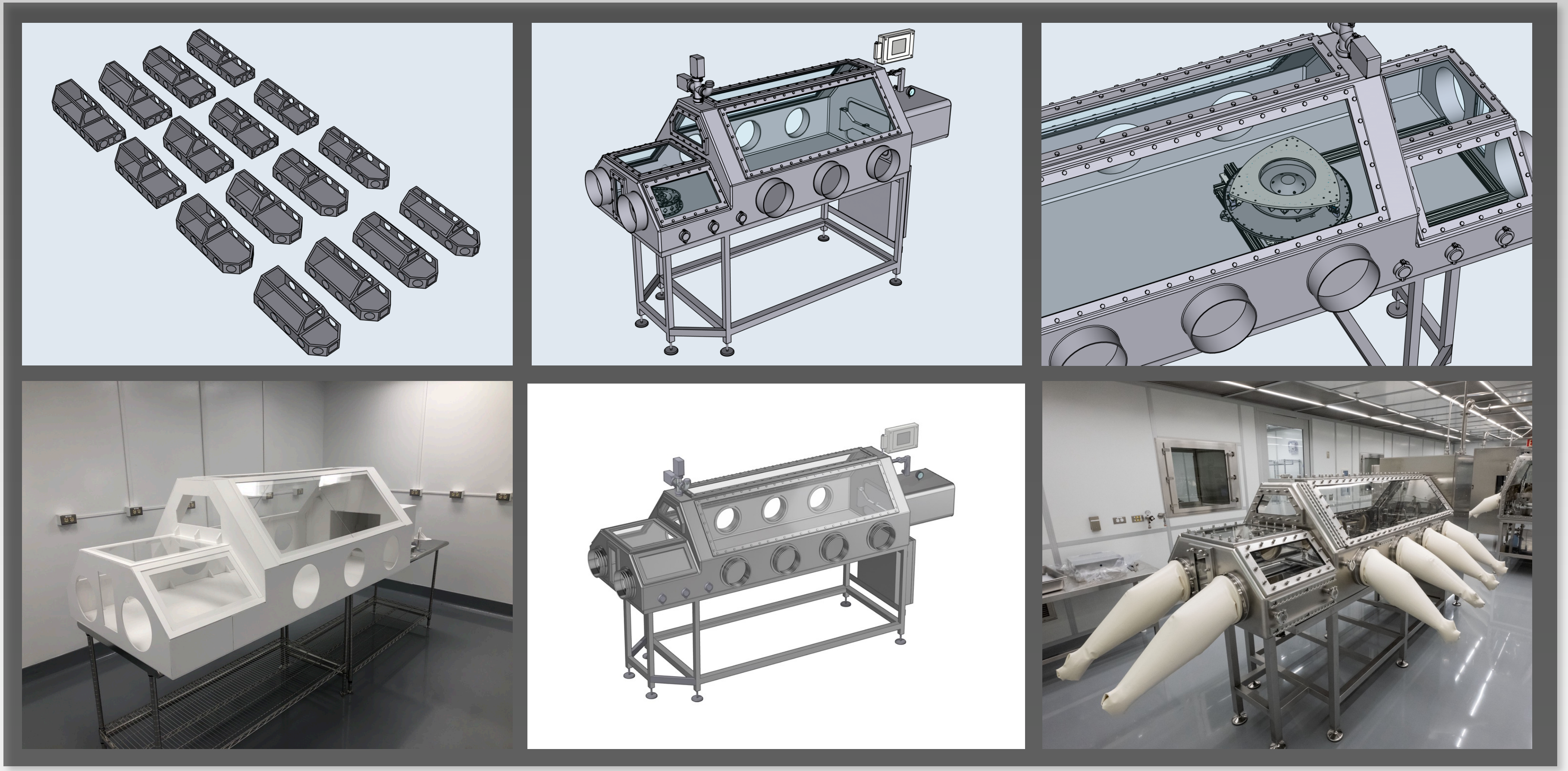
Glovebox Design Considerations for the Curation of Extraterrestrial Samples



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JSC Astromaterials Acquisition & Curation Office

- **Johnson Space Center is the home to all of NASA's current and future astromaterials collections.**

- **Astromaterial: A sample that has been recovered from space, or a sample that has been collected on Earth with an extraterrestrial origin**

- **Astromaterials curation: Samples must be processed, documented, and stored in such a way as to preserve their integrity for current and future scientific research**

The Scientific Importance of Astromaterials

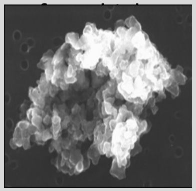
- Astromaterials provide information about the origin of the Solar System and potentially about the origins of life
- Theories of planet formation that developed from studying meteorites have been confirmed by astronomical observations
- Some meteorites come from the Moon and Mars – Martian meteorites are the only physical samples we have from that planet.
- Lunar, Martian and Asteroid samples provide information about potential In-situ resource utilization for human colonization of space

Astromaterials Collections at Johnson Space Center

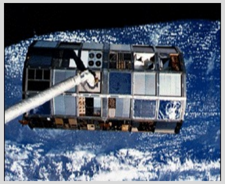
Lunar
(1969)
Apollo program lunar rocks and soils; Luna samples

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

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

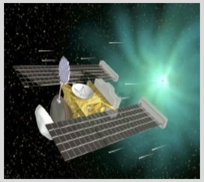


Space Hardware
(1985)
Space exposed hardware from spacecraft



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

The Future . . .

Hayabusa II
(2020)
Subset of samples collected from JAXA asteroid mission to (162173) 1999 JU_3

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

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

Phobos
(~2030s +)
Japan Sample Return from Martian Moon Phobos

2026 planned launch; Earth return in 2031

Mars
(~2030s +)
Various Mars Sample Return

Over 50 years in the planning (est. 1964)

Preserving Scientific integrity of our Collections

- **Samples are stored and processed in gloveboxes and desiccators that are purged with pure (<1ppm trace impurities) nitrogen gas – main line of defense against sample contamination**

