

Spacecraft concept for active de-tumbling and robotic capture of Ariane rocket bodies

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Background

The 2009 Iridium-Kosmos collision highlights a growing hazard to satellites from space debris. Expended upper stages, also called Rocket Bodies (RB), represent a significant fraction of the debris population that can cause catastrophic loss of space-based assets. Active Debris Removal (ADR) will play a crucial role in mitigating rapid growth of the debris population over the coming decade.

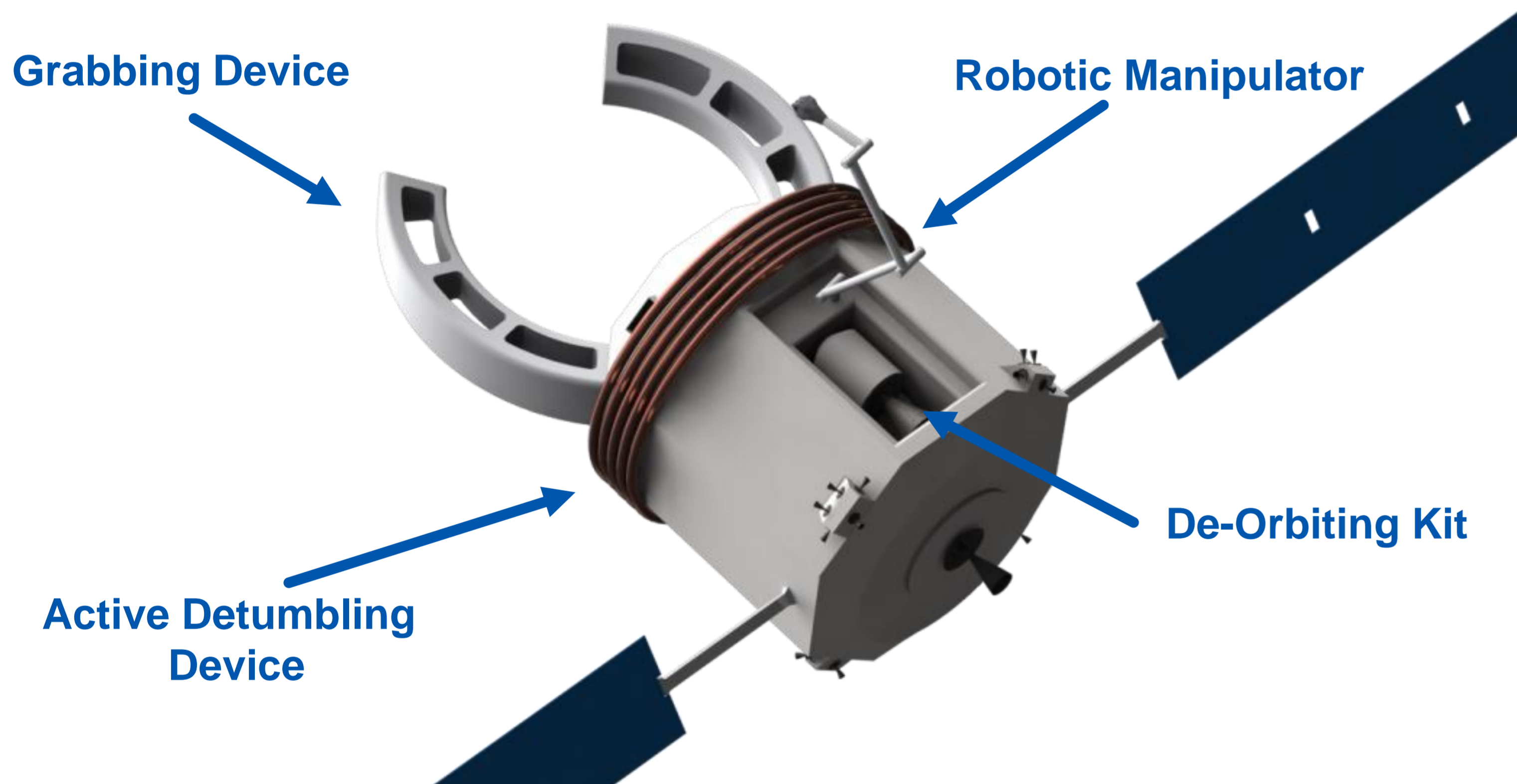
Mission Goal

The Agora mission will:

