MOSAR
Project Update

PERASPERA Workshop
Brussels, 02/04/2019

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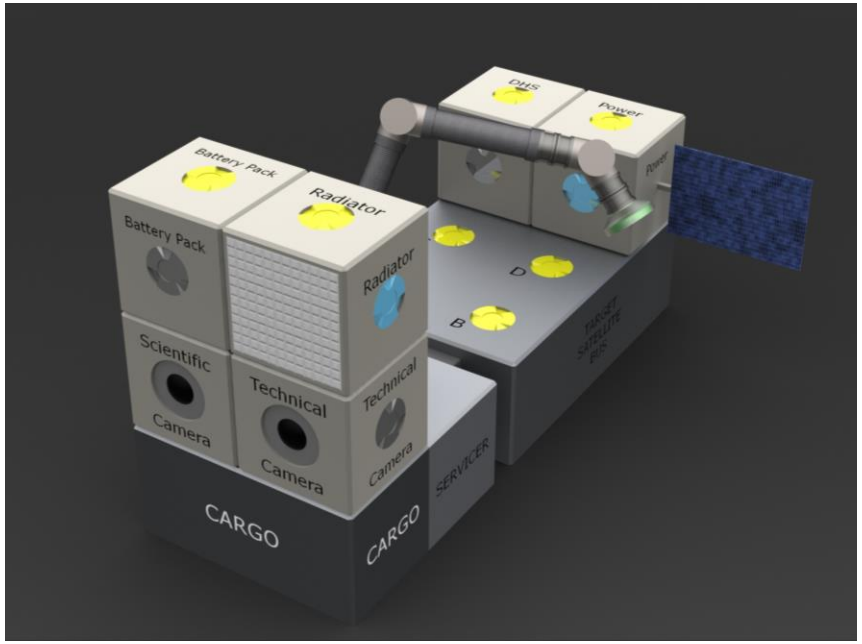
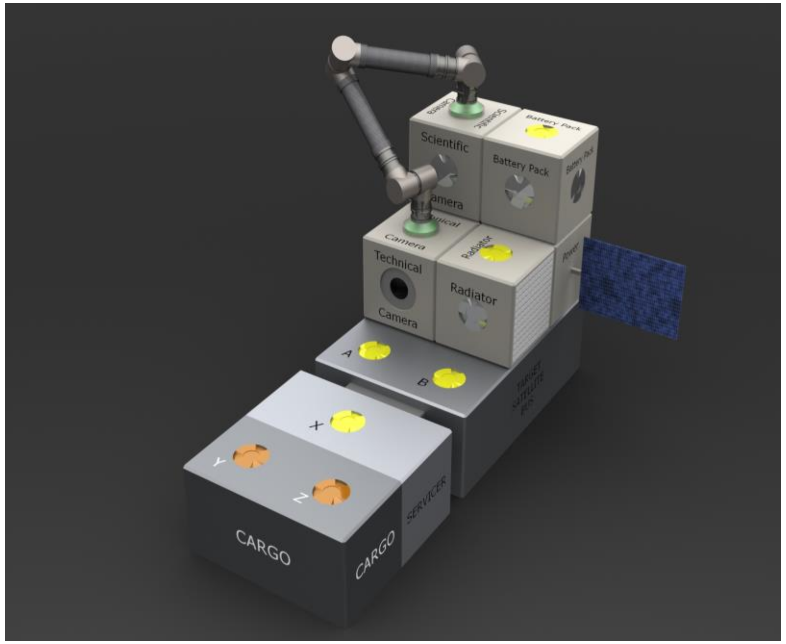
MOSAR in a nutshell

- Funded under the EC Horizon 2020 SPACE-12-TEC-2018 (3.9M Eur) «SRC - Strategic Research Cluster - Space Robotics Technologies»
- 24 months long project: March 1st 2019. - February 28st, 2021.
- 9 partners from 6 countries

MOSAR Main Objectives

- Elaborate and refine the concept of modular and re-configurable spacecraft
- Identify and recommend technologies , standards and designs for its realisation
- Development of a ground demonstrator of on-orbit modular satellite reconfiguration relying on robotic capabilities and simulation
- Analyse the path for progressive deployment and economical exploitation

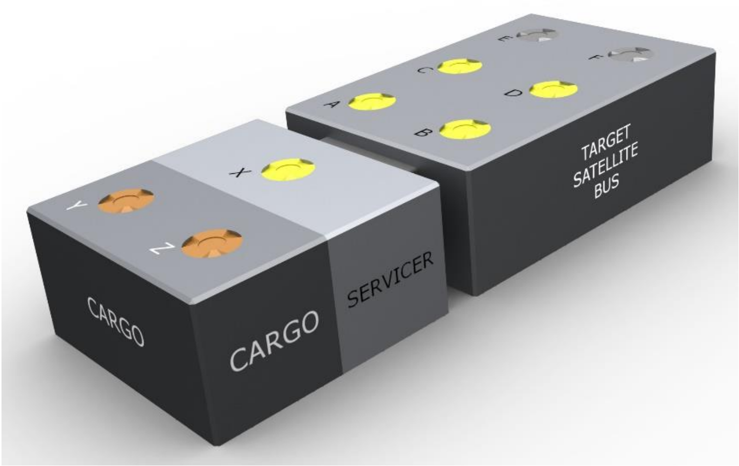




MOSAR Base Line Scenario

- **<u>Base Line scenario</u>:** Servicer Spacecraft (SVC) transporting a cargo of Spacecraft Modules (SM) and a dedicated Walking Manipulator (WM), performing a rendez-vous and docking with a Target Spacecraft (TGT) bus and then performing a number of operations with the SM from and to the TGT.

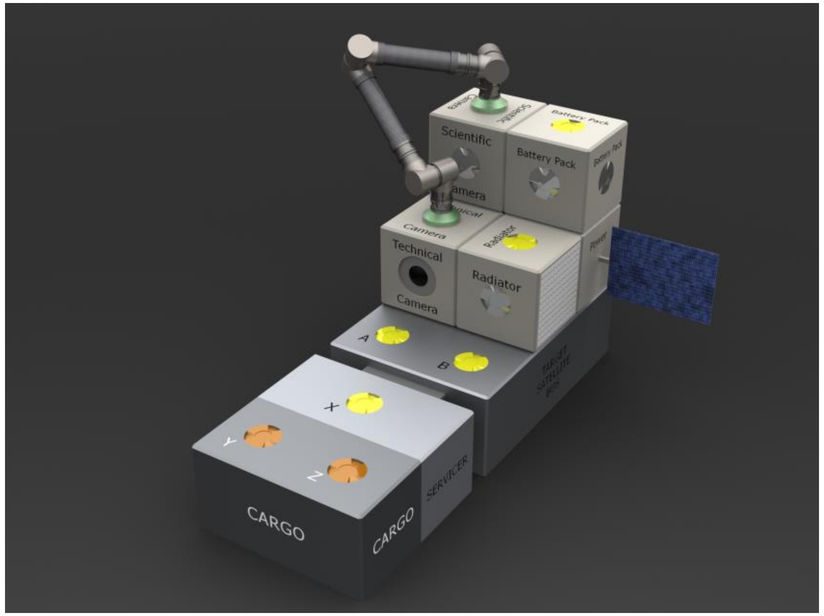
- RDV and docking are not in the scope of this activity, focus on the operations with the Spacecraft Modules once the docking is secured