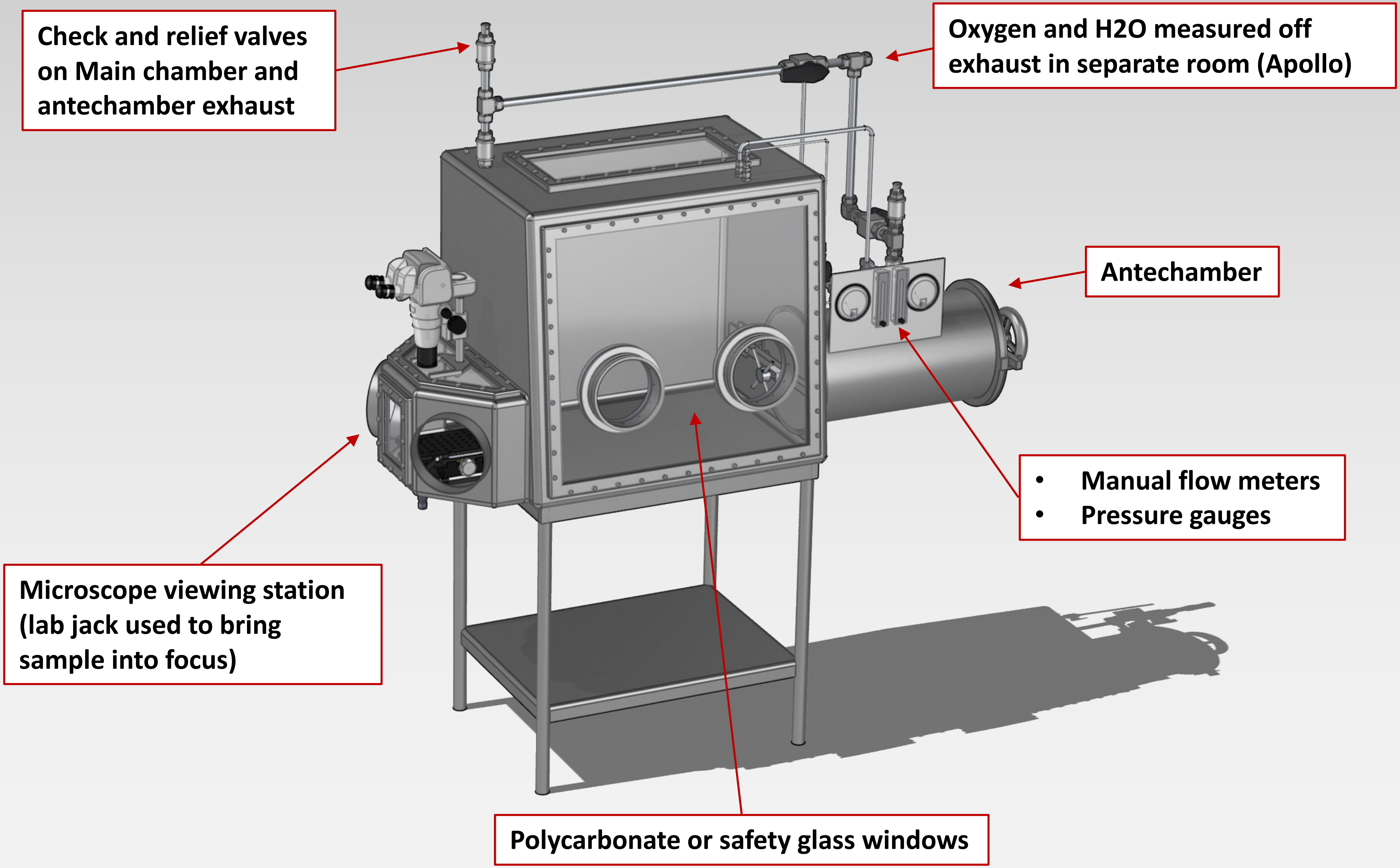
- **Contamination risks include:**
  - Alteration from H_2O and O_2
  - Elemental/Isotopic contamination (e.g. U/Pb chronology)
  - Organic compounds
  - Microbial alteration

- **Restricted list of materials approved for curation apparatus design**
  - Aluminum (6061,6063, 2024, 7075)
  - Stainless steel (316, 301,302,303, 18-8, 17-7PH)
  - Glass, quartz/fused silica, sapphire
  - Teflon/PTFE
  - Viton/FKM

Gloveboxes for Apollo Lunar Sample Curation

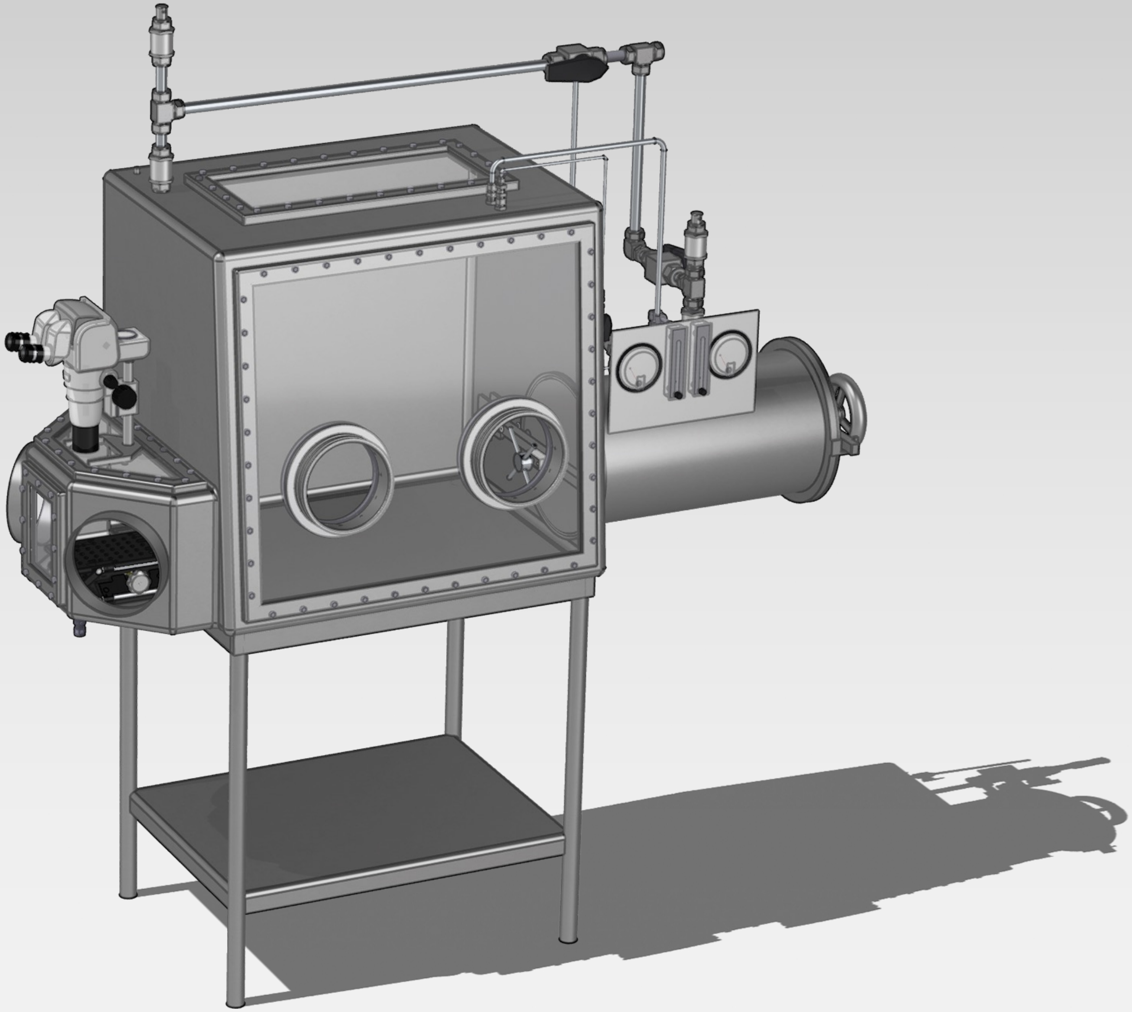
- **Johnson Space Center's Astromaterials Curation Facility has ~50 gloveboxes for extraterrestrial sample processing and storage**
- **Most of these gloveboxes were made for the Apollo Lunar samples by Stainless Equipment Company**
- **These gloveboxes have been in service for a half century – some are now used for the Antarctic Meteorite Collection**

