CAT

A SATELLITE CAPTURE PAYLOAD BAY FOR ADR SERVICING

Clean Space Industry Days
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Introduction to CAT: A Satellite Capture Payload

- One of the goals of ESAs Zero Debris Strategy is to foster **in-orbit servicing** for removal of vehicles in case of failure.
- ESA is taking a proactive role in Active Debris Removal by preparing the new generation of Copernicus earth-observation satellites for a potential **removal** as part of the **End-of-Life management** which in the future may be adopted by other satellites.
- A Design for Removal (D4R) Interface Requirements Document produced by ESA describes client-side elements to facilitate servicing.
- It is encouraged that in the future, most missions should meet D4R guidelines to enable its uncooperative capture and deorbiting if needed.
- Client-side D4R requirements are designed to work in close cooperation with **active capture systems** at servicing vehicles.

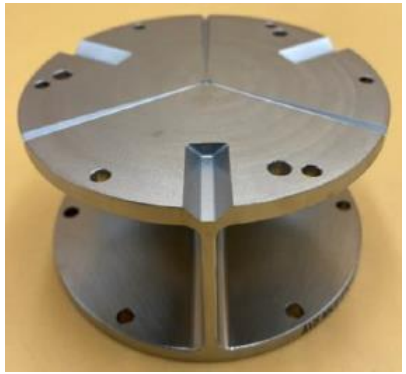
We present preliminary results from development and maturation of the key technologies for capture and removal at servicer vehicle side. A **capture payload** (CAT) has been designed, manufactured and integrated to perform testing.

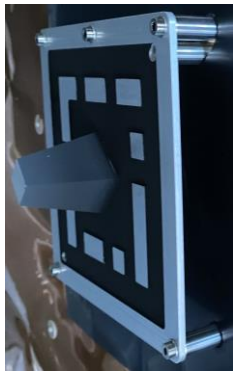
Design for Removal Assumptions

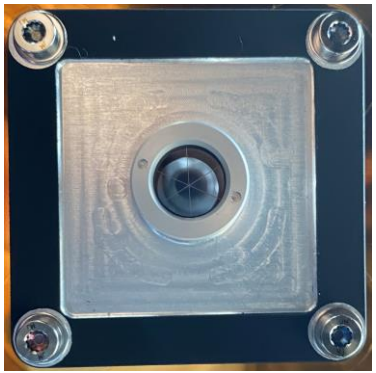
Some of the proposed D4R interfaces relevant for CAT include:

- ❑ A passive mechanical interface for capture and end-of-life (MICE)
- ❑ *Rendezvous marker (3D marker)*
- ❑ *Rendezvous and mission preparation markers (Laser retroreflector 2D markers)*
- ❑ *Interface for disposal loads (VEGA C Launch Adaptor Ring – LAR, "VAMPIRE 1194 VG").*

In previous activities, the consortium has designed the capture interface and rendezvous aids to be placed at client-side. All are currently undergoing qualification and are being used in CAT.

