CAT-IOD

ESA Clean Space Days

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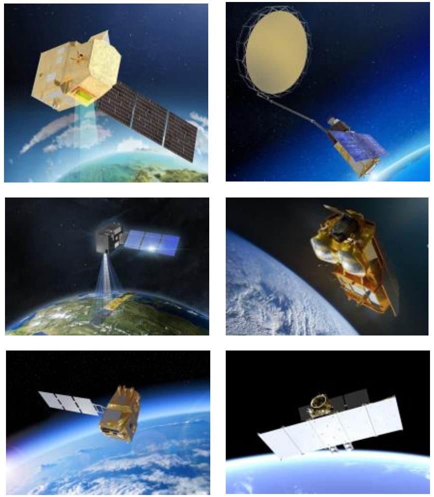
CAT-IOD

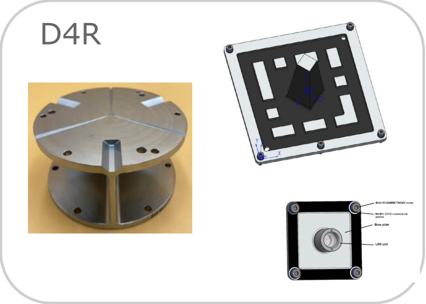
Background

- ESA Design for Removal (**D4R**) Interface Requirements Document (IRD) adopted by the six **Copernicus Sentinel Expansion Missions** and is being used to prepare these satellites for possible removal missions
- GMV leading a consortium responsible for designing and validating a **CAT** (**Capture Bay for Active Debris Removal**, ADR) system (TRL4 by Q2 2024):

  Thursday afternoon 16:00 - Design for Removal session

  - Capture equipment (gripper/hexapod/control SW) + securing devices (clamping) + close proximity navigation & avionics
- **CAT** has the vocation to become the **cost-effective capture payload** of choice for LEO ADR, covering both cooperative and uncooperative



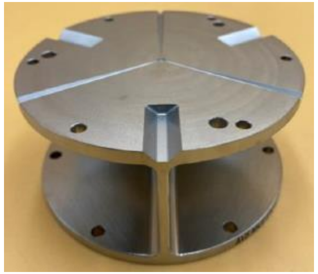


Thursday afternoon 14:10 - Design for Removal session

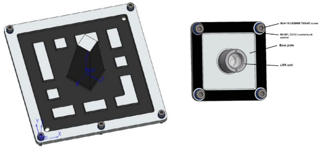
CAT-IOD

The mission

- Assessment study for a **cost-affordable In-Orbit Demonstration mission** with focus on both Servicer (CAT) and Client (D4R aids) technologies for **Copernicus Sentinel Expansion Missions** removal.