Apollo-Era Glovebox Features

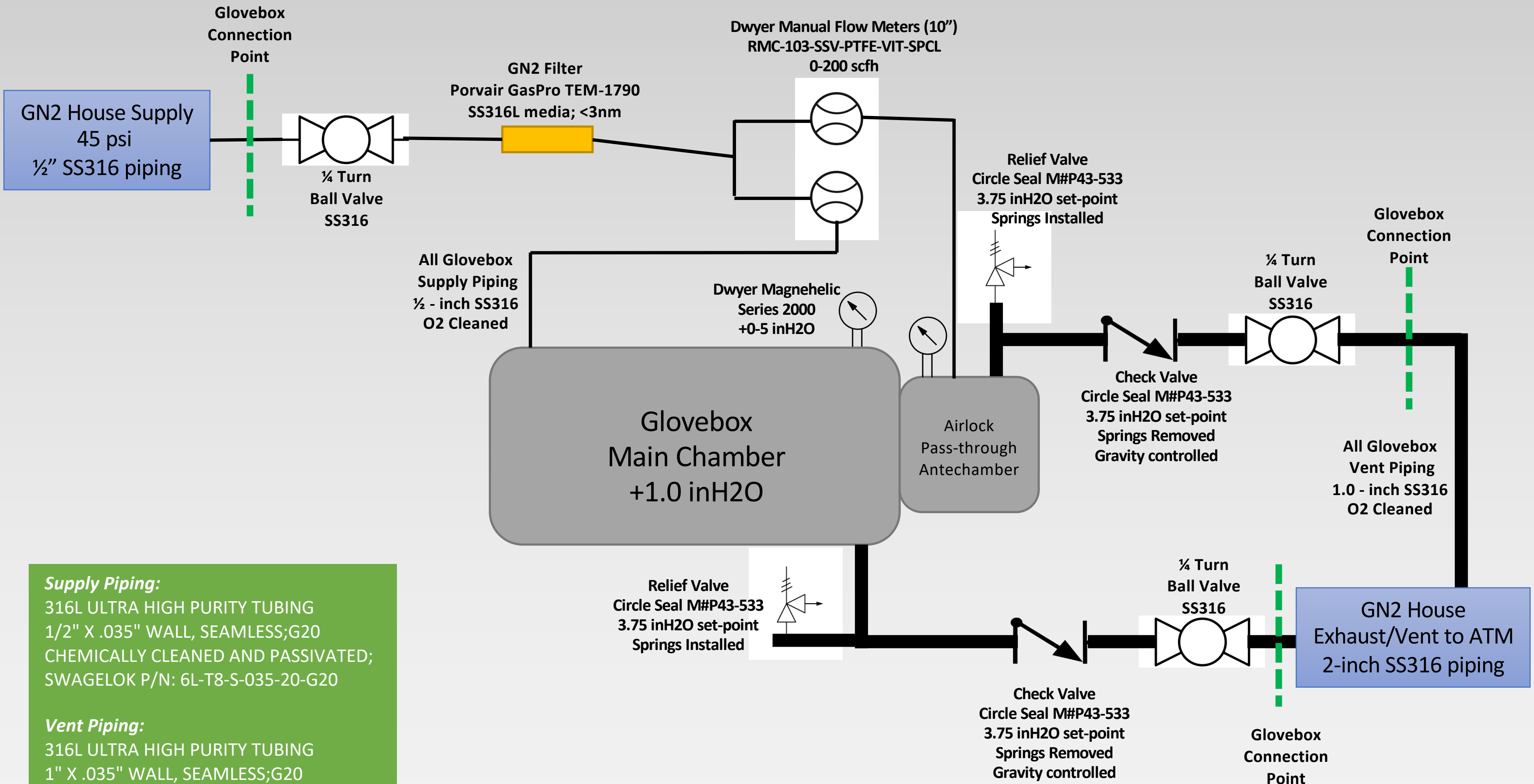


Curation Glovebox Operational Conditions:

- Gloveboxes are continuously purged with pure N_2 (<1 ppm trace impurities); no purifiers/scrubbers
- Flow range: 0-250 SCFH (~150-200 SCFH for normal operations, ~200 SCFH for antechamber purge, ~50SCFH for overnight idle (no samples open)
- Main chamber operates at 1" H_2O/250 Pa positive pressure GN_2
- Relief valves set at 4"H_2O (1000 Pa)



