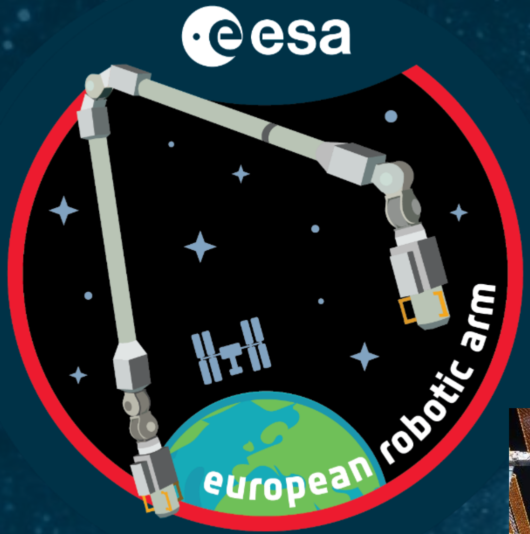
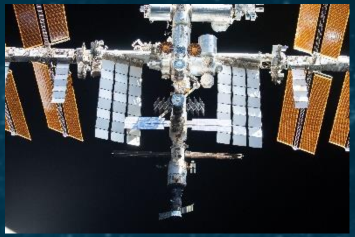
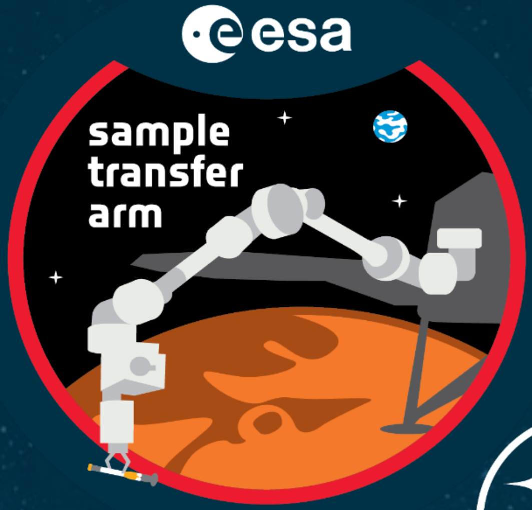






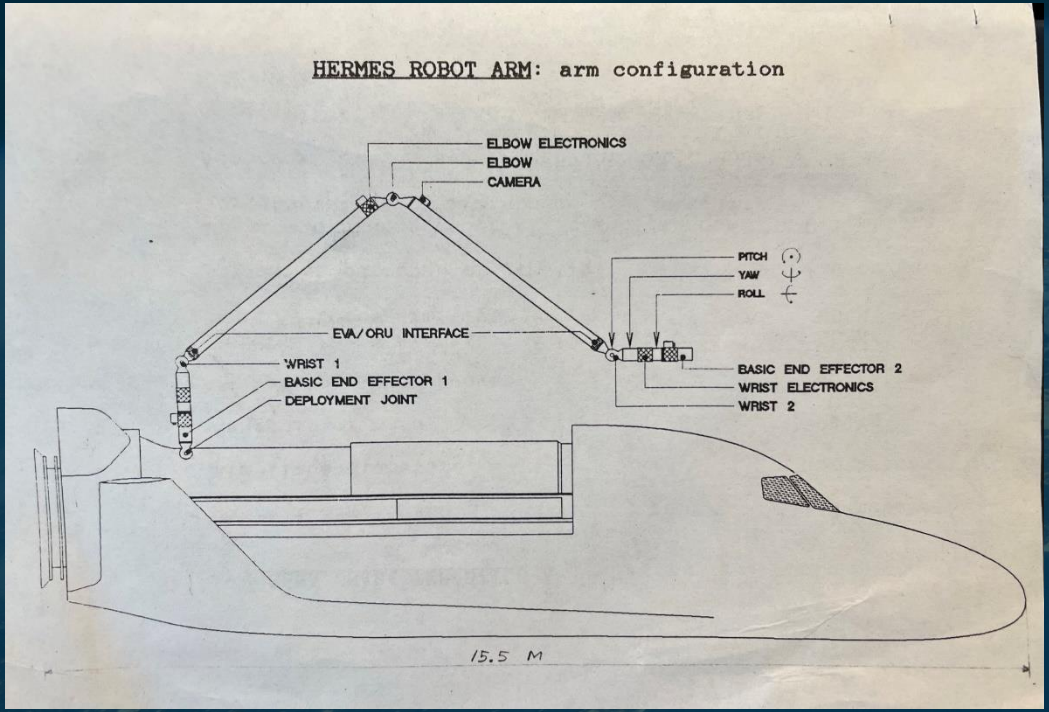
NASA/ESA MARS SAMPLE RETURN

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

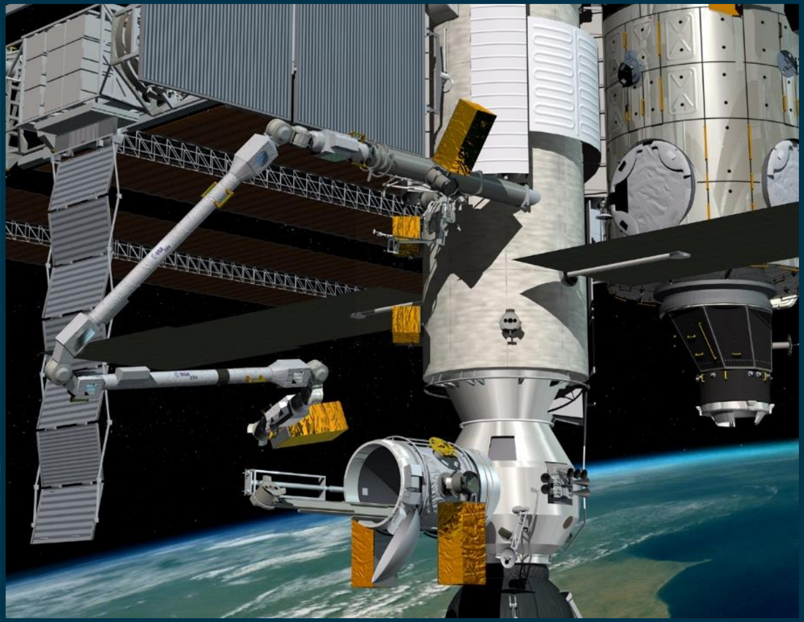
Philippe Schoonejans (ESA)
project manager in human spaceflight and exploration

ASTRA conference
18 October 2023

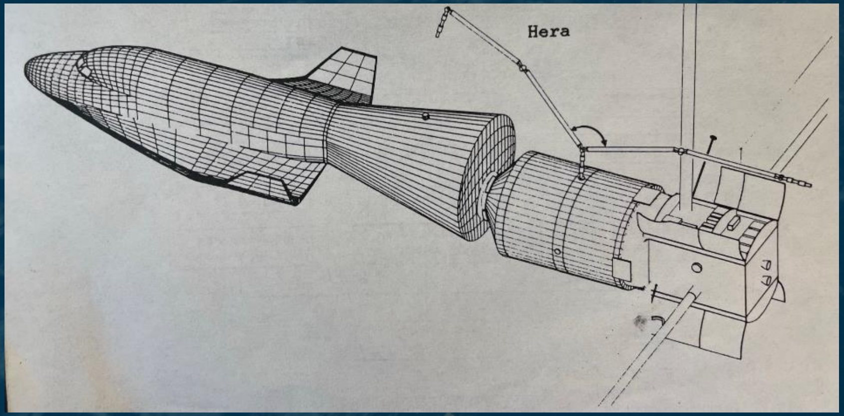
Starting with HERA - design evolution from 1986



