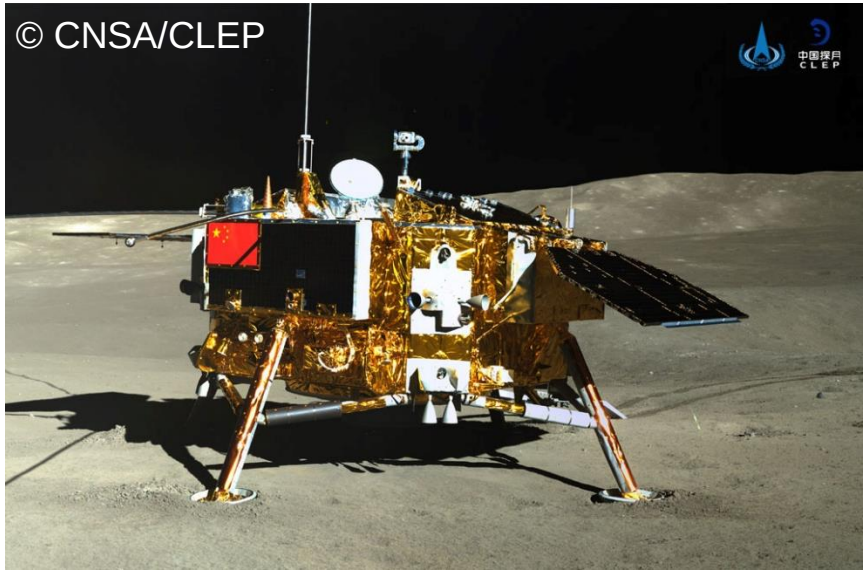
NASA ARTEMIS I MISSION AND THE MARE EXPERIMENT

Thomas Berger for the MARE Team

Radiation: Exploration

Ehresmann, B., et al. (2022) *The Martian surface radiation environment at solar minimum measured with MSL/RAD* ICARUS https://doi.org/10.1016/j.icarus.2022.115035



Zhang et al. (2020) First measurements of the radiation dose on the lunar surface. *Sci. Adv.* 6:eaaz1334 https://doi.org/10.1126/sciadv.aaz1334

Berger T et al. (2020) Long term variations of galactic cosmic radiation on board the International Space Station, on the Moon and on the surface of Mars. J. Space Weather Space Clim. 10:34 https://doi.org/10.1051/swsc/2020028

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

Kiel University
Christian-Albrechts-Universität zu Kiel

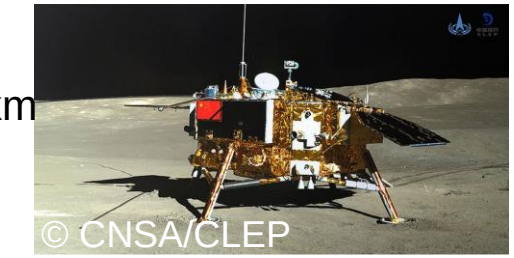
Radiation: Exploration (January 2019)

6x10^7 km

Mars MSL-RAD **29 µSv/h**

Daten: MSL Rad Team Berger et al. (2020) *J. Space Weather. Space Clim.*10:34

3x10^5 km



Mond LND **57 µSv/h**

Daten: LND Team Zhang et al. (2020) *Sci.Adv*. 6:eaaz1334

420 km

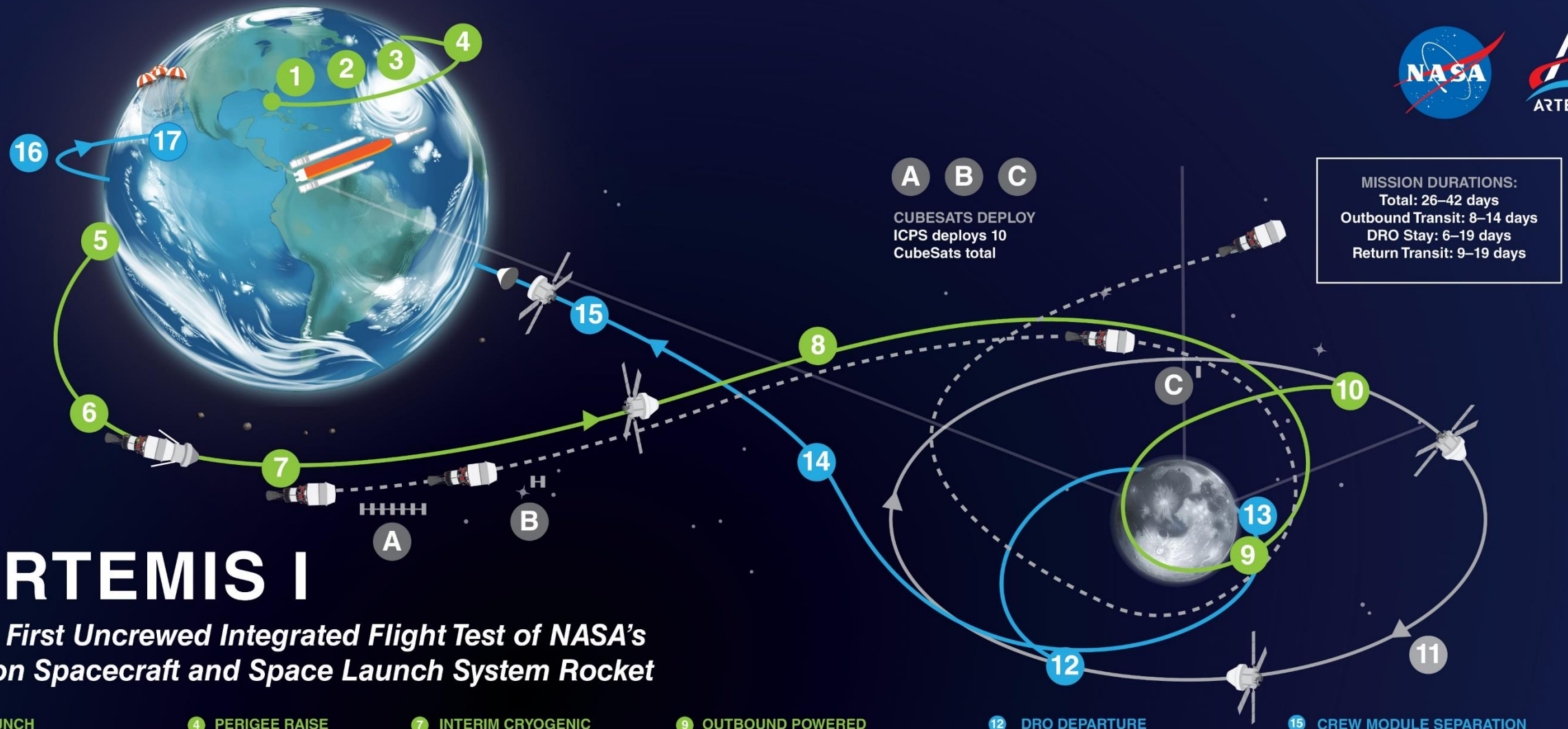
ISS DOSTEL **30 µSv/h**

Daten: DOSIS 3D Team Berger et al. (2020) *J. Space Weather. Space Clim.* 10:34

0.3 km

Erde Köln **0.1 µSv/h**

NASA ARTEMIS I



ARTEMIS I

The First Uncrewed Integrated Flight Test of NASA's Orion Spacecraft and Space Launch System Rocket

CUBESATS DEPLOY
ICPS deploys 10 CubeSats total

MISSION DURATIONS:
Total: 26–42 days
Outbound Transit: 8–14 days
DRO Stay: 6–19 days
Return Transit: 9–19 days

1. **LAUNCH**
SLS and Orion lift off from pad 39B at Kennedy Space Center.

2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**

3. **CORE STAGE MAIN ENGINE CUT OFF**
With separation.

4. **PERIGEE RAISE MANEUVER**

5. **EARTH ORBIT**
Systems check with solar panel adjustments.

6. **TRANS LUNAR INJECTION (TLI) BURN**
Maneuver lasts for approximately 20 minutes.

7. **INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION AND DISPOSAL**
ICPS commits Orion to moon at TLI.

8. **OUTBOUND TRAJECTORY CORRECTION (OTC) BURNS**
As necessary adjust trajectory for lunar flyby to Distant Retrograde Orbit (DRO).

9. **OUTBOUND POWERED FLYBY (OPF)**
60 nmi from the Moon; targets DRO insertion.

10. **LUNAR ORBIT INSERTION**
Enter Distant Retrograde Orbit.

11. **DISTANT RETROGRADE ORBIT**
Perform half or one and a half revolutions in the orbit period 38,000 nmi from the surface of the Moon.

12. **DRO DEPARTURE**
Leave DRO and start return to Earth.

13. **RETURN POWERED FLYBY (RPF)**
RPF burn prep and return coast to Earth initiated.

14. **RETURN TRANSIT**
Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere.

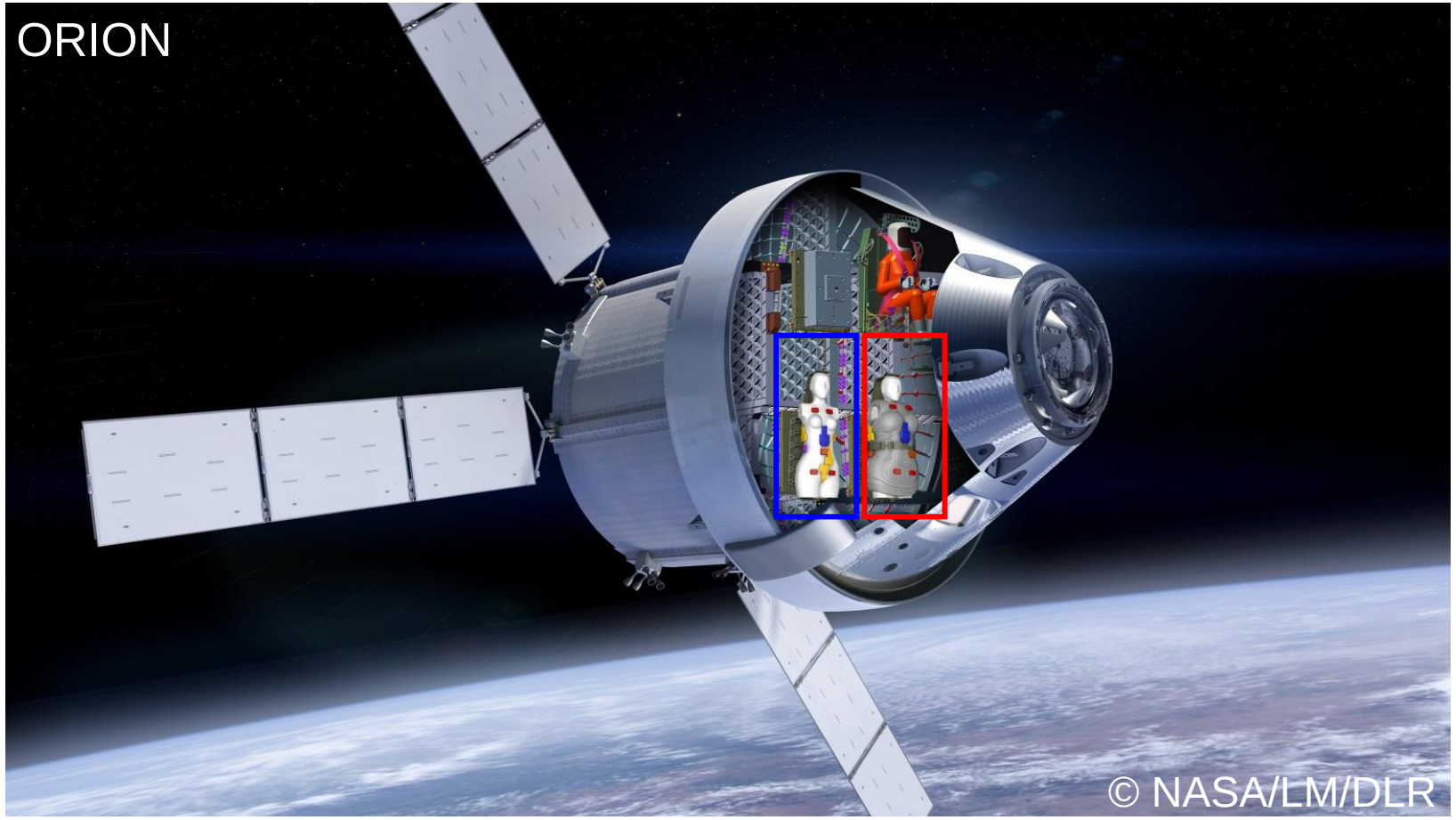
15. **CREW MODULE SEPARATION FROM SERVICE MODULE**

16. **ENTRY INTERFACE (EI)**
Enter Earth's atmosphere.

17. **SPLASHDOWN**
Pacific Ocean landing within view of the U.S. Navy recovery ship.

