ANGSA INITIATIVE, A LOW-COST LUNAR "SAMPLE RETURN MISSION". SCIENCE AND ENGINEERING GOALS, SPECIAL SAMPLES, TEAMS, AND PROGRESS. C.K. Shearer[1,2], F. McCubbin[3], R. Zeigler[3], J. Gross[3,4], J.J. Barnes[5], K. Burgess[6], B.A. Cohen[7], N. Curran[7], J.E. Elsila[7], M.D. Dyar[8], A. Sehlke[9], R.C. Walroth[10], K.C. Welten [11], ANGSA science team[12], and the ANGSA curation team[13]. [1]Dept. of Earth and Planetary Science, Institute of Meteoritics, University of New Mexico, Albuquerque, New Mexico 87131; [2]Lunar and Planetary Institute, Houston TX 77058 (cshearer@unm.edu); [3] ARES, NASA Johnson Space Center, Houston (JSC) TX 77058-3696, [4] Depart. of Earth and Planetary Sciences, Rutgers University, Piscataway NJ 08854, [5]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721; [6]United States Naval Research Laboratory, Washington DC 20375; [7]NASA Goddard Space Flight Center, Greenbelt, MD 20771; [8]Department of Astronomy, Mount Holyoke College, South Hadley MA 01075; [9]NASA Ames Research Center, Moffett, CA 94035; [10]SLAC National; Accelerator Laboratory, Menlo Park, CA 94025; [11]Space Sciences Laboratory, University of California, Berkeley, CA 94720; [12]the list of co-authors includes all members of the ANGSA Science Team (https://www.lpi.usra.edu/ANGSA /teams/); [13]the list of co-authors includes all members of the JSC lunar laboratory curation team that participated in the processing of these special lunar samples (https://www.lpi.usra.edu/ANGSA/teams/JSC/).

Introduction: The Apollo Program returned 381 kg of samples. Analyses of these samples have provided fundamental insights into the origin and history of the Earth-Moon system and how planets and even solar systems work. These samples have provided ground truth for every post-Apollo mission to the Moon for the interpretation of remotely sensed data. After 50 years of analysis and study, our sophistication for handling and examining samples has greatly increased. Some special samples that were collected or preserved in unique containers or environments, remain unexamined by standard or advanced analytical approaches. The Apollo Next Generation Sample Analysis (ANGSA) initiative was designed to examine a subset of these special samples. The ANGSA consortium consists of 9 original teams funded by NASA. The initiative was purposely designed to functions as a new sample return mission with processing, preliminary examination, and analyses utilizing new and improved technologies and recent mission observations. The ANGSA initiative links the first generation of lunar explorers (Apollo) with future explorers of the Moon (Artemis) [1-4]. The purpose of this abstract is to highlight the special samples, teams, science and engineering goals, and progress made so far. Related abstracts and talks will focus on the links between Apollo and Artemis, geologic context, and initial examination, processing, and results.

Apollo Program Special Samples: With great foresight, Apollo mission planners and sample scientists devised sample containment and preservation approaches that more rigorously attempted to capture delicate and potentially transitory characteristics of lunar samples that were disturbed or lost during standard sample collection, curation, and handling. The teams involved in the ANGSA initiative are examining three distinct types of special samples: (1) Apollo 17 (A-17) double drive tube, consisting of an unopened vacuum sealed core samples (Core Sample Vacuum Container; CSVC) and its unsealed but unstudied companion core, (2) Apollo samples that were placed in cold storage approximately 1 month after their return in the early 1970s, and (3) Apollo 15 Special Environmental Sample Container (SESC) samples opened in a helium cabinet and continuously stored in He.

In many cases, the purpose of samples placed in sealed containers was to protect characteristics that could be modified by interactions with spacecraft cabin conditions, the Earth's environment, or agitation of regolith samples [4]. A total of 9 containers of lunar samples were sealed on the lunar surface and transported to Earth during the Apollo Program. The SESC and CSVC have knife edge-indium seals. Current unopened samples include two CSVCs (69001 and 73001) and a SESC (15014). For the CSVC from both Apollo sites, drive tube cores were immediately placed in vacuum containers on the lunar surface. Upon return to the Lunar Receiving Lab each CSVC was placed in an additional vacuum container. The samples were stored in the Lunar Laboratory Pristine Sample Vault. Combined these three unopened samples contain 1.7 kg of unstudied and probably pristine lunar material. This exceeds the mass returned by all the robotic Soviet Luna missions and projected returned masses for many proposed lunar robotic missions. As such, each unopened sample should be treated as an individual lunar mission with science goals appropriate for their lunar environment.

Core sample 73001 and 73002 are one the targets for the ANGSA initiative. The double drive tube core penetrated a lunar landslide deposit in the Taurus-Littrow Valley. One of the Apollo goals for this double drive tube was to sample potential gases derived from the Lee-Lincoln scarp and trapped within the overlying landslide deposit. The total double drive tube core length is approximately 71 cm with 73001 representing the deeper part of the core. The temperature at the bottom of the core was approximately 250°K [5]. Sample 73001 was placed in a CSVC on the lunar surface and its upper companion core resided unexamined (until 11/2019) in a sealed aluminum double drive tube [4,6].