HERA (fixed) and Hermes



ERA and MLM airlock



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

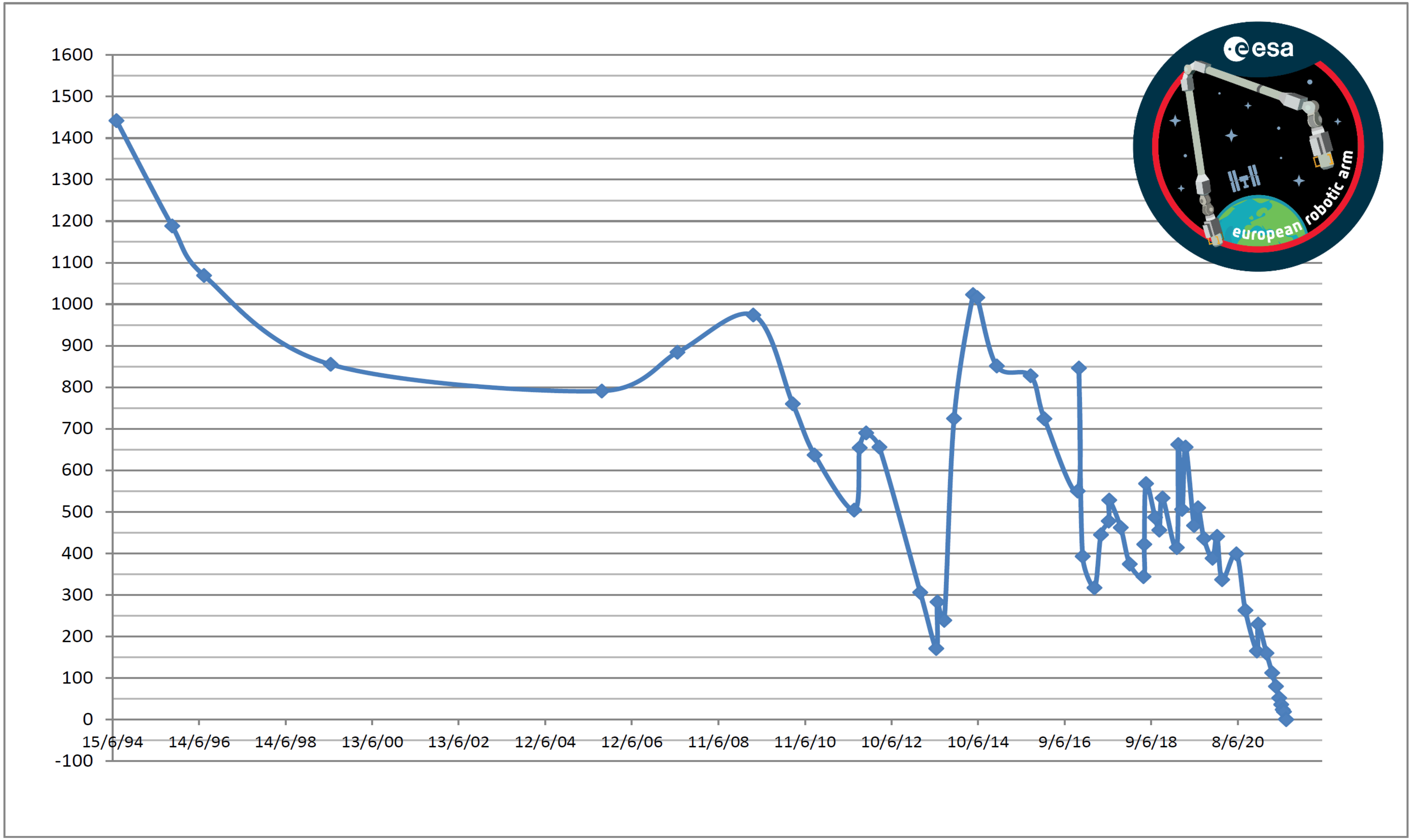
2021 – Launch!

2021 – fix of data connections to MLM

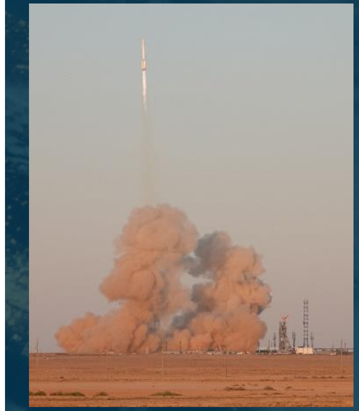
2022 – in orbit commissioning

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

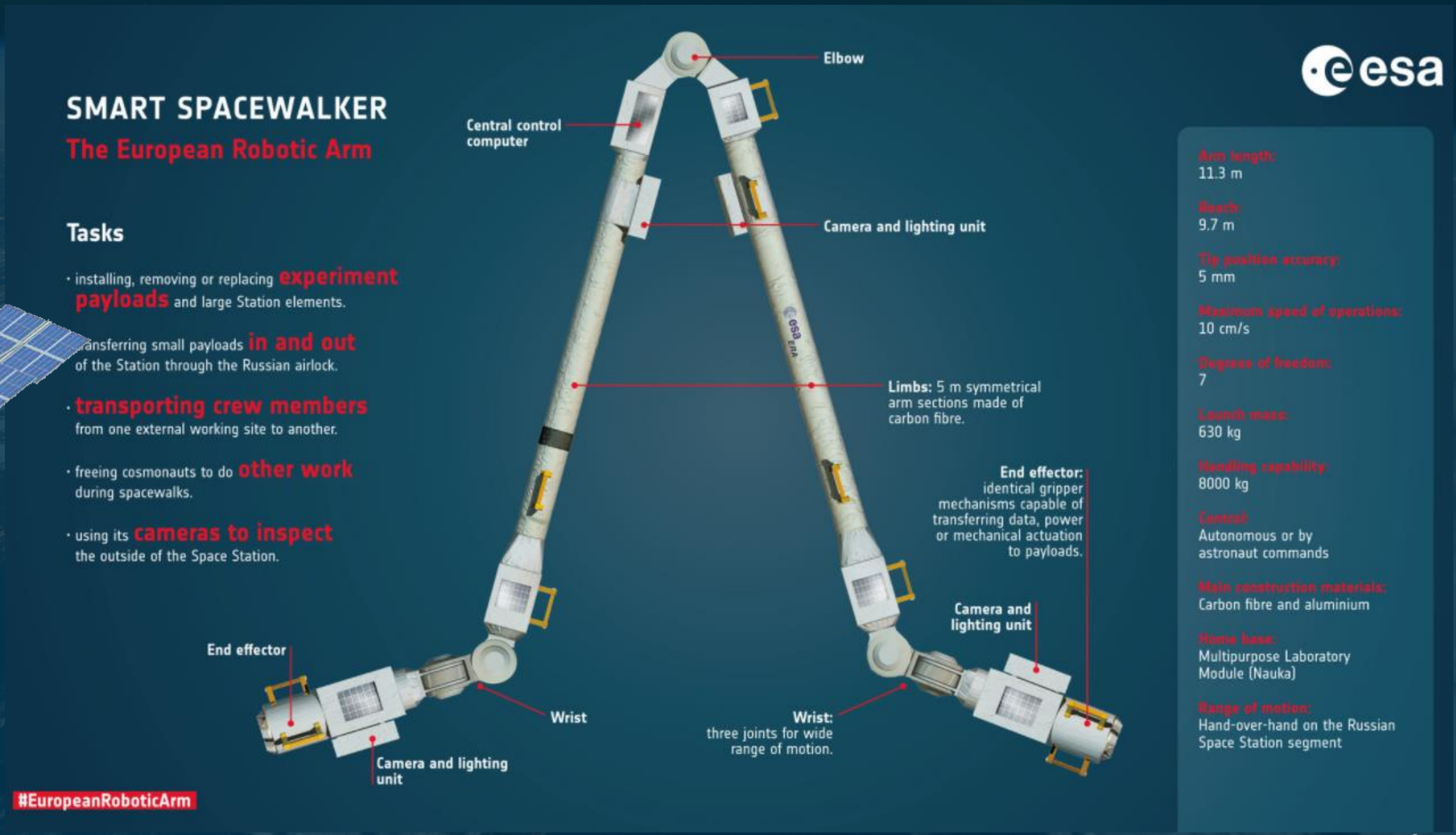
Netherlands	
Dutch Space	Prime
NLR	MPTE
Stork	MJS Mechanics
Belgian	
Sabca	MJS
Spacebel/Trasys	IMMI, MPTE
Alcatel	EGSE
Germany	
EADS/Bremen	EES, MJS, OBC
Bosch	Parts
Italy	
OG	CLU
Technospacio	Software
Fiar	EMMI
Denmark	
Per Udsen	GEO, WET
Terma	Software
Switzerland	
HTS	MLS
Sweden	
Saab	OBC