Calaway diagram - 1977 Lunar Glovebox Main Chamber GN2 Supply/Vent



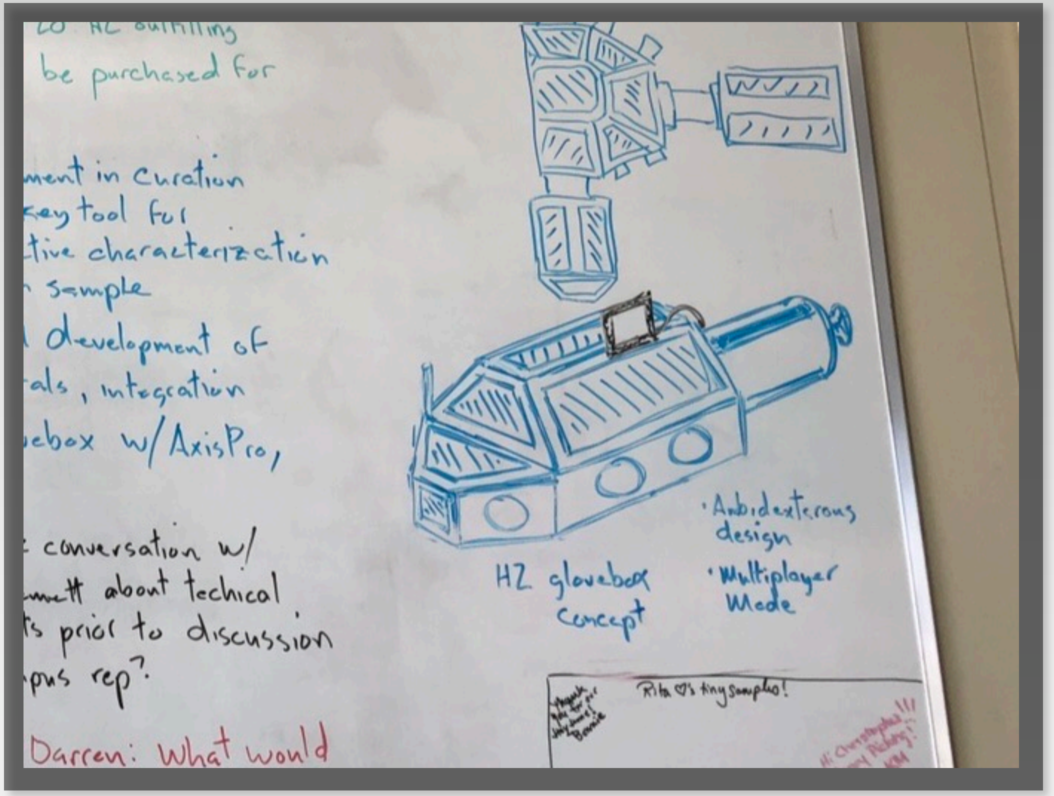
Supply Piping:
316L ULTRA HIGH PURITY TUBING
1/2" X .035" WALL, SEAMLESS;G20
CHEMICALLY CLEANED AND PASSIVATED;
SWAGELOK P/N: 6L-T8-S-035-20-G20

Vent Piping:
316L ULTRA HIGH PURITY TUBING
1" X .035" WALL, SEAMLESS;G20
CHEMICALLY CLEANED AND PASSIVATED;
SWAGELOK P/N: 6L-T16-S-035-20-G20

Note: Piping sizes may vary dependent on glovebox design.

What Does a Next Generation Curation Sample Glovebox Look Like?

- Robotic missions return less mass than Apollo; gloveboxes should be optimized for smaller scale
- Gloveboxes should be double-sided so multiple users can perform coordinated processing operations
- Oxygen and humidity sensors should be incorporated directly into glovebox for real-time environmental monitoring
- Gloveboxes should be designed to facilitate high-resolution imaging



Glovebox Design Considerations: Form

- Double sided gloveboxes facilitate multi-user operation and manipulation of apparatus
- Windows should be angled inward to ~45 degrees (+/- 10 degrees)
- Mechanical operation whenever possible – electronic/pneumatic mechanisms add contamination pathways and additional infrastructure requirements
- Glove ports should be welded to glovebox body
- Large/numerous window surfaces enable work using ambient room lighting and provide many perspectives for imaging
- Microscope/photodocumentation bumpout for detailed sample examination
- Built-in O_2 and H_2O monitoring
- Ports for electronics, drain for cleaning ease

