JSC ADVANCED CURATION: RESEARCH AND DEVELOPMENT FOR CURRENT COLLECTIONS AND FUTURE SAMPLE RETURN MISSION DEMANDS. M. D. Fries[1], C. C. Allen[1], M. J. Calaway[2], C. A. Evans[1], and E. K. Stansbery[1]. [1]NASA Johnson Space Center, Astromaterials Acquisition and Curation Office, Houston, TX, [2]Jacobs, NASA Johnson Space Center, Houston, TX. marc.d.fries@nasa.gov.

Introduction: Curation of NASA's astromaterials sample collections is a demanding and *evolving* activity that supports valuable science from NASA missions for generations, long after the samples are returned to Earth. For example, NASA continues to loan hundreds of Apollo program samples to investigators every year and those samples are often analyzed using instruments that did not exist at the time of the Apollo missions themselves. The samples are curated in a manner that minimizes overall contamination, enabling clean, new high-sensitivity measurements and new science results over 40 years after their return to Earth. As our exploration of the Solar System progresses, upcoming and future NASA sample return missions will return new samples with stringent contamination control, sample environmental control, and Planetary Protection requirements [1,-3]. Therefore, an essential element of a healthy astromaterials curation program is a research and development (R&D) effort that characterizes and employs new technologies to maintain current collections and enable new missions – an Advanced Curation effort [4]. JSC's Astromaterials Acquisition & Curation Office is continually performing Advanced Curation research, identifying and defining knowledge gaps about research, development, and validation/verification topics that are critical to support current and future NASA astromaterials sample collections. The following are highlighted knowledge gaps and research opportunities.

Sample Handling Research: NASA has specific needs relating to understanding the behavior of geological samples in clean environments. Outside of NASA, however, most clean sample handling facilities do not focus on geological samples and as a result relatively little R&D work is available to leverage. Even within NASA's Curation facilities at the Johnson Space Center (JSC), sample environments are different from the planetary or space environment; introducing potential for sample alteration and contamination. Advanced Curation efforts in this arena include development of sample subdivision and processing techniques and hardware for NASA collections [1,5,6]. Upcoming efforts include sample handling, subdivision and preparation for analysis in clean and controlled environments – specifically to assist new data, quantify and constrain particulate generation, contamination persistence, and cross contamination.

Organic Cleanliness Research: Advanced Curation efforts include a lengthy series of experiments to control and quantify organic contamination in Curation facilities [2,6-9]. Organic contamination is an important subject matter for Mars 2020, OSIRIS-REx, and future NASA missions that feature mission goals pertaining to collection of organics-specific materials, organics-sparse materials, a life-detection component, or a combination of these factors. The Mars 2020 caching mission presents particular difficulties, since multiple laboratory studies [10-12], multiple landed NASA missions [13-16], and multiple studies of martian meteorites [17,18] show that martian organic compounds occur at very low levels, making them extremely difficult to locate and characterize. Martian organics are also of extremely high importance to our understanding of life in our solar system as stated in NASA Mars Exploration Program goals, the MEPAG goals document, and the National Research Council Planetary Science Decadal Survey. In addition, several NASA panels [19-22] unanimously agreed that Mars organic contamination control is critical for Mars sample return missions and that strict contamination limits are required. Advanced Curation research topics in this area include but are not limited to: high-precision cleaning/validation research (<10 ng/cm^2 total organic carbon (TOC) methods development), cleanliness preservation (encapsulation techniques, controlling environment, containment) and supplemental recleaning technology. Supplemental recleaning is a contamination control approach where flight and/or curation hardware is first treated and verified to a high state of cleanliness, and then a supplemental cleaning procedure is performed after/during processing operations that introduce contaminants into the system. Options for this technique include the use of UV-ozone treatment, plasma cleaning, hardware heating, exposure of a "getter" material, and/or thermal cycling of a cold finger.

Inorganic Cleanliness Research: Inorganic cleanliness has been a Curation priority since the Apollo program [23 and references therein]. One aspect of this contamination is that as technology improves, the range of elements used for new scientific research expands. Therefore, inorganic contamination control must account for elemental contamination that may become scientifically interesting in the future. Advanced Curation research topics include high-precision cleaning/validation research and inorganic cleanliness preservation (encapsulation, environmental control, contaminant abatement).

Mission Operations and Spacecraft Design: Sample return missions are unique in that they effectively continue for an indefinite period after the flight portion of the mission is complete, and NASA's experience is that curation effectively begins at mission design [2]. Material selection and hardware design that allows the ability to properly clean hardware is essential for the level of contamination control needed for analysis of samples that can occur decades later. On planetary surfaces, curation is important as a component of mission operations for human and robotic sample acquisition for continual contamination control and maintenance of sample archives. JSC curation teams have the ultimate long-term responsibility for the scientific integrity of the samples and are a critical mission team link between engineers and scientists. JSC curation analog mission involvement [24,25] has helped define critical operational junctures for future missions. In addition, curation is central to SRC recovery and development of contingency plans (e.g. recovery of the Genesis SRC) [26]. Future missions will require highly specialized sample containment and consequently require strategic JSC curation input into Sample Return Capsule (SRC) development.

Robotics and Sample Handling Technology: Curation has sought robotic solutions for future NASA mission needs [27,28] because some future human and robotic sample return missions can foreseeably require isolation containment systems for strict control of inorganic and organic contamination. This is especially true for missions with a life-detection component and/or where samples contain trace levels of organic compounds. In addition, specialized transport containers are required to maintain an inert environment under specific temperature and pressure, requiring new container sealing and opening technology. Also, any potential mission requiring examination of astromaterials in microgravity will require constant contact to secure samples during manipulation [24]. Future robotic or robotically assisted surface missions may require robotic sample manipulators developed for autonomous use in environments where the robotic manipulator cannot rely on complete knowledge about its surroundings. The development of specialized sample handling tools may also be required for astronaut use.

Cold Curation: Future sample return missions may collect samples that have been preserved at sub-freezing or even cryogenic temperatures. The ability to store, document, sub-divide, and transport extraterrestrial geologic samples while maintaining sub-freezing or cryogenic temperatures, possibly as low as 40 K, is required for these missions [29]. The 2013-2022 NRC Planetary Science Decadal Survey highlighted two notable missions that will require technology for cryogenic curation: (1) Comet Surface Sample Return (CSSR) and (2) Lunar South Pole-Aitken Basin Sample Return. The CSSR white paper concluded that sample temperatures must be restricted to less than 125 K from collection to curation facility. Critical cryogenic curation technological development is also aligned with several NASA Technology Area Roadmaps and NASA Space Technology Grand Challenges. Cryogenic curation is feasible with current technologies developed for the superconductor industry. Cold curation at 250 K is the next step for developing advanced curation technologies for future missions with minimal investment, while monitoring the development of cryogenic technologies that could be used for future sample return missions that wish to preserve samples at very low temperatures.

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