- demonstrate technologies to remove an Ariane RB
- within a cost cap of €200M FY2015
- by 2025 at the latest

The key technologies that will be demonstrated are:

- novel, active detumbling device based on eddy currents
- robotic grabbing system, including a semi-rigid clamping mechanism and a robotic manipulator
- usage of a de-orbiting kit for ADR
- autonomous, robust GNC system for proximity operations



Agora spacecraft concept

Spacecraft Concept

The Agora technology demonstrator will be designed to enable fully-autonomous removal of non-cooperative RBs. The chaser will detumble, capture, and de-orbit its target RB: the upper stage used to place it on-orbit. The detumbling device will use eddy currents to actively reduce the tumbling rate of the target. During the capture phase, the semi-rigid clamp will be employed to secure the target, so that the robotic manipulator can deploy the de-orbiting kit within the main nozzle of the target RB.

Spacecraft Specifications

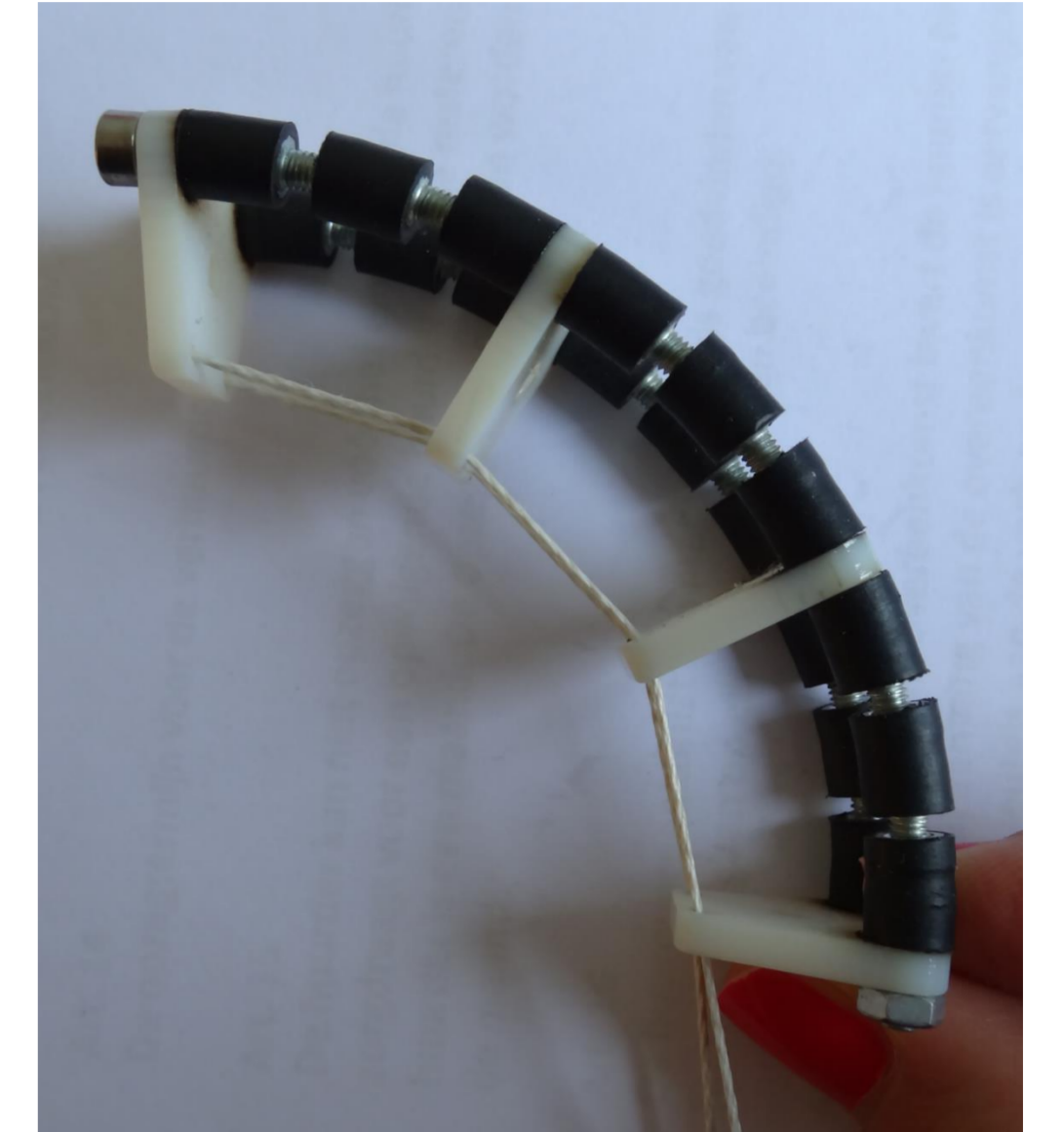
Mass	Dry Mass	2000 kg
	Propellant Mass	500 kg
	Total Mass	2700 kg
Power		709 W
Size		5.4 (L) x 3.3 (D) m
Volume		22 m ³