Note: Table does not show equipment level

European Robotic Arm final design

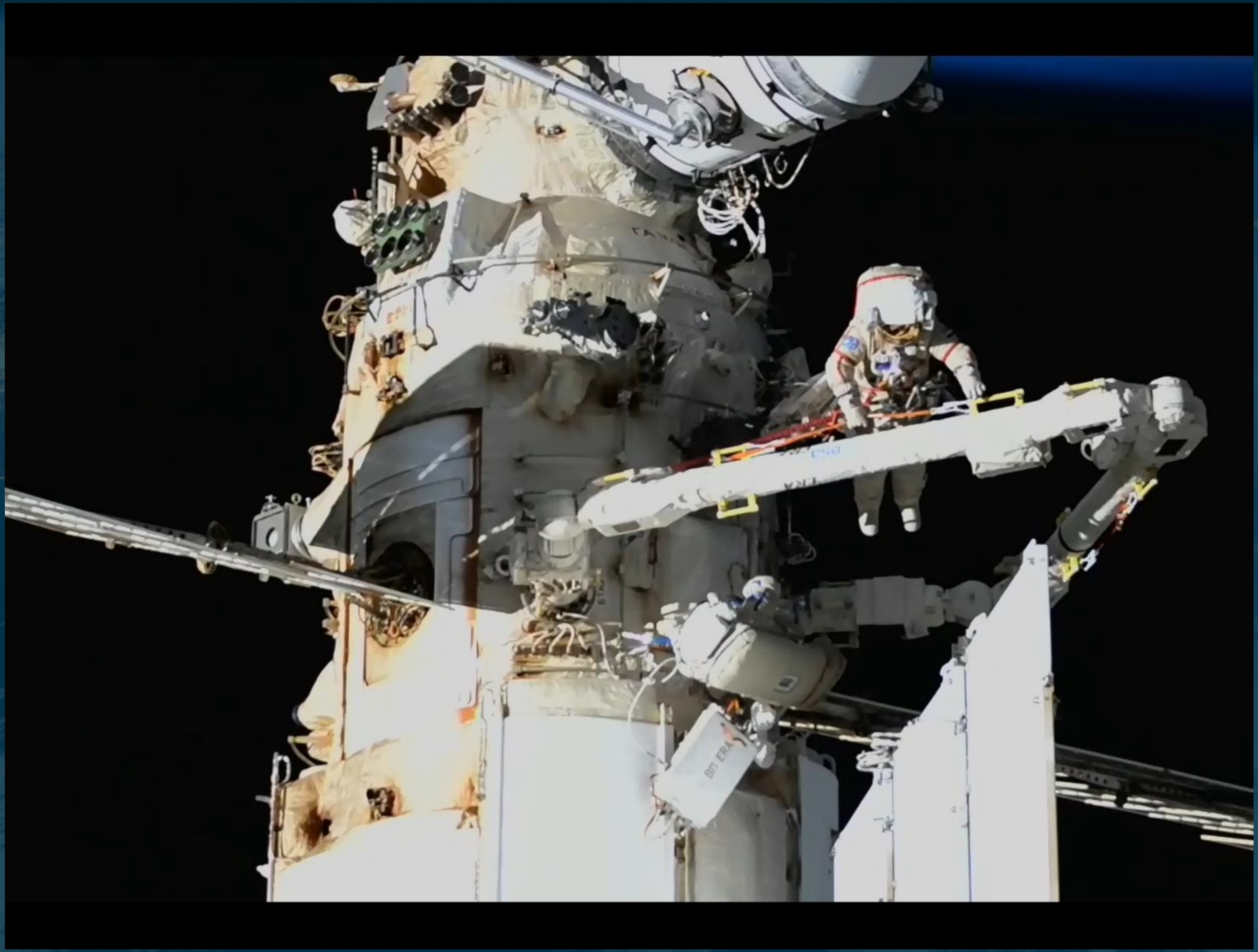
MLM = Multipurpose Laboratory Module (developed by Khrunichev)

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



Many EVAs from unpacking to final outfitting on ISS

EVA52 - Apr 2022

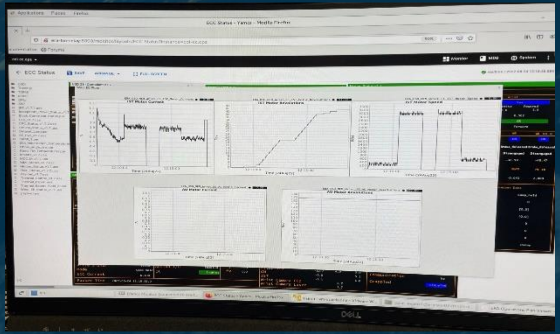


EVA58 - May 2023

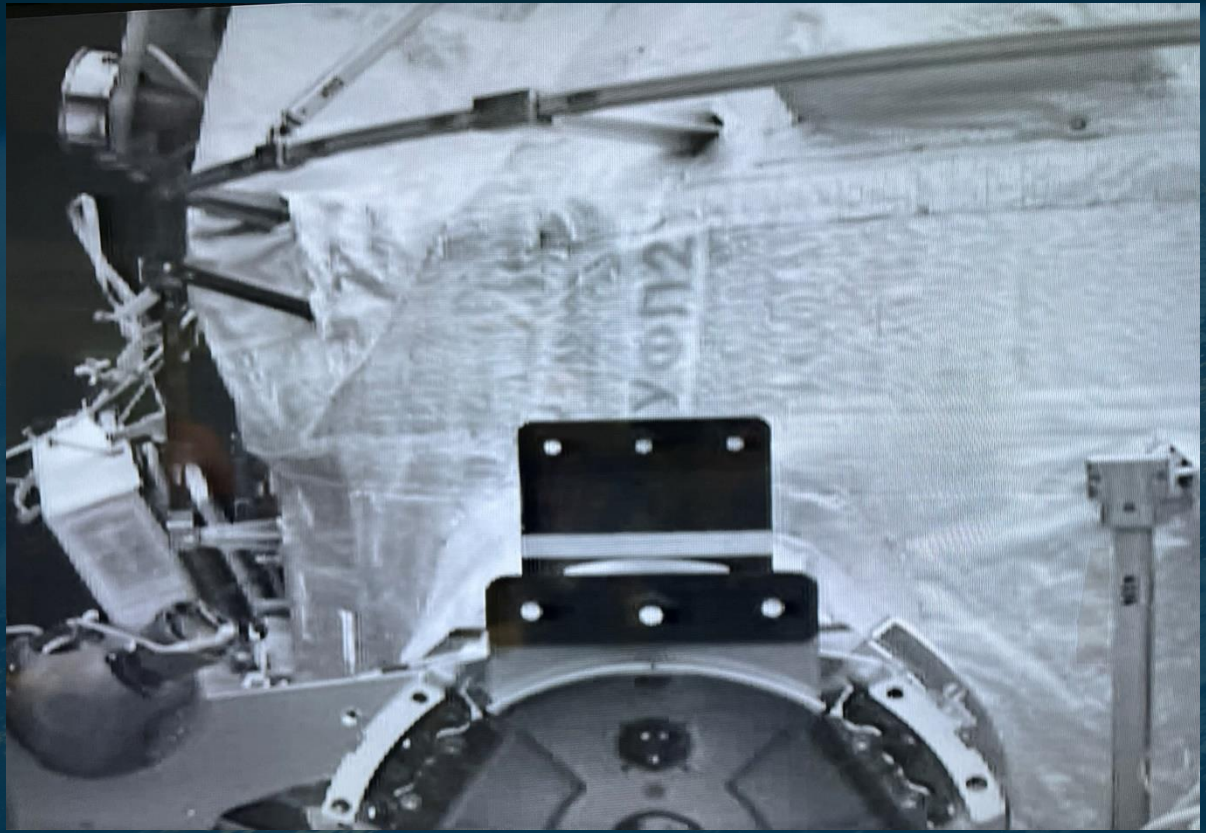
ERA commissioning, test missions and operational missions	EVA	Date
ERA unpacking and installation	52	24/3+18/4 2022
Initialization mission, first ERA motion between basepoints	53	28/4+5/5 2022
ERA move to a safe position after failure to grapple second basepoint	-	13/5 2022
Test mission to investigate 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
1st 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
Radiator installation started on 25 Nov and 14 Dec but unfinished due to EVA suit issues and Soyuz leak respectively		
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

