

Active debris removal and on-orbit servicing

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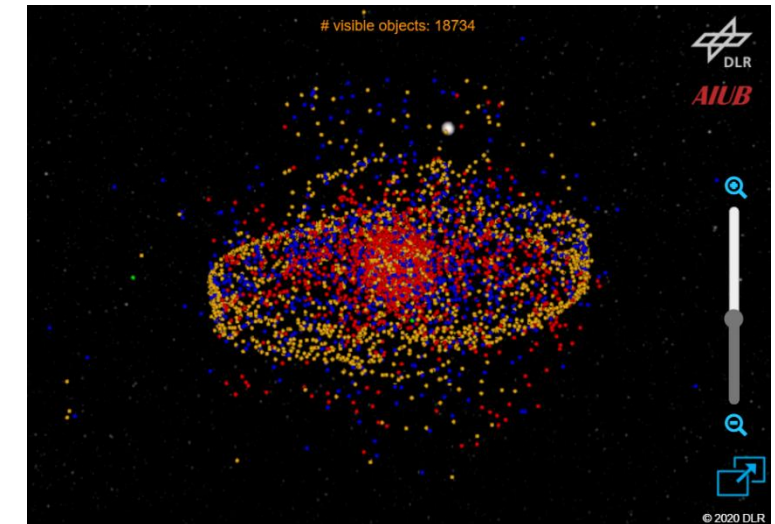
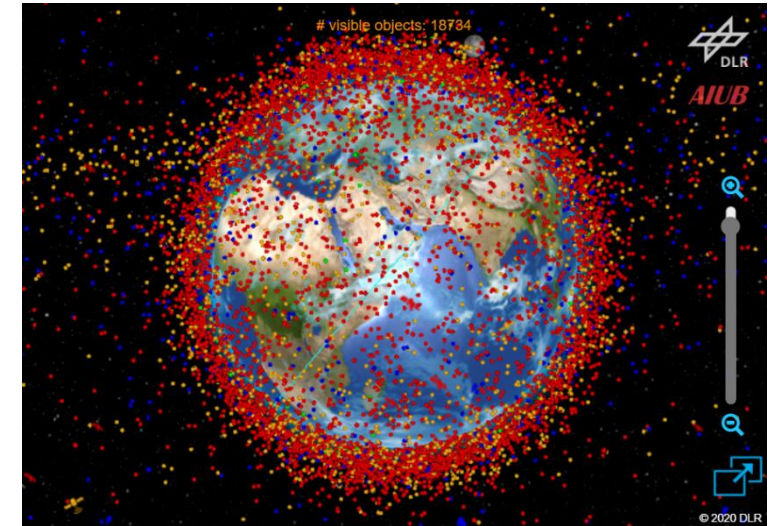
Knowledge for Tomorrow



Motivation

- **Current situation:** Increase of objects and space debris in Low Earth Orbit (LEO), see talk of Prof. Anselmo, but also in Medium Earth Orbit (MEO) and Geostationary Orbit (GEO)
- **Decrease only by**
 - natural re-entry (atmospheric drag)
 - active de-orbit at the end of a satellite's lifetime
- **Problems:**
 - Re-entry time increases exponentially with the orbit height (~1 year at 400km, ~25 years at 600km, ~100 years at 700km)
 - Many satellites are not equipped with a propulsion system to perform an end-of-life de-orbit maneuver
 - Many non-operational satellites, fragments, rocket bodies cannot actively de-orbit

→ **Need for active debris removal by a service satellite**



Source: Space debris viewer of DLR
[DLR - Space Debris Viewer](#)



A “typical” debris object

- There is no typical / standard debris object...
- Various types of objects
 - Rocket bodies
 - Fragments
 - Non-operational satellites
 - ...
- No precise knowledge about their orbit and orientation
- No communication with these objects
- High risk by
 - large non-operational satellites (high mass, large size)
 - uncontrolled orbit and attitude (tumbling objects!)
 - debris in strategic orbits such as LEO, MEO and GEO

