Leonardo Space

Robotic system and mechanical interface design for the Italian In-Orbiting servicing demo mission

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Electronics

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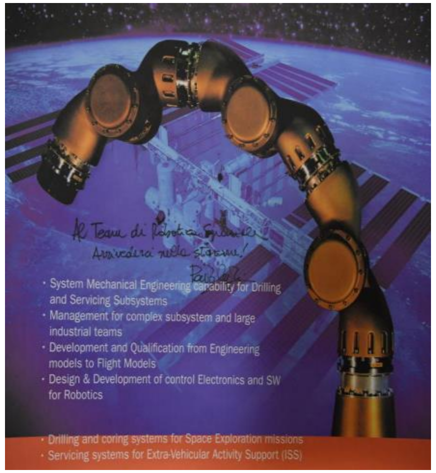
SUMMARY

- Leonardo Space Robotics
- Introduction to the Italian In-Orbit Servicing Demo Mission
- Overview of the main challenges of the robotic system:
    - **Robotic arm**
    - **End-Effector**
    - **Hard Berthing mechanism**
- Overview of the main challenges of the refuelling mechanical interface
- Conclusions

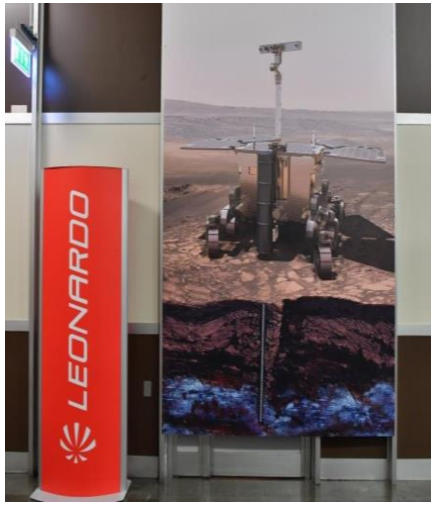
Leonardo Space Robotics

Leonardo Space Robotics Product Portfolio

- Robotic arms for in-orbit servicing and planetary exploration
- Drilling & Sampling Systems, including sample manipulation
- Motion Control Systems (including electronics and SW)
- Sample containers and bio-container systems for planetary sample return



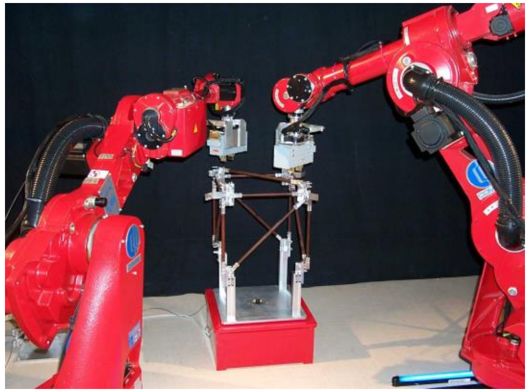
Robotic arms for space applications



Drilling & Sampling Systems

Leonardo Space Robotics – Robotic Arms heritage

- Since ‘90s, LEONARDO has been involved in various space projects funded by ESA or ASI on Robotic Arms for on-orbiting service or planetary exploration tasks
- The two currently recognized standards for ESA robotic arms are **DEXARM** and **DELIAN**
- Development of the Sample Transfer Arm within the NASA/ESA Mars Sample and Return Mission



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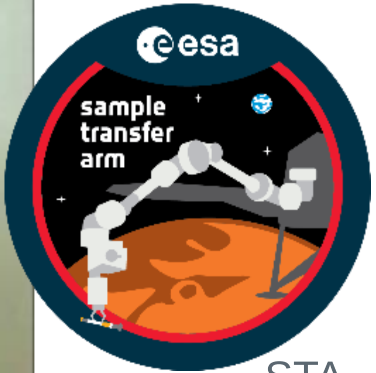
SPIDER



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CONTEXT

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Leonardo Space Robotics – DELIAN\DEXARM

