

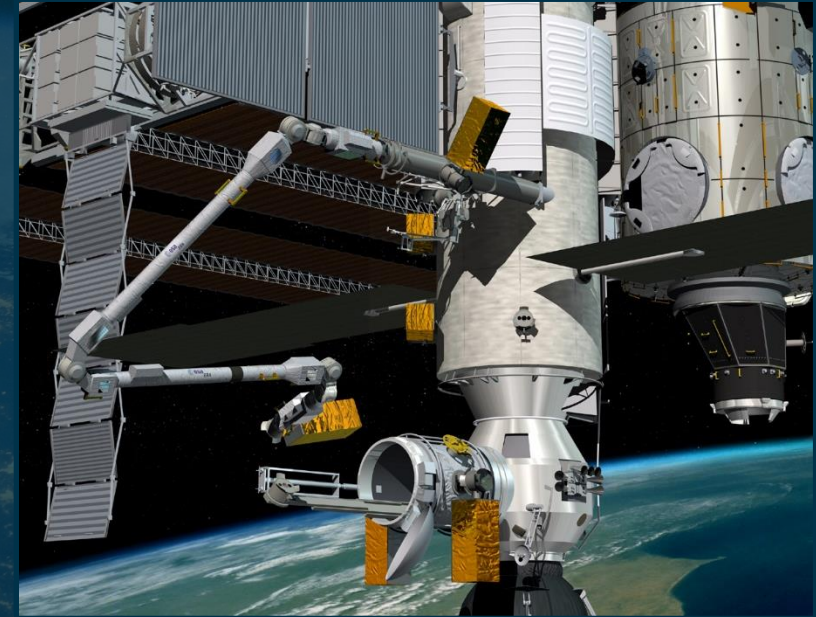
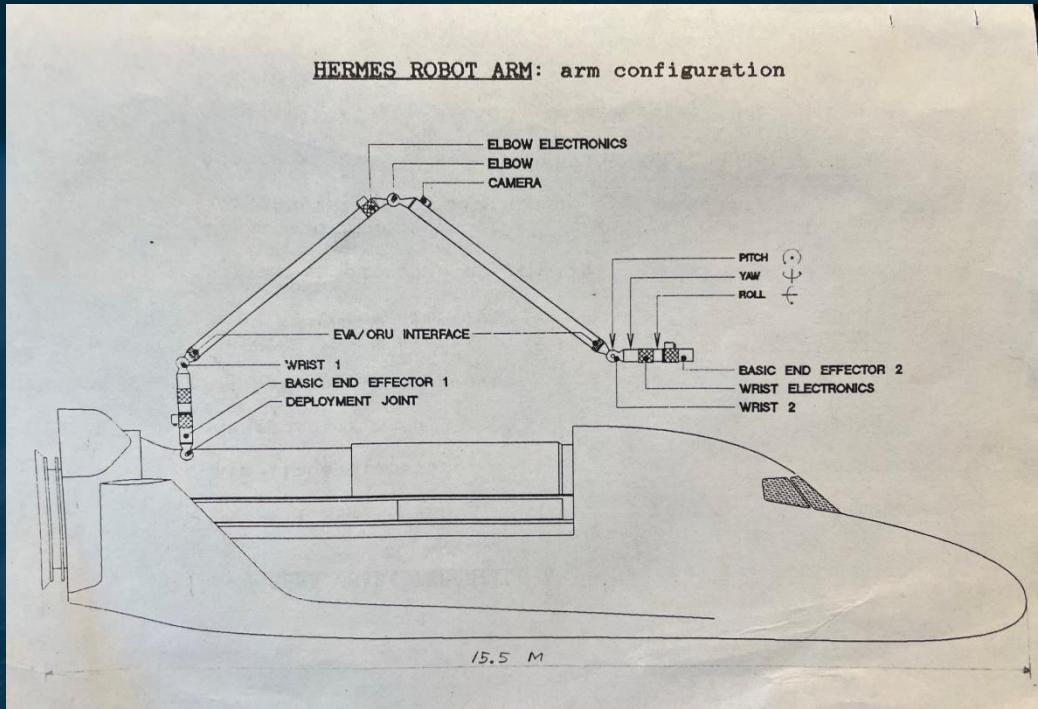
NASA/ESA  
**MARS  
SAMPLE  
RETURN**

# European Robotic Arms for ISS (ERA) and Mars (STA - Sample Transfer Arm)

Philippe Schoonejans (ESA)  
project manager in human spaceflight and exploration

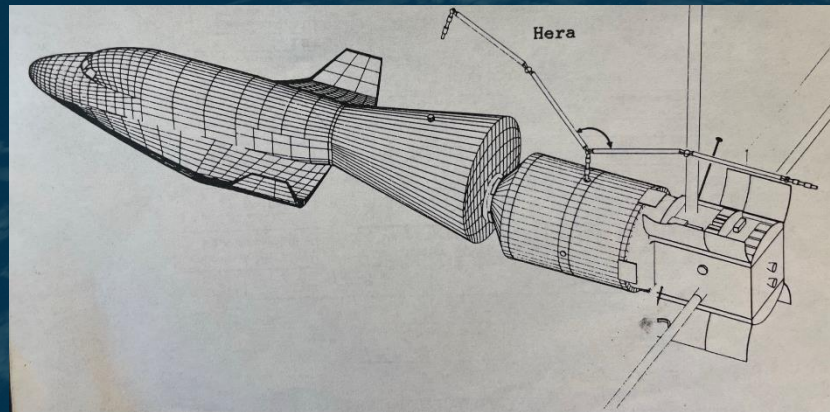
ASTRA conference  
18 October 2023

# Starting with HERA - design evolution from 1986



ERA and MLM airlock

HERA (fixed) and Hermes

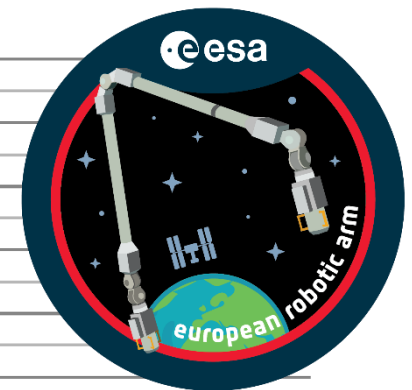
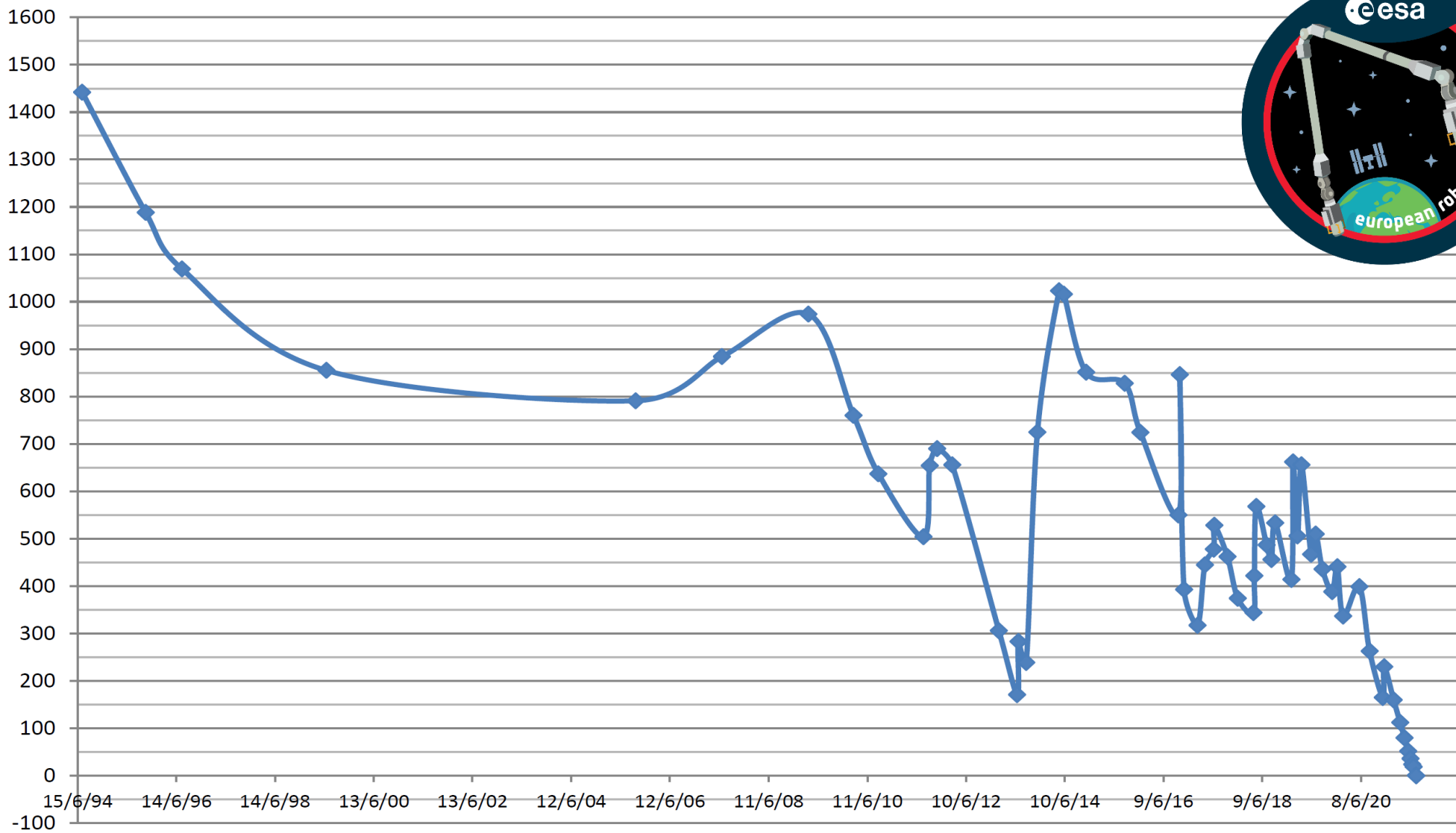


HERA (relocatable) and MTFF

# ERA history – key dates

- 1986 - Start of requirements work – Hermes Robot Arm – Dutch programme
- 1991 – ESA programme – Hermes Robot Arm – later changed to European Robotic Arm (ERA) for ISS
- 1994 – PB and IPC approval
- 1995 – signature of industrial contract with Fokker Space – later Airbus DS NL
- 1995-2004 – changes of launch vehicle Proton->Shuttle->Proton and ISS host module SPP (cancelled)
- 2004 – acceptance against the ESA-Russia ICD because there was no launch vehicle and no ISS purpose
- 2005 – Introduction of Multipurpose Laboratory Module on ISS, as ERA host module
- 2008 – move of ERA to Russia
- 2008-2021 – endless series of MLM launch delays
- 2021 – Launch!
- 2021 – fix of data connections to MLM
- 2022 – in orbit commissioning
- 2023 – key ERA operations!

