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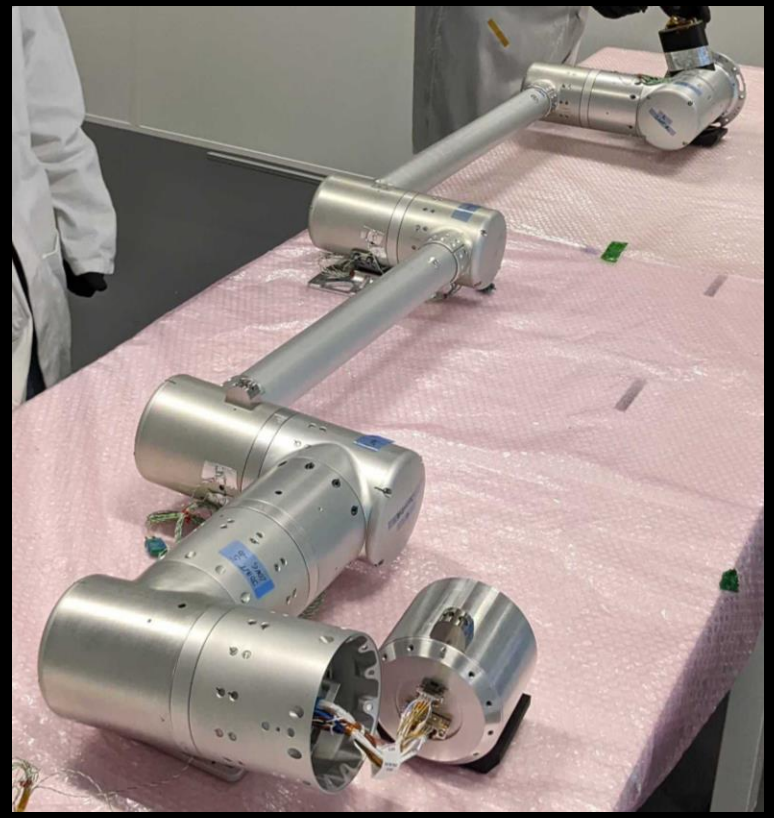
STAARK

Affordable and Mission-Agnostic Robotic Arm



Dr. Jan Dentler

BUILD ABOVE™

What We Do

Redwire is accelerating humanity's expansion into space by delivering reliable, economical and sustainable infrastructure for future generations.

Integrated Mission Enabler

Redwire is a key mission enabler with products relevant to almost every space mission.

Explore, Live, and Work in Space for the Benefit of Humanity

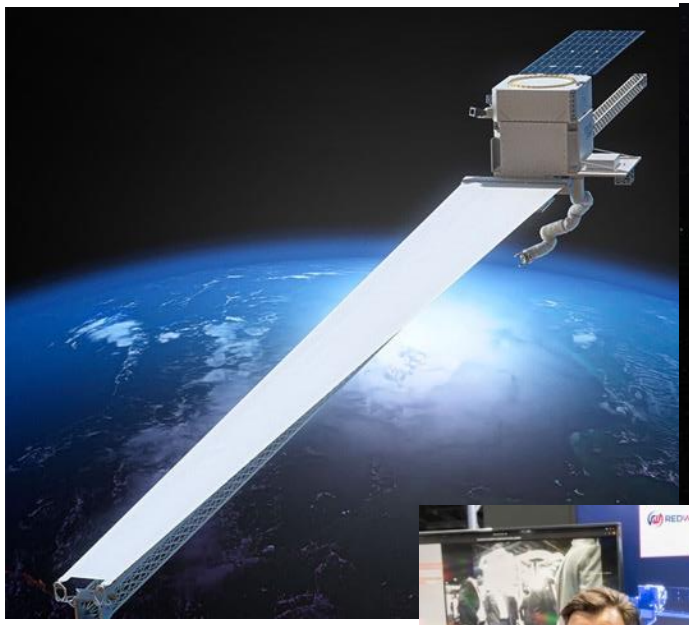
Redwire is developing capabilities that are critical for people to live and work in space.

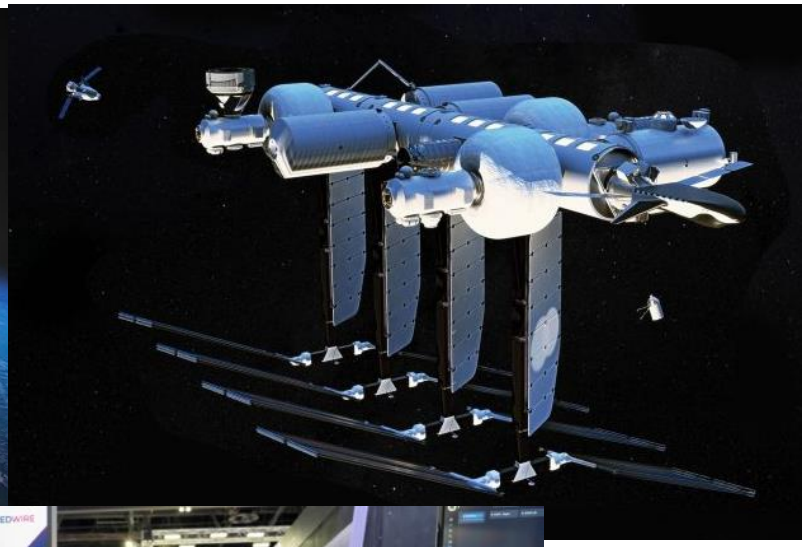
Multinational Mission Support

Redwire is supporting ambitious, multinational space exploration.