MOSAR Walking Manipulator

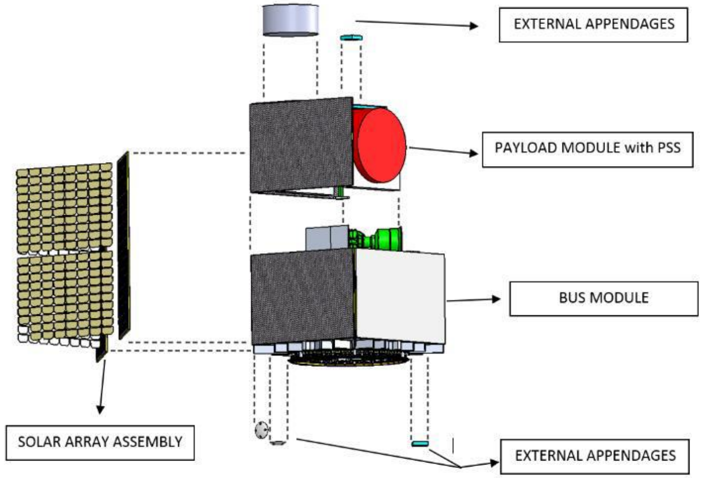
- **Objectives:**
  - Manipulation of Spacecraft Modules (target Module weight 7kg)
  - Specific design for walking/relocation along the structures and the Modules
  - Connection through the Standard Interfaces
  - Validation and demonstration in ground laboratory conditions (no gravity compensation)
  - Modular design for ground/space optimization
  - Target TRL: 4-5

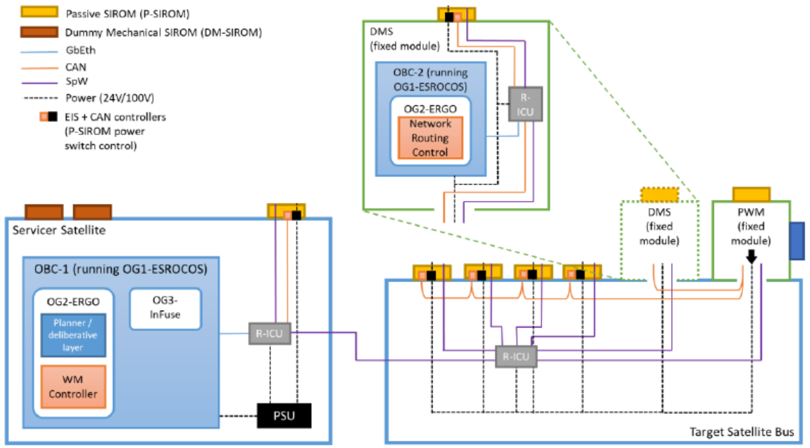
- **Challenges:**
  - Lifting capability for validation conditions
  - Symmetric design
  - Compactness and SIROM integration
  - Connections topology and data/power reconnections
  - Design compatibility with space environmental conditions

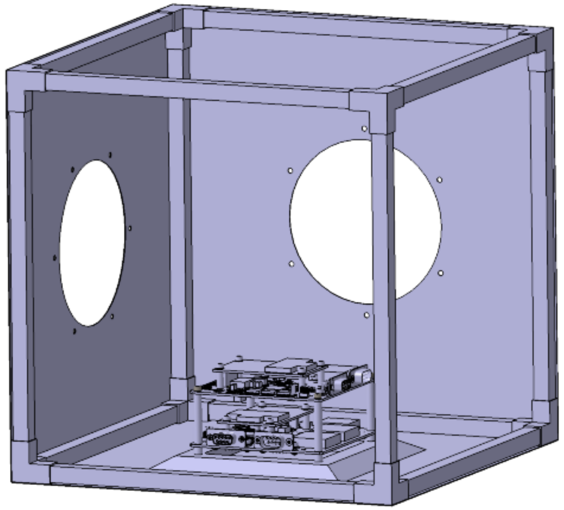


MOSAR Spacecraft Modules

- **Objectives:**
  - Developing a modular Spacecraft Modules ecosystem (ASM/APM)
  - Enabling platform assembly and reconfiguration through standard interfaces
  - Suitable power and data buses technologies allowing flexible, hot-reconfiguration
- **Challenges:**
  - Structure and interface standardization to address different functions
  - Added mass and volumes due to increment harnessing and mechanical interface
  - Connections topology and data/power reconnections
  - Design compatibility with space environmental conditions



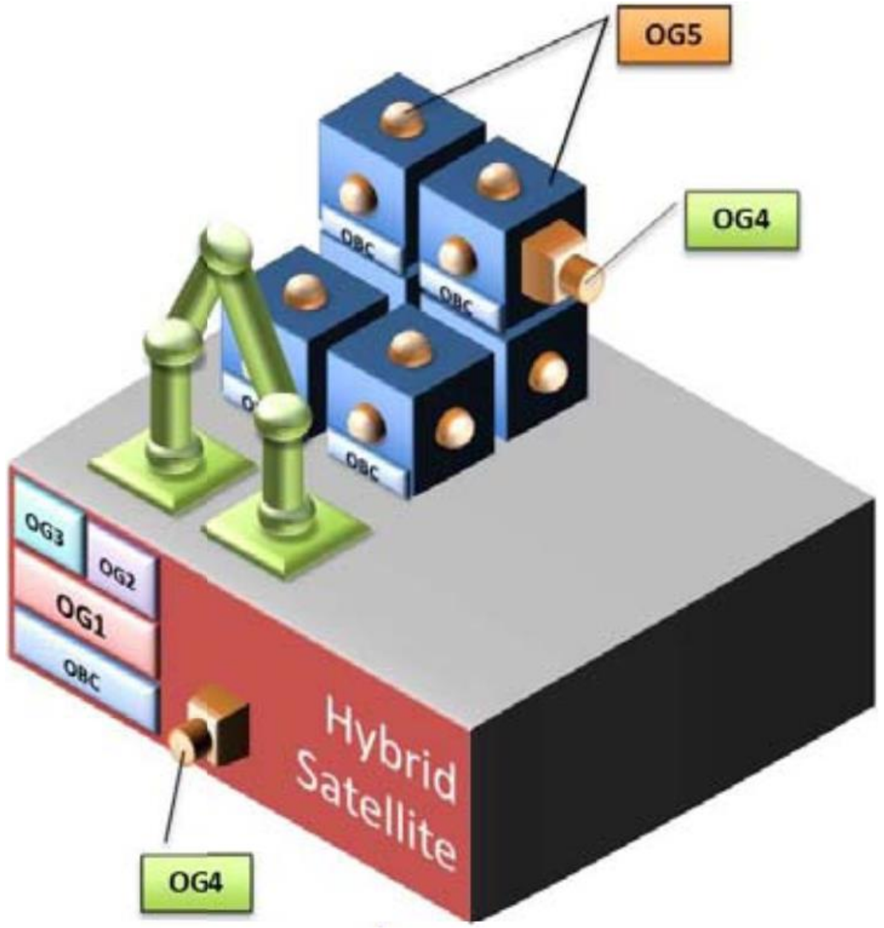




MOSAR Functional Engineering Simulator

- Multi-physics simulator as Functional Engineering Simulator
  - Substitute for real system and for demonstrator hardware in early project phases
  - Support for:
    - Modular satellite configuration and design
    - Multiphysics verification
    - Operation planning (task, path)
    - Verification of assembly and disassembly operations
    - System monitoring and data analysis

