CONTAMINATION CONTROL AND KNOWLEDGE DURING CONSTRUCTION OF NEW CURATION FACILITIES AT NASA JOHNSON SPACE CENTER.
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Introduction: Beginning in early 2019, NASA Johnson Space Center (JSC) Astromaterials Acquisition and Curation Office will commence construction of six new curation cleanroom laboratories by remodeling over 560 m^2 of existing space inside JSC Building 31, current home of all of NASA's extraterrestrial sample collections. The new facilities will accommodate two new collections housing material returned from NASA's OSIRIS-REx mission and a subset of material returned from JAXA's Hayabusa2 mission, as well as advanced curation and cleaning laboratories.

The ultimate goal of curation is to ensure all samples remain preserved as much as possible in a pristine state to enable science investigations in the indefinite future. Integrity of the samples is maintained by handling the samples in specifically designed cleanrooms, with a limited number of carefully selected materials. At JSC, all collections are stored and processed in cleanroom laboratories ranging from ISO Class 4 to ISO Class 7: Lunar (ISO Class 6), Meteorite (ISO Class 6), Cosmic Dust (ISO Class 5), Microparticle Impact (ISO Class 5), Genesis Solar Wind (ISO Class 4), Stardust Comet/Interstellar (ISO Class 5), and Hayabusa Asteroid (ISO Class 5). Housekeeping protocols as well as cleanroom gowning apparel (garments, gloves, etc.) are adapted to each collection.

Contamination Control and Knowledge (CCK) is a mandatory part of any clean process. A cleanroom by itself is not enough to ensure cleanliness, as contaminants come from many sources (staff, building materials, equipment and consumables, etc.). Contamination can occur in various forms (particulate, organic, abiotic or biotic, molecular, etc.). Even though cleanrooms are kept at positive pressure in accordance to international standard ISO 14644-4, the immediate surrounding environment can have an impact on them, by eddies against the airflow, and ingress of staff [1].

The construction, that should span over at least 14 months, is directly adjacent to a number of curation and research laboratories. These curation and research laboratories plan to remain operational during this construction with as minimal downtime as possible, which emphasizes the importance of contamination control.

This abstract will provide an overview of the current contamination control and knowledge (CCK) activities, monitoring and testing that will maintain the cleanliness and pristine state of the current astromaterial collections during construction.

Impacted Cleanroom Laboratories: During construction, several critical research and curation laboratories will be impacted from the construction. Building 31 1st floor houses the Center for Isotope Cosmochemistry and Geochronology (CICG) research laboratory. The 2nd floor houses Stardust, Meteorite, Cosmic Dust, and existing precision cleaning (PreClean/Final Clean) curation cleanroom laboratories. The Stardust cleanrooms will be the most impacted since this laboratory is directly adjacent to the new construction of OSIRIS-REx/Hayabusa2 suite and it also shares the same air handler which will be replaced during construction.

In this context, CCK serves three goals: 1) Make sure that it is possible to keep working in the curation laboratories, or decide when it is necessary to secure the samples in storage; 2) Establish a list of all contaminants found even temporarily in existing ARES cleanrooms that might impact future scientific discoveries, and 3) Gather best practices for future construction work. It will also help us verify that the effort of the construction contractors to minimize and mitigate unwanted airborne release of outgassing and particulate generation are sufficient.

Current monitoring of cleanrooms: Cleanrooms are routinely monitored for airborne particulates, room-to-room differential pressure, temperature, humidity, fan filter units (FFUs) velocity, and air changes per hour. HVAC is continually monitored and particle counts (along with temperature and humidity) are currently taken on a weekly basis to ensure a particle load is within the cleanroom parameters. Cleanroom positive pressure cascade airflow and FFU velocities along with a full ISO audit of particulates are conducted annually. In preparation for the increased organic limits for OSIRIS-REx [2] and Hayabusa2, JSC Curation conducted an organic contamination baseline study [3] that provided a long-term historical perspective on curation cleanroom affected by organics.

New curation facilities construction: The OSIRIS-Rex and Hayabusa2 missions are set to sample organic-rich asteroids. Both samples curation facilities are being tailored for these samples by reducing organic outgassing products [4] and reduction of total organic carbon in the lab that could hamper scientific investigations. The other new cleanrooms are a precision cleaning ISO Class 5/6 cleanroom laboratory for cleaning curation support equipment, advanced cleaning ISO Class 6 cleanroom laboratory for developing advanced curation cleaning methods, and an advanced curation ISO Class 7 cleanroom space for developing advanced curation technologies and procedures.

