Human Impacts at Mars and Necessary Baseline Measurements

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08/01/2024

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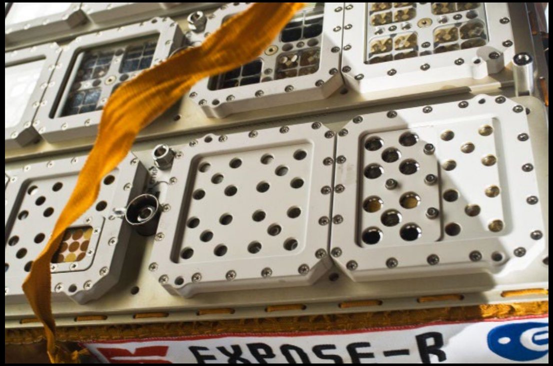
- PhD in Geoscience and Biogeochemistry (Penn State 2011)
- Started in the astromaterials curation office in 2017
  - Scientists who take care of NASA's extraterrestrial samples
  - Responsible for microbial monitoring of curation clean rooms
  - Quality Assurance for OSIRIS-REx recovery
- JSC Planetary Protection Lead
  - Forward contamination requirements for Artemis
  - Backward planetary protection plan for Mars Sample Return
- Hobbies
  - Rock climbing, cycling, cooking

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

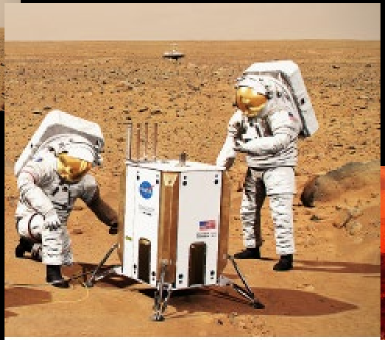
Tardigrades survived extended ISS exposure… *and then reproduced*

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

Potential Sources of Organic Contamination During Apollo Missions

1. Surface contamination of sample containers (rock box)
2. Surface contamination of sample collection tools
3. Exhaust products from descent engine and reaction control system
4. Lunar Module Outgassing
5. Spacesuit leakage
6. Particle shedding from spacesuits
7. Lunar module venting from: fuel tanks, oxidizer tanks, cabin atmosphere, and waste systems
8. Spacesuit venting

Total organic contamination was 1 µg C/ g for Apollo 11 and 0.1 µg C/ g for subsequent missions

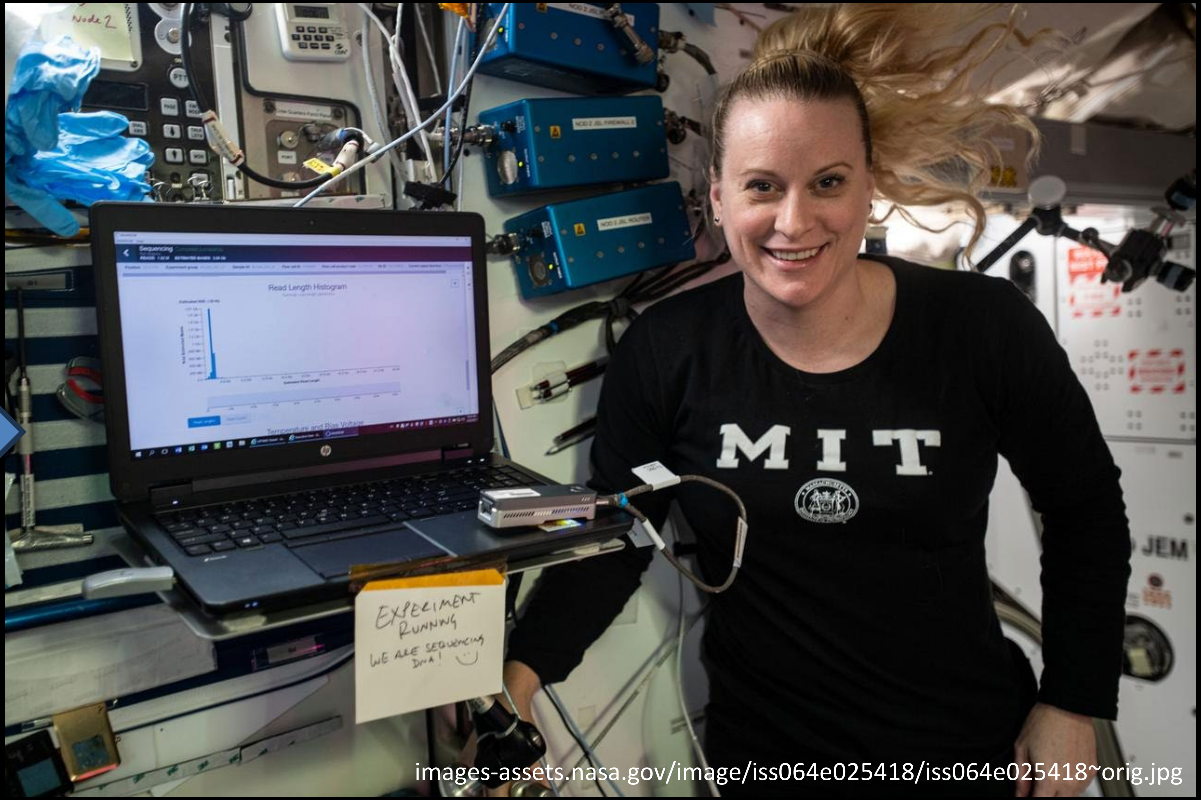
B. R. Simoneit and D. A. Flory (1970) Apollo 11, 12 and 13 Organic Contamination Monitoring History, UC Berkeley