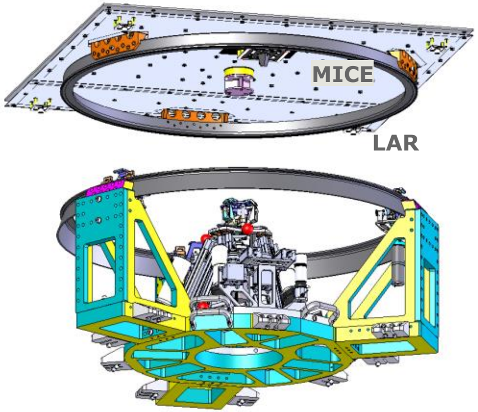


MICE

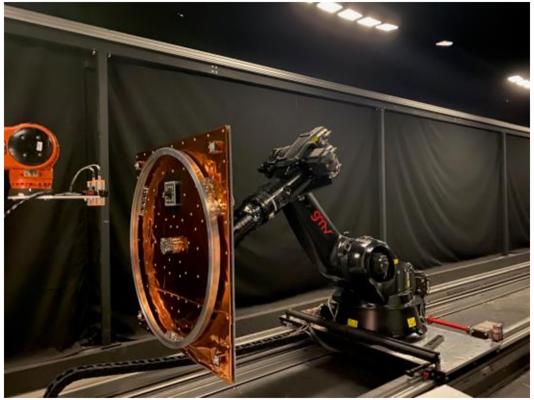


2D and 3D markers

CAT robotic assembly



CAT bay



CAT Client Mock-up

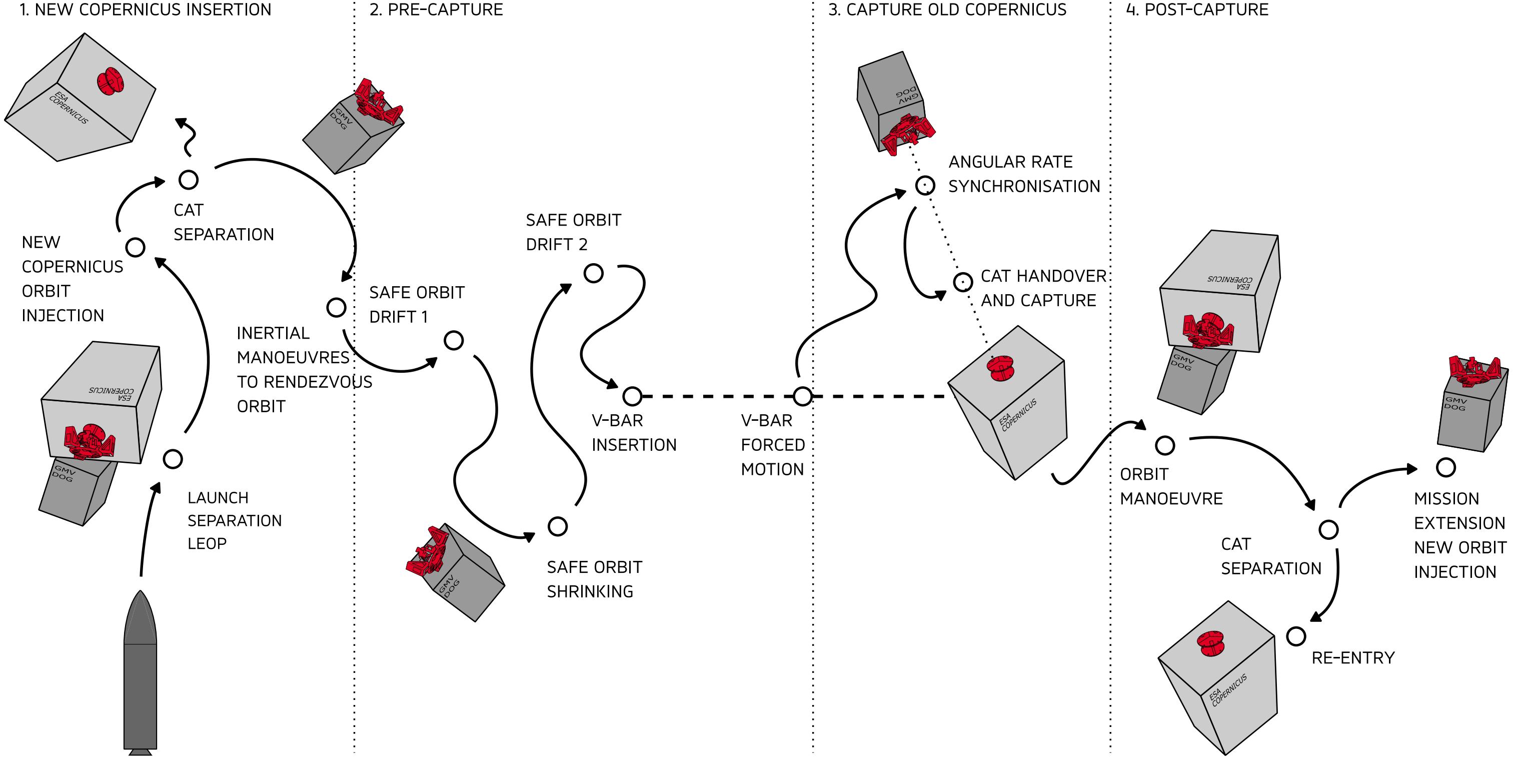
CAT-IOD

Object

- **CAT-IOD shall be as representative as possible of an ADR mission for removing the next generation of Copernicus satellites using the MICE device and navigation aids.**
    - Primary objective is to test CAT functionalities.
- **CAT-IOD** main **objectives** and **requirements:**
    - CAT-IOD shall preliminarily design a Servicer satellite, named DOG (Debris Orbital Grapper), carrying on-board the CAT capture payload.
    - CAT-IOD shall use a target of opportunity: the **AVS's LUR-1** satellite.
    - CAT-IOD shall demonstrate the scalability towards larger client satellites (i.e. Copernicus).
    - CAT-IOD shall evaluate the technical feasibility of the proposed mission in terms of costs and representativity.
- The **applicability of CAT to other missions** will also be assessed.

Copernicus NG ADR

Uncooperative Mission Profile



Capturing is the phase in which CAT-IOD shall demonstrate full representativity

Copernicus ADR devices

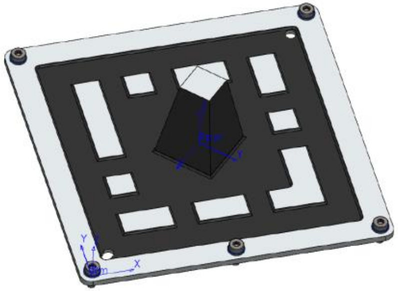
ESA D4R Technologies

ESA D4R Technologies:

