ORGANIC INVENTORIES FOR SAMPLE RETURN MISSIONS: LESSONS LEARNED FROM APOLLO TO OSIRIS-REX

National Aeronautics and Space Administration

Aaron B. Regberg

02/27/2024

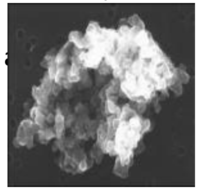
The Astromaterials Acquisition and Curation Office

Our Past 50 years – planning for and curating multiple collections

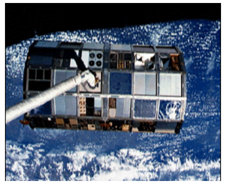
Lunar
(1969)
Apollo program lunar rocks and soils; Luna samples

Meteorite
(1977)
Antarctic Search for Meteorites (ANSMET) program

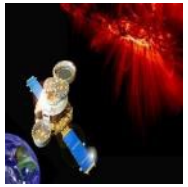
Cosmic Dust
(1981)
Cosmic dust grains from Earth's stratosphere



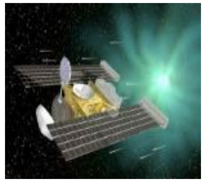
Micro-particle
(1985)
Space exposed hardware from spacecraft



Genesis
(2004)
Genesis solar wind samples at Earth-Sun L1 point



Stardust
(2006)
Cometary and interstellar samples from Comet Wild 2



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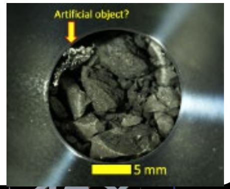
(2012)
Samples collected from JAXA asteroid mission to Itokawa

Hayabusa II
(2020)
Subset of samples collected from JAXA asteroid mission to 162173 Ryugu



OSIRIS-REx
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Asteroid sample return from 101955 Bennu

Our Near Future . . .

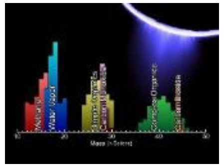
Artemis
(2025)
Lunar South Pole. Cold Sample return?

Our More Distant Future . . .

Mars
(~2030s)

(est. 1964)

Comet
Enceladus
Europa
Ceres



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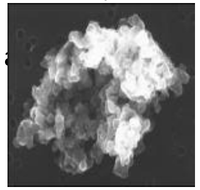

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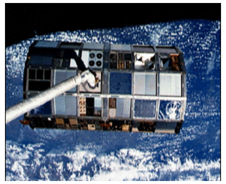

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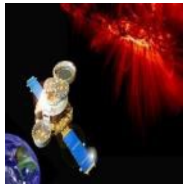

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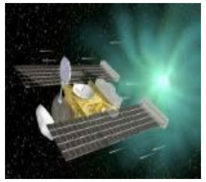

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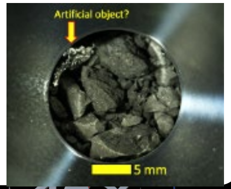

