

SAMPLE RETURN FROM THE MOON. LESSONS LEARNED FROM ANGSA AND ENABLING INFRASTRUCTURE ON THE MOON AND EARTH. C.K. Shearer^{1,2}, B.J. Jolliff³, C.R. Neal⁴, and J.J. Barnes⁵.

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Introduction: Analyses of the samples returned by the Apollo Program have provided fundamental insights into the origin and history of the Earth-Moon system and how planets and even solar systems work. Artemis and future robotic missions will explore and return samples from terrains and environments distinct from those sampled by the Apollo, Luna, and Chang'E missions to the lunar surface. Here, we discuss lessons learned from the Apollo Next Generation Sample Analyses (ANGSA) Program as they pertain to sample return infrastructure that should evolve on the Moon as human sustainability on the lunar surface evolves, and sample curation and science investments on Earth that should be made as human and robotic activities increase on the Moon.

Lessons Learned from the ANGSA initiative: The ANGSA initiative has been conducted as a lunar sample return mission, thus the activities have implications for the Artemis Program and associated sample returns to Earth. The ANGSA Lessons Learned Document can be accessed through the LPI-hosted ANGSA website (https://www.lpi.usra.edu/ANGSA/news/ANGSA-Lessons-Learned-Final-September_1_2021.pdf) [1]. This document addresses (a) the diversity and funding of sample science teams; (b) issues tied to sealed samples such as defining the science associated with each sealed container and designing-testing not only the container but also the sampling strategy, allocation, and long-term preservation; (c) the importance and approach for integrating the science team into the preliminary examination (PE) of the returned samples; (d) the advantages of new imaging technologies for PE and making sample allocations; (e) the importance of having sample scientists engaged in mission planning for defining science and selection of appropriate samples and preparing for unanticipated yet scientifically valuable samples; (f) effectiveness of volatile sampling containers on the lunar surface and working with those containers on Earth.

Sample return infrastructure on the Moon: During the initial Artemis missions, the amount of sample return infrastructure on the Moon may be minimal and not exceeding that of the Apollo Program. However, as human, and robotic activities increase in duration and sophistication, it is critical to consider what potential infrastructure that would enable sample

collection, preservation, analysis, and return to fulfill important science and exploration goals. More proficient sample return would be enabled by Moon-wide communications, increased astronaut mobility, capability to sample to depths greater than the Apollo 17 deep drill core (3 m), long range sample return rovers that interact with Earth-based science teams and astronauts on the lunar surface, docking & repair stations for sample return rovers, surface analytical capability for real time assessment of resources, analysis of “fragile” samples and/or ephemeral sample properties, or carrying out PE, and containment-storage facility for sample preservation. An example of the usefulness of select infrastructure capabilities is the Planetary Science Decadal Survey’s (PSDS) top lunar science priority [2]. Sampling of the South Pole Aitken (SPA) has long been a high priority science goal [3]. The most recent PSDS approach for the exploration of the SPA basin is with a medium-scale rover (Endurance-A) that would traverse about 2000 km of the SPA basin collecting samples from science-rich targets that would later be picked up and returned by astronauts. Infrastructure capabilities as noted above would enhance this mission.

Sample return infrastructure on Earth: Important infrastructure needs are critical to successful sample return missions associated with the future exploration of the Moon. The most valuable asset is a trained and diverse work force and NASA should continue to invest in this. The ANGSA program has taken a step forward in training the next generation of sample scientists. Strategic investments in multi-user, state-of-the-art instrumentation capabilities at NASA centers, research centers, and universities is critical. A coordinated assessment of lunar sample curation needs on Earth to accommodate potential returned sample masses, unique samples and storage conditions, and PE is valuable and should be undertaken.

References: [1] ANGSA Science Team (2021) ANGSA Initiative, Lessons Learned for Future Exploration 2019-2022. [2] National Academies of Sciences, Engineering, and Medicine 2022. *Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/26522>. [3] Jolliff, B. L., Shearer Jr, C., Gaddis, L. R., Pieters, C. M., Head, J. W., Haruyama, J., ... & Petro, N. E. (2010). MoonRise: Sampling South Pole-Aitken basin as a recorder of Solar System events. In *AGU Fall Meeting Abstracts* (Vol. 2010, pp. P43A-01).