National Aeronautics and
Space Administration

Adaptive Curation at NASA Johnson Space Center – Preparing for Artemis Samples by Leveraging Proven Practices and Innovative Solution

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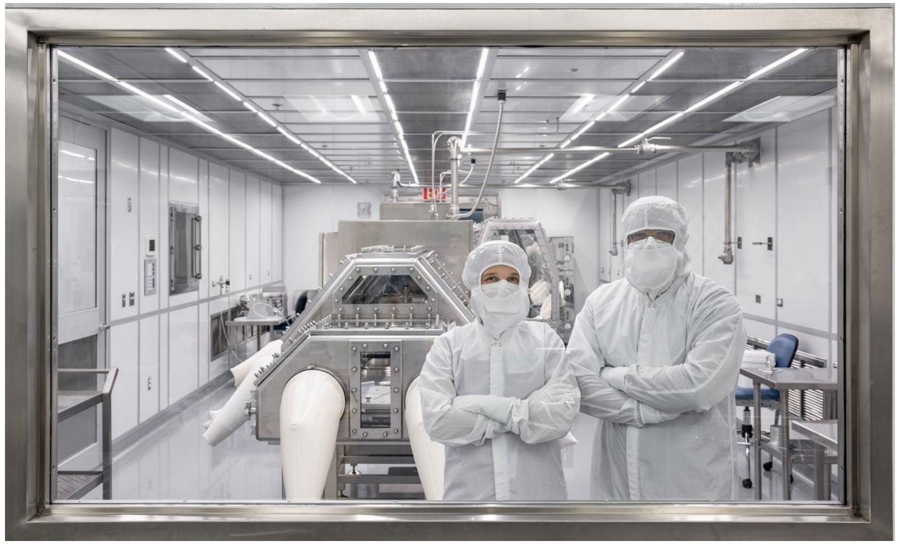
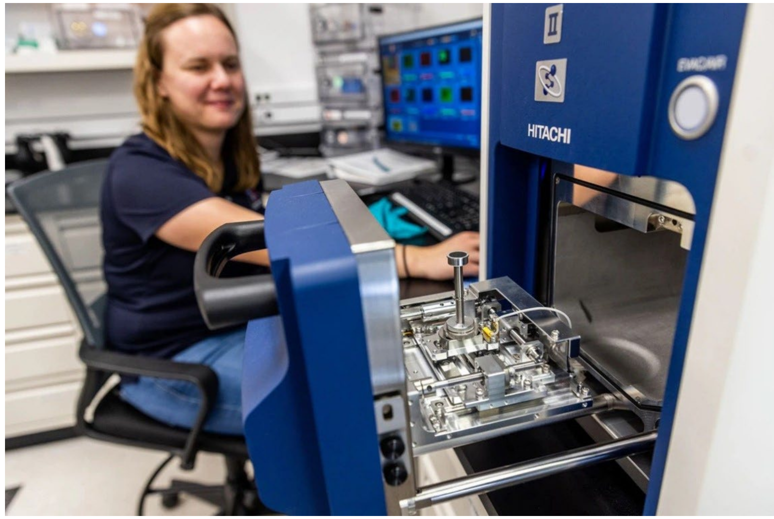
Artificial Intelligence (AI) Usage Disclosure
A conceptual image in the presentation was created with assistance from ChatGPT. The content has been reviewed and edited by A. D. Harrington.

Introduction & Context

- Astromaterial curation is vital for enabling scientific investigations across generations

- Ensuring sample integrity supports mission requirements, evolving research questions, and future discoveries





Governing Documents & Directives

- The Astromaterials Acquisition and Curation Office at NASA Johnson Space Center (JSC) is charged with "the curation of all extraterrestrial materials under NASA control, including future NASA missions" as per NASA Policy Directive (NPD) 7100.10F + derivative NPR "Curation of Extraterrestrial Materials."

