ISS External Microorganisms: Collecting Planetary Protection Samples During Extravehicular Activity

National Aeronautics and Space Administration

Aaron B. Regberg, Mary Sue Bell, Richard E. Davis, Martin L. Tschirschwitz, Sarah Wallace

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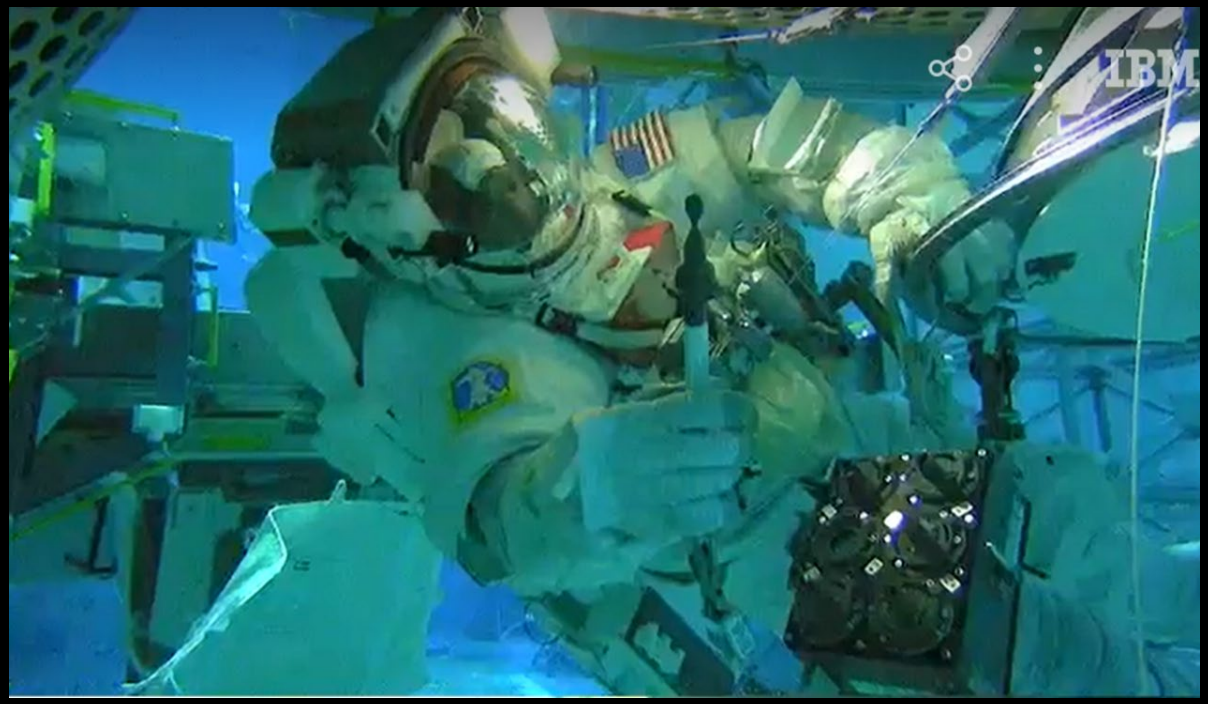
07/14/2024

OUTLINE

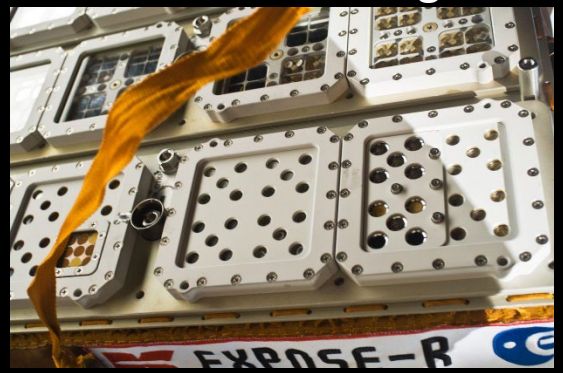


- **COSPAR/NASA Planetary Protection Knowledge Gaps for Crewed Missions**
- Prototype Hardware
- Ground Test Results
- Flight Hardware
- ISS Sampling Plan

COSPAR and NASA Have Defined Planetary Protection Knowledge Gaps that need to be Addressed before Crewed Missions Arrive at Mars

BACKGROUND

Some organisms can survive exposure to space!



images-assets.nasa.gov/image/iss018e039227/iss018e039227~orig.jpg

Cyano-bacteria, lichen and fungi survived up to 500+ days outside ISS

Tardigrades survived extended ISS exposure… *and then reproduced*

We also know that all crewed, pressurized volumes will leak or vent

ISSUE

But we *don't* know what's actually leaking/venting from our current systems, how long those organisms could survive, or how far they may travel under destination conditions

Does proximity to a warm spacecraft matter?

How close can crew get without compromising science?

How far could our hitchhikers spread

The answers will drive element design (i.e. closed vs. open ECLS), where we place elements, and who/how we collect science samples

https://www.nasa.gov/sites/default/files/atoms/files/moon-investments-prepare-us-for-mars.pdf

Knowledge Gap 2H. What microbial contaminants would vent from an extravehicular activity (EVA) suit or other vehicles?

Apollo 12 Mission image - Astronaut Bean deploys ALSEP Central Station

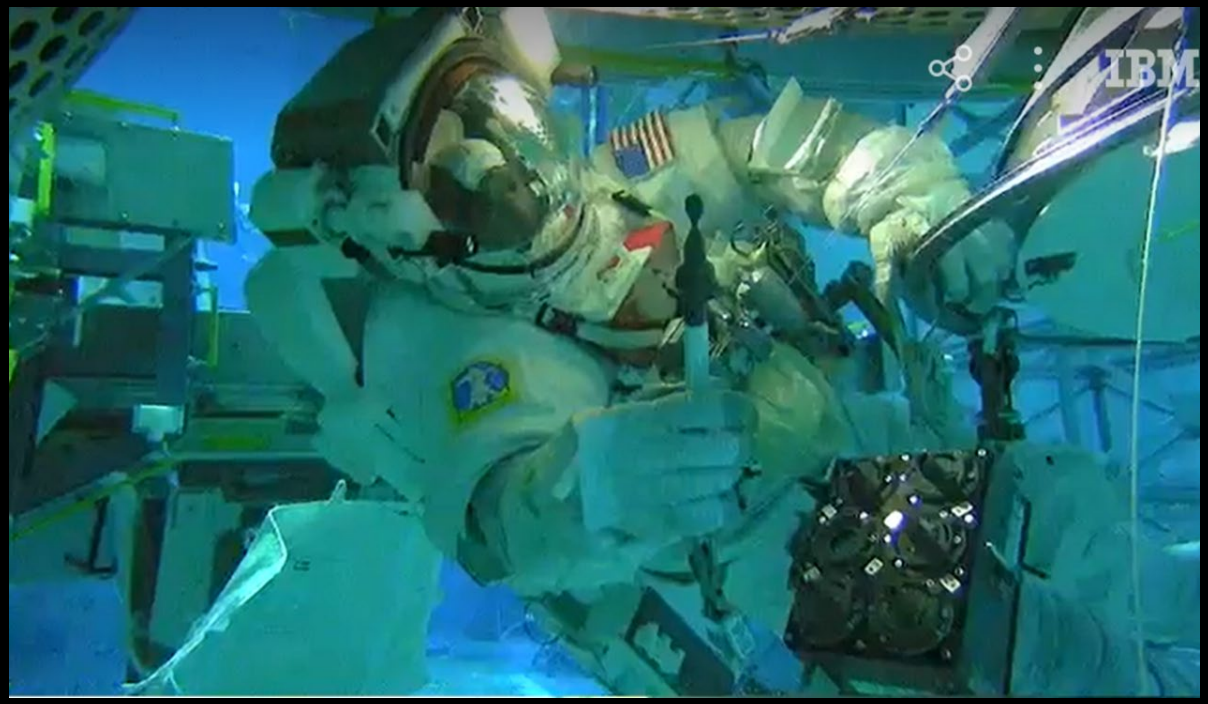
- Do we need to filter all of our vented products?
- How close can an astronaut get to a sample without contaminating it?
  - Should we use robots to collect and contain sensitive samples?

Knowledge Gap 2B. What level of non-viable microbial contamination escape is acceptable?