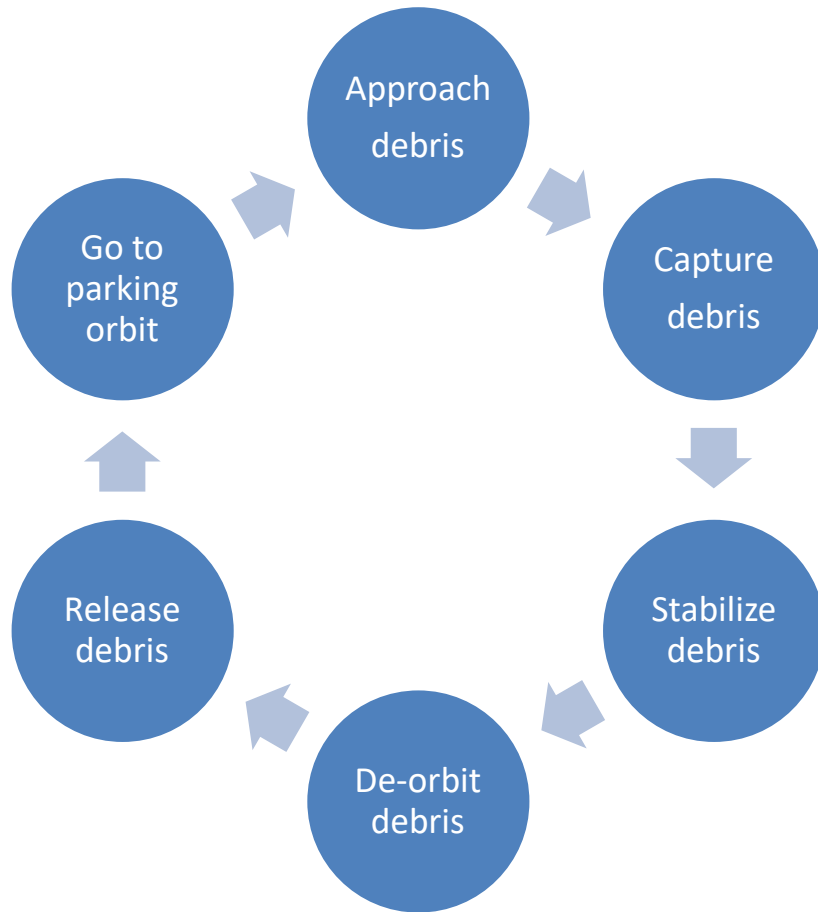
European satellite Envisat

Size:	~26m x 10m x 5m
Mass:	~ 8000kg
Non-operational:	since 2012
Orbit height:	~770 km



Source:
<https://upload.wikimedia.org/wikipedia/commons/8/87/Pictorial-view-of-the-ASAR-antenna-on-ENVISAT-and-in-near-field.jpg>

The main phases of an active debris removal (ADR)



- **Approach:** Safely approach the debris object (rendezvous) by several maneuvers by a service satellite
- **Capture:** Connect with the debris by docking tool, robotic arm or some tether, net etc.
- **Stabilize:** Stabilize a tumbling motion, break, take over attitude and orbit control of the coupled system
- **De-orbit:** Dependent on the orbit, move debris to a low altitude orbit (LEO) or to a graveyard orbit (above GEO)
- **Release:** Physically disconnect with the object
- **Go to parking orbit:** Maneuver to a safe parking orbit, wait for next ADR task



Challenges of ADR



- No retro-reflectors / LEDs / markers to support rendezvous navigation
- No dedicated docking port / capture ring etc.
- No communication with the object
- Little information about the target (no detailed geometrical model)
- Eventually damaged object (damaged satellite, fragment)
- In LEO: no permanent contact between servicer and ground → on-board autonomy needed!
- In GEO: time delay between ground and space of some seconds

→ Much is different compared to cooperative rendezvous and docking in space (like supply vehicles and ISS)