MARE ON ARTEMIS I

MARE: on NASA Artemis I mission

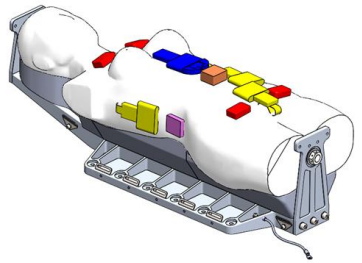


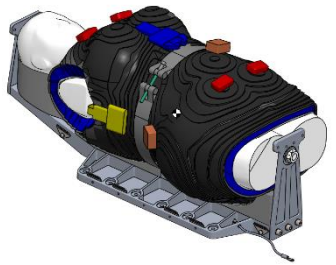
Artemis I Mission:

MARE –
Matroshka AstroRad Radiation Experiment

https://www.dlr.de/mare_en/

Two female phantoms Helga and Zohar, Zohar wearing the AstroRad vest





MARE: female phantoms I

https://www.cirsinc.com/

SUN NUCLEAR
A MIRION MEDICAL COMPANY

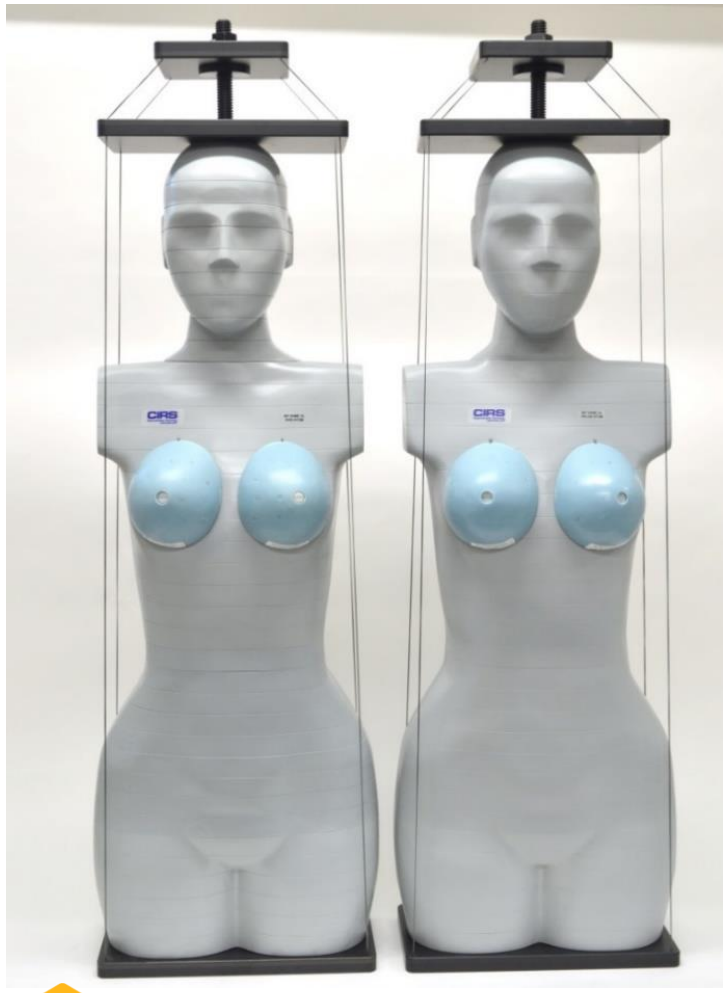
MARE: female phantoms II

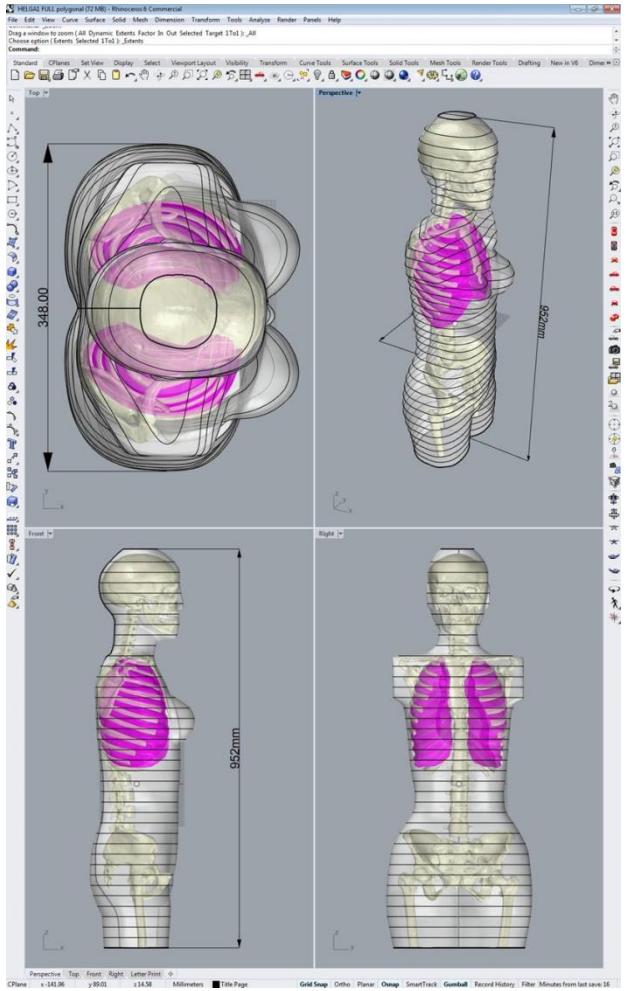


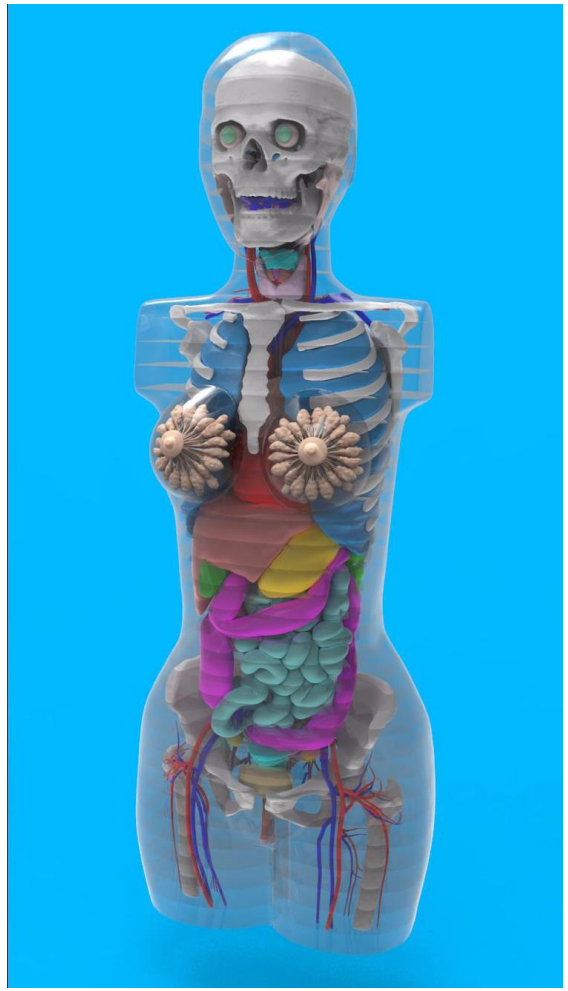

https://www.cirsinc.com/

SUN NUCLEAR
A MIRION MEDICAL COMPANY

MARE: female phantoms III

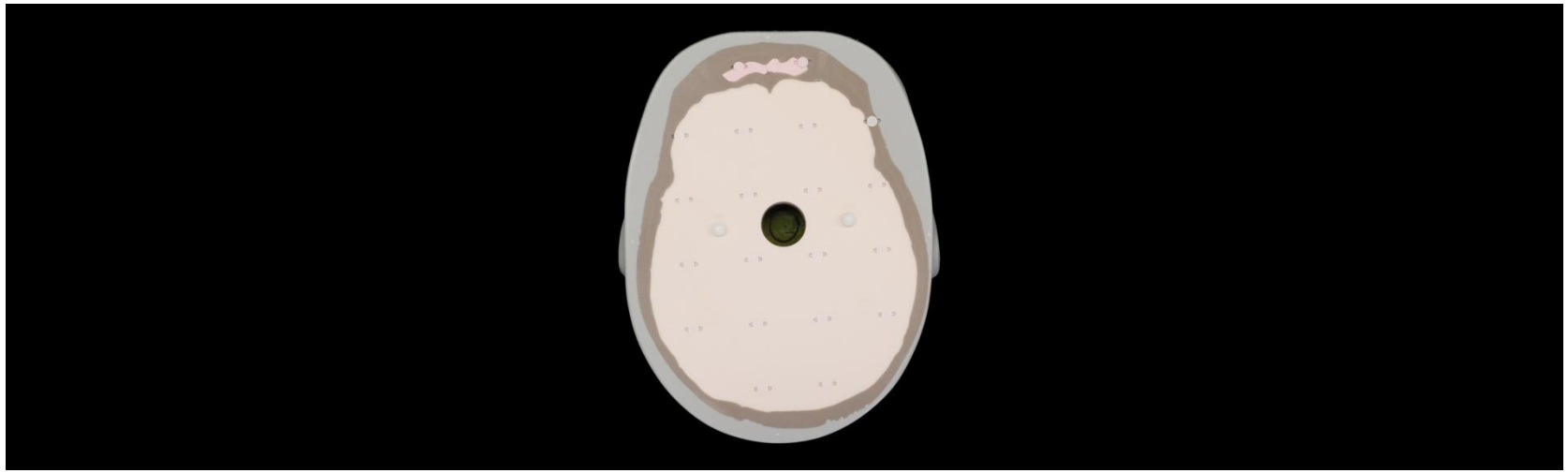


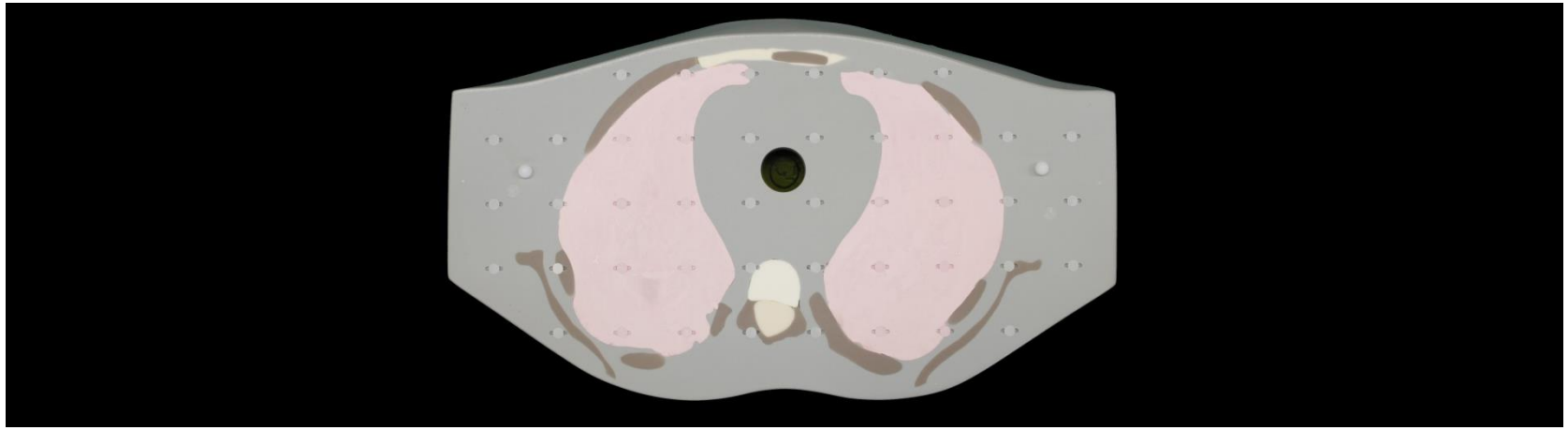


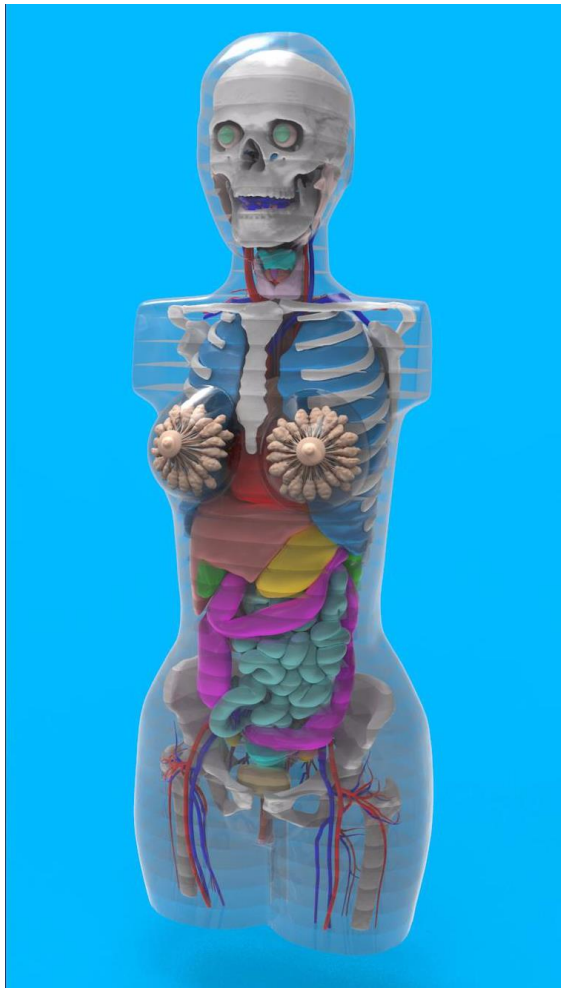