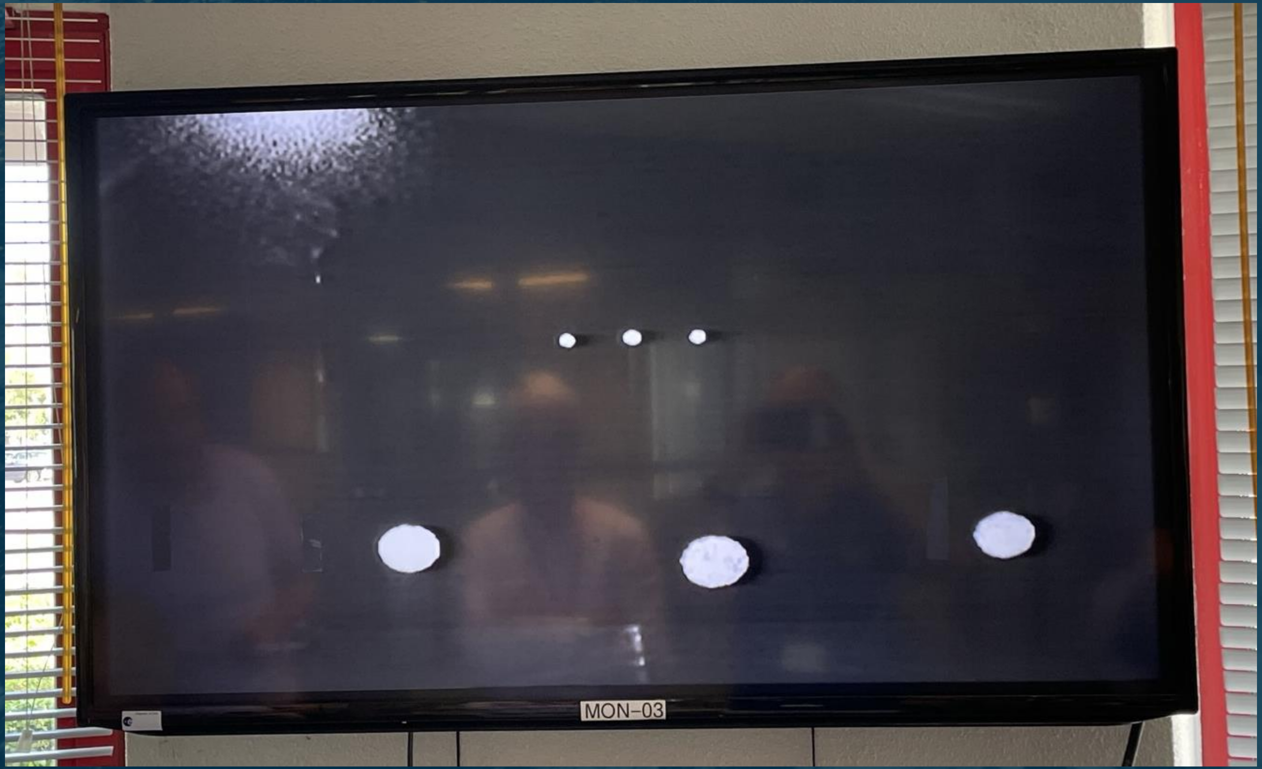


Real time video from ERA End Effector camera



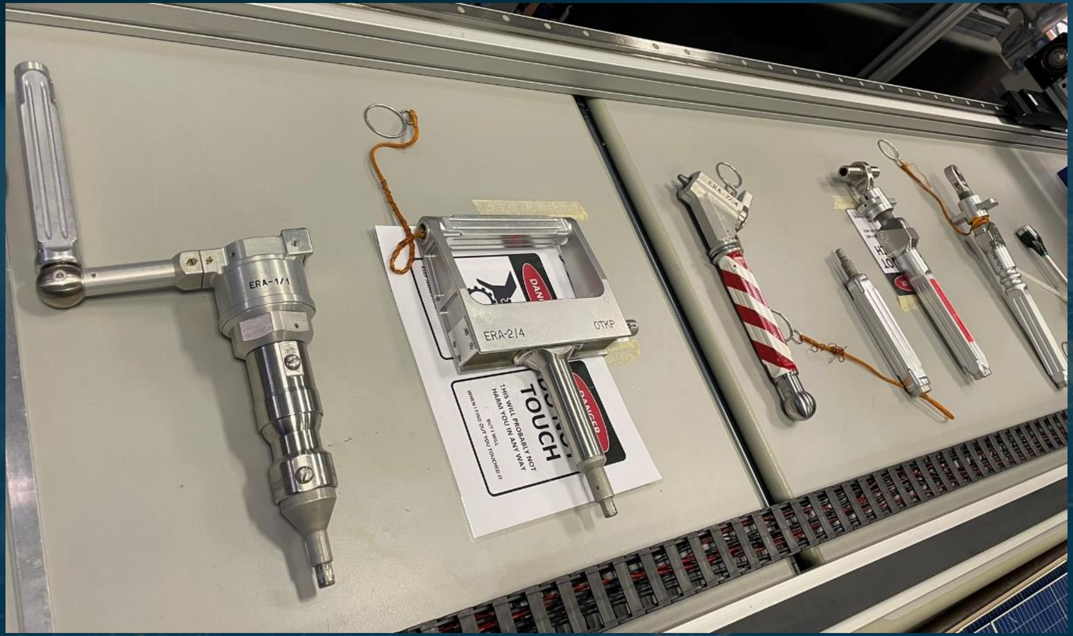
Camera in imaging mode
24-8-2022

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



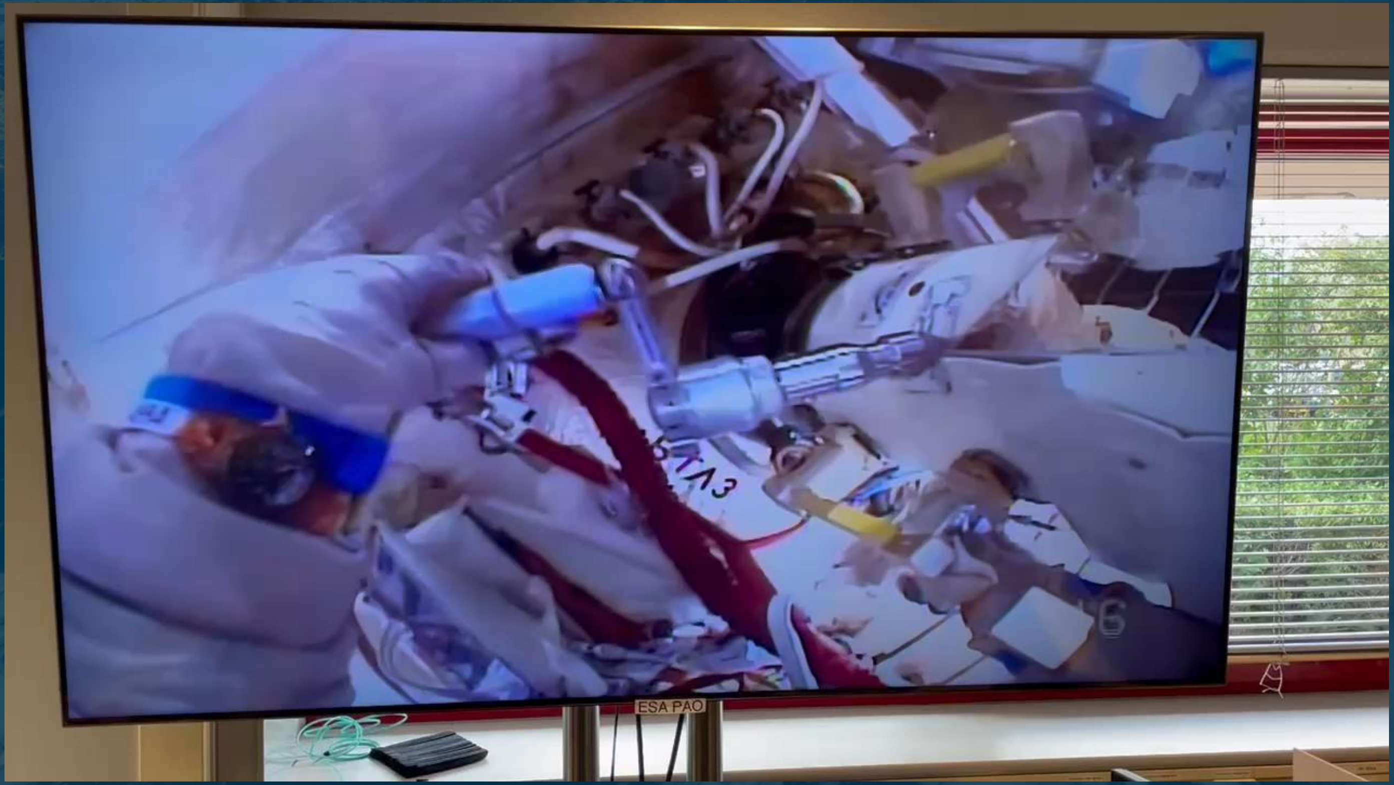
THE EUROPEAN SPACE AGENCY

Real time video from EVA helmet camera



EVA tools built by RSC Energia

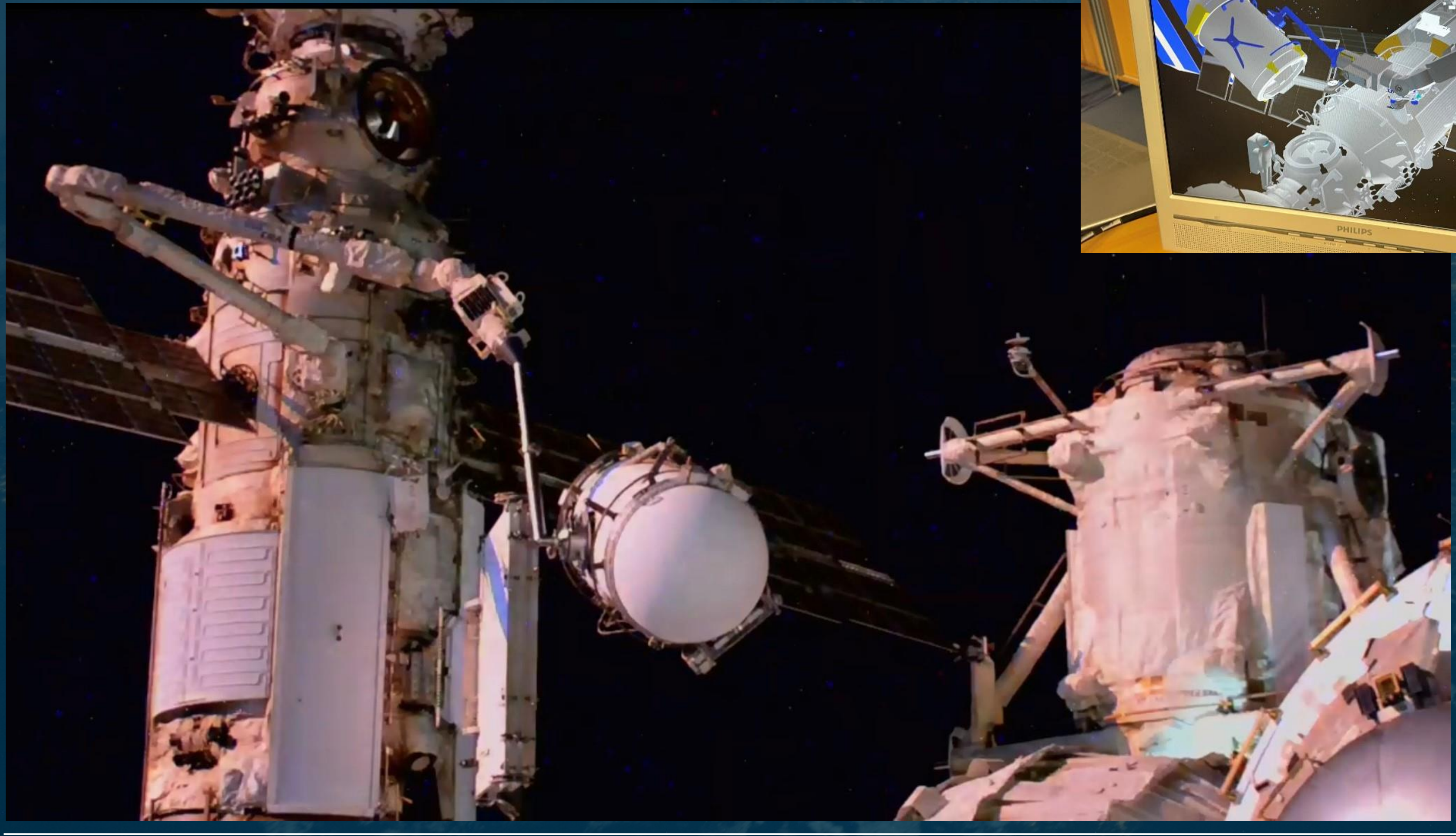