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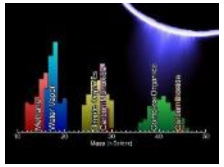
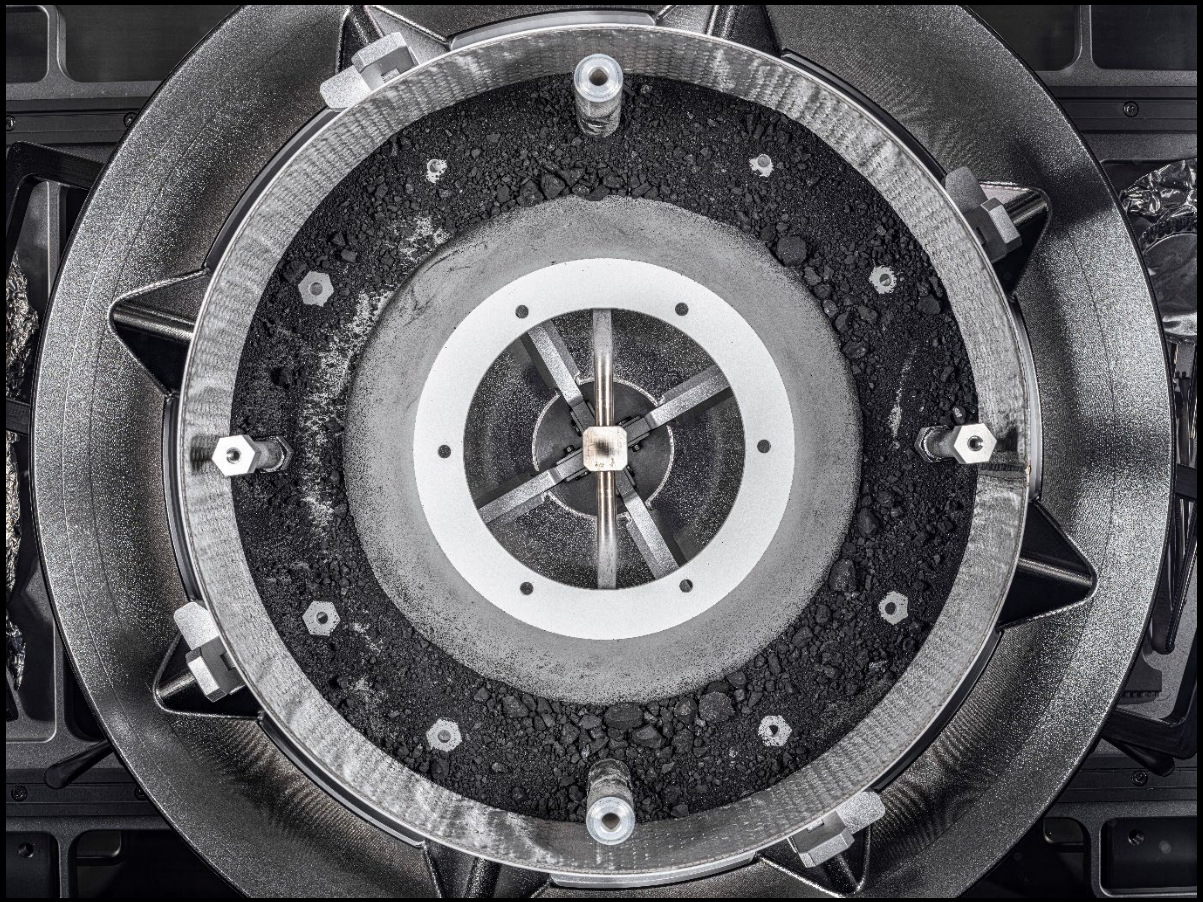


Proximity to the Sample May Be a Better Indicator of Risk than Total Mass

Hayabusa2: Chamber C

OSIRIS-REx TAGSAM



Potential Sources of Organic Contamination During Apollo Missions

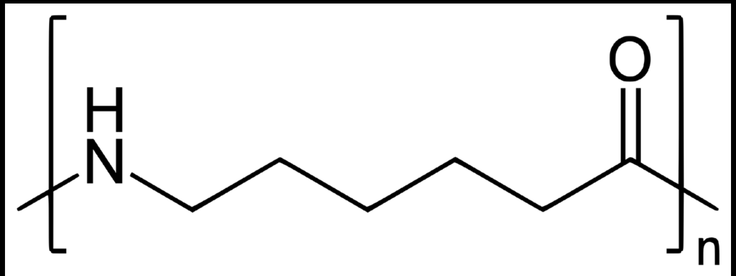
1. Surface contamination of sample containers (rock box)
2. Surface contamination of sample collection tools
3. Exhaust products from descent engine and reaction control system
4. Lunar Module Outgassing
5. Spacesuit leakage
6. Particle shedding from spacesuits
7. Lunar module venting from: fuel tanks,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