- The Directive goes on to define Curation as including "…documentation, preservation, preparation, and distribution of samples for research, education, and public outreach."
  - As a part of documentation and preservation, the Curation Office also coordinates sample capture, containment, and transportation to the curation facility.

- A major part of the Curation Office's charge is to integrate requirements, develop implementation strategies, and deliver a facility capable of meeting Mission goals while satisfying requirements levied by the Project, Planetary Protection, the Agency, and Regulatory Authorities.

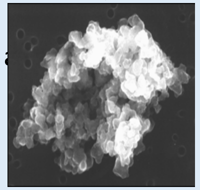
- Proper curation enables science.
  - Objective-Driven & Opportunity Science – Characterize and allocate samples in order to accomplish Project science goals and early science.
  - Future Science – Conserve a representative quantity of pristine samples for future generations of scientists with innovative ideas and more advanced analytical equipment.

Legacy Collections

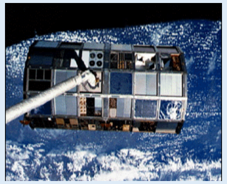
Lunar
(1969)
Apollo program lunar rocks and soils; Luna samples

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

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



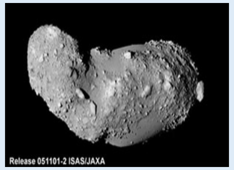
Microparticle Impact Col.
(1985)
Space exposed hardware from spacecraft



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

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

Hayabusa
(2012)
Samples collected from JAXA asteroid mission to Itokawa



Hayabusa II
(2020)
Subset of samples collected from JAXA asteroid mission to (162173) 1999

OSIRIS-REx
(2023)
Asteroid sample return from 101955 Bennu

Our Near Future . . .

Artemis
(~2028+)
Lunar polar region;
Lunar rocks, soils, and volatiles

Phobos
(~2031)
10% of a JAXA mission to bring back Phobos material

JAXA sample return mission
MMX

Authority from NPD 7100.10F + derivative NPR

Our More Distant Future . . .

Moon
(2020s)
Non-volatile-rich farside/polar sample return

Next New Frontiers Call

Comet
(2020s)
Cold curated (?) surface sample return from a comet

Next New Frontiers Call

Mars
(~2030s+)

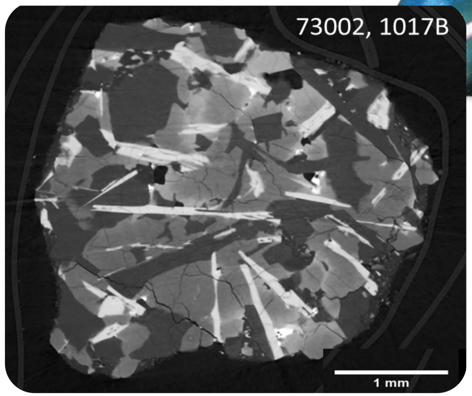
Various Mars Sample Return

Over 50 years in the planning (est. 1964)

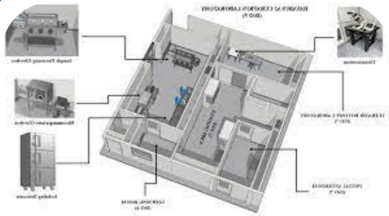
Decades of experience inform best practices for sample handling and preservation

Applied Curation Responsibilities

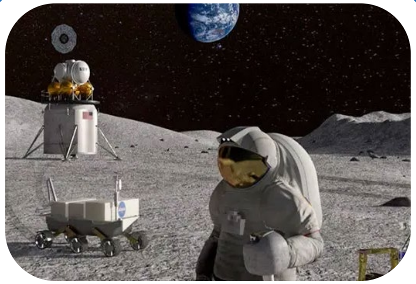
- **<u>Preserve</u>** samples (incl. rocks, hardware & volatiles) from collection on the lunar surface to their return to Earth
- **<u>Provide</u>** initial sample characterization and catalog development to enable scientific studies of these materials
- **<u>Curate, conserve, and protect</u>** samples for the long term, to ensure their future scientific value
- **<u>Facilitate</u>** maximum scientific investigations world-wide through allocations while following above points, keeping in mind technologies that will be developed in the future