References

1. Ortiz Gómez, N. & Walker, S.J.I.; 'Eddy Currents applied to De-tumbling of Space Debris: Analysis and Validation of Approximate Proposed Methods'; Acta Astronautica, April 2015; DOI: doi:10.1016/j.actaastro.2015.04.012.
2. Jankovic, M., Paul, J., Kirchner, F.; 'GNC architecture for autonomous robotic capture of a non-cooperative target: preliminary concept design'; Advances in Space Research, Special Issue: Asteroids & Space Debris, September 2014 (*in press*).
3. Jankovic, M., Kumar, K., Romero Martin, J., Ortiz Gómez, N., Kirchner, F., Topputo, F., Vasile, M., Walker, S.J.I.; 'Autonomous robotic system for active debris removal: requirements, state-of-the-art and concept architecture of the rendezvous and capture (RVC) control system'; 5th CEAS Air & Space Conference; Delft, The Netherlands; conference paper, abstract 31 (*abstract accepted*).
4. Kumar, K., Ortiz Gómez, N., Jankovic, M., Romero Martin, J., Topputo, F., Walker, S.J.I., Kirchner, F., Vasile, M.; 'Agora: Mission to demonstrate technologies to actively remove Ariane rocket bodies'; IAC 2015; Jerusalem, Israel; paper IAC-15,A6,6.1,x28851 (*abstract accepted*).