PREDICTED NUMBER OF DAYS TO ERA LAUNCH (vs date of prediction)



Approval  
1994  
.  
.  
.  
Launch  
21 July  
2021



# Industrial consortium

- 22 companies incl equipment level
- Most of them have been taken over
- Or merged
- Or gone out of business
- Or left the space business
- Not all archives kept
- In the final years the work was only done by Airbus NL, Spacebel, TERMA and NLR
- At the end only Airbus NL, having taken over the expertise and tools to update the flight SW
- The three Italian ERA companies (Officine Galileo, TecnoSpazio and Fiar) are now all part of Leonardo Elettronica

|                    |               |
|--------------------|---------------|
| <b>Netherlands</b> |               |
| Dutch Space        | Prime         |
| NLR                | MPTE          |
| Stork              | MJS Mechanics |
| <b>Belgian</b>     |               |
| Sabca              | MJS           |
| Spacebel/Trasys    | IMMI, MPTE    |

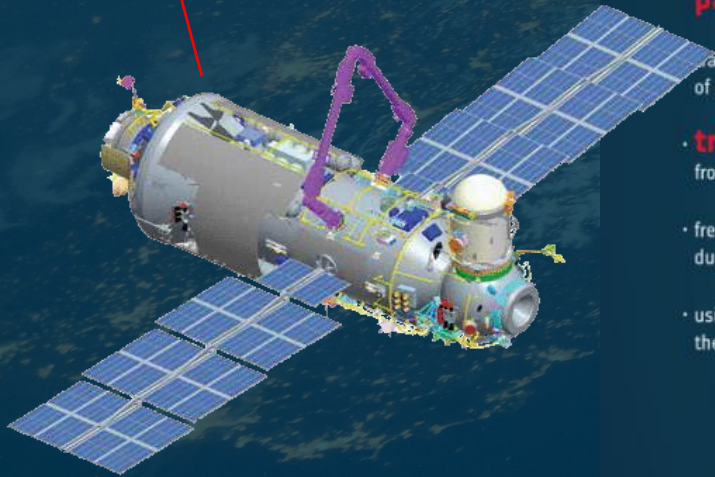
|                    |               |
|--------------------|---------------|
| Alcatel            | EGSE          |
| <b>Germany</b>     |               |
| EADS/Bremen        | EES, MJS, OBC |
| Bosch              | Parts         |
| <b>Italy</b>       |               |
| OG                 | CLU           |
| Technospacio       | Software      |
| Fiar               | EMMI          |
| <b>Denmark</b>     |               |
| Per Udsen          | GEO, WET      |
| Terma              | Software      |
| <b>Switzerland</b> |               |
| HIS                | MLS           |
| <b>Sweden</b>      |               |
| Saab               | OBC           |

Note: Table does not show equipment level



# European Robotic Arm final design

MLM = Multipurpose Laboratory Module (developed by Khrunichev)



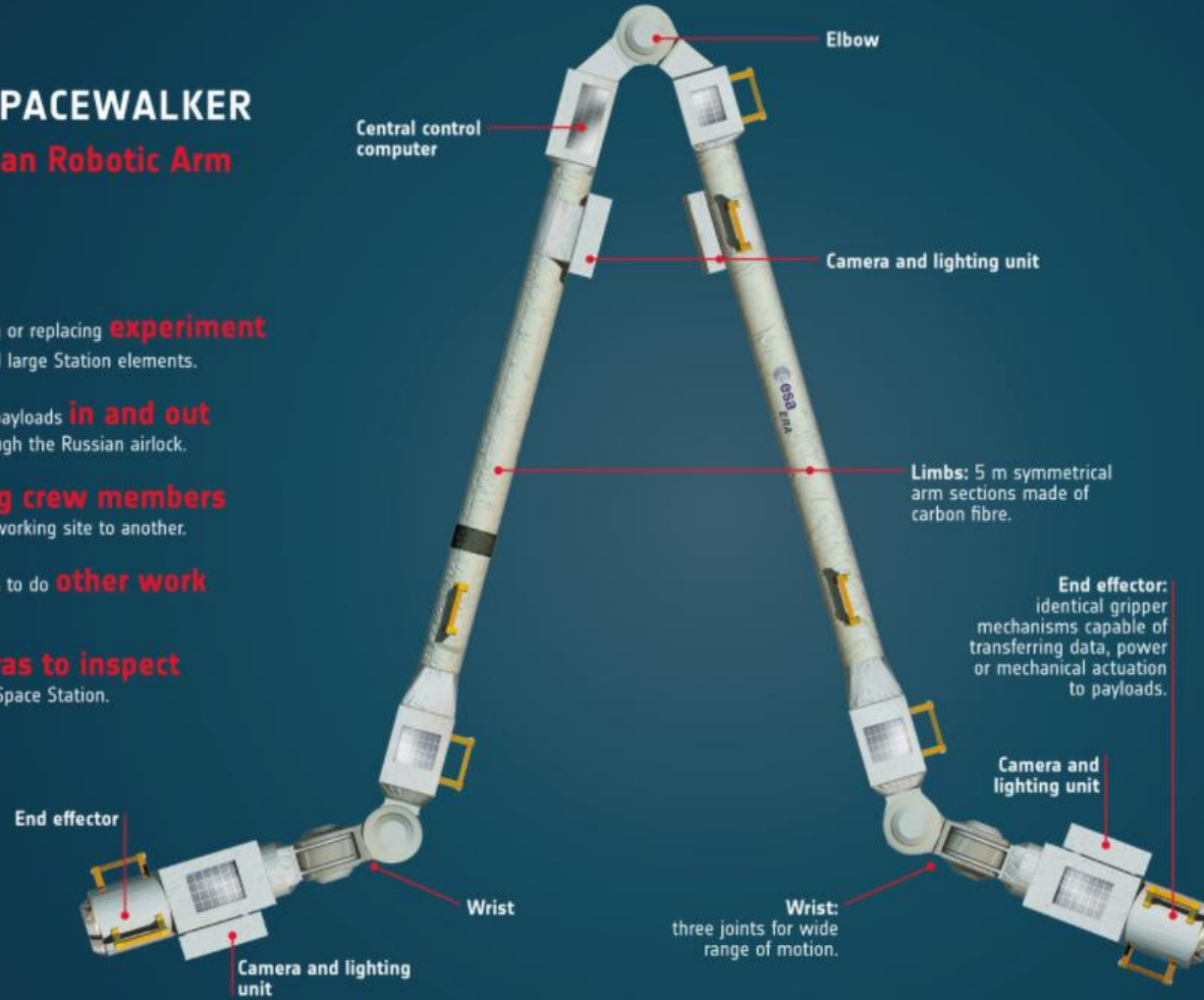
The arm can “walk” from basepoint to basepoint around the MLM.

## SMART SPACEWALKER The European Robotic Arm

### Tasks

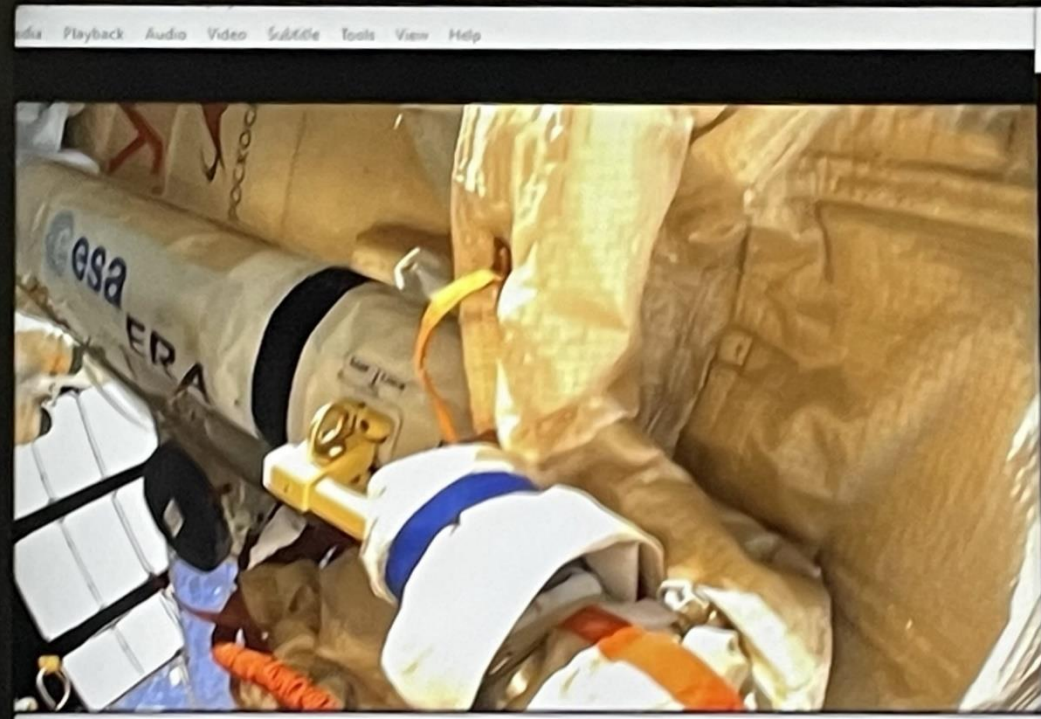
- installing, removing or replacing **experiment payloads** and large Station elements.
- transferring small payloads **in and out** of the Station through the Russian airlock.
- transporting crew members** from one external working site to another.
- freeing cosmonauts to do **other work** during spacewalks.
- using its **cameras to inspect** the outside of the Space Station.