Curation Starts at Mission Inception



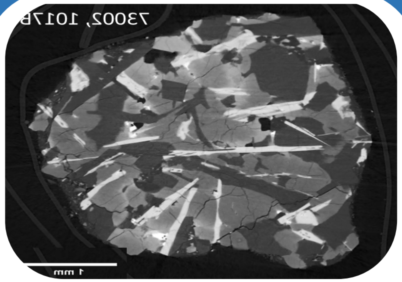
Pre-mission planning



During active mission

Sample Curation Lead with Advanced Curation Team

Recovery and Transport



Preliminary Examination (PE)

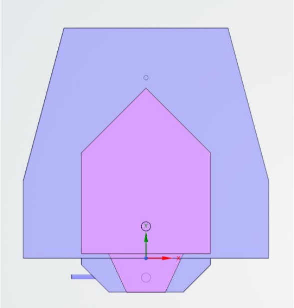
Long term curation

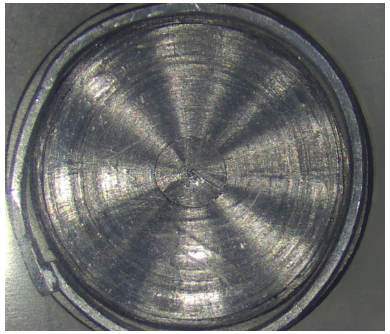
Sample Collection Curator and Processing Team

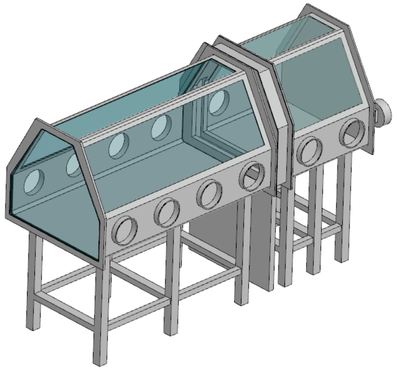
Artemis Program Curation Overview

- Artemis introduces new scientific and operational challenges for curation
  - Both ambient and cold sample returns
  - Enhanced contamination control relative to Apollo
    - Stricter ISO Class Cleanrooms – ISO 5-6 laboratories versus ISO 6-7 laboratories allows for higher air exchange rates and requires stricter gowning
    - Stricter organic contamination considerations – Select cleanrooms have 300 series stainless steel walls and ducting
  - Ignition, the restructured Artemis Program plan announced in the Spring, notionally accelerates the sample return cadence from every 1-2 years to 1-2 sample returns annually

- Requires both proven practices and innovative solutions
  - Cleanrooms
  - Custom gloveboxes for ambient and cold samples for sample handling and storage
  - Ultrapure GN2
  - Specialized containers and sample handling tools
  - Strict material utilization and prohibition requirements
  - Robust framework for contamination control and documentation







Cold Glovebox System Development

- Cold Curation – Specific Action Team (CC-SAT)
  - Find existing technologies and methods relevant for cold (–85°C/188K) curation
    - Manipulation, transferring, preservation
  - Investigated many industries
    - Space, federal facilities, military, academia, and commercial (e.g., biological, physics, energy, semiconductor, food, metal 3D printing, etc.)
    - Adoptables and adaptables, –272.9 to 1400°C (0.1–1673K)
  - Conducted site visits, video calls, phone calls, literature search
  - Team consisted of curation scientists, astromaterial processors, and engineers
    - Travel team (left to right): Rachel Funk, Ardith Bravenec, Gabriel Lugo, Michael Huh, and Jeremy Kent

Four Strategies for Cold Curation (-85°C/188K)