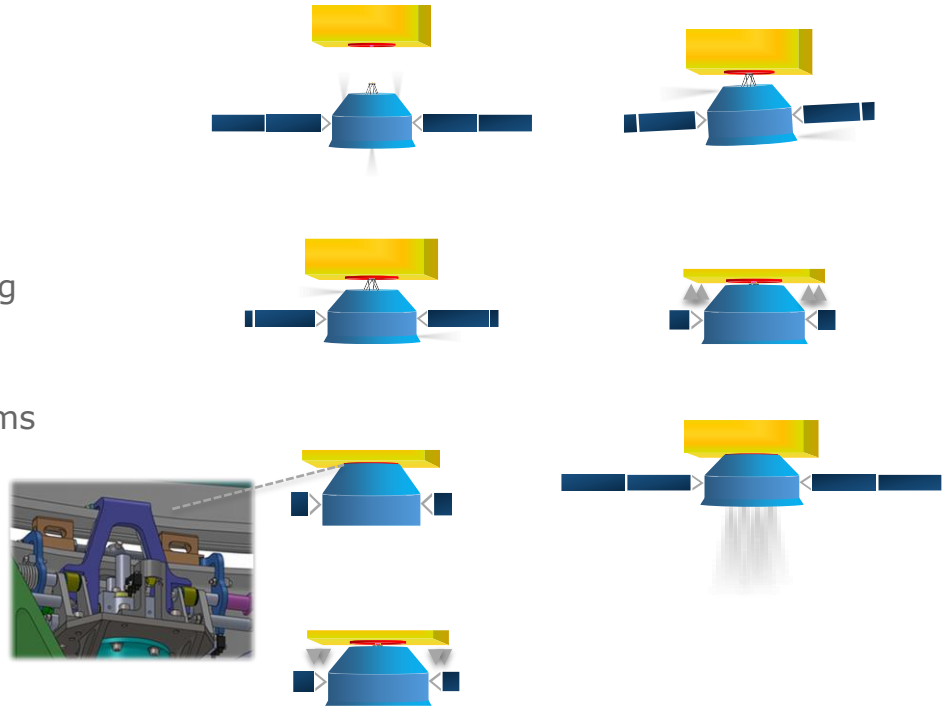






CAT Design Drivers

- Perform relative tracking of the target during last approach phase (5m down to mating)
- Alignment of the robotics assembly with the target spacecraft to minimize relative errors during cooperative and uncooperative approaches.
- Perform a soft capture using the end-effector.
- Absorb and minimize residual contact energy during capture.
- Relocation and retraction to align both LARs.
- Structural reinforcement using clamping mechanisms to support high thrust maneuvers.

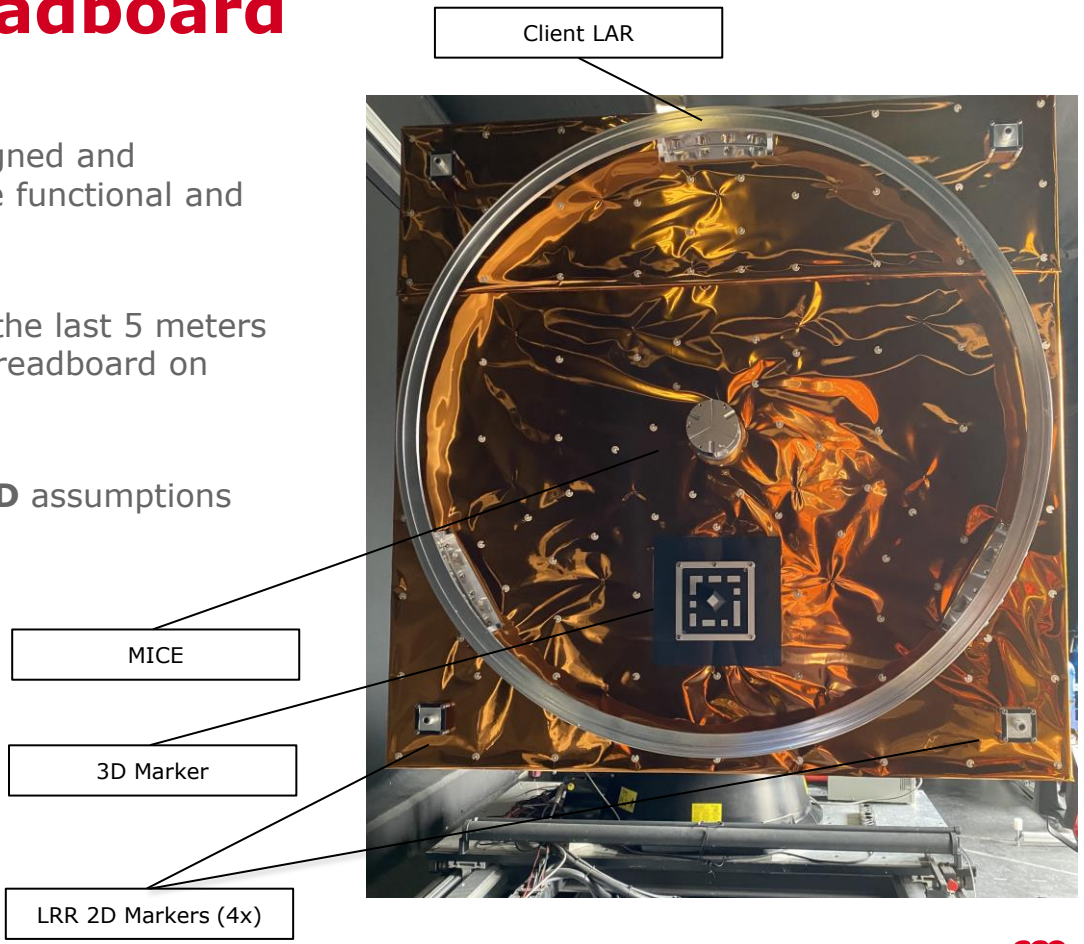


CAT Client-Side Breadboard

A **client-side breadboard** has been designed and manufactured to verify through testing the functional and performance requirements of the system.

End-to-end rendezvous and capture from the last 5 meters down to mating is being tested with this breadboard on GMV's robotized ***platform-art*** test facility.

The Breadboard is compliant with **D4R IRD** assumptions including a full-size 1194 LAR.