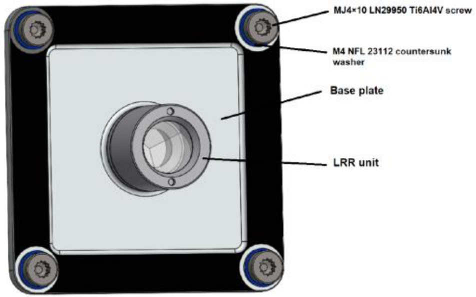
- **MICE** (GMV/AVS), Passive Mechanical Capture interface for capturing (+LAR for final clamping)
- **3D marker** (Admatis) for very close relative navigation (<5m from the target) .
- **2D markers** (Admatis) for mid-distance relative navigation (<50m from the target).
- **Retroreflectors** (integrated in the 2D marker) for far distance relative navigation aids and on-ground spin rate and axis determination.

Main Configuration Requirements:

- 1 3D marker close to LAR centre
- 4 2D markers on LAR face + 4 on all the other faces except 1 & forming unique pattern for unequivocal identification of each face



3D marker



2D marker + retroreflector

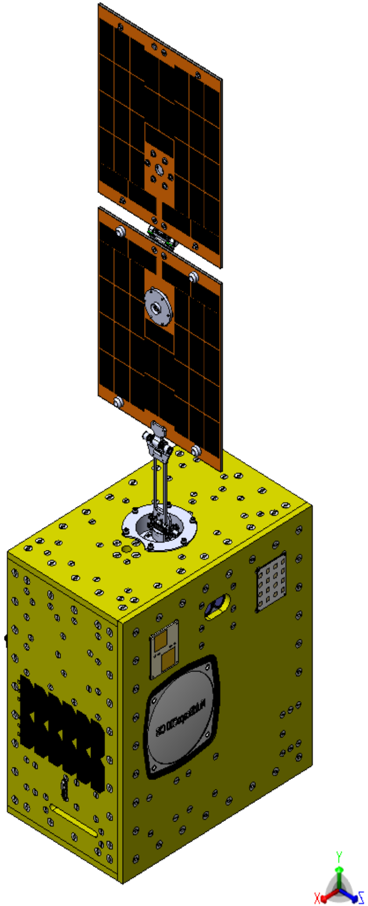
Target of opportunity

LUR-1 Satellite Intro

AVS LUR-1 Mission:

- Microsatellite Platform, **57kg** wet mass
- Nominal SSO 500 km altitude
- Optical payload with 1.5m to <1m GSD
- QKD Comms Physical Layer IOD PL
- IOD of AVS Platform, propulsion and mechanisms
- EO Data & Insights provision to clients
- Launch **Q3 2024**

LUR-1 is much smaller than Copernicus and it is due to launch soon (2024). It is under AIT activities, so as target of opportunity there is not anymore room for further changes to make it better as Client.