Vapor Cooling

Enveloping gases at target temperature

Vacuum

Within vacuum chambers

Liquid Cooling

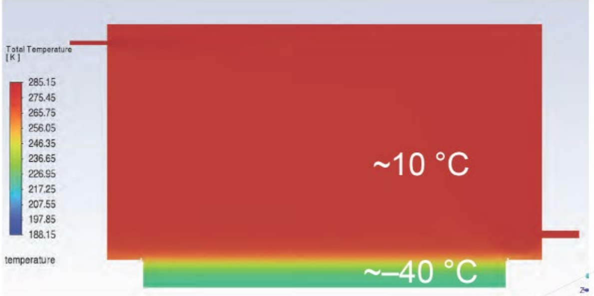
Submerged in liquid

Global Cooling

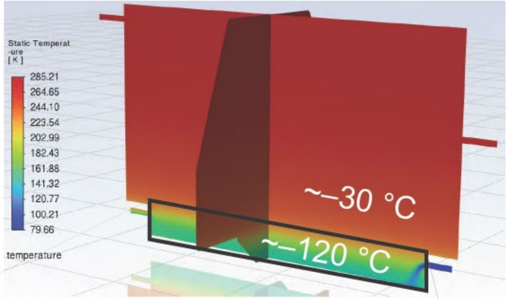
Human in cooled volume

Preliminary Thermal Modeling – Vapor Cooling

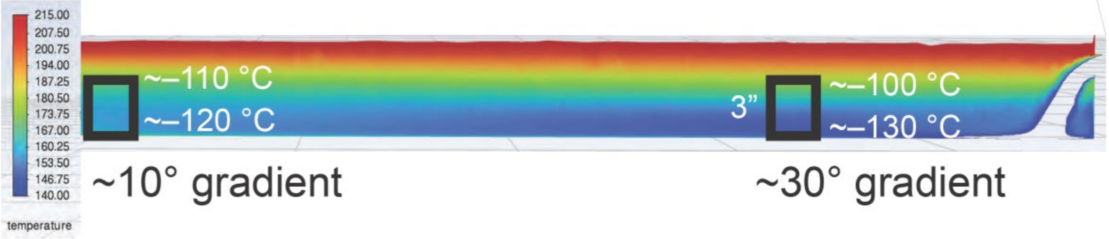
- Dimensions of the glovebox must accommodate the samples, containers, and processors.
- The notional dimensions are for processing smaller samples.
- Multiple configurations likely necessary.



Warm flow: 12 °C (285 K) @ 200 scfh
Cold flow: –85 °C (188 K) @ 10.5 scfh
Outlet(s): one warm outlet

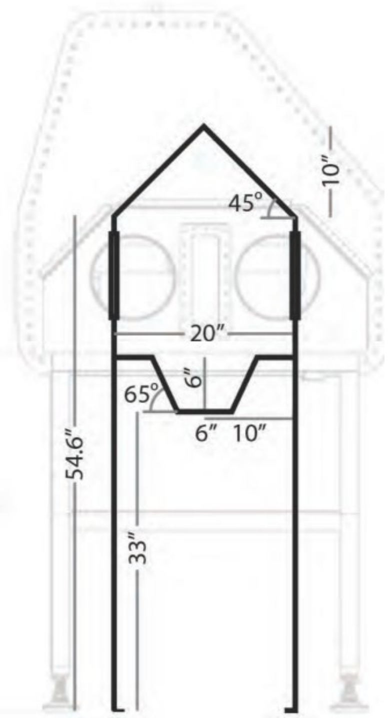


12 °C (285 K) @ 150 scfh
–193 °C (80 K) @ 100 scfh
one warm, one cold



~10° gradient

~30° gradient



The thermal gradient within the glovebox is controlled by the relative flowrates and temperatures of the ambient and cold inlets.