SUN NUCLEAR
A MIRION MEDICAL COMPANY

MARE: female phantoms IV



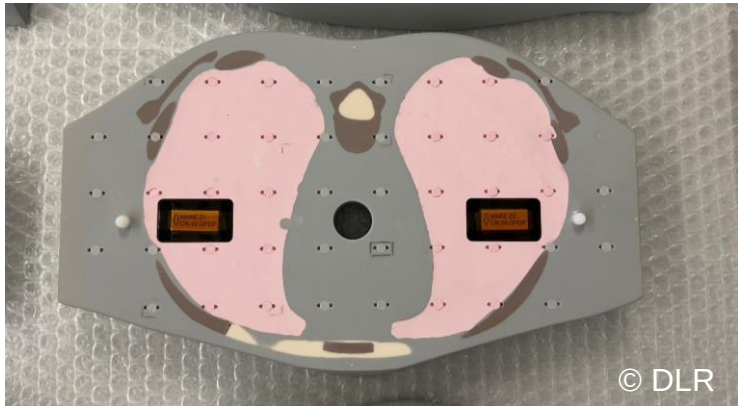




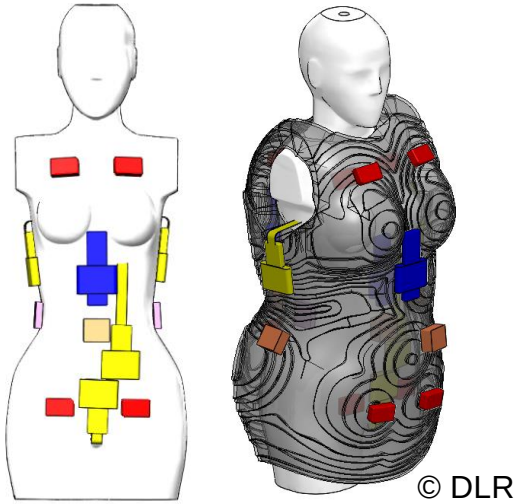
SUN NUCLEAR
A MIRION MEDICAL COMPANY

MARE: the radiation detectors

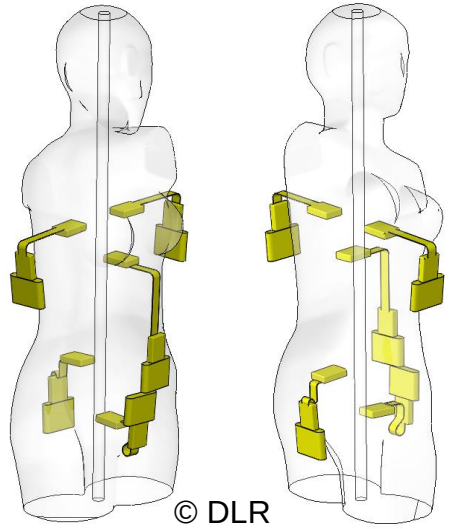
Over 6000 passive detectors per phantom



Active detectors above and beneath the vest



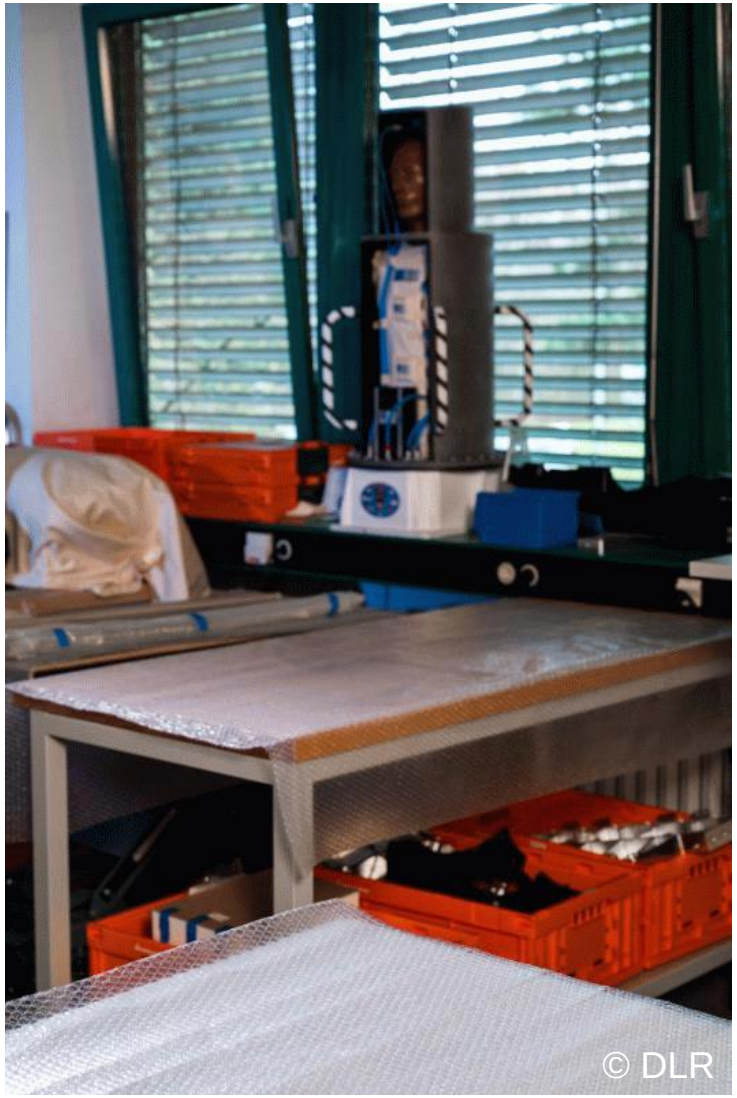
Active detectors in the organs (DLR M42)



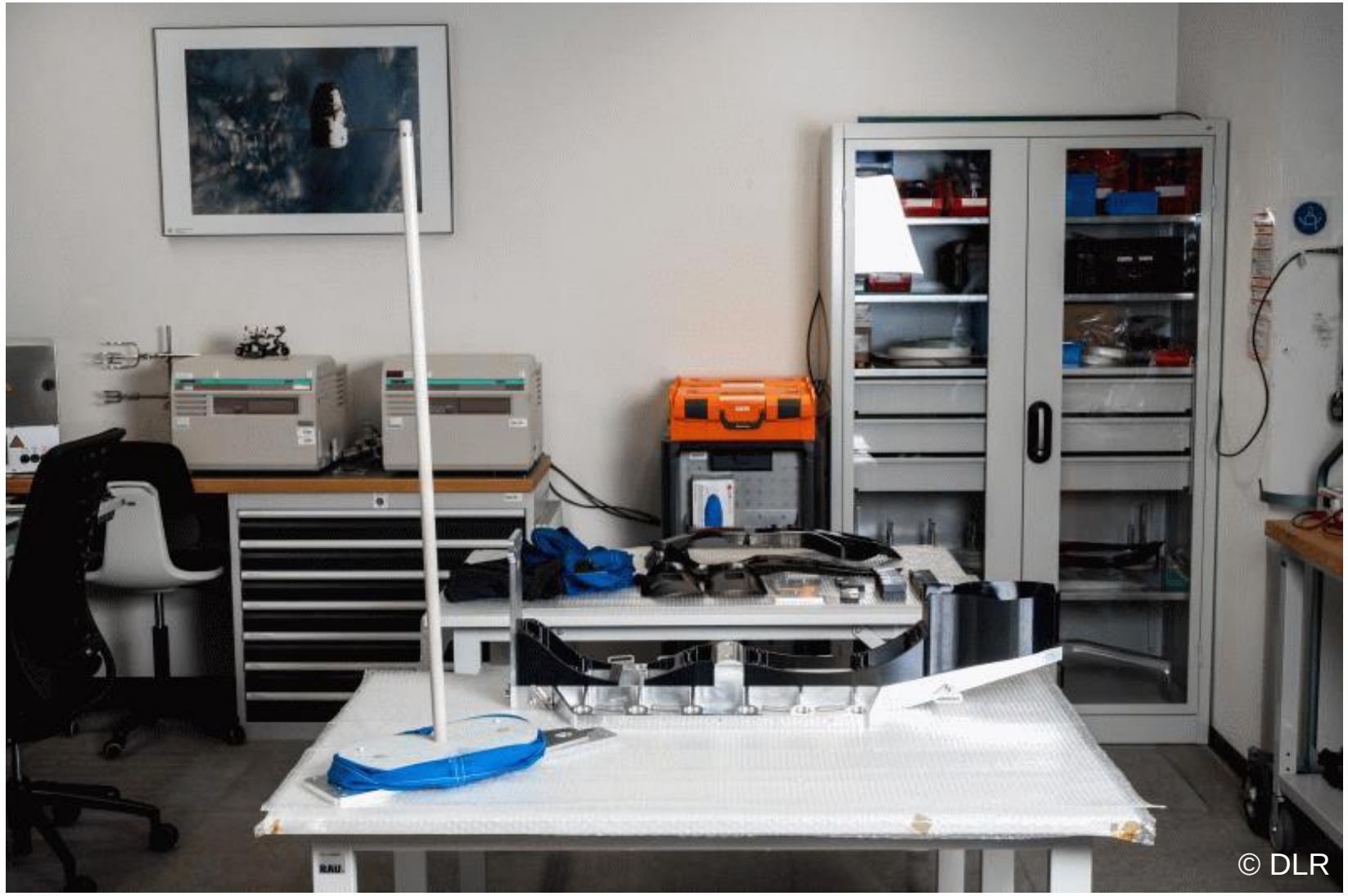
- Over 1400 measurement points per phantom (over 10.000 TLDs + CR-39 detectors)
- Active radiation detectors (DLR M-42) in the lungs, stomach, uterus and spine & front and back
- Active radiaton detectors (NASA CAD) at front and back side of the phantoms