#EuropeanRoboticArm

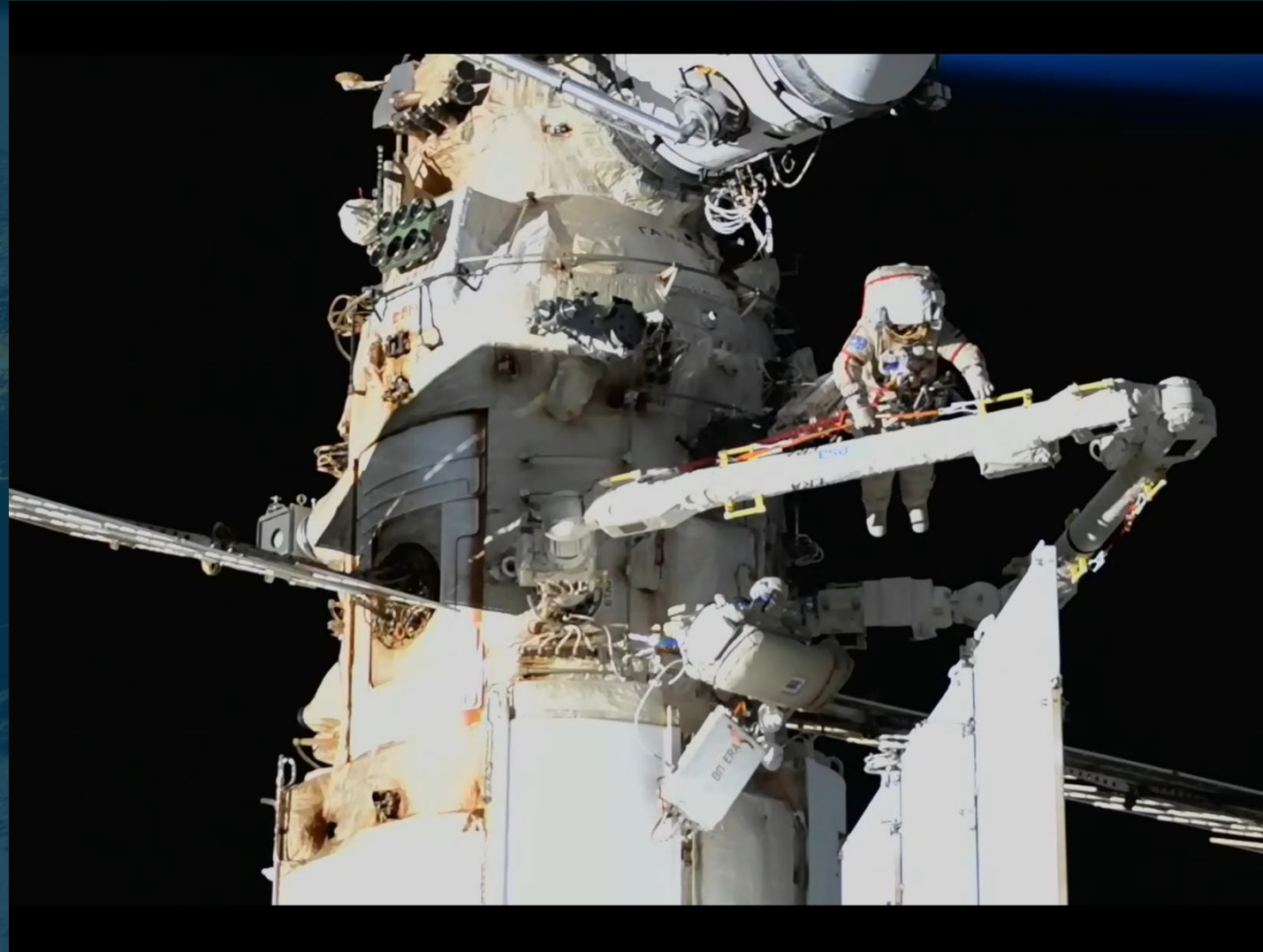


- Arm length:** 11.3 m
- Reach:** 9.7 m
- Tip position accuracy:** 5 mm
- Maximum speed of operations:** 10 cm/s
- Degrees of freedom:** 7
- Launch mass:** 630 kg
- Handling capability:** 8000 kg
- Control:** Autonomous or by astronaut commands
- Main construction materials:** Carbon fibre and aluminium
- Home base:** Multipurpose Laboratory Module (Nauka)
- Range of motion:** Hand-over-hand on the Russian Space Station segment

# Many EVAs from unpacking to final outfitting on ISS



EVA52 - Apr 2022



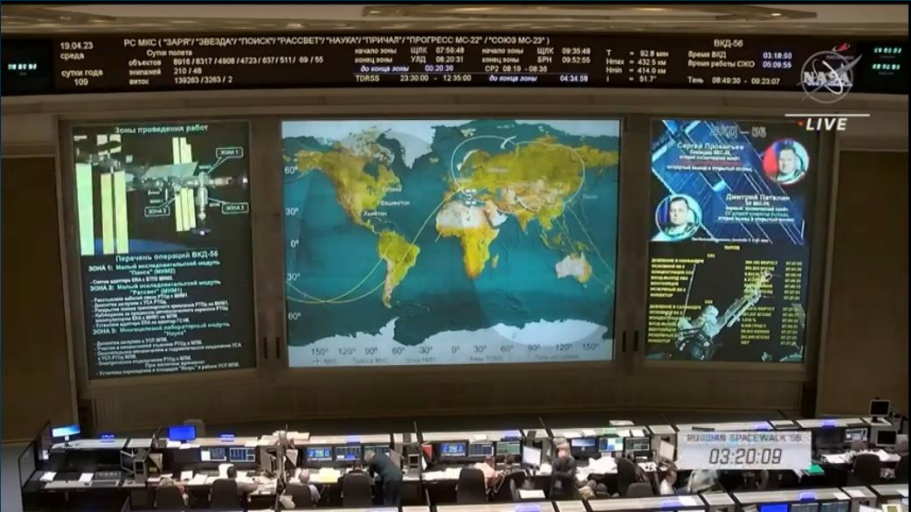
EVA58 - May 2023

| ERA commissioning, test missions and operational missions   | EVA | Date              |
|---|-----|-------------------|
| ERA unpacking and installation  | 52  | 24/3+18/4 2022    |
| Initialization mission, first ERA motion between basepoints   | 53  | 28/4+5/5 2022     |
| ERA move to a safe position after failure to grapple second basepoint   | -   | 13/5 2022         |
| Test mission to investigate grapple issue and test its cameras  | -   | 21-22/6+12/7 2022 |
| Samantha Cristoforetti's Russian EVA, outfitting ERA and replacing a polluted camera window                                 | ESA | 21/7 2022         |
| ERA brakes run-in, solved grapple issue, image interpretation SW worked well with new window                                | -   | 28-29 7 2022      |
| Installation of ERA elbow cameras   | 54  | 17/8 2022         |
| 1 <sup>st</sup> pick and place test (successful), including (un)latching using ERA's "screwdriver"                          | -   | 24/8 2022         |
| Test manual overrides, replace another camera window  | 54a | 2 Sept 2022       |
| In orbit validation mission, testing all performances (braking, positioning, force control)                                 | -   | 13-14/9 2022      |
| Training and test missions to be declared ready for radiator and airlock installation                                       | -   | 20 Oct+1Nov 2022  |
| <i>Radiator installation started on 25 Nov and 14 Dec but unfinished due to EVA suit issues and Soyuz leak respectively</i> |     |                   |
| ERA laptop harddisk replacement, including ERA switch on  | -   | 1 Feb 2023        |
| Training mission on 31 March for new operator, including inspection of MRM1 docking port                                    | -   | 31 Mar 2023       |
| MLM Nauka radiator installation   | 56  | 18-20 Apr 2023    |
| MLM Nauka airlock installation (with first a training mission on 27 Apr)  | 57  | 2-4 May 2023      |
| ERA final outfitting (tethers installation) and the freshly installed radiator was now deployed                             | 58  | 12 May 2023       |
| Last ERA test mission for full commissioning – In Orbit Validation Completed!   | -   | 1 June 2023       |
| ERA transports an astronaut   | 60  | 9 Aug 2023        |
| Inspection of Nauka radiator leak   | -   | 17 Oct 2023       |





