RECOMMENDATIONS FOR REAL-TIME COORDINATION FOR ARTEMIS LUNAR SURFACE GEOPHYSICAL SCIENCE INVESTIGATIONS. E. R. Bell[1], N. C. Schmerr[1], B. F. Feist[2], J. A. Richardson[3], P. L. Whelley[3], and K. E. Young[4], [1]University of Maryland, Department of Geology, 8000 Regents Dr., College Park, MD 20742 ebell1@umd.edu; [2]Jacobs Technology, Inc; [3]University of Maryland, Astronomy Department; [4]NASA Goddard Spaceflight, Center

Apollo Missions Background: The Apollo lunar missions provided the initial, and currently only, opportunity and experience of astronauts executing field geophysical science studies on a planetary body other than the Earth. Apollo provided the first insights into the importance of how on-location astronauts plus terrestrial based scientists can combine to perform high-quality geophysical investigations of the lunar surface.

The Apollo missions had a diverse suite of geophysical science activities including active and passive seismic arrays, magnetic observations, gravimetric experiments, heat flow experiments, surface electrical properties experiment, radar sounding, and others. [1] Many of these were included as part of the Apollo Lunar Surface Experiments Packages (ALSEP) that were flown on Apollo 12 through Apollo 17. [2] These geophysical experiments helped to and continue to revolutionize our understanding of the structure of the lunar subsurface, the impact process, lunar seismicity, the space weathering environment, and test hypotheses for the formation and evolution of the Moon.

During the Apollo missions, a science backroom was staffed with scientists who were experts on the mission's scientific objectives. These scientists were responsible for supporting the EVA activities as a tactical team providing geologic analysis and interpretation to address crew questions and advised the crews in real-time on deviations from the planned timelines. [3] The communications from these scientists was routed from the science backroom to the Mission Operations Control Room (MOCR), and then through Capcom on to the crew on the lunar surface.

The Apollo mission science tasks consisted of two types of activities. First there were the package deployment of instrumentation such as the ALSEP. Deployments required the astronauts to assemble and position instrument packages that were then left on the surface. The second type were traverse based science investigations. [4] These traverses included both walking and later Lunar Rover Vehicle (LRV) excursions out from the Lunar Module (LM). During traverses, scientific instruments were used to make multiple measurements across a range of locations.

Pre-mission geologic training was given to the crew, Principal Investigators, Capcoms, Flight Directors, flight controllers, and other ground support personnel. Training for these science activities consisted of both weekly classroom activities and monthly field exercises. Training included simulating hardware deployment tasks. One significant aspect of pre-flight Apollo training was "paper sims" where science backroom personnel were exposed to and gained familiarity with hardware limitations, suit consumables limits, and the creation and execution of contingency plans for off-nominal situations. This training also promoted team building and trust between crew and ground colleagues. [5,6]

Geophysics for Artemis: Many of the same types of geophysical instruments deployed during the Apollo missions are anticipated to be included on Artemis missions, including seismometers, magnetometers, gravimeters, heat flow probes, electromagnetic sounding equipment, and others. [7] Fifty years of technology development will provide for the inclusion of advanced data collection capabilities such as increased memory, accuracy, resolution, and bandwidth for sensors. Additionally, engineering advances have resulted in mass reduction; increases in power capacity, data storage and transmission capacity; and thermal control, all of which provide for options to increase both quantities of instruments and environmental limits, as well as total data acquired.

Quantity of instrumentation and increased mission duration coupled with dedicated geophysical science traverses can provide for execution of specific deployment models: 1) single point locations, 2) transects, and 3) area surveys, based on the scientific problem in question. For these deployment models, geolocation requirements for specific instrument placement will vary, and surveys will range from tight grids to single lines.

It is important to note that some tasks will require dedicated crew time while others can be strategically merged into traverse/EVA activities timelines. Additionally, the real-time science backroom support requirements will vary depending on instrument or survey complexity and methods.