MARE: phantoms set-up

HELGA



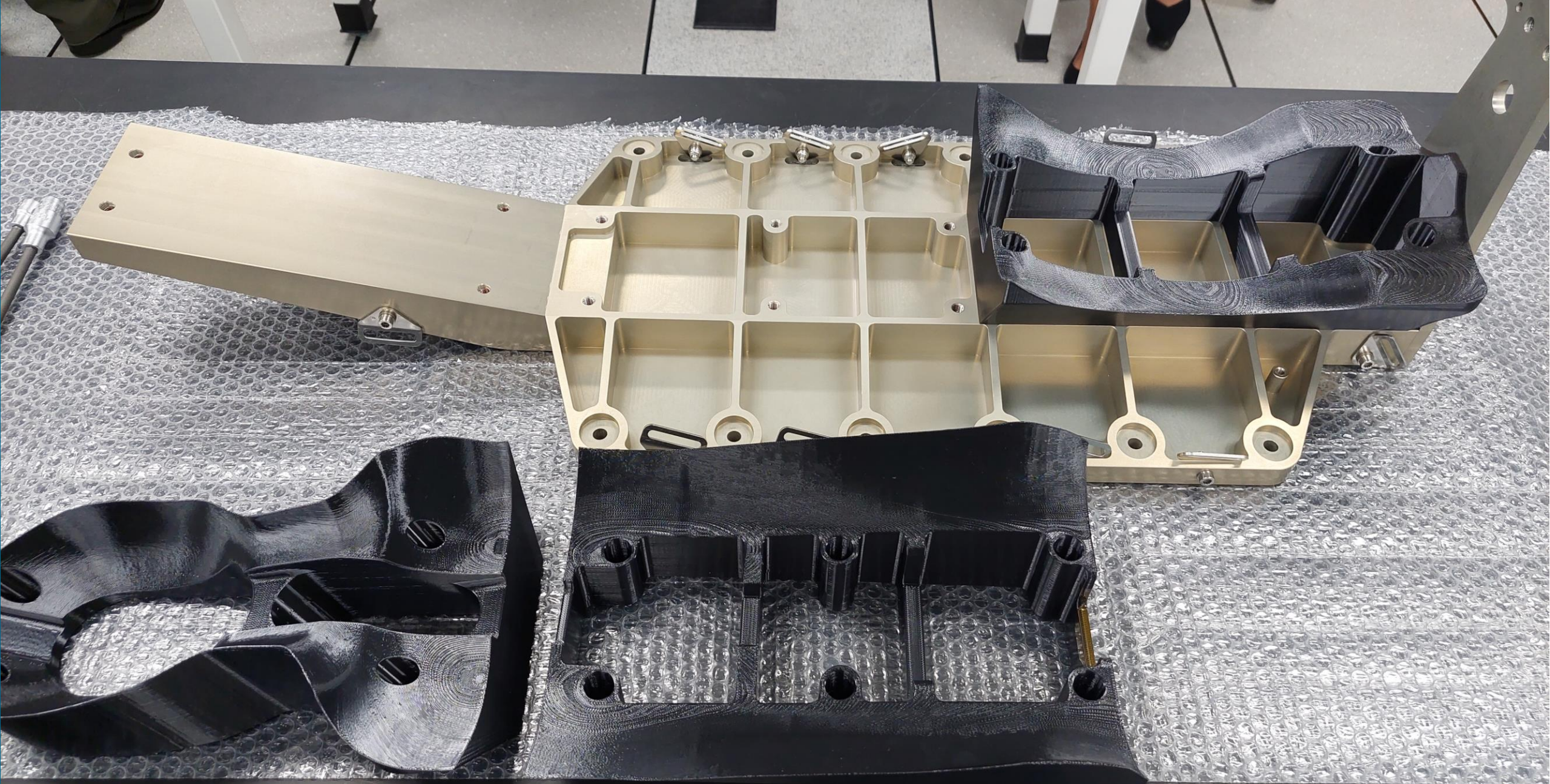
ZOHAR

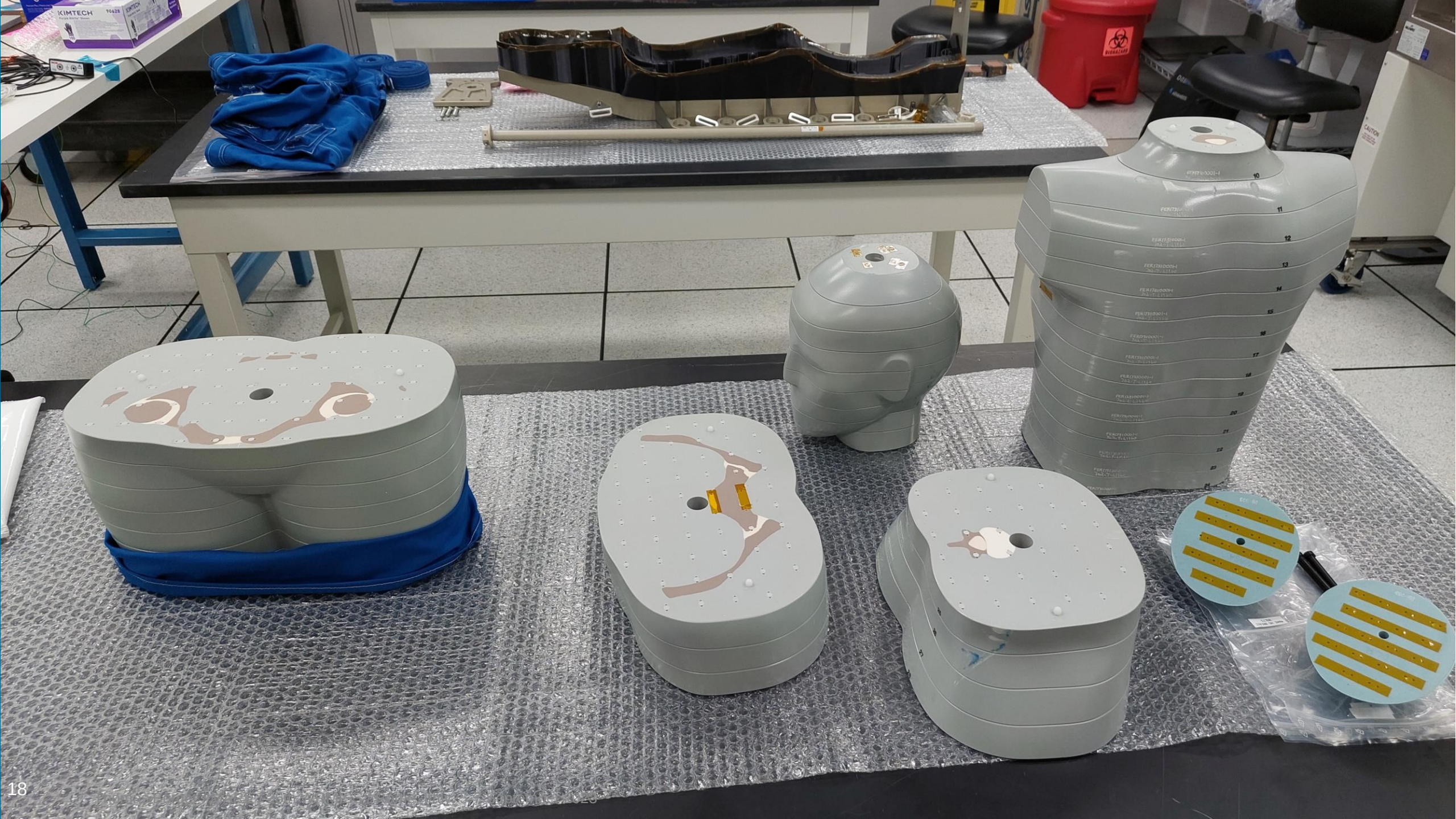


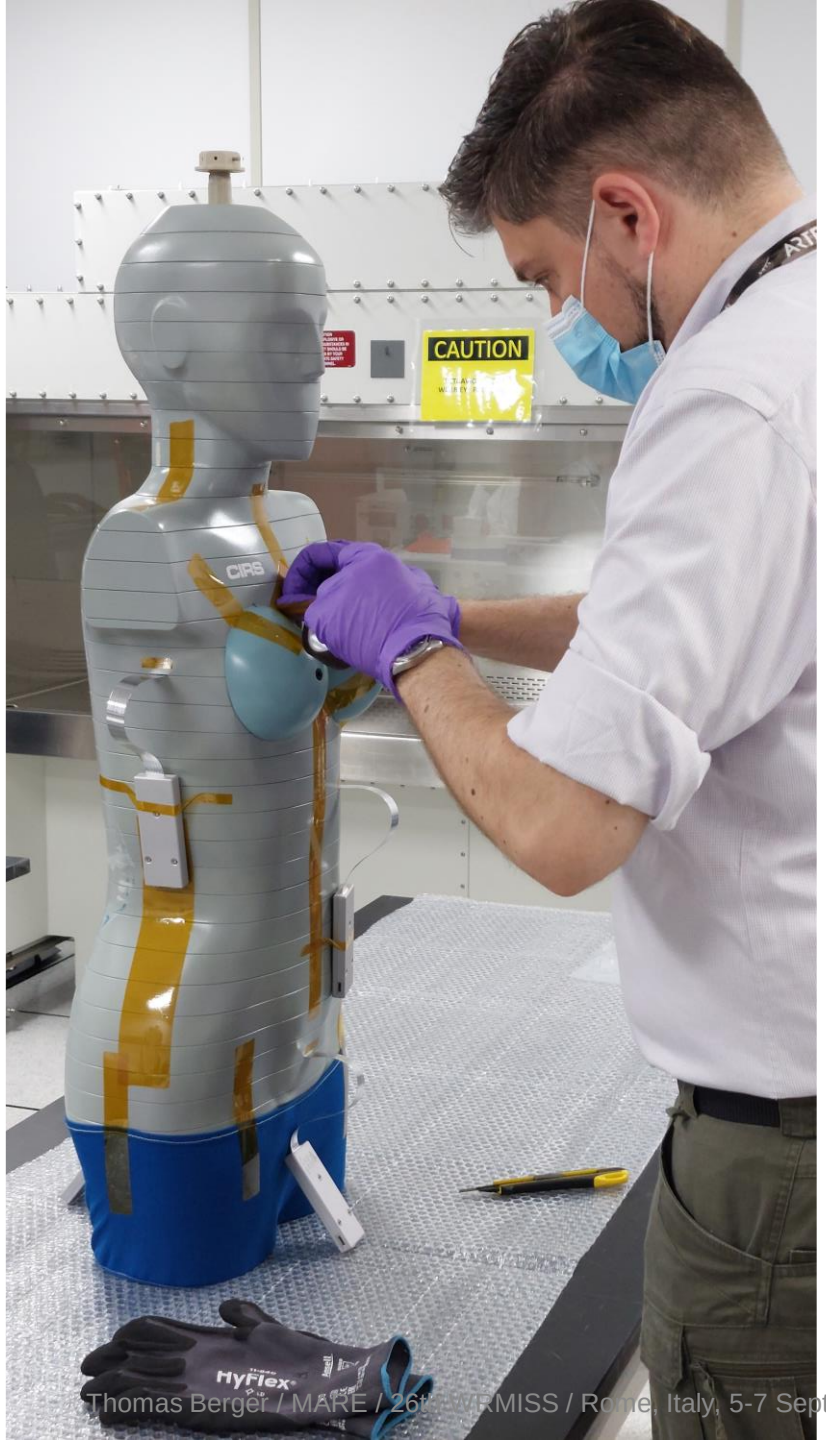
MARE: TLDs (NASA-SRAG/DLR)