Report of the COSPAR Workshop on Refining Planetary Protection Requirements for Human Missions
G Kminek, BC Clark, CA Conley, MA Jones, M Patel, MS Race, MA Rucker, O Santolik, B Siegel & JA Spry (Eds.)

- Do we need to filter all of our vented products?
- How close can an astronaut get to a sample without contaminating it?
  - Should we use robots to collect and contain sensitive samples?
- What if our spacecraft create an artificial habitable zone?

OUTLINE



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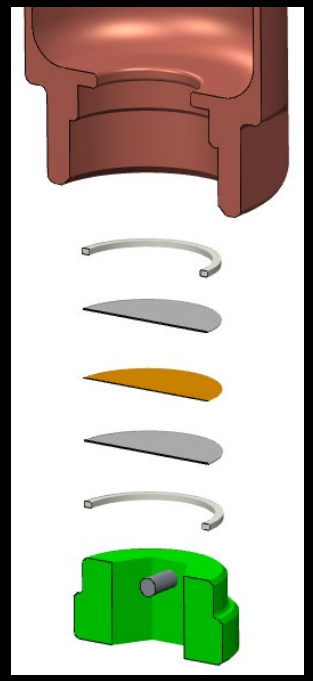
Prototype Payload 8-Sample EVA Swab Kit

- 6 on top, 2 on bottom (not shown)
- 0.22 micron pore Microbial filter in bottom of each container to accommodate pressure changes



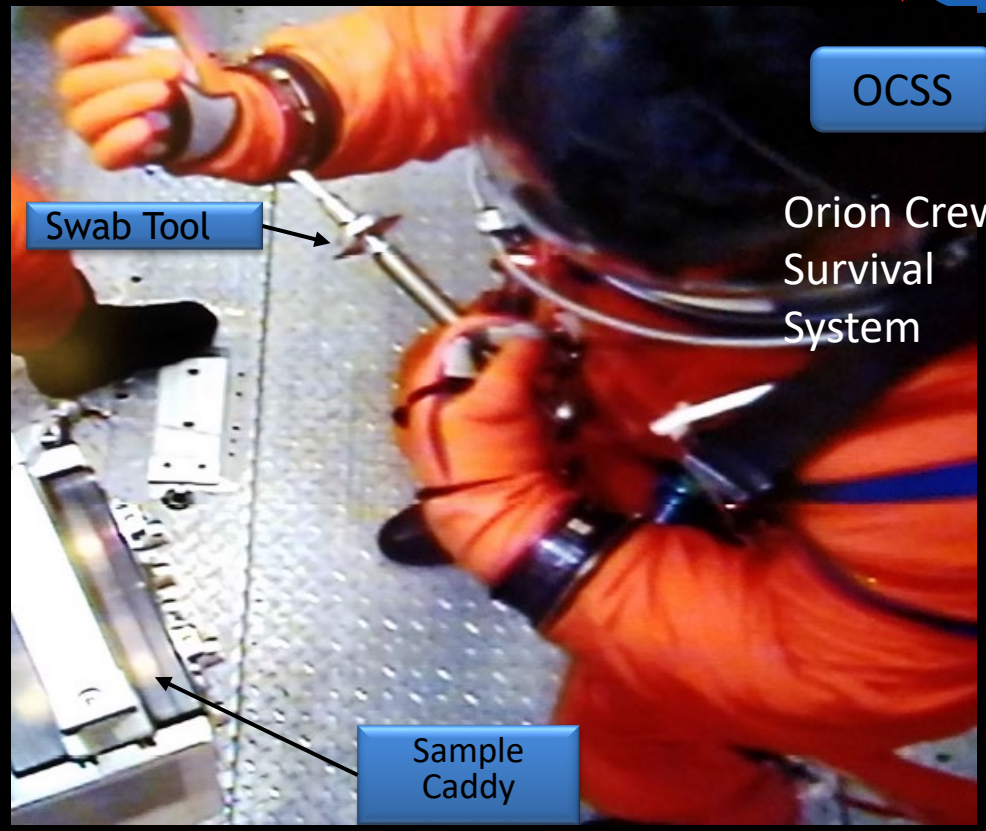
Repurposed Shuttle tile repair handle

Rucker, Michelle A., Drew Hood, Mary Walker, Kasthuri J. Venkateswaran, and Andrew C. Schuerger. 2018. "EVA Swab Tool to Support Planetary Protection and Astrobiology Evaluations." In 2018 IEEE Aerospace Conference, 1–9. IEEE. https://doi.org/10.1109/AERO.2018.8396381.

Ground Testing With Flight Like ISS and Orion Suits

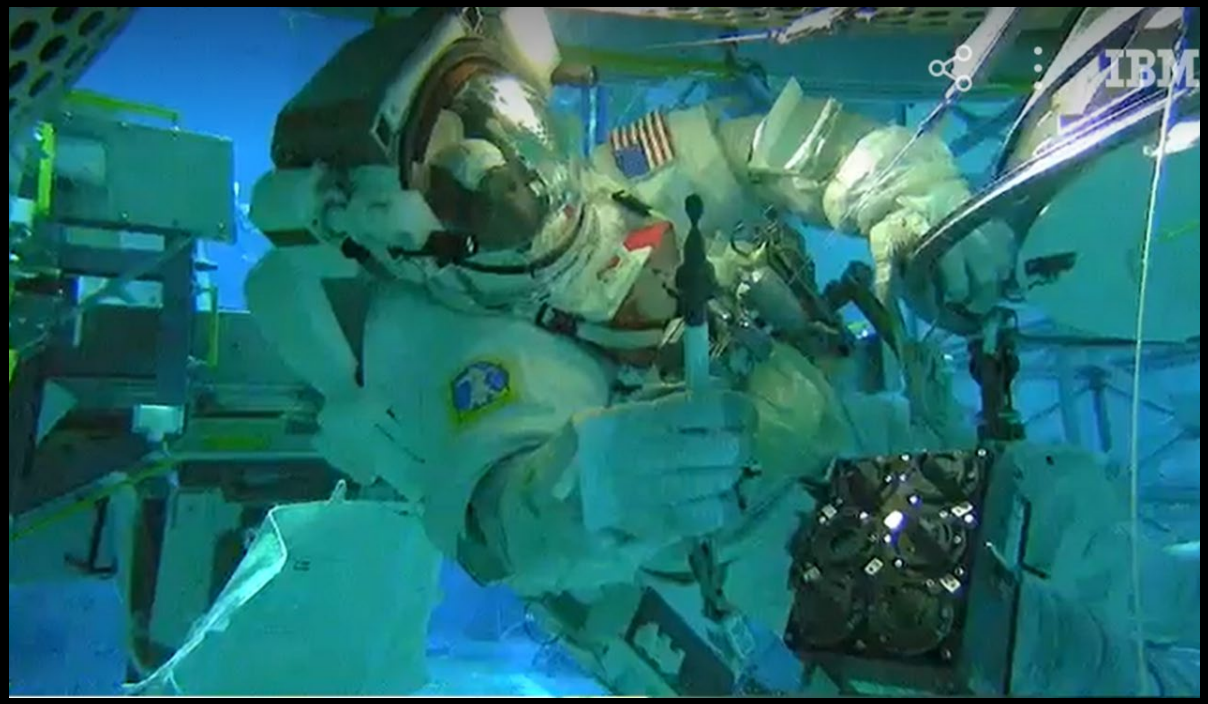
Sampling suit joints during pre-breathe
Internal suit pressure is 4.2 psig (29.6 Kpa) above atmospheric pressure

NOTE: we would NOT expose EMU wrist joints on ISS



Sampling suit at vacuum in the 11 ft. chamber at Johnson Spac Center
Internal suit pressure is 4.2 psia 29.6 Kpa)