To Date we have not observed biological Contamination of Pristine Apollo Samples

Fig. Apollo 12 astronaut Pete Conrad and a photographer with the Surveyor III camera prior to bagging and storage (NASA JSC photo S-69-62290).

Rummel, J. D., Allton, J. H., and Morrison, D. (2011). A Microbe on the Moon? Surveyor III and Lessons Learned for Future Sample Return Missions., in *The Importance of Solar System Sample Return Missions to the Future of Planetary Science*, 5023. Available at: https://ui.adsabs.harvard.edu/abs/2011LPICo1611.5023R

However… Our Tools Have Improved Dramatically



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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?

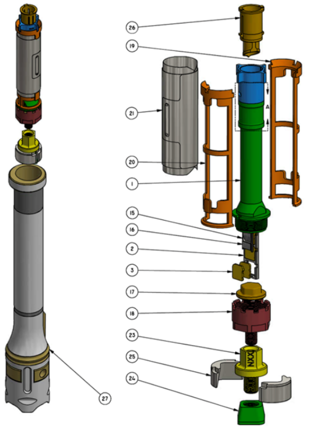
Knowledge Gap 2B. What level of non-viable microbial contamination escape is acceptable?

https://www.nasa.gov/image-article/ammonia-pictured-venting-outside-of-international-space-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?
- What if our spacecraft create an artificial habitable zone?

Eliminating Contamination is Impossible
Characterizing Contamination is Necessary

The Sampling and Caching Subsystem (SCS)... Page 31 of 43 5



Item	Quantity	Description
1	1	Main Structure weldment
2	2	Smooth witness retainer
3	12	Smooth witness
15	2	Getter retainer
16	2	Getter foil
17	1	Gasket plug
18	1	Gasket cap
19	1	Particle witness frame, keyed
20	1	Particle witness frame
21	1	Particle sieve
23	1	Screw base
24	1	Square plug
25	2	Clamshell anchor
26	1	Flexured poker
27	1	Sample tube

Fig. 39 Witness Assembly is installed into a Sample Tube (left). Exploded view shows the major component assemblies: **a**) an anchoring mechanism to retain the assembly within the Sample Tube; **b**) hermetically sealed compartment (green); **c**) particle trap, consisting of perforated fine sieves wrapped around the sealed compartment, and **d**) a puncture mechanism to open the hermetic compartment. Inside the sealed compartment are 2 getter foils and 12 individual polished gold witnesses

Moeller, R. C., Jandura, L., Rosette, K., Robinson, M., Samuels, J., Silverman, M., et al. (2021). The Sampling and Caching Subsystem (SCS) for the Scientific Exploration of Jezero Crater by the Mars 2020 Perseverance Rover. *Space Science Reviews* 217, 1–43. doi: 10.1007/s11214-020-00783-7

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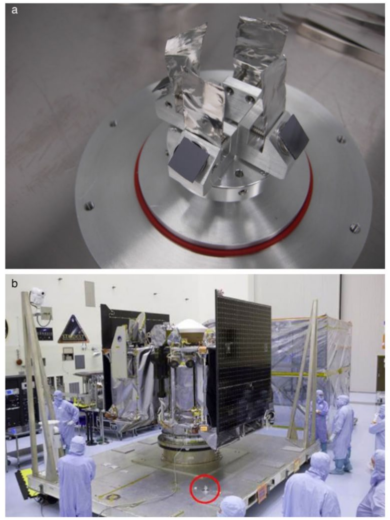
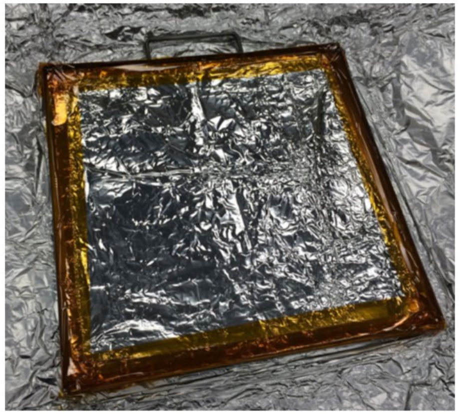
Fig. 12 (**a**) Contamination knowledge plates consisted of precision cleaned silicon wafers mounted on SEM sample holders to collect particles and high-purity aluminum foils for organic NVR analysis. These were deployed in parallel with the contamination monitoring plates. Following one month of exposure, the entire unit was sealed in an aluminum housing bolted to the baseplate after exposure. (**b**) Location of contamination knowledge witness plate (in *red circle*) on shipping container base soon after arrival in the PHSF