testing manual override of mechanisms with tool “EVA-1” EVA54a 2-9-2022

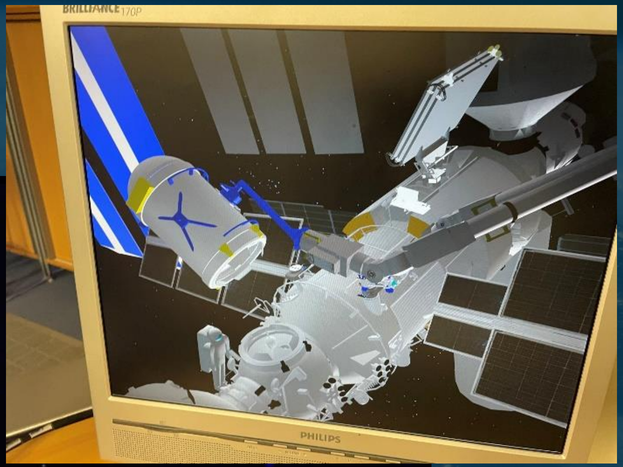


ERA's first main ISS assembly operations

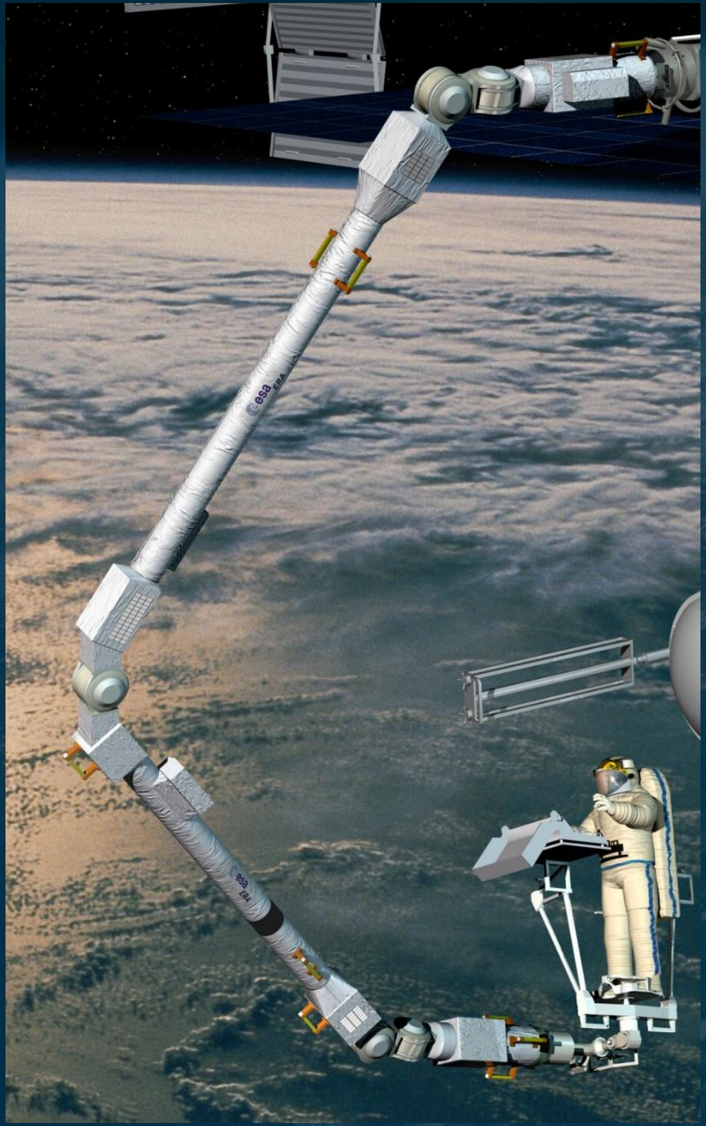
ERA's first operational mission in a 2 mins timelapse

Even more complex – installing MLM Airlock on 4 May ‘23





Transport of an EVA crew – August 2023



A cool artist impression became reality

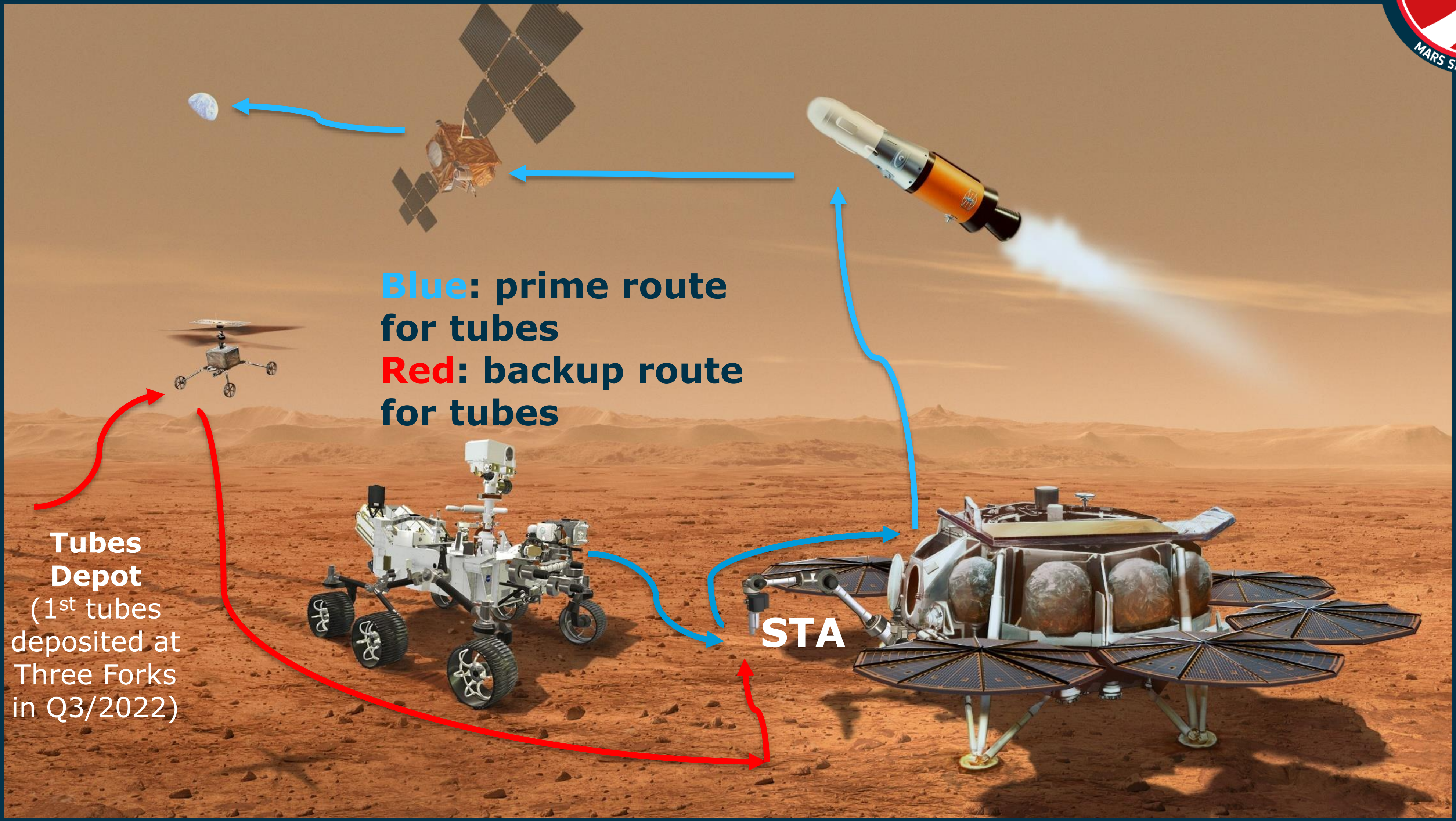
All ERA functions ready for use!

