MIRROR – A Modular and Relocatable Multi-Arm Robot Demonstrator for On-orbit Large Telescope Assembly

17th Symposium on Advanced Space Technologies in Robotics and Automation

Leiden, 18-20 October 2023

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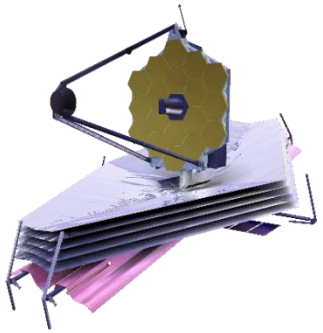
CONTENT

INTRODUCTION

INTRODUCTION – MIRROR PROJECT

- Current Context

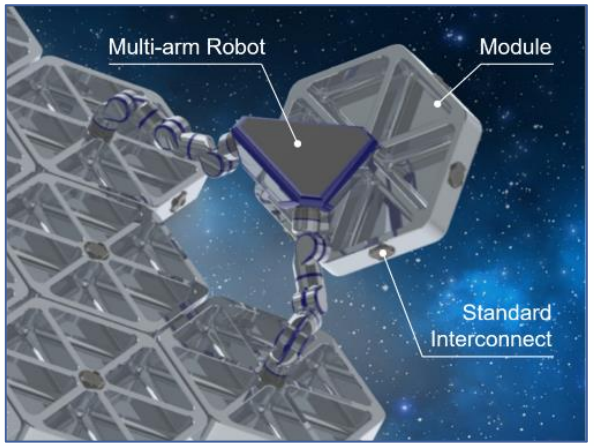
  Large structure in space *are an* ***essential*** *and recurring element* ***for space exploitation and exploration*** *continuously increasing in size to bring increased economic and scientific benefits (e.g. James Webb telescope).*



- Future Context

  Next structures will be too large to be launched into orbit as a single self-deploying piece that can be contained in standard launcher fairings. These ***larger structures could be divided into subassemblies*** *(orbital replacement unit 'ORU', modules, reflector segments etc.) that are launched disassembled and* ***later assembled in orbit****.*

- ESA TRP MIRROR : Multi-arm Installation Robot for Readying ORUs and Reflectors



- Foreseen Technologies in MIRROR

  The modules of a ***large space telescope*** *will be equipped with* ***standard interconnects*** *and* ***a robotic system*** *will* ***relocate*** *over a spacecraft for* ***deploying*** *them from their stowed location to their operational location.*

MIRROR & MAR CONCEPTS

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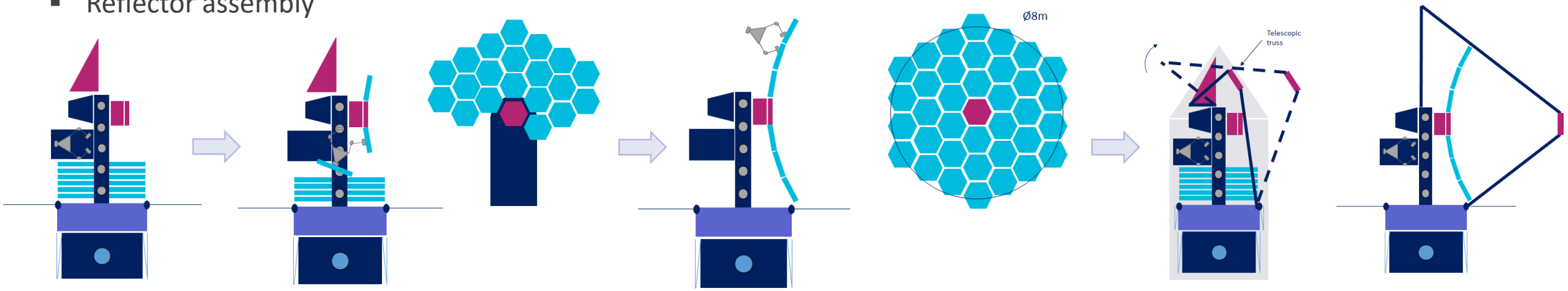
MIRROR CONCEPT

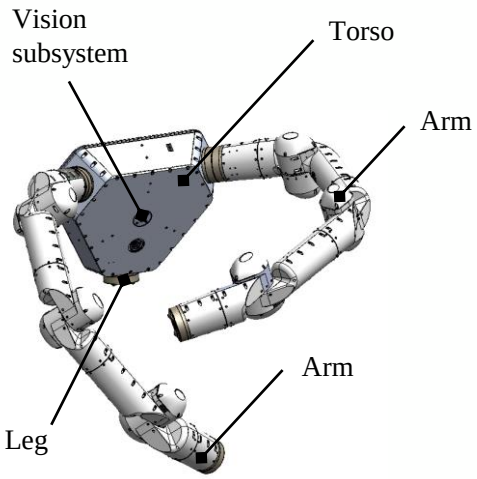
- Reflector assembly

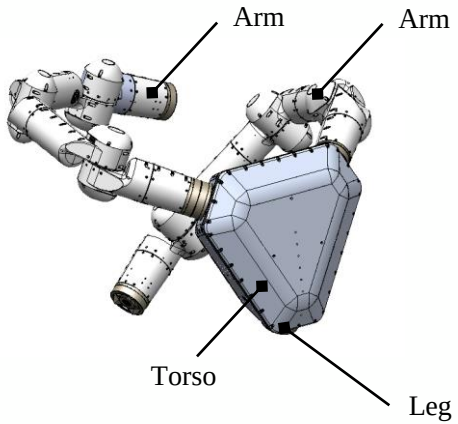


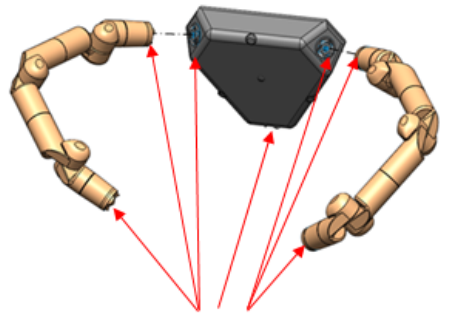
Initial condition | Assembly of mirror's tiles | Assembly completed | Deployment of the secondary mirror

- Multi-Arm Robot (MAR)

- The MAR features a **modular approach** using HOTDOCKs **standard interconnects**.
- The MAR is composed **three modules**:
  - A **torso**, featuring a 1-DOF leg, a vision subsystem and a battery.
  - Two 7-DOF **robotic arms**.