Scalable in-space robotics

- During the development of Archinaut One mission Redwire identified need for low-cost robotic arm for broad in-orbit operations
- Redwire had been searching for a robot arm vendor for Archinaut and couldn't find a solution under **$10mm**.
- In 2019 Redwire established robotics centre of excellence in Luxembourg with the objective to create and produce **affordable robotic arm products** to support its in-orbit manufacturing and assembly ambitions and offer them on the global market
- In 2019 contracted with the Luxembourg Government to develop a flight-ready (TRL7) robotic arm subsystem "**STAARK**"





MOMENTUS

AIR FORCE RESEARCH LABORATORY

ThalesAlenia Space
a Thales / Leonardo company

TERRAN ORBITAL

THINK ORBITAL

LUXEMBOURG SPACE AGENCY

esa

SNT
securityandtrust.lu

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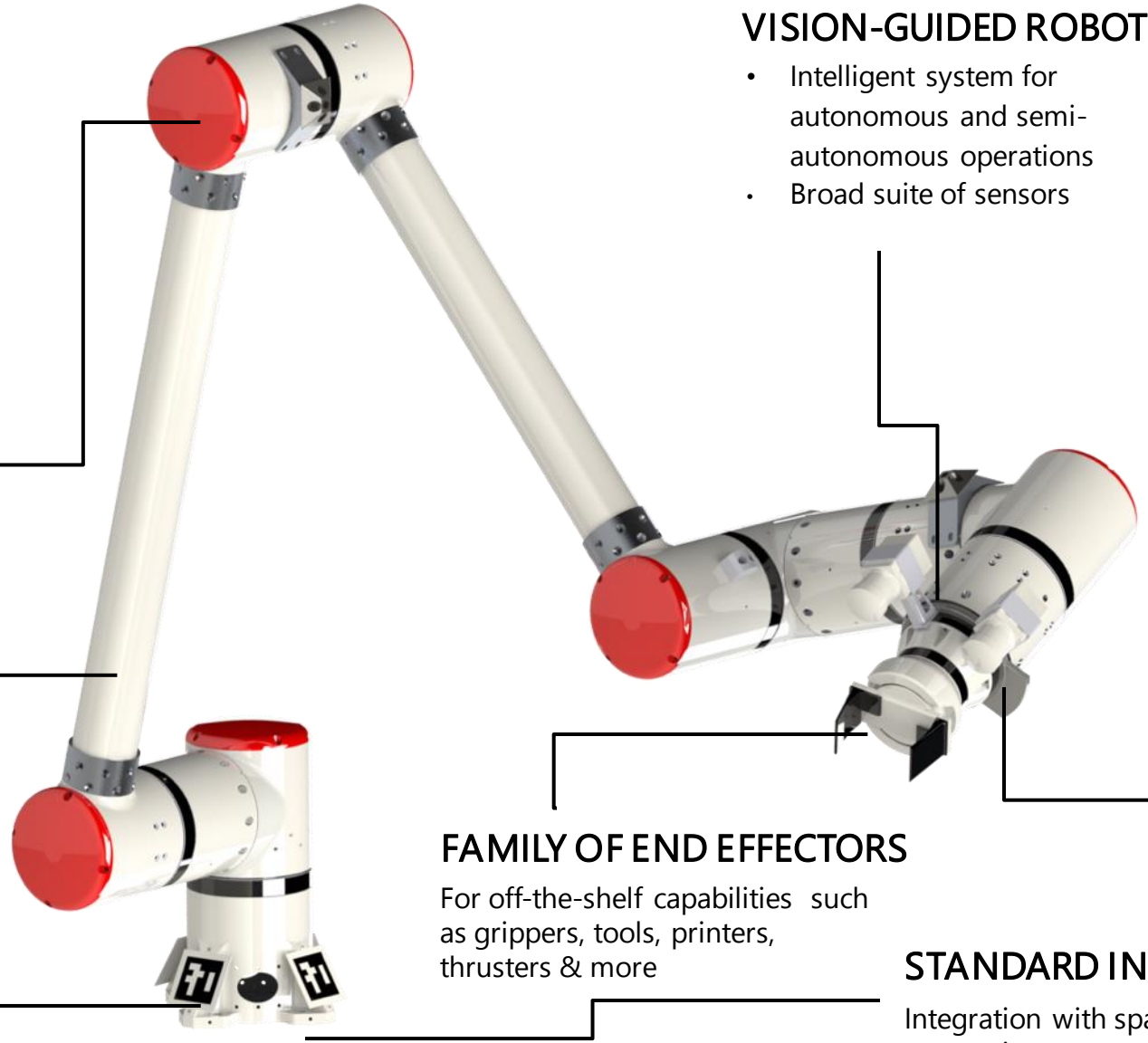
STAARK in a nutshell



VISION-GUIDED ROBOTICS

- Intelligent system for autonomous and semi-autonomous operations
- Broad suite of sensors

SCALABLE AND MODULAR

- Customizable DOF
- Select best configuration & reach
- Adjust for optimal loads transfer
- New features can be installed

OPTIMIZED

- Integrated avionics
- Easily programmable software
- Lightweight components
- High performing systems