Robotic Payload

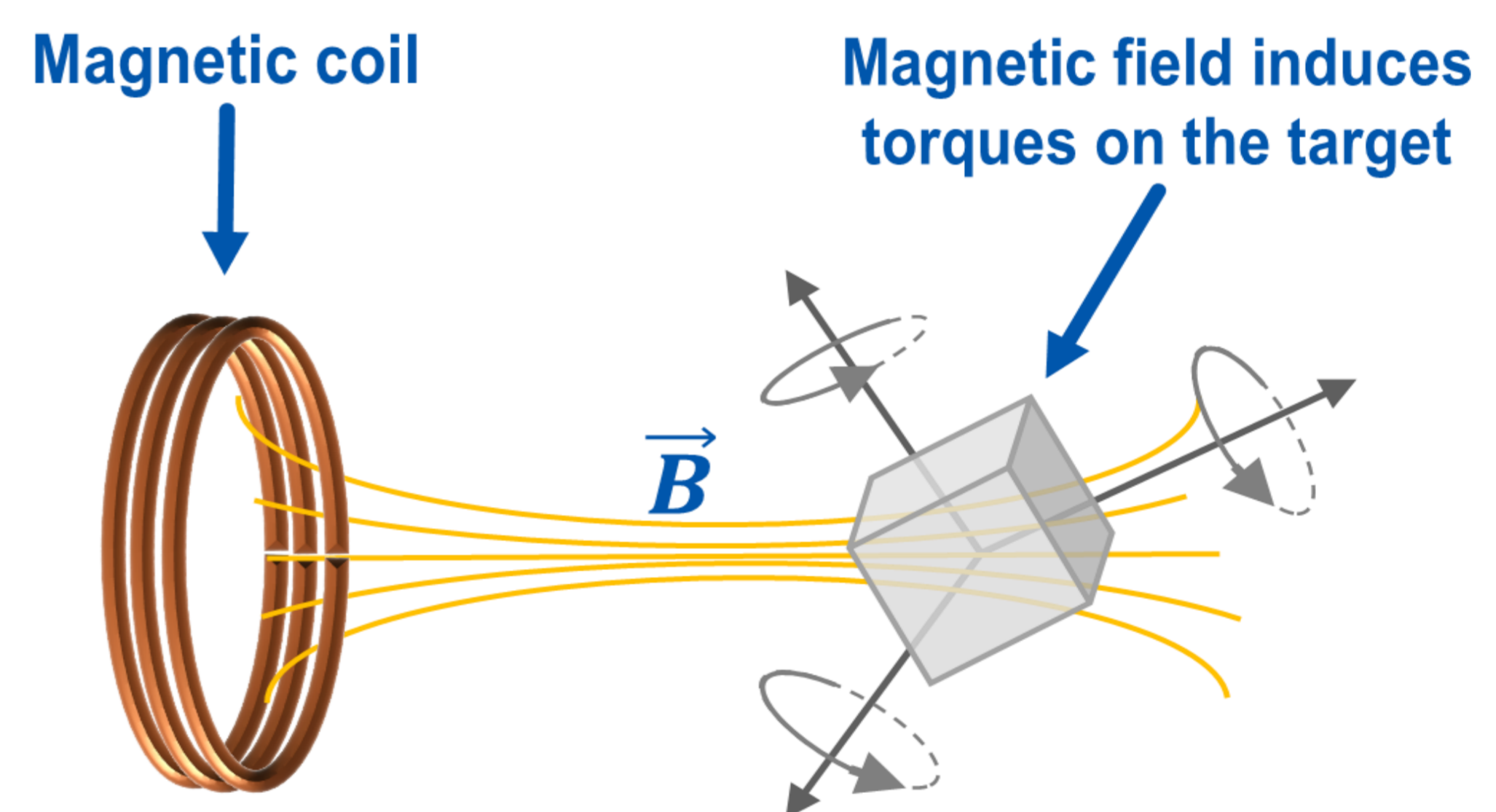
- Robotic manipulator:
 - 7-DOF lightweight design
 - space-proven hardware
- Grabbing device:
 - semi-rigid clamping mechanism
 - anthropomorphic design
 - lightweight design
 - feature-independent grasping