ERA Lessons Learned (technical)

- 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

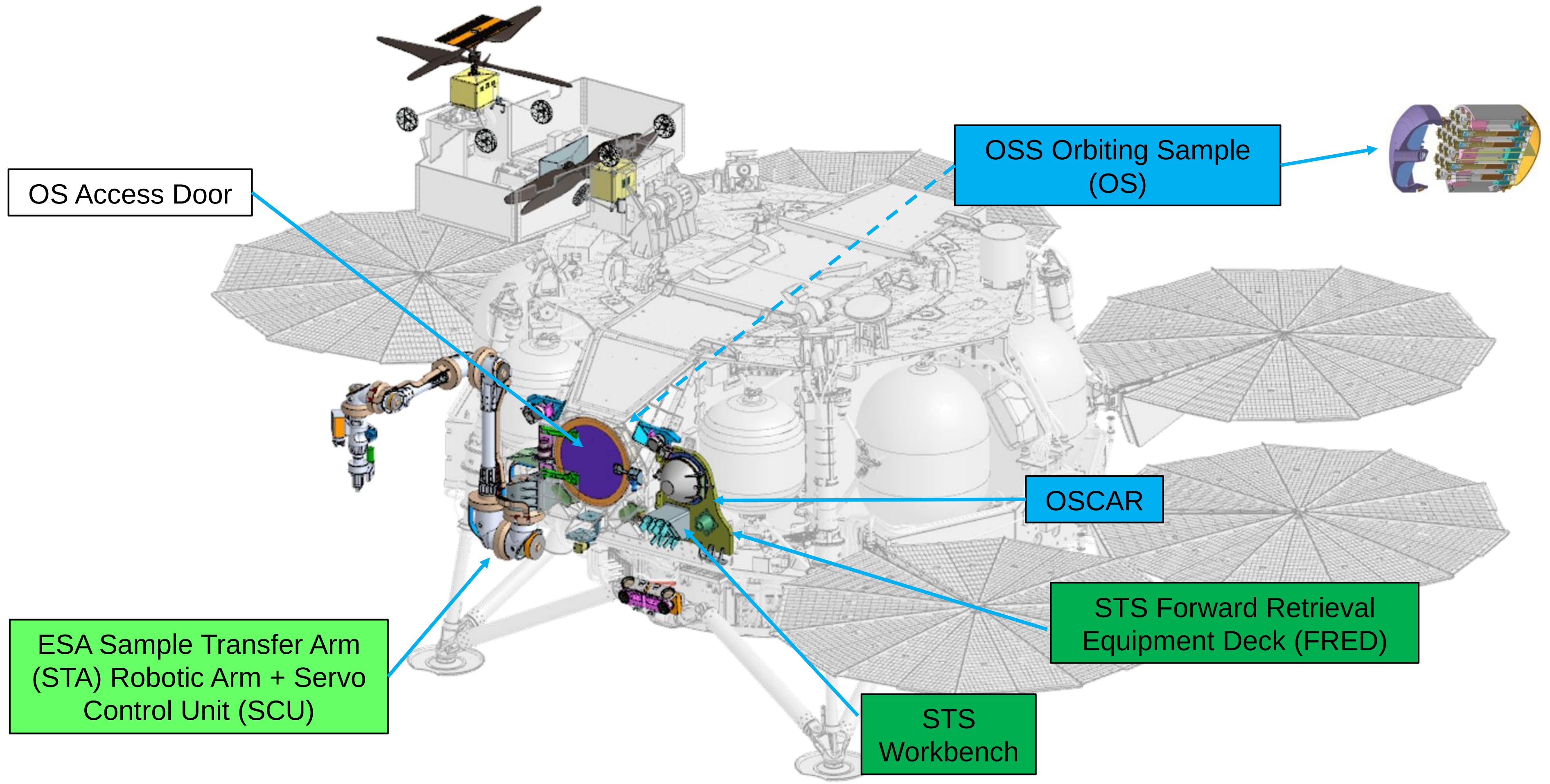
- During commissioning and ops, EVA crew availability is an asset – too bad for Mars robots….

Mars Sample Return



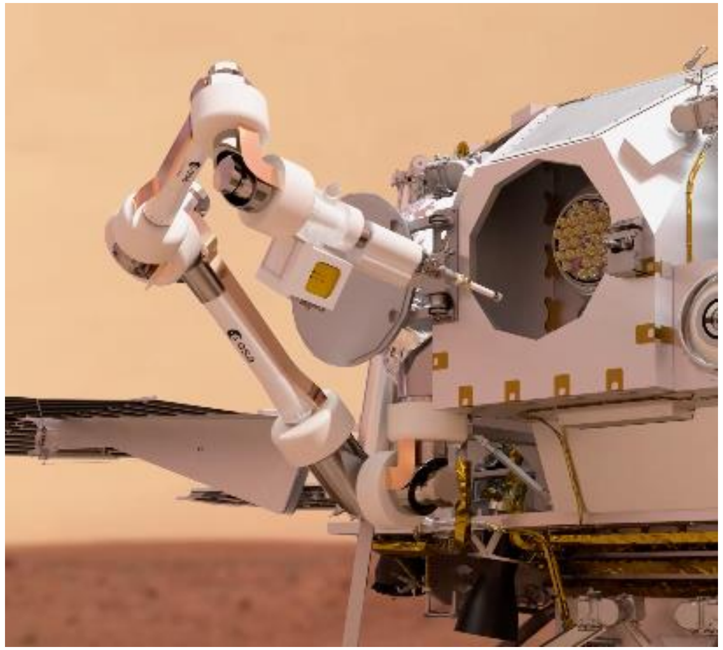
- Launch in 2028, landing in 2030
- Surface mission required is 372 Martian days (but currently planned is 216)
- The duration of main operations will be shorter: 80 to 90 Martian days for 30 Sample Tubes