FAMILY OF END EFFECTORS

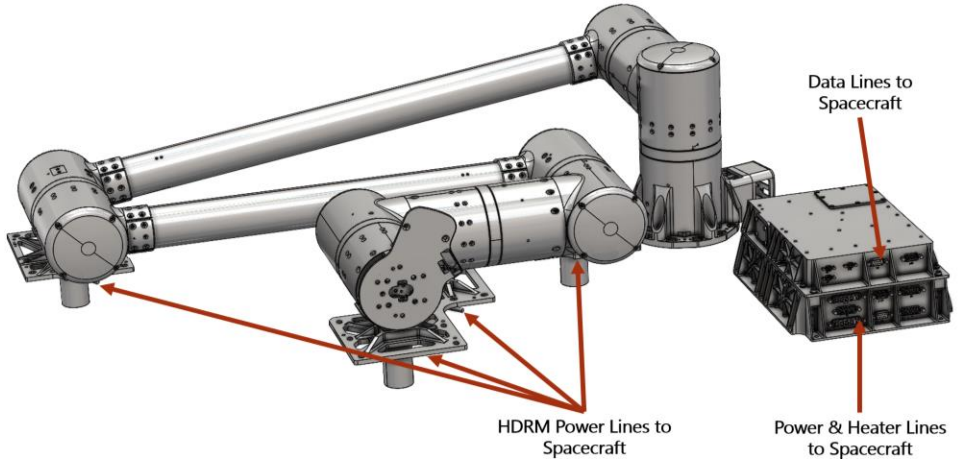
For off-the-shelf capabilities such as grippers, tools, printers, thrusters & more

STANDARD INTERFACES

Integration with spacecraft and connecting custom end-effectors

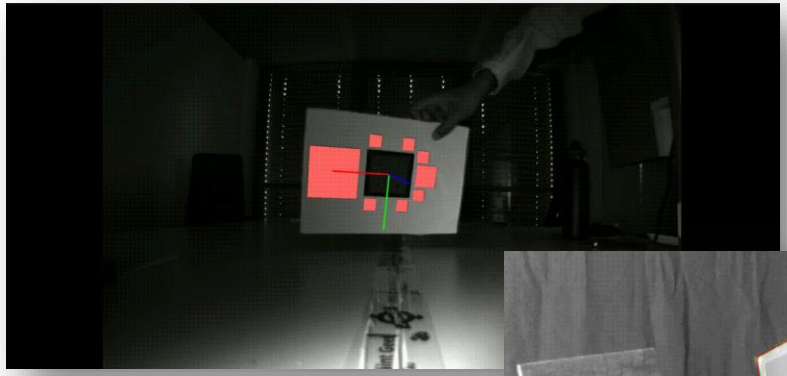
STAARK LEO-S10

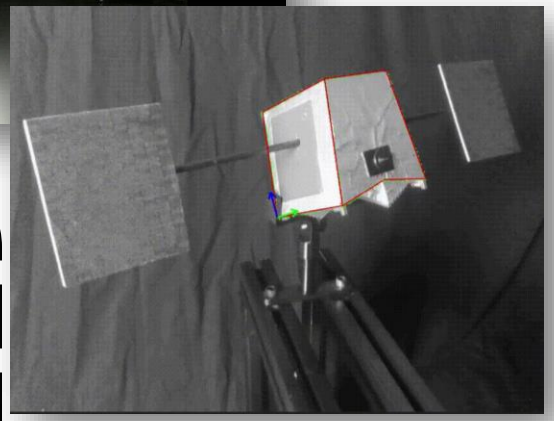
- **Baseline Specification:**
  - 6 DoF robotic manipulator
  - 1.965 m reach without end effector
  - 1 x Robotic Control Unit per manipulator (data/power interface to customer)
  - 1 x Flight Internal Harness Set
  - 1 x STAARK Flight Software
  - 4 x Hold Down Release Mechanisms
  - Operating Temperature: -30°C to +50°C
  - Non-Operating Temperature: -40° C to +70° C
  - Power: 28 VDC regulated (unregulated to be ready in '24)



Parameter:	Value:
Manipulator mass	35.4 kg (CBE, 10% margin)
Spacecraft subassemblies mass	4.1 kg (CBE, 10% margin)
Reach	1.965 m
Stowage Volume	994mm x 652mm x 273mm
Degrees of Freedom	6
Joint torque rating	220 Nm
Max tip speed	25 mm/s (adjustable)
Max manipulatable mass	1900kg @10 mm/s^2 max acceleration
Control type	Cartesian control, joint space control
Joint control type	Field Oriented Control with Encoder
Joint control accuracy	0.05°

STAARK Autonomy State & Roadmap



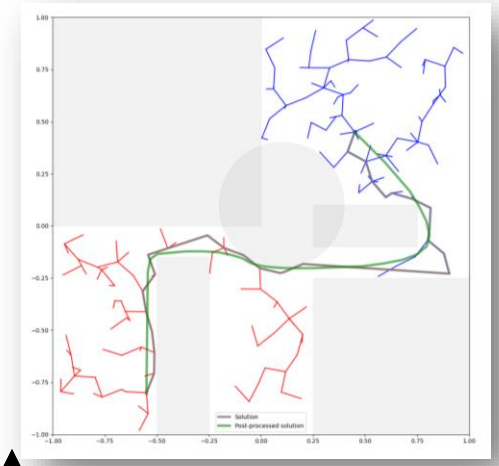


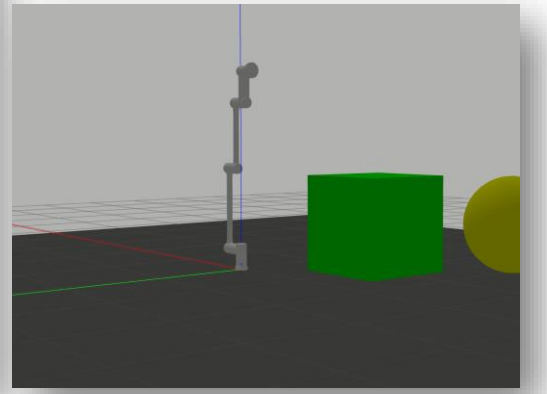
Basic STAARK capabilities

- Software infrastructure
- Joint space control
- System housekeeping
- Basic TMTC

Enhanced STAARK capabilities

- Task management
- Path planning
- Static collision detection
- Cartesian space control
- Space Packet Protocol
- Kinematic simulator





Advanced STAARK capabilities

- Perception integration
- Fiducial marker pose estimation
- Tool integration
- Visual servoing
- Compliance control
- Dynamic simulator
- Advanced FDIR

Future STAARK capabilities

- Grasping of unknown object
- Advanced behaviours (assembly, etc.)