OUTLINE



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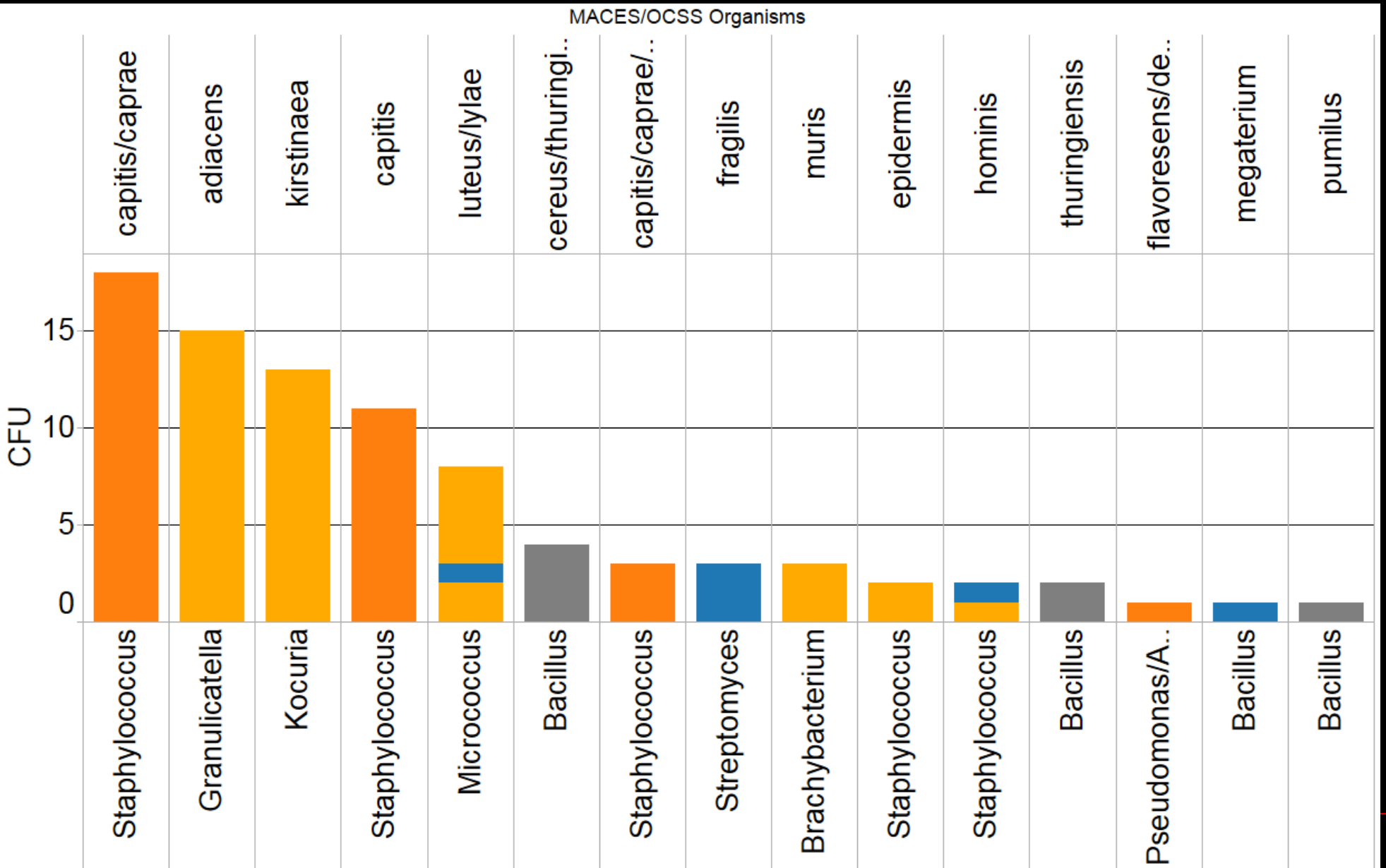
4-6 Hours of Vacuum does not Kill Bacteria on Space Suit Surfaces



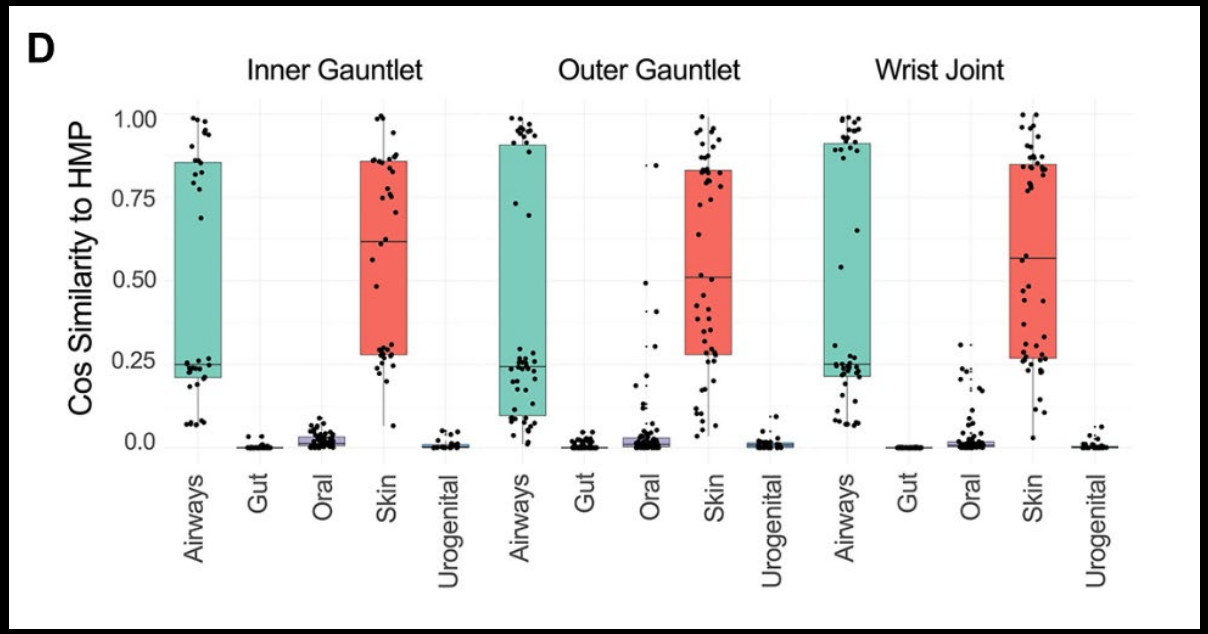
Suit type 1

Suit type 2

Pre-Test Chamber

Post-Test Chamber

Microbes on Spacesuits are similar to Microbes from Human Skin and Airways



- We used Shotgun metagenomic sequencing to further characterize the microbial community in these samples
- Spacesuits are cleaner than human skin but external surfaces are not sterile.

David Danko

Danko, D., Malli Mohan, G. B., Sierra, M. A., Rucker, M., Singh, N. K., Regberg, A. B., et al. (2021). Characterization of Spacesuit Associated Microbial Communities and Their Implications for NASA Missions. Frontiers in Microbiology, 12, 1900. https://doi.org/10.3389/fmicb.2021.608478

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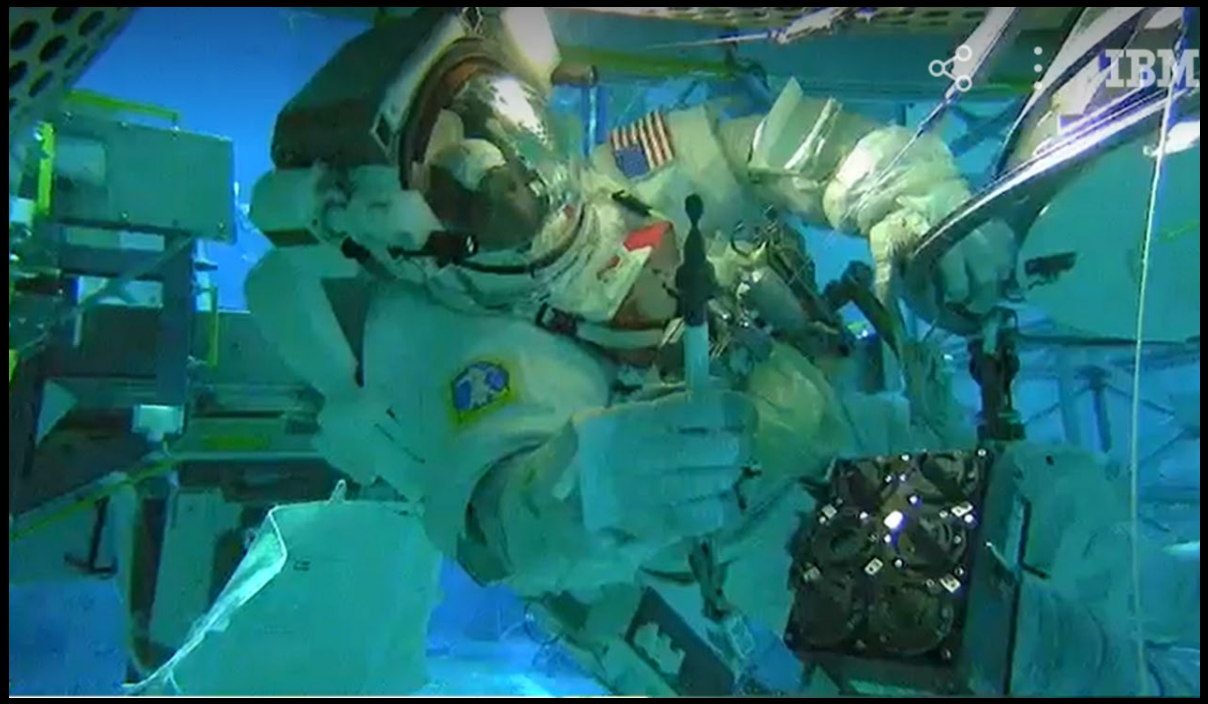