LUR-1 Modifications

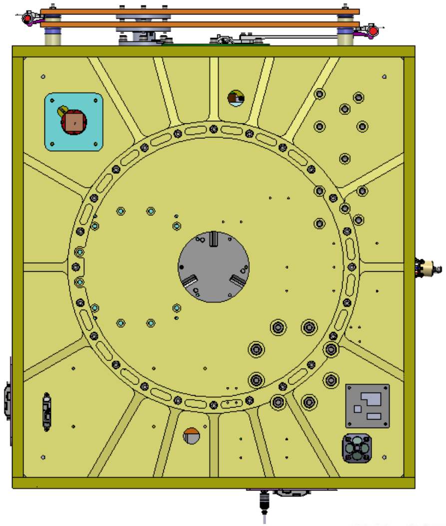
Initial D4R technologies configuration

Initial D4R technologies:

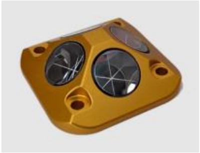
- **MICE** as Passive Mechanical Capture interface for capturing was installed.
- NO Admatis 3D marker -> size not compatible with flat surface on the LAR side of the allowable satellite envelope on the SpaceX Rideshare envelopes. Substituted by one **2D ArUco marker**.
- NO Admatis 2D markers -> incompatible with de LUR-1 mission financial and programmatic constrains.
- NO Retroreflectors integrated in Admatis 2D marker -> substituted by one **Lumi Space** vectorial retroreflector.

Representativeness (1 out of 4 mission phases):

- CAT capturing MICE.
- Very close relative navigation (<5m from the target) not fully representative with only 1 2D ArUco marker.
- Mid distance relative navigation (<50m from the target) not possible since there are less than 4 2D markers per face.
- Far distance relative navigation aids and on-ground spin rate and axis determination uncertain since there are no performance data from Lumi Space for a single retroreflector.



avs
added value solutions



LUR-1 Modifications

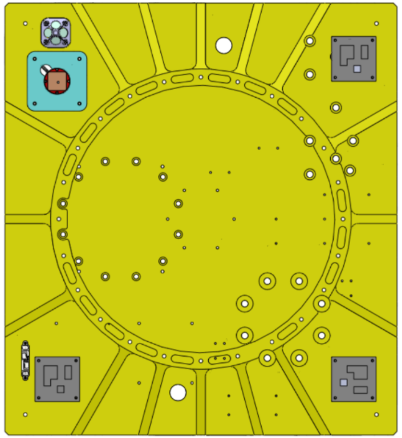
First Iteration

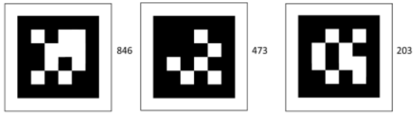
Modifications I:

- Added **3 Lumi Space 2D markers on LAR face**.
    - moved to the corners with new pattern which include a white border to improve detectability (**similar to 3D marker design** from Admatis).
    - dimension has changed to let space for the white borders and to include a thermal flat tape around markers to avoid reflections in wrinkles.
    - Each 2D marker will use a different ArUco numbers, the current selected ones are the 846, 473 and 203.
- Same **Lumi retroreflector** has been maintained, and it has been moved to the upper left corner to let space for the 2D markers.

Representativeness (2 out of 4 mission phases):

- CAT capturing MICE.
- Very close relative navigation (<5m from the target) very similar to 3D marker based.
- Mid distance relative navigation (<50m from the target) not possible since there are less than 4 2D markers per face.
- Far distance relative navigation aids and on-ground spin rate and axis determination uncertain since there are no performance data from Lumi Space.