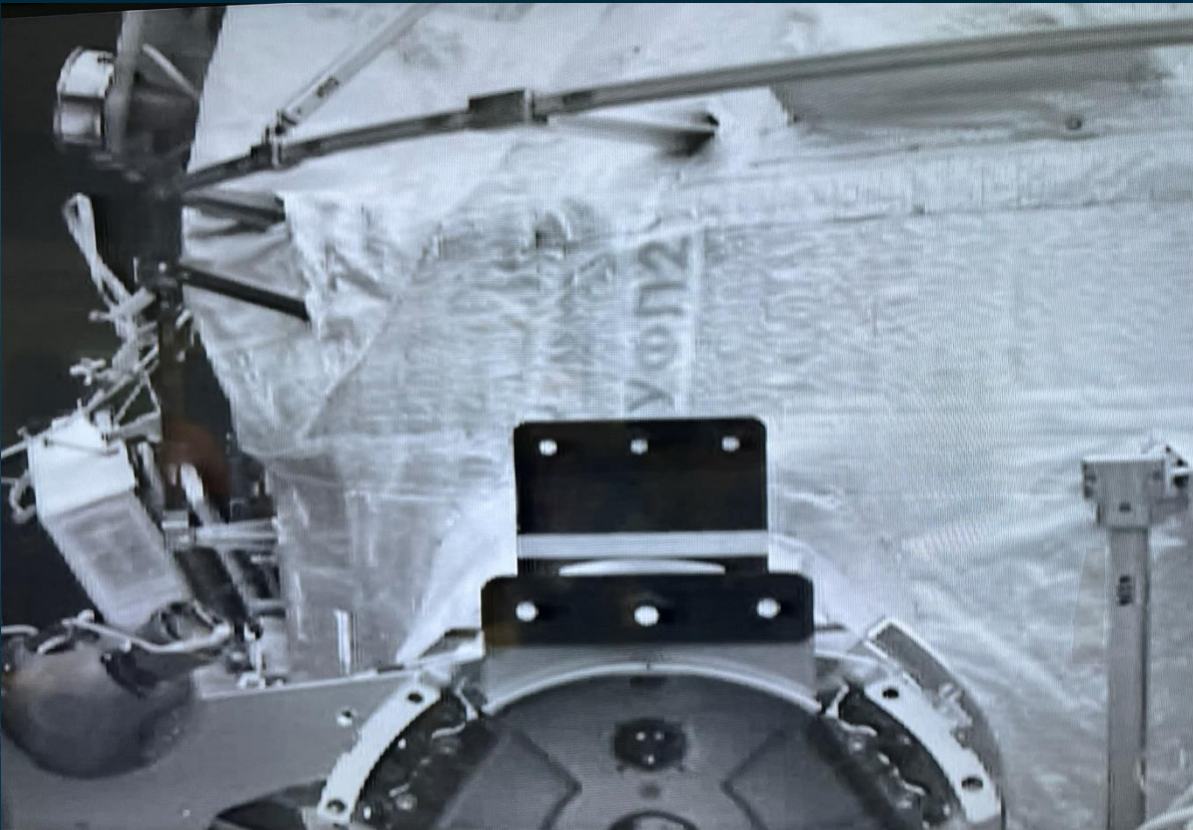
# ERA operations supported on-line (2022-2023)



Real time data and video connection  
ISS->MCC-M->Estec

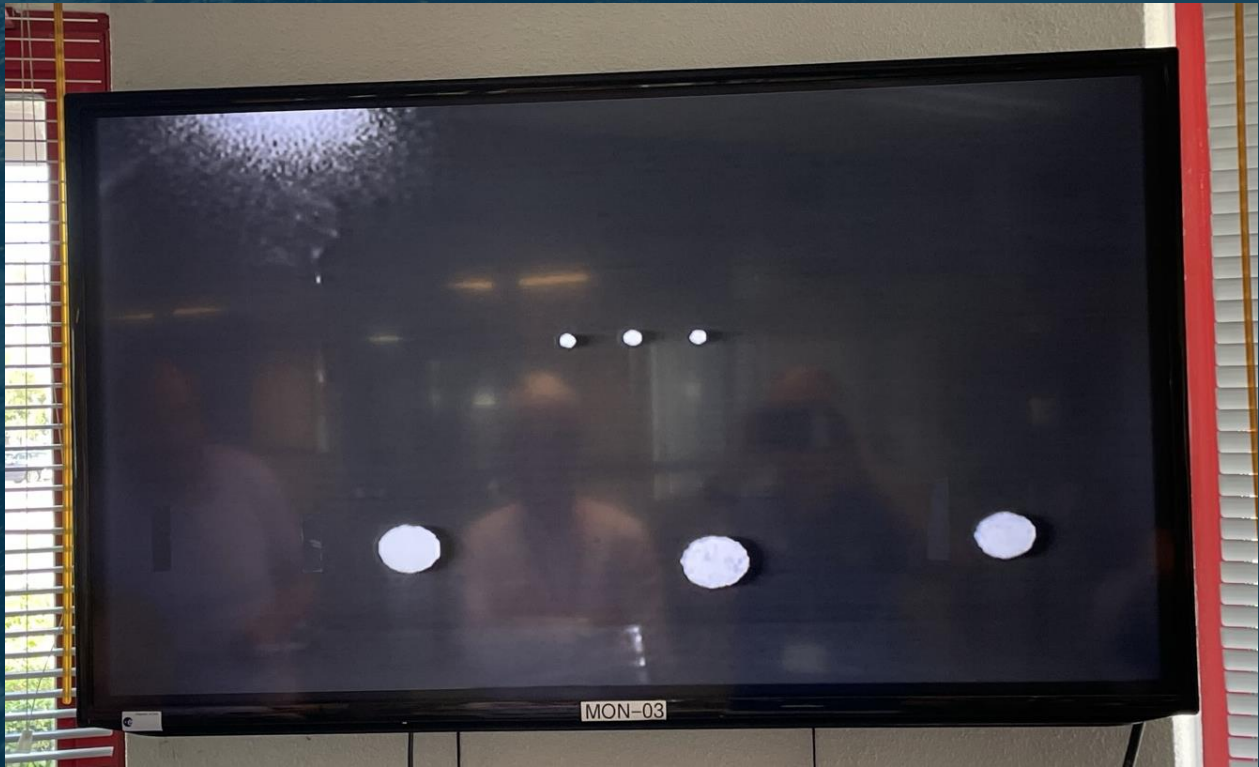


# Real time video from ERA End Effector camera



Camera in imaging mode  
24-8-2022

Camera in proximity  
mode – thresholding for  
reflective dots only  
24-8-2022



# Real time video from EVA helmet camera



EVA tools built by RSC Energia

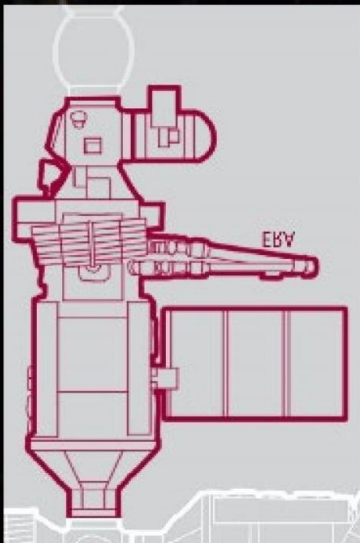
testing manual  
override of  
mechanisms  
with tool "EVA-1"  
EVA54a 2-9-2022



# ERA's first main ISS assembly operations

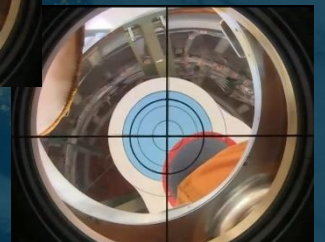
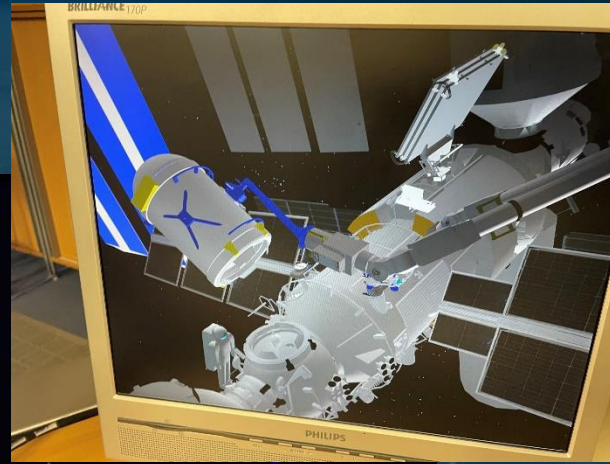
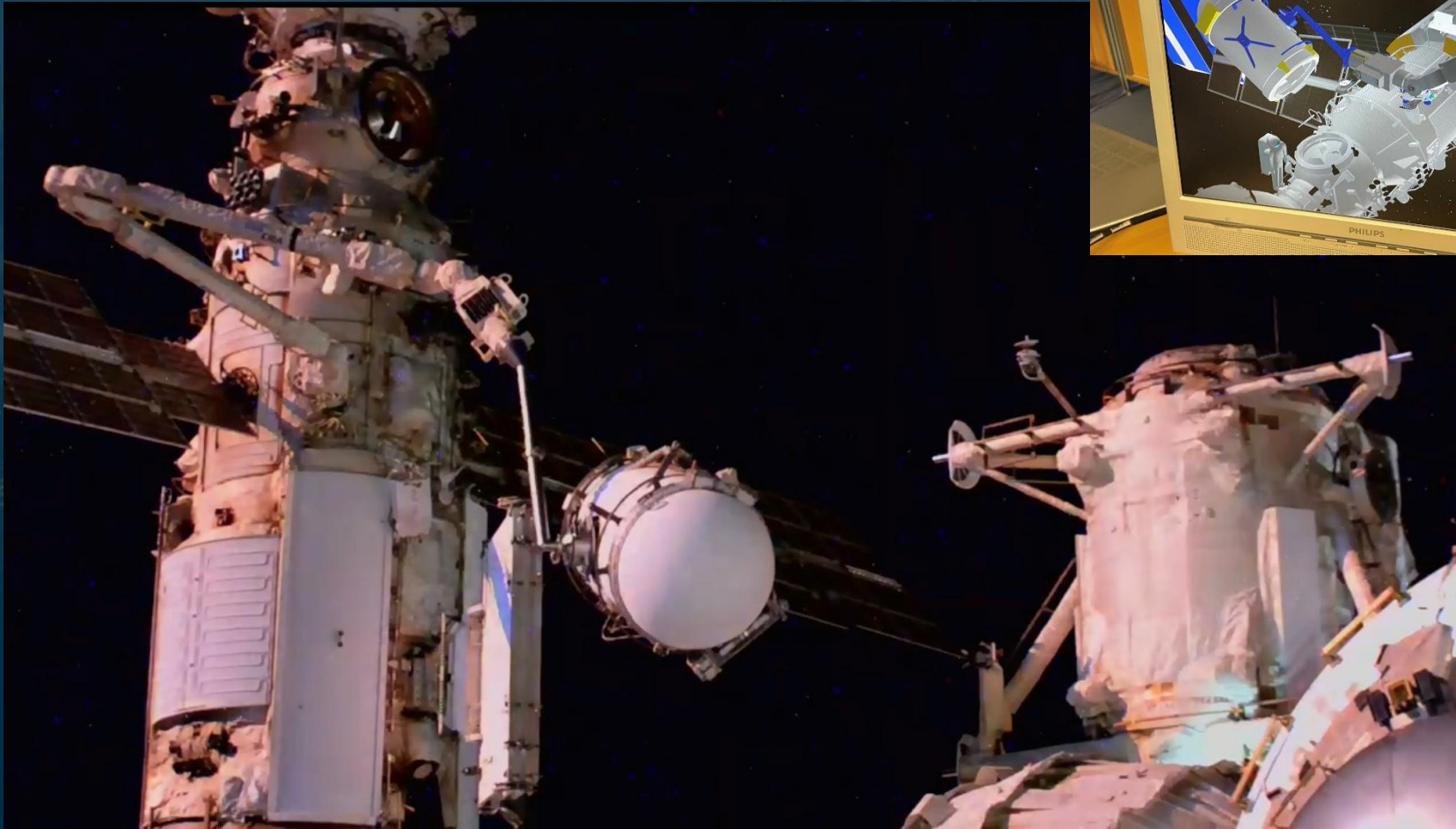
Radiator installation 19 Apr 2023  
Airlock installation 4 May 2023