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- **Flight Hardware**
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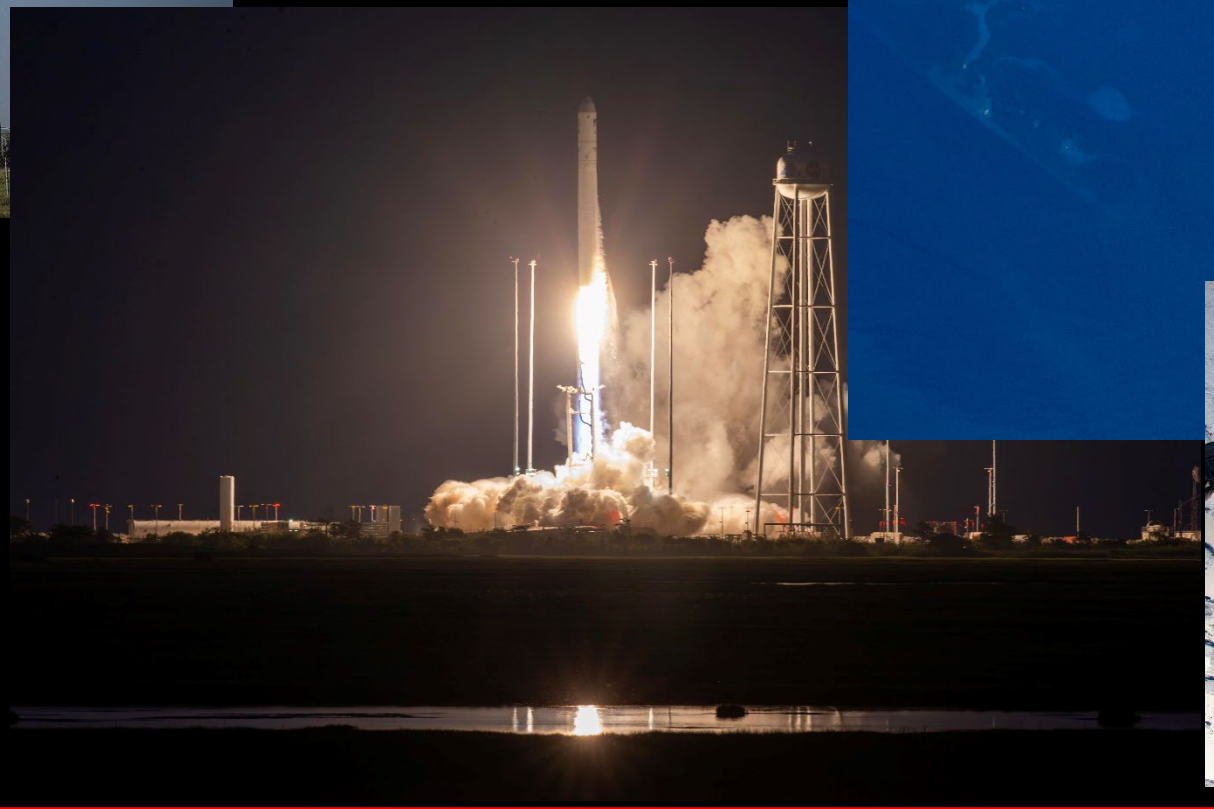
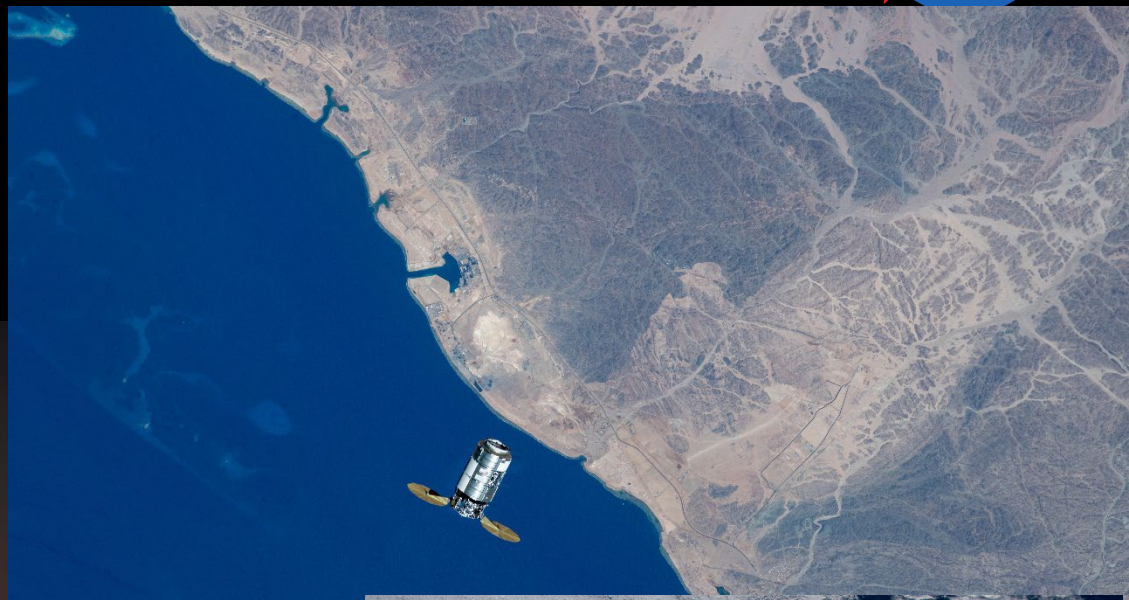
Hardware Design was Updated Based on Ground Testing Results and NASA EVA Safety Requirements