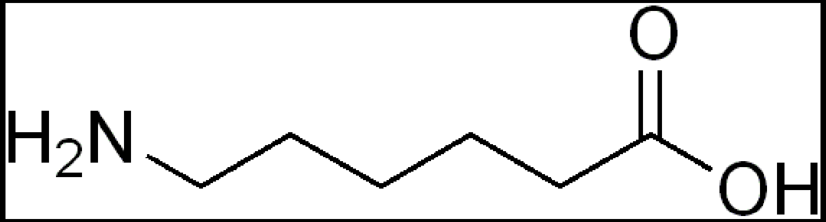
B. R. Simoneit and D. A. Flory (1970) Apollo 11, 12 and 13 Organic Contamination Monitoring History, UC Berkeley

Organic Contamination From Nylon Bags in Apollo and Meteorite Collections

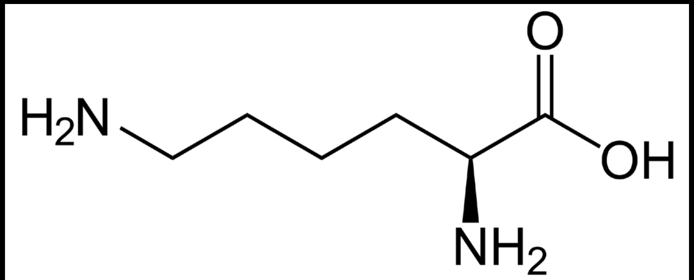
Nylon 6

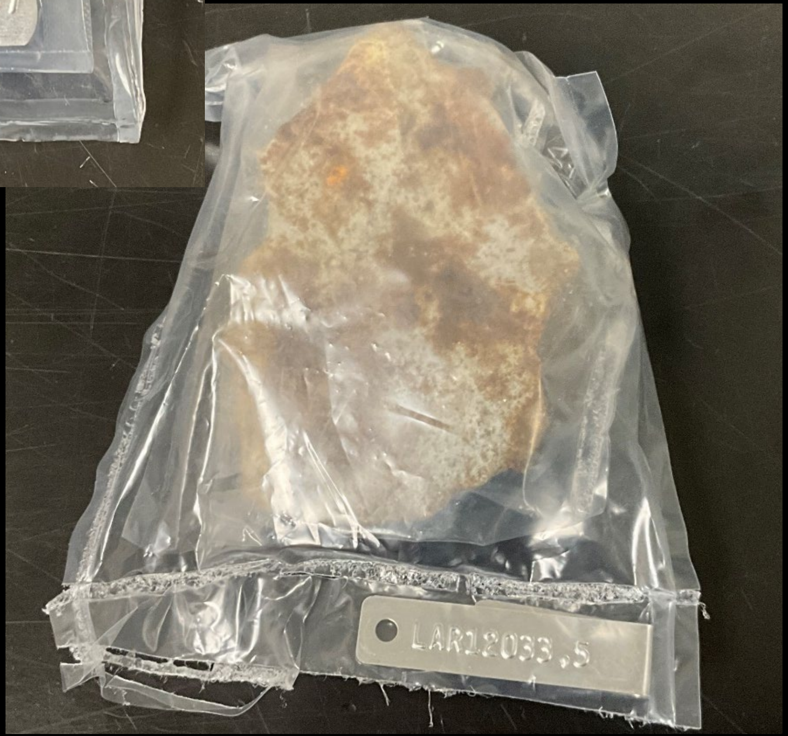


Aminocaproic acid



L-lysine





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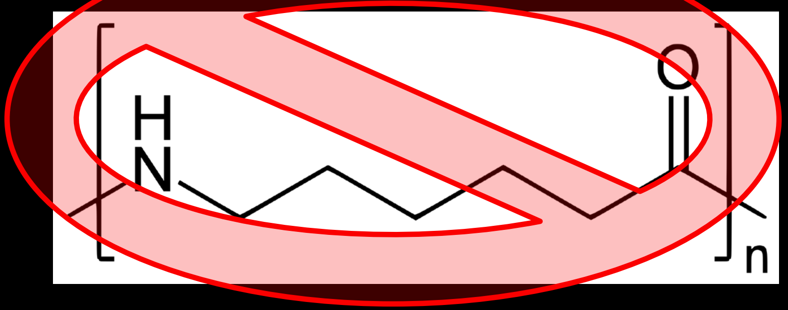
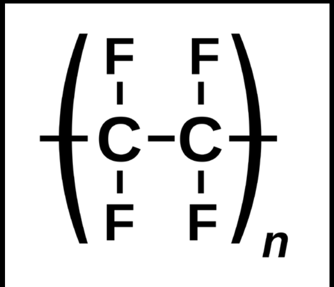
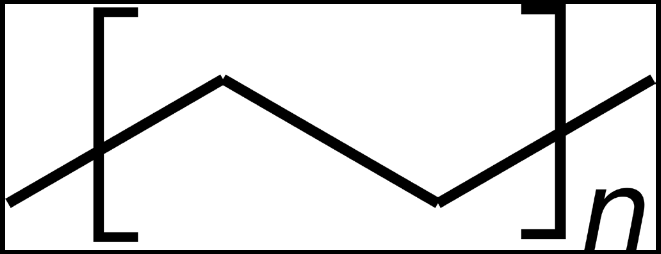