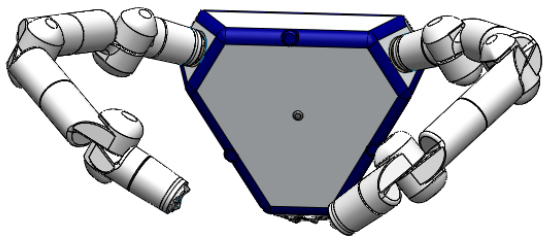




mech, power & data transfer

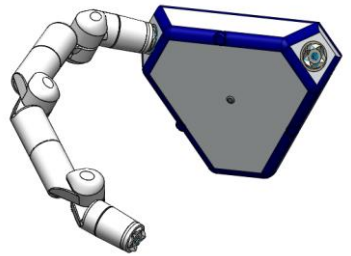
MULTI-ARM ROBOT OVERVIEW

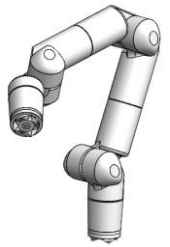
Nominal configuration

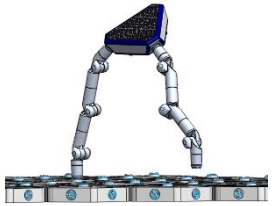


Reconfiguration

Alternative configurations

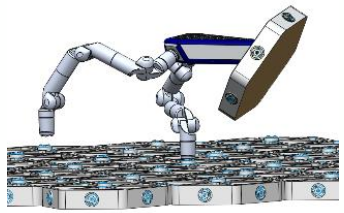




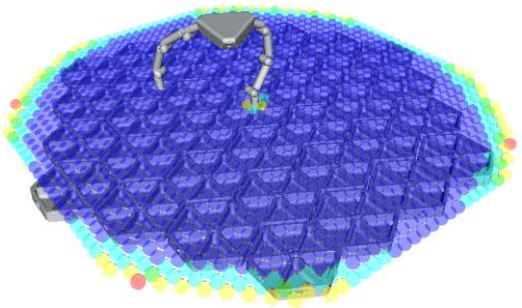


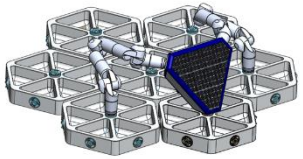
walking

Nominal operations

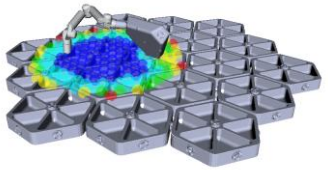


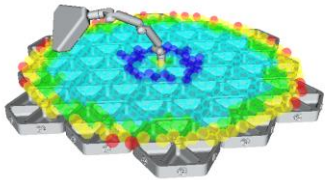
transporting

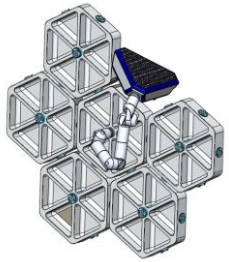




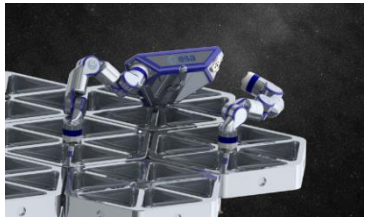
positioning



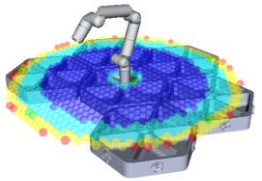


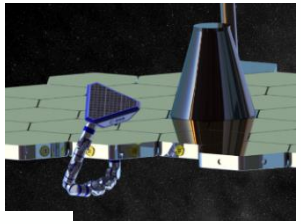


alternative operations

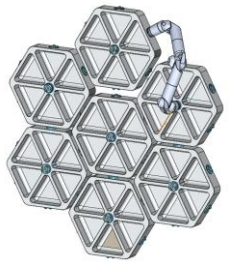


dissociation





inspection



TECHNOLOGICAL DEMONSTRATOR

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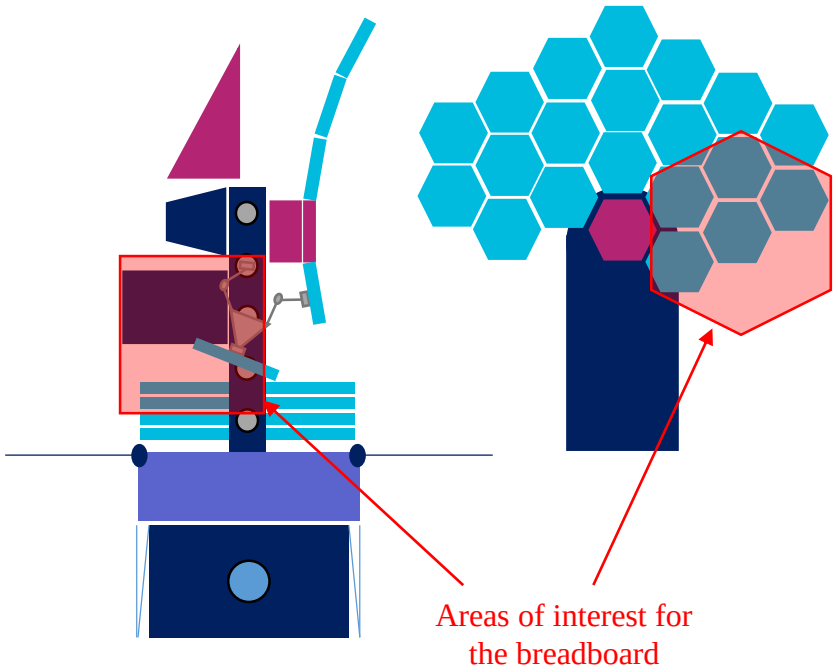
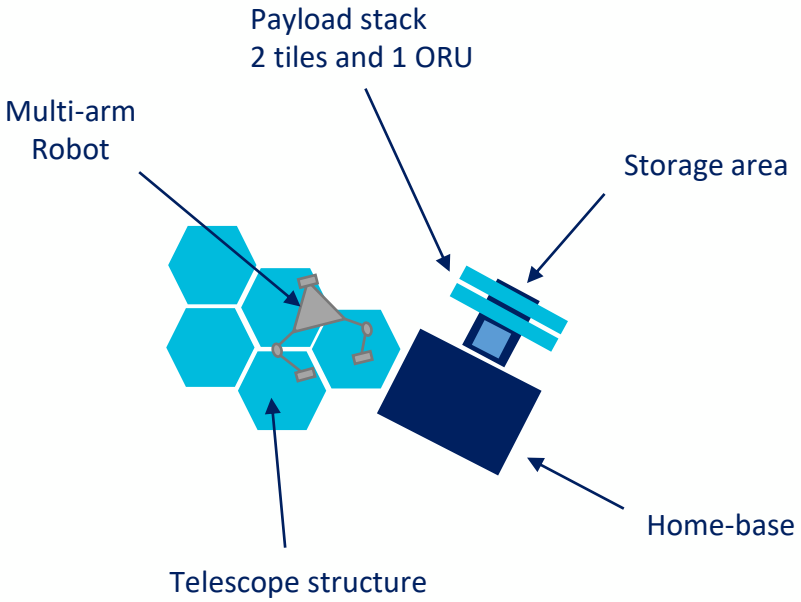
DEMONSTRATOR DERIVATION FROM THE MISSION SCENARIO