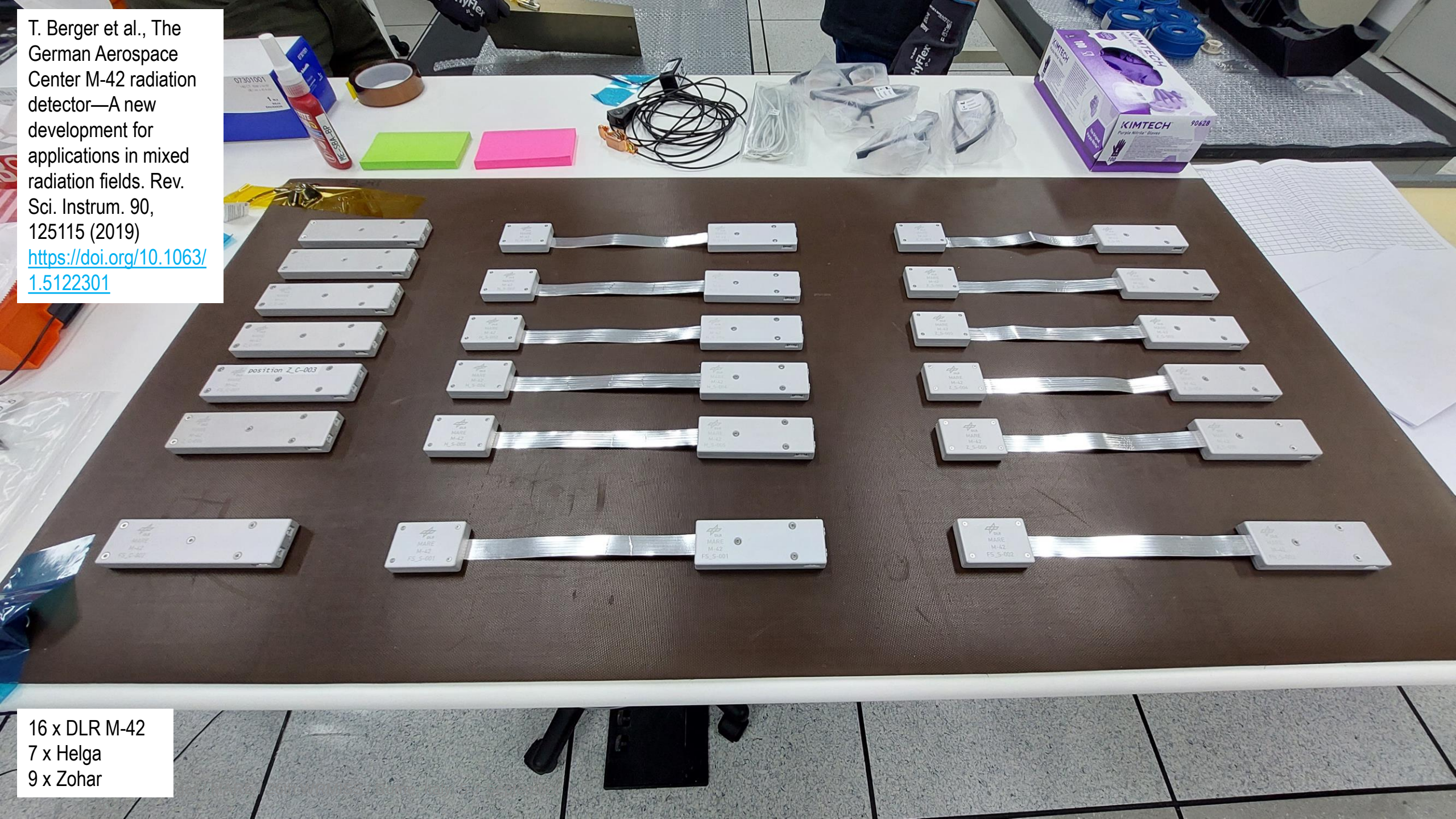

10
11
01
02
MARE ZH
CR-39 OPDR
ZOHAR FM

WORK AT NASA, KSC



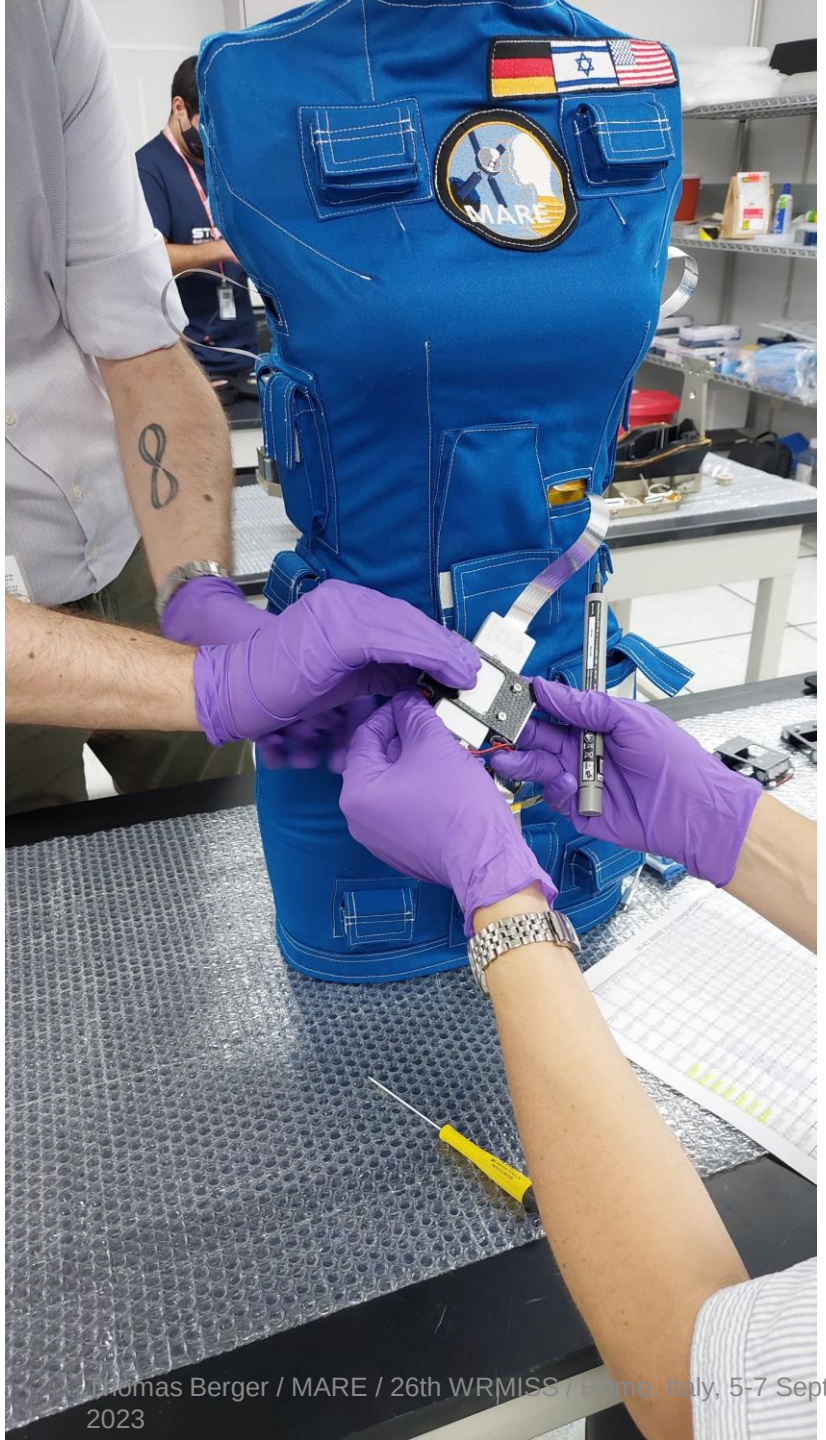

KIMTECH
90628
BIOHAZARD
CAUTION


CAUTION
CIRS
HyFlex

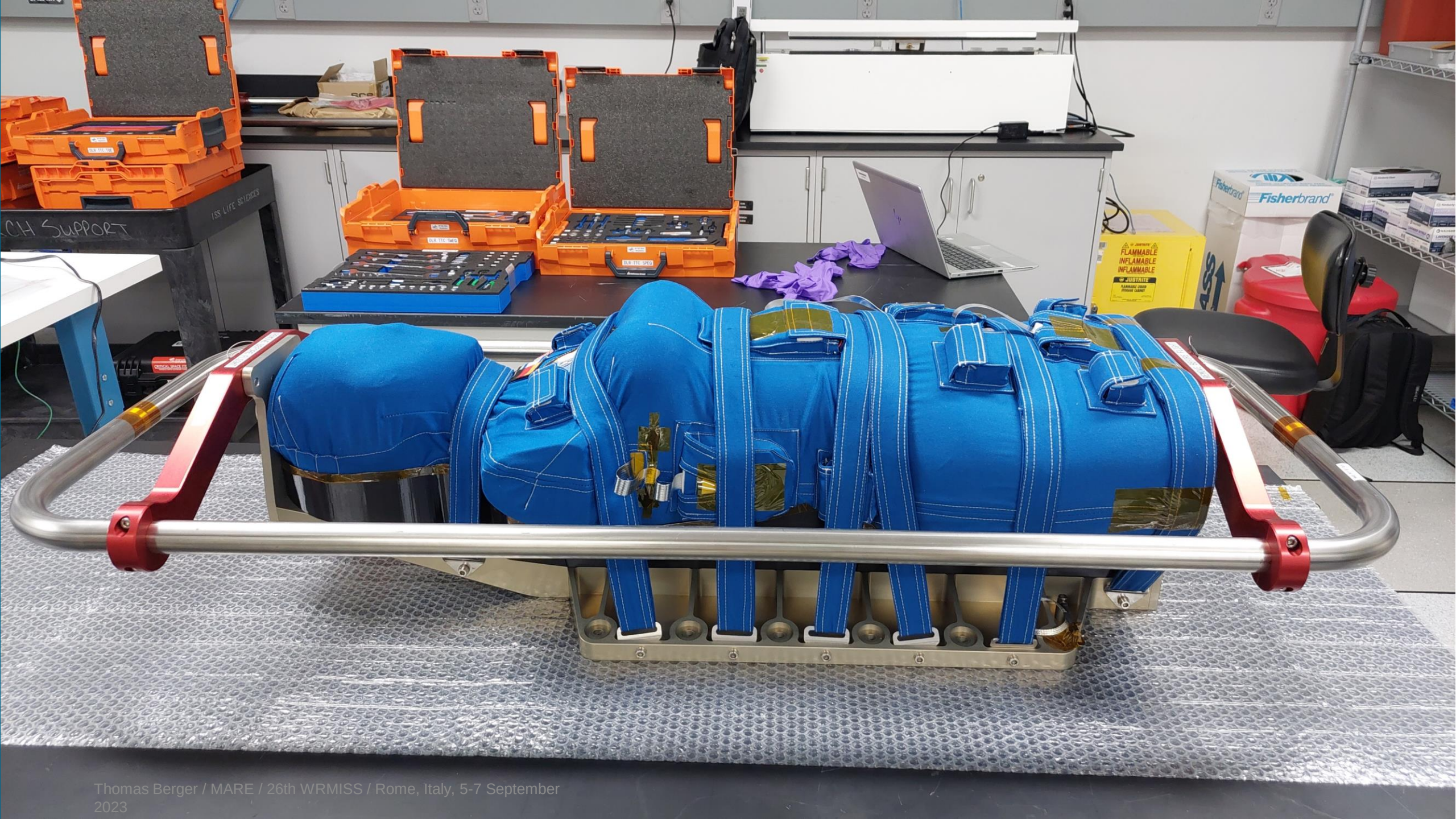

T. Berger et al., The German Aerospace Center M-42 radiation detector—A new development for applications in mixed radiation fields. Rev. Sci. Instrum. 90, 125115 (2019) https://doi.org/10.1063/1.5122301
16 x DLR M-42
7 x Helga
9 x Zohar
KIMTECH
position Z_C-003

R. Gaza et al. The Importance of Time-Resolved Personal Dosimetry in Space: The ISS Crew Active Dosimeter. Life Sciences in Space Research (2023) https://doi.org/10.1016/j.lssr.2023.08.004

18 x NASA CAD
6 x Helga
12 x Zohar


MARE


MARE


CH SUPPORT
ISS LIFE SCIENCES
FLAMMABLE
INFLAMMABLE
INFLAMMABLE
Fisherbrand
Fisherbrand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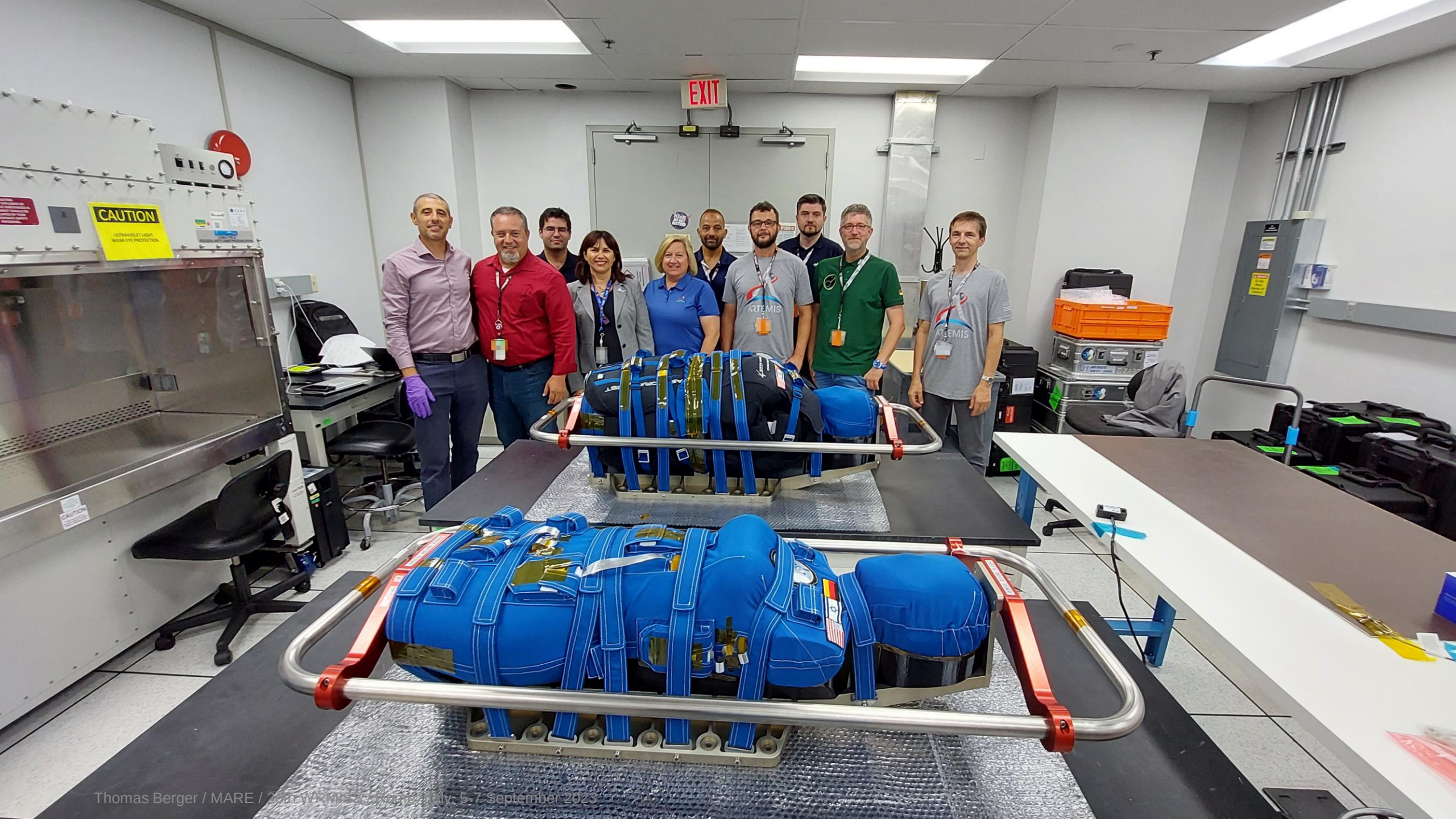
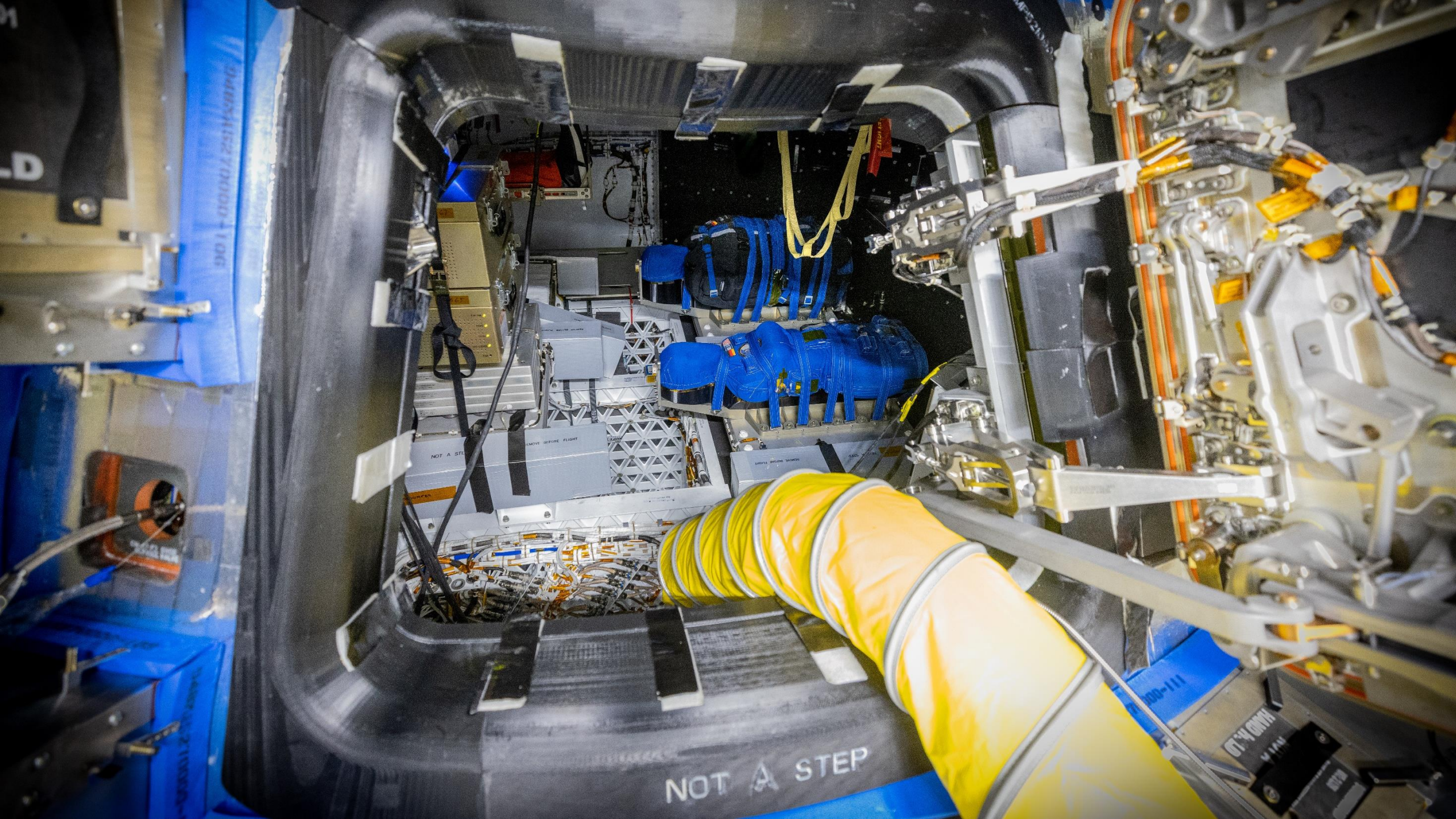
STOP THE SPREAD OF COVID-19