Desired final situation when the Nauka radiator and the Nauka airlock (seen in the front) have been moved from MRM1 Rassvett to Nauka/MLM

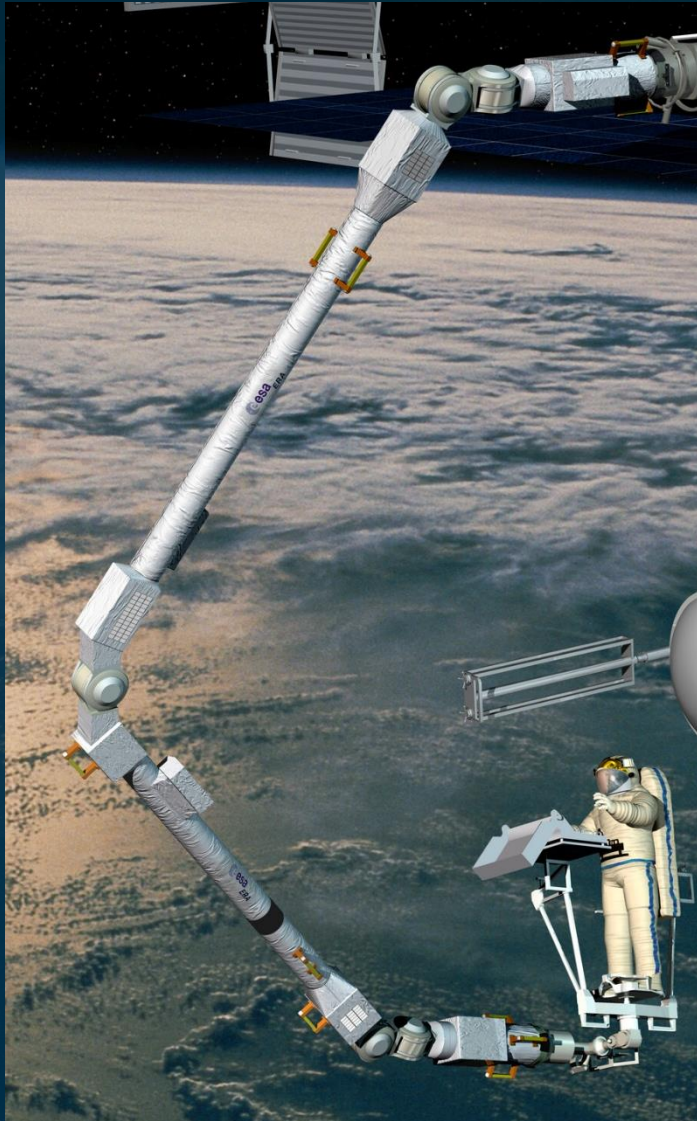


International Space Station  
Roscosmos Spacewalk 56  
19 April 2023

# Even more complex – installing MLM Airlock on 4 May '23



# Transport of an EVA crew – August 2023



A cool  
artist  
impression  
became  
reality

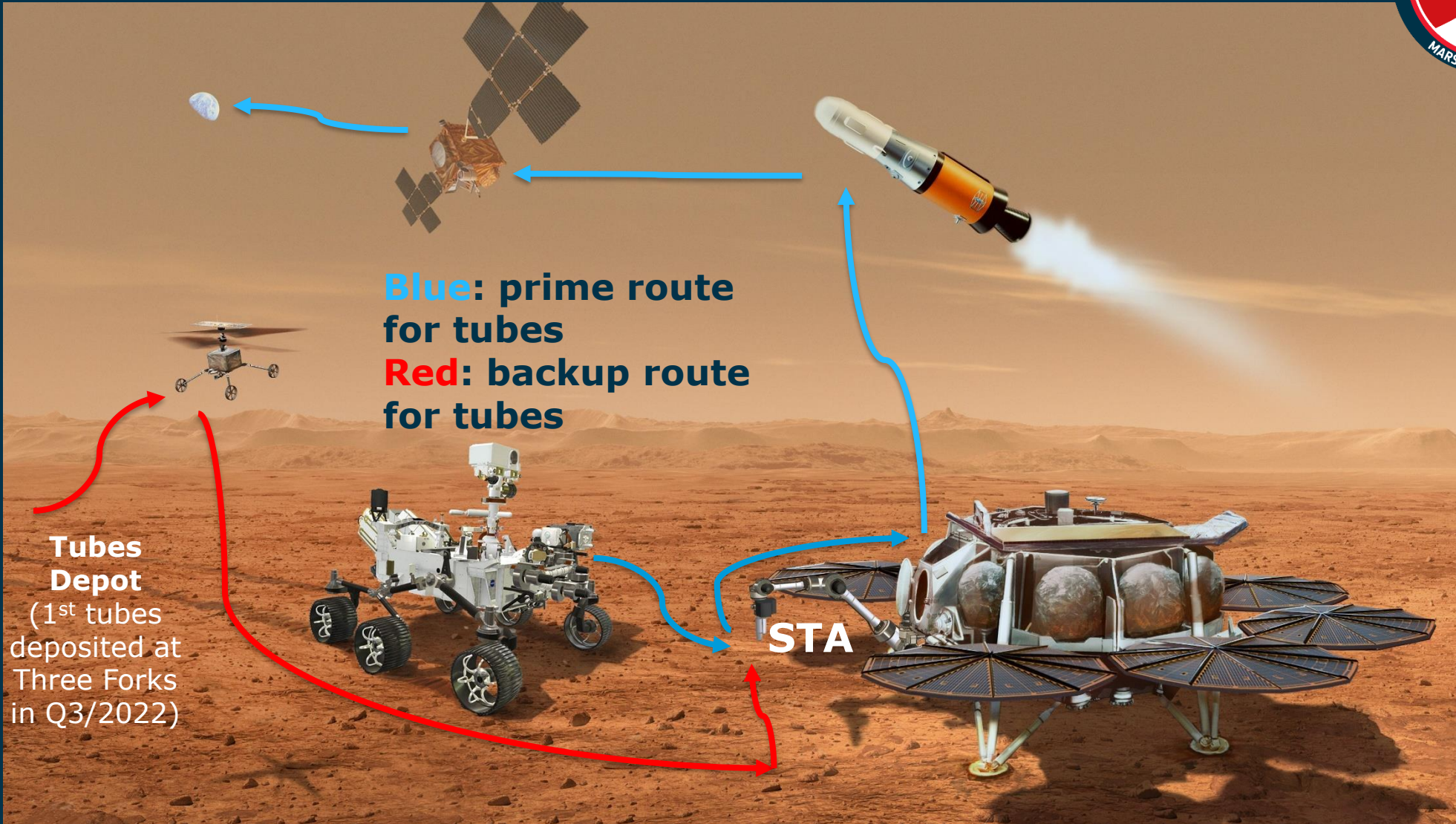
All ERA  
functions  
ready for  
use!



- Mechanism motor currents are quite temperature dependent
- Vision software needs tuning when used in real space light conditions
- Minimise non-maintainable software/firmware – it is a constraint during commissioning and fine tuning
- A space robot is a complex system and needs significant commissioning time
- Operations can take longer than expected and planning should make sure all robotic tasks that do not need EVA are done (the day) before EVA starts
- Ground segment to take into account all cyber security policies – we had trouble with cyber security becoming really crucial only after we had built our ground segment
- During commissioning and ops, EVA crew availability is an asset – too bad for Mars robots....