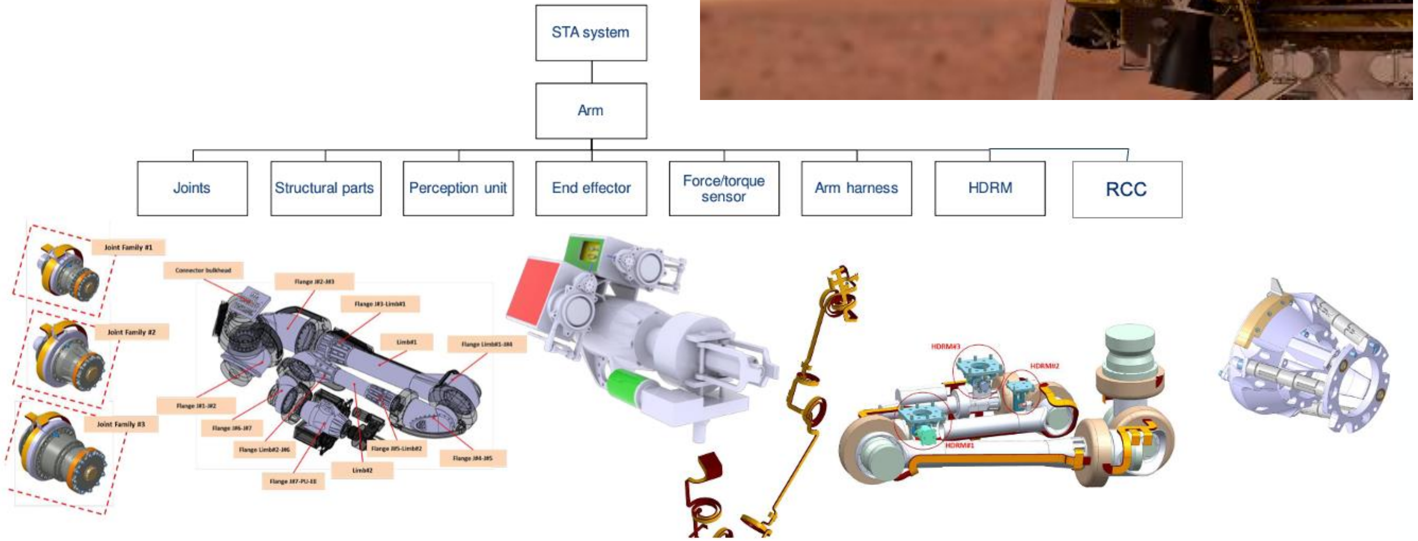
The Sample Transfer Arm



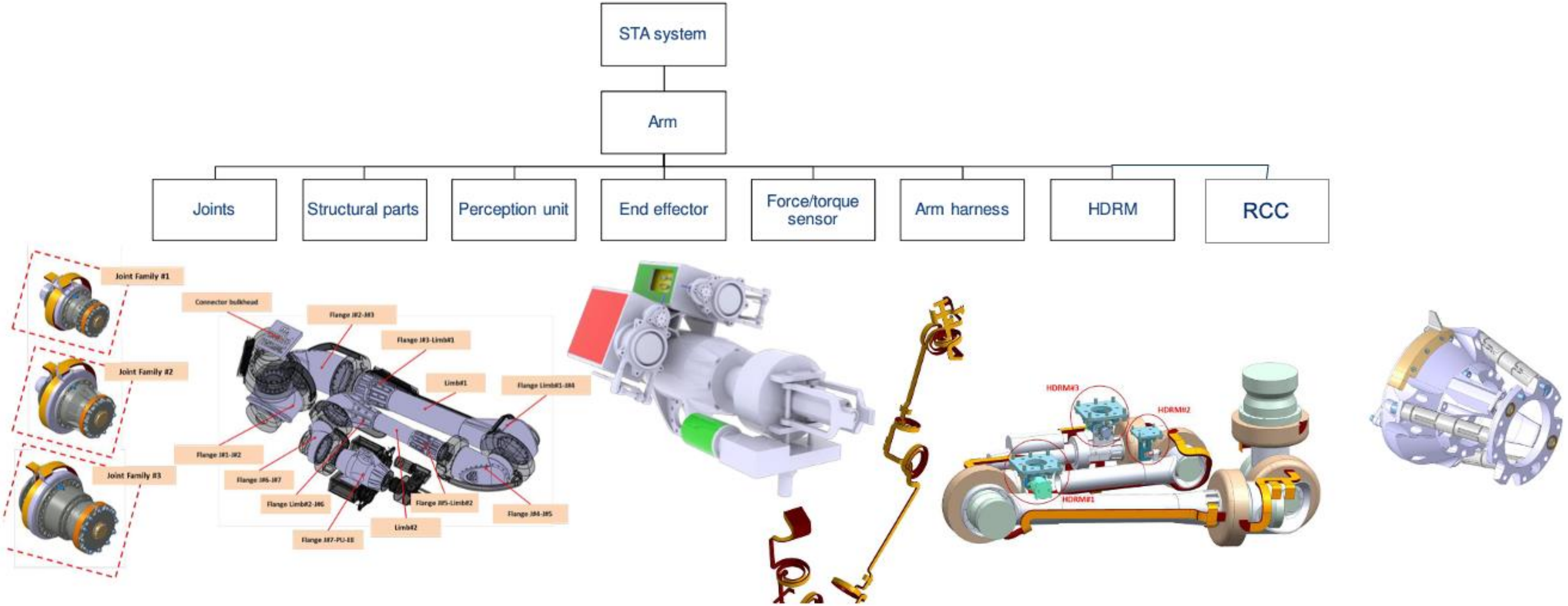
STA System Description

- 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.