Teflon (PTFE)



Polyethylene



Organic Contamination from Xylan Lubricant

- Xylan 1010 was thought to be a pure Teflon (PTFE) lubricant
- Used as a replacement for molybdenum disulfide from 1972 – 1990 in curation facilities to prevent galling of stainless-steel bolts
- Xylan contained
  - PTFE Teflon
  - FEP Teflon
  - Polyamide
  - Ethyl Acetate
  - N,N Dimethlyformamide
  - Xylene
  - N-Methyl-2-pyrrolidone

Calaway, M. J., Allen, C. C., & Allton, J. H. (2014). Organic Contamination Baseline Study in NASA Johnson Space Center Astromaterials Curation Laboratories (p. 108). Hanover, MD: NASA.

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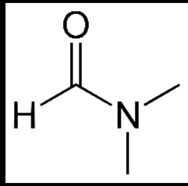

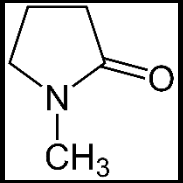

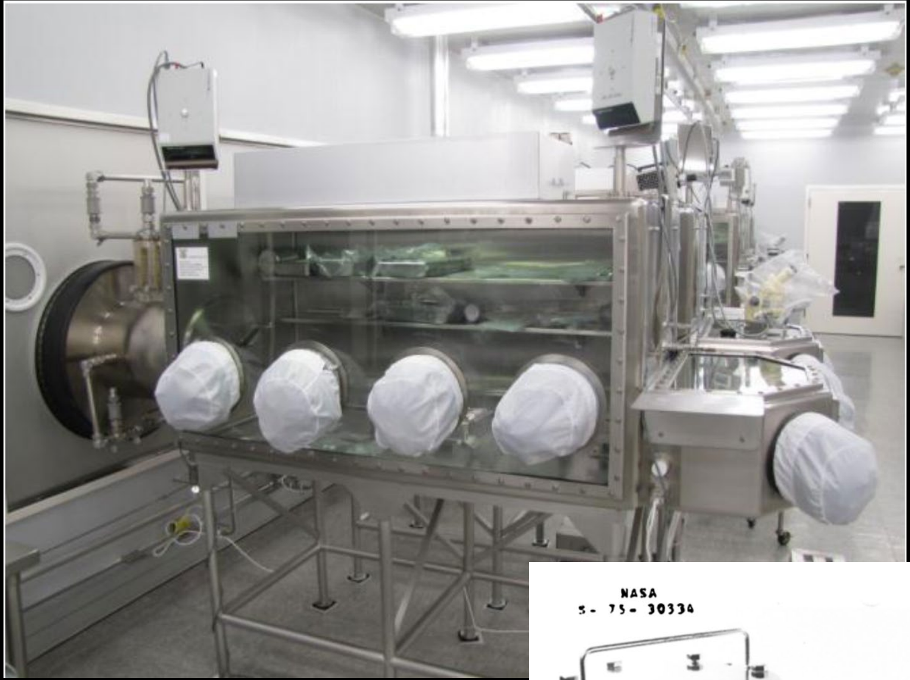

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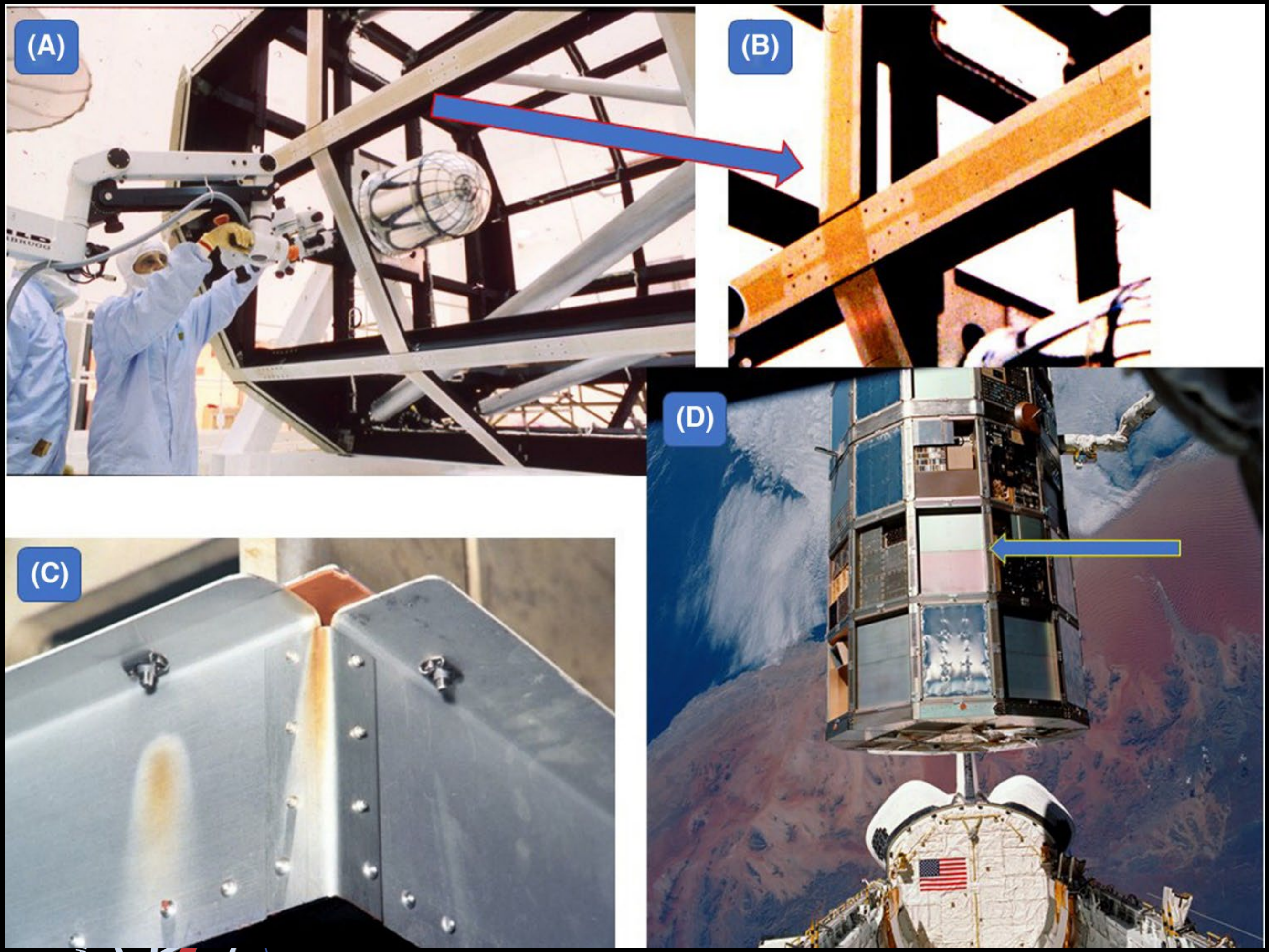
Long Duration Exposure Facility captured the Organic Contamination effects of outgassing that also affected Genesis



- Facility in orbit for 6 years (1984 – 1990)
- Visible evidence of outgassing and redeposition on optics and other surfaces.
  - Silicon based adhesive (RTV)
  - Organic lubricants
- Outgassing driven by temperature differences

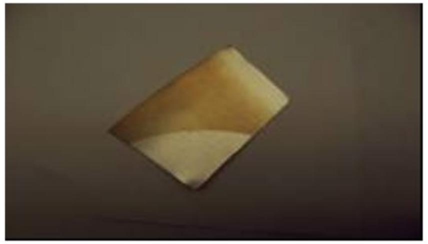


Figure 2. A section of the aluminum canister thermal shield post-flight, showing areas with and without brown discoloration.