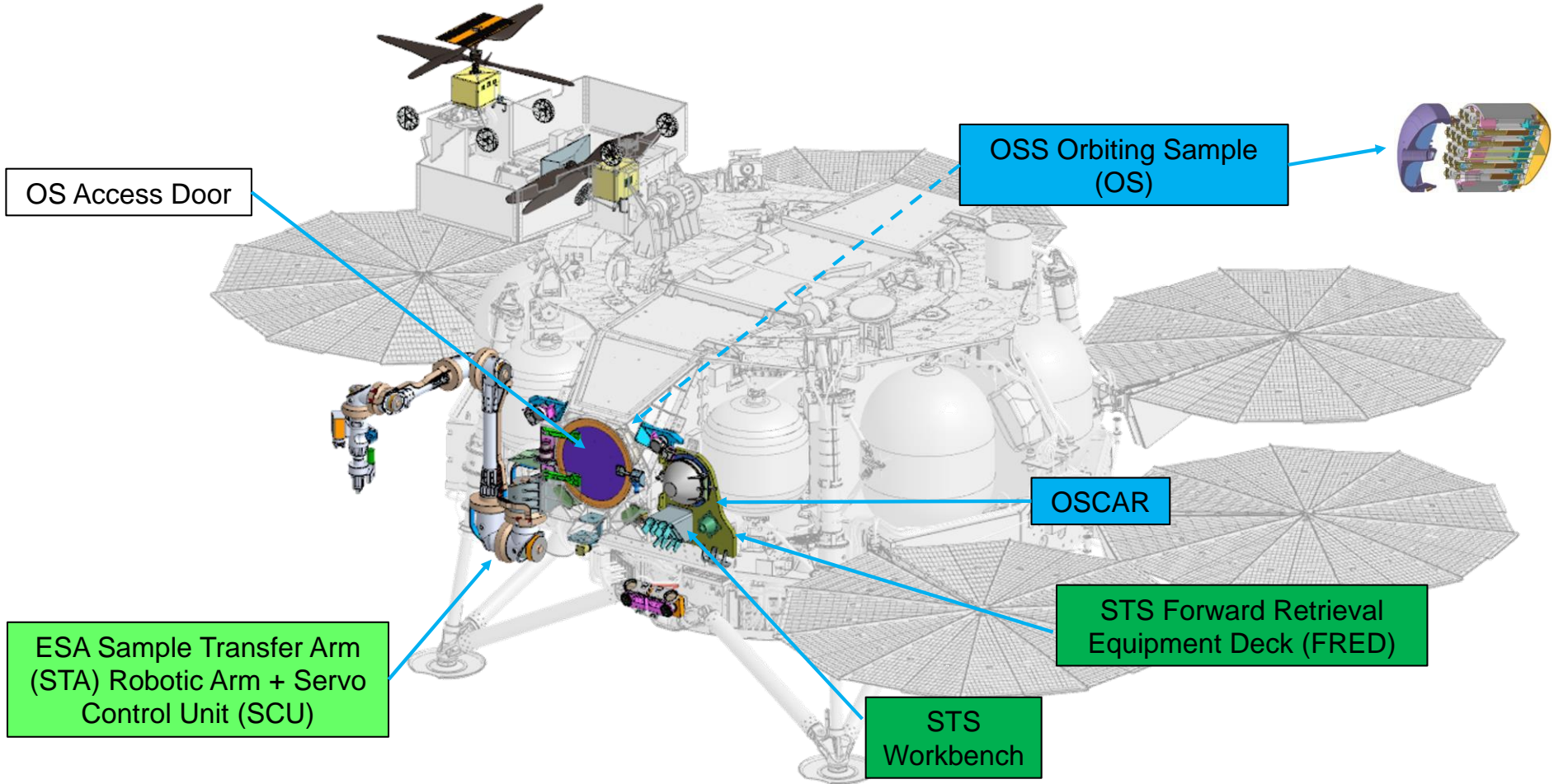
# Mars Sample Return



- Launch in 2028, landing in 2030
- Surface mission required is 372 Martian days (but currently planned is 216)
- The duration of main operations will be shorter: 80 to 90 Martian days for 30 Sample Tubes



# The Sample Transfer Arm



11-13 Apr 2023

The technical data in this document is controlled under the U.S. Export Regulations; release to foreign persons may require an export authorization.

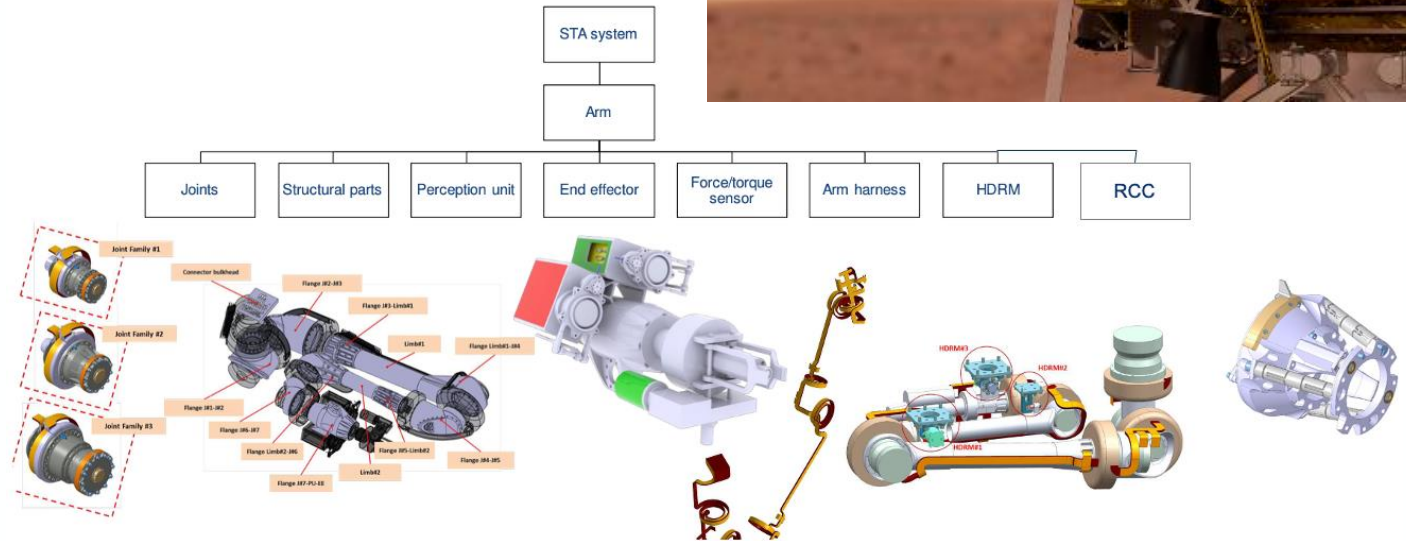
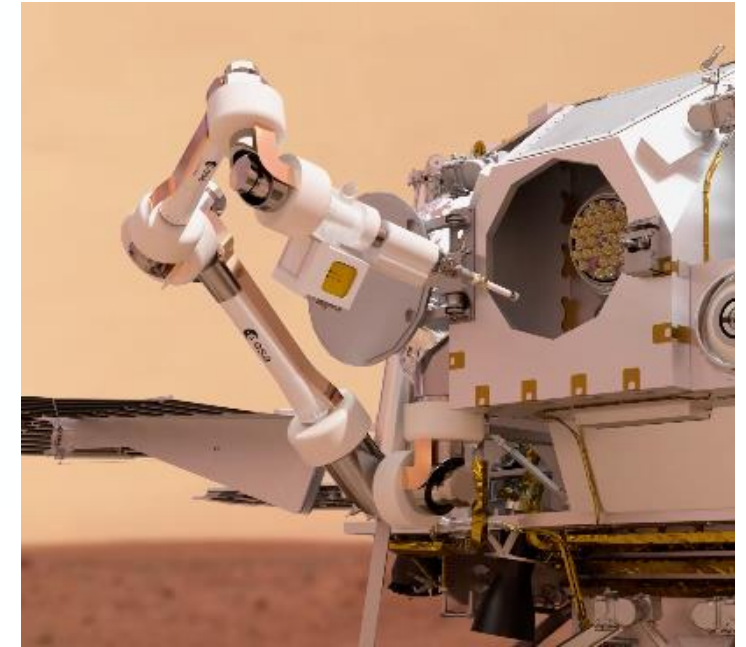
2