5 years

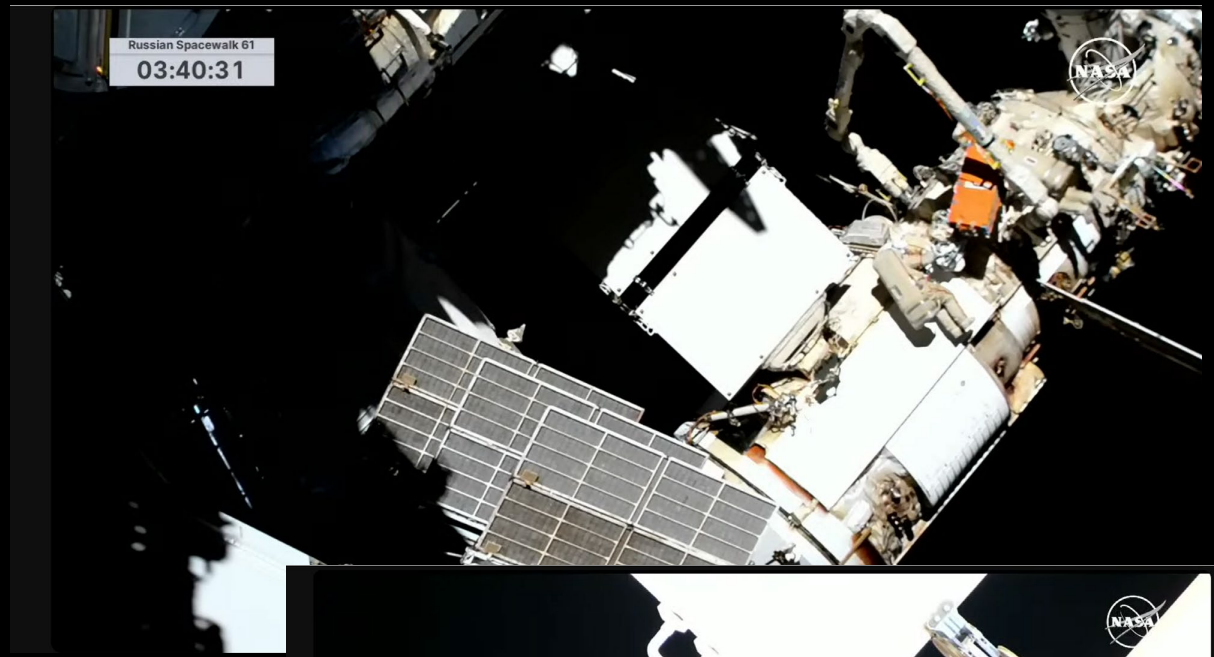
Delivered for launch in August 2023

LAUNCHED ON NG-19 IN AUGUST OF 2023





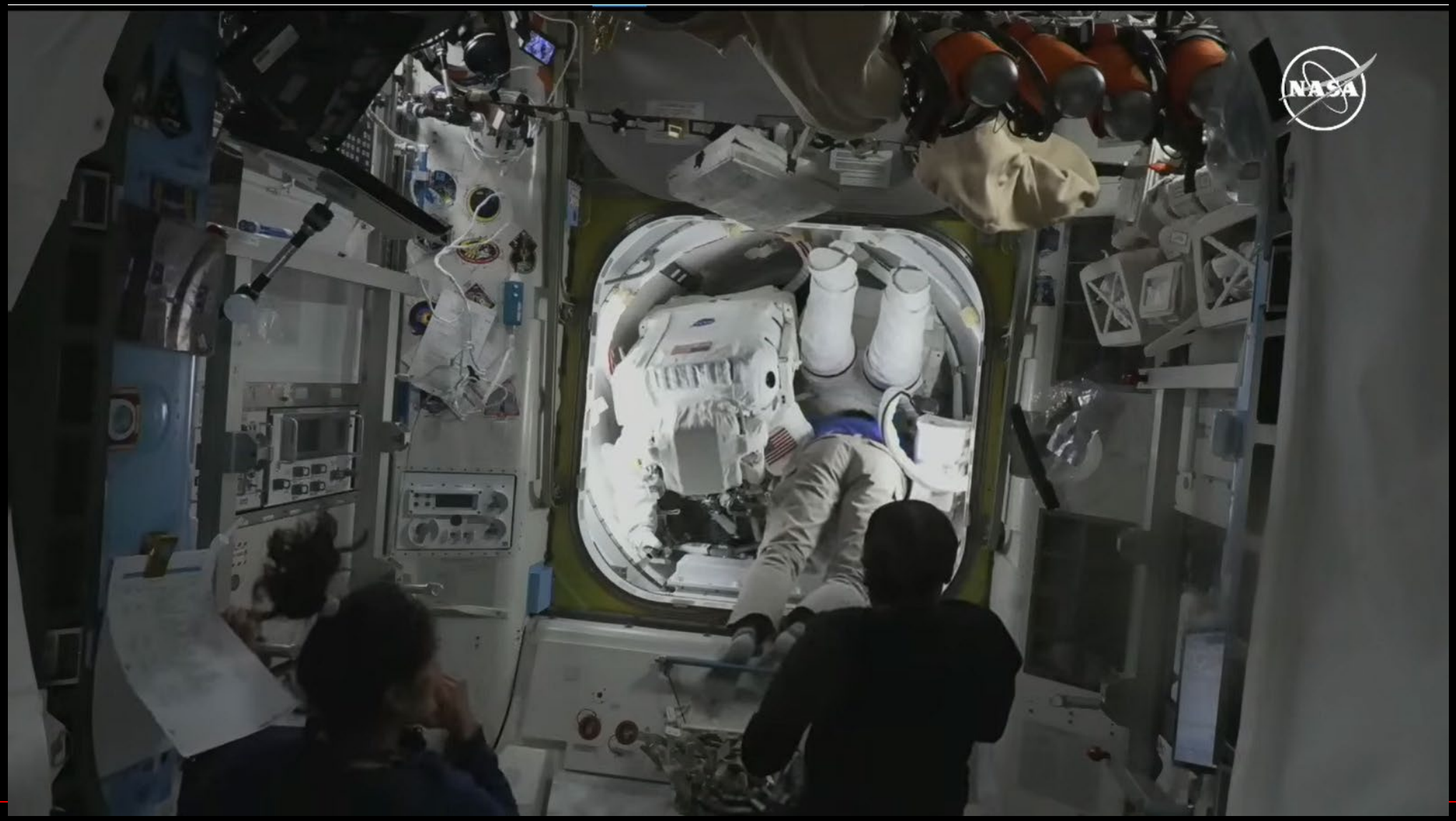
EVA Delayed from October 2023 to 6/13/2024



- Radiator coolant leak delayed US EVA's
- Coolant is non-toxic silicone oil

6/13 EVA scrubbed Due to Suit Discomfort Rescheduled for 6/24

6/24 EVA scrubbed Due to an Umbilical Water leak Rescheduled for 7/29



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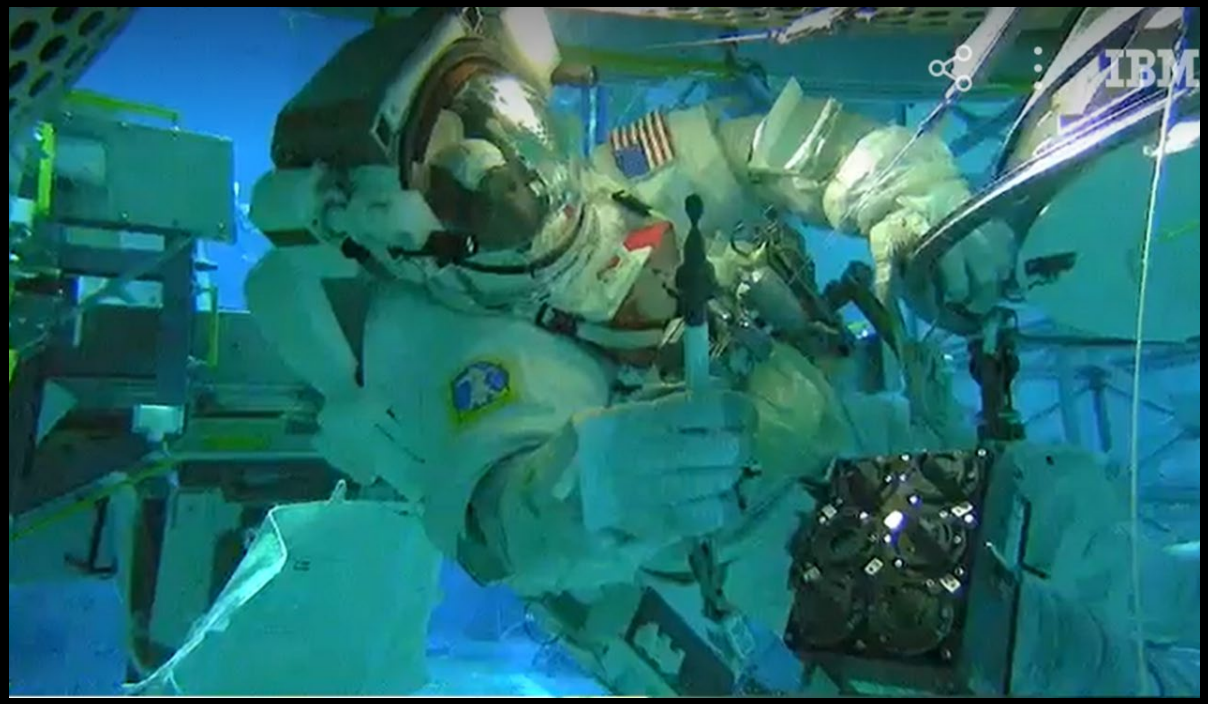