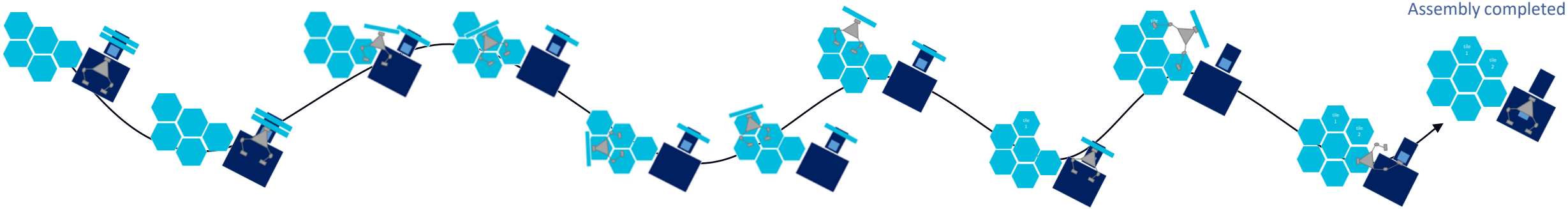


Adaptation to 1g demonstrations



Demonstration sequence

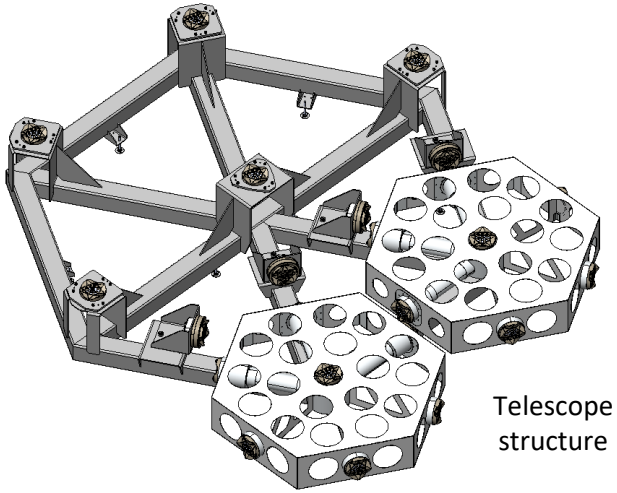
Initial condition



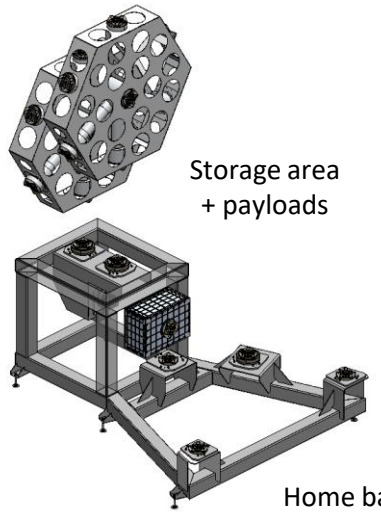
Assembly completed

DEMONSTRATOR OVERVIEW

- **Flight segment**
  - The **MAR** capable of grasping, releasing, and transporting modules.
  - The testbed: **dummy spacecraft**, hexagonal **telescope tiles** and **ORU** equipped with **HOTDOCKs** and a **weight compensation device**.
- **Ground segment**
  - The "**Monitoring and Control Station**" that allows users to supervise MAR's tasks.