LABSOLUTE
FLAMMABLE
INFLAMMABLE
INFLAMMABLE


EXIT
CAUTION
ULTRAVIOLET LIGHT
WEAR EYE PROTECTION
ARTEMIS
ARTEMIS


NASA
ARTEMIS
F GATE

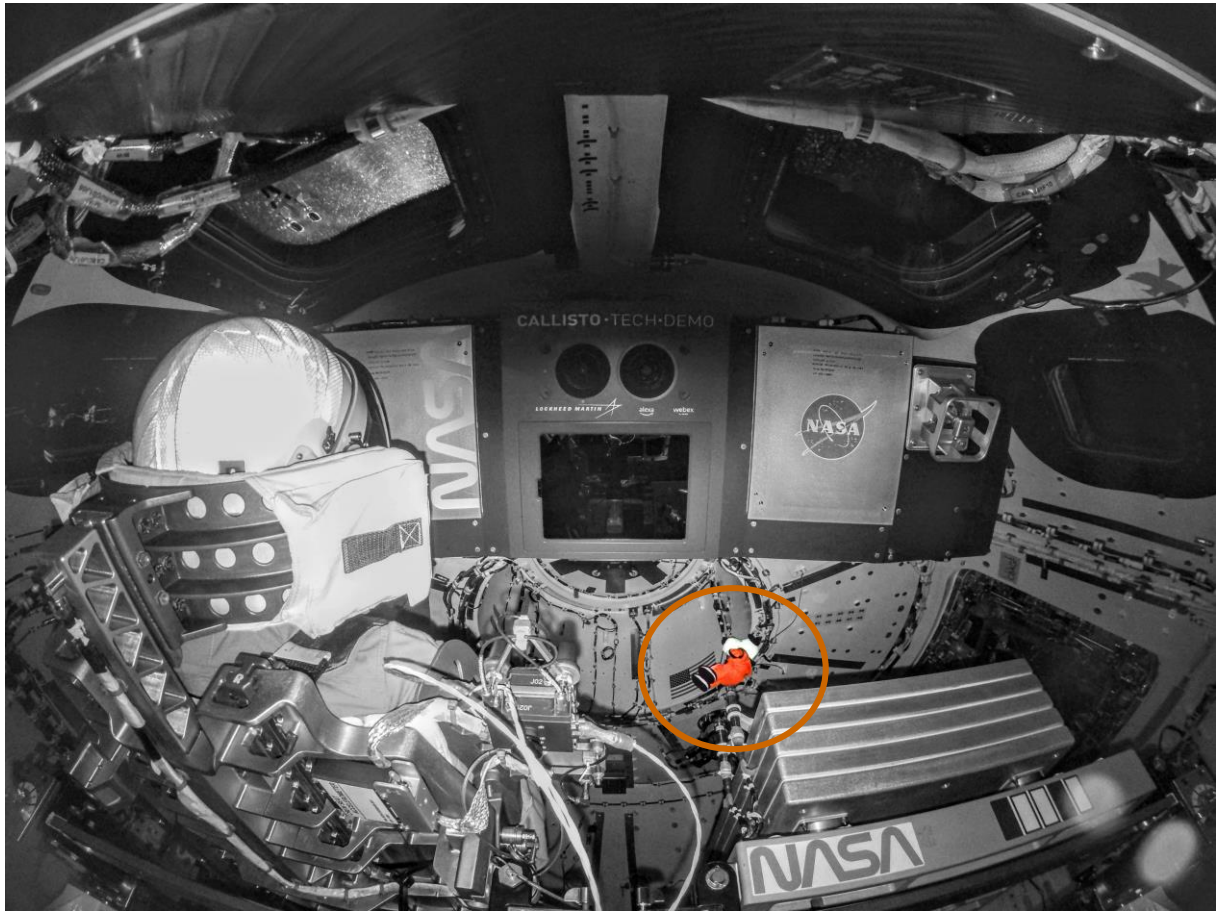

United States

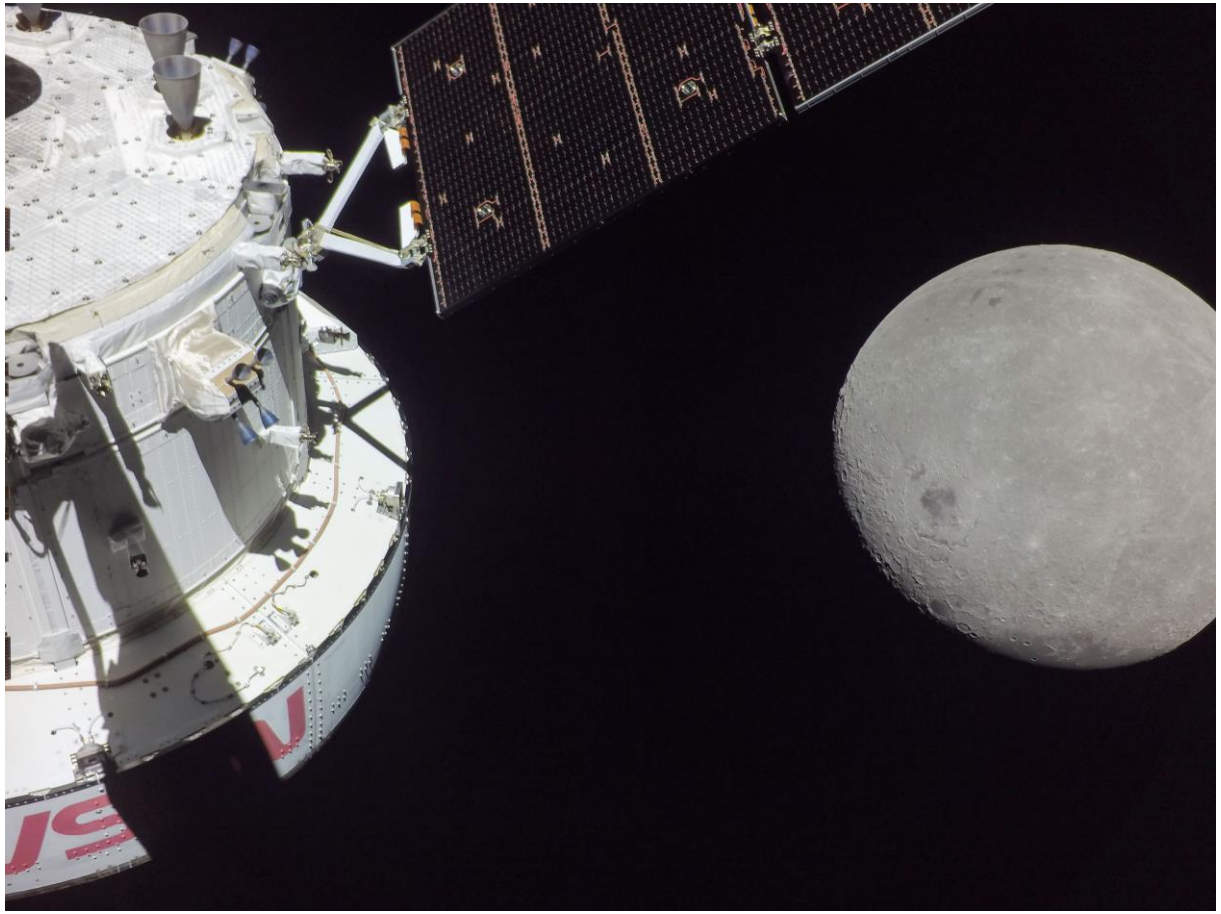

NOT A STEP

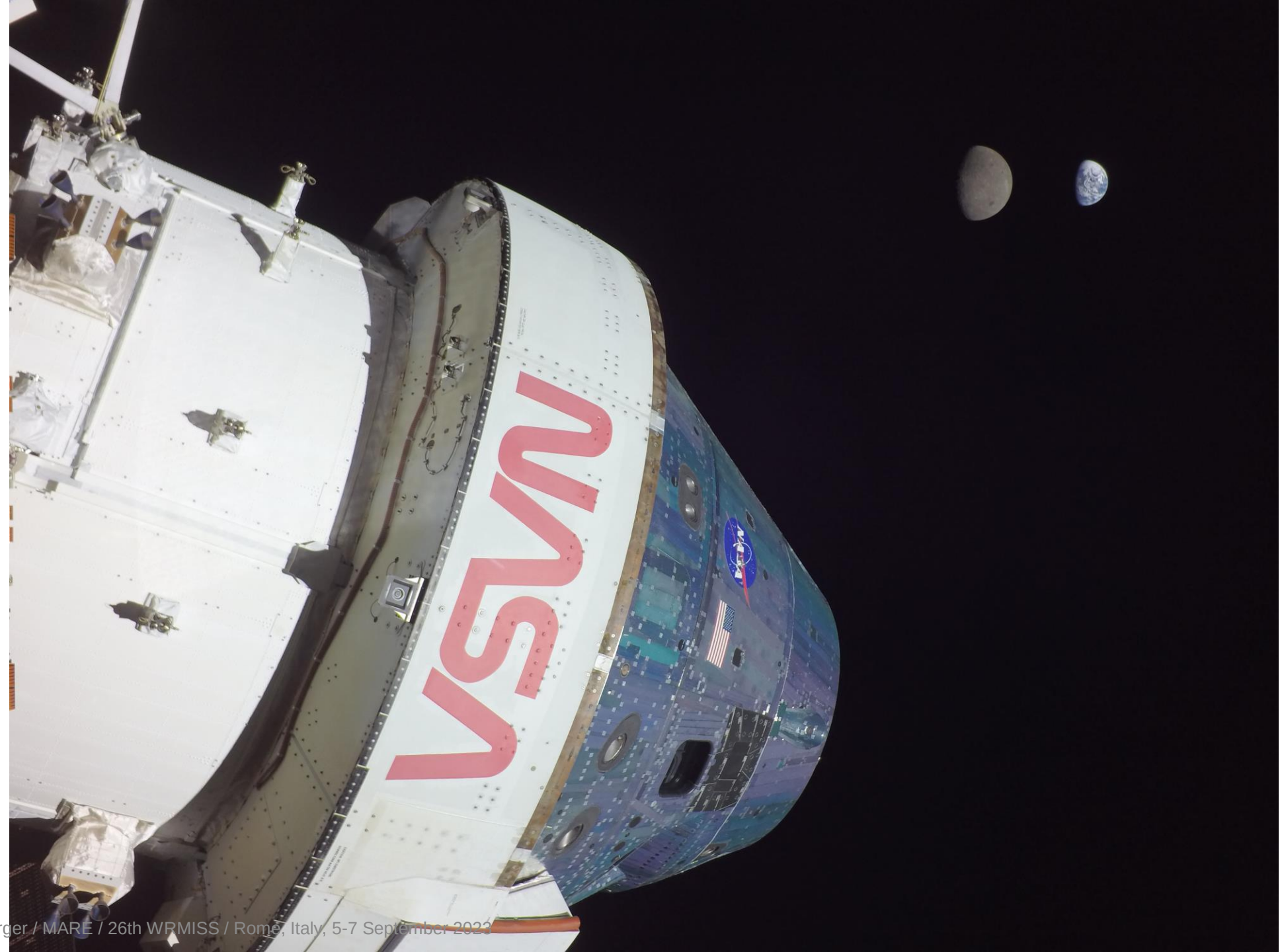

REMOVE BEFORE FLIGHT
NOT A SEAT