- Scope of Functional Engineering Simulator
  - Models of the orbital environment (environmental disturbances)
  - Mechanical models of the spacecraft modules, walking manipulator and standard actuated interfaces
  - Communication and control interfaces
  - 3D visualization, scope views and data logging
  - Compatible with OG1-OG6 building blocks as required

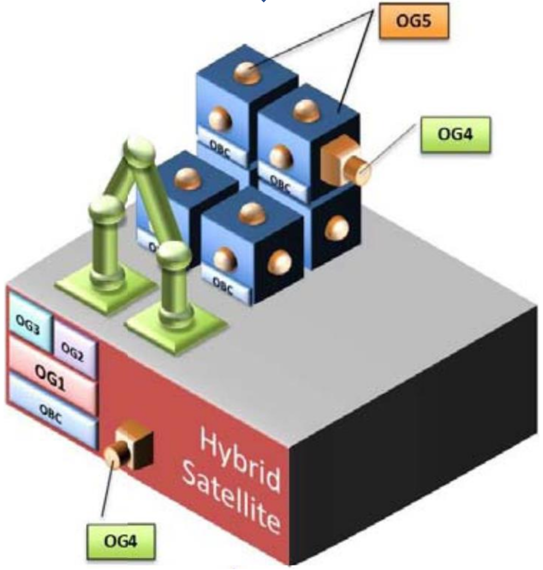


Re-Use and Adaptations of SRC Building Blocks

ERGO
Task, path and manipulation planners

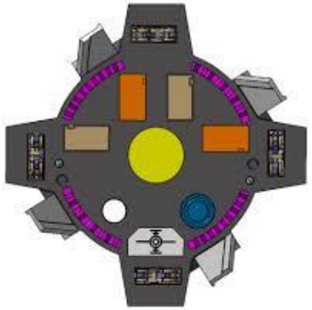
ESROCOS
Robotics Control Operating System

INFUSE
Sensor/data fusion framework



MOSAR

SIROM



Standard mechanical, power, data and thermal interface thermal

I3DS
INTEGRATED 3D SENSORS
Sensors and control unit

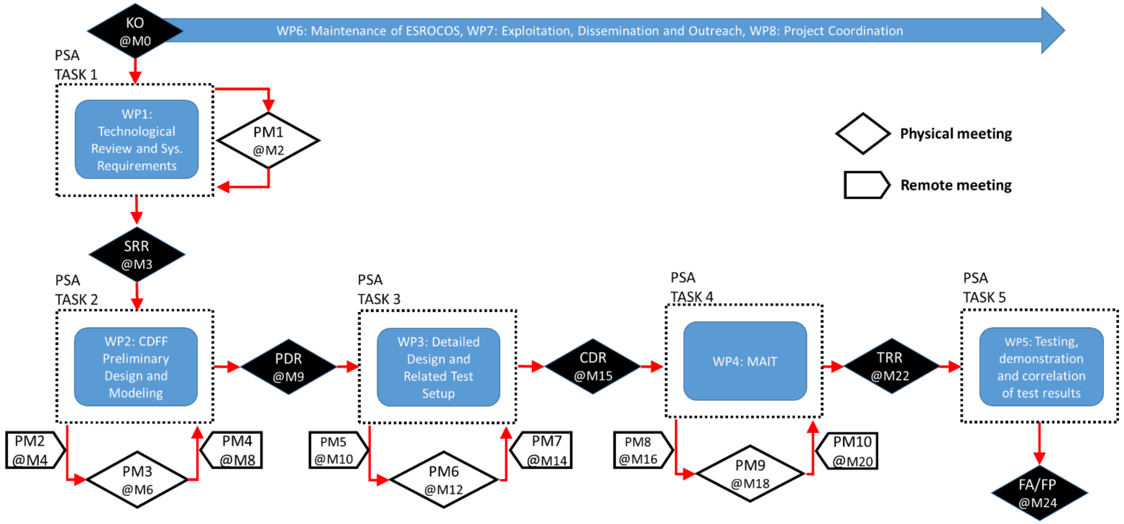
MOSAR Project Status

WP#	Title	Lead
WP1	**Technology Review, System Requirements**	**TASF**
T1.1	Review of OG1-5 Products	GMV
T1.2	Review of State of Art	TASF
T1.2	Operations Concept Consolidation	DLR
T1.3	System Requirements Specification	SPACEAPPS
WP2	**Preliminary Design and Modelling**	**SPACEAPPS**
T2.1	OG1-5 Adaptations & Extensions Specification	GMV
T2.2	Specification of hybrid satellite platform with connected ASMs/APMs	SITAEL
T2.3	Specification of satellite-mounted robot system (inc. control)	SPACEAPPS
T2.4	Specification of ground support tools (design and simulation S/W)	DLR
T2.5	Preliminary Development & Integration Plan	SPACEAPPS
T2.6	Demonstration Test Plan Specification	DLR
T2.7	Preliminary System Architecture & ICD (System Technical Specification)	SPACEAPPS
WP3	**Detailed design of Demonstrator and Related Test Setup**	**SPACEAPPS**
T3.1	Detailed Design of OG1-5 Adaptations & Extensions	GMV
T3.2	Detailed Design of hybrid satellite platform with connected ASMs/APMs	SITAEL
T3.3	Detailed Design of satellite-mounted robot system (inc. control)	SPACEAPPS
T3.4	Detailed Design of ground support tools (design and simulation S/W)	DLR
T3.5	Updated Development & Integration Plan	SPACEAPPS
T3.6	Demonstration Test Procedures Specification	DLR
T3.7	System Architecture & ICD Consolidation	SPACEAPPS
WP4	**Manufacturing, Assembly and Integration of Dem. and Test Equipment**	**DLR**
T4.1	MAI of OG1-5 Adaptations & Extensions	GMV
T4.2	MAI of hybrid satellite platform with connected ASMs/APMs	SITAEL
T4.3	MAI of satellite-mounted robot system (inc. control)	SPACEAPPS
T4.4	MAI of ground support tools (design and simulation S/W)	DLR
T4.5	System Integration & Testing (verification)	SPACEAPPS
T4.6	Demonstration Test Procedures Consolidation	DLR
WP5	**Execution of Tests, Demonstration and Correlation of Test Results**	**SPACEAPPS**
T5.1	System Validation Campaign	DLR
T5.2	System Final Acceptance & Demonstration	SPACEAPPS
WP6	**Maintenance of OG1 / ESROCOS**	**GMV**
T6.1	Liaising with OG7 to OG11	GMV
T6.2	Maintaining ESROCOS software and documentation	GMV
WP7	**Exploitation, Dissemination & Outreach**	**SITAEL**
T7.1	Exploitation	SITAEL
T7.2	Dissemination	USTRAT
T7.3	Outreach	SPACEAPPS
WP8	**Administrative, Technical and Financial Management**	**SPACEAPPS**
T8.1	Administrative & Financial (including liaising with EC, reporting)	SPACEAPPS
T8.2	Day to day coordination and risk management	SPACEAPPS
T8.2	Liaising with PERASPERA PSA (and other OGs)	SPACEAPPS

TMS	Technical Milestones
TMS1	System Requirements Review (SRR)
TMS2	Preliminary Design Review (PDR)
TMS3	Critical Design Review (CDR)
TMS4	Test Readiness Review (TRR)
TMS5	Final Acceptance (FA)

- MOSAR KO performed on the 18-19th of March 2019
- First status meeting between partners on the 4th of April
- MOSAR workshop and SRR dates under discussion (need feedback)
- PM1 meeting foreseen early May