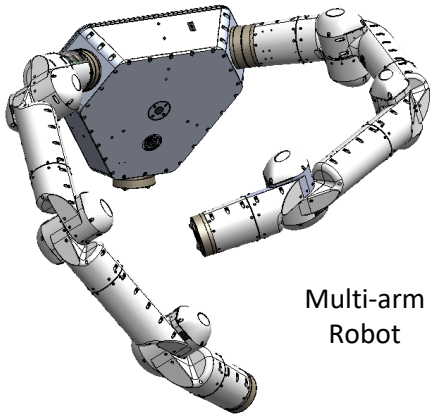


Telescope structure

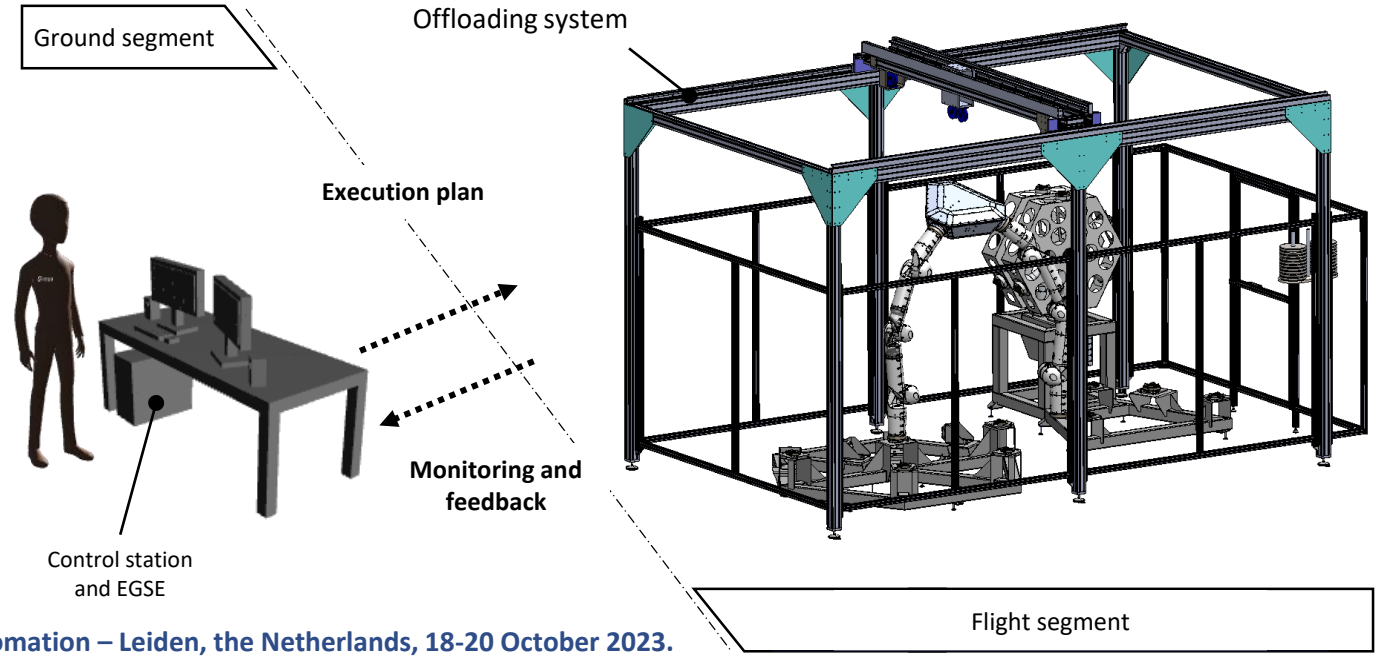


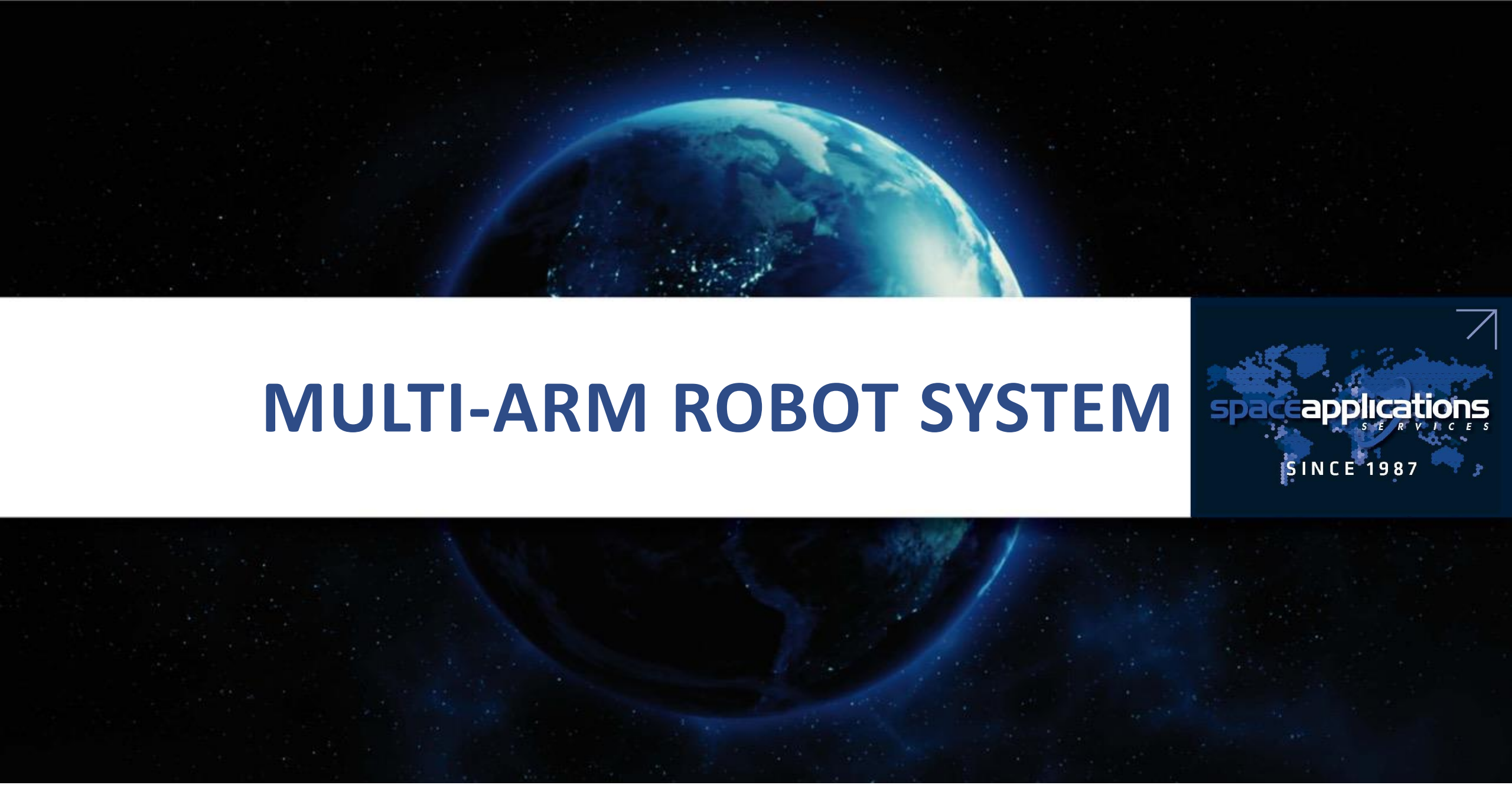
Storage area + payloads

Home base



Multi-arm Robot





MULTI-ARM ROBOT SYSTEM

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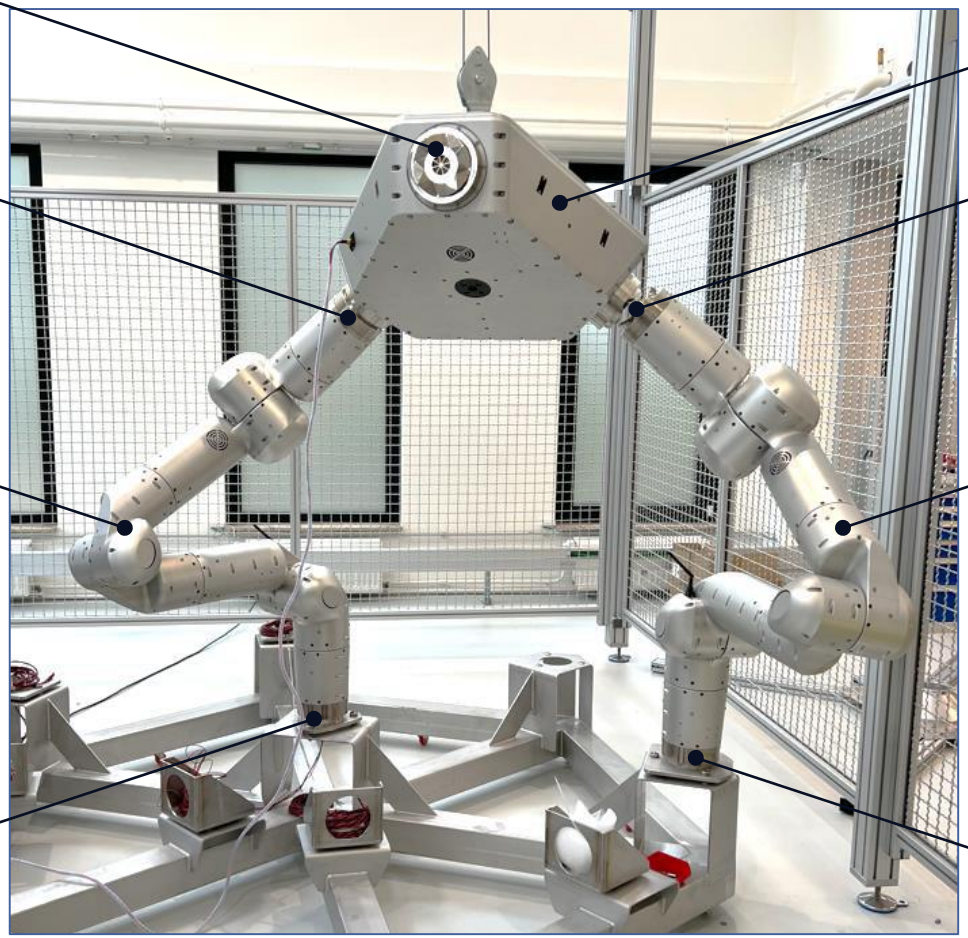