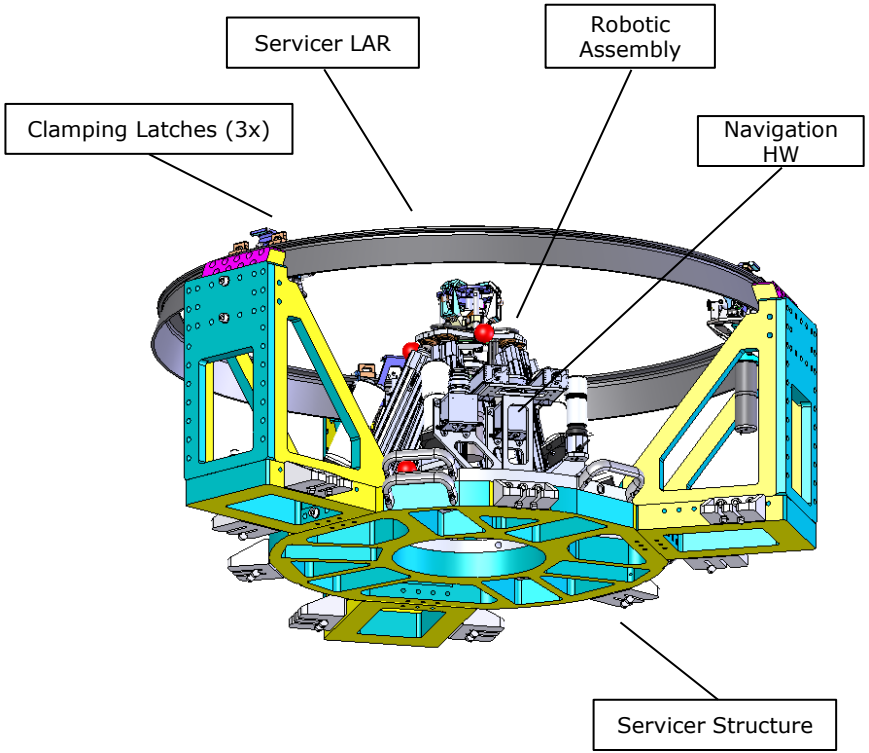
CAT Servicer-Side Breadboard

A **servicer-side breadboard** has been designed and manufactured to verify through testing all CAT active functions.

The breadboard includes a **payload bay structure** containing CAT components including a full-size 1194 LAR.

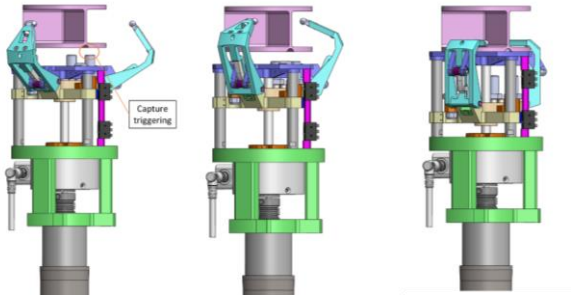
CAT components include a **robotic assembly** (hexapod mechanism with end-effector), **clamping devices**, optical navigation **cameras and lighting**, **OBC** and integrated **controllers**.

These elements are being consolidated and integrated in a TRL 4 system ready for end-to-end hardware-in-the-loop testing including interactions with the servicer.



CAT Robotic Assembly

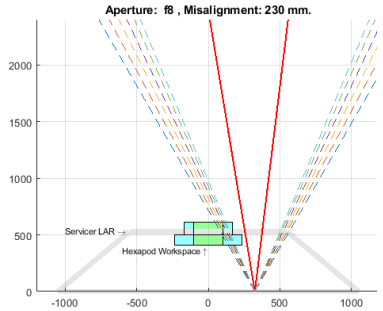
- **Gough-Stewart platform** compatible to misalignment and load requirements
- **Force/torque feedback** for compliant modes
- Co-engineering for control and operational aspects: Workspace designed to avoid collisions between spacecrafts, approach and contact dynamics drive performances.
- Integrated gripper **end-effector** mechanism compatible with the MICE interface allowing capture before contact. Soft-capture: after some point of the capture process MICE is not fully grasped but can not escape.

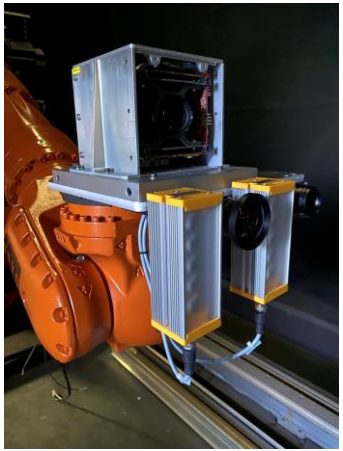


CAT Perception Components

- CAT Navigation & Avionics:
  - Last approach 6 DoF navigation w.r.t. 3D marker and transition from 2D markers
  - Provides navigation, status and safety/limits information to the vehicle MVM/GNC
  - Can accommodate COTS cameras and flight cameras
  - Two cameras for far range and close range coverage (with partial overlap)
  - Actively regulated lighting device to cope with rapidly changing sun conditions for the uncooperative case