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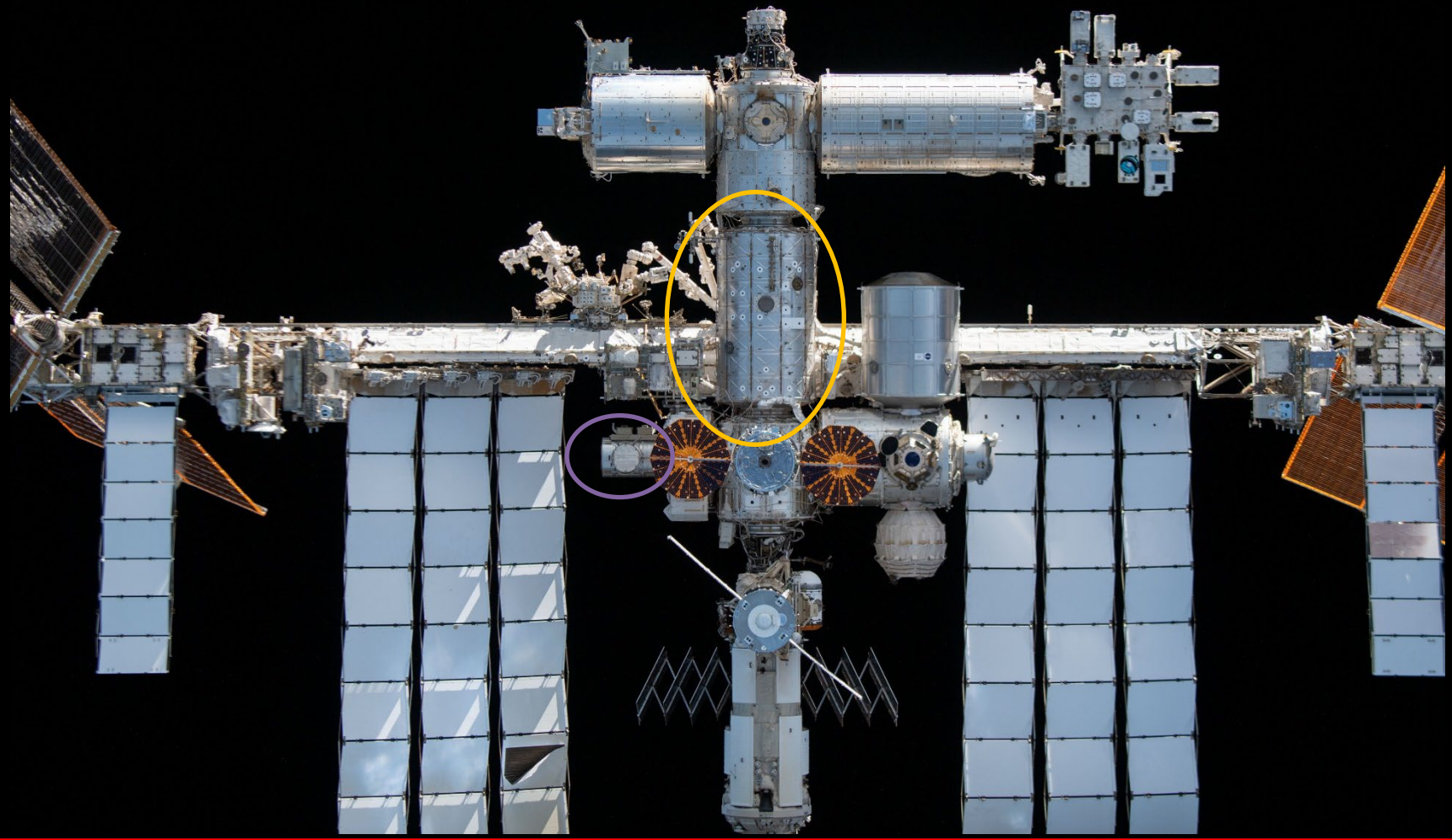
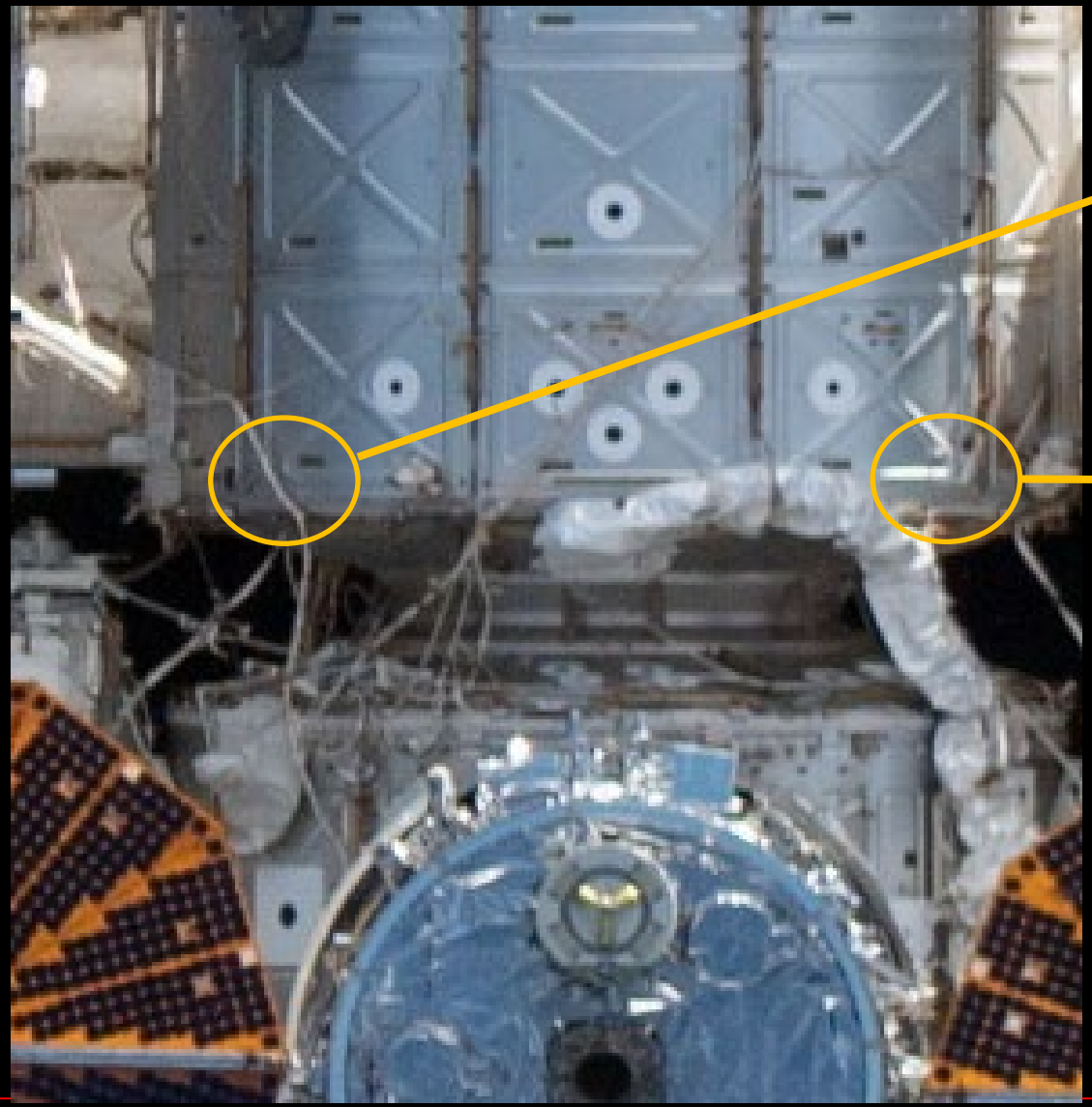
Sample Locations Near the Airlock and on the Lab Module



https://www.nasa.gov/image-article/space-station-pictured-from-spacex-crew-dragon-3/