- Presentation of the MOSAR activity @ERF 2019



MOSAR On-Going Tasks

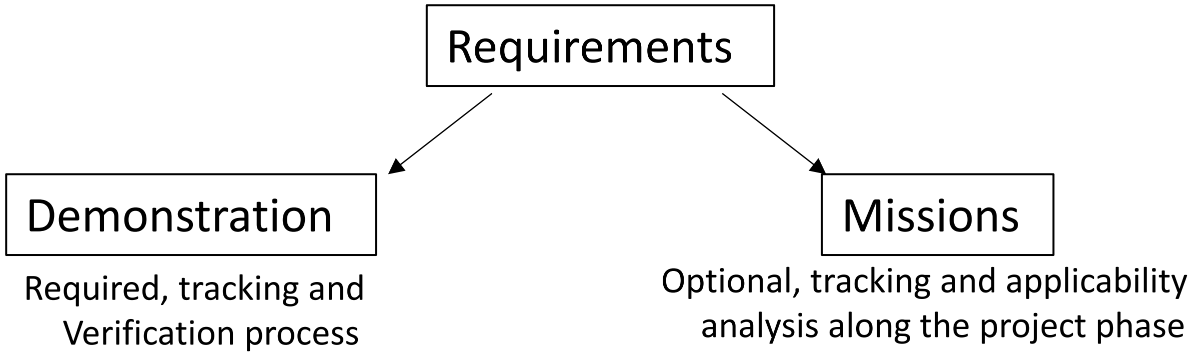
- Task 1.1: Review of OG1-5 products (GMV)

- Task 1.2: Technology Review (TAS-F)
  - Market Analysis and exploitation
  - Declination from high level needs to specific mission requirements and identification of enabling technologies.
  - Preliminary Analysis provided during the KOM

- Task 1.3: Operational Concept Consolidation (DLR)
  - Missions scenarios and detailed specification for demonstration phases
  - Preliminary discussions with TAS-UK (system architecture), MAGSOAR (thermal transfer), DLR (simulation and manipulator design), GMV (ESROCOS, ERGO)
  - Evaluation of the use of OG3/Infuse

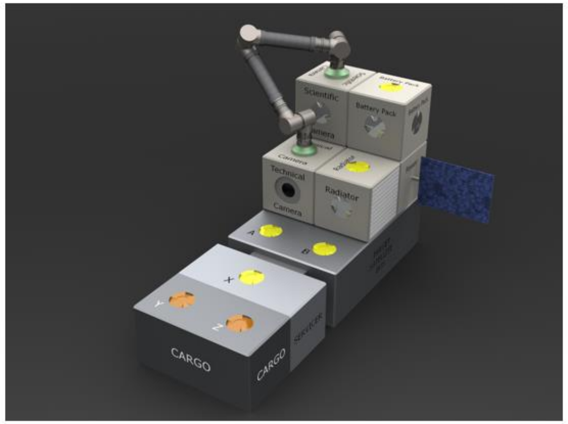
MOSAR On-Going Tasks

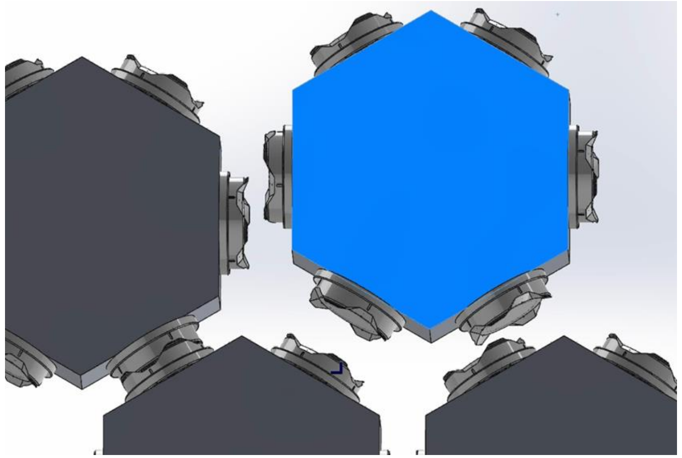
- Task 1.4 : System Requirements Specifications (SpaceApps)
  - Started Month 2
  - Consolidation and formalization of the requirements
    - PERASPERA guidelines
    - Technology review, market analysis, mission scenario (T1.2)
    - Use cases, demonstration scenarios and system architecture definition (T1.3)
    - OG1-5 products review (T1.1)

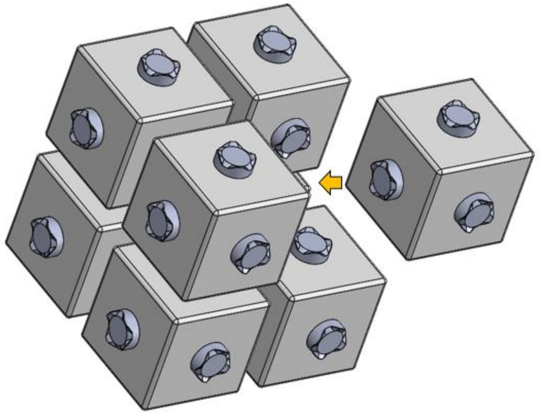


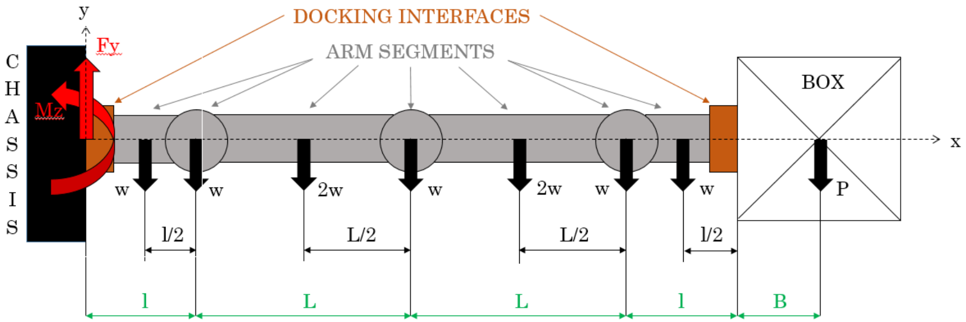
Standard Interface Requirements Analysis

- Load Transfers
- Approach angles
- Approach guidance
- Design symmetry
- Mass, volumes and integration
- Power transfer and management
- Data transfer and control
- Robustness and manufacturability
- Future exploitation, IPR









Standard Interface Schedule

1. De-Risking

02/2019 — 03/2019 — 05/2019 — 06/2019

Preliminary SA Investigations
- Technology analysis and comparison
- Interactions with iBOSS/Sener
- Interactions with stakeholders
- Initial design
- Early prototyping

KO OG7-8-11b (02/2019)
- General strategy
- Risk preliminary analysis

KO OG9 (03/2019)
- SA Technology Patent Filed
- Updated strategy
- Detailed planning and Test Plan
- SA technology presentation
- SA prototype presentation (rapid prototyping of the mechanism)

Workshop (05/2019)
- Interactions with partners and Stakeholders
- SA prototype presentation (metal version of the mechanism)
- SA technology preliminary evaluation by external experts (names TBC)
- Preliminary Tests Results

SRR (06/2019)

Final decision on the selected technology after discussion with EC and PSA

2. Development

10/2019 — 03/2020 — 09/2020

PDR (OGs PDR-2) (10/2019)
- Advanced design review
- Iterative validation process