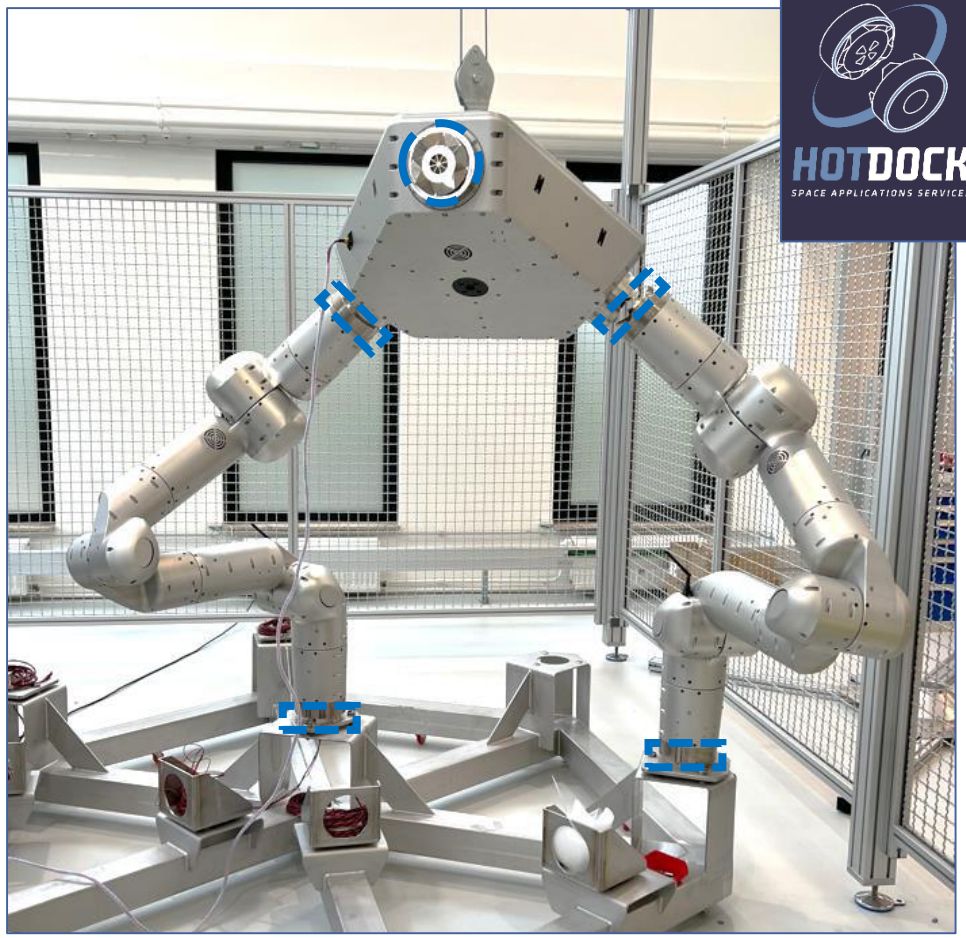
MULTI ARM ROBOT SYSTEM



MULTI ARM ROBOT SYSTEM – STANDARD INTERCONNECT

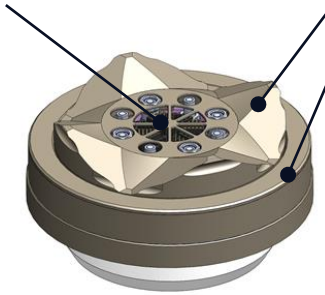


Central Functional interface (power/data)

- Pogo pins and pads

Mechanical interface (alignment/coupling / load transfer)