Benefits of Real-time Support of Artemis Geophysics Investigations: Real-time support of crew activities by MCC Science Backroom would ensure geophysical investigations' success and enhance science return by enabling: 1) optimal science instrument placement, 2) instrument deployment verification, and 3) coordinated data collection.

Science Instrument Placement: Refined instrument positioning results from the crew's on-location scientific assessments combined with MCC science backroom advisement and verification. This coordinated effort will reduce the need to repeat activities, or move instruments on subsequent EVAs.

Science Instrument Verification: Verifying instruments are collecting data is critical to perform as early as possible during instrument deployment. Real-time data transmission to Earth can allow the science backroom to perform this function, and work with crew to troubleshoot issues as necessary.

Data Collection Support: Data quality control is another important area of support from the Science Backroom. For example, for active seismic studies the science backroom can minimize the quantity of shots required to increase the signal-to-noise ratio. This support increases the science return of an investigation and the time efficiency of the activity.

Tactically, initial science backroom data analysis can enhance science outcomes and lead to serendipitous discoveries, provided timeline flexibility. Strategically, the science backroom can use results from initial geophysical analysis to modify future crew tasks (such as sample collection) to complement initial findings.

MCC to Crew Science Communication Coordination: For the Artemis missions it will be prudent to incorporate the best practices of MCC operations that are used for the International Space Station, where there is both a Capcom and a Payload Communications Manager, or PAYCOM. Capcom's role is primarily for communicating the operational and maintenance functions/activities of the station with the crew, while the PAYCOM, who is located with the ISS payloads operations center, manages communication for scientific investigations directly between the crew and researchers around the world. The variation of PAYCOM for Artemis missions would be to include a Science Communicator (SciCom) role to communicate with the crew on scientific activities. [6,8,9]

During EVAs the SciCom could communicate to the crew in one of two variants. The first variant would be for the SciCom to communicate with an IV (intra-vehicular) crewmember who would be performing what is termed IV duties for Shuttle and ISS EVAs. The IV crewmember receives updates and advisement from MCC regarding the EVA and then forwards these to the EVA crew at the appropriate time to unburden the them from the need to assimilate and modify their tasks while simultaneously performing them. The second SciCom variant would be to perform the IV role directly with the EVA crew on the lunar surface. Assuming electronic displays, procedures and messages may be able to be seamlessly updated from MCC to the crew.

Conclusions: We recommend that real-time geophysical science support and analysis are critical to ensure Artemis lunar surface investigation success and enhance investigation outcomes. This real-time support includes incorporating geophysical expertise into the MCC Science Backroom for instrument deployment, real-time data collection and analysis, and traverse and EVA stages of investigations.

We recommend uses of several best practices that can be drawn from both the Apollo lunar missions and the space shuttle and ISS mission operations. These will merge nicely with NASA spaceflight operations plan–train-fly functions, but are not inclusive of all needed steps to ensure completely smooth and efficient synchronization between Earth based science expertise and lunar surface crew operations.

First, we recommend continued geophysical and geologic Apollo style training including crew, scientist, flight controllers. Continue integrated sims to provide cross-training familiarization. Scientists learn hardware nominal ops, limitations, and contingency plan procedures and resulting timeline impacts, all within the time constrained pressure of human spaceflight operations. Additionally, the scientists learn the protocols and communication hierarchy within Mission Control, while flight control officers gain an understanding of the requirements to fulfill the scientific objectives of the mission.

Secondly, we recommend mission planners and geophysics investigators incorporate specific deployment modes (single point / permanent stations, transects, or area surveys) for geophysical instruments with other activities to optimize the mission timeline, but to also provide dedicated geophysical prioritized traverse/EVA times.

Finally, it is recommended to include the use of a SciCom position in MCC to communicate scientific information to the crew in a fashion similar to a modified PAYCOM position for ISS operations.

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