CDR (OGs CDR-3) (03/2020)
- Final design review
- Iterative validation process

Delivery to OGs (09/2020)

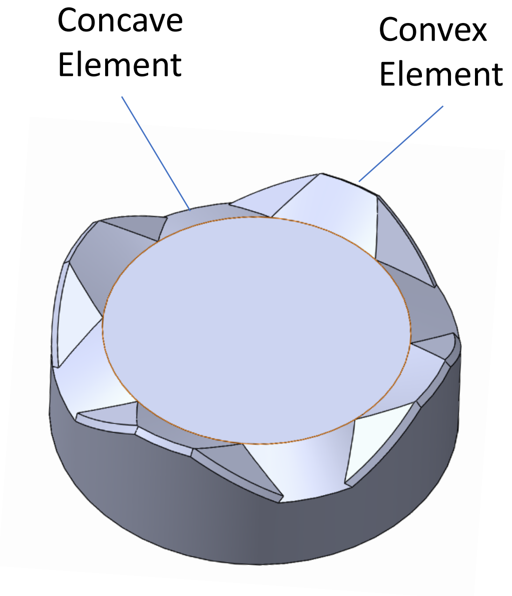
HOTDOCK Interface

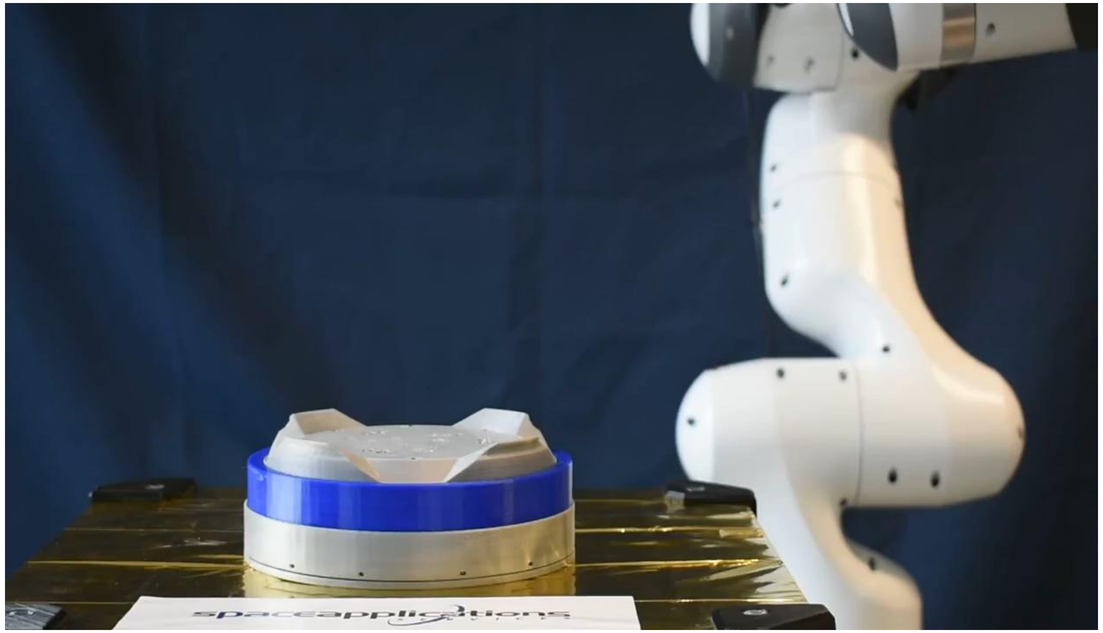
HOTDOCK Geometry

The initial geometry of the body (especially the circular front face)
is equipped with convex/concave elements.
This allows for androgynous coupling of two identical coupling elements.

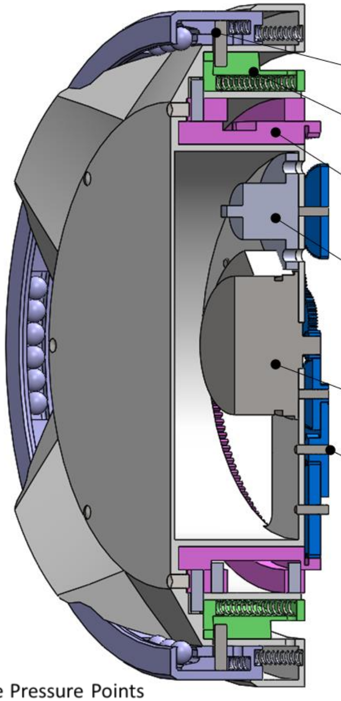
Features

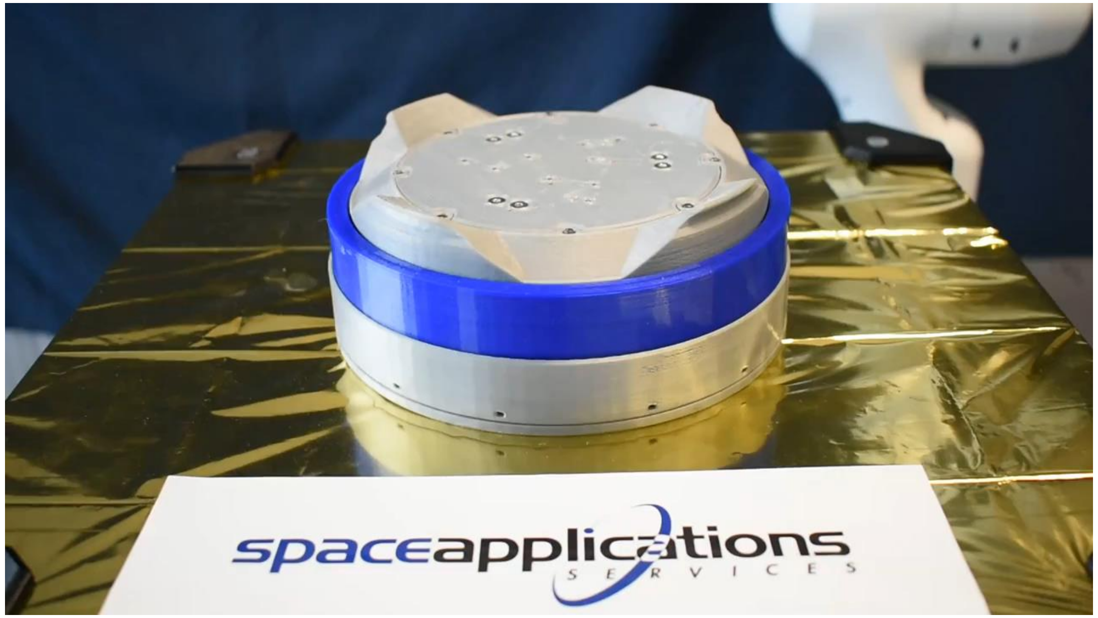
- Androgynous
- 90 deg symmetry
- Round shape
- Load transfer support
- Diagonal engagement



