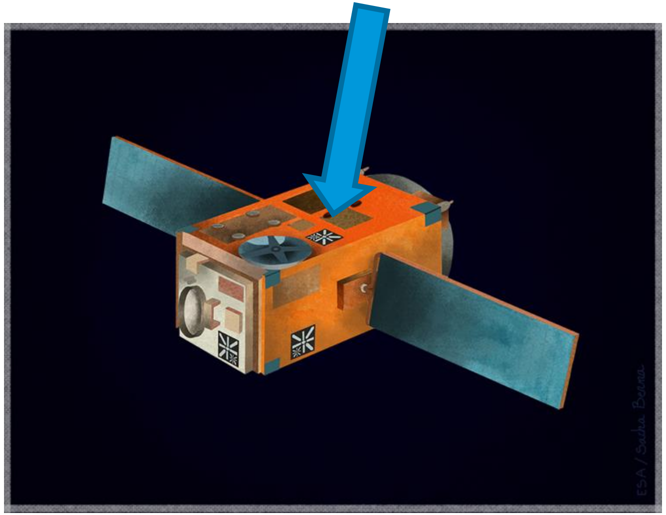
Design for Removal Objective

Objective: To prepare for removal future ESA LEO satellites, which may be controlled or uncontrolled (w.r.t. attitude), but are not capable of performing their EoL disposal (i.e. controlled or uncontrolled re-entry)

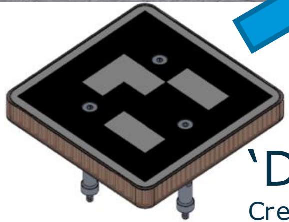


Operators Embarking In-Orbit Servicing Technologies

ESA / Copernicus: Design for Removal



OneWeb Grappling Interface



'DOGTAG' Capture Inte

Credits: Altius Machines/OneWeb

Lockheed Martin to upgrade GPS satellites for in-orbit servicing

by Sandra Erwin — February 26, 2021

WHAT?

Compliance Verification Guidelines - Update

Removal will be included in ESSB-HB-U-002.

→ As a mitigation action in case of failure in orbit

→ Dedicated Annex being prepared

"Design for Removal needs the following main functions:

- **Tracking and attitude reconstruction on ground**, in order to have accurate knowledge of the target attitude and orbit of the client spacecraft before starting its removal operation.
- **Acquisition of suitable attitude**, in order to ensure compatibility of the client spacecraft with the operational envelope of the servicer spacecraft.
- **Relative navigation support**, in order to minimise or avoid any risk for the close proximity and rendezvous operations through precise synchronisation of the servicer spacecraft with the client spacecraft and simplification of the capture.
- **Mechanical capture interface**, in order to allow the capture of the client spacecraft by the servicer spacecraft and the transfer of the mechanical loads between them during the removal operations."

DRAFT

Design For Removal (D4R) Technologies

Objective : Develop technologies to ease removal of future LEO satellites

→ **4 technologies under development funded by ESA EOP**

Markers to Support Navigation (MSN)

2D markers and 3D markers to help relative navigation (attitude, distance, velocity, etc.)

Mechanical Interface for Capture (MICE)