In-Orbit Servicing Demo Mission

In-Orbit Servicing Demo Mission Overview

- **Goal of the mission**: definition, development, implementation, and validation of the technologies and functions necessary to perform in orbit servicing (IOS) tasks

- **Environment:** Low Earth Orbit

- **Space Assets:**
  - Servicer: a vehicle carrying the IOS technologies to be validated
  - Target: a satellite to support the in-orbit validation of the IOS operations

- **Main functions:**

Near-term future
- Target tracking and inspection
- Safe rendezvous and approach
- Target capture and rigidization
- In-orbit services:
  - AOCS takeover
  - Relocation of the target
  - Disposal of the target

→ Non-collaborative satellite

Mid-term future
- Refueling of the target tank(s)
- Refurbishment of the target satellite, i.e., Orbit Replaceable Unit transfer

→ Collaborative satellite

Capture/rigidization interface: LAR

In-Orbit Servicing Demo Mission Overview

- **Mission approach:**
  - Incremental risk approach

Complexity

Cooperative target → Non-cooperative target (tumbling motion)

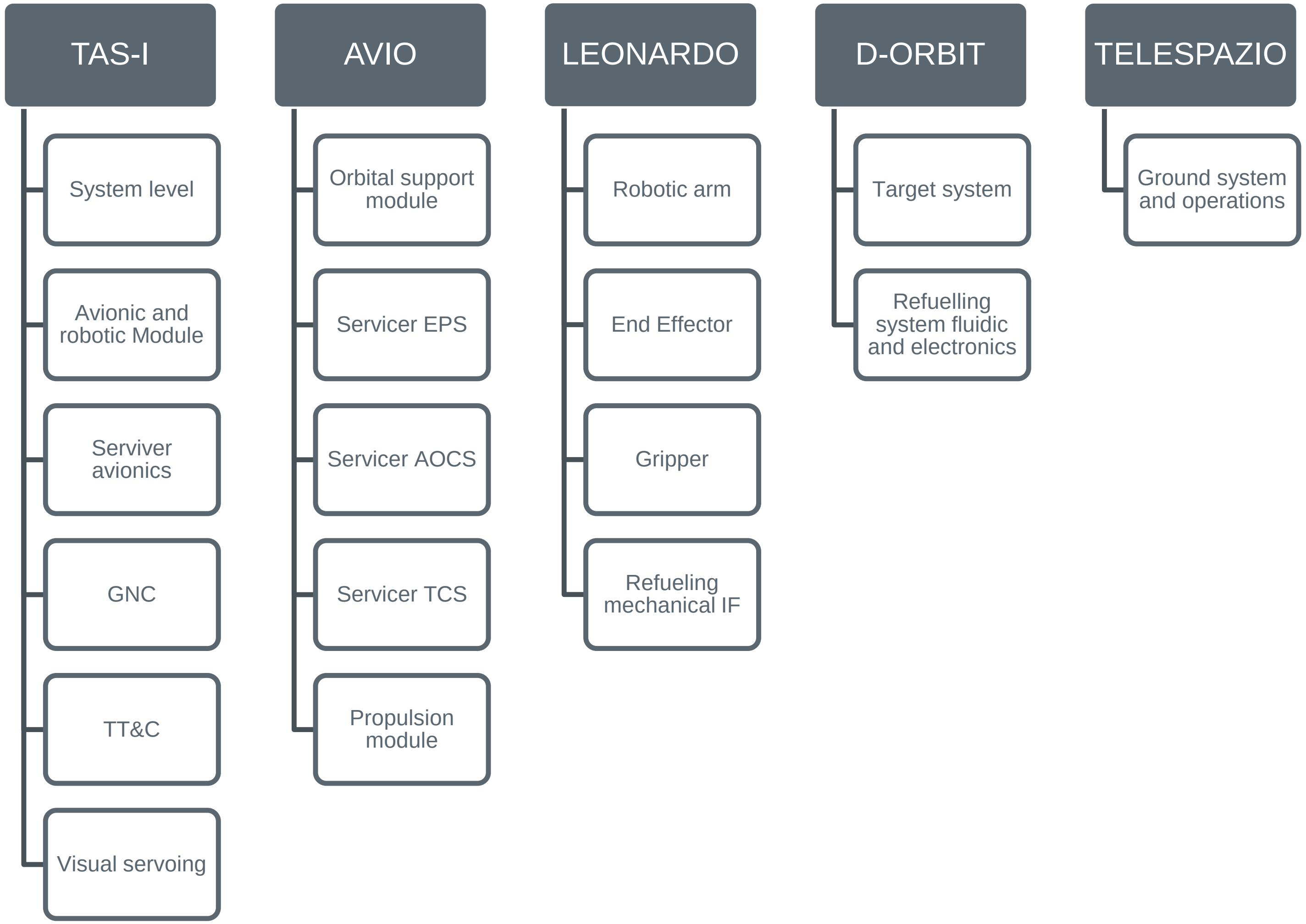
  - Scalability

Target size

Small satellite class (Demo target) → Cosmo Skymed/Sentinel (only by analysis)