Comparison cooperative – non-cooperative target

Cooperative (coordinated)

- Fully attitude stabilized target
- Passive and active optical markers
- Handles, fixtures, docking ports
- Full status known (telemetry)
- Inter-satellite communication or space-ground communication with the target



Source:
https://commons.wikimedia.org/wiki/File:STS-125_May_17_EVA.jpg

Non-cooperative (non-coordinated)

- Completely non-operational
- Spinning, tumbling
- Not designed for ADR
- No communication at all
- Arbitrary piece of debris/junk in orbit



Source:
https://commons.wikimedia.org/wiki/File:Square_print.jpg

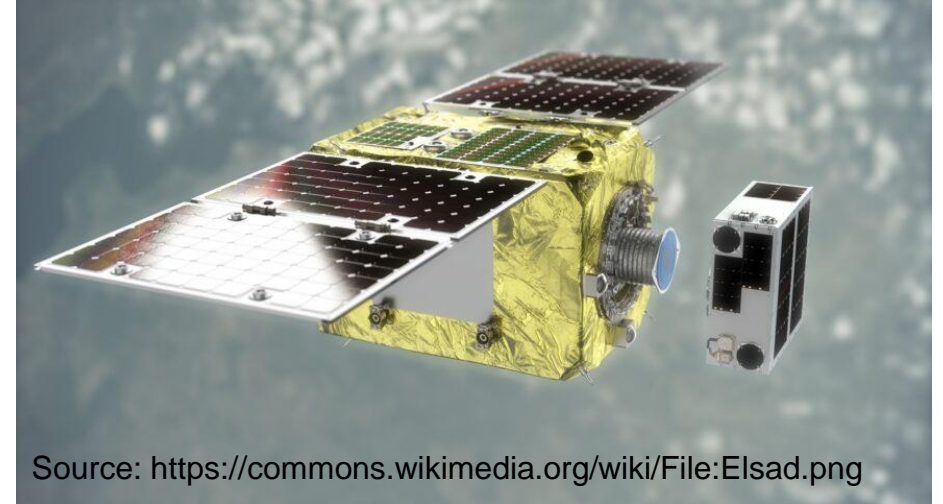
Exemplary missions

- **End-of-Life Services by Astroscale demonstration (ELSA-d)**

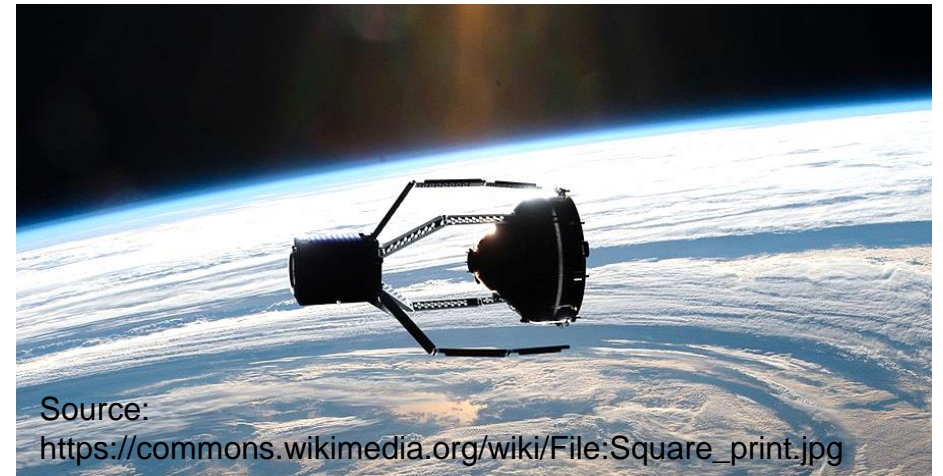
- Demonstration of technology for space debris docking and removal
- Servicer and client satellite launched together in March 2021
- Servicer: 175 kg, Client: 17 kg in a 550 km orbit
- Magnetic capture system successfully tested in August, 2021.

