SURFACE OPERATIONS REAL-TIME REPLANNING DURING APOLLO 17: EXAMPLES OF RAPID DECISION MAKING AND IMPLICATIONS FOR ARTEMIS. N. E. Petro[1], H. H. Schmitt[2], and B. F. Feist[3]. [1]NASA Goddard Space Flight Center, Greenbelt, MD 20771, [2]University of Wisconsin-Madison, P.O. Box 90730, Albuquerque NM 87199, [3]Jacobs Technology, Inc.

Apollo Traverse Planning: Traverses for Apollo missions were planned so that for each sample station tasks were defined for each crewmember and a timeline was established [e.g., 1]. During the course of each Apollo mission, unanticipated discoveries and impacts to EVA timelines led to changes, commonly the deletion or re-prioritization of tasks at a station or, in one instance, the deletion of a station.

Examples of changes to Apollo 17s traverse plan, specifically changes to plans at Stations 1, 3, and 4 and the deletion of Station 10B are given. The role of the Science Support Room (SSR) in making and communicating its recommendations will be discussed as will the impact such changes had on the mission and what lessons might be applied for upcoming Artemis missions. Specific events during the Apollo 17 mission, reference the Ground Elapsed Time (GET) and provide a link to the "Apollo 17 In Real Time" website for that moment in context of the full mission.

In addition to the continued implementation of a simulation-based, monthly geological training regimen, a key part of that success was due to an experienced field geologist as a crew member. He provided critical insight into the planning and execution of the mission. A similar arrangement on Artemis will ensure a critical science perspective is applied to each aspect of the mission.

In modern NASA parlance the field geologist on the surface of the Moon would be a Science PI, implementing the science plan of the mission while in Mission Control, the lead scientist in the SSR would be a Project Scientist, working with the instrument teams and field geology support team to support the Science PI.

A key lesson from Apollo 17 is that clear, concise communication from the ground to the crew is critical to maximize crew time on the surface. Several examples described here where communication was not clear or contradictory, highlight the importance of extensive training between the SSR, CapCom, and crew [2] to minimize confusion.

Notable Revisions to Apollo 17s EVA Plans:

EVA-1, Station 1: The first traverse destination for the Apollo 17 crew was the northeast rim of Emory crater (Fig. 1). However, due to running about 35-40 minutes behind schedule during ALSEP deployment and to Commander Cernan's elevated oxygen consumption, there was not adequate time to fulfill Station 1 objectives at Emory crater (GET=121:12:02) a new plan was developed that shortened the total traverse time while maintaining the goal of characterizing subfloor material and collect materials of the dark mantle within the relatively young Crater Cluster [1]. Sample acquisition from the northern rim of Steno crater met the science goals of the station, while maintaining sufficient Portable Life Support System (PLSS) reserves. In total this revision had minimal impact to the science results from the mission.

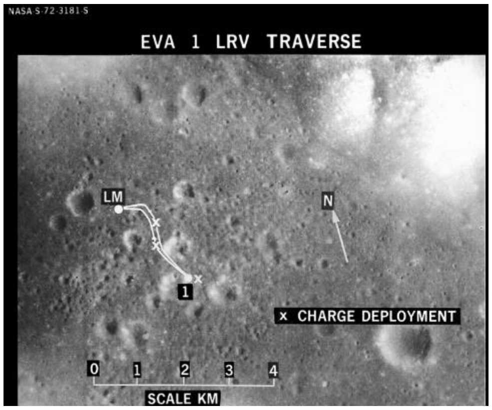

Figure 1. Planned route for Apollo 17's first traverse which was supposed to collect samples from the rim of Emory Crater [1].

EVA-2, Station 3: During Apollo 17's first EVA Commander Cernan broke the right rear fender from the LRV which led to additional dust to kick up onto the rover. This required a fix to the fender which was performed at the start of EVA 2. The extra time allocated to the fix the fender was removed from stops planned during the traverse, however the total time removed accounted for the slightly less time needed to drive from the LM to Station 2, as the LM landed further west than planned. Prior to EVA 2 it is was reported to the crew that adjustments to the plan at Stations 3 and 4 would accommodate the extra time (GET=138:23:32). At that time the crew was notified that the task at Station 3 to be removed was the LMP's trench sampling at the base of the Lee-Lincoln scarp, which in fact didn't shorten the time at Station 3 as that did not impact the plan for the CMD. The initial plan for Station 3 included multiple objectives for the LMP, including documented sampling of the light mantle and a rake sample, and a trench at the face and base of the scarp [3], this was changed upon arrival to Station 3 where the LMP should perform "solo sampling" (GET=144:29:22), which was not a normal part of the crew training [4].

During sampling at Station 3 the major impact of the plan revision is that the LMP had to collect and bag samples on his own, which was inefficient at first [5]. In the post-mission evaluation, the LMP reported that it was unclear, following the mission, how much of an impact that change had overall, as the samples collected now support the ongoing examination of core sample 73001/2 [6]. Despite this, it is clear that changes to operations should be evaluated on overall impact to sample collection and overall efficiency.

