

CURATING NASA'S PAST, PRESENT, AND FUTURE EXTRATERRESTRIAL SAMPLE COLLECTIONS. F. M. McCubbin, J. H. Allton, C. A. Evans, M. D. Fries, K. Nakamura-Messenger, K. Richter, R. A. Zeigler, M. Zolensky, and E. K. Stansbery, NASA Johnson Space Center, 2101 NASA Parkway, Mail Code XI2, Houston, TX 77058. francis.m.mccubbin@nasa.gov.

Introduction: The Astromaterials Acquisition and Curation Office (henceforth referred to herein as NASA Curation Office) at NASA Johnson Space Center (JSC) is responsible for curating all of NASA's extraterrestrial samples. Under the governing document, NASA Policy Directive (NPD) 7100.10E "Curation of Extraterrestrial Materials", JSC is charged with "...curation of all extraterrestrial material under NASA control, including future NASA missions." The Directive goes on to define Curation as including "...documentation, preservation, preparation, and distribution of samples for research, education, and public outreach." Here we describe some of the past, present, and future activities of the NASA Curation Office.

Past: Curatorial activities began at JSC (Manned Spacecraft Center before 1973) as soon as design and construction planning for the Lunar Receiving Laboratory (LRL) began in 1964 [1], not with the return of the Apollo samples in 1969, nor with the completion of the LRL in 1967. This practice has since proven that curation begins as soon as a sample return mission is conceived, and this founding principle continues to return dividends today.

The LRL was designed both as a quarantine facility to protect the Earth from contamination by potential lunar organisms carried by the astronauts or samples and to protect the samples from contamination by the terrestrial environment. In addition to the curatorial laboratories, the LRL also contained state-of-the-art research facilities (e.g., a noble gas lab, gas chromatography-mass Spectrometer, etc.) that were intended to be used by the preliminary examination team (PET) for the initial characterization of the samples. It also served as a contingency facility for additional studies in case the samples needed to stay under quarantine. The facility was intended to be later used as stand-alone research labs if the quarantine was lifted.

The six Apollo landings returned ~2200 samples (382 kg) of rock, coarse fines, regolith, and soil cores from various geologically diverse locations on the Moon. Samples from each mission had to be stored and processed in separate environments, and each sample type required different handling procedures. As the enormity of the effort involved with the long term curation of the Apollo samples became apparent and as NASA began to discuss new sample return missions, a new long-term curation facility was constructed at JSC known as building 31N. Completed in 1978, 31N became the new (and current) home to the Apollo samples.

As new collections have been acquired by NASA, new laboratories were added to building 31N (or to the adjacent building 31). Collocating all of NASA's astromaterials collections allows new labs to leverage both common infrastructure components already in place at JSC and take advantage of common skills by personnel experienced in the NASA Curation Office.

Present: JSC presently curates 9 different astromaterials collections in seven different clean-room suites: (1) Apollo Samples (1969; ISO class 6 + 7); (2) Antarctic Meteorites (1976; ISO class 6 + 7); (3) Cosmic Dust Particles (1981; ISO class 5); (4) Microparticle Impact Collection (1985; ISO class 7; formerly called Space Exposed Hardware); (5) Genesis Solar Wind Atoms (2004; ISO class 4); (6) Stardust Comet Particles (2006; ISO class 5); (7) Stardust Interstellar Particles (2006; ISO class 5); (8) Hayabusa Asteroid Particles (2010; ISO class 5); (9) OSIRIS-REx Spacecraft Coupons and Witness Plates (2015; ISO class 7). Consequently, we currently curate large rock samples (Apollo, Meteorites), bulk regolith and core samples that are intimate mixtures of particles ranging from submicron to 1 cm (Apollo), micron-scale individual particles (Cosmic Dust, Hayabusa), micron-scale particles embedded in aerogel (Stardust), atoms of the solar wind implanted in various materials, physical pieces of spacecraft that have astromaterials embedded in them (Microparticle Impact Collection), and materials that capture contamination knowledge for returned extraterrestrial samples (Genesis, Stardust, OSIRIS-REx). Although sample handling procedures, materials, and equipment for each collection are collectively unique, portions of each process are similar, and our staff are cross-trained to work in multiple labs to great effect.

In addition to the labs that house the samples, we have installed and maintained a wide variety of facilities and infrastructure that are required to support the clean rooms: HEPA-filtered air-handling systems (typically at least one HVAC system for each laboratory), ultrapure dry gaseous nitrogen systems, an ultrapure water (UPW) system, and cleaning facilities to provide clean tools and equipment for the labs. We also have sample preparation facilities for making thin sections, microtome sections, and even focused ion-beam (FIB) sections to meet the research requirements of scientists across the globe.