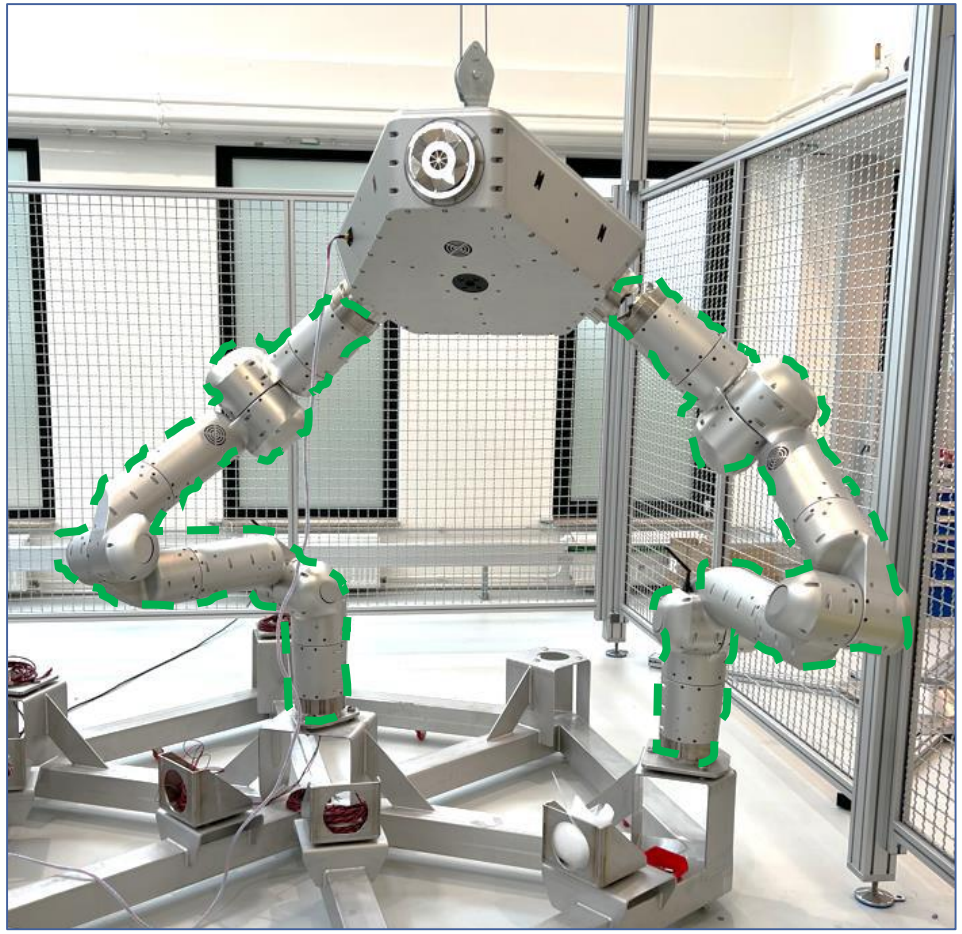
- Form fit geometry
- locking mechanism



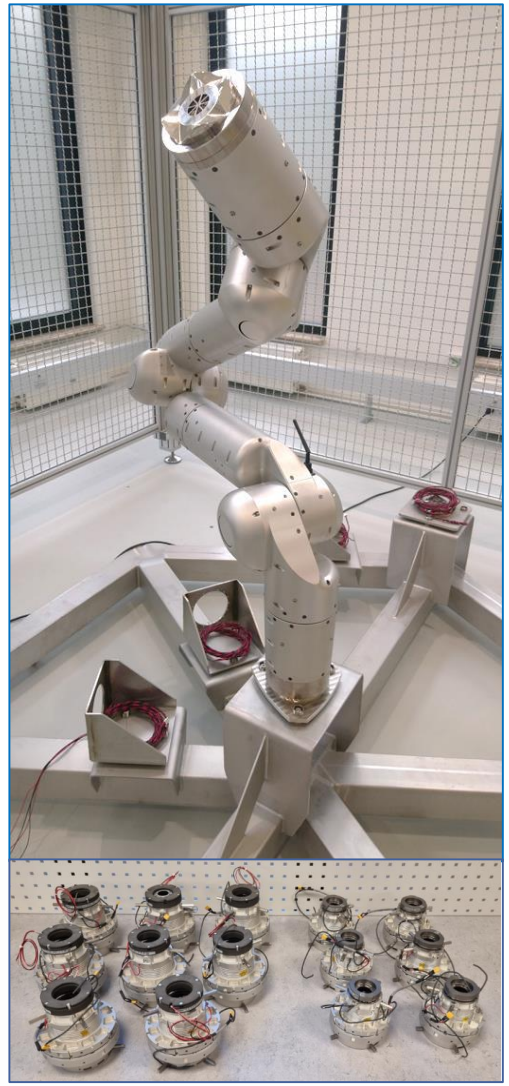
- **7 Active interconnects** (2 per arm and 3 on the torso)

- **HOTDOCK** is an androgynous standard interconnects, providing:
  - Mechanical interface with locking mechanism for structural coupling
  - Electrical interface to control and distribute electrical power between connected systems
  - Bi-directional data interface, compatible with different high rate data transmission
  - Optional thermal interface

