JETT3: DYNAMIC SCIENCE PRIORITIZATION IN A HIGH-FIDELITY LUNAR ANALOG MISSION.
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Introduction: Prioritization of observations and stations is a crucial step in maximizing science return from remote geologic science (i.e., in situ spacecraft missions). Priorities can be deceptively quantitative, however, as science prioritization is arrived at qualitatively and is highly subject to discovery-driven change. Science prioritization for human-enabled lunar exploration operates within even more challenging strategic and tactical decision space, with crewed missions requiring a different approach than the robotic missions of the past decades. The Joint EVA Test Team 3 (JETT3) field campaign was the highest-fidelity lunar analog conducted to date in support of the Artemis missions and allowed us to evaluate science prioritization within a dynamic exploration environment [1].

Pre-mission planning: The JETT3 Science Team, composed of members who would be positioned in the field with the crew as well as those stationed in the Science Evaluation Room (SER – roughly equivalent to the Apollo science backroom) during the mission, developed a Science Traceability Matrix (STM) based on four motivating science goal themes: volcanology, surface processes, tectonics, and age relationships [2]. Each of these themes included 3-5 objectives; objectives were not ranked within their goals, nor across goals. Sub-teams within the Science Team used these objectives to identify target field sites within the designated field area and ranked the value of each proposed site based on how well it supported the data and observational needs of their science goal. Based on these rankings and spatial clustering of proposed locations, a final suite of science stations was selected for distribution across four EVAs (see Fig. 1 in [1]). Station priority value was calculated as an average of the priority rankings (four-point scale) from each of the science goals. While some objectives were easily mapped to specific science stations (e.g., compositional similarities/differences connected to sample collection at all four massifs and the surrounding planar units; see Table 1 in [2]) others were more generalized due to the lack of specific features visible with the restricted resolution of orbital data [e.g., 3]. These relied on opportunistic observations of relevant features that were below the resolution available in pre-mission planning (e.g., evidence of tectonic events; see Table 1 in [2]).

Field campaign execution: Each deviation from the original plan had cascading effects on science priorities that rippled through all four EVAs. For example, early in the first EVA, it became clear that the original distances and slope angle limits given to the Science Team to define their traverse plans were too optimistic, requiring the team to redesign traverse plans [1,2]. This resulted in the loss of some of the highest priority stations from the original traverse plan on short notice; this loss required an immediate reassessment of all remaining stations, as well as station priorities in each subsequent EVA, as the SER assessed how they could retain key science goals with alternate stations. The reduction in EVA traverse lengths also caused the loss of key tectonics targets (e.g., Station M15, [2]), while re-routing reduced access to topographic "handrails" to guide astronauts to low-relief sites relevant to surface processes. EVA1 required on-the-fly redesign based on the evolving feedback from the astronaut team; subsequent EVAs had the benefit of additional lead times to facilitate SER discussion of re-prioritization. We utilize some of these examples below, in discussing how the SER reprioritized sites.

Tension points driving re-prioritization:

Distance. Given the driving cause of science reprioritization, the first guiding condition was the distance from the lander to a given station. While the SER could have elected to keep a distal science station by sacrificing several more proximal stations, this was never actually done. Two of the three highest pre-mission priority stations were lost from EVA1 due to communications and distance problems and were not considered available for future re-plans; had one or both high-priority stations been deemed potentially accessible, it is possible that the SER may have chosen it over several closer, lower-priority stations.

Pre-mission priority values. Official science station priority values were not recalculated during the mission to reflect evolving scientific or operational knowledge. As such, these values were only given limited consideration when replanning EVA traverses. Further, the use of pre-mission station priority values was complicated by how they were calculated; an averaged priority value of 2.5 could either indicate middling value to all goals or a split between very high and very low value between the science sub-team goals. This highlights the difficulty the SER had in translating qualitative, discovery-driven science priorities into quantitative priority numbers whose meaning diminished rapidly as the field campaign progressed.