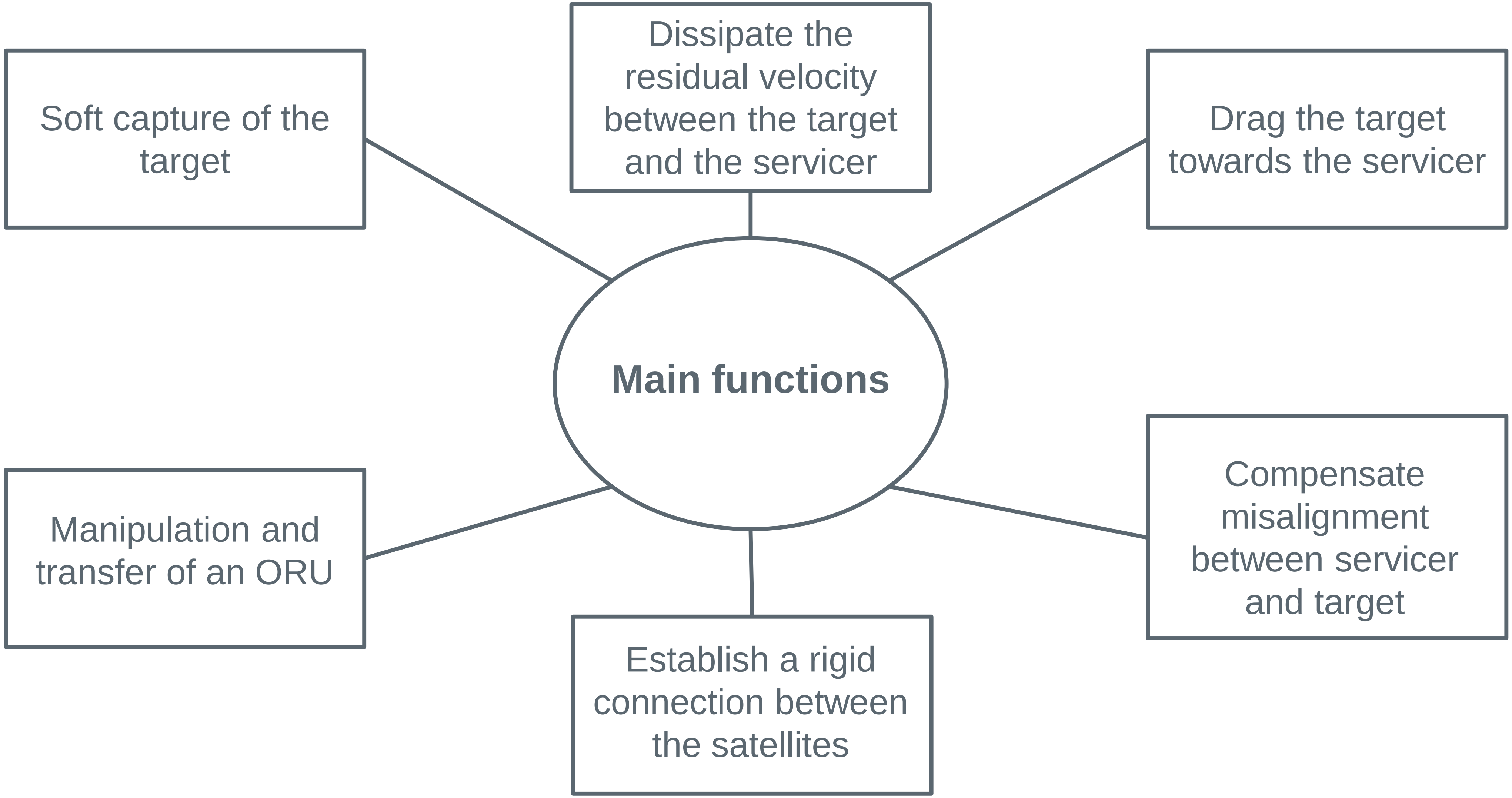
Industrial Consortium

The In-Orbit Servicing mission will be developed within an ASI contract financed by the Next Generation EU via the Italian