LUNAR PROCESSING CABINET 2.0: RETROFITTING GLOVEBOXES INTO THE 21ST CENTURY.

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Introduction: In 2014, the Apollo 16 Lunar Processing Glovebox (cabinet 38) in the Lunar Curation Laboratory at NASA JSC received an upgrade including new technology interfaces. A Jacobs – Technology Innovation Project provided the primary resources to retrofit this glovebox into the 21st century. NASA Astromaterials Acquisition & Curation Office continues the over 40 year heritage of preserving lunar materials for future scientific studies in state-of-the-art facilities. This enhancement has not only modernized the contamination controls, but provides new innovative tools for processing and characterizing lunar samples as well as supports real-time exchange of sample images and information with the scientific community throughout the world.

History: JSC building 31N Lunar Curation Laboratory Facility was established in 1979 to permanently house the Apollo 11, 12, 14, 15, 16, and 17 lunar materials. The Lunar Sample Analysis and Planning Team (LSAPT) facility subcommittee from 1975 to 1979 established strict material requirements for controlling contamination. Gloveboxes for the 31N facility were purchased between 1977 and 1978 from the Stainless Equipment Company in Englewood, CO. These gloveboxes were specially designed with limited materials and physical properties that would offer low particle shedding and outgassing characteristics:

- 316L stainless steel (SS-316L) with continuous welds; glovebox shell, airlock, and gloveports
- Viton gaskets
- Neoprene gloves
- Safety glass windows (4 windows, including the gloveport)

Due to gloveport glass fractures during initial sample handing and subdivisions, many gloveport windows were replaced with a clear polycarbonate, Lexan.

Today, the Lunar Curation Laboratory operates 26 positive pressure gaseous nitrogen (GN_2) gloveboxes: 8 for sample characterization and processing, 12 for long-term storage, and 6 specialized gloveboxes that include a band saw for sample subdivision, core extraction, return sample processing, and experiments. All gloveboxes are maintained with a GN_2 inert environment at 1.0 inH_2O positive pressure, < 20 ppm O_2, and < 50 ppm H_2O. The majority of the gloveboxes have their original materials with visible deterioration on most polycarbonate windows and gaskets. In addition, each processing glovebox is currently configured with out-of-date technology.

Glovebox Upgrades: The existing SS-316L glovebox was retrofitted with new windows, gaskets, lights, and gloves as well as integrated with the latest technology for processing lunar samples. All materials were chosen to either maintain or improve contamination control with low particle shedding and outgassing characteristics. In addition, most electronics and instrumentation are situated outside of the inert environment to reduce cross-contamination.

Fig. 1: The new upgraded Apollo 16 Lunar Processing Glovebox (cabinet 38) in the Lunar Curation Laboratory at NASA JSC.

The glovebox received the following upgrades (fig. 1):

- Mettler-Toledo XP5003SDR balance with bluetooth wireless technology for sample weighing. For contamination control, the balance was fitted with a custom designed Al 6061 housing and PTFE wire harness (fig. 2) as well as the primary electronic components and controls were placed outside of the glovebox environment.
- Axis P5534 PTZ IP network camera for overview sample imaging is situated outside of the glovebox environment above the top window for viewing samples in the main chamber (fig. 3).
- Leica DMS1000 macroscope for sample sorting and microscopic imaging is situated outside of the glovebox environment at the end vertical window on a custom mount.
- Dell XPS 18 all-in-one touch-screen computer interface was fitted to a custom pole mount. The computer can be used for sample viewing as well

as uploading images and weight data directly to the Lunar database on the JSC network.

- Waldmann flat LED task lighting replaced the fluorescence light box on the top window (fig. 3).
- Hypalon gloves (polyurethane/chlorosulfonated polyethylene) replaced the six neoprene gloves.
- Schott Amiran antireflective laminated low-iron window glass (SiO_2/TiO_2 multilayer with 98% light transmission and < 1% reflectance) and Mosites #1028 Viton gaskets replaced three original glass windows and one polycarbonate gloveport window.
- Four custom MBraun 316L stainless steel 8 in. gloveports were installed in the new window. The 9.5 mm thick glass was precision cut on an OMAX 80X waterjet with a ±1 mm hole tolerance.

Fig. 2: Mettler-Toledo balance with custom designed Al 6061 housing, 316L SS weighing plate and PTFE wire harness.

Fig. 3: Top Window: PTZ network camera for overview sample imaging and LED lights replaced old fluorescence lighting.

Technology Infusion: Many of the new materials and technologies were chosen from past curation technology demonstrations funded by JSC IR&D resources. The following demonstrations helped infuse technology into the updated lunar glovebox:

GeoLab Glovebox in the Habitat Demonstration Unit (2009 – 2012) [1, 2]: window materials, glove materials, LED lighting, stereomicroscope systems, IP PTZ cameras, remote O_2, H_2O, and pressure monitoring, all-in-one computers, and instrumentation testing.

GeoLab Glovebox at Desert RATS (2010 – 2011) [2]: glovebox ergonomics, custom designed crew interface with glovebox instrumentation, and crew feedback on glovebox designs.

GeoLab Glovebox in the 2012 AES Deep Space Habitat [1]: robotic arm inside glovebox, advanced avionics integration, automatous mission operations, advanced crew interfaces, and crew feedback on designs.

Organic Contamination Baseline Study (2010 – 2012) in lunar gloveboxes [3]: ultrapure water cleaning tests, SEM particle counts, TD-GC-MS organic analyses, TD-GC-MS organic analyses on house GN_2, and developed new cleaning strategies.

3D Scanner: In addition to the glovebox upgrade, Jacobs provided the resources for a NextEngine 3D scanner model 2020i for future infusion into curation processing gloveboxes. 3D scans of complex rock geometry can produce accurate volume measurements used to calculate density. 3D rock models can also help plan complex sample subdivisions as well as produce 3D printed rock models for practice cuts.

The scanner uses a MultiStripe Laser Triangulation technology with twin arrays of four Class 1M, 10 mW solid state lasers with custom optics operating at 650 nm wavelength. The scanner is also designed with twin 3.0 megapixel CMOS imaging sensors. The scanner is capable of capturing objects from 12.95 x 9.65 cm to 57.15 x 42.55 cm. Experimental tests found that the scanner is capable of a volume measurement accuracy of ±0.001 cm^3 with well-defined fiducial marks and ±0.030 cm^3 without fiducial marks.

Future: The updated lunar glovebox is currently being tested and used for processing Apollo 16 samples. In addition, initial work has started to integrate a 3D scanner into a glovebox for routine sample processing. The Lunar Processing Cabinet 2.0 project designs and information gathered from functional tests can be used for planning future glovebox upgrades in JSC curation laboratories.

References: [1] Evans, C.A. et al. (2013) *Acta Astronautica*, 90:289-300. [2] Calaway, M.J. et al. (2011) *LPSC XLII*, 1473. [3] Calaway, M.J. et al. (2014) *NASA TP*-2014-217393.

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