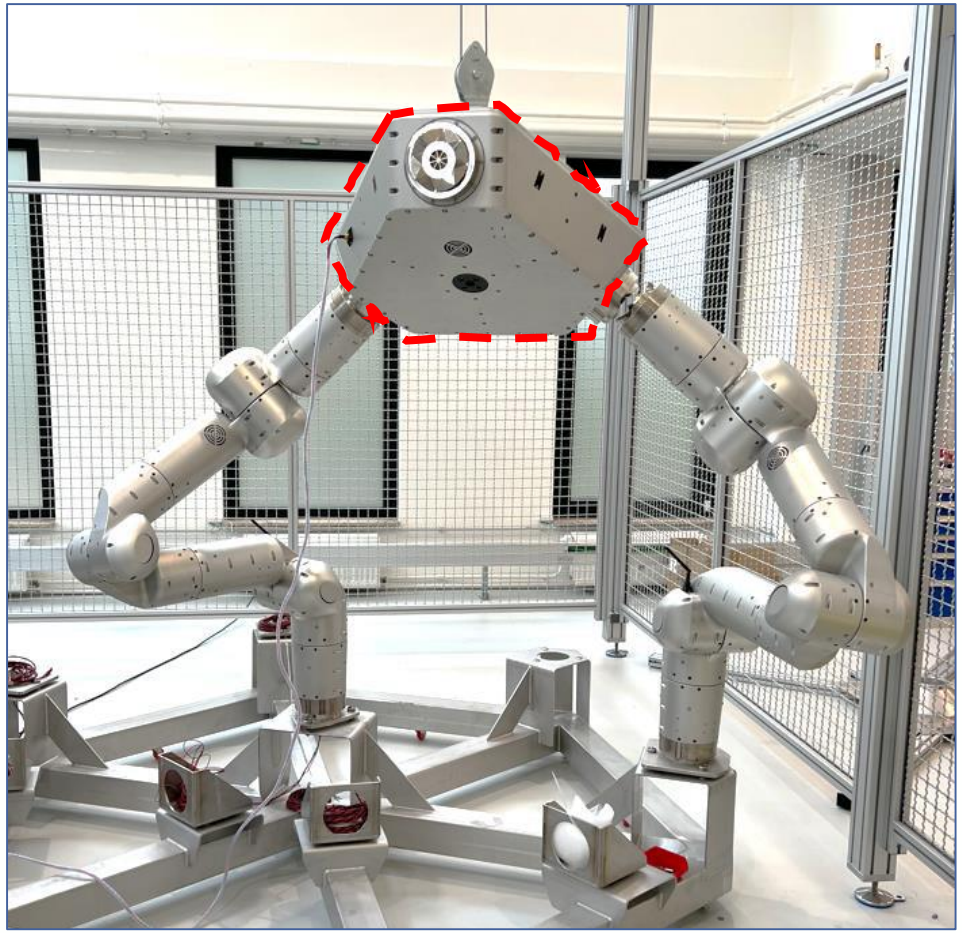
MULTI ARM ROBOT SYSTEM – ROBOTIC ARMS



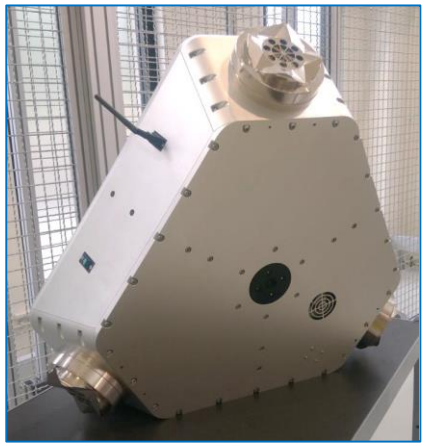
- **Structure (limbs)**
  - Symmetrical design
  - Eight subassemblies
  - Human-like arm with asymmetric joints
  - 1.85m – 40kg
- **Motorization (joints)**
  - Integrated into the limbs
  - 7 Revolute hollow shaft joints
  - Symmetric configuration R⊥R⊥R⊥R⊥R⊥R⊥R
  - Two joint sizes (165Nm and 350Nm)
- **End effectors / SIs** (HOTDOCKs)
- **Embedded Avionics:** RCU, SCUs, power switch units, data (CAN, EtherCAT) and power (48V) buses, internal cable routing.

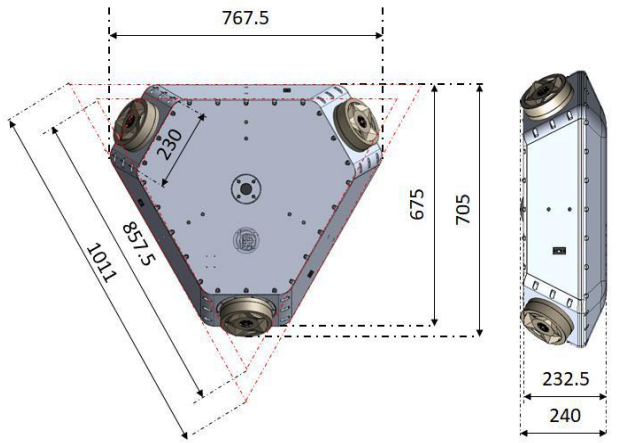


MULTI ARM ROBOT SYSTEM –TORSO



- **Mechanical Structure** – A hub that can equip three other modules (limbs or payloads) by means of standard interconnects. Approx. 28kg.
- **Two fixed active standard interconnects** – Static HOTDOCKs for attaching the two “robotic manipulators”.
- **Leg – Rotary standard interconnect** – Attachment point to the spacecraft or to a payload.
- **Perception Sensors and Lighting Modules** – Monitoring the assembly and manipulation tasks.
- **Embedded Avionics** – RCU, SCU, PDU, Battery, power (48V) and data buses (CAN, EtherCAT).





TESTBED

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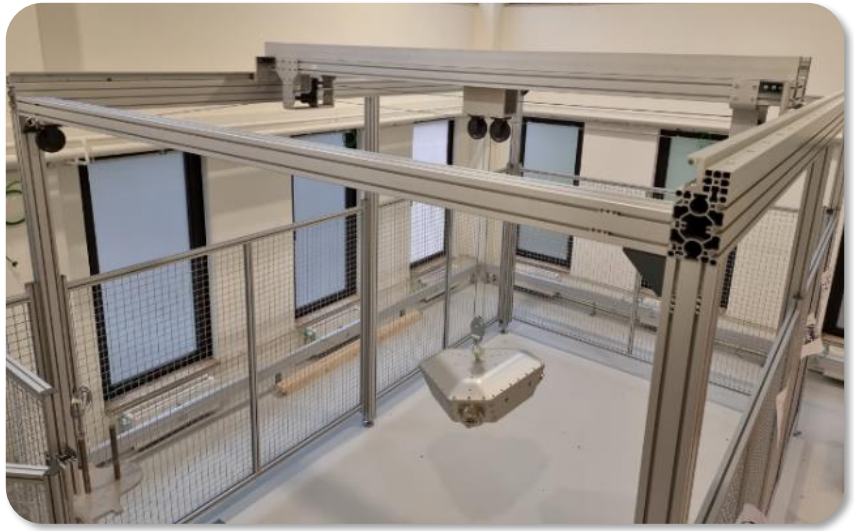
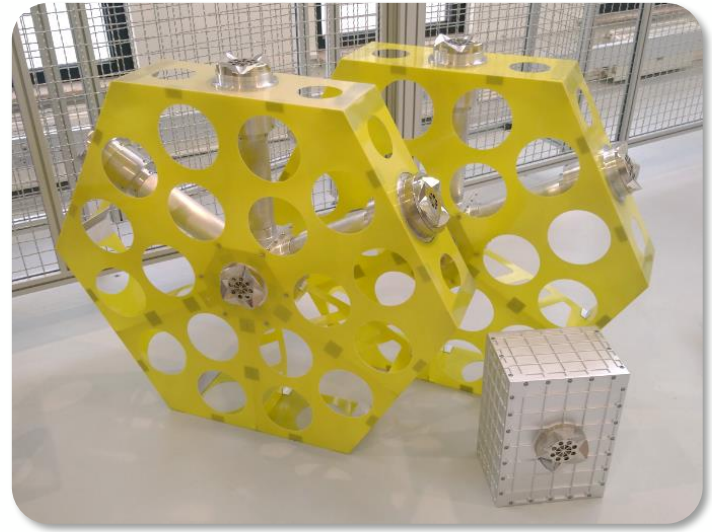
TESTBED