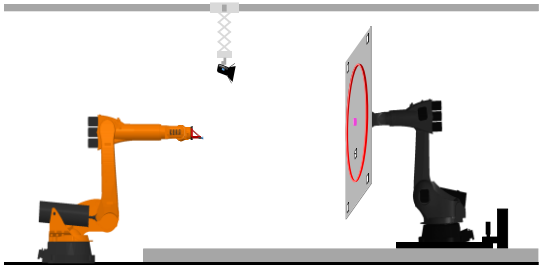
- Enable testing of algorithmic performances, optical parameters, compatibility to illumination conditions, safety of capture and occlusions avoidance.
- Onboard computer (SoC architecture) provides flexibility of control behaviors.

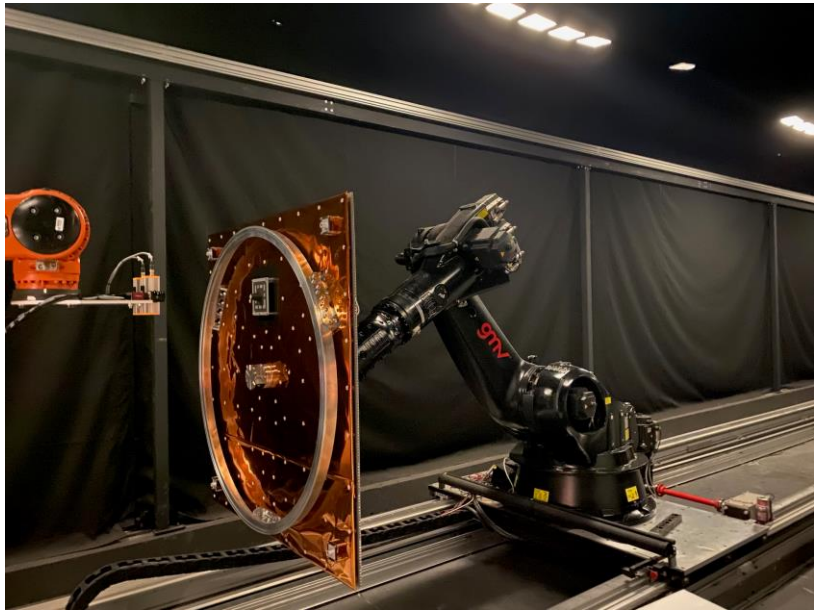


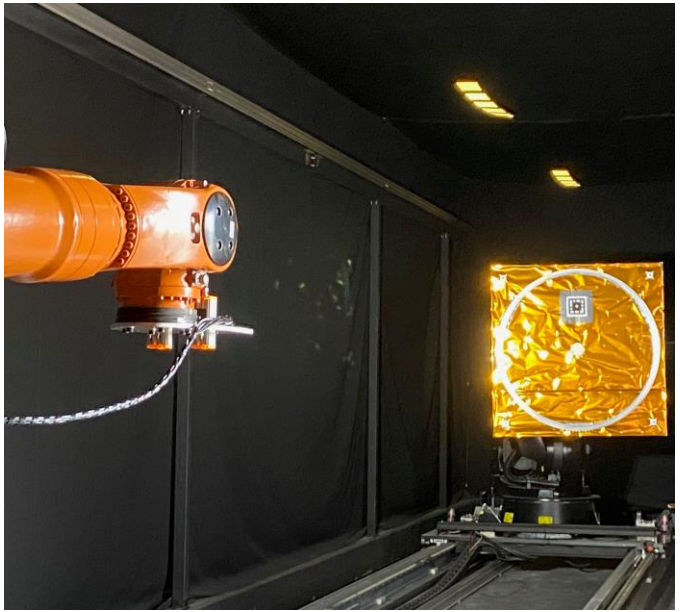


CAT V&V

- HIL facility (platform-art) set-up for navigation from 7m to contact and control tests (including stack phases).







CAT breadboarding and V&V

- Monte-Carlo of vehicle trajectories and sun sinusoids to check navigation performances
- Allows to test worst case conditions such as sun to shadows transitions & non-nominal cases

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Summary & Conclusions

- CAT is bridging **D4R** at Client side with technologies on the **Servicer** side to produce a Capture Bay system that is functional and cost-effective for ADR in LEO
- Interrelations and dependencies at different levels between mechanisms, robotics, navigation and control, mission management, safety monitoring etc… call for **co-engineering** of the different units and design iterations.
- Breadboarding of client side and servicer side components beyond those that are capture specific is allowing to perform **operational end-to-end** tests vital for consolidation and maturation of the capture payload.
- A **functional breadboard** of the CAT payload has been assembled and integrated. Target TRL is 4.
- An ongoing **testing campaign** will enable to verify and validate navigation, control and mission operational functions, performances.

Thank you

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