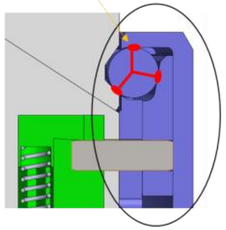


HOTDOCK Locking Mechanism and Procedure



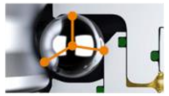


Three Pressure Points

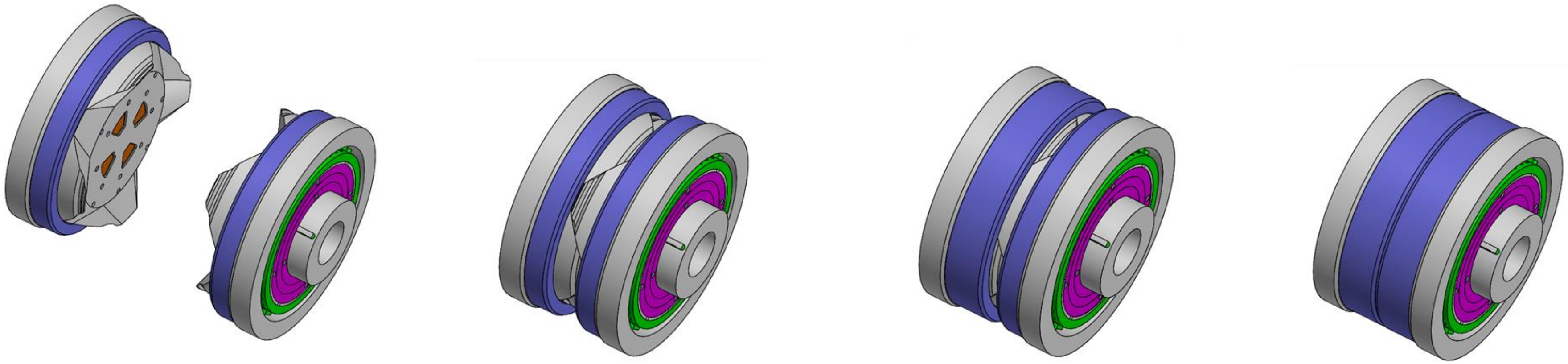


Added Locking (blue rings)
Ring with steel balls.

Similar!



(AMF Zero Locking)



spaceapplications SERVICES · DLR · gmv INNOVATING SOLUTIONS · ThalesAlenia Space (a Thales / Leonardo company) · SITAEL AN ANGEL COMPANY · MAG SOAR · University of Strathclyde Glasgow · Ellidiss Technologies

HOTDOCK Main Features

- Androgynous
- 90-Deg-Symmetry
- Diagonal Engagement Possibility
- Form-Fit Feature (Supports Positioning)
- Well Applied Locking Mechanism (Self Locking)
- Powerful Load Transfer (Transfer of Load on the Circumference)
- Well Embedded Mechanism (Round, Symmetric Shape)
- Can Engage and Disengage with just one Active Side (Changing of Active Side Possible)
- Good Sealing Properties (dirty/dusty environment)

Standard Interface Technology Comparison

Characteristic	HOTDOCK	SIROM	IBOSS
Envelope Dimension (not including electronics)	156mm / 130mm ⌀ 55mm height	120mm ⌀ 75mm	120mm ⌀ 70mm (TBC)
Mass	1.2kg	1.33kg (TBC)	0.8kg
Androgynous Design	X	X	X
90deg Symmetry	X		X
Allowing Diagonal Engagement	X		X
Position Finding by Form-Fit	X		
Locking Support by Form-Fit	X	X	
Design suited for sealing	X		
Can force passive side to dock/undock	X (Full)	X (elec)	X (mech)
Docking sequence duration	< 30 sec	[8-2.5] min	< 30 sec
Load Transfer Axial (no SM)	20.000N (TBC)	1600N (TBC)	6.000N
Load Transfer Radial (no SM)	TBC	TBC	TBC
Load Transfer Moment (no SM)	1.500Nm (TBC)	80Nm (TBC)	360Nm
Power Transfer	[2kW-5kW] @ 120V	120W @ 100V	6kW
Data Transfer	Ethernet/TTE/SpaceWire, CAN	SpW/CAN	Ethernet/CAN
TM & TC	CAN	CAN	CAN

SIROM Workshop

- Purpose:
  - Support the technology selection for the standard interface in the context of the SRC
  - Align technology selection with future product exploitation
  - Synergy and synchronization among all OGs (based on previous interactions)
  - Set the foundations for the establishment of a standard

- Organization:
  - Open to SRC project members and other stakeholders having relevant experience with related technologies or interest for future exploitation (under NDA)
  - Organized around end of May / early June (final date TBC)
  - Invitation sent to main SRC representatives, and possibly on request (pierre.letier@spaceapplications.com)

MOSAR

https://www.h2020-mosar.eu/

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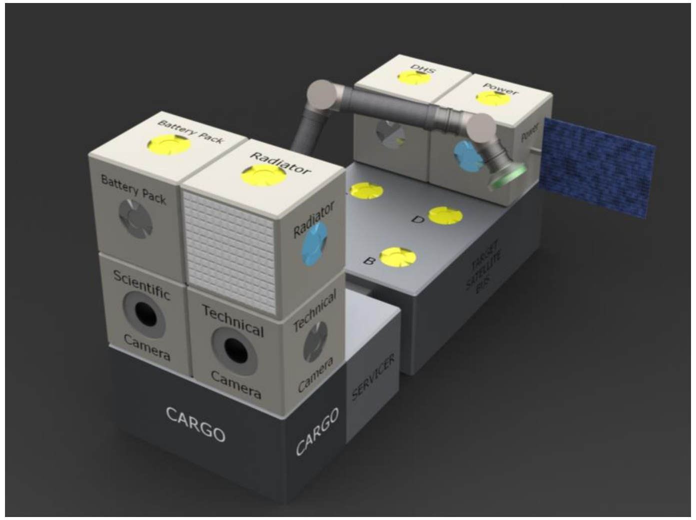
MOSAR Demonstrations Scenarios

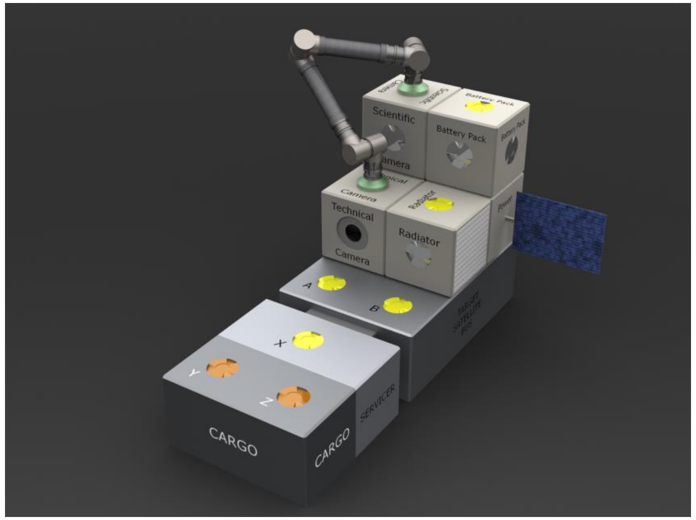
- **Scenario 1:** Initial Assembly of 6 SMs

- **Objective:** Demonstrating the assembly of several SMs onto a TGT spacecraft bus – including both the placement of SMs on the TGT itself, and on other SMs (stacking).

- **Initial Conditions**: The WM is stowed in parking position, and the SVC (docked to the TGT) has a stock of 4 SMs to be deployed in proper configuration on the TGT.