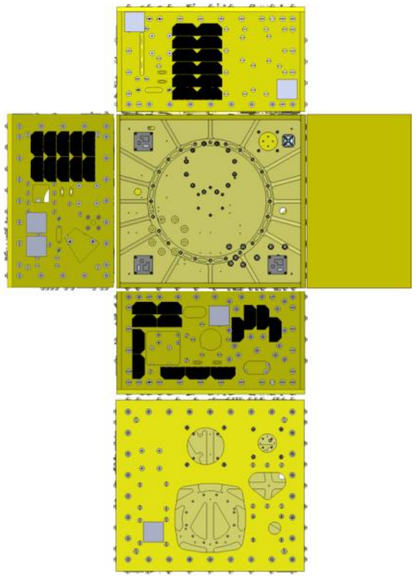


LUR-1 Modifications

Second Iteration

Modifications II:

- Goal is to add as many 2D markers (with retroreflectors) as possible to allow on-ground spin rate and axis determination.
    - added one Admatis 2D marker on +Z, one on -X, two on +X as separated as possible, two on -Y as close as possible and leaving +Y empty.



Representativeness (2 out of 4 mission phases):

- CAT capturing MICE.
- very close relative navigation (<5m from the target) possible.
- mid distance relative navigation (<50m from the target) difficult since there are less than 4 2D markers per face.
- far distance relative navigation aids and on-ground spin rate and axis determination: this pattern should be enough to guarantee this functionality, although still uncertain since there are no analysis on retroreflectors performance.

The additional 2D markers are being glued on their LUR-1 faces.