Passive interface on satellite for capture

For cooperative & uncooperative

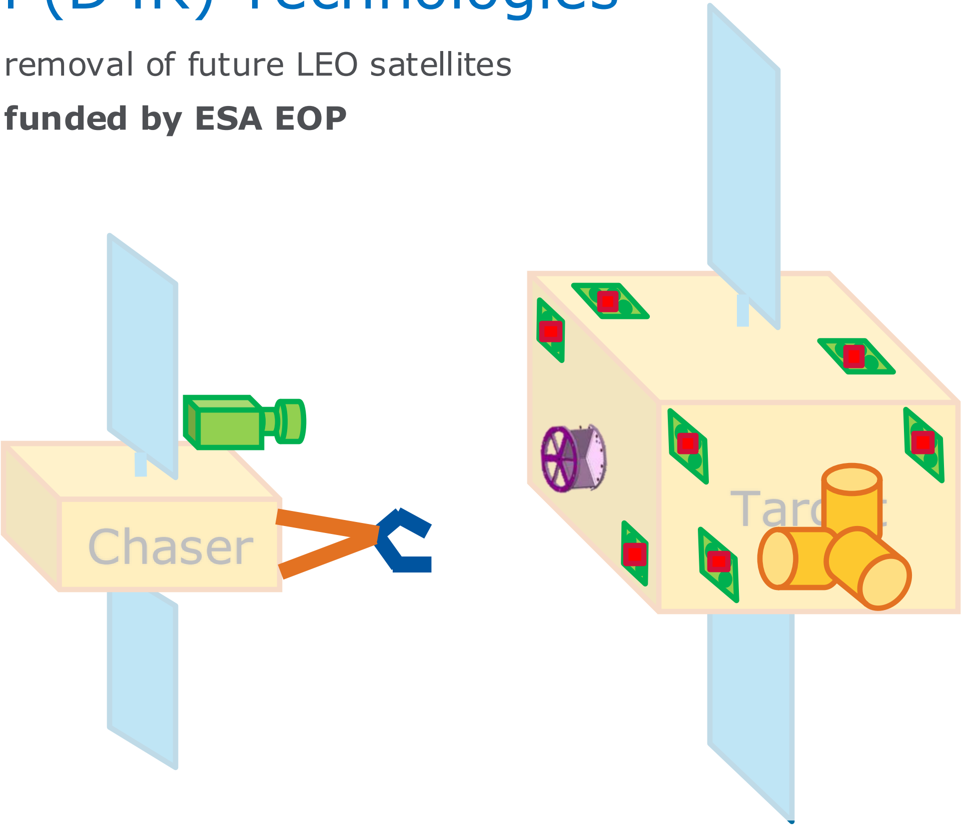
Passive Magnetic Detumbling (PMD)

Short-circuit magnetorquers to detumble at EoL

Retroreflectors Attitude Determination System (RADS)