Prototype of the grabbing device

Detumbling Payload

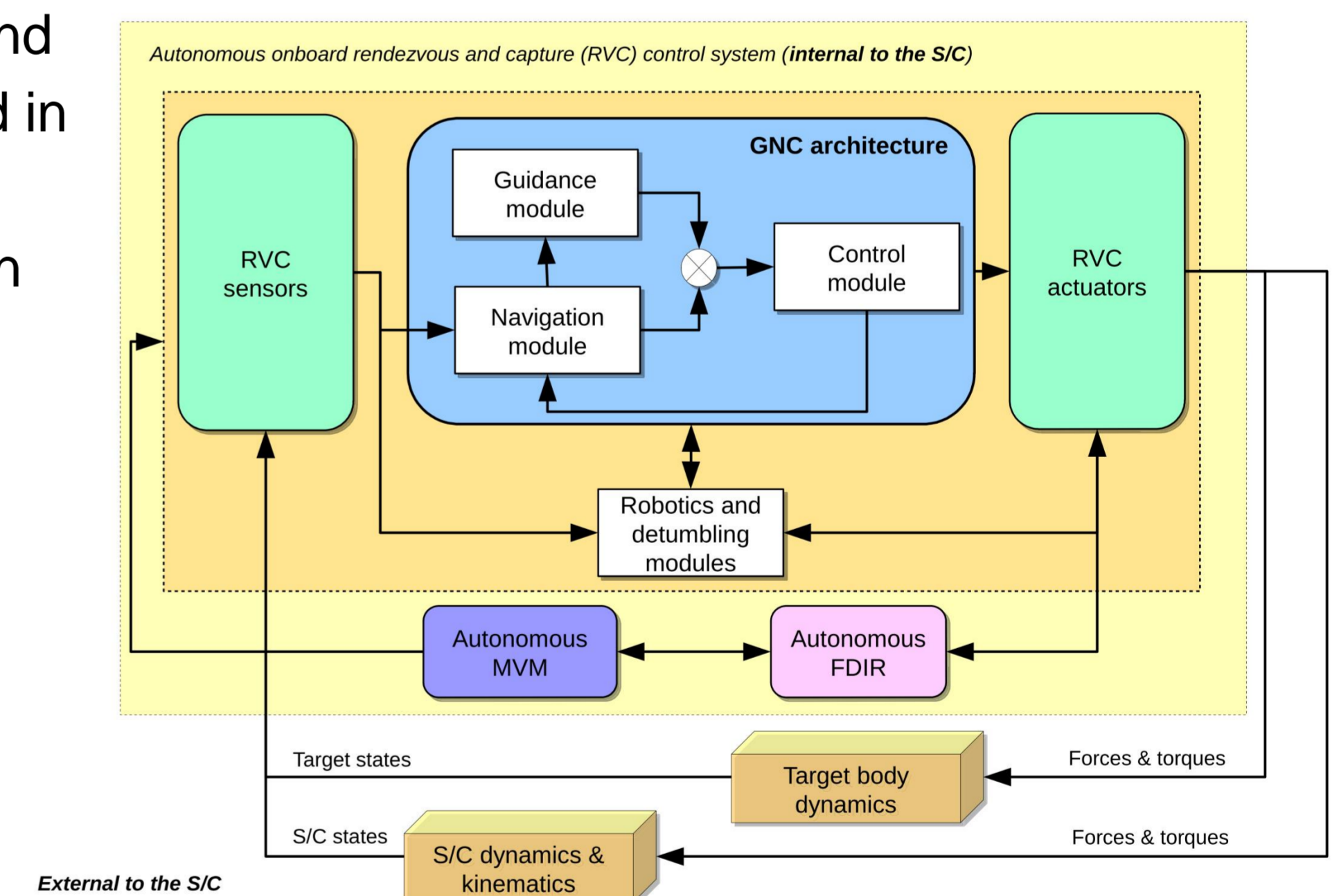
- Active de-tumbling method based on the generation of eddy currents:
 - dissipative process based on Joule's effect
 - non-invasive: no risk of generating new debris
 - all angular components can be damped
- Magnetic coil based on 2nd generation High Temperature Superconducting (HTS) wires
- Active cooling based on Loop Heat Pipe (LHP) and cryocoolers
- Experimental tests carried out at Airbus Defence & Space



Schematic illustration of the detumbling process

GNC architecture: key characteristics

- Fully autonomous: ground station is not considered in the loop
- Modular, scalable design
- Dedicated to proximity operations
- Prediction and compensation of non-linear, free-floating dynamics



Autonomous onboard RVC control system architecture

Future steps

- GNC simulations including fly-around, de-tumbling and capture phases
- Optimization of the design of chaser subsystems
- GNC code implementation
- Experimental tests
 - de-tumbling process
 - GNC code validation at DFKI's INVERTAS HIL facility

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