LUR-1 Representativeness

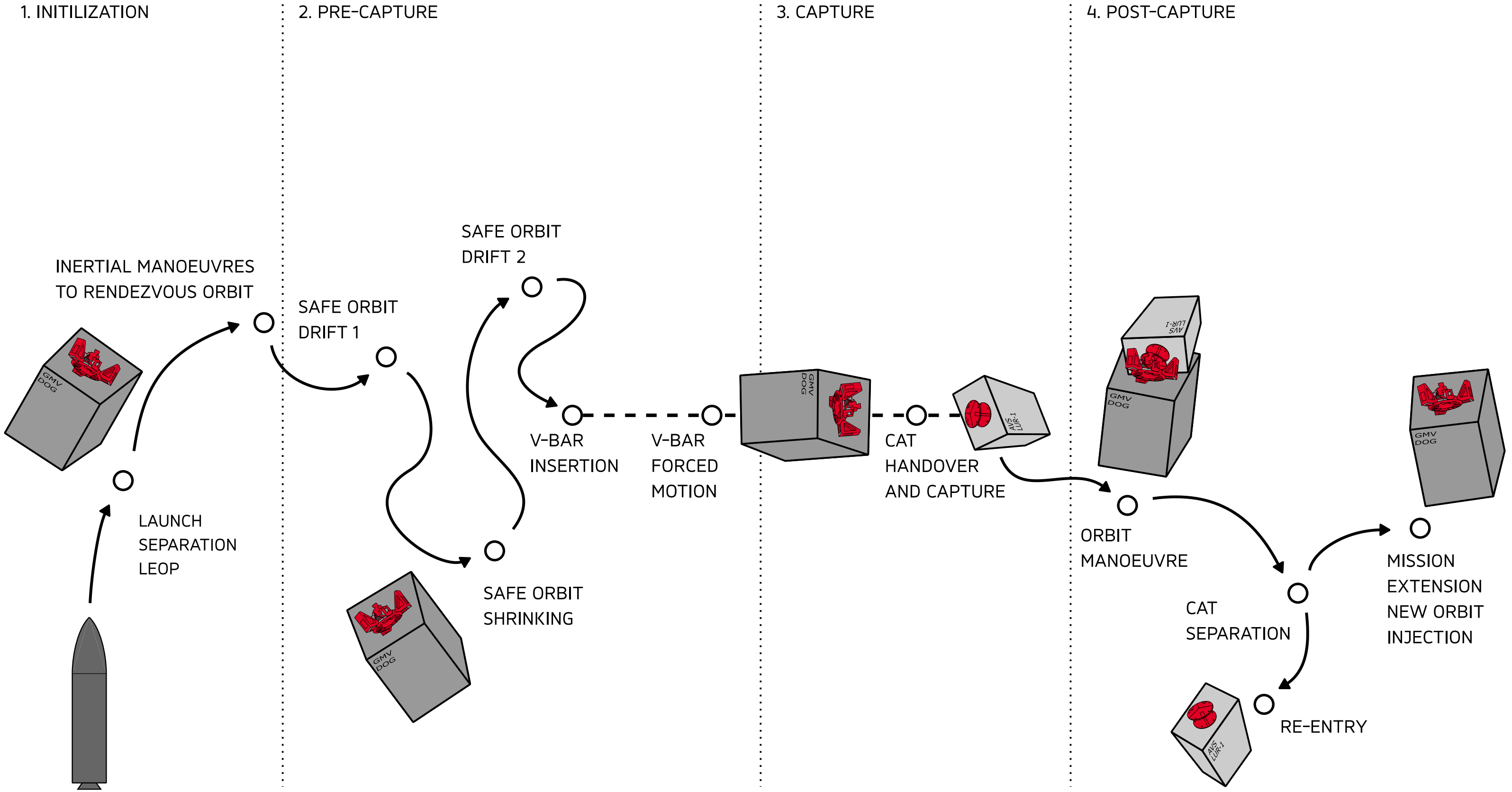
D4R Technologies

		Phase 1: far rendezvous (>50m)	Phase 2: mid rendezvous (50m – 5m)	Phase 3: close rendezvous (5m – 0m)	Phase 4: capture (0m)
Cooperative Scenario	**ESA / Copernicus**	Ground navigation aids exploiting target's telemetry	PnP relative navigation algorithm exploiting four Admatis 2D markers	PnP relative navigation algorithm exploiting one Admatis 3D marker at the LAR center	CAT capturing MICE and clamping with LAR
	LUR-1 active	Ground navigation aids exploiting target's telemetry or centroiding relative navigation algorithm	Model based tracking (MBT) relative navigation algorithm	PnP relative navigation algorithm exploiting three ArUco 2D markers on the LAR face	CAT capturing MICE and possibility of clamping with LAR, under investigation if needed
	LUR-1 no active	Mission unfeasible -> another Target satellite needed			
Uncooperative Scenario	**ESA / Copernicus**	Ground navigation aids exploiting target's retroreflectors	PnP relative navigation algorithm exploiting four Admatis 2D markers	PnP relative navigation algorithm exploiting one Admatis 3D marker at the LAR center	CAT capturing MICE and clamping with LAR
	LUR-1 active	Ground navigation aids exploiting target's retroreflectors or centroiding relative navigation algorithm	Model based tracking (MBT) relative navigation algorithm	PnP relative navigation algorithm exploiting three ArUco 2D markers on the LAR face	CAT capturing MICE and possibility of clamping with LAR, under investigation if needed
	LUR-1 no active	Mission as per LUR-1 active if ground can determine through retroreflectors signals that the LUR-1 spin axis and rate is suitable for the mission.			

Remark: Full representativity is guaranteed during close rendezvous and capture. So, CAT can be tested completely, both its SW and its HW. Clamping is the only functionality that cannot be tested since LAR is missing on LUR-1.