Glovebox Design Considerations: Materials

- **Body:**
  - **316 SS, 8-11 gauge**
  - **#4 or better finish (15-30 Ra)**
  - **Passivated or electropolished**
- **Stand: 304 SS**
- **Piping/Service attachments: 316 SS**
- **Gaskets: FKM/Viton – <u>no adhesive backing</u>**
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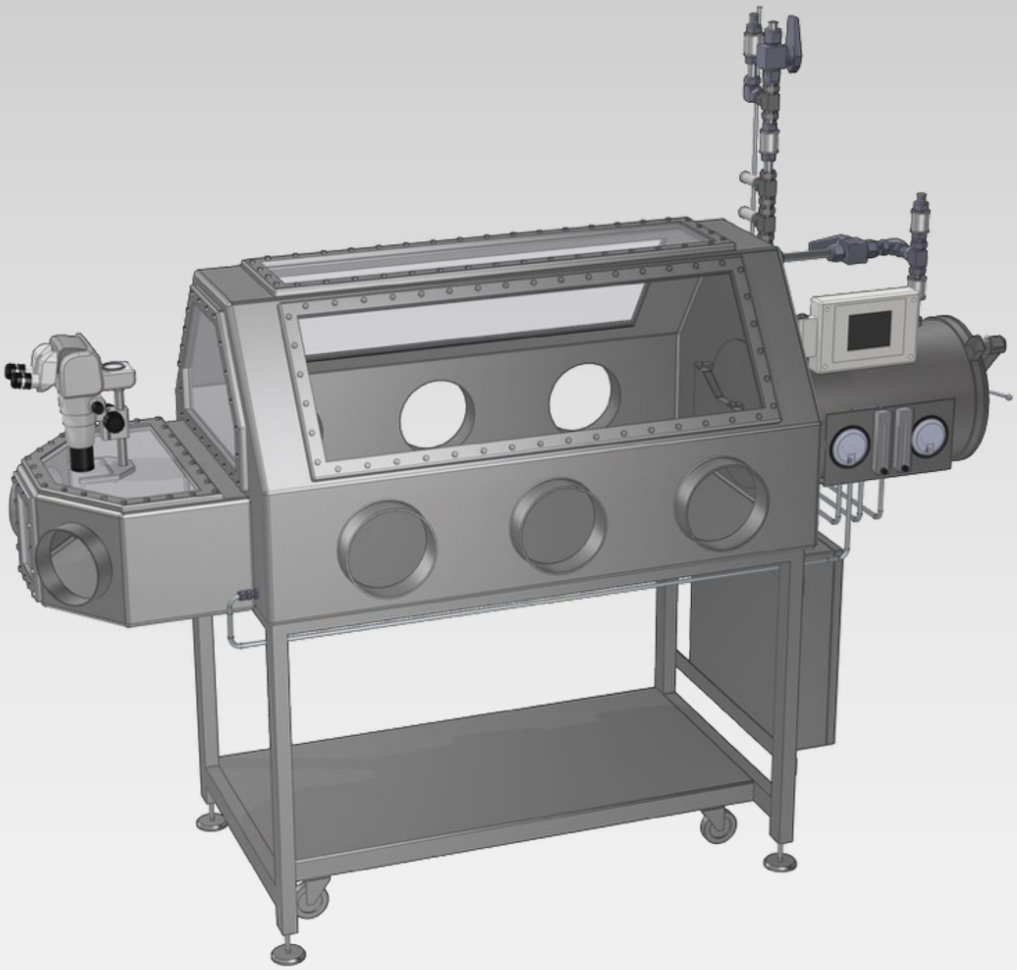
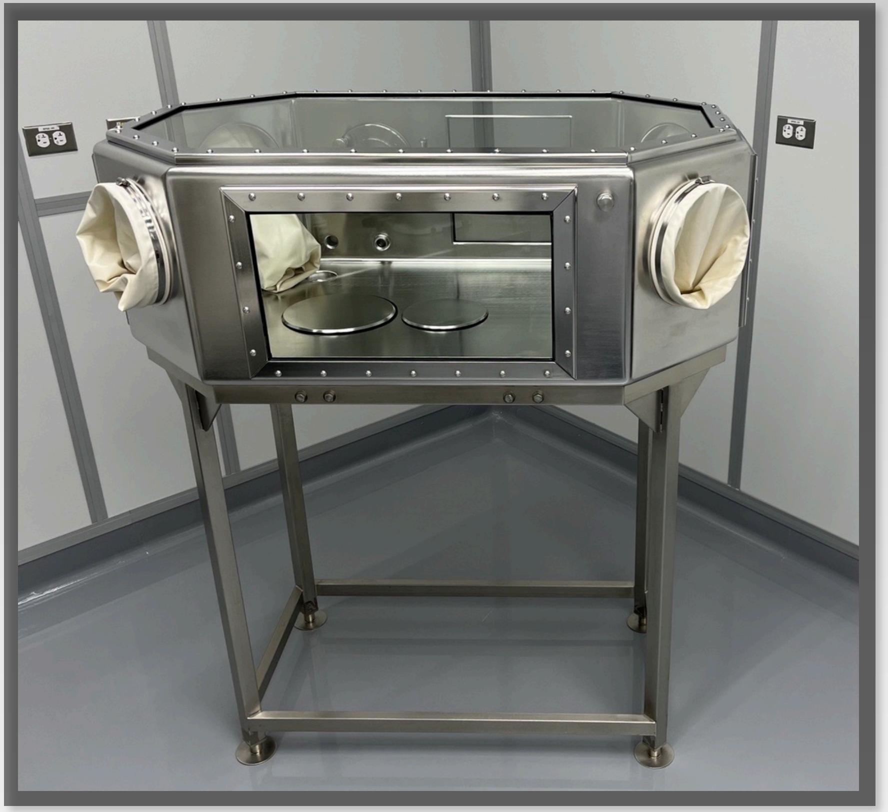
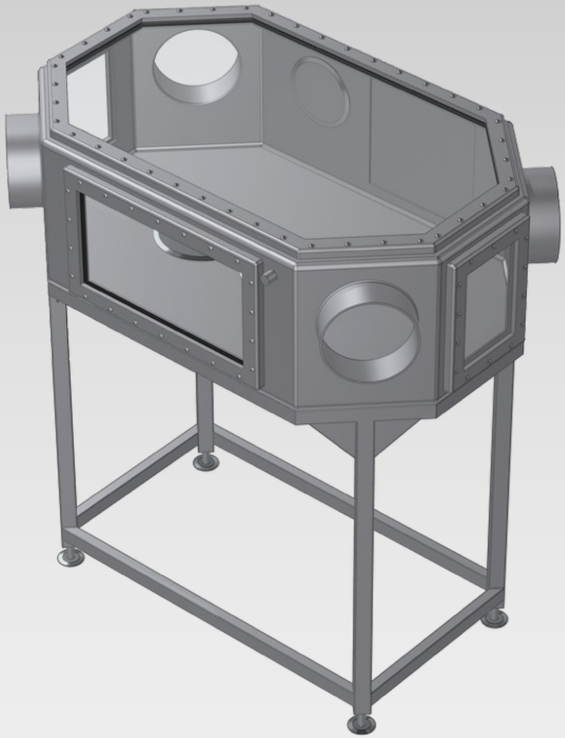
- **Windows: Laminated safety glass, 3/8" thick**
- **Gloves: Hypalon/CSM**
- **No sealants (e.g. polysulfide) used for leak tightness**



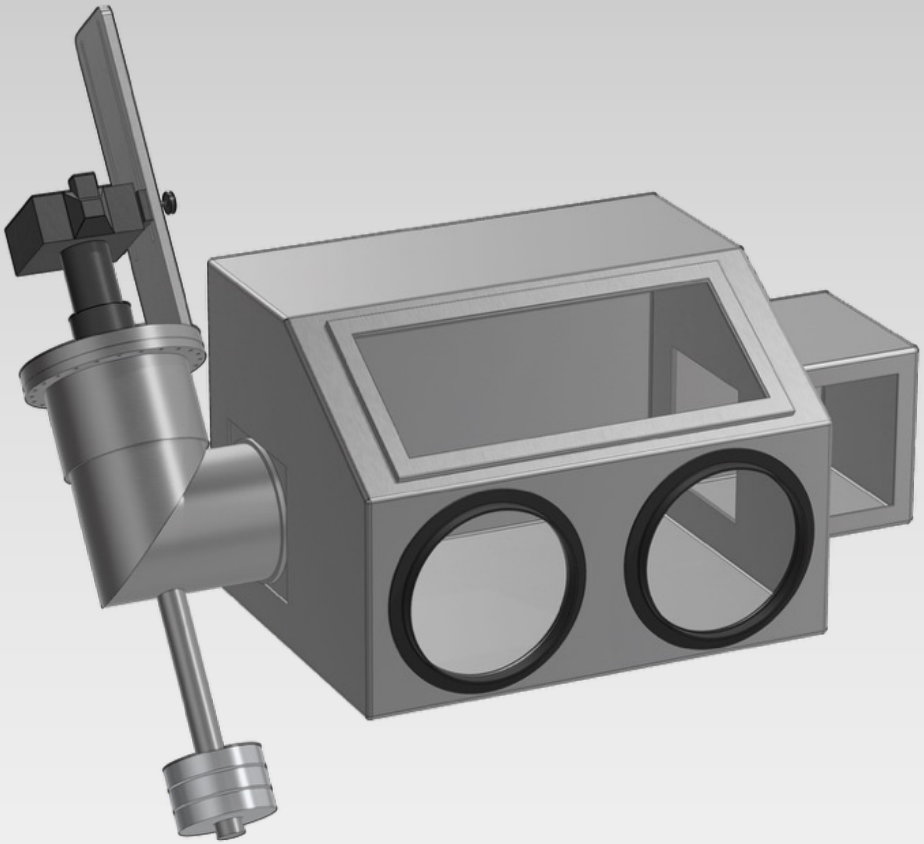
Glovebox Design Considerations: Surface Finish