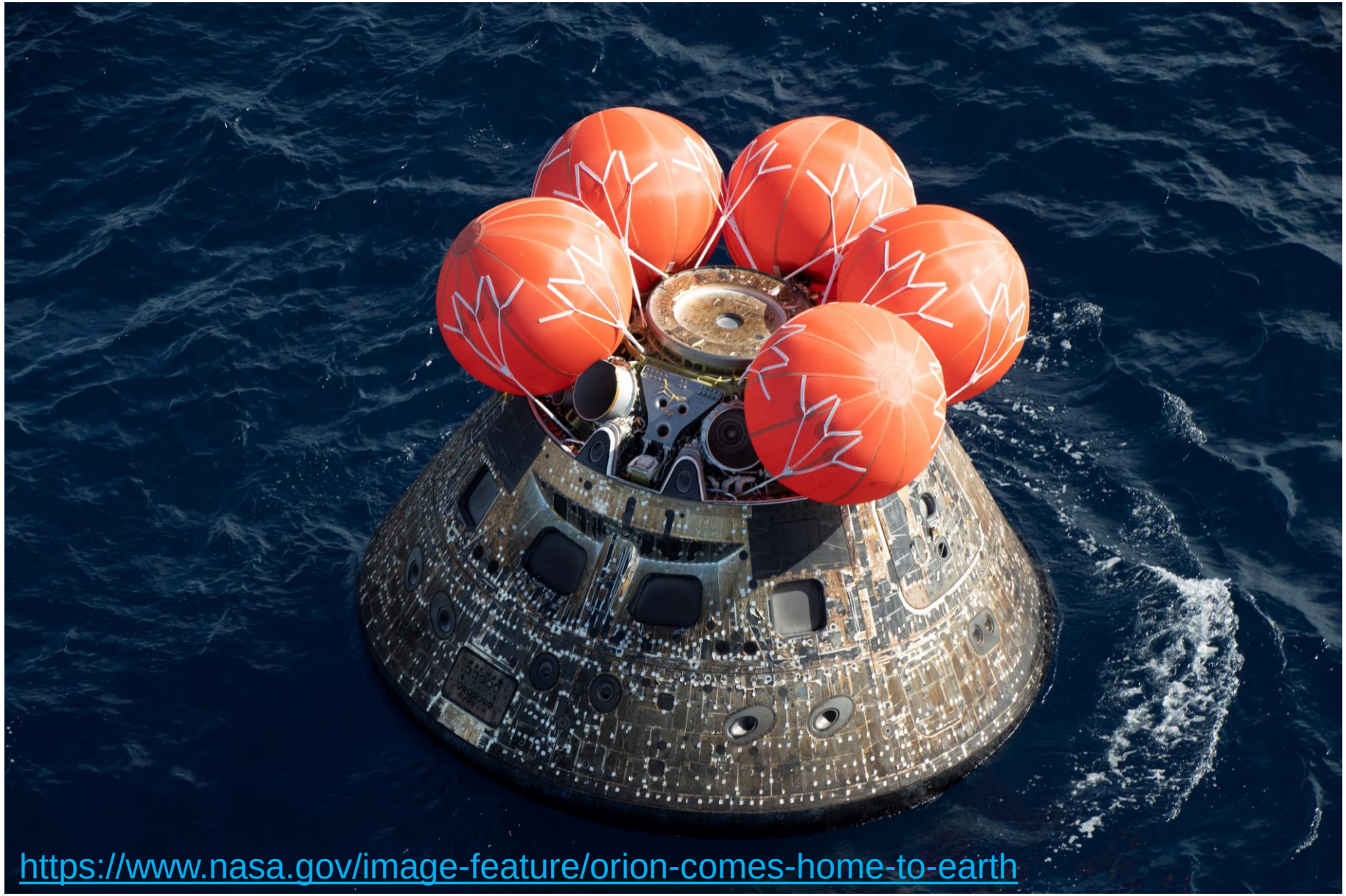
ARTEMIS I LAUNCH 16 NOV 2022

MARE: … and the Moon … and Snoopy

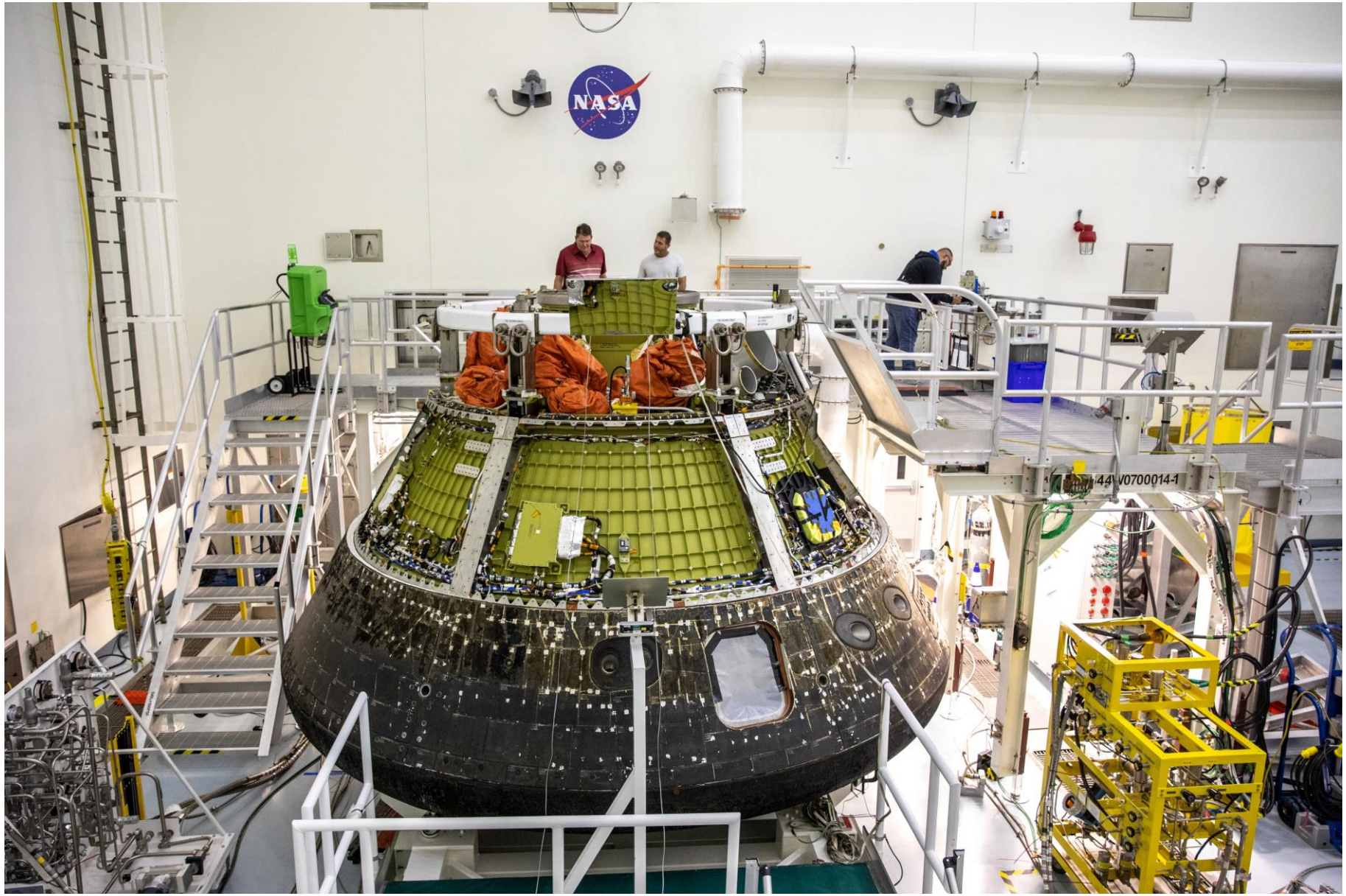





NASA



https://www.nasa.gov/image-feature/orion-comes-home-to-earth



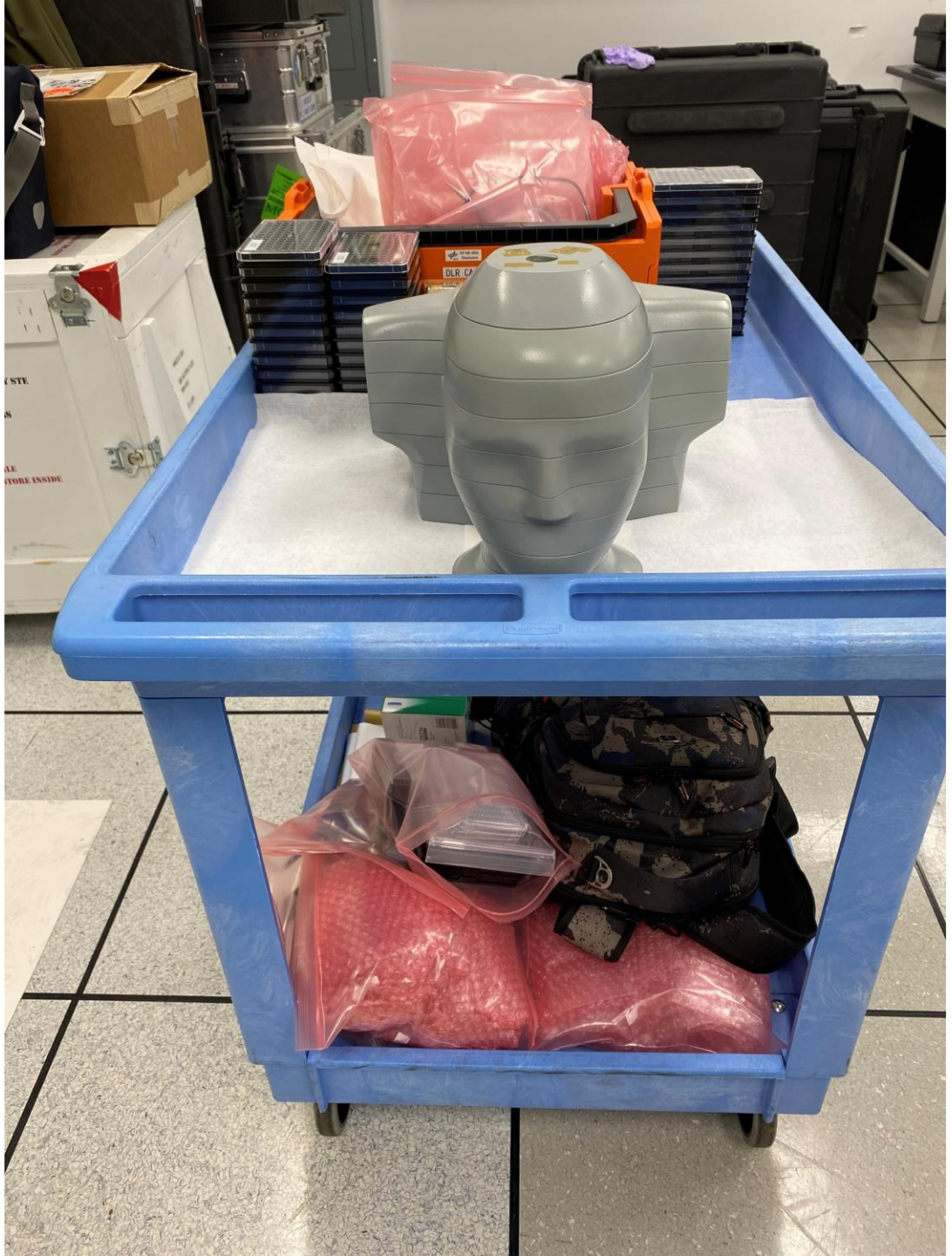
https://www.nasa.gov/image-feature/inspecting-orion