EVA-2, Station 4: The discovery of orange soil at Station 4 in the rim of Shorty Crater introduced a different impact to the traverse plan. Unlike other issues where science might have been removed from the plan, the orange soil discovery forced the plan to be revised to accommodate unexpected science. No less than 30 seconds after the discovery of the soil was made the LMP reports "I've got to dig a trench Houston." which served as an alert to the SSR that whatever plan had been in place would be revised on the spot. With the objective of not wasting precious EVA time, Schmitt began the trenching task without waiting for consensus from the SSR. Immediately after that comment the CapCom reported "I guess we'd better work fast." Approximately 3 minutes after the discovery, the LMP reported (GET=145:29:59) "Hey, I think we hit one of those things we've got to reconsider on, Houston." Suggesting that the rest of the EVA (which included Station 5 at Camelot crater) be re-evaluated. The crew was informed that the conservative PLSS "walkback" requirements did not allow for much flexibility with the timeline. Roughly 10 minutes after the discovery, the crew was asked to take a double-core sample (GET=145:36:18). In the meantime, the crew had proceeded to sample and document the orange deposit.

The orange soil at Station 4 had been a surprise (later found to be extremely fine-grained volcanic ash), and a major discovery and the possibility of returning to Shorty Crater on EVA-3 to continue sampling was seriously discussed in the Science Backroom, In addition to the major objective of sampling boulders at the base of the North Massif, Station 9 at Van Serg Crater was thought to be a possible twin to Shorty and home to similar material, and the complete revising of a traverse was not implemented. In this event, the entirety of the EVA plan was well-formulated by the ground team and crew, and a major revision to the plan would not have likely added scientific value in light of the major discoveries made during EVA-3 and the high efficiency of sampling at Shorty Crater.

EVA-3, Station 10B: Despite the major science discoveries at each station during the Apollo 17 traverses, one station was entirely removed due to time constraints. Initially planned to sample boulders on the rim of Sherlock crater (Figure 2) and provide a comparison sample to Stations 1 and 5. This stations removal was done with little discussion during the EVA (GET=168:36:16). The deletion of Station 10B also opened the possibility of obtaining a double core tube at Station 9, which was added. When this was communicated to the crew the LMP commented that the ejecta blanket may be too rocky for such a core, and that they would waste time in obtaining the sample ("Well, I don't like to try things that there is a probability of failure on - if you can - You're just going to lose some time." And later "Well, you're not even - okay. Not even going to debate the issue."). Ultimately the double core was collected, and the crew completed the tasks at Station 9 with little time to spare.

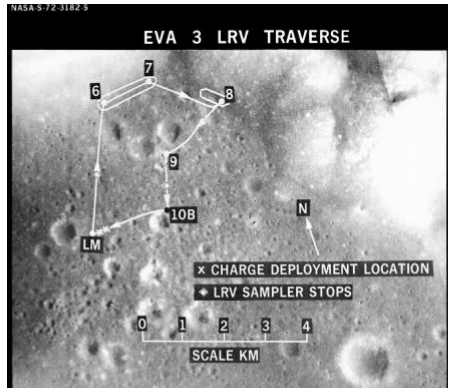

Figure 2. Planned traverse route for EVA-3, including a stop (10B) at Sherlock crater.

Lessons-Learned and Implications for Artemis: The Apollo 17 mission highlighted the importance of having an experienced field geologist as part of the crew, who was part of the planning process, and who helped establish the goals and objectives for each sample site. As changes to the traverse are needed, Apollo 17 shows that having crew input seriously considered is important.

What is also key is having the opportunity for the crew to communicate indirectly with scientists in mission control, as has been done directly during Shuttle experiments [7]. During Apollo communication between the science back room and the crew was done in short briefs, through the CapCom, between EVAs (GET=138:20:07). These discussions often were edited and not as direct as might occur during a conversation of like-minded geologists [4]. Time at the end of an EVA and prior to an EVA to review what was learned, discuss any impacts to the upcoming EVA, and discuss possible changes, *with crew input*, will result in an optimization of crew time and science return and feed forward to Mars exploration.

References: [1] MSC, (1972) Apollo 17 Traverse Planning Data. [2] Schmitt, H. H., et al., (2020) Lessons Learned for Artemis from Science Back Room Support of the Apollo Missions. [3] Bland, D. A., et al., (1972) Apollo 17 Final Lunar Surface Procedures I: Nominal Plans. [4] Schmitt, H. H., (2020) *Diary of the Twelfth Man*. [5] MSC, (1973) Apollo 17 Technical Crew Debriefing. [6] Schmitt, H. H., (2020) Geologic Context of ANGSA Apollo 17 Double Drive Tube Core 73001/2, 1121. [7] Shayler, D. and C. Burgess, (2007) *NASA's Scientist Astronauts.*