National Recovery and Resilience Plan (PNRR)

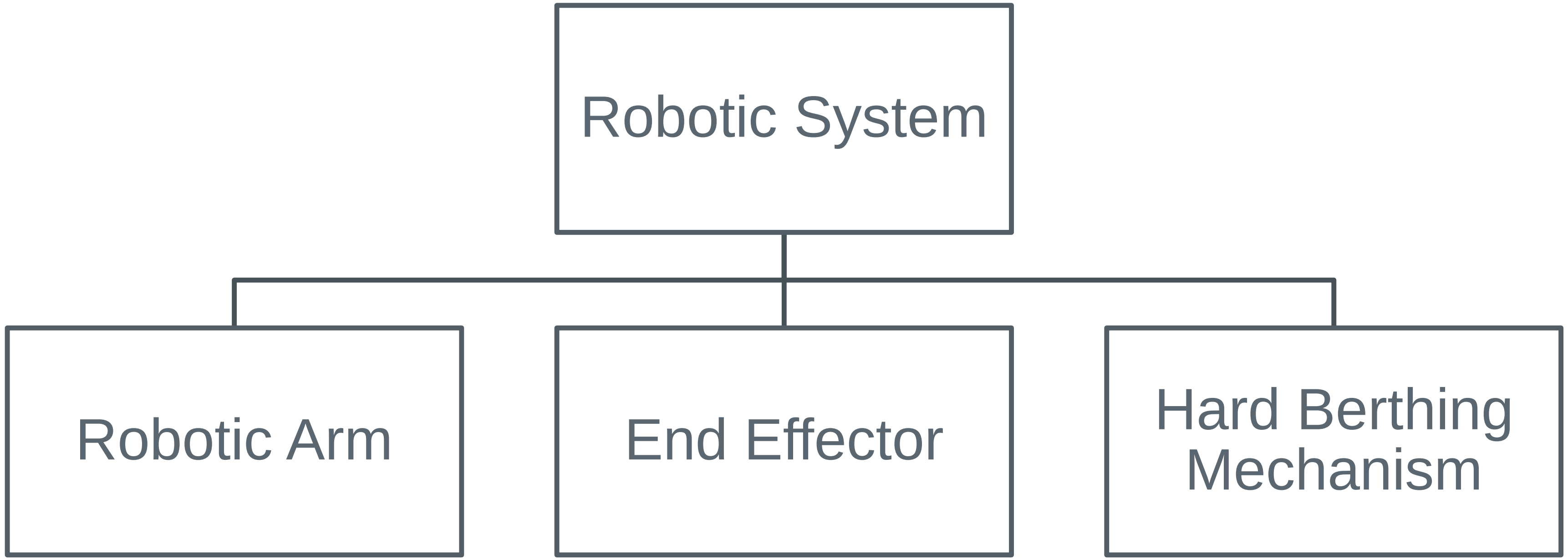


Robotic system

Robotic System Overview



Robotic System Overview



Robotic Arm

Functions:

