THE ANGSA PROGRAM: A LOW-COST LUNAR "SAMPLE RETURN MISSION". AN OVERVIEW AND PROGRESS OVER THE LAST 18 MONTHS. F.M. McCubbin[1], C.K. Shearer[2,3], J.J. Barnes[4], K. Burgess[5], B.A. Cohen[6], N. Curran[6], M.D. Dyar[7], J.E. Elsila[6], J. Gross[1,8], J.L. Mitchell[1], A. Sehlke[9], R.C. Walroth[10], K.C. Welten[11], R.A. Zeigler[1], and The ANGSA Science Team[12]. [1]ARES, NASA Johnson Space Center, Houston (JSC) TX 77058 (francis.m.mccubbin@nasa.gov), [2]Dept. of Earth and Planetary Science, Institute of Meteoritics, University of New Mexico, Albuquerque, New Mexico 87131; [3]Lunar and Planetary Institute, Houston TX 77058; [4]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721; [5]United States Naval Research Laboratory, Washington DC 20375; [6]NASA Goddard Space Flight Center, Greenbelt, MD 20771; [7]Department of Astronomy, Mount Holyoke College, South Hadley MA 01075; [8]Depart. of Earth and Planetary Sciences, Rutgers University, Piscataway NJ 08854; [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/), which includes members of the JSC curation team that participated in ANGSA (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) Program was designed to examine a subset of these special samples. The ANGSA consortium consists of 9 original teams funded by NASA that have combined into a single science team referred to as the ANGSA Science Team. The program was designed to function as the sample analysis portion of a sample return mission with processing, basic characterization, preliminary examination, and analyses utilizing new and improved technologies and recent mission observations. The ANGSA Program links the first generation of lunar explorers (Apollo) with future explorers of the Moon (Artemis). The purpose of this abstract is to highlight the ANGSA samples and progress made so far.

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 Program are examining two distinct types of samples: (1) Apollo 17 (A-17) double drive tube, consisting of an unopened vacuum sealed core sample (Core Sample Vacuum Container; CSVC 73001) and its unsealed but unstudied companion core 73002, (2) Apollo samples that were placed in cold storage approximately 1 month after their return in the early 1970s.

Core samples 73001 and 73002 constitute the double drive tube core that 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 [1]. 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 [2,3].

In addition to these sealed samples, the ANGSA Science Team will examine Apollo samples that were handled and curated at 253 K. 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 [2,3].

Teams: The ANGSA Science Team consists of the 9 original teams funded by NASA and the JSC lunar curation team. The team consists of 126 scientists and engineers. Members are from NASA centers, national labs, universities and colleges in the USA, and international partners at universities and space agencies. The team also consists of people over a broad range of career stages, including students and postdocs. As many of these special samples were collected during the A-17 mission, A-17 astronaut Harrison Schmitt is a member of the team.

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. The A-17 station 3 double drive tube sample 73002 was the first sample selected for processing as part of the ANGSA Program. Before opening the sample, we scanned the entire core using X-ray computed tomography (XCT). The XCT data provided valuable information on the number, types, sizes, and locations of clasts. Furthermore, we were able to get preliminary information on the petrology of the clasts, which is typically difficult through visual inspection because of pervasive dust coatings. We also used the XCT data to look for any variations in the distribution of clasts and fine-grained material throughout the core. This information was important for knowing what to expect during the processing of the core. For example, knowing the sizes of clasts and approximately where they are located allowed us to better plan when to extract clasts from the core during its dissection. After the XCT data were collected and processed, we opened and extracted the 73002 core and de-rinded the core. Given that some of the scientific investigations had a time-sensitive component, we allocated material shortly after core extrusion for organic and bulk D/H analyses because the former is highly susceptible to minor contamination and the latter may be affected by sitting in the core-processing glovebox, which has a continuous flow of dry gaseous N_2 with <10 ppm H_2O [4]. Furthermore, members of the Science Team set up a multi-spectral and hyperspectral imaging system that could sit outside of the core-processing glovebox and collect spectra along the length of the core as the core sat in the pristine glovebox environment [5]. The spectral and hyperspectral measurements were taken prior to core dissection but after de-rinding. Subsequently, we commenced with processing the first pass of the 73002 core. Every step of core processing was documented, and this process was conducted collaboratively between members of the curation office and outside scientists from the ANGSA Science Team (Fig. 1). Shortly after completion of processing the first dissection pass of core 73002, JSC went to a Stage 3 status due to the COVID-19 Pandemic, and sample processing activities ceased in about mid-March of 2020 and did not start again until November of 2020. We are currently processing the second pass of the core sample, and we have started to allocate samples from the first pass for scientific investigations. Given that JSC is not operating nominally, all sample processing has been done by members of the JSC Curation Office without the participation of outside science team members. For each of the clasts in the 4-10 mm and >10 mm size fractions, we are collecting dedicated XCT datasets to identify the petrologic type of the clast and provide contextual information for future subdivision of the clasts.

Figure 1. Pre-pandemic photographs of the basic characterization and core processing of sample 73002 in the Apollo core-processing glovebox room.

For the ANGSA samples that are stored cold, we have not started to process or allocate samples as of yet because we are in the process of setting up a cold curation glovebox in a -20 walk-in freezer that has been retrofitted to operate as a clean room. Sample processing under cold conditions reveals some unique challenges in materials performance and PPE [4, 6-7]. We were in the process of testing out cold-curation glovebox when JSC went to Stage 3 in March of 2020, and we were not able to make any progress towards setting up our cold-curation capability between mid-March and November of 2020. Now that JSC is at Stage 2 operations, we have continued with this activity following safe social distancing and mask protocols, and we expect to have a functioning cold-curation glovebox in early 2021 prior to the LPSC virtual meeting.

Planning continues for the opening of CSVC sample 73001. We do not plan to start processing this sample until after we complete the dissection of 73002, which should be early 2021. However, before we open 73001, we first need to extract any gas from the core. Furthermore, we will want to conduct XCT analysis of 73001 given how valuable that information was for the processing of 73002. The ANGSA Science Team is in the process of building a gas-manifold system and a piercing tool that will be used to extract gas from 73001. Substantial progress has been made in designing the gas-extraction system and the piercing device over the last year. Our goal is to extract the gas and collect XCT data on 73001 by the end of the 2021 Atlantic Hurricane season so we can begin core extrusion and processing without risk from hurricanes. This schedule is driven by the fact that we cannot move or disturb the core once it is opened, so we would not move the core to the water-tight lunar sample vault in the event of a strong storm. Our mitigation strategy would be to bag the core in Teflon and leave it in the core-processing cabinet, which we did for 73002 throughout much of the 2020 Atlantic Hurricane season.

Despite a global pandemic, the ANGSA program is making progress, and we look forward to seeing what exciting science results are gleaned from the Program. ANGSA 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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