LRR to enhance attitude reconstruction on ground

Only for uncooperative



D4R System Impacts - LAR surface

- **Accommodation**

Allocate areas and keep-out zones in order to integrate D4R technologies

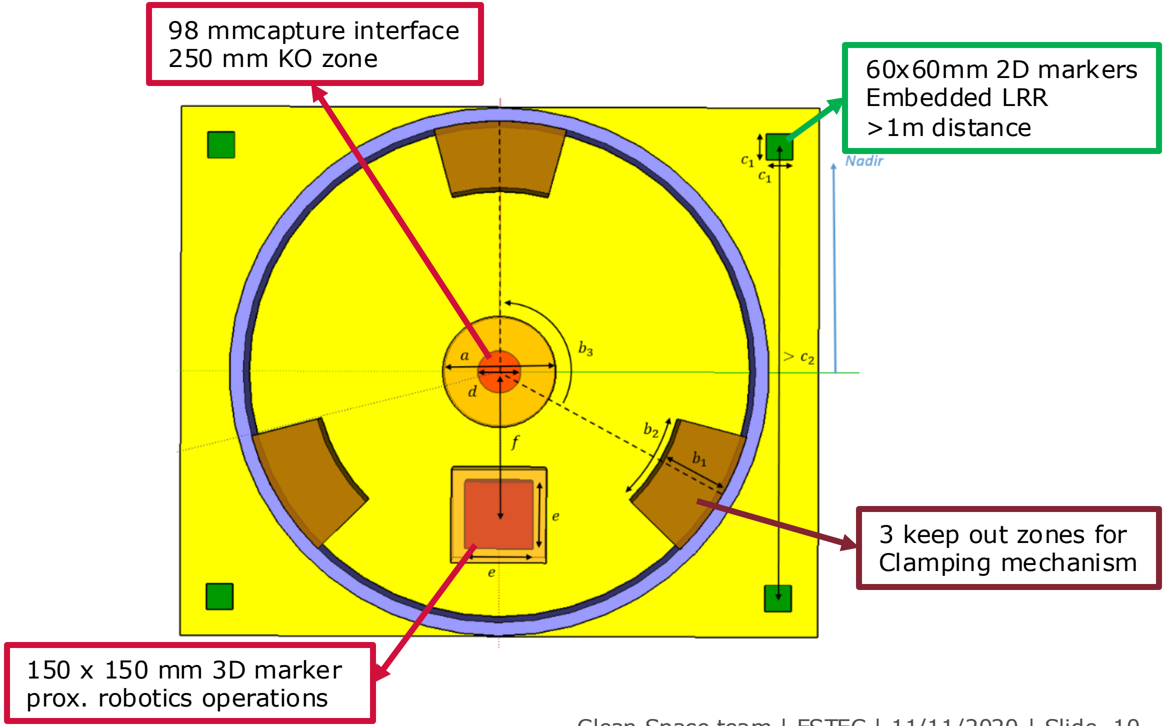
- **Loads**

Ensuring a safe capture of the satellite through tailored mechanical interfaces

- **Other potential interferences**

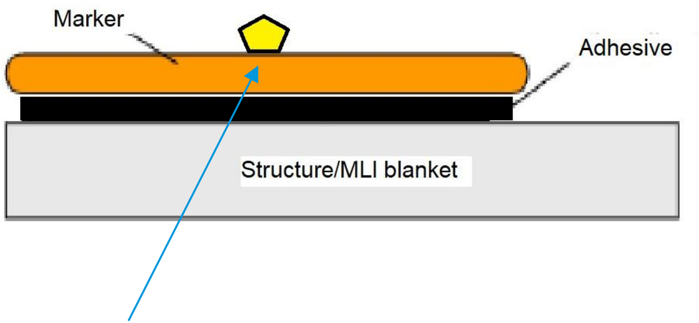
Guarantee little impact on the nominal mission design

- Disposal loads, spring pushers…



Technologies under development

Markers to Support Navigation & Tracking



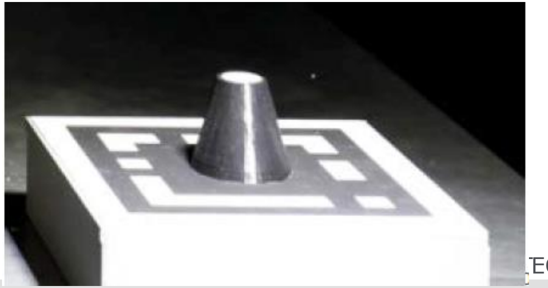
Retroreflectors – Attitude Determination from Ground:
Laser retroreflectors (corner cube) in the middle of 2D Markers, used for ground-based attitude determination before launch using configuration patterns on several faces of the S/C.

2D Markers – Relative Navigation:

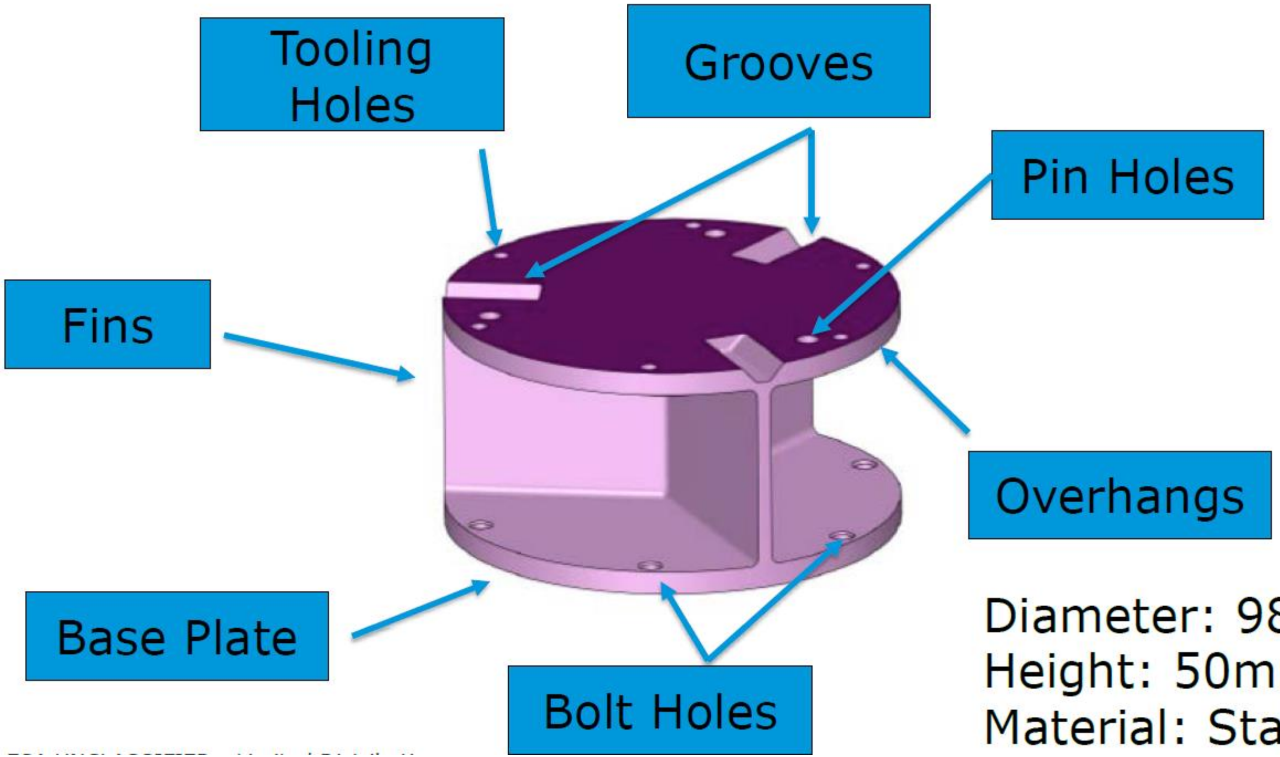
To support rendezvous from 50m to 5m distance in all illumination conditions, thanks to contrast with the satellite's MLI