18

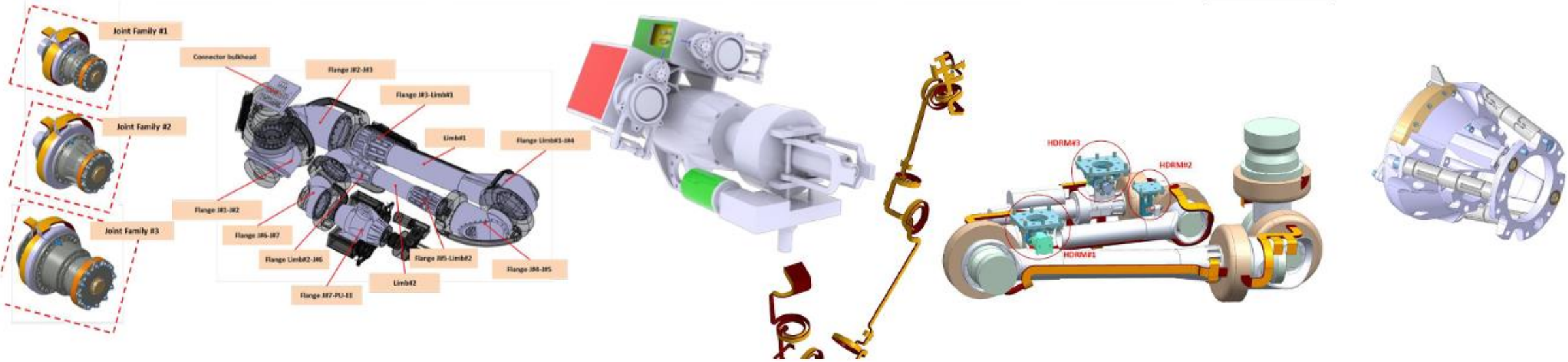
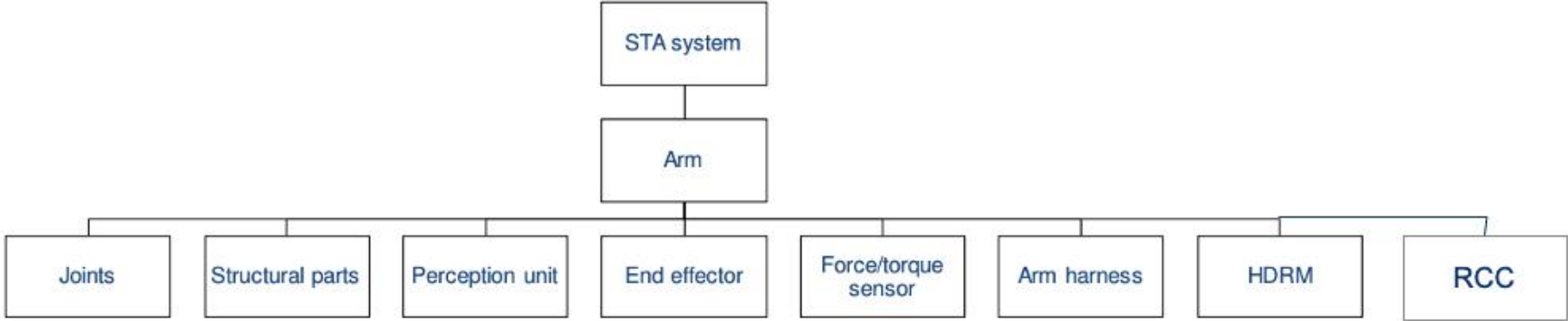


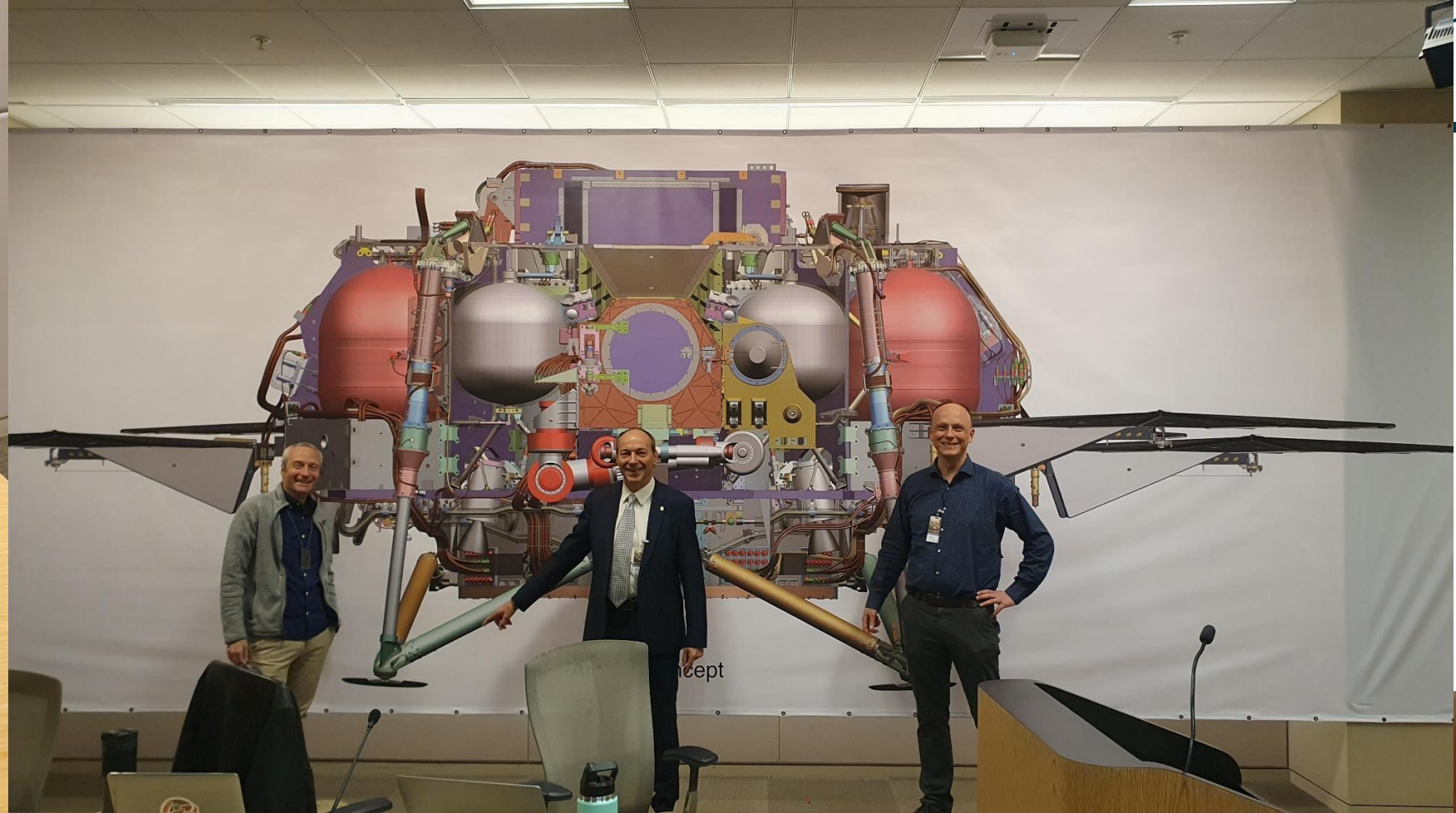
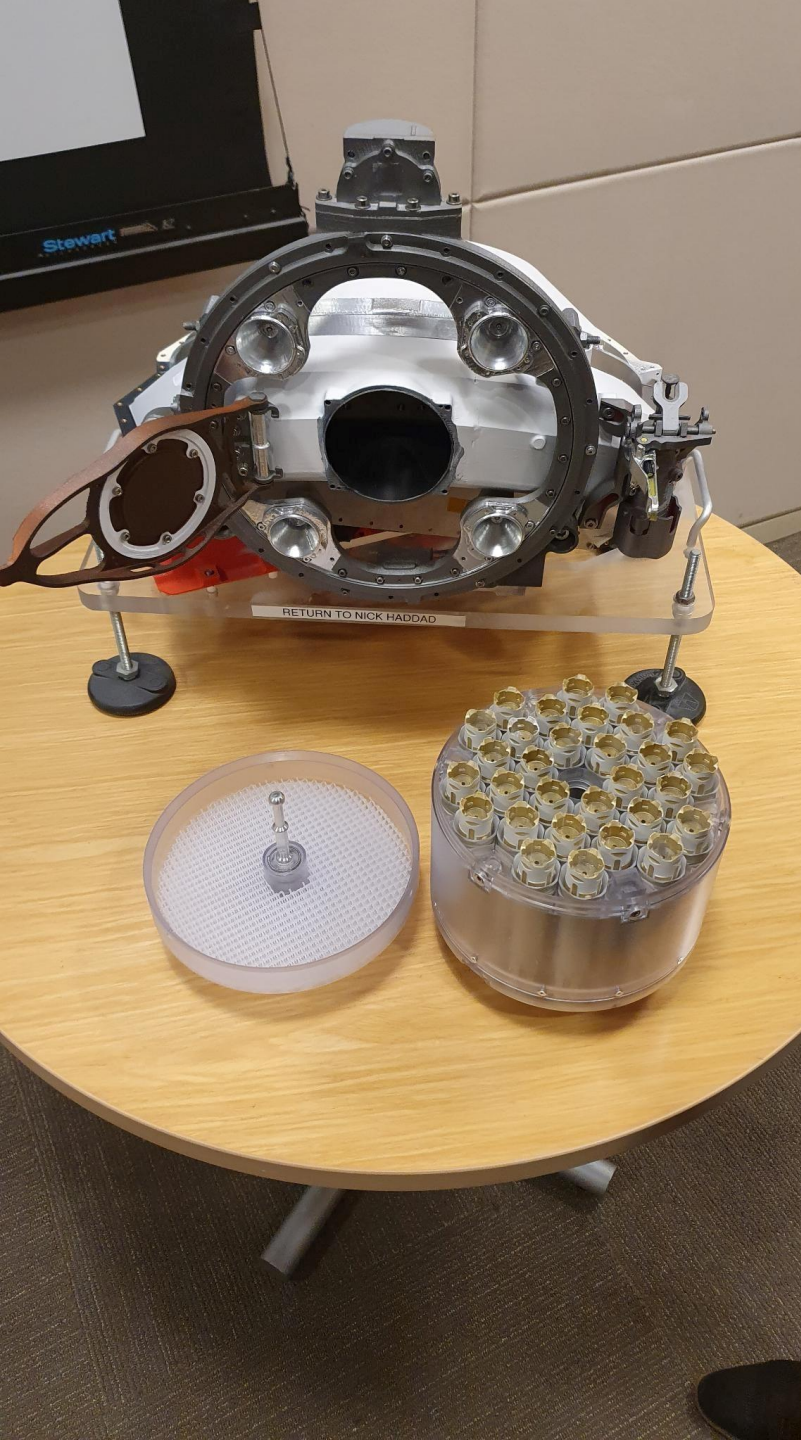
# STA System Description

- 7 degrees of freedom 2m long robotic manipulator.
- A Perception Unit localizes Rover, Sample Tubes, and Orbiting Sample container
  - Camera
  - Martian Dust Protection
  - Vision Software
- A Force/Torque Sensor measures and controls interaction forces during contact with the Rover and the Orbiting Sample container.
- End Effector with 2 degrees of freedom to handle Sample Tubes and OS lid.
- Remote Centre Of Compliance (RCC)
- Hold Down and Release Mechanisms (HDRMs) to stow the arm in launch configuration.