Quantifying how Curation Materials React to Volatiles

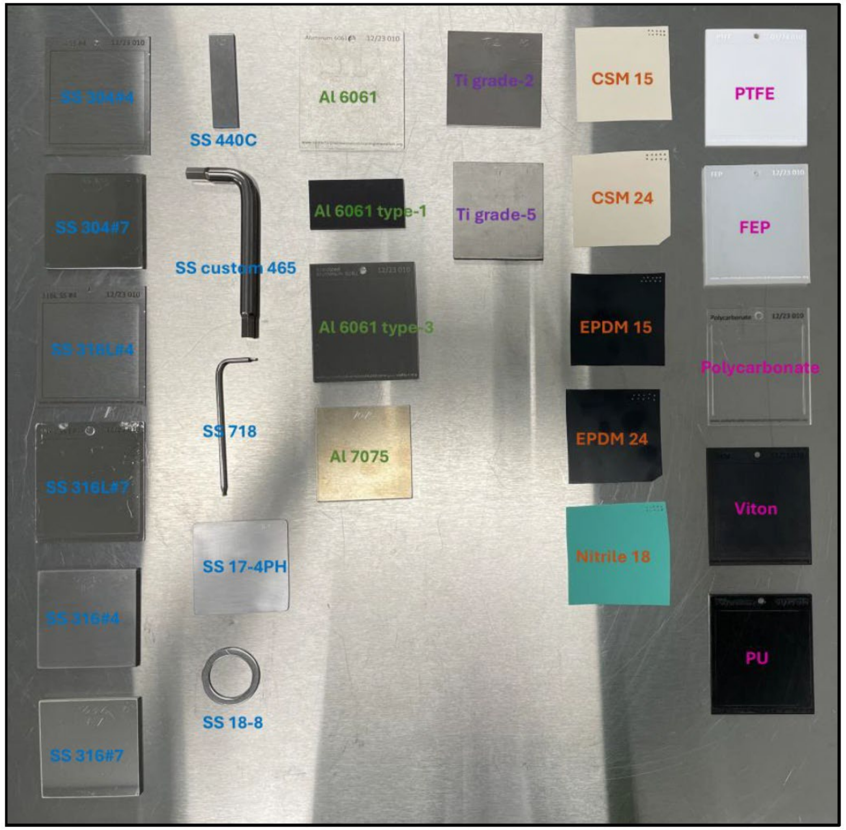


Figure 4. Selected material coupons procured for iHP-VHP compatibility assessment.

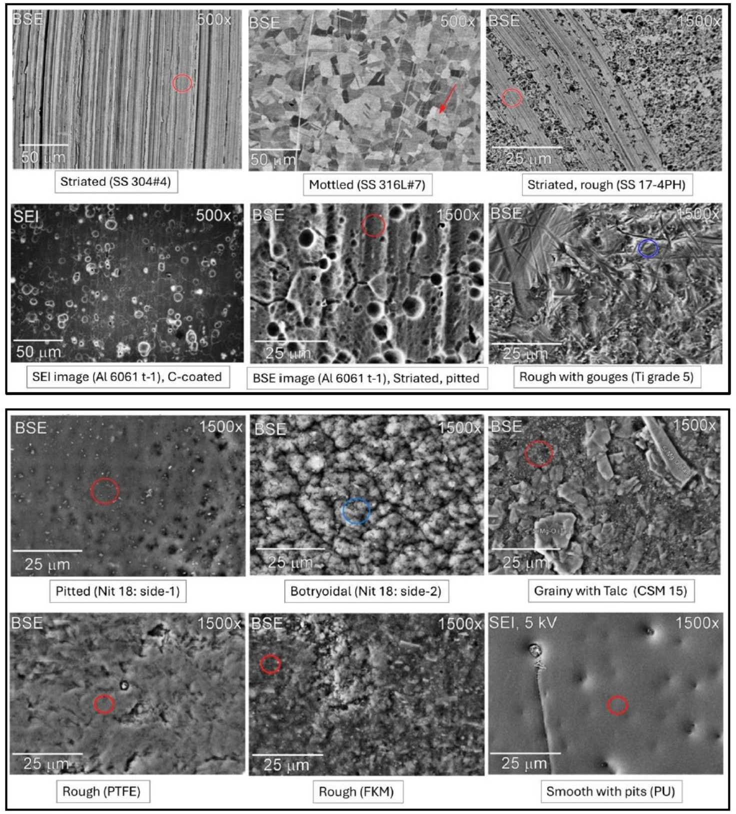


Figure 9. Example images of some material coupons generated by JEOL 7600 FESEM equipped with Oxford Ultim Max EDX detector at NASA-JSC. Here, same material examples were selected as Figure 8 for comparison.

