THE INTEGRATION OF SCIENCE INTO ARTEMIS SURFACE MISSION PLANNING: LESSONS LEARNED FROM THE JETT3 ARTEMIS MISSION SIMULATION. K. E. Young[1], A. H. Garcia[2,3], C. N. Achilles[1], E. R. Bell[4,1], A. W. Britton[2,3], B. A. Cohen[1], L. A. Edgar[5], A. L. Fagan[6], W. B. Garry[1], T. G. Graff[2,3], J. M. Hurtado[7], S. R. Jacob[8], J. A. Richardson[1], M. J. Miller[2,3], S. E. Kobs Nawotniak[9], J. Skinner[5], C. M. Trainor[2,3], A. R. Yingst[10], T. E. Caswell[3,11], D. Coan[3,12], I. Theriot[3], B. H. Scheib[3,11], C. L. Kostak[3,11], J. Lindsey[3,12], L. D. Welsh[3,11], Z. Tejral[2,3]. [1]NASA GSFC, Greenbelt, MD (kelsey.e.young@nasa.gov); [2]NASA JSC, Houston, TX; [3]Jacobs, Houston, TX; [4]UMCP, College Park, MD; [5]USGS Astrogeology, Flagstaff, AZ; [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: Although we have decades of experience conducting extravehicular activities (EVAs) with both the Space Shuttle and International Space Station (ISS) programs, our only experience conducting scientifically-motivated, discovery-based EVAs was with the six Apollo lunar surface missions (1969-1972). In Apollo, science was embedded in several key areas and phases of each mission, including science training of astronauts and mission support personnel [1], landing site characterization and traverse planning, and real-time EVA execution in a science backroom. Artemis missions will once again include astronauts conducting science-driven EVAs, and thus it is critical that we leverage lessons learned from Apollo, Shuttle, ISS, and analog mission experience to design a structure for integrating science throughout Artemis missions. This work is already well underway for Artemis [2], and science will be tightly integrated across both mission preparation and real-time mission and EVA execution.

Artemis Science Team Integration: Discussed in detail in [2], each Artemis surface mission will be supported by the Artemis Science Team (AST). This team will assist the EVA Flight Control Team (FCT) with mission and traverse planning and support real-time operations from the Science Evaluation Room (SER) [2]. The EVA Science Officer (ESO) will be the senior science officer in Mission Control, and they will work closely with the EVA Officer and with two other primary EVA console positions: EVA Task, who tracks crew timeline, activities, tool use, etc.; and EVA Systems, who tracks the health and performance of the space suit. This submission details recent experience in the pre-mission phase of science integration based on lessons learned from recent analog testing.

The JETT3 Artemis Mission Simulation: As discussed in detail in [3], the JETT3 (Joint EVA & Human Surface Mobility Test Team 3) mission simulation, conducted in Oct. 2022, was the most complete Artemis EVA mission simulation to date. Two crewmembers conducted four EVAs in five days, supported by a full EVA Flight Control Team (FCT), including a JETT3 Science Team (JST) [2]. The JETT3 mission was designed to mimic the Artemis 3 mission as closely as possible, including the EVA constraints and the integration of the science team into the EVA FCT [2], both in the mission preparation and real-time execution phases. This abstract focuses on lessons learned from the pre-mission phase, during which science questions and priorities were generated to feed EVA traverse planning and the generation of operations products to support real-time execution.

Overview of Pre-Mission Science and Planning Workflow: The JETT3 pre-mission workflow was designed to mimic current expectations for Artemis surface mission workflow, although the JETT3 team had only approximately six months to complete this work, whereas future Artemis teams are anticipated to have more time for some of these steps. The workflow and order of operations, however, are consistent with Artemis expectations, and are detailed below and summarized with the following: (1) Science Team Onboarding; (2) Exploration Area Orientation and Discussion; (3) Geologic Mapping; (4) Science Question Definition; (5) Station Definition (6) Traverse Definition and (7) Operations Products Development.

Pre-Mission Science Workflow: Following Science Team selection and **Onboarding** (including team introductions, orientation to test objectives, schedule, FCT and console training, etc.), the JST was introduced to the selected landing site for the analog mission, a 2-km radius area adjacent to SP Mountain north of Flagstaff, AZ (Fig. 1).

The **Exploration Area Orientation and Discussion** phase included group observations and discussions of the site using imagery of the location (at resolutions consistent with Artemis expectations), as well as early discussions of possible science hypotheses and objectives.

Next, the **Geologic Mapping** phase was led by a smaller subset of the JST, though mapping progress was frequently briefed to and discussed with the JST. This mapping took place at two scales (1:20,000 and 1:4,000), with the mapping team working offline from JST meetings [4]. Though most mapping would ideally be completed before subsequent phases, our limited time for this analog exercise meant that the more detailed mapping was completed concurrently with subsequent phases.