- **Cleospace-1**

- ESA debris removal mission
- Approach, capture and remove an ESA owned item (Vega secondary payload adapter, left in an ~800 km by 660 km orbit)
- Launch of the servicer planned for 2025/26
- Capture with four tentacle-like arms



Source: <https://commons.wikimedia.org/wiki/File:Elsad.png>



Source: https://commons.wikimedia.org/wiki/File:Square_print.jpg

On-orbit servicing (OOS)

Goal of ADR: Remove debris

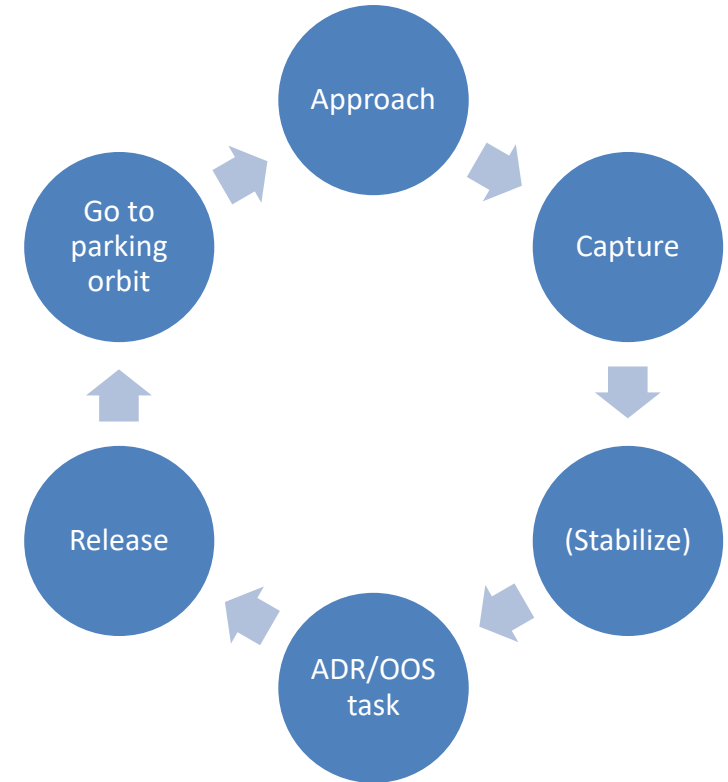
Goal of OOS: Lifetime extension by servicing