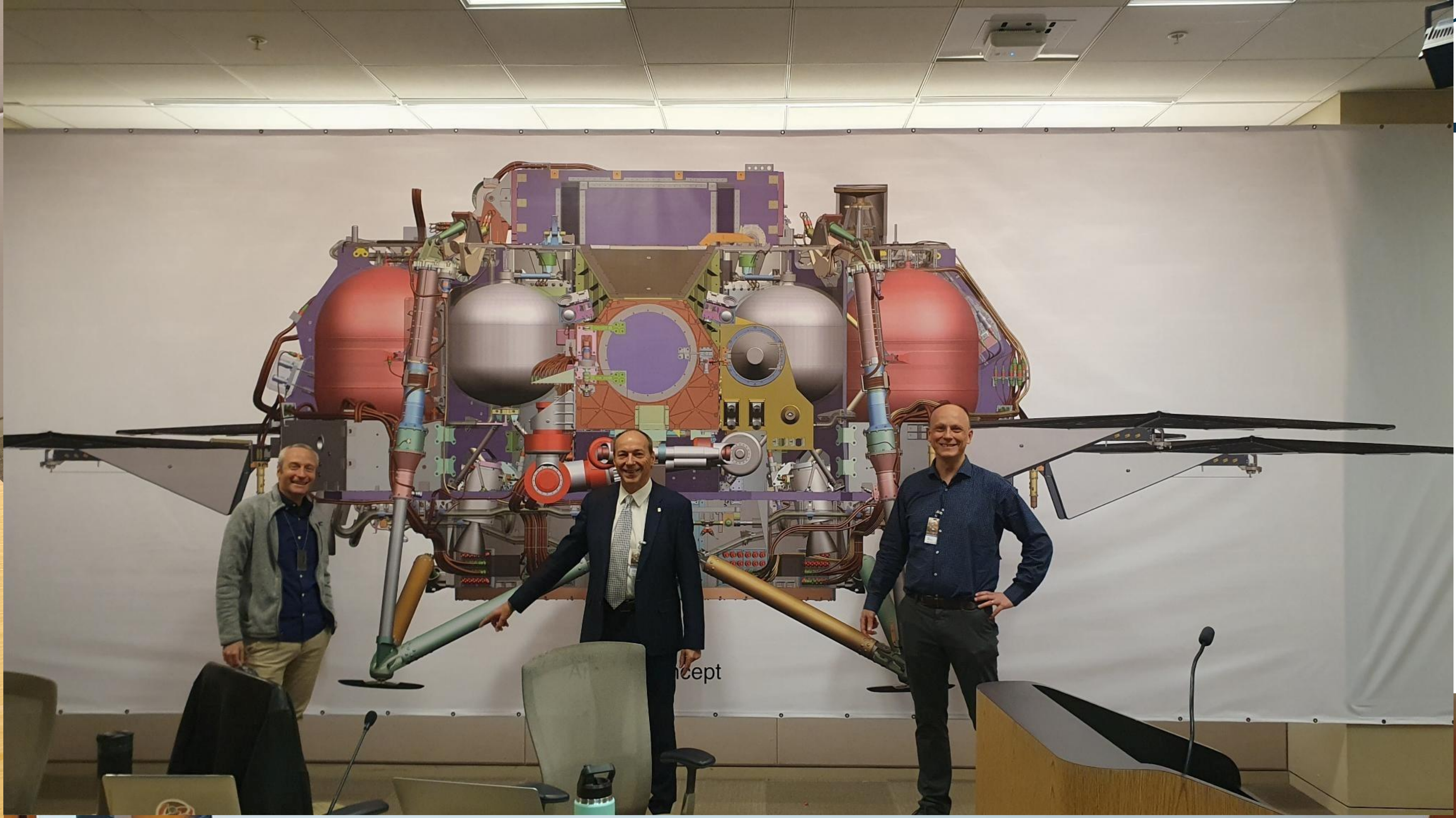




MSR Sample Transfer Arm

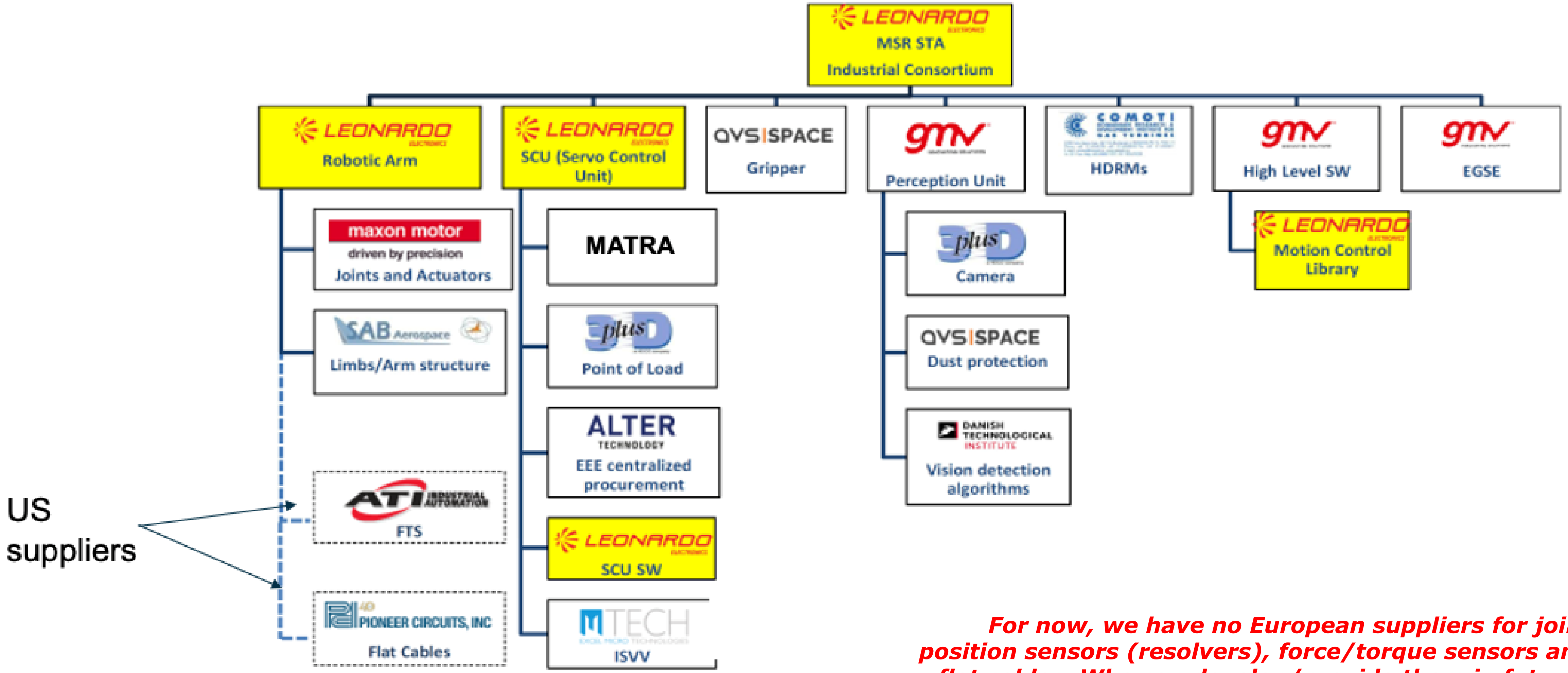



Stewart
RETURN TO NICK HADDAD



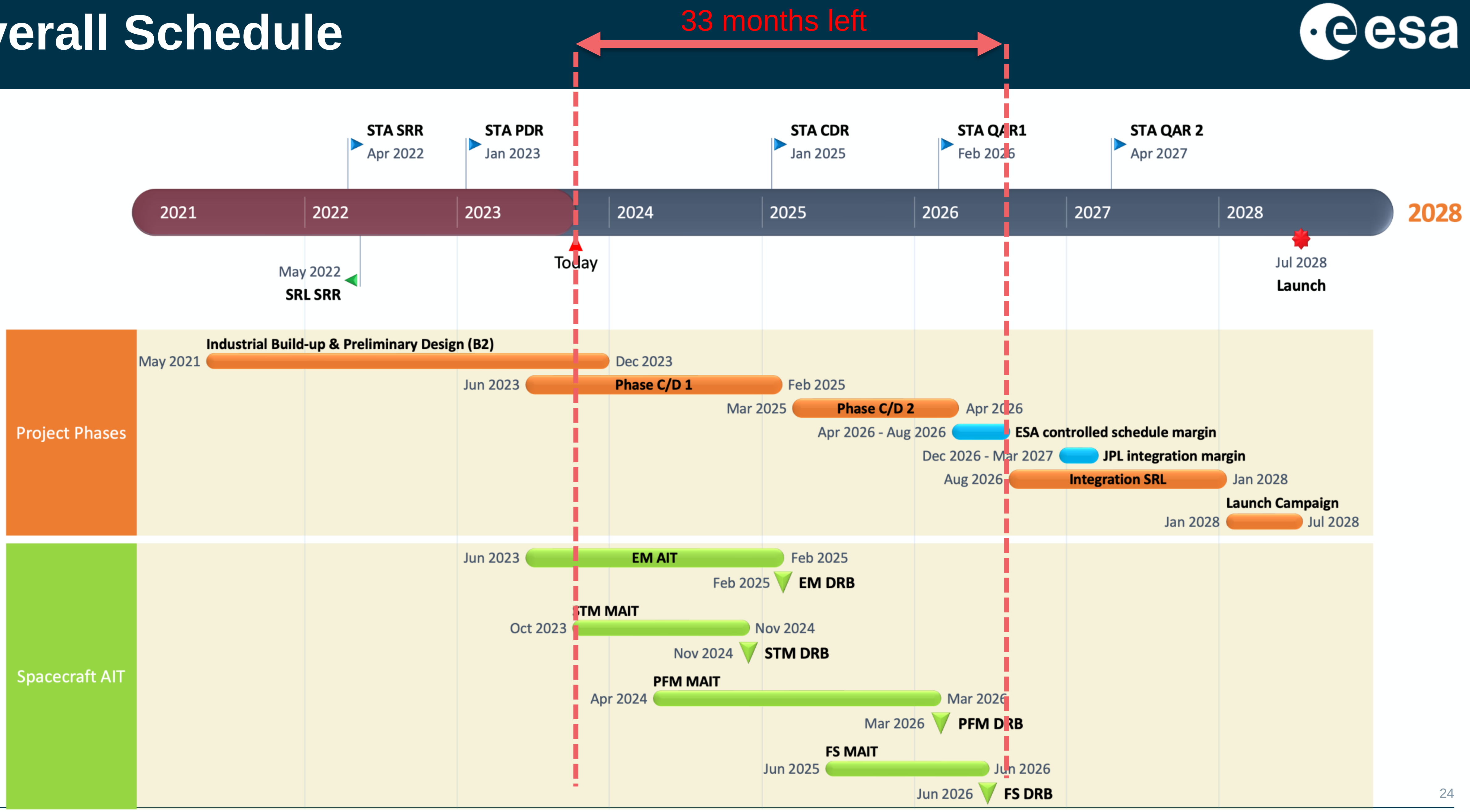

esa

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



Main MSR event 2023 - a NASA independent review

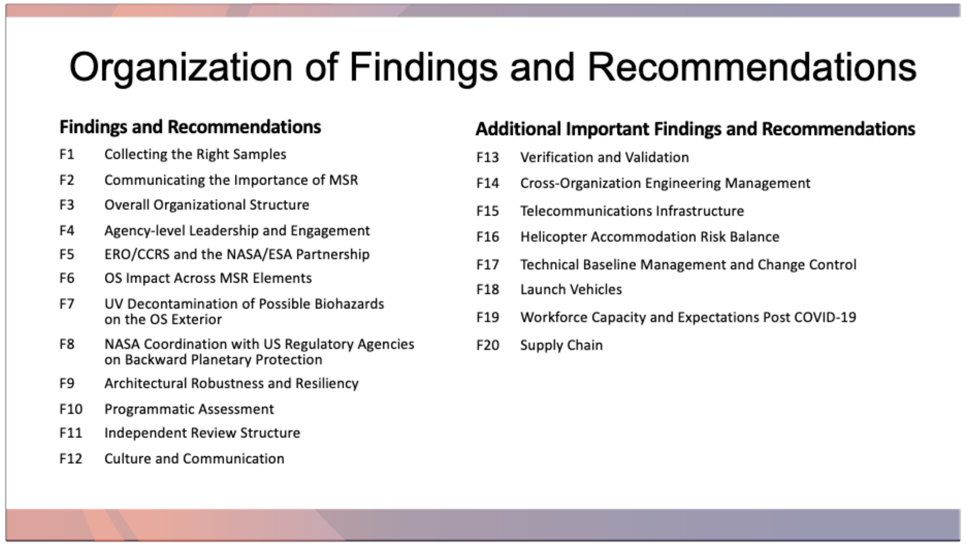
The Independent Review Board report was released. It is public and available here:

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

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



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