In order to ensure that we are keeping the samples as pristine as possible, we routinely monitor the cleanliness of our clean rooms and infrastructure systems. This monitoring includes measurements of inorganic or or-

ganic contamination in processing cabinets [2-3] and weekly airborne particle counts in most labs. Each delivery of liquid N₂ is monitored for contaminants (typically <20 ppm Ar, and <1 ppm all others combined), and the stable isotope composition of the gaseous N₂ is measured monthly ($\delta^{15}\text{N} = -0.88\%$). The quality of our UPW system is monitored daily.

In addition to the physical maintenance of the samples, we track within our databases the current and ever changing characteristics (weight, location, destructive analysis spots, etc.) of >250,000 individually numbered samples across our various collections. Similarly there are hundreds of thousands of images associated with the samples that are stored on our servers. We also have the sample processing and sample handling records (many hand written) for our older collections (over 400 linear feet just for the lunar samples). Collectively, these digital and paper records contain each sample's history in curation, information that could be of vital importance to future researchers.

Curation is more than just keeping the samples safe, secure, and clean. It is also about providing samples to scientists to maximize the science return from each of the sample collections. For the past 10 years, we have handed out nearly 1,400 samples each year to >350 principal investigators (PIs) around the world. Because these are sample loans, we must track the >25,000 different samples that are with the PIs, and we require the PIs to perform an annual inventory.

JSC Curation is collocated with JSC's Astromaterials Research Office, which houses a world-class suite of analytical instrumentation [4] and scientists. We leverage these labs and personnel to better curate the samples (e.g., PET efforts for OSIRIS-REx will utilize many of the facilities described in [4]).

Future: As each new sample collection is returned, new facilities are added to accommodate them. The next missions returning samples to JSC are Hayabusa 2 and OSIRIS-REx, in 2021 and 2023 respectively (the Hayabusa 2 samples are being provided as part of an international agreement with JAXA). The clean rooms that will house these missions are currently in the planning stages, and the spaces should be completed in 2020. Because we have built other clean rooms in the recent past (e.g., Hayabusa in 2012), we are already familiar with current best practices in astromaterials clean rooms.

In addition to adding clean rooms to house samples, we are augmenting our analytical facilities as well. A micro-CT laboratory dedicated to the study of astromaterials will be coming online in summer 2016 within the JSC Curation office, and we envisage adding additional facilities that will enable non-destructive (or minimally-destructive) analyses of astromaterials in the near future (micro-XRF, confocal imaging Raman spectroscopy).

copy). These facilities will be available to be utilized by PET for future sample return missions, for retroactive PET-style analyses of our existing collections, and for periodic assessments of samples in the existing collections.

Part of the curation process is planning for the future, and we refer to these planning efforts as "advanced curation". Advanced Curation is tasked with developing procedures, technology, and data sets necessary for curating new types of collections as envisioned by NASA exploration goals. We are (and have been) planning for future curation, including cold curation, extended curation of ices and volatiles, curation of samples with special chemical considerations such as perchlorate-rich samples, and curation of organically- and biologically-sensitive samples. These efforts will be useful for Mars Sample Return and sample return from cometary surfaces, both of which were named in the NRC Planetary Science Decadal Survey 2013-2022. We are fully committed to pushing the boundaries of curation protocol as humans continue to push the boundaries of space exploration and sample return. However, we must never forget our founding principle that curation begins at the conception of a sample-return mission or campaign (in the case of Mars 2020), not at the time of sample collection or return.

Concluding Remarks: The return of every extraterrestrial sample is a scientific investment, and the curation facilities and personnel are the primary managers of that investment. Our primary goals are to maintain the integrity of the samples and ensure that the samples are distributed for scientific study in a fair, timely, and responsible manner. It is only through the long-term stability and support of curation facilities that the maximum returns on that scientific investment are achieved. NASA has committed to supporting its curation facilities through NASA Policy Directive (NPD) 7100.10E. Consequently, the Astromaterials Acquisition and Curation Office at JSC is the past, present, and future home of NASA's extraterrestrial sample collections.

References: [1] Mangus, S. & Larsen, W. (2004). Lunar Receiving Laboratory Project History. NASA/CR-2004-208938. NASA, Washington, DC. [2] Calaway, M.J., et al., (2014) Organic Contamination Baseline Study in NASA Johnson Space Center Astromaterials Curation Laboratories, NASA TP-2014-217393, July 1, pp. 108. [3] Allen, C. et al., (2011) Curating NASA's extraterrestrial samples-Past, present, and future. *Chemie Der Erde-Geochemistry*, 71, 1-20. [4] Draper, D.S. and Astromaterials Research and Exploration Science Division (2016) NASA Johnson Space Center's Planetary Sample Analysis and Mission Science (PSAMS) Lab: A National Facility for Planetary Research. 47th LPSC #2013.