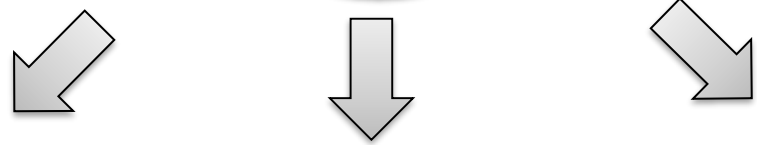
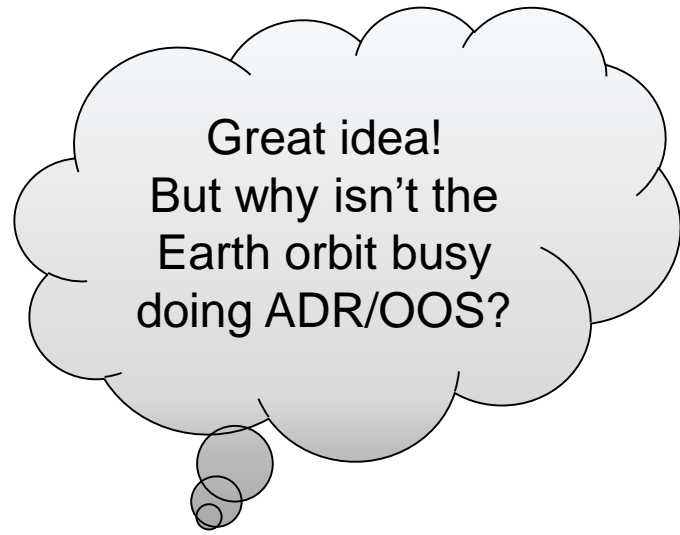
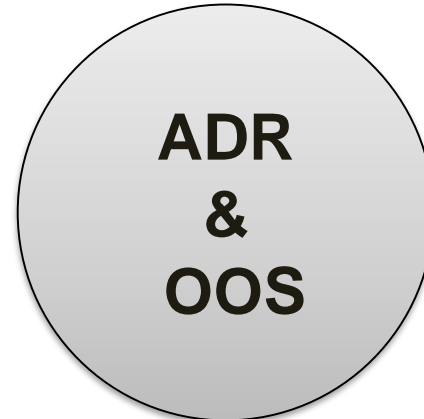
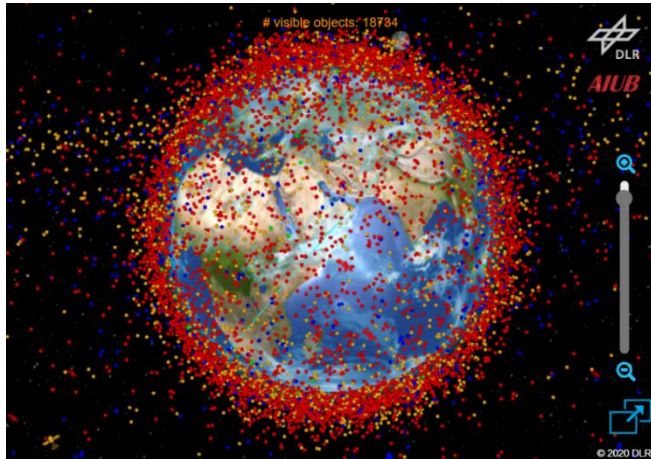
Service tasks:

- Refueling
- Take over of orbit and attitude control
- Repairing
- Exchange or add of components

Similarities:

- New type of mission
- Targets presently in orbit are not prepared for ADR/OOS (no markers, no visual aid, no dedicated docking tool/adaptor, etc.)
- Similar phases (see right)
- Similar autonomy constraints etc.





Broken targets/fragments

High degree of autonomy

New operational concepts

Danger of collision

Tumbling targets

Dynamic range of illumination

New sensors

New algorithms

High power requirements

Computationally expensive

Handling errors / anomalies

Different ranges: km's to cm's

High reactivity

Coupling of servicer and capture device

Non-cooperative targets

New type of manipulation task

Visually difficult material mix



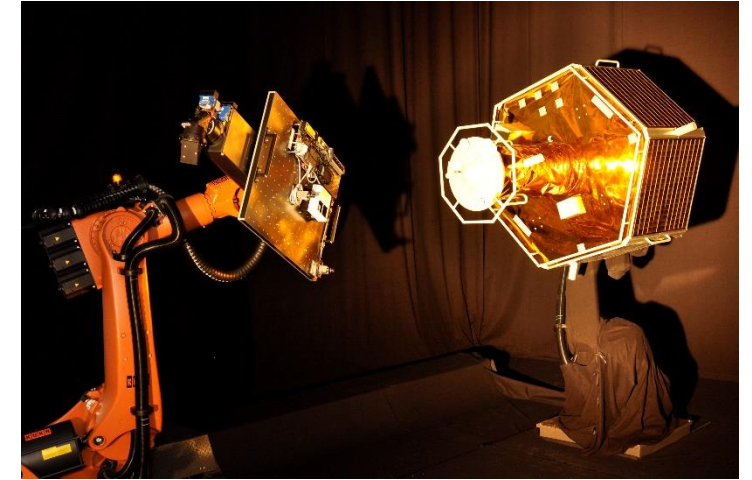
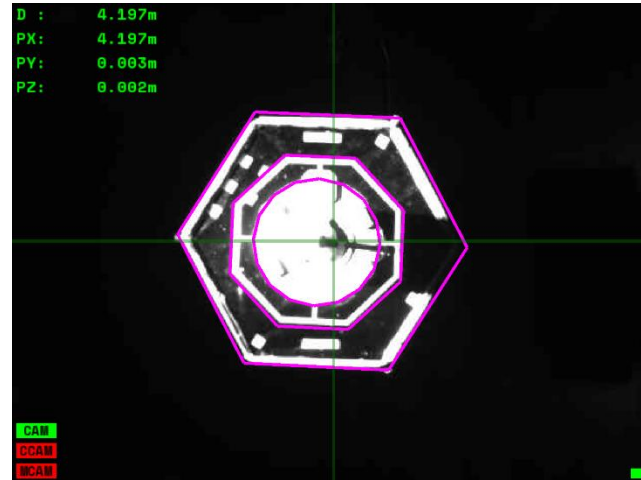
DLR's approach: holistic development and test of ADR/OOS technology