Q4 2019 | Q2 2023 | Q2 2025 | 2027

Depends on safety requirements

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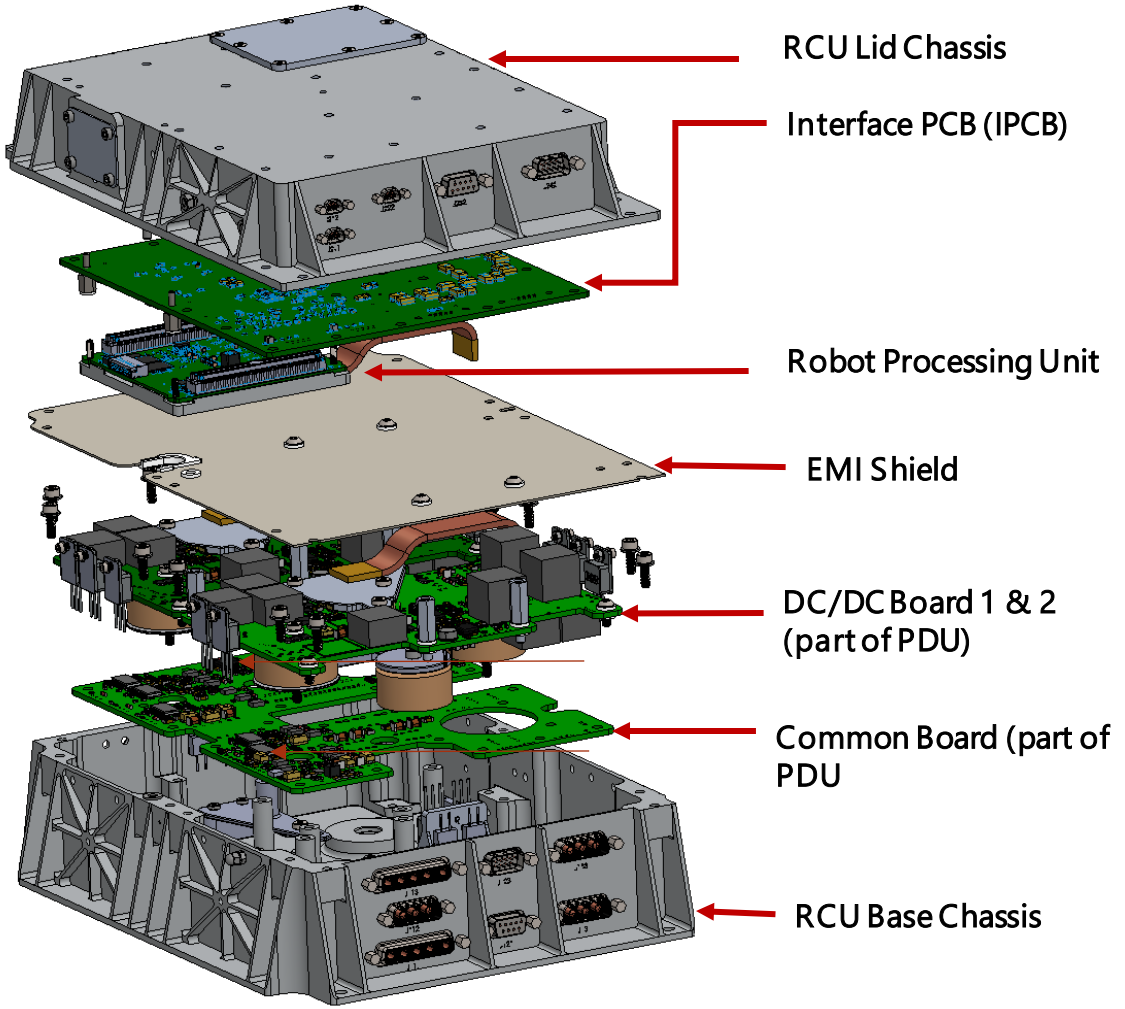
Robotics Control Unit (RCU) Overview