Sample Locations on the Lab Module



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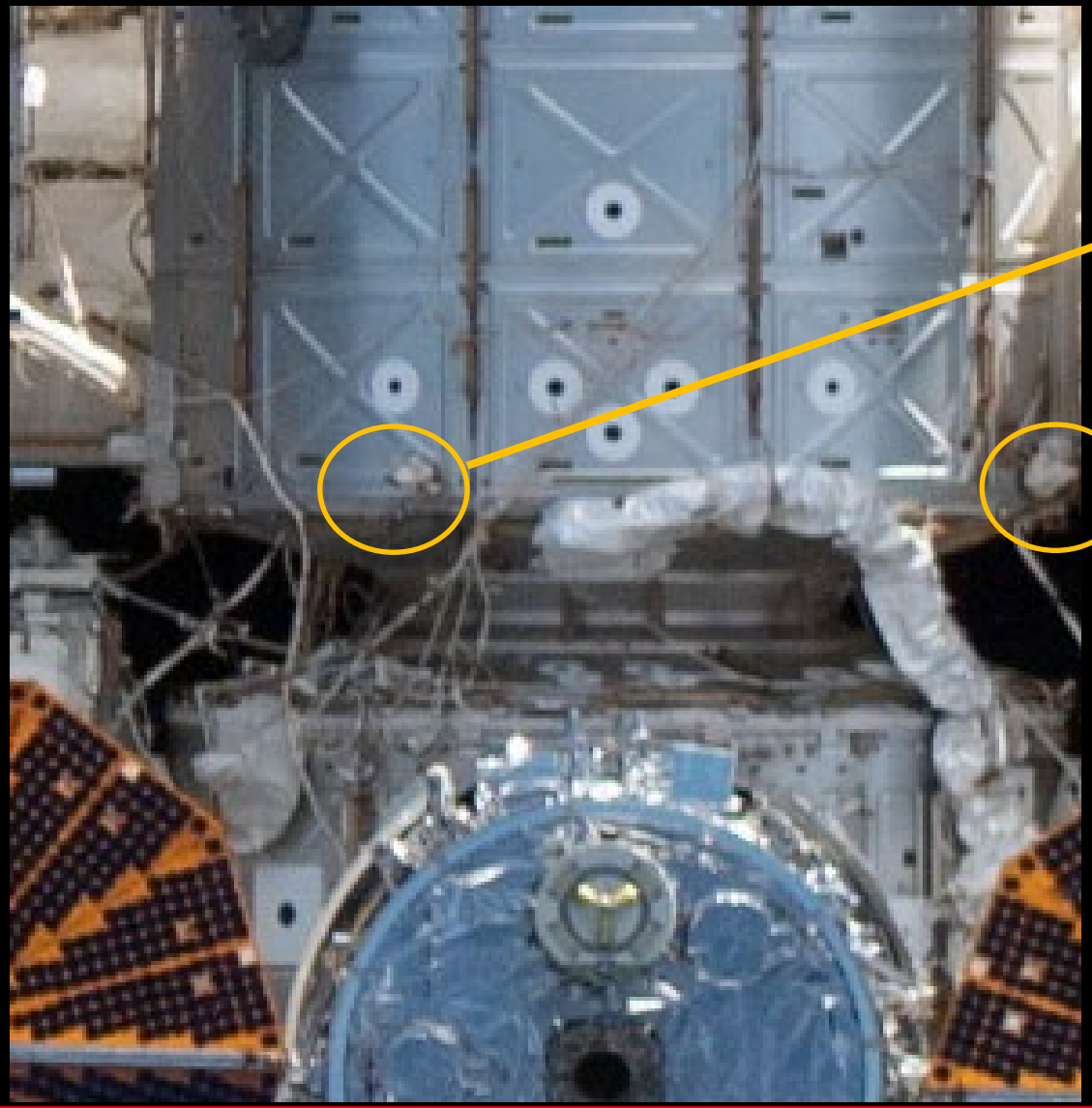

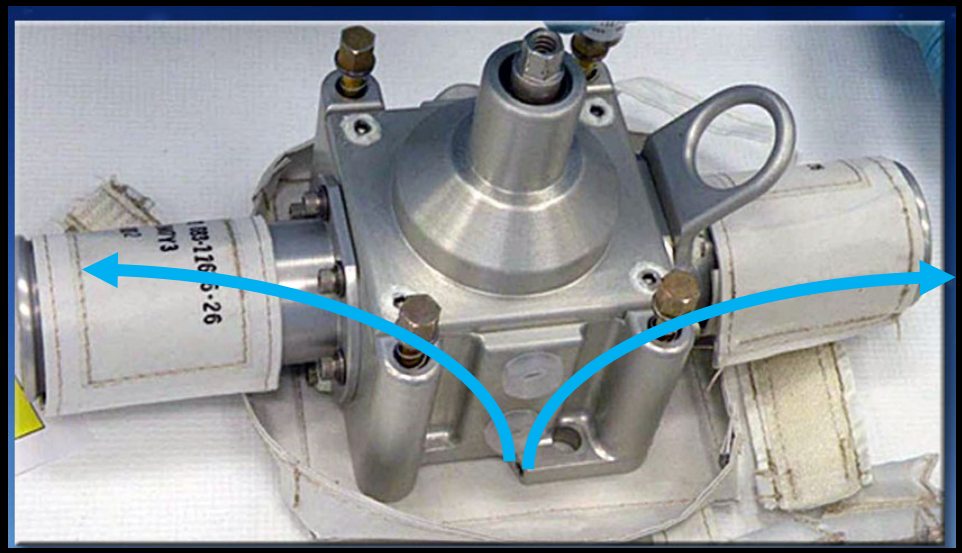

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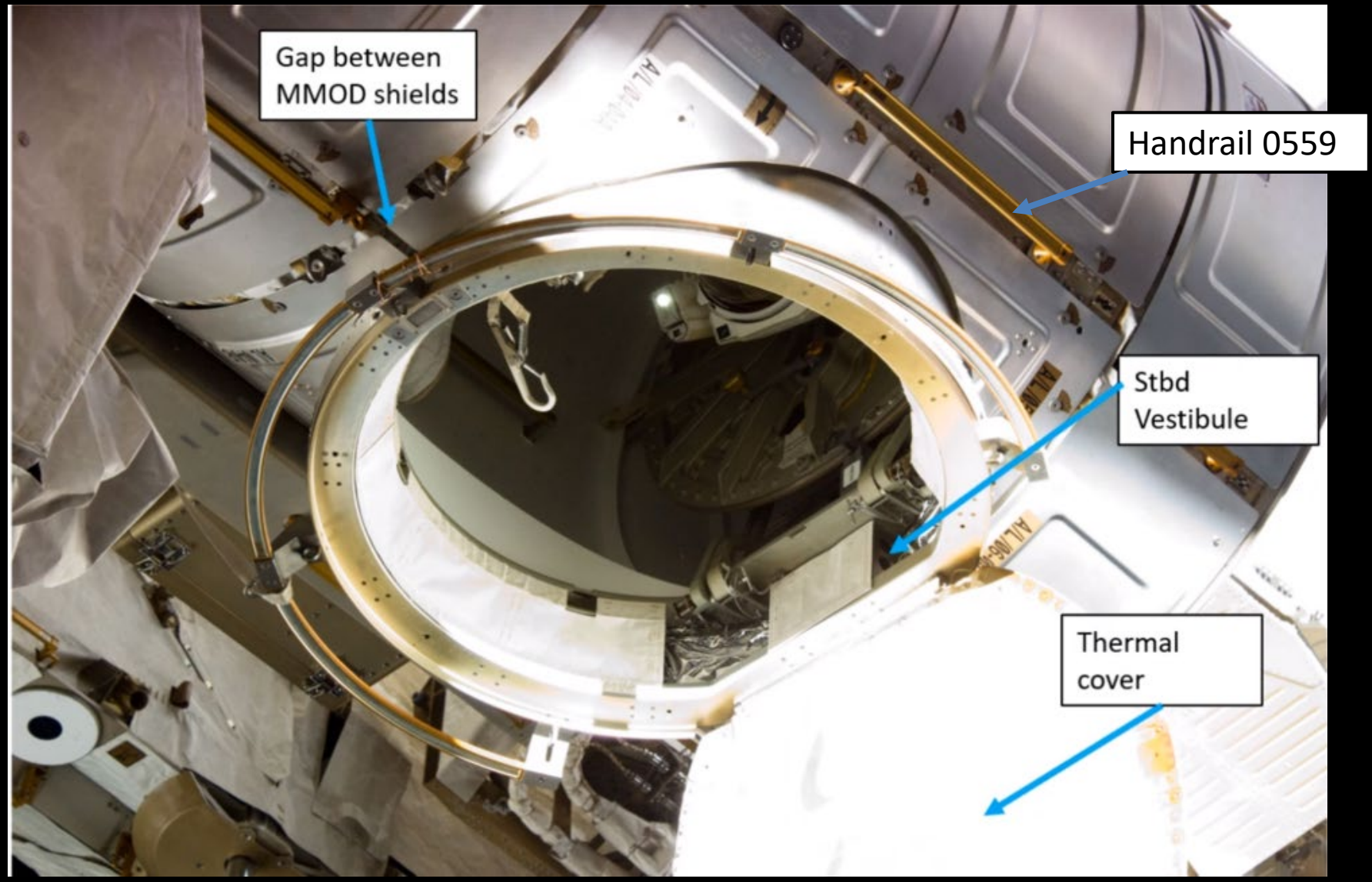
https://www.flickr.com/photos/nasa2explore/24330153925