Burnett, D. S., McNamara, K. M., Jurewicz, A., & Woolum, D. (2005). Molecular Contamination on Anodized Aluminum Components of the Genesis Science Canister. Retrieved from https://ntrs.nasa.gov/citations/20050167043

Zolensky, M. (2021). The Long Duration Exposure Facility—A forgotten bridge between Apollo and Stardust. *Meteoritics & Planetary Science*, *56*(5), 900–910. https://doi.org/10.1111/maps.13656

Organic Contamination in the Stardust Aerogel

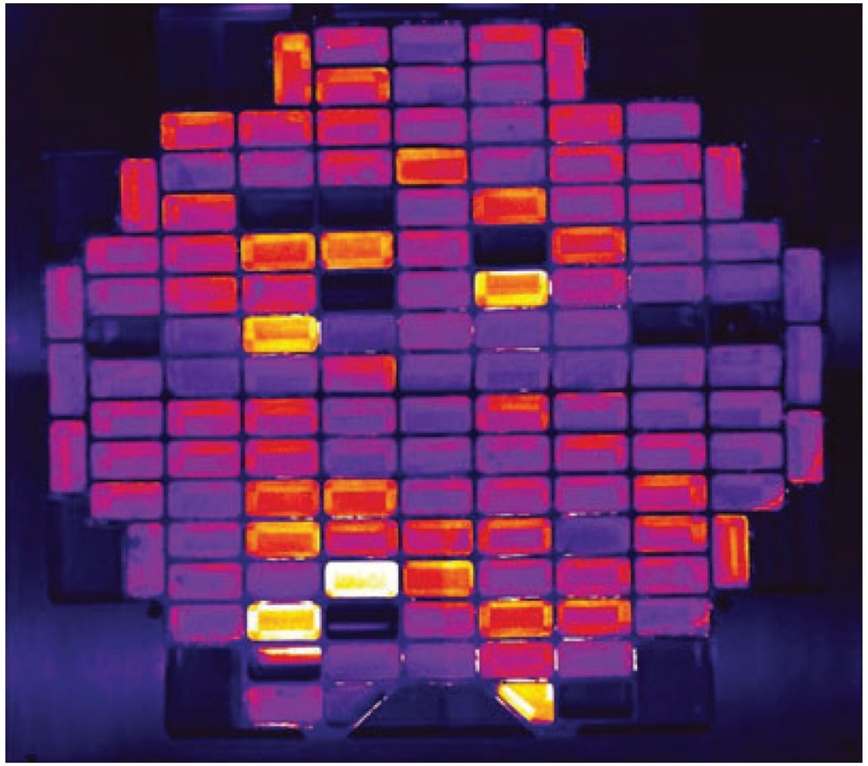


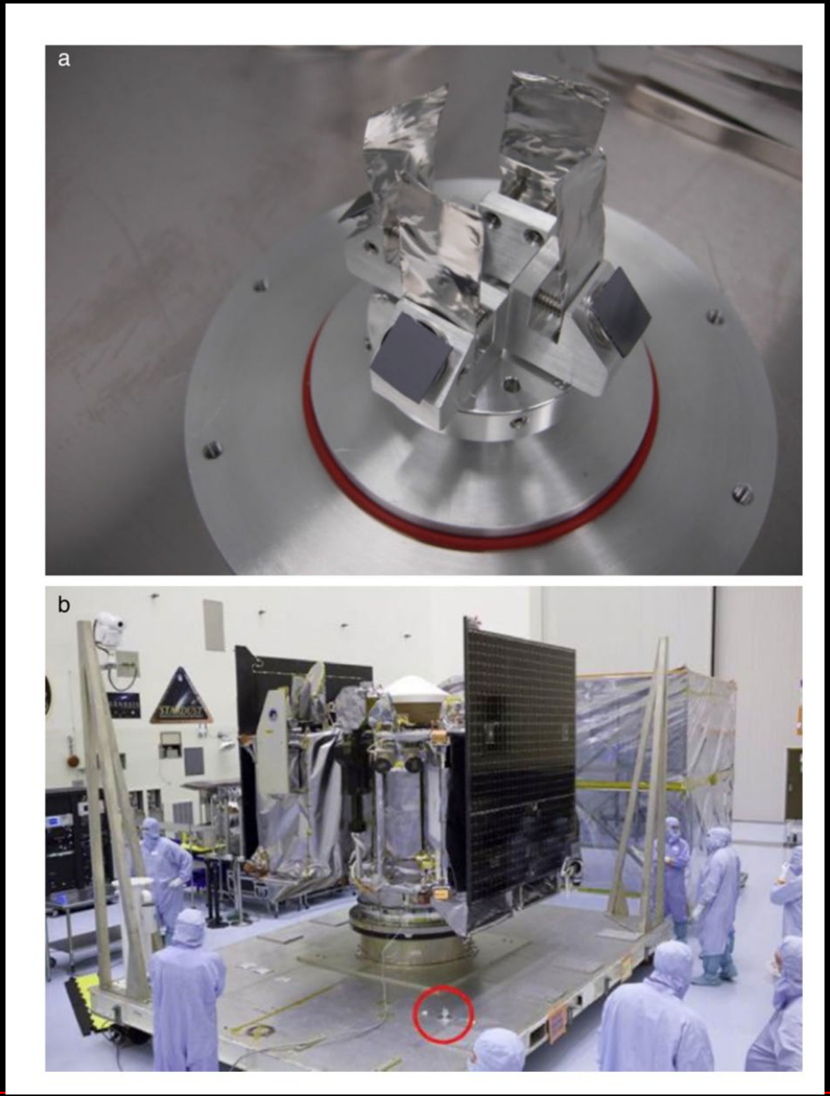
Fig. 7. Photograph of the tile luminescence in the cometary tray. Dark rectangles represent locations where tiles had already been removed for PE analysis. It is clear from these images that the luminescence is not uniformly or smoothly spread across the collector tray.

254 nm excitation

- Aerogel in the collector contained organic compounds including amino acids, and polyaromatic hydrocarbons
  - Organic solvents used during synthesis
  - Synlube 1000 used as a mold release
  - Additional organic capture from propellant, and secondary impact to the Whipple shields, and solar panels
- Aerogel samples archived at JCC
  - 10 batches in the cometary collector
  - 19 batches in the interstellar collector
- Non-uniform distribution of contamination
- Bakeout at 350 °C did not remove all the contamination
  - High temperature bakeouts damaged the aerogel
- Likely alteration of organics during particle impact into the aerogel

Sandford, S. A., Bajt, S., Clemett, S. J., Cody, G. D., Cooper, G., Degregorio, B. T., et al. (2010). Assessment and control of organic and other contaminants associated with the Stardust sample return from comet 81P/Wild 2. *Meteoritics & Planetary Science*, *45*(3), 406–433. https://doi.org/10.1111/j.1945-5100.2010.01031.x

Contamination Knowledge and Organic Inventories have Been Important for OSIRIS-REx



- Witness materials were used to quantify the organic baseline
  - Also got some DNA sequencing data for “free”
- Contamination Knowledge material archive is currently being used to further refine this baseline

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*(9). https://doi.org/10.1007/s11214-017-0439-4

We Expect the Contamination Knowledge Archive will be Critical for Mars Sample Return

