FIELD-BASED OBSERVATIONS OF CREW ACTIONS DURING SIMULATED ARTEMIS LUNAR EXPLORATION: FINDINGS AND RECOMMENDATIONS. L. A. Edgar[1], J. A. Skinner[1], K. E. Young[2], C. N. Achilles[2], E. R. Bell[3,2], A. W. Britton[4,5], Z. M. Cardman[4], B. A. Cohen[2], A. L. Fagan[6], A. J. Feustel[4], A. H. Garcia[4,5], W. B. Garry[2], T. G. Graff[4,5], J. M. Hurtado[7], S. Jacob[8], J. A. Richardson[2], M. J. Miller[4,5], S. K. Nawotniak[9], C. M. Trainor[4,5], A. R. Yingst[10], T. E. Caswell[5,11], D. Coan[5,12], I. Theriot[5], B. H. Scheib[5,11], C. L. Kostak[5,11], J. Lindsey[5,12], D. Welsh[5,11], Z. Tejral[4,5]. [1]USGS Astrogeology Science Center, Flagstaff, AZ (ledgar@usgs.gov); [2]NASA GSFC; [3]UMCP, College Park, MD; [4]NASA JSC, Houston, TX; [5]Jacobs, Houston, TX; [6]WCU, Cullowhee, NC; [7]UTEP, El Paso, TX; [8]ASU, Tempe AZ; [9]ISU, Pocatello, ID; [10]PSI, Tucson, AZ; [11]KBR Wyle, Houston, TX; [12]Aerospace Corp., Houston, TX.

Introduction: In 2022 NASA conducted the Joint Extravehicular Activity (EVA) & Human Surface Mobility Test Team 3 (JETT3) operations test, which represented the first Artemis simulation involving a full science team contributing to training, mission preparation, generation of operational products, and participation in the simulation [1,2]. From May to September, the full science team worked together to prepare for the simulation. The field analog test occurred in October near SP Mountain in northern Arizona. While the majority of the science team participated in the Science Evaluation Room (SER) in Houston, several science team members participated in the field to shadow crew on EVAs and provide science ground-truth for their observations. Lessons learned from the SER are provided by [3-7]. Here, we report on the field-based observations of crew actions as they were informed by remote-based science observers and offer findings and recommendations to shape future analog tests and Artemis geology investigations.

JETT3 Field Analog Simulation: The JETT3 field test took place in a 2-km radius area located immediately east of SP Mountain in the San Francisco Volcanic Field. The region was selected based on a variety of geologic units and terrain types, as well as logistical ease of access and precursor data. The simulation consisted of two crew members (EV1 and EV2) participating in 4 EVAs: planned as 2 four-hour EVAs and 2 six-hour EVAs, using both EXCON mockup spacesuits and backpacks [2], to test the concept of operations, including some simulated suited mobility restrictions. To best approximate the lighting conditions expected at the lunar south pole, the field tests occurred at night, with a portable spotlight from a near constant eastward direction to simulate low lighting conditions. The crew continuously used helmet-mounted and variably used waist-mounted and easel-mounted lights to illuminate their local area.

Role of Science Field Support Personnel: Two science team members were assigned to shadow the crew on EVAs and ground-truth their observations at each station. Prior to the simulation, Science Field personnel were involved in orbital geologic mapping [8-9], station identification and traverse planning, creating the science traceability matrix (STM) [4, 7], and participating in the SER dry run and crew training, so they were familiar with the science objectives and intent for each EVA. Science Field personnel also conducted field-based geologic mapping and sampling prior to the simulation to generate an "answer key" for comparison to crew observations.

During the October 2022 field test, Science Field personnel were assigned to shadow EV1 or EV2 and observe their actions, descriptions, and interpretations. When the crew would move on from a station, Science Field personnel would quickly go to the work site to verify observations and note deviations, using both crew descriptions and the guidance the crew received from Houston to evaluate the science outcome, including samples collected. The field team did not communicate with the crew or the SER during the test.

Findings and Recommendations: A complete list of science findings and recommendations are provided in the JETT3 Final Science Report [1], but here we focus on a subset of Science Team recommendations (REC) for future field tests and relevance to Artemis operations.