- Place the end effector within a workspace compatible with the GNC limits and grasping performance of the end effector
- Dissipate residual motion between the satellites
- Drag the captured target towards the services
- Perform ORU manipulation (peg-in-hole tasks)

Required performance:

- Good positional accuracy for the capture phase and ORU manipulation
- Compliant behavior during contact situations
- High dexterity
- Good velocity performance to accurately track the moving grasping point

Robotic Arm – joint architecture

Need of relatively high torque for 1-g testability and high speed for grasping point tracking

Single stage transmission

VS

~~Double stage transmission~~

DEXARM is considered as reference architecture:

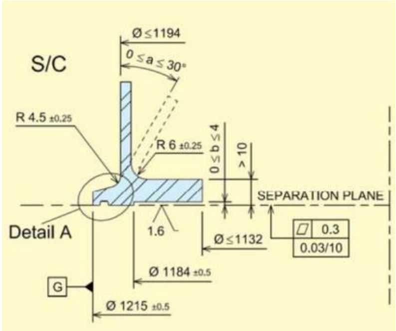
- Brushless motor
- Fail-safe brake
- Harmonic drive
- Motor absolute position sensor
- Output absolute position sensor
- Output torque sensor
- Local electronic board

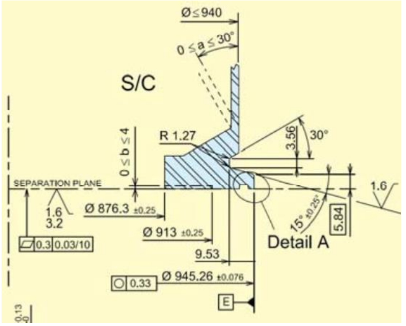
End Effector

The main function of the End Effector is to properly grasp the LAR interface

The key design features of the End Effector are:

- Compatibility with different LAR size and geometry
  - Guarantee sufficient contact points
  - Stable grasp
- Maximum opening width and grasping capability
  - Compatibility with positioning errors from arm, vision system and GNC
  - Fast closure to avoid target escape
- Structural capability to withstand loads
  - Capture phase and contact situations
  - Centrifugal forces due to target tumbling motion
  - Interaction with hard berthing mechanism
  - Peg-in-hole and engagement tasks (ORU)





Hard Berthing Mechanism

The hard berthing mechanism is in charge of rigidizing the servicer-target stack

The key design features of the Hard Berthing are:

- Compatibility with different LAR size and geometry
  - Mechanism adaptable to different diameters and cross section

- Compensation of residual error due to inaccuracy of arm, end effector, and vision system
  - If not compensate, it can lead to impossibility to grasp the satellite and wrong loads distribution
  - This function can be performed exploiting also the compliant behavior of the arm

- Structural capability to withstand loads
  - Tumbling motion
  - De-tumbling operations
  - De-orbiting maneuver
  - Orbit transfer maneuver for target relocation

Refueling Mechanical Interface

- The refueling mechanical interface is part of the refueling system whose purpose is to demonstrate the feasibility of transferring a fluid between two spacecraft.

- It is composed of two coupled parts, one mounted on the servicer and the other one on the target

- After the rigidization, a dedicated sensor suite confirms the correct mating and the refueling process will start

- The mechanical interface shall fulfill the following main functions:
  - Maintain a sealed fluidic connection between the servicer and the target, ensuring fluidic transfer
  - Provide the sensors that allow to establish when the interface is ready to perform the fluidic transfer

- To correctly mate the two parts, any residual misalignment coming from the rigidization shall be compensated

- A critical element of the design is the sealing system which shall minimize possible leakage, shall withstand multiple mating/de-mating cycles, and shall be compatible with the pressure and max flow rate of the fluid.

Conclusions

- An overview of the Italian In-Orbit Servicing Demo Mission has been provided
- Attention has been focused on the requirements, high level input, and challenges for the design of the robotic system and refueling mechanical interface
- Currently the program is undergoing the Preliminary Design Review

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