The **Science Question Definition** phase followed, in which the JST subdivided into four primary science theme areas (Volcanics, Surface Processes, Tectonics, and Age Relationships). These four subteams worked separately to develop science objectives, after which the entire JST reconvened to create the JETT3 Science Traceability Matrix (STM). This STM included Science Goals, Science Objectives, and requested Crew Actions to address these objectives (i.e., samples, field observations, images) [5,6,7]. Eventually, the STM was updated to include EVA Station #'s at which each objective would be addressed. This STM served as a key deliverable for both mission preparation and execution as well as JETT3 team and crew science training.

The final science mission planning phase was **Station Definition**. Here, the four subteams again divided to work on preferred stations within the exploration area to address each subteam's science objectives. All four subteams then worked together to create a Merged Station list to best reflect all science objectives. The deliverables here included a map of merged stations with priorities (Fig. 1, based on the merging of each subteam's priorities) and a spreadsheet that included metadata for each merged station (requested crew activity, estimated time hack, science hypotheses for observations, etc.). These two deliverables were critical for the next phase of pre-mission planning, where EVA traverses were drafted.

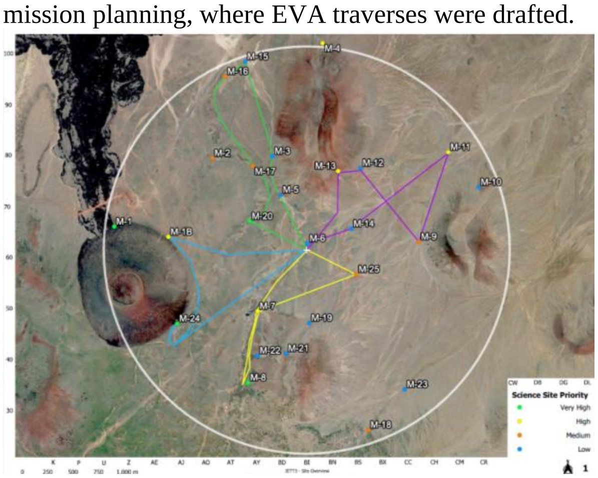

Figure 1: Traverse map of planned JETT3 traverses. The color of the station icon indicates science priority.

Traverse Definition: The mission Tasks and ESOs led the traverse definition phase, wherein the science stations were shaped into four EVAs. It should be noted that JETT3 did not include any EVA objectives besides science objectives, so this phase would include additional, non-science objectives for future Artemis missions. The traversable distances and times were determined by the JETT3 test team to balance Artemis 3 expectations with other test objectives and hardware [3]. Initial traverses were developed that maximized the requested, prioritized Science Team stations and balanced other mission parameters (i.e., time for each EVA, estimated traverse speed). Traverse definition was done using the Artemis EVA Geographic Information System (AEGIS), a lunar surface EVA planning tool that blends geospatial map data with mission parameters [8].

Following the development of the initial traverses the Tasks and ESOs iterated several times with the JST about several questions and trades that arose during the traverse planning process. This phase was more abbreviated than what is expected for Artemis due to the limited time available for the analog exercise. Artemis traverse planning development is anticipated to include multiple iterations with not only the Science Team but also mission management teams, EVA Officers and other FCT personnel, astronaut fcrew, etc. Nevertheless, this abbreviated iteration phase was useful in refining JETT3 traverses, despite the limited time.

Operations Products Development: Following traverse definition and iteration with both the JST and other members of the FCT, the traverse plans and associated information (imagery, maps and other scientific data products, procedures, troubleshooting reminders, etc.) were incorporated into operations products that the crew could access real-time during an EVA. These included a cuff checklist (worn on each astronaut's wrist) and a Map Book (8.5x11" book with imagery of the site and each traverse as well as derived science products). These ops products were critical real-time resources for the crew to recall traverse details and science priorities. Future work will evaluate and test ideal content in each EVA ops product.

Conclusions: Integrating science priorities and objectives into pre-mission planning (in addition to real-time operations) is critical in accomplishing high-priority science objectives with Artemis missions. The JETT3 mission simulation offered us vital experience in developing the workflow that Artemis Science Teams will use to define science objectives, priorities, and key deliverables to incorporate science into mission planning. More work is needed to further refine this workflow and necessary science team deliverables, as well as to continue to define the ESO/Task workflow as well as integration with the rest of the EVA FCT.

Acknowledgments: The authors thank the entire JETT3 team, which included 100+ engineers, flight controllers, astronauts, scientists, and more.

References: [1] Phinney et al. (2015) NASA/SP-2015-626. [2] Young et al. (2023) LPSC 54. [3] Caswell et al. (2023) LPSC 54. [4] Skinner et al. (2023) LPSC 54. [5] Fagan et al. (2023) LPSC 54. [6] Kobs Nawotniak et al. (2023) LPSC 54. [7] Jacob et al. (2023) LPSC 54. [8] Miller et al. (2023) LPSC 54.