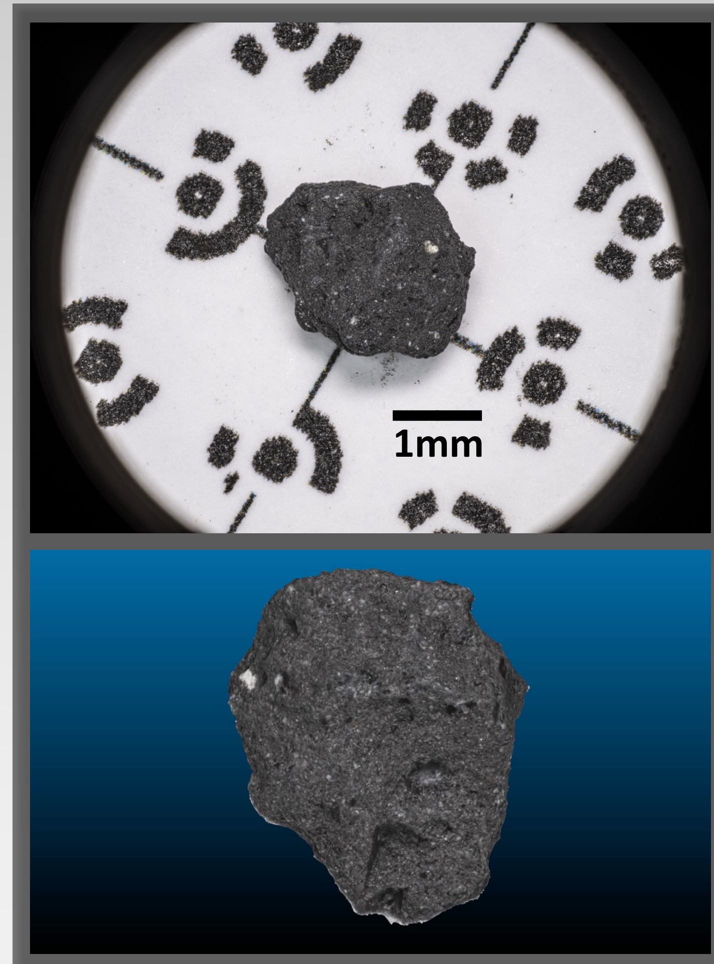




- Small experimental glovebox (the octagon) made for robotic manipulation of samples – Absolute Control Systems, 2000
- This glovebox has <u>most desirable</u> surface finish for extraterrestrial sample handling – #4, then electropolished (?)
- High-mirror surface finishes are visually distracting – makes visual identification of samples and hardware difficult, inhibits depth perception

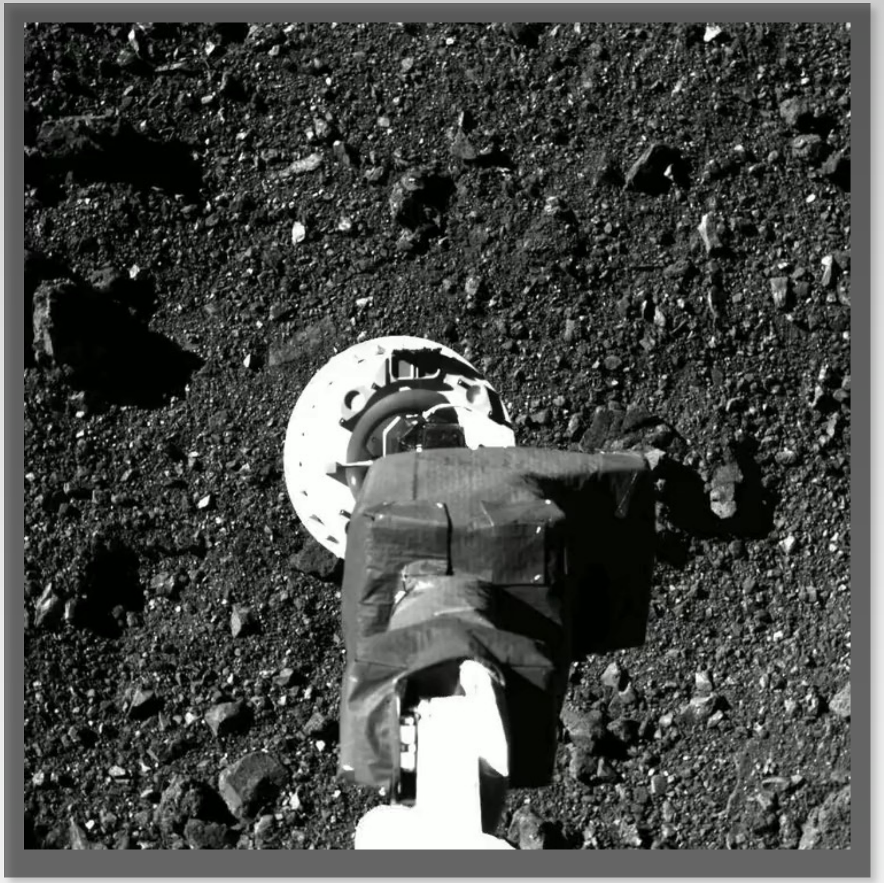
Glovebox Design Considerations: Sample Imaging