- The **dummy spacecraft** in the MIRROR project features a home base, a storage area, and a telescope structure, with Standard Interconnects (SIs) for robot access and payloads placement.
- The **weight compensation** device is a passive gantry crane mechanism with a rolling bridge for X and Y movement, supported by a cable system with counterweights for Z-axis load.
- **Payloads** consist of two hexagonal mirror tiles (1.2m wide, 10kg each) and one parallelepiped ORU (5kg), all equipped with SIs.
- The ground segment includes a programming and control station (**MCC**) running on Linux and an Electrical Ground Support Equipment (**EGSE**) providing power, data components, and wireless communication for remote connection.

MIRROR dummy spacecraft



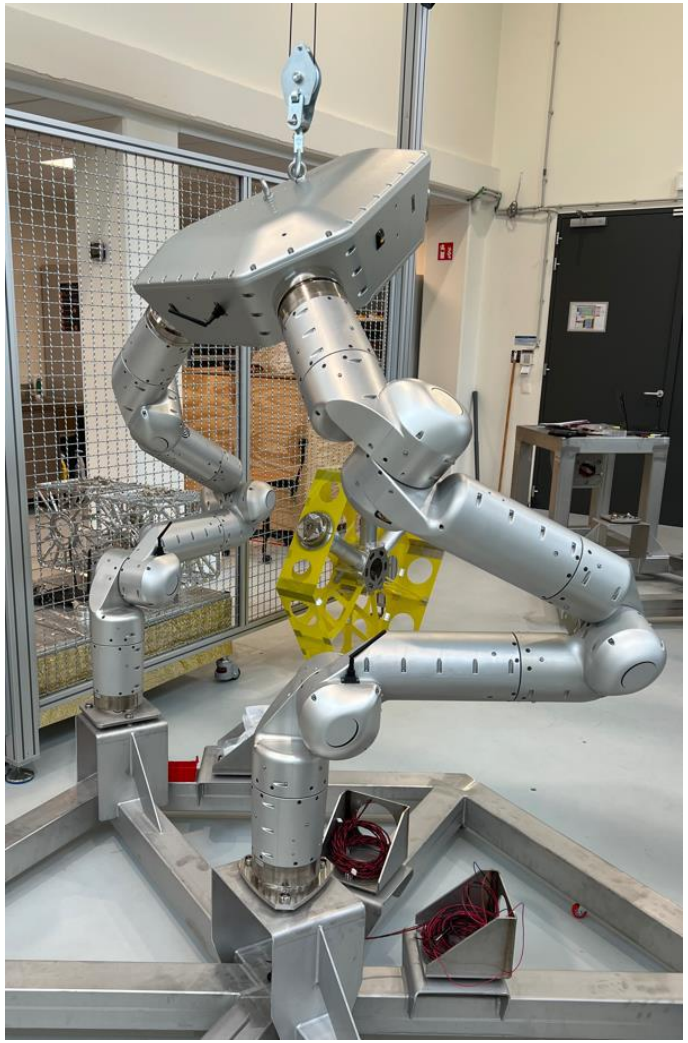
Weight compensation device



Payloads and ORU

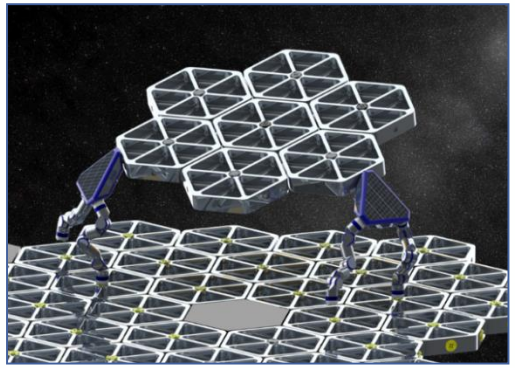
CONCLUSION

CONCLUSION & PERSPECTIVES



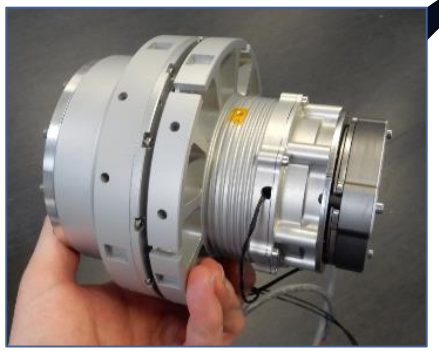
- Introduction of the ESA TRP MIRROR project.
- Demonstrator design and preliminary integration of the MAR concept, a multi-arm robotic system for on-orbit large assembly:
  - Featuring a modular approach,
  - Using Standard Interconnects,
  - Offering a complete panel of operation regardless of the robot configuration.

- Future work will focus on the testing activities of the ground demonstrator.
- Study of very large assembly in space involving modular robotics and multi-robot cooperation
  → OSIP ESA SKYBEAM project.



CONCLUSION

Standard interconnect
2019 -2020

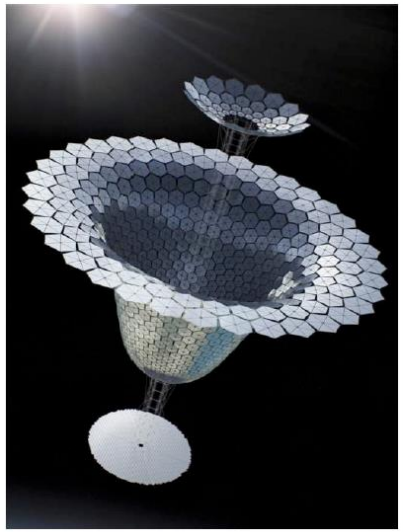


Robotic joint 2020

Walking manipulator 2021

Multi-arm robot 2023

Towards orbital very
large structure assembly
and beyond !



CONTACTS AND ACKNOWLEDGMENTS

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