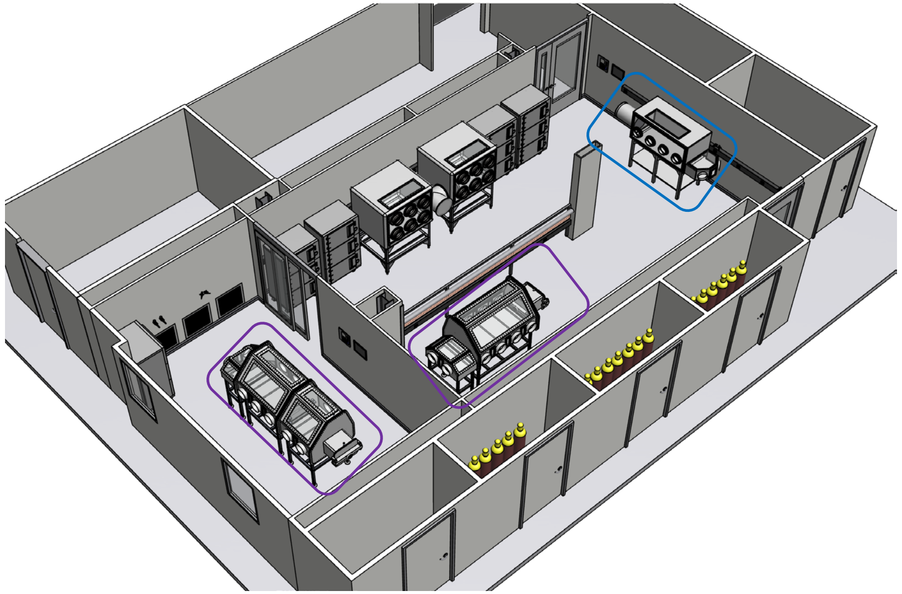
- In preparation for Mars Sample Return, curation materials were exposed to ionized- and vapor hydrogen peroxide (IHP, VHP)
- Goal: Determine how curation materials react to IHP and VHP
- Expand on this study by exposing to cold volatiles

Artemis Specialized Glovebox Systems

- Astromaterials Glovebox Systems – Design & Fabrication (A-BOX)
  - Five-year Indefinite Delivery, Indefinite Quality Contract for the procurement of 20+ glovebox systems (RFI Closed July 29th)
    - Nine unique glovebox system designs for ambient and cold sample receiving, preliminary examination, processing, and storage
  - https://www.nasa.gov/johnson/jsc-procurement/a-box/

Artemis Curation Space & Laboratory Design

- Phased approach for Artemis IV+ Sample Curation Laboratories
- Optimizing the use of new Annex and Apollo laboratory space for certain functions
- Integration of glovebox systems and storage optimization strategies