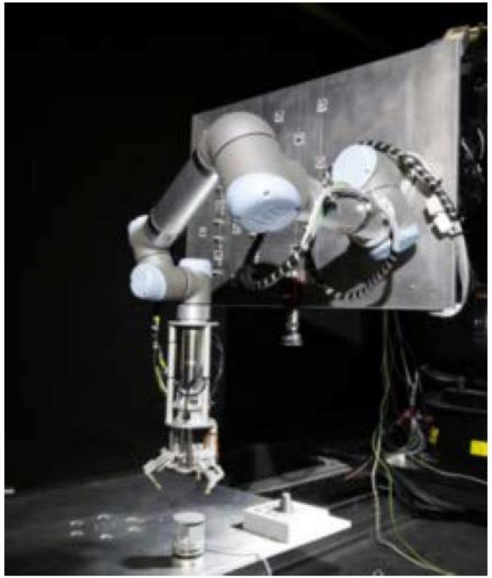
3D Marker –Capture System Servoing:

Relative navigation from 5m to capture, thanks to the Pattern and 3D feature, to be used for visual servoing.



Mechanical Capture Interface





Diameter: 98 mm
Height: 50mm
Material: Stainless Steel

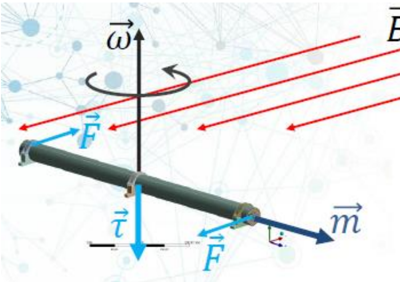
Detumbling through the magnetorquers

Patent Reference:
213130EP TE/BD

Short-circuited magnetorquer

If short-circuited, a magnetorquer will dissipate energy helping detumbling:

1) a rotating satellite in LEO sees a time-dependent magnetic field created inside the magnetorquer
2) the magnetic flux variation produces an electromotive force at the magnetorquer terminals
3) an induced current is generated on the coil wire
4) resulting in the magnetorquer magnetic moment and generated torque
5) the dissipation of rotational kinetic energy is achieved through Joule effect inside the magnetorquer



Magnetic moment induced by changes in magnetic flux

Proof of concept of short-circuit triggering system (left) and short-circuited magnetorquer (right)