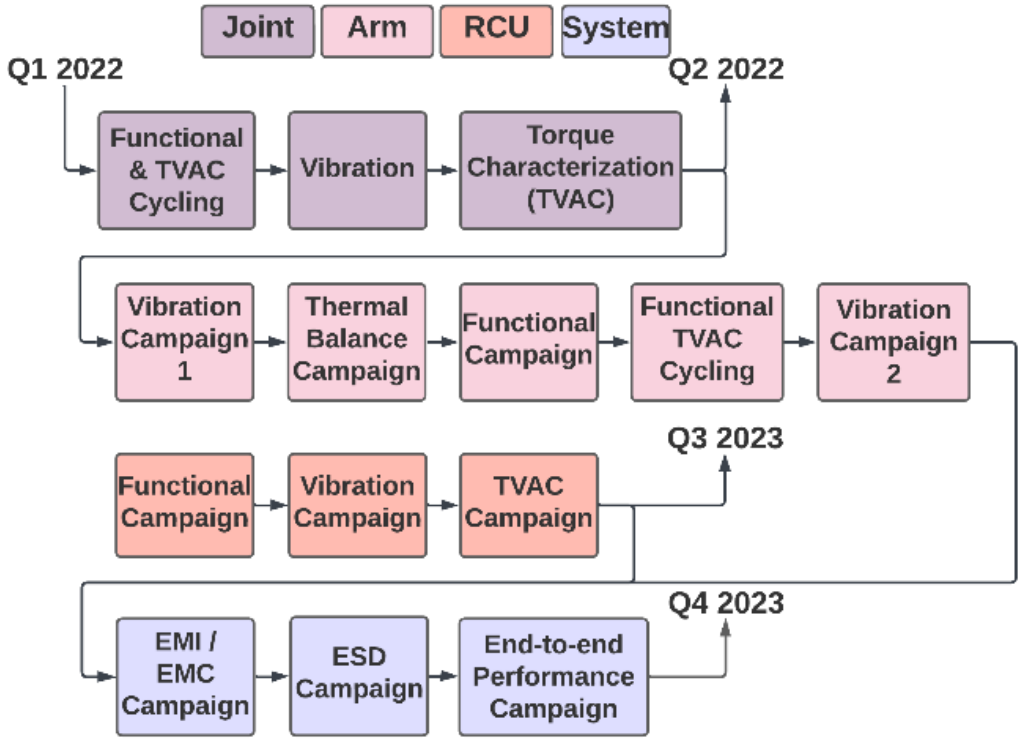
The Robotics Control Unit has 3 sub-units:

- Interface Printed Control Board - IPCB:
  - Ethernet for video data processing capability
  - RS-422 for interaction with customer
- Robotics Processing Unit - RPU:
  - 1 x Supervisor for internal arm level FDIR, fault handling
  - High performance application processor to run joint and arm utilities in pseudo-real-time
- Power Distribution Unit – PDU:
  - Galvanic isolation and power management
  - Heater latch-up current limiters to each joint group



System Testing

EQM Verification Philosophy



Applicability List for test campaign

Document Name and Number	UUT			Baseline Tests Involved in Document											
				1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2
	Joint	Arm	RCU	Subsystem check	Functional	Performance	Life Cycle	Physical Mes.	Random Vib.	Sine Vib.	Shock	TVAC (Functional)	TVAC (Cycle)	EMI / EMC	ESD
Joint level Functional Test Procedure Doc. Nr. TBC	✓			Y											
EQM Vibration Test Procedure Doc. Nr. RWE-ESA-STA-PRO-6545		✓			Y				Y	Y	Y				
EQM Performance Test Procedure Doc. Nr. *TBC*		✓	✓			Y									
EQM TVAC Test Procedure Doc. Nr. *TBC*		✓										Y	Y		
RCU TVAC Test Procedure Doc. Nr. *TBC*			✓									Y	Y		
EQM+RCU EMI/EMC and ESD Test Procedure Doc. Nr. *TBC*		✓	✓											Y	Y
RCU Vibration Test Procedure Doc. Nr. *TBC*			✓						Y	Y	Y				
System Level TVAC Test Procedure Doc. Nr. *TBC*		✓	✓									Y	Y		
Life Cycle Test Procedure Doc. Nr. *TBC*	✓						Y								

Y : Tests from the baseline are covered in the test procedure

✓: Unit under test include these sub-systems

Qualification Status

STAARK Qualification Campaign

STAARK Qualification Model is currently under qualification to the following lev

Thermal

- Joint TVAC Qualification (2021) ☑
- Robot Arm Thermal Cycling (2023) ☑
- Robot Arm Thermal Balance (2022) ☑
- RCU Thermal and Vibration Campaign (Q3/4 2023)

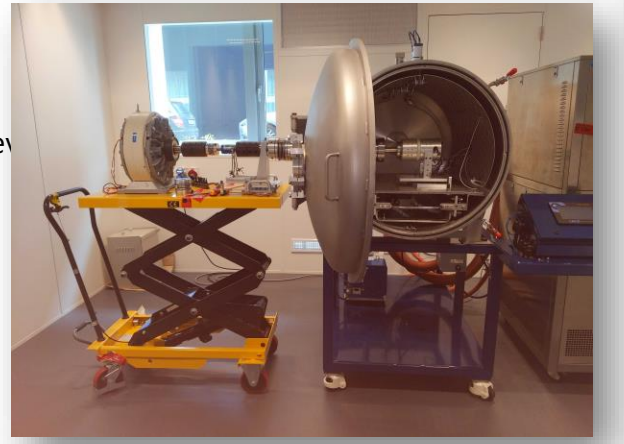
Structural:

- Random (14.3 GRMS) (qualified in 2023) ☑
- Sine (25g in X/Y/Z) (qualified in 2023) ☑
- Shock (upon request)