- We are exploring concepts for a glovebox that will enable 360 degree imaging of small (<1cm) extraterrestrial samples - expansion of Astromaterials 3D capabilities:

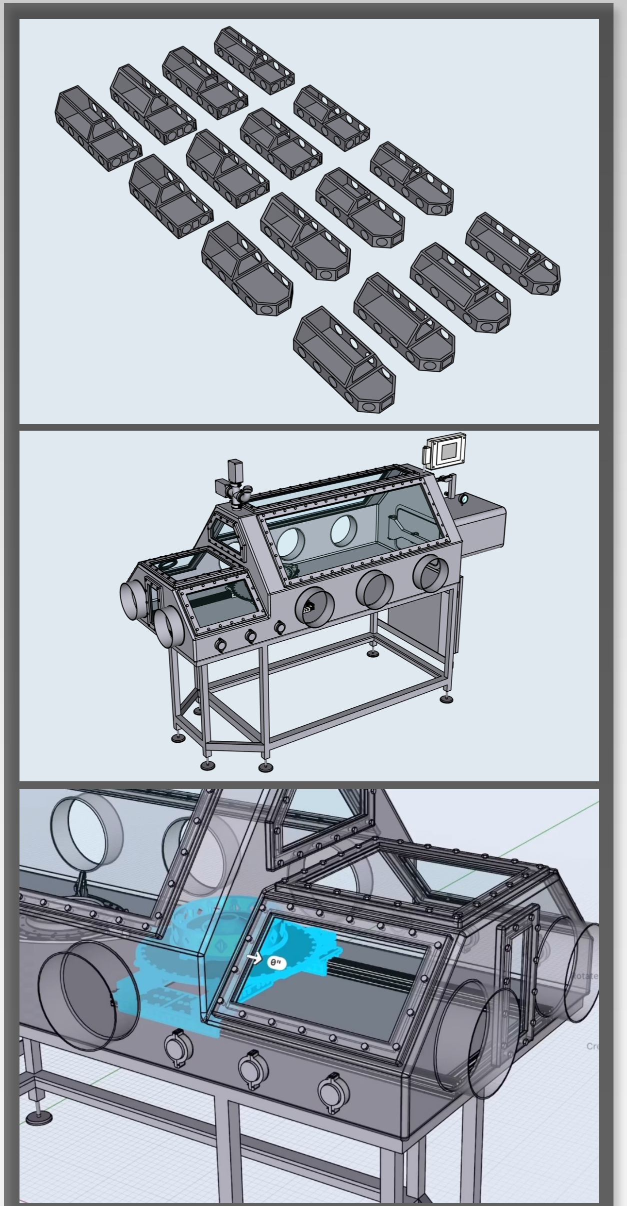
OSIRIS-REx – NASA's Newest Astromaterials Collection



- OSIRIS-REx: Origins, Spectral Interpretation, Resource Identification, Security Regolith Explorer
- Asteroid 101955 Bennu – Carbon-rich asteroid 500 meter diameter
- Small probability of impact with Earth (0.04%) in ~150 years
- Sample collected from the surface using Touch And Go Sample Acquisition Mechanism (TAGSAM)
- NASA curation goal: open science canister, disassemble TAGSAM in pure nitrogen environment

Glovebox Design Challenges for Hardware Disassembly

- Two major steps to access asteroid samples:
  1) open science canister lid and remove TAGSAM from avionics deck
  2) Disassemble TAGSAM
- Science canister and TAGSAM were not designed to be disassembled in enclosed environment
- What glovebox morphologies would enable complex disassembly operations?
- Science analysis team provided curation with in situ imaging requirements for TAGSAM glovebox; design iterated many times to find satisfactory configuration
- Design meetings between scientists, engineers and curation staff were completely virtual due to pandemic



Glovebox Mockup Construction

- **Mockups are useful tools for assessing the ergonomics of a proposed glovebox design**
- **Mockups are also very useful for understanding glovebox workflows**
- **Foam-core is a good material for constructing inexpensive models; plywood and aluminum extrusion are used for mockups that need to support more weight**

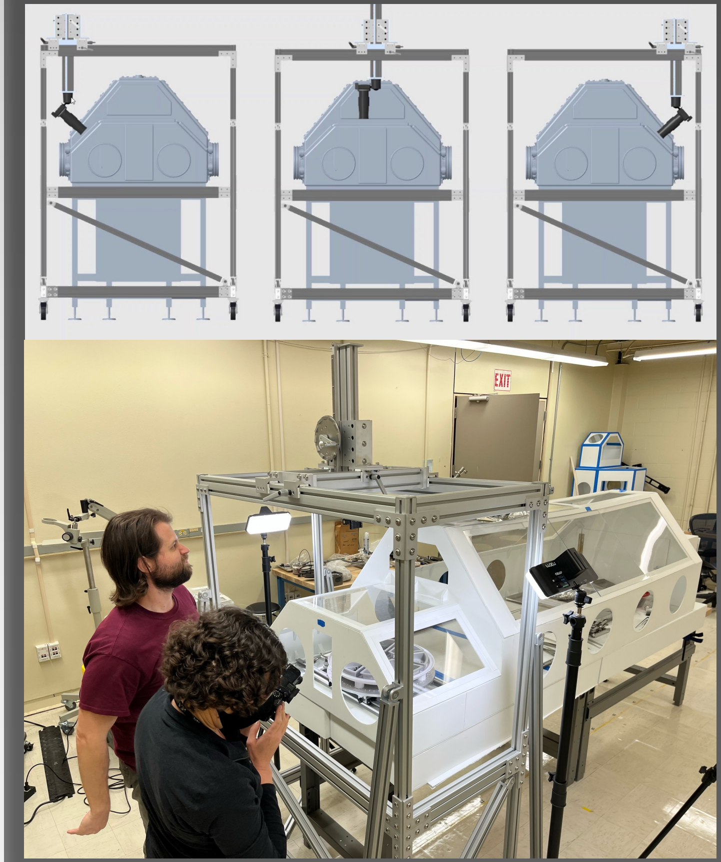
- **We built one canister disassembly glovebox mockup and one TAGSAM disassembly glovebox mockup**

Glovebox Mockup Rehearsals

- **Curation team frequently rehearsed canister opening and TAGSAM disassembly in both glovebox mockups using 3D printed models and flight-like hardware**
- **Initial rehearsals with TAGSAM disassembly mockup revealed more space was needed; the foamcore model was modified to incorporate two additional gloveports – 18 inches added to overall length**