In addition to these sealed samples, the ANGSA initiative will examine Apollo samples that were handled and curated using non-standard approaches (e.g., frozen, Helium processing). Upon return, several A-17 sample splits for deep drill core 70001-70006, permanently shadowed soils (72320, 76240), soil (70180) and vesicular high-Ti basalt (71036) were permanently frozen at 253°K [4,6]. Samples from an Apollo 15 SESC (15012/13) were removed from the SESC and processed in an organic clean space under He atmosphere rather than nitrogen at the Univ. of California Berkeley. They have been continuously stored in He at JSC [6-8].

Teams: The ANGSA consortium consists of the 9 original teams funded by NASA and the JSC lunar curation team. The consortium consists of over 40 scientists and engineers. Consortium members are from NASA centers (e.g., JSC, GSFC), national labs (e.g., LLNL, USNRL), universities and colleges in the USA (e.g., WUStL, Mount Holyoke, UND), and international partners at universities (e.g., The Open University) and space agencies (ESA). As many of these special samples were collected during the A-17 mission, A-17 astronaut Harrison Schmitt is a member of this consortium.

Science and Engineering Goals: The ANGSA initiative has numerous investigations being pursued using the samples in the A-17 St-3 double drive tube, frozen samples, and He stored samples. Together, these samples leverage the uniqueness of sample containment (CSVC, SESC), geological setting (landslide, permanently shadowed areas), and curation-processing (frozen for over 47 years; organic clean lab, He curation).

Investigations of the volatile reservoirs and volatile cycles on the Moon: Over the last decade numerous studies and missions have pointed to a lunar volatile cycle with three principal components: primordial (interior) volatiles, surficially-formed volatiles, and polar (sequestered) volatiles. Lunar regolith contains evidence for these various volatile reservoirs, their origins, and their interactions. The CSVC may better preserve weakly bound volatiles and volatile coatings on mineral surfaces, and limited contamination of lunar H-species, Xe, Pb isotopes, and organics. The results of this integrated study of volatiles in lunar regolith and lithic clasts will shed light on (1) the concentration, distribution and behavior of volatiles in the lunar regolith; (2) the role of volatiles in lunar processes; (3) the interactions among lunar volatile reservoirs; (4) the potential existence of pre-mare degassing events [9]; (5) the noble and other gas composition of the solar wind as recorded on the Moon; (6) the indigenous noble gas content of the Moon; and (7) characteristics and origin of organic species in the lunar regolith.

Determine the stratigraphy and chronology of lunar landslide deposits to refine our understanding of lunar surface processes: Establishing a stratigraphy for the double drive tube provides an important context for other data collected from the core. Further, it defines (1) the regolith evolution processes active in the upper portion of a lunar landslide deposit; (2) important variables (e.g., temperature, volatiles) and their role in lunar landslide events; (3) triggers and chronology (e.g., impact events, activity along lunar scarps) for lunar landslide events; (4) dynamics of a lunar landslide deposit; (5) properties of the regolith that are important for the concentration and retention of lunar volatiles; and (6) identification of exotic South Massif components represented in the regolith.

Integrated and overarching evaluation of the collection and preservation of volatile-rich samples for future exploration: Future lunar missions will emphasize the definition of lunar volatile reservoirs and their in-situ resource utilization potential. In-situ analyses will provide information concerning undisturbed volatile reservoirs prior to sampling. For both in-situ measurements and sampling, methods should be designed that are cleaner and simpler than used for Apollo, and that disturb the soil less drastically. These samples represent our best chance to evaluate these approaches and to inform future missions on requirements for in-situ measurements. Furthermore, they will provide engineering guidance for the design of future containment, storage, and processing of lunar volatiles [1].

Progress: Themes in this session will focus upon the role of the ANGSA initiative in linking Apollo to future lunar missions, geological context for special samples, processing, curation, and preliminary examination of special samples, and initial results. As of the LPSC deadline (1) A-17 station 3 double drive tube sample 73002 has been selected for processing, examination and analysis. (2) Station 3 core was placed in geological context using surface investigations, orbital data from LRO, and landslide surface samples. (3) Core sample 73002 was imaged by μXCT. (4) The core was extruded from drive tube in dry nitrogen environment. (5) Samples were selected for organic and D/H analyses. (6) Processing and preliminary examination (PE) of core has started. This includes science PE team activities, μXCT imaging and classification of lithic fragments, and multi-spectral analysis of the core. (7) Initial organic and stable isotope analyses of the core were carried out. (8) A gas extraction system was designed for examining CSVC sample 73001. ANGSA initiative updates may be followed at https:/curator.jsc.nasa.gov/lunar/catalogs/specially_curated_samples.cfm and https: //www.lpi.usra.edu/ ANGSA/.

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