Weighting goals. While all four science goals were formally given equal weight in terms of priority calculation and SER representation, the team defaulted to prioritizing volcanology and surface processes over tectonics and age relationships. This may have been influenced by the nature of the backgrounds of the SER team members, but we interpret that the most significant driver of this unofficial prioritization is related to the ability of the team to identify clearly relevant science stations in the pre-mission imagery for volcanology and surface processes, along with EVA1 observations. While targets for tectonics and age relationships aimed for topographic features such as steps, ridges, and grooves, surficial "regolith" frequently obscured potential observations of contacts or offsets. As such, the SER re-prioritization process emphasized collecting samples from the various massifs and planar units and investigating differences between light and dark surficial deposits; most tectonic or age relationship observations were made in the process of pursuing volcanic/surface process targets. Both proximity and volcanology were central motivators for the SER to redesign EVA4 to include station M25, a location that had previously been cut from EVA2 due to time limitations but provided the best remaining opportunity to sample from a step in a planar unit that could have been the result of either a lava flow terminus or a tectonic feature.

Back-up plans. Whenever possible, the revised plans from the SER included a series of continually iterated backup alternatives designed to maximize data collection while minimizing decision time during an EVA. Backup plans were generally triggered by getting ahead of the intended schedule, either by completing EVA tasks early or by losing a station or task to inaccessibility/time/distance. The final station of EVA4 was M25, described above as a strategic return to a station cut from EVA2 due to time; M25 was only achievable in EVA4 due to time savings earlier in the traverse, including the elimination of the most distal station during re-prioritization. Other EVAs included a final "get-ahead" station at the lander return location (M6); this station was never actually studied, as (a) planned and unplanned disruptions generally prevented the astronaut team from completing the entire traverse circuit within an EVA, and (b) the SER consistently placed higher priority on other science stations.

Recommendations: Overall, the combination of the profound changes required in EVA traverse plans and the limited time available to the SER to implement such changes resulted in the team working from a largely reactive position. While these challenges are consistent with the types of issues that may arise for the actual Artemis 3 SER, changes to the prioritization system could have enabled the team to conduct strategic replanning focused more on science objectives.

First, the inclusion of 16 distinct science objectives in the STM, each nominally the same priority as the others, created complications. While preemptively abandoning viable science objectives is not a viable choice, real-time re-prioritization would have been better supported by collectively identifying 2-3 primary objectives intended to drive major traverse planning decisions and relegating the remaining objectives to secondary and tertiary positions. While this was inadvertently and partially accomplished by the preference for volcanic and surface process objectives, ten competing objectives remained. Choosing a small number of high-priority objectives, and formally prioritizing them would have allowed the team to evaluate various science stations and revised plans more clearly in terms of their likelihood to enable the completion of those objectives. If operational limitations (such as we encountered in EVA1) or novel discoveries in the field occurred during an EVA, the SER might have been able to reevaluate the feasibility and relative importance of the prioritized objectives, possibly downgrading objectives compromised by inaccessible or ambiguous observations or upgrading objectives based on exciting discoveries.

While the JETT3 Science Team maintained excellent collaboration and cooperation to balance various interests during re-planning, much of the reevaluation was based on internal conversations that were difficult to adequately explain to non-SER team members, including crew, when decisions appeared to deviate from the pre-mission prioritization. Given the need for a quantitative system of prioritization to support crew and engineering requirements, a priority-tiered suite of objectives would have enabled greater clarity across the larger JETT-3 team. Additionally, a daily update on any revisions based on unfolding mission achievements and discoveries would have allowed greater cross-team understanding of the science rationale behind evolving priorities.

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References: [1] Caswell T.E. et al. (2023) *LPSC 54*. [2] Fagan, A.L. et al. (2023) *LPSC 54.* [3] Richardson J.A. et al. (2023) *LPSC 54.*