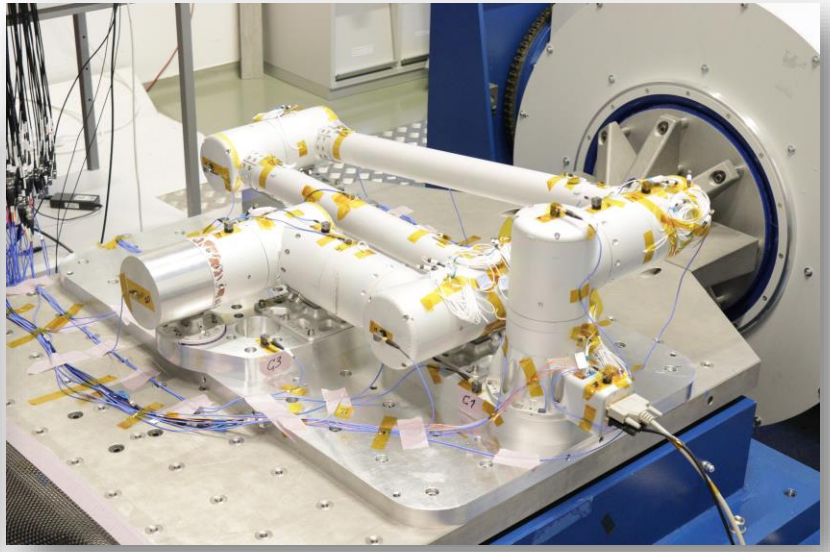
EMI / EMC

- Radiated RE, RS – ECSS/MSFC/GEVS (Q4 2023)
- Conducted CE, CS – ECSS/MSFC/GEVS (Q4 2023)
- ESD/FCD (first contact discharge) with target (Q4 2023)