- **Success**: Once deployed on the TGT, the different SMs should be powered and operational. It should be possible to receive data / telemetry from each deployed SM, and possibly send commands to each of them (if relevant) from the OBC located in the SVC or TGT (and indirectly from the MCC)





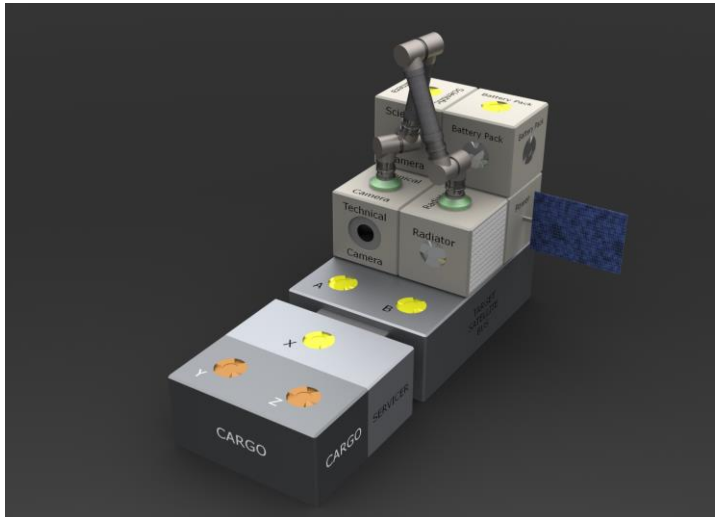
MOSAR Demonstrations Scenarios

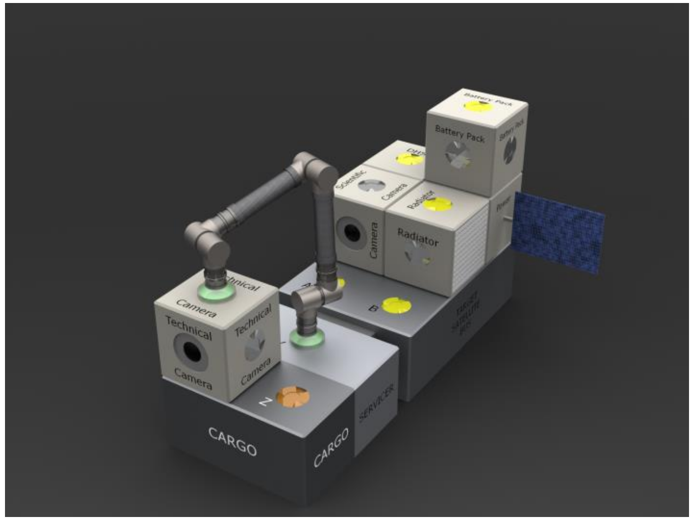
- **Scenario 2:** Reconfiguration after Module Failure

- **Objective:** Demonstrating the replacement of a failing module, by a working equivalent module, with a hot-reconfiguration procedure. Will also demonstrate the automatic re-routing of network and power when the failure occurs.

- **Initial Conditions**: The WM is stowed in parking position, and the TGT (docked to the SVC) and the TGT has 6 modules already in place.

- **Success**: The faulty module should be brought back in the cargo area of the SVC, and a camera module should be successfully put in place at the same location (substitution). Recovery of functions should be confirmed (doing a full check) after the replacement module is successfully connected.





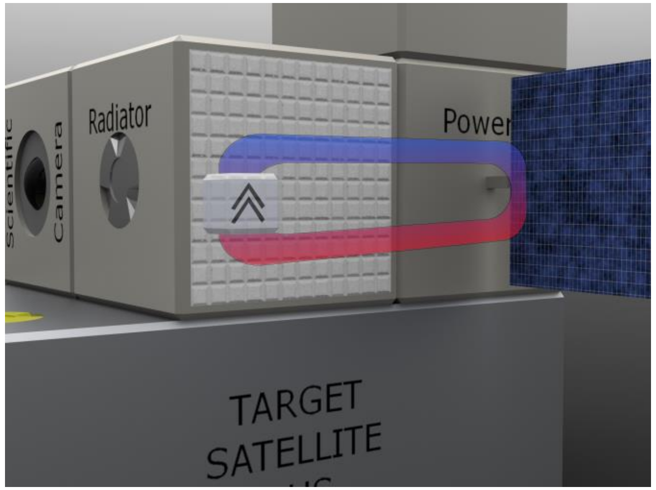
MOSAR Demonstrations Scenarios

- **Scenario 3:** Thermal Transfer through SIROM Interface

- **Objective:** Demonstrating the active cooling of a module producing heat (PWS) by a dedicated thermal handling module (THS).

- **Initial Conditions**: The THS and the PWM modules are mechanically coupled and operational (following e.g. the assembly procedure of Scenario 1).

- **Success**: A heat transfer should be observed between the 2 modules (through telemetry reading with heat probes on the 2 sides). No leaks should have been observed.



MOSAR Walking Manipulator

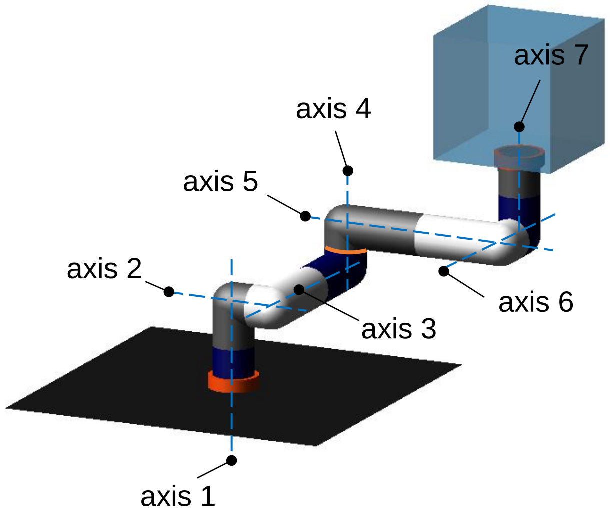


Fig. Joint/Axis definition

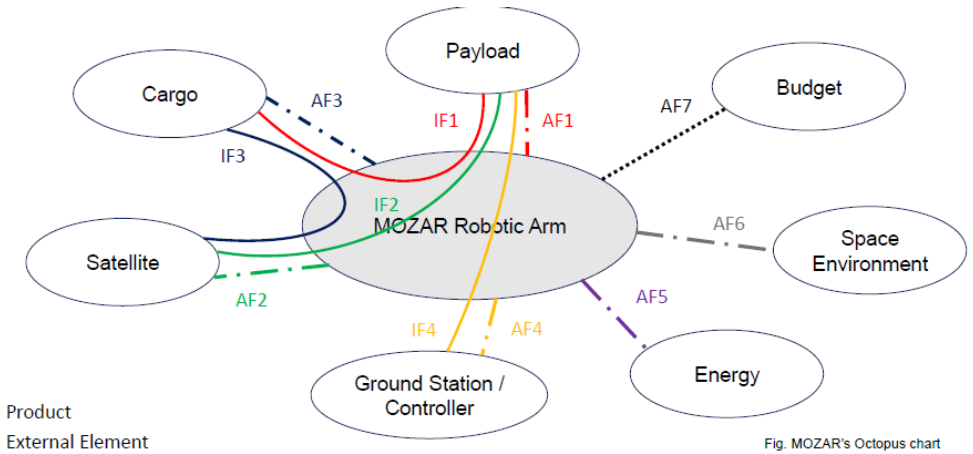
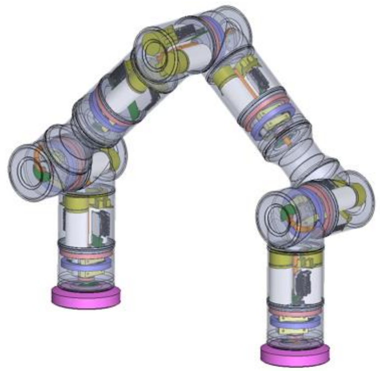
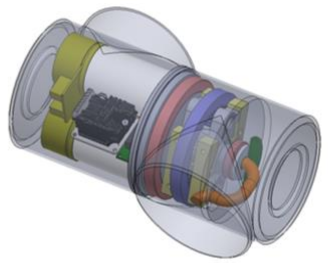