Development and research areas:

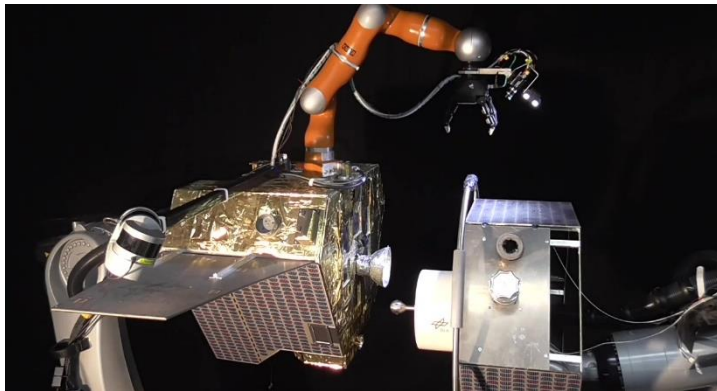
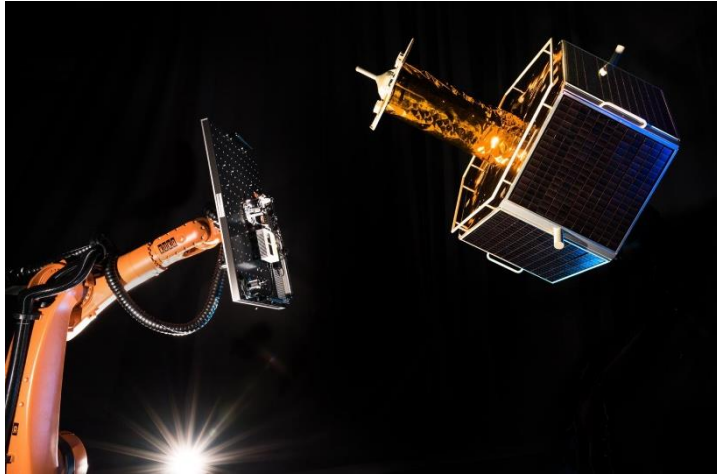
- Inspection
- Rendezvous
- Capture
- Stabilization
- Ground Operations

Test & verification:

- Software tests
- Sensor / hardware tests
- Hardware-in-the-Loop tests with robotic test facilities (like EPOS 2.0)
- End-to-End test: fully integrated simulation environment with real optical sensors and robotic hardware for capture, real operation system, real mission control room at DLR's German Space Operations Center (GSOC)



Thank you!



The screenshot shows a YouTube video player interface. The video title is "On-Orbit Servicing - End-to-End Simulation" by DLR. The video has 2,198 views and was uploaded on 27.03.2018. The video player shows a scene of a robotic arm in a dark environment, likely a simulation. The video player includes standard controls like play, pause, and volume. Below the video player, there are engagement buttons for likes, dislikes, shares, and a subscribe button labeled "ABONNIEREN". The DLR logo is visible in the top right corner of the video frame.



<https://www.youtube.com/watch?v=ADS-qGI5kOc>