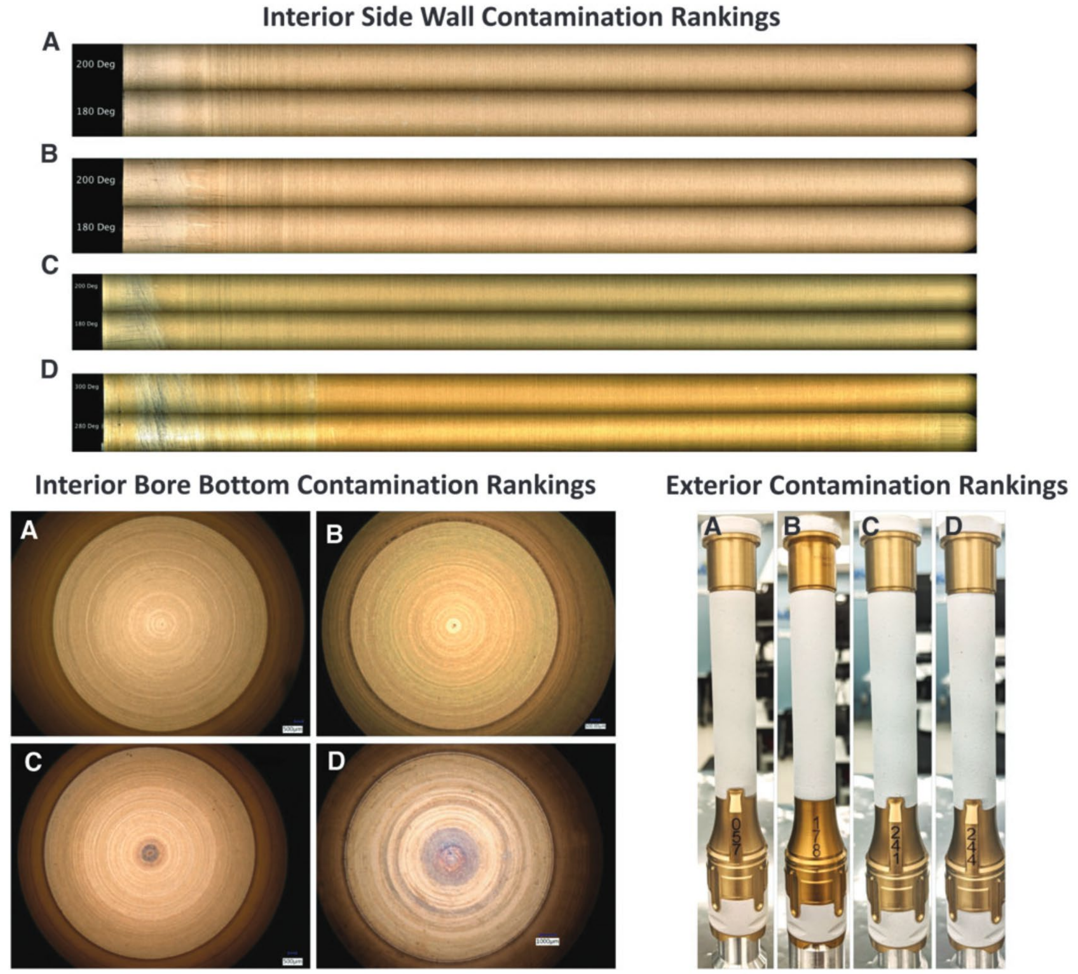


FIG. 8. Examples of contamination rankings for ST interior and exterior surfaces during visual inspection. Rankings of A are visually considered the best quality STs, while rankings of D are the lowest.

- Changes to bakeout conditions may have left organic compounds behind
  - High temperature bakeouts damaged the sample tubes, similar limitation to stardust
- Collection includes
  - Final hexane rinse of sample tubes
  - Lubricants used in rover arm (Braycote)
  - Flight spares of sample tubes
  - ~900 other items

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*. https://doi.org/10.1089/ast.2022.0049

Lessons Learned Relevant to Curation

- Material archives are critical for sample return missions
- Proximity to the sample may be more important that total mass on the space craft
  - Sample intimate hardware
- Anthropogenic compounds can degrade during flight, sample collection, and or storage to create ambiguous signals
- Contamination can vary greatly between different batches of the same material
- Do not introduce new materials without independent analysis and review
- Independent verification of material composition is vital
- Material archives allow us to characterize unexpected contamination