Fig. MOZAR's Octopus chart





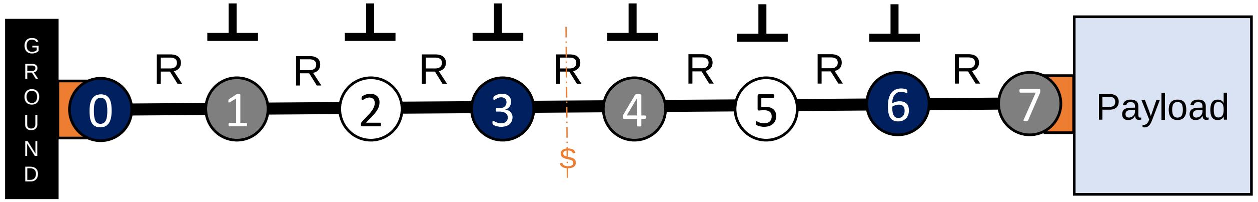
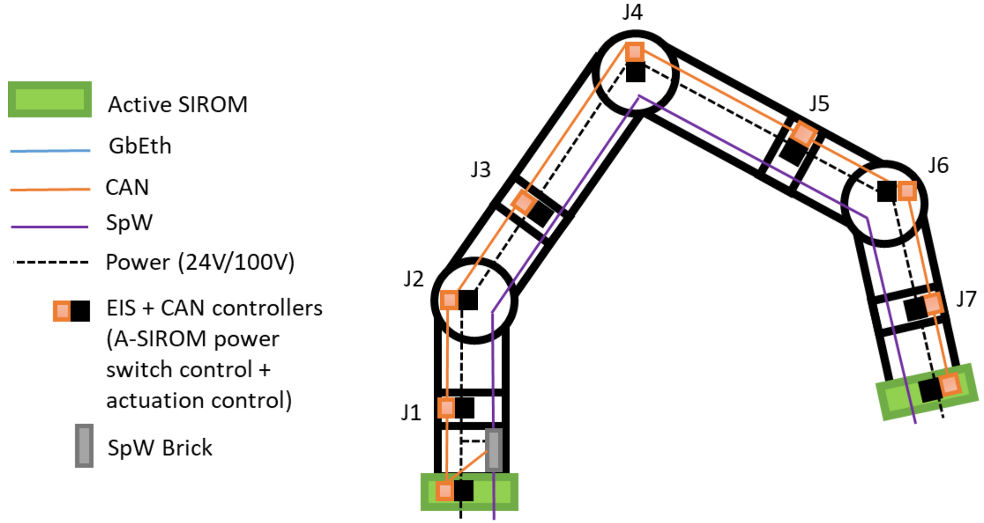
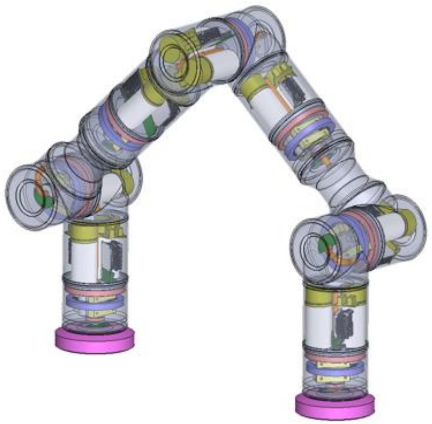
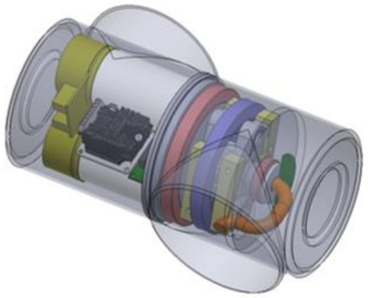


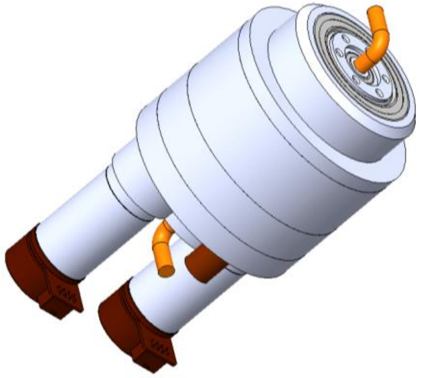
Fig. Kinematic architecture



MOSAR Walking Manipulator

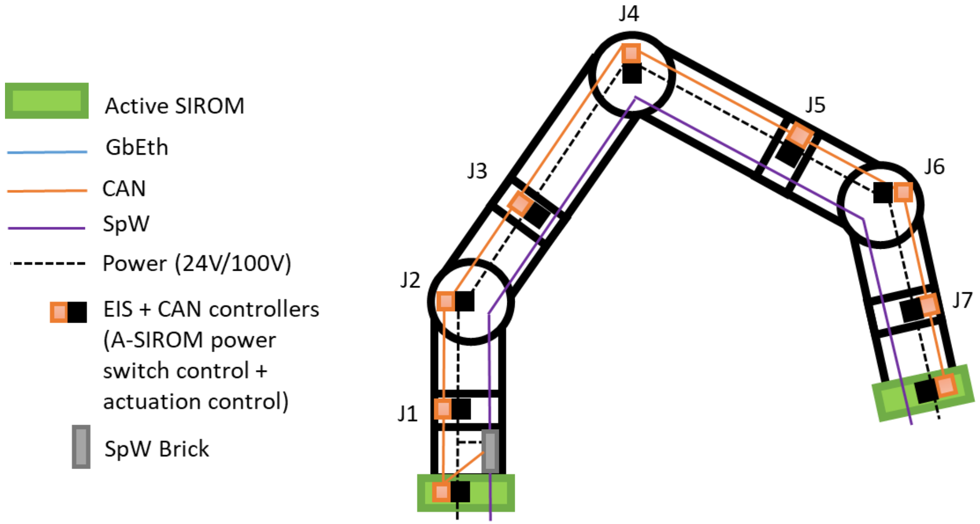






Ongoing Concept analysis and preliminary design

Joint features
Modular and Adaptable
Internal cabling
Backlash free
Torque output [150-250] Nm
Outer diameter: max 120mm
Position, Torque sensors
CNC, 3D printing, Laser cutting



Robotic Arm data and power architecture

MOSAR Simulator Technology

- European Technology
- Dymola (Dassault Systèmes)
  - Modelling workbench
  - Simulation engine
- Modelica modelling language
  - Object oriented, non-causal
  - Multi-physics modeling (MOSAR: mechanical, electrical, thermal domains)
  - Comprehensive standard library collection
- Relevant DLR libraries to be applied
  - SpaceSystems library (incl. Environment)
  - Robots and RobotDynamics libraries
  - FlexibleBodies library (solar arrays, etc.)
  - SimVis Visualization library
  - Device Drivers library (bus systems and communication interfaces)
- Support of Functional Mockup Interface (FMI) standard