Joint TVAC Performance Testing

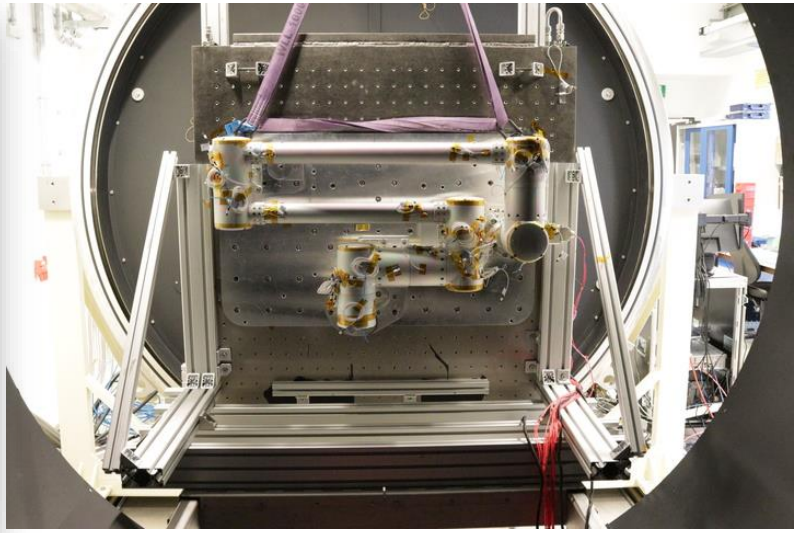


STAARK Vibration Testing



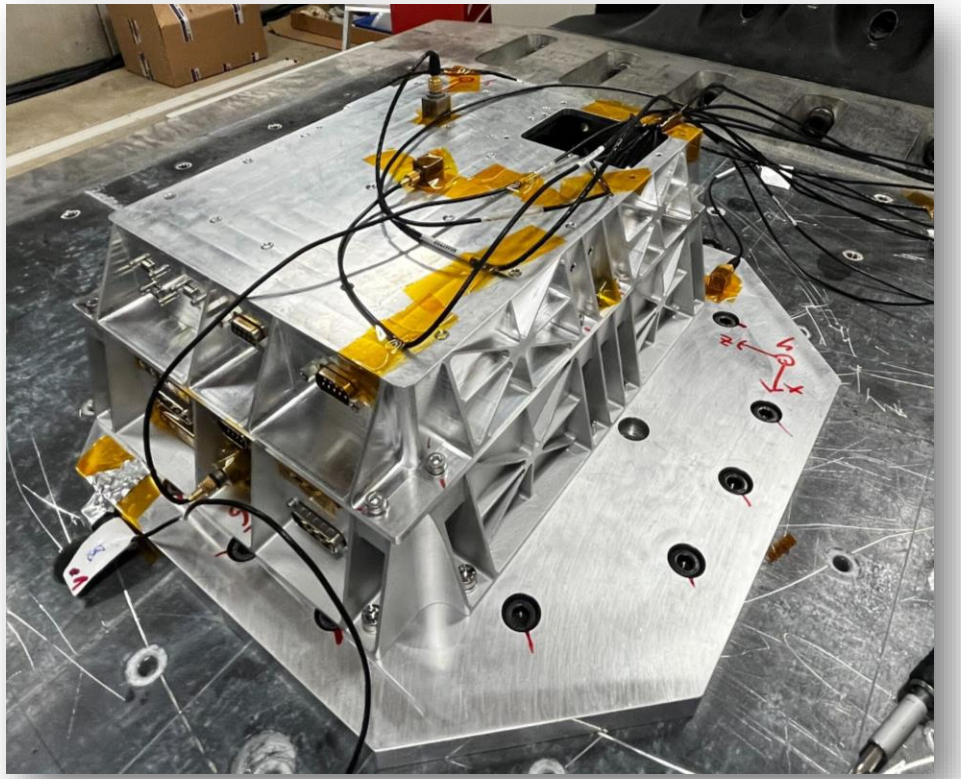
STAARK Functional Testing

STAARK Thermal Balance Testing

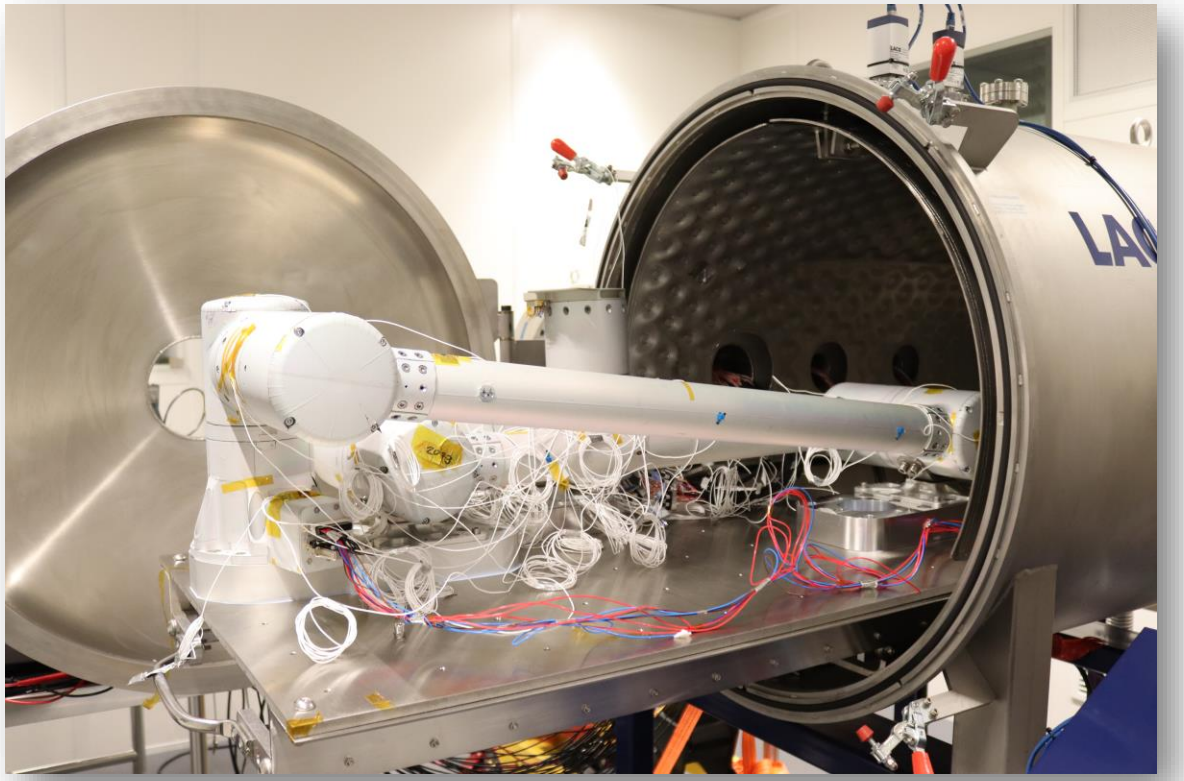


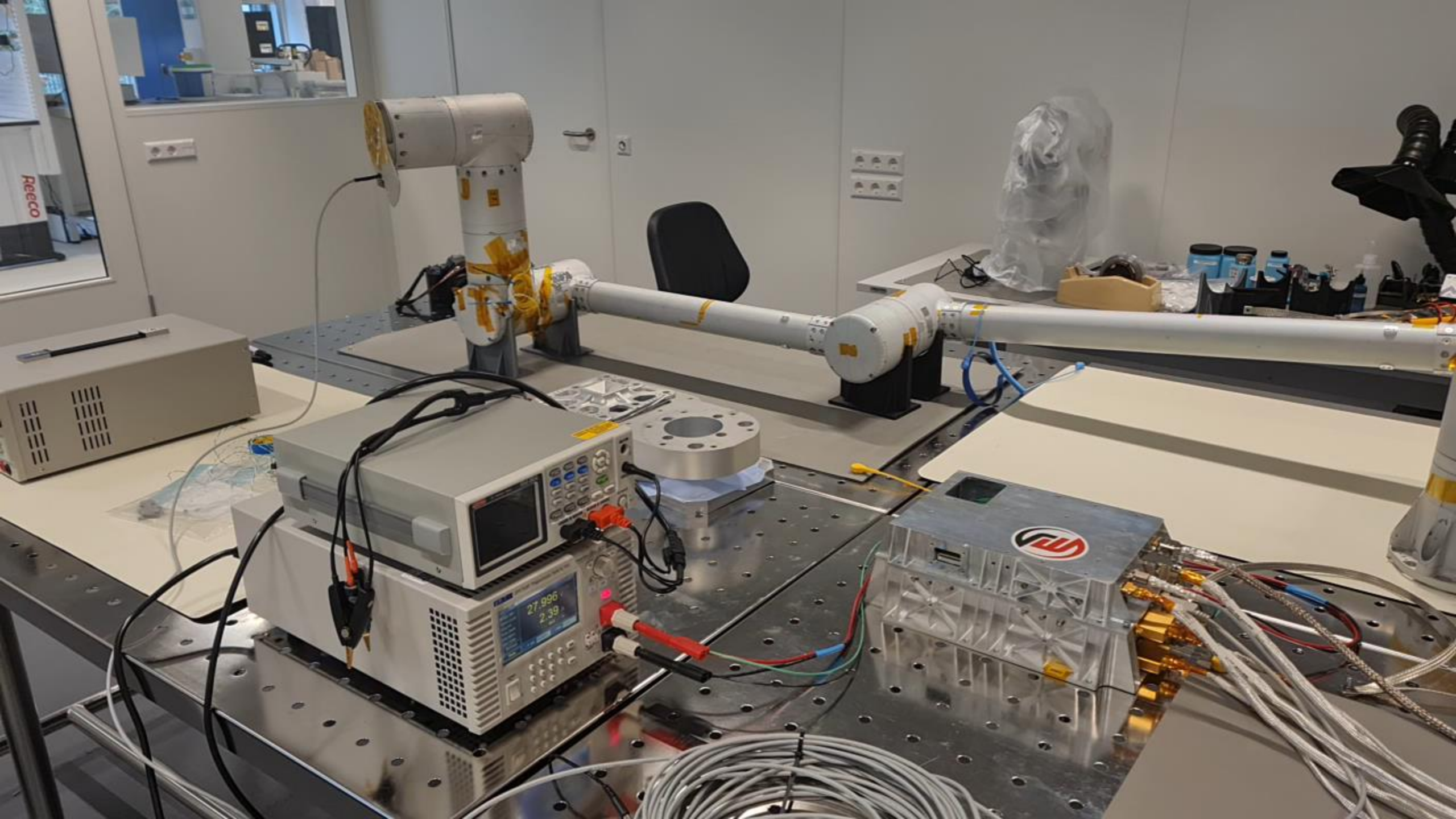
Latest Arm & RCU Testing

RCU STM Vibration Testing



Arm EQM TVAC Testing

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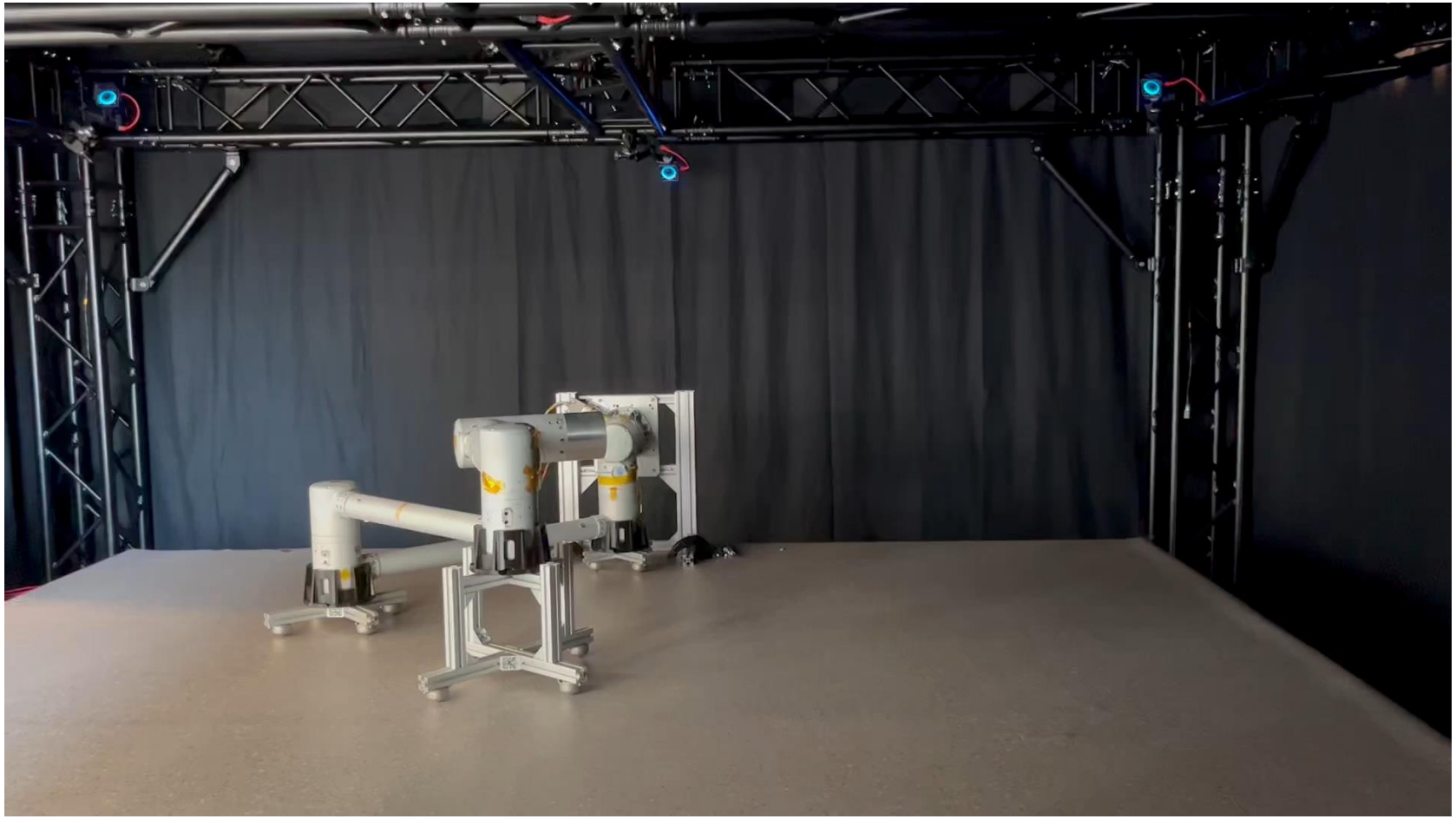
Next steps

- Mechanisms
- Qualification of input shaft position sensor
- Manipulator Performance tests
- Software qualification
- Robotics capabilities
  - Visual servoing
  - Compliance Control
  - Tool integration
  - Dynamic model identification

Looking for:

- F/T sensors
- End-effectors



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Menelaos Vidakis
menelaos.vidakis@redwirespaceeurope.com
Dr. Jan Dentler
jan.dentler@redwirespaceeurope.com