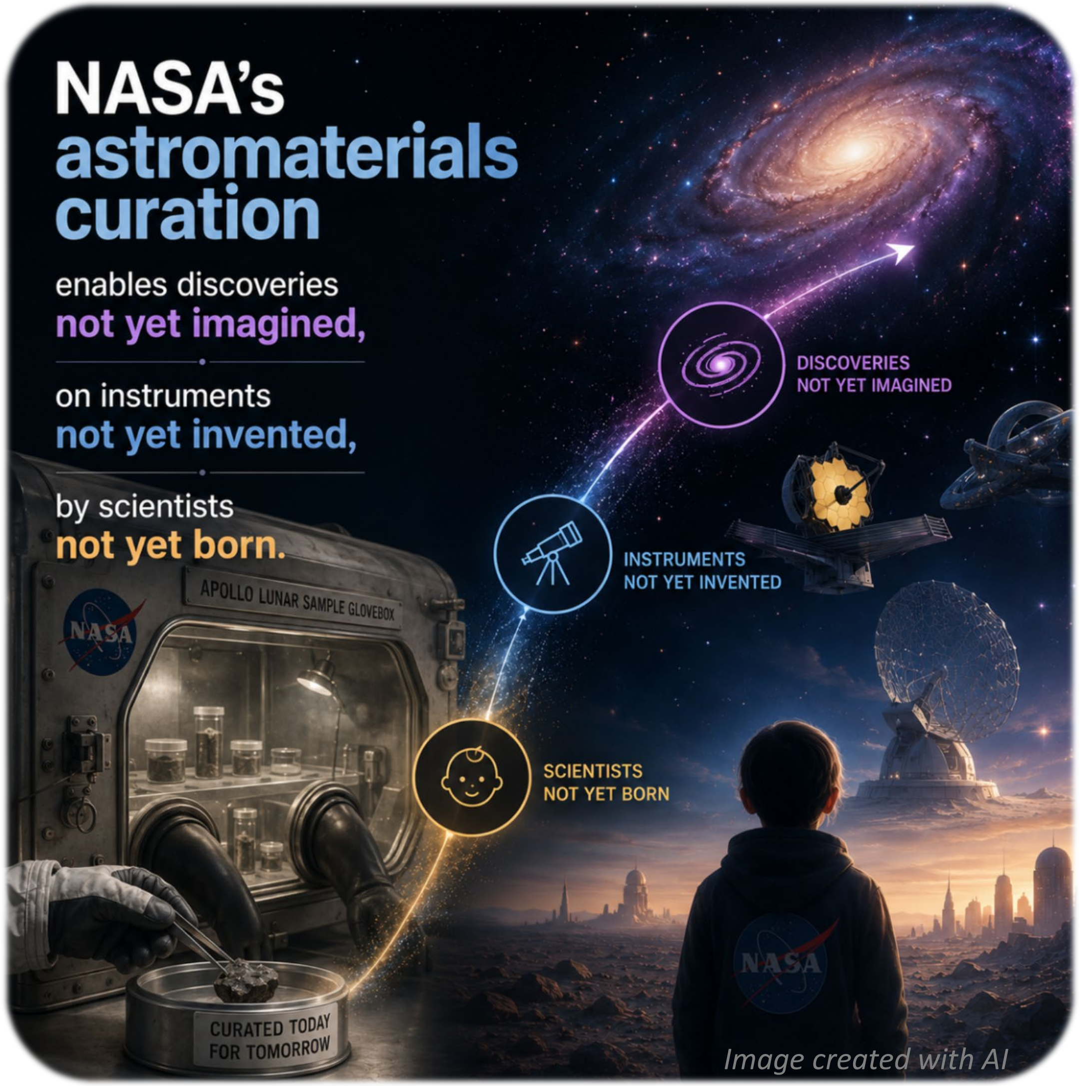
Summary & Outlook

- Adaptive curation at JSC combines the reliability of proven methodologies with forward-looking innovations to meet the scientific and operational demands of Artemis.

- Due to evolving schedules and requirements, the Curation Office must be ready to pivot and adapt as needed.

- NASA is preparing to maximize the scientific return from Artemis samples and preserve their value for generations of researchers.
  - Enhanced contamination control
  - Advanced cold curation capabilities
  - An understanding of known and evolving future science priorities

Questions



NASA's
astromaterials
curation
enables discoveries
not yet imagined,
on instruments
not yet invented,
by scientists
not yet born.
DISCOVERIES
NOT YET IMAGINED
INSTRUMENTS
NOT YET INVENTED
SCIENTISTS
NOT YET BORN
APOLLO LUNAR SAMPLE GLOVEBOX
NASA
CURATED TODAY
FOR TOMORROW
NASA
Image created with AI