Next Steps

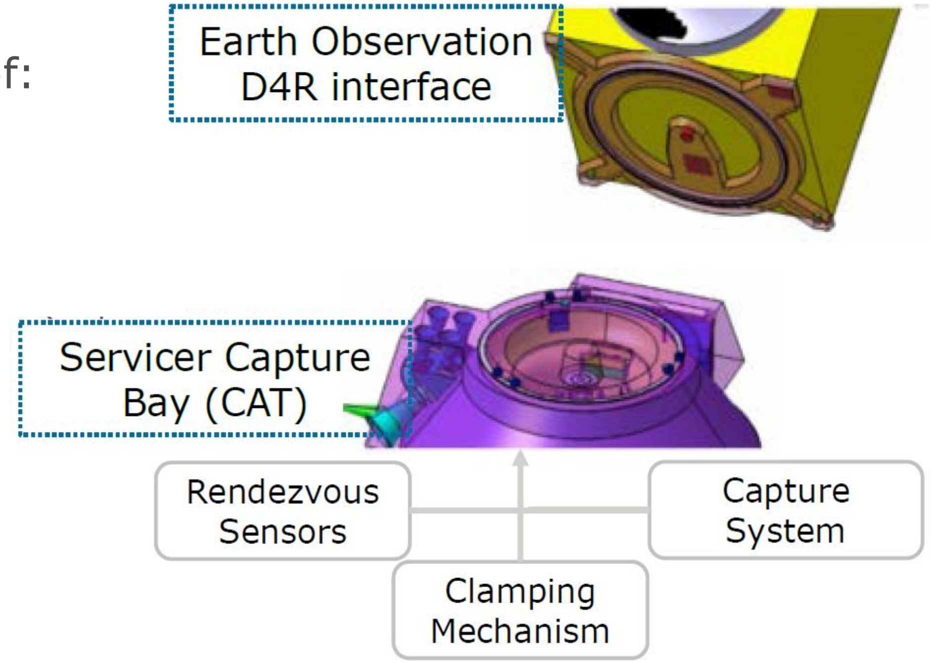
CAT Activity –Capture Bay Design and End-to-end Verification of Design for Removal (CAT)

Objective:

Verification of integrated system consisting of:

- Design for Removal Interfaces for EO satellites
- Chaser rendezvous & capture equipment bay)

Funding	1 M€ (Open Competition)
Duration	24 months
Programme	Space Safety / S2P
Status	Open ITT:

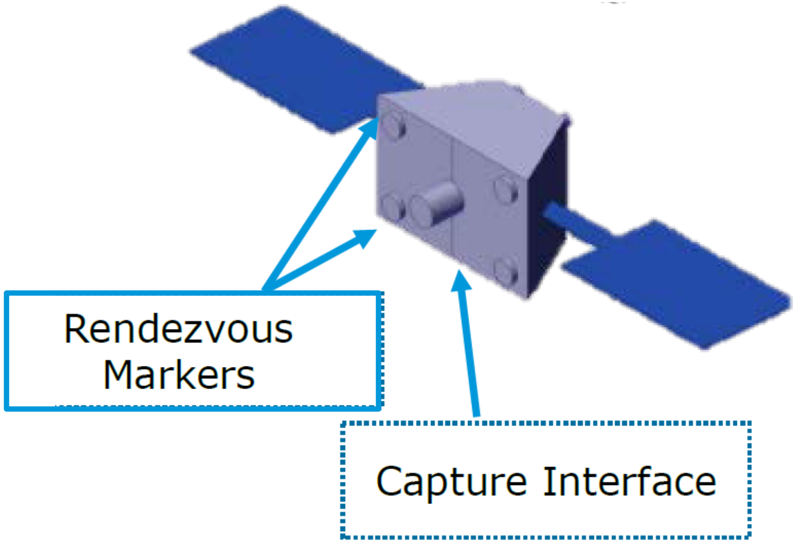


Critical breadboarding enabling the removal of failed small satellites from low earth orbit

Objective: Design, manufacture and test technologies enabling the removal of failed small (<500kg) satellites (e.g. tumbling) from low earth orbit, including breadboard and testing of:

- A passive, fail-safe detumbling system
- Rendezvous markers
- Grappling interface for capture

Funding	**800 k€**
Duration	**24 Months**
Program	**ARTES-AT**
Status	**Workplan 2021**
TRL Target	**4**



Differences with D4R for EO:
- Detumbling technique
- Disposal loads/capture interface