FINDING**:** Illumination provided by helmet lights (and waist/easel lights when used) produced a "cone of light" that was sufficient for identifying rock texture and mineralogy in outcrop and hand samples but tended to focus observations exclusively within the immediate environment. REC**:** Crew should be trained to be aware of the tendency to focus on their immediate environment and be reminded to observe and orient themselves with features on the horizon beyond their "cone of light".

FINDING**:** The geologic maps produced for this simulation did not effectively demonstrate the location of outcrop versus regolith, and basemaps used color stretched products which suggested greater variability in color and tone than actually observed in the field. REC**:** Mission-supportive geologic maps should identify outcrop locations and inferred regolith thickness and should use unstretched, true color base images. REC: After an EVA (or during space-to-ground tag-ups prior to subsequent EVAs), crew and science representatives in Houston should review expected tones, textures, and other outcrop characteristics and extrapolate to other areas of the geologic map to estimate regolith and outcrop character.

FINDING**:** Crew fatigue led to reduced crew movement around outcrops and missed observations of mineralogy and texture, which undercut the science return related to geologic variability and history. REC: The Science Team should adjust expectations for what suited crew may be able to accomplish during field tests and lunar surface activities. REC**:** Encourage acquisition of field photos to help offset fatigue and provide break opportunities while accumulating science observations.

FINDING**:** Estimates of location, direction, and distance were challenging for crew [8]. REC**:** Advocate for a crew navigation/tracking system to be included in future Artemis missions. REC**:** Include orienteering in the training portfolio and couple it with data-centric training in AV/VR and/or 3-D fly-overs of exploration sites to impart familiarity with the traverse. REC**:** Emphasize that the subtle shape of a landscape is helpful for determining and reporting location. REC**:** Sustain the calibration of crew pace counts before each EVA to enable distance estimates.

FINDING**:** Crew used samples collected from different areas to compare each other's findings (samples were already in bags) to synthesize their notes and descriptions. REC**:** Sustain access to samples during and after EVAs for improved science synthesis.

FINDING**:** Crew naturally balanced workload and maximized their time on EVA without prescribed roles, e.g., while one EV was sampling the other was continuously describing their observations. REC**:** Sustain flexibility in sampling and documentation roles.

FINDING**:** It was unclear to the science team when the crew was giving site description versus sample marker description. REC**:** Remind crew to more clearly define what is being described. REC**:** Develop a common language among the crew and science team prior to the mission.

FINDING**:** Crew cannot capture observations in a way that is easy for them to quickly access, so they must rely on recall. Because the crew cannot take and refer to notes, they found it difficult to know if they obtained a full station description. REC**:** Make clear to participants that crew is trying to augment and refine geologic context based on verbal descriptions. It is hard for them to comprehensively view or assess accumulated observations. REC**:** Ensure Capcom/ESO communicates to crew when full descriptions are provided at each station.

FINDING**:** On approach to a station, the crew was verbally reminded of the intended tasks (e.g., acquire a chip sample of lava flow), but the crew indicated that they also needed a reminder of the science objectives (e.g., test if this lava flow is the same as previously observed). REC**:** Refer to the geologic map, STM, and list of outstanding science questions in the Execute Package prior to each EVA. REC**:** Verbally remind crew of science objectives and hypotheses while traversing to a station.

Observed Science Benefits from having "boots on the ground": Despite the challenges of working in a physically demanding environment and under difficult lighting conditions, the crew was able to accomplish numerous science tasks and make unique observations that enabled a greater understanding of the geologic history of the field site than previously recognized through the use of pre-mission orbital data. As a result of having astronaut field geologists in the AZ test site, the following was accomplished:

1) Crew discovered and documented a new geologic unit in multiple locations that was not identified from orbital geologic mapping. 2) Crew refined age relationships that could not previously be determined from orbital data alone. 3) Crew tested and confirmed a hypothesis developed by orbital geologic mapping related to lava flow emplacement. 4) Crew identified the main mineralogy of five distinct volcanic units and described a variety of geologic processes. 5) Crew recognized a greater exposure of lava flow than previously mapped. 6) Crew discovered a brecciated flow front that was not known from orbital mapping that provides a more complete understanding of volcanic processes.

The science gained from the JETT3 test is encouraging for future Artemis missions. The unique perspective gained by having science team members in the field is critical for understanding the full range of science takeaways during field tests, and it is recommended that future mission simulations include support for both SER and field team participation. The recommendations provided here based on field observations are intended to help shape future analog tests and to maximize the science returned from human exploration of the lunar surface.

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