Sample Locations Around the Airlock



Russia has Also Sampled Their Segment

BioNanoScience
https://doi.org/10.1007/s12668-019-00712-1

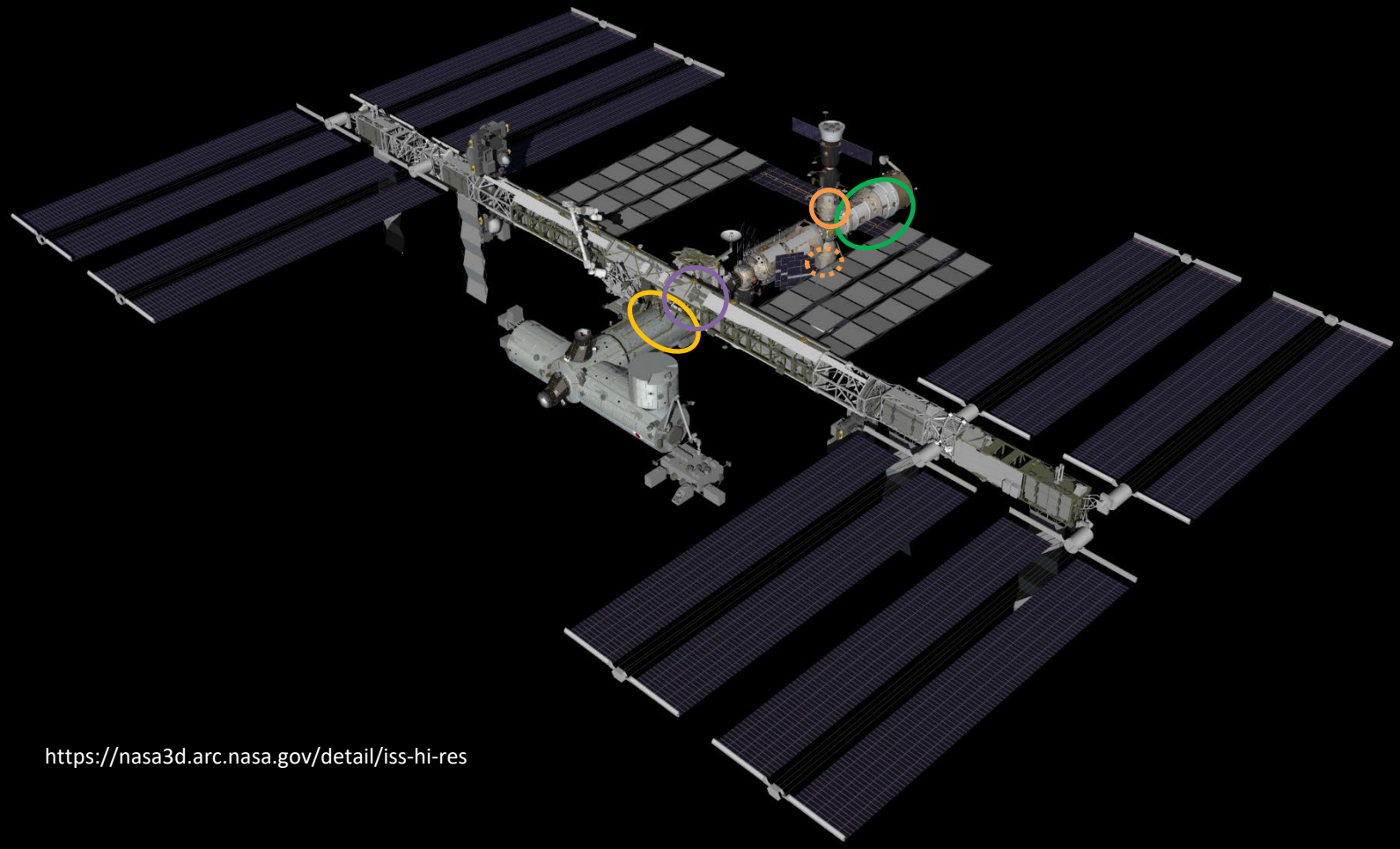
Microbiological Investigation of the Space Dust Collected from the External Surfaces of the International Space Station

Elena A. Deshevaya[1] · Elena V. Shubralova[2] · Svetlana V. Fialkina[1,3] · Aleksandr A. Guridov[1] · Natalia D. Novikova[1] · Oleg S. Tsygankov[4] · Pavel S. Lianko[2] · Oleg I. Orlov[1] · Sergey P. Morzunov[5] · Albert A. Rizvanov[5,6] · Irina V. Nikolaeva[7]

Table 4 Microorganisms isolated on the ISS external surfaces in SE TEST

EVA/date	Location sampled	Swab appearance
EVA-25 15 November 2010	Valves of trace contamination removal unit	Black spots
EVA-35 22 August 2013	Porthole of the exit hatch VL2 of the module "SEARCH"	Black spots
EVA-35 22 August 2013	Porthole of the exit hatch VL2 of the module "SEARCH"	Gray spots
EVA-38 19 June 2014	SM, window 2	Black spots
EVA-41 10 August 2015	SM, between tubes of radiator (STR)	Black spots
EVA-42 26 February 2016	The exit porthole of the module "PIRS" surface	Gray spots
EVA-42 26 February 2016	The exit porthole of the module "PIRS," window, and hatch frame	Black and gray spots, bright grains

EVA, extravehicular activities
VL2, exit porthole 2
SM, SERVICE MODULE
STR, thermal control system



https://nasa3d.arc.nasa.gov/detail/iss-hi-res

RESULTS FROM THE RUSSIAN SEGMENT

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Table 4 Microorganisms isolated on the ISS external surfaces in SE TEST

EVA/date	Location sampled	Swab appearance	Microorganisms
EVA-25 15 November 2010	Valves of trace contamination removal unit	Black spots	*Bacillus licheniformis*
EVA-35 22 August 2013	Porthole of the exit hatch VL2 of the module "SEARCH"	Black spots	*Bacillus sphaericus*; *B. subtilis*
EVA-35 22 August 2013	Porthole of the exit hatch VL2 of the module "SEARCH"	Gray spots	*B. subtilis*
EVA-38 19 June 2014	SM, window 2	Black spots	*Bacillus pumilus*
EVA-41 10 August 2015	SM, between tubes of radiator (STR)	Black spots	*Bacillus pumilus*; *Aureobasidium* sp.
EVA-42 26 February 2016	The exit porthole of the module "PIRS" surface	Gray spots	*Bacillus sphaericus*
EVA-42 26 February 2016	The exit porthole of the module "PIRS," window, and hatch frame	Black and gray spots, bright grains	*Bacillus licheniformis*; *Bacillus pumilus*; assemblage of *Agrococcus jenensis*, *Skermanella aerolata*, *Deinococcus aerolatus*, and *Staphylococcus hominis*

EVA, extravehicular activities
VL2, exit porthole 2
SM, SERVICE MODULE
STR, thermal control system

Table 2 The dust sampling chronology

EVA	Date	Cosmonauts who collected samples
EVA-25 (two samples)	15.11.2010	F. Yurchikhin
EVA-35 (two samples)	22.08.2013	A. Misurkin
EVA-38 (two samples)	19.06.2014	O. Artemiev
EVA-39 (two samples)	18.08.2014	O. Artemiev
EVA-40 (two samples)	20.10.2014	A. Samokutiaev
EVA-41 (five samples)	10.08.2015	M. Kornienko
EVA-42 (three samples)	26.02.2016	O. Volkov, Yu. Malenchenko

- All identified organisms also found inside ISS
- Only able to culture organisms from stained samples
- Not able to cultivate microorganisms from beneath thermal blankets

CONCLUSIONS

- NASA has developed and tested a tool kit for collecting microbiological samples during EVA.
- Results from this experiment should help close planetary protection knowledge gaps for crewed missions and allow us to develop life support systems that minimize forward contamination.
- The payload is on station, and we hope to collect samples in July of 2024.
- Working with flight operations on a science payload has been good practice for conducting EVA science on Artemis missions.
- The tool kit could also be used to collect organic. contamination knowledge samples on other crewed or robotic missions.