Glovebox Photo Gantry

- **Structure is constructed from 80/20 extrusion (materials-compliant); Z-axis incorporates a geared locking support arm.**
- **Gantry designed to support a variety of imaging and lighting equipment**
- **Gantry structure couples to glovebox via L-track interfacing, reducing vibrations and image shifting during focus-stacked imaging**



OSIRIS-REx Sample Curation Gloveboxes

Canister Disassembly Glovebox | **TAGSAM Glovebox**

- Canister Disassembly glovebox and TAGSAM glovebox delivered to Johnson Space Center in April 2023
- Gloveboxes manufactured by Comecer
- Several manufacturer-supplied glass windows were replaced with Schott Amiran low-Fe Antireflection glass

Sample Return Dress Rehearsal: June 2023

Mockup rehearsal

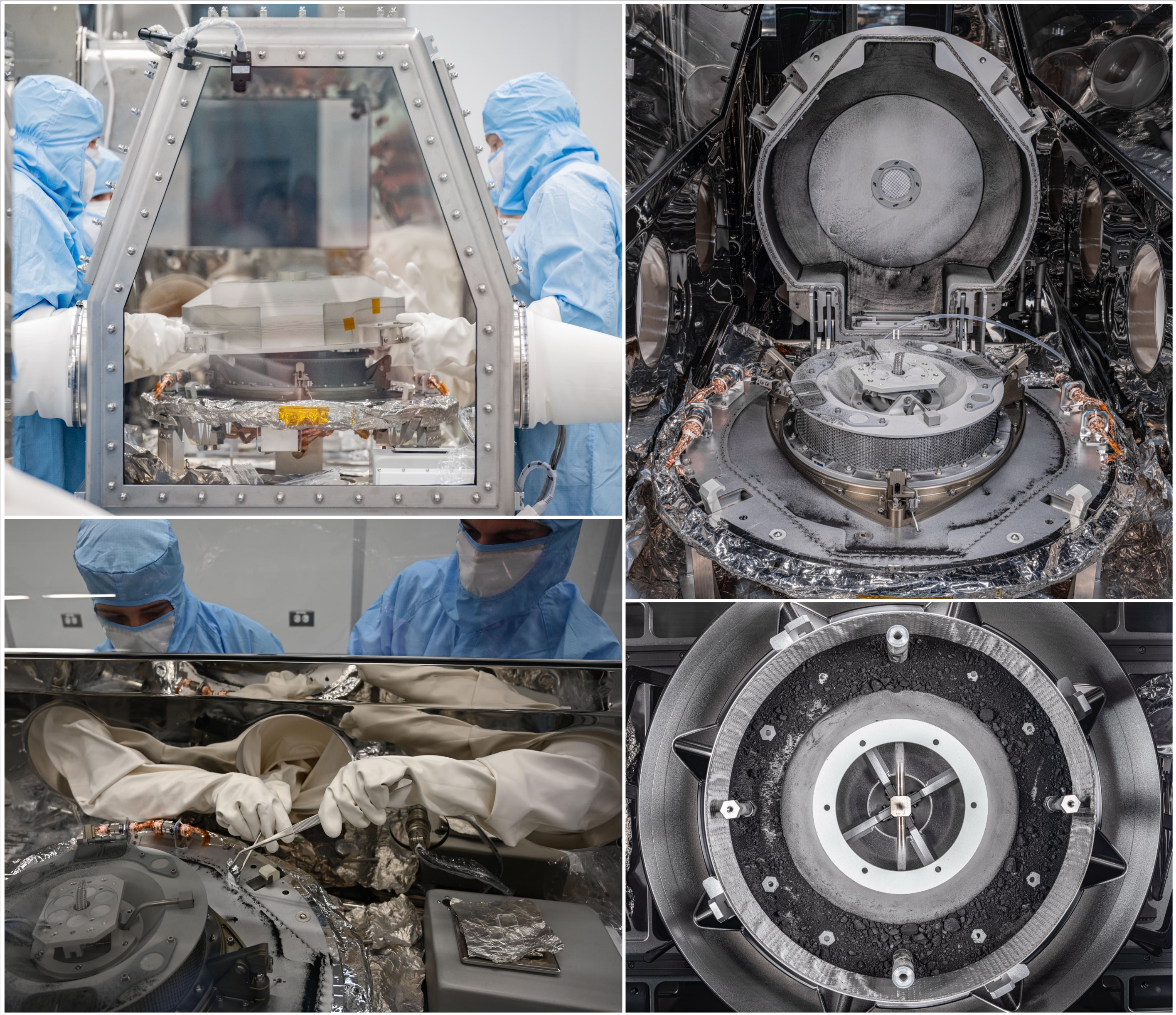
TAGSAM glovebox rehearsal

- **Frequent rehearsals in the mockups enabled curation sample processors to develop best practices, muscle memory and familiarity working with fellow team members**
- **Final rehearsal in June 2023 using flight-like hardware, polydisperse PTFE spheres to simulate asteroid samples**
- **High-resolution sample imaging also successfully rehearsed in June 2023**

OSIRIS-REx Earth Return: September 24th, 2023

- **Sample Return Capsule (SRC) landed at the Utah Test and Training Range (UTTR)**
- **SRC was transported by helicopter to a temporary cleanroom facility, where sample canister was removed and place on a nitrogen purge**
- **The samples were then transported back to Johnson Space Center in Houston on a C-17 military plane (September 25th, 2023)**

Gloveboxes in Action – Success!



What Have We Learned from Bennu Samples So Far?

- Complex organic molecules found in Bennu samples (e.g. amino acids) – unambiguously extraterrestrial (as opposed to compounds found in meteorites, which may be contaminated by terrestrial environments

- Abundant hydrated minerals – could asteroids like Bennu be a possible source for Earth's water?

- Magnesium phosphates found in Bennu samples – extremely rare in meteorites; presolar material, diverse lithologies

- Careful sample handling in well-designed gloveboxes reduce the potential for terrestrial contamination to compromise these important findings

A Bright Future for Astromaterials Curation

- NASA is currently preparing for future samples that will be returned from the Moon, Mars, Phobos, and comets
- Other countries are bringing back extraterrestrial samples: Japan, China, ESA, India, Russia; partner countries will also have the need to curate astromaterials
- Curation apparatus will increase in complexity, with requirements to preserve cryogenic samples; remote manipulation will be needed
- NASA has been curating astromaterials in gloveboxes for over half a century; what will the next 50 years of astromaterials sample curation look like?