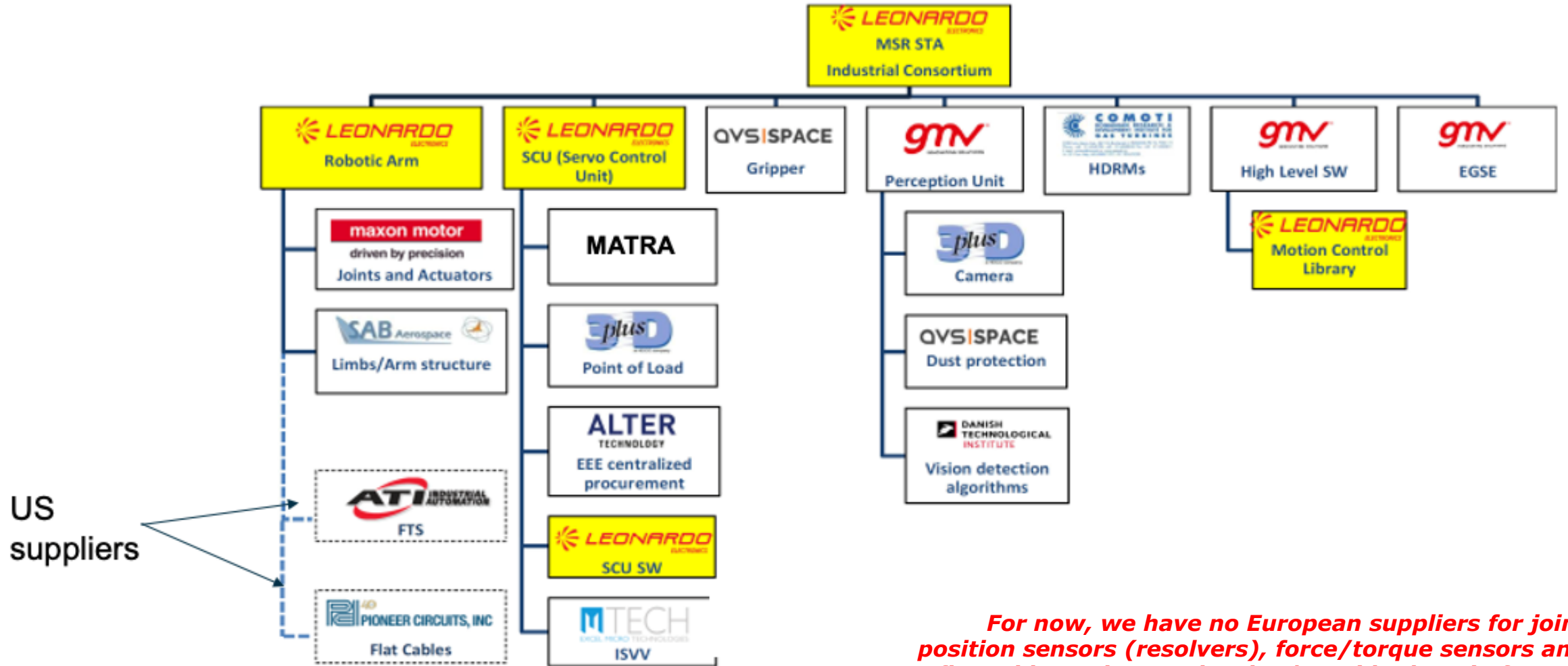
# MSR Sample Transfer Arm







# STA Industrial Consortium

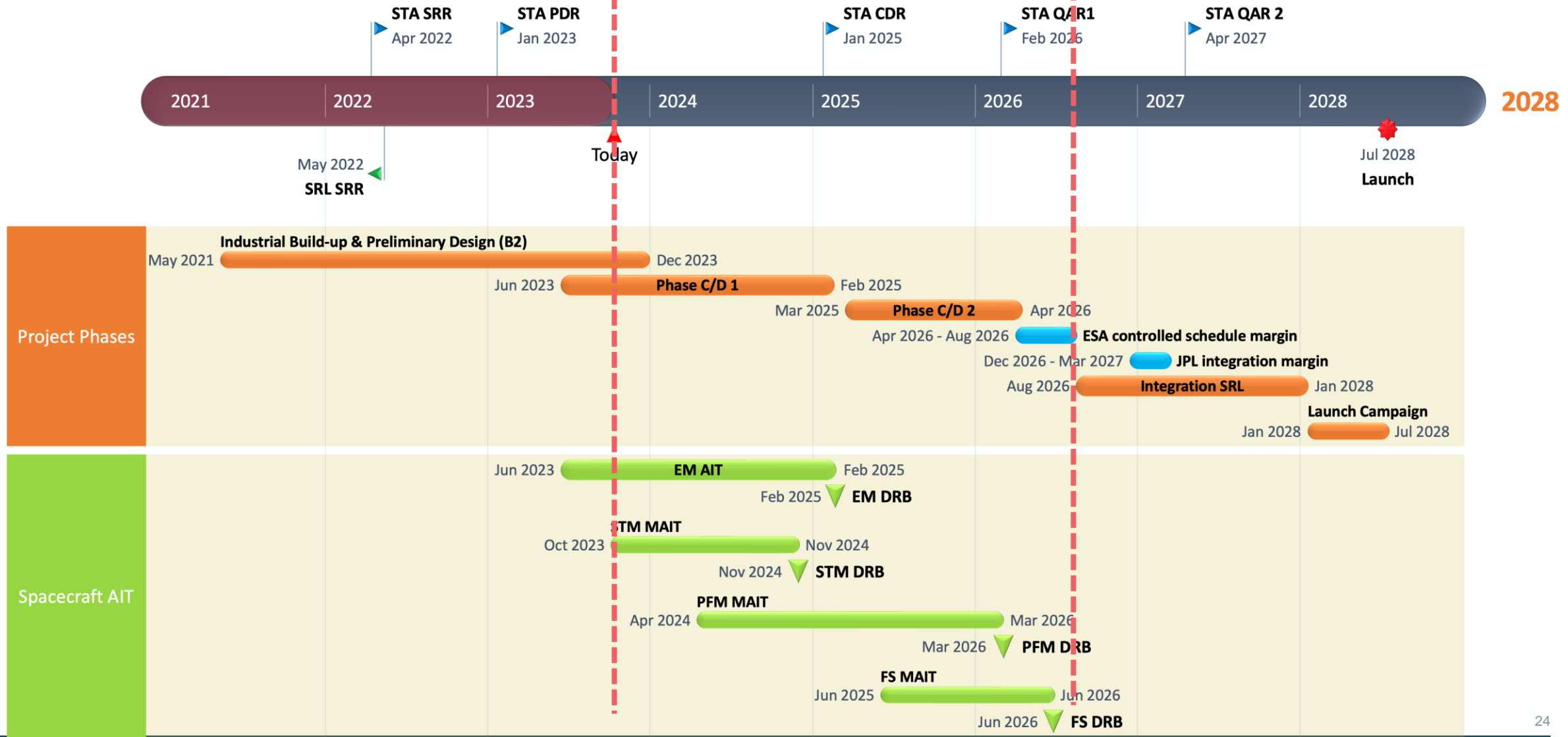


*For now, we have no European suppliers for joint position sensors (resolvers), force/torque sensors and flat cables. Who can develop/provide them in future?*

# Overall Schedule



33 months left





# Main MSR event 2023 - a NASA independent review



The Independent Review Board report was released. It is public and available here:

<https://www.nasa.gov/wp-content/uploads/2023/09/msr-irb-report-final-copy-v3.pdf>

Key takeaways for the STA:

- There is very strong support for the Mars Sample Return programme to continue and for the cooperation with ESA.
- The STA is barely mentioned in the report
- There is likely to be an architecture change. TBC if it will affect the STA interface.
- There could very well be a launch delay



## Organization of Findings and Recommendations

### Findings and Recommendations

- F1 Collecting the Right Samples
- F2 Communicating the Importance of MSR
- F3 Overall Organizational Structure
- F4 Agency-level Leadership and Engagement
- F5 ERO/CCRS and the NASA/ESA Partnership
- F6 OS Impact Across MSR Elements
- F7 UV Decontamination of Possible Biohazards on the OS Exterior
- F8 NASA Coordination with US Regulatory Agencies on Backward Planetary Protection
- F9 Architectural Robustness and Resiliency
- F10 Programmatic Assessment
- F11 Independent Review Structure
- F12 Culture and Communication

### Additional Important Findings and Recommendations

- F13 Verification and Validation
- F14 Cross-Organization Engineering Management
- F15 Telecommunications Infrastructure
- F16 Helicopter Accommodation Risk Balance
- F17 Technical Baseline Management and Change Control
- F18 Launch Vehicles
- F19 Workforce Capacity and Expectations Post COVID-19
- F20 Supply Chain

For now we continue on the assumption that there is no change



**Both stories, ERA and STA, to be continued....**