 https://www.nasa.gov/image-feature/a-well-traveled-beagle

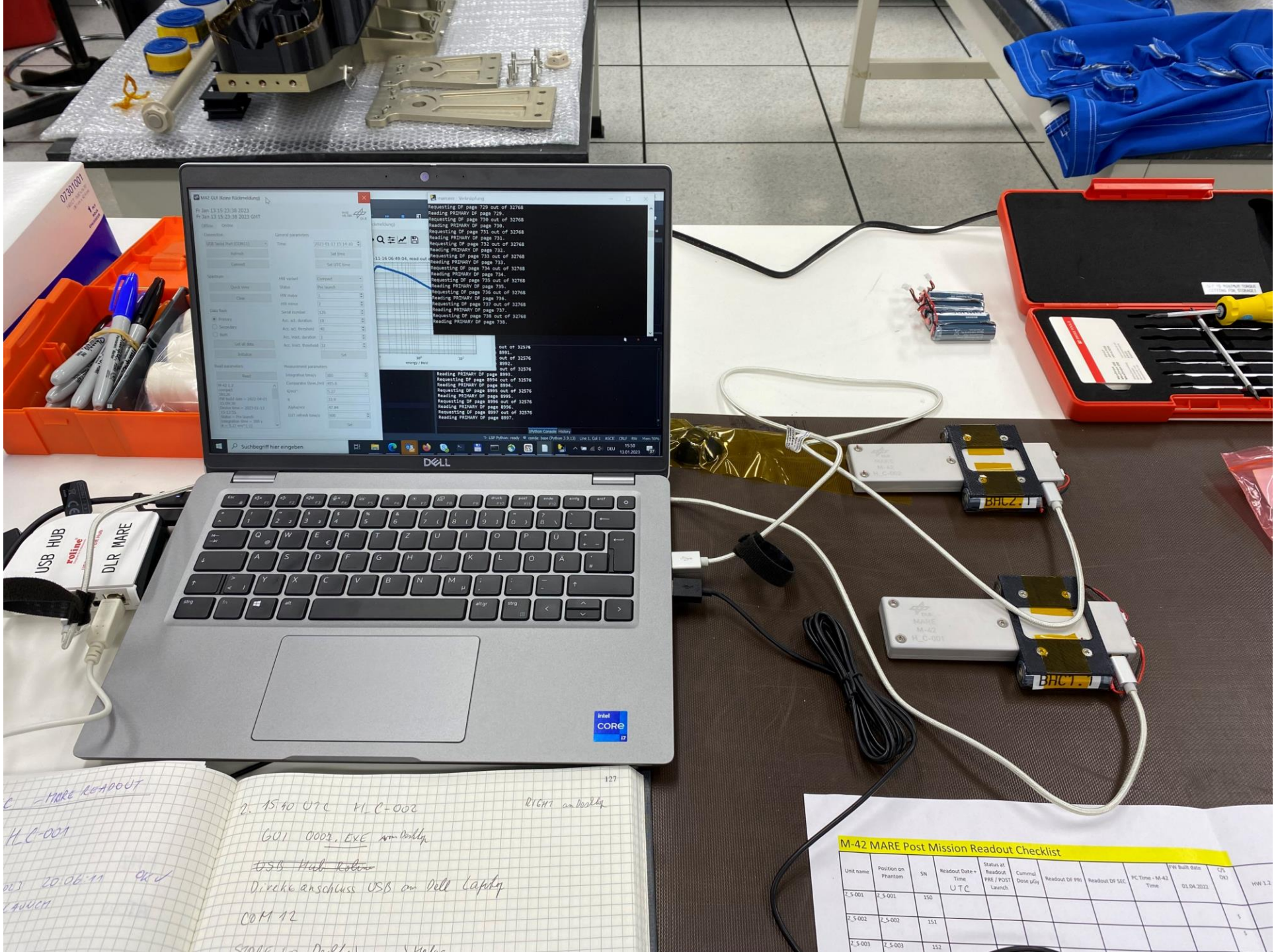
MARE JANUARY 2023


REMOVE BEFORE FLIGHT
F


REMOVE BEFORE FLIGHT
F



NASA TLD
Removal
KSC

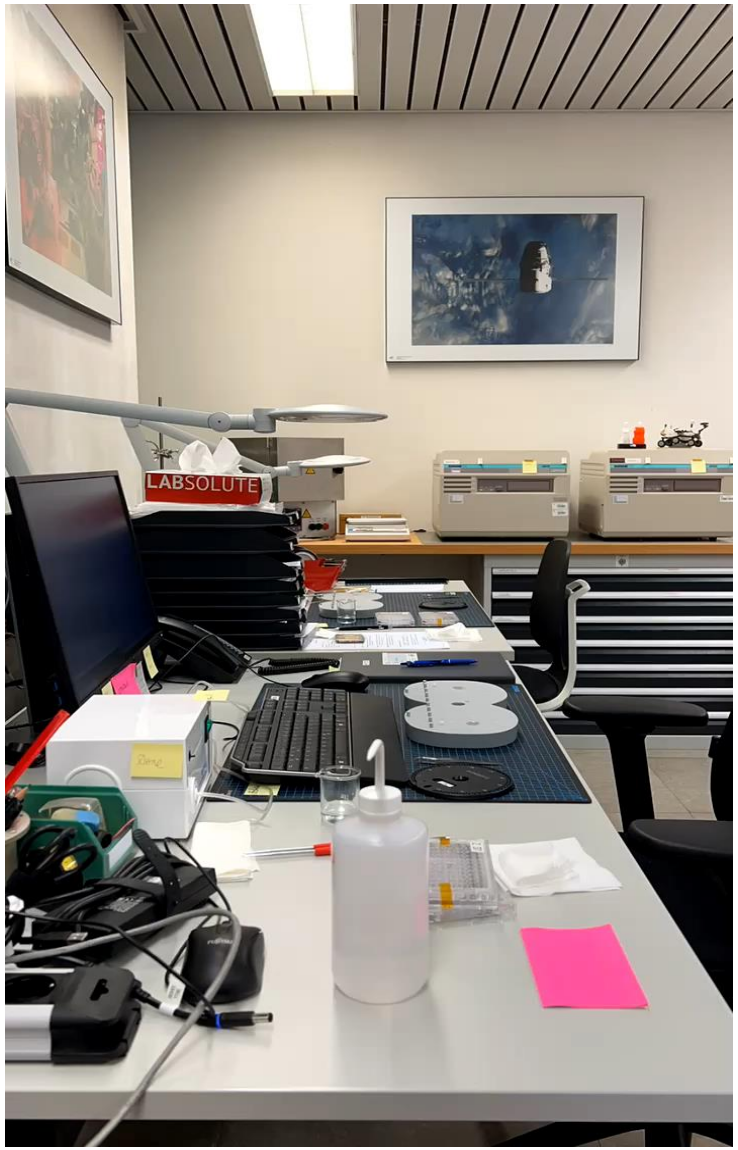


DLR M-42
Data Read Out
NASA, KSC,
USA
January 2023


NASA
ARTEMIS
CAUTION
STEMRAD

MARE: TLD Read-Out DLR, Cologne

- Helga / Zohar TLDs (DLR/NASA/IFJ)
- Helga / Zohar DOSIS 3D PDP Packages
- Helga / Zohar CR-39 Detector Packages
- Helga / Zohar TLD/OSLD „travel background“



NASA Artemis I: All Radiation Detectors

- NASA HERA Detectors
- NASA CAD Detectors
- NASA RAM Detectors

N. N. Stoffle *et al.*, HERA: A Timepix-based radiation detection system for Exploration-class space missions. *Life Sciences in Space Research*, (2023). https://doi.org/10.1016/j.lssr.2023.03.004

- ESA EAD Detectors

U. Straube, T. Berger, M. Dieckmann, The ESA Active Dosimeter (EAD) system onboard the International Space Station (ISS). *Zeitschrift für Medizinische Physik*, (2023). https://doi.org/10.1016/j.zemedi.2023.03.001

- MARE Experiment
  - DLR M-42 detectors
  - NASA CAD detectors

T. Berger *et al.*, The German Aerospace Center M-42 radiation detector—A new development for applications in mixed radiation fields. *Rev. Sci. Instrum.* **90**, 125115 (2019) https://doi.org/10.1016/j.lssr.2023.08.004

R. Gaza et al. The Importance of Time-Resolved Personal Dosimetry in Space: The ISS Crew Active Dosimeter. *Life Sciences in Space Research* (2023) https://doi.org/10.1016/j.lssr.2023.08.004

MARE Team

DLR

An international project:

DLR NASA LOCKHEED MARTIN STEMRAD ISA Israel Space Agency סוכנות החלל הישראית

With partners from Austria, Poland, Hungary, Belgium, Czeck Republic, Switzerland, Japan, USA:

ATOMINSTITUT

THE HENRYK NIEWODNICZAŃSKI INSTITUTE OF NUCLEAR PHYSICS POLISH ACADEMY OF SCIENCES

Centre for Energy Research

SCK•CEN STUDIECENTRUM VOOR KERNENERGIE CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

Nuclear Physics Institute of the CAS public research institution

PAUL SCHERRER INSTITUT PSI

NIRS

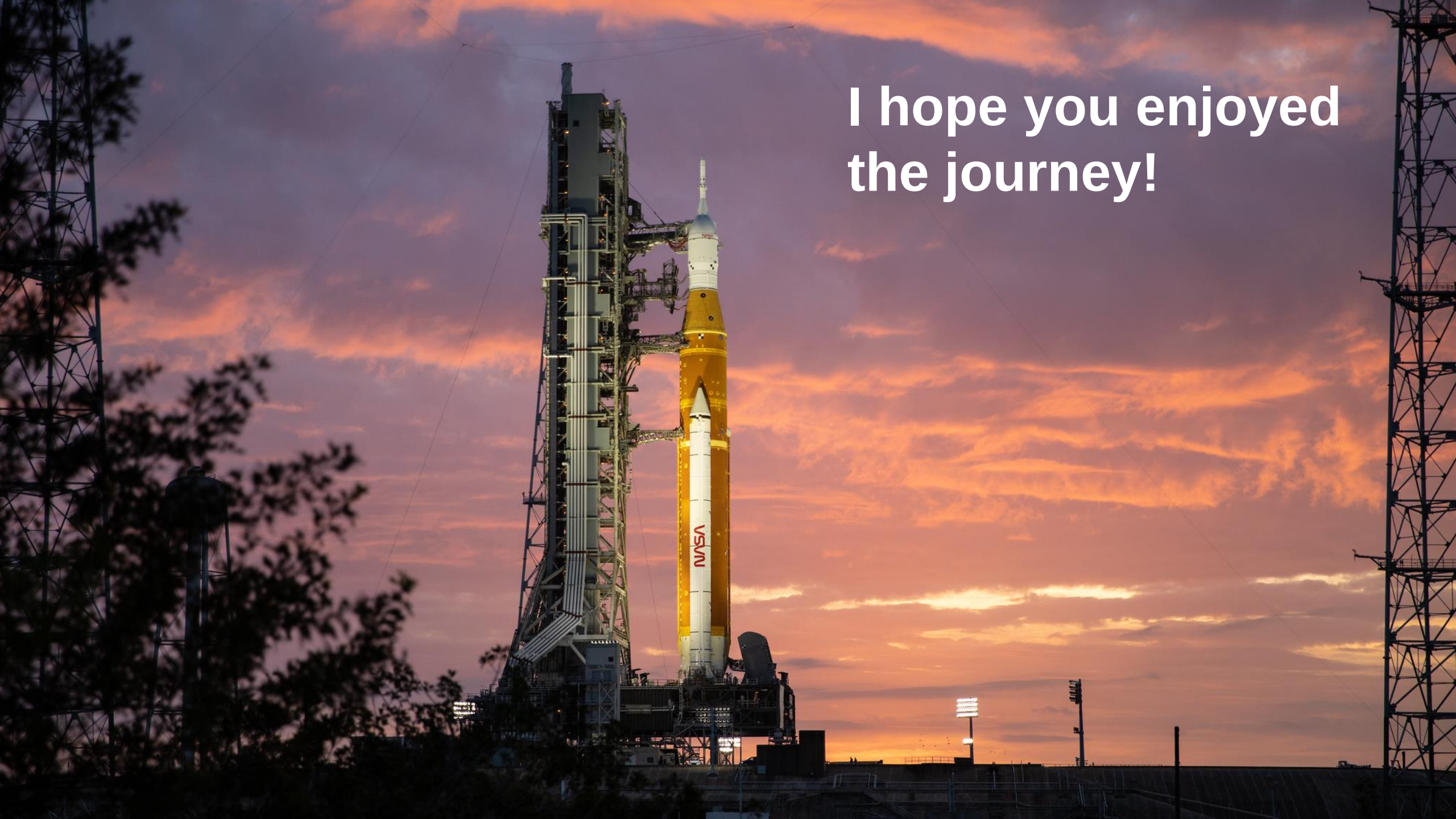
CARL E. RAVIN ADVANCED IMAGING LABORATORIES

With support from:

CIRS Tissue Simulation & Phantom Technology

OHB

SUN NUCLEAR A MIRION MEDICAL COMPANY


I hope you enjoyed
the journey!

Impressum

Topic:	**NASA Artemis I mission and the MARE Experiment**
Venue:	**26th WRMISS, Rome Italy**
Date:	5 – 7 September 2023
Authors:	Thomas Berger for the MARE team
Picture ©:	NASA, ESA, „DLR (CC BY-NC-ND 3.0)“