Dworkin, J. P., Adelman, L. A., Ajluni, T., Andronikov, A. V., Aponte, J. C., Bartels, A. E., et al. (2018). OSIRIS-REx Contamination Control Strategy and Implementation. *Space Sci Rev* 214. doi: 10.1007/s11214-017-0439-4

Fig. 5 Amino acid contamination monitoring plate adapted from a standard 1 × 1 ft. ASTM E1235-12 NVR plate for the 4-m Atlas V fairing



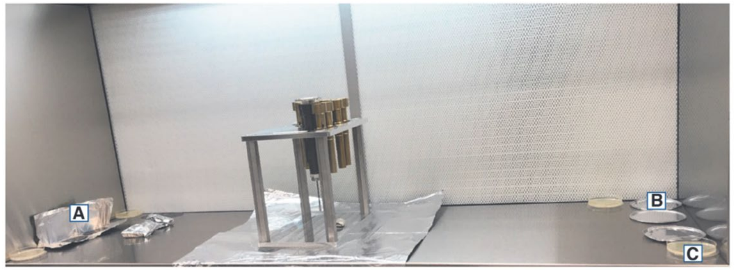
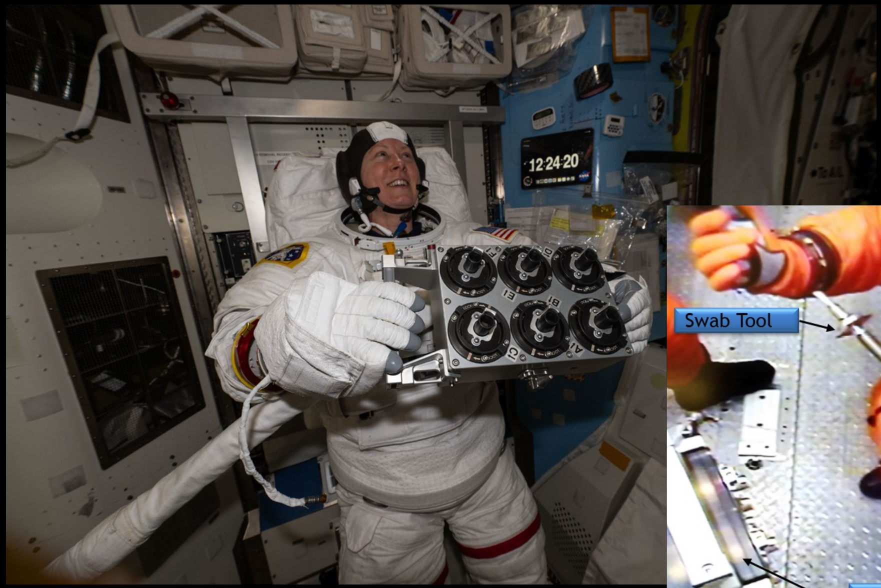
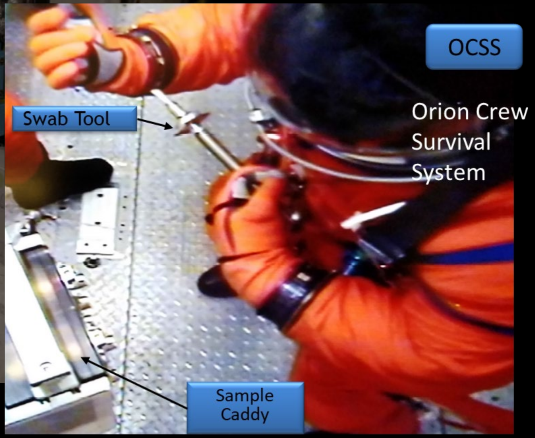


FIG. 6. A typical ISO5 flow bench witness plate set up for monitoring the ST assembly. Silicon wafer (**A**) and aluminum witness plates (**B**) were placed around the edges of the work space for contamination control. Petri dishes (**C**) with agar growth media were also used for monitoring biological fallout.

Maltais, T. R., Boeder, P., Soares, C., Mennella, J., Heinz, N., Gomez, V., et al. (2023). An Accounting of Contamination Control Requirements, Implementation, and Verification of the Sample Tubes for the Mars 2020 Mission and Future Return Sample Science. *Astrobiology*. doi: 10.1089/ast.2022.0049

What will this Look Like on Mars?





- Necessary Baselines
  - Organic contamination baseline
  - Inorganic contamination baseline
    - Water
    - Particulates
  - Temperature effects
  - Biological contamination baseline
  - Magnetic field baseline
  - Radiation baseline
- Potential Solutions
  - Return blanks and witness materials with the samples
  - Have astronauts collect contamination knowledge samples
  - Send clean robots to collect samples
  - Send clean robots to predeploy sensors or samples to monitor contamination
  - Others?