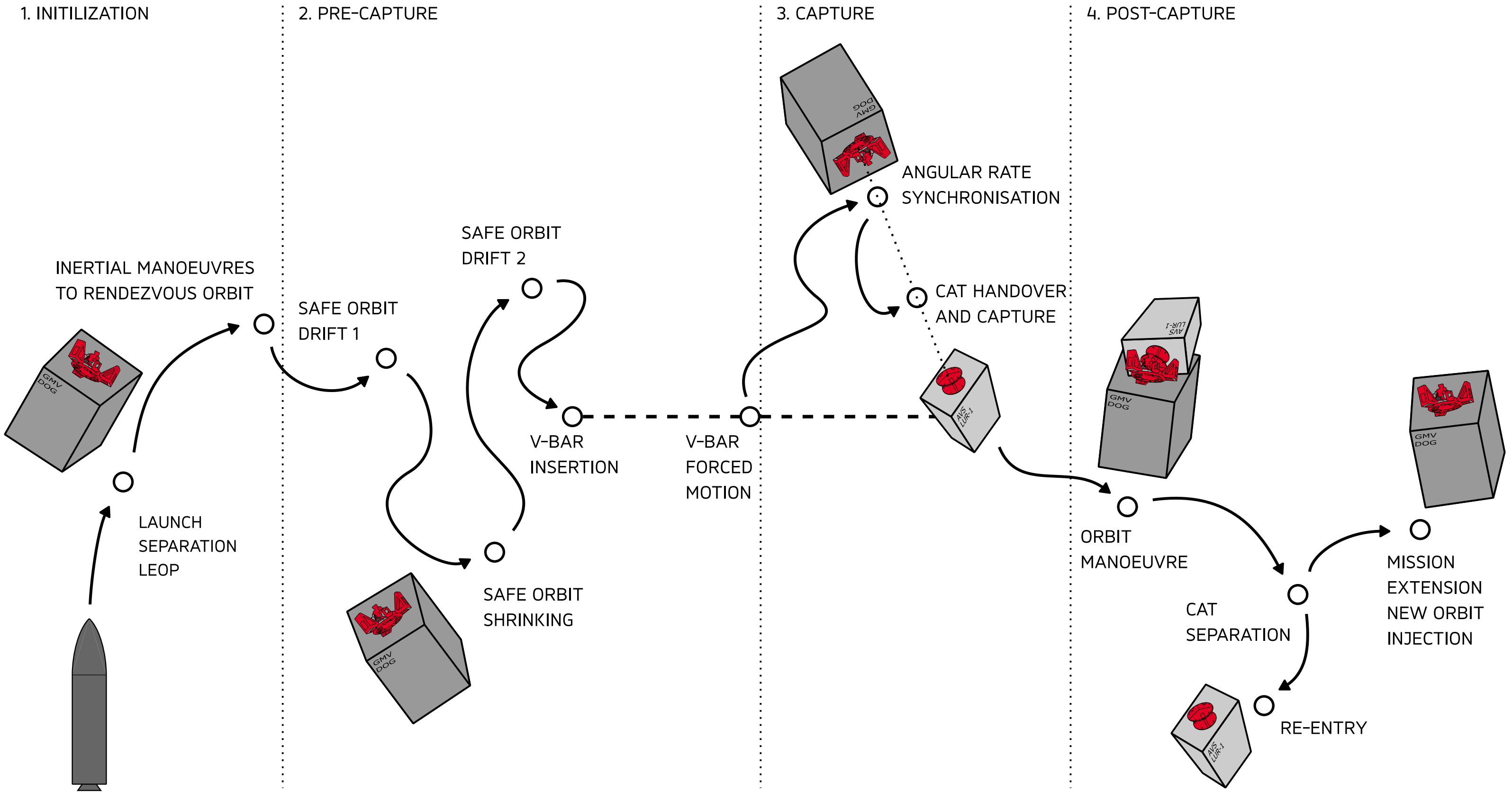
CAT-IOD Mission Scenarios

Cooperative CAT-IOD Mission Profile



CAT-IOD Mission Scenarios

Uncooperative CAT-IOD Mission Profile



Conclusion

CAT-IOD

- ESA Design for Removal (**D4R**) Interface Requirements Document (IRD) already adopted by the six **Copernicus Sentinel Expansion Missions** and is being used to prepare these satellites for possible removal missions: **MICE** + **Navigation Aids** + Magnetorquer short-circuit.
- Servicer side technology: **CAT** (Capture Bay for Active Debris Removal) close to the end of Breadboarding and functional verification phase at GMV's *platform-art*©.
- Both CAT/D4R technologies would benefit from an IOD Mission to overcome limitations from ground testing.
- GMV, together with AVS, are currently involved into the **assessment** of a **CAT-IOD** Mission: **cost-affordable In-Orbit Demonstration** of CAT technology.
- The **AVS's Lur-1** satellite, equipped with a MICE device and navigation aids considered as target of opportunity and adapted accordingly.
- The study will assess the **feasibility** of CAT-IOD and its **representativeness** w.r.t. the CSEM EoL needs and to deliver a preliminary design of Mission and Servicer vehicle. Expected to become an active key contributor to the ESA's Zero-debris policy.

Thank you

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