This extensive remodeling will include phases of asbestos abatement, demolition of interior walls and floors, construction of new walls and mechanical spaces, as well as pouring of concrete and epoxy floors. Even though protective measures will be taken to isolate the construction site from the rest of the building (negative pressure during asbestos abatement, isolating curtains, etc.), each phase of construction will impact the surrounding environment in a specific way. For example, demolition is expected to increase particle load, and epoxy paint and floors could introduce organic contamination.

Contamination Control and Knowledge Plan: The CCK plan has been designed to include the existing measurement routine and develop new protocols to target air and surface contamination from organic and inorganic sources.

CCK efforts began in December 2018 to acquire a strong baseline of contamination knowledge before construction starts. Baseline tests are being conducted at rest (i.e., without any work being conducted at the same time), since the goal is to assess the cleanrooms themselves, and not the activities. Over the span of the construction a mix of long-term and immediate tests will be performed. Long-term tests to reach Goal 2, and short-term tests to reach Goals 2 and 3. Within the cleanrooms, tests will be placed in locations and areas where samples are handled and processed. Manipulation and processing of samples has the potential to lead to more significant contamination than the storage time. Hallways outside of the critical laboratories will be also monitored for particle load and AMCs.

Airborne particle monitoring. Hallways in front of the critical laboratories should be monitored weekly following the same protocol as for the cleanrooms.

Differential pressure. Differential pressure will be checked more frequently between the entrance points of each critical laboratory and the hallway. During the construction, replacement or deactivation of air handlers can disrupt the pressure balance at the building scale. Sensitive work should not be conducted if the cleanrooms are not at least 0.03 inH_2O above the outside pressure.

Airborne Molecular Contamination (AMC). AMC occurs when contaminants are in molecular form without forming particle aggregates in the airflow. Contaminants can be in the form of trace inorganic, organic and biological species. Even though AMCs should be evacuated out of the cleanroom by the airflow, they can interact with surfaces, and deposit to become Surface Molecular Contamination (SMC), posing a threat to the integrity of samples. Long-term molecular organics and molecular metals will be measured using a protocol developed for OSIRIS-REx spacecraft assembly [2]. Silicon wafers and aluminum foil will be exposed for several weeks. Wafers will be then analyzed for inorganic contaminants and particles with an SEM, and foil should be studied for organics using a GC-MS. Short-term (24 to 72h) AMC tests focused on specific construction events will be performed using wafers and air sampling tubes provided by Air Liquide-Balazs NanoAnalysis. While goal 1 of the CCK plan is strictly based on airborne particle counts (monitored weekly), AMC monitoring is important for goals 2 and 3.

Surface contamination. Curation facilities surfaces (floors, walls, etc.) are being routinely cleaned, and work stations are frequently wiped when in use. However, no study has been conducted to understand how much and which particles and AMCs are depositing on surfaces. We envision two methods of studying surface contamination. First, collecting particles on the surface using tape, analyzing them using an SEM to monitor what type, size and composition of particles that are deposited. Second, using critical wipes, where a surface is wiped using a low-lint wipe, the wipe is then rinsed in an adapted solvent to monitor either organics or trace metals.

Tracing sources of contamination. Even though materials to be used in the new cleanrooms have been chosen for their low outgassing properties, materials being used for the construction around the cleanrooms are not controlled. Developing a protocol to assess a range of construction materials in case some unknown AMCs are detected will allow us to promptly react and potentially ban certain materials from being used during the construction. A protocol under consideration would be to outgas samples of building materials in an emission chamber, and to collect AMCs in solvent tubes for analysis through desorption in a GC-MS [4].

Conclusion: The Contamination Control and Knowledge plan encompasses a range of tests to reach Goals 1 to 3. It should enable the Curation Office to more accurately track contamination, its sources, and its vectors. Understanding these processes should lead to an reevaluation of the current contamination mitigation protocols, e.g. housekeeping, cleanroom gowning apparel, gloves and staff behavior in the Curation Office.

References: [1] IEST Recommended Practice: IEST-RP-CC003.3. [2] Dworkin et al. (2018) Space Sci Rev, 214: 19. [3] Calaway et al. (2014). NASA/TP-2014-217393. [4] Calaway et al. (2019) *LPSC L*:1448. [5] Kataoka H. et al. (2012) *InTech*: 161-184.