ARTEMIS SCIENCE PLANNING AND INTEGRATION: OVERVIEW AND LESSONS LEARNED FROM THE JETT5 MISSION SIMULATION. L. A. Edgar[1], K. E. Young[2], C. N. Achilles[2], M. Banks[2], M. Borel[3,2], J. Broddrick[4], B. Cohen[2], B. W. Denevi[5], A. N. Deutsch[6,4], C. Evans[7], R. Ewing[7], A. Garcia[8,7], W. B. Garry[2], T. J. Graff[8,7], J. Gross[7], M. Henderson[3,2], A. Huff[9], J. Hurtado[10], S. Jacob[8,7], N. Lanza[11], Z. Morse[12,2], A. Needham[2], D. Needham[13], K. Prissel[14], J. Richardson[2], S. Schmidt[8,7], J. Skinner[1], A. Slabic[8,7], C. Trainor[15,12], A. Turner[16,2], S. Valencia[17,2], C. Weitz[18], [1]USGS Astrogeology Science Center, (ledgar@usgs.gov), [2]NASA GSFC, [3]University of Maryland Baltimore County, [4]NASA ARC, [5]Johns Hopkins University Applied Physics Laboratory, [6]Bay Area Environmental Research Institute, [7]NASA JSC, [8]Amentum, [9]Arizona State University, [10]University of Texas at El Paso, [11]Los Alamos National Laboratory, [12]Howard University, [13]NASA Headquarters, [14]Purdue University, [15]The Aerospace Corporation, [16]ADNET, [17]University of Maryland College Park, [18]Planetary Science Institute

Introduction: Analog mission simulations provide essential testing and training opportunities in preparation for NASA's return to the Moon through the Artemis program. Artemis astronauts will conduct science-driven extravehicular activities (EVAs) on the lunar surface, requiring science integration through pre-mission planning, mission execution, and post-mission analysis. Analog operations tests are an important way to prepare for many components of lunar surface activities. Herein we focus on the planning, integration, and science operations relevant for Artemis III.

In May 2024, the Joint EVA and Human Surface Mobility Test Team (JETT) conducted the fifth test in a series of analog missions, known as JETT5. The test consisted of two astronauts in the field at a lunar analog site near Flagstaff, AZ, supported by a Flight Control Team (FCT) in Houston, TX. Similar to JETT3 (October 2022) [1-9], the JETT5 test involved a NASA Science Mission Directorate (SMD) team working with the FCT to plan and execute a series of simulated lunar EVAs. Below we report on the science test objectives, mission planning workflow, and science operations.

Test Overview: JETT5 was the highest fidelity Artemis III EVA mission simulation conducted to date. Two crew members (astronauts Kate Rubins and Andre Douglas) conducted four EVAs over a five-day simulated mission (Fig. 1a). The analog field site was located in the San Francisco Volcanic Field, north of Flagstaff, AZ. The team planned for both a prime and a backup landing site, and each site was limited to a 2-km-radius traverse area. The simulation involved variable EVA conditions (time of day, EVA duration, suit type, video restrictions, real-time image availability) to meet different test objectives. The majority of the ~30-person science team supported the test from the Science Evaluation Room (SER) in Houston, split between two daily operational shifts (Execute and Planning). A few science team members supported the field test in Flagstaff, shadowing the crew during EVAs to provide science ground-truth and additional observations.

Science Test Objectives: Science objectives for the test involved refining the process for identifying and implementing science priorities at multiple landing sites; further developing the roles and responsibilities of the science team in the SER; identifying the workflow of the Planning shift; validating requirements for the physical layout of the SER [10]; assessing mass and sample management considerations; evaluating images acquired by crew and their real-time return; maturing science operations products and tracking tools; assessing the fidelity of science observations by astronauts, and providing feedback on science/tool concepts of operation, among others.

Mission Planning Workflow: JETT5 provided an opportunity to test the development of the science planning process for more than one potential landing site, consistent with Artemis expectations. The science team followed a similar workflow that was developed during JETT3 [1], involving landing site characterization and geologic mapping (Fig. 1b), development of a Science Traceability Matrix (STM), identification and prioritization of points of interest

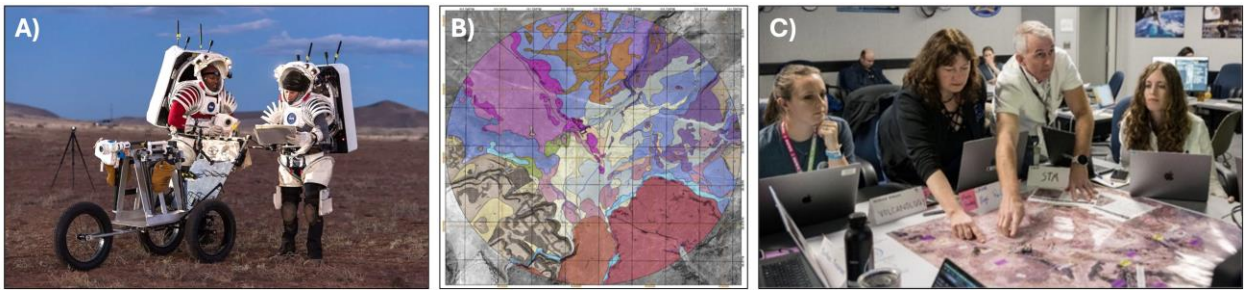

Figure 1.A) Crew members assessing the mapbook to prepare for an EVA traverse. B) Geologic map of the JETT5 prime field site. C) Team members on the SER Execute Shift tracking the location of crew during EVA.

(POIs) and crew actions, station and traverse definition, and the development of operations products (mapbook, procedures, and cuff checklists). This science planning workflow also enabled the evaluation and development of software tools to aid in the process. Each step of the mission planning workflow resulted in multiple findings and recommendations, which will be made available in the final test report and will be used to inform future Artemis planning.

Science Operations:

Operational Shifts: JETT5 was the first Artemis test to simulate two daily operational shifts. The SER Execute Shift provided real-time science input and evaluation during EVAs (Fig. 1c), while the Planning Shift worked between EVAs to evaluate science progress and propose modifications to upcoming EVAs to maximize mission science goals. Strategies for the efficient exchange of information between SER Execute and Planning shifts were also tested through both direct (face-to-face) and indirect (documents-only) handovers between shifts.

SER Roles: Roles staffed in the SER during the Execute shift were similar to those identified in JETT3 [2], with the addition of a Deputy Lead, a Science Decision Documentarian, and two Real-Time Imaging positions, for a total of 17 positions. Seven roles were staffed for the Planning shift, including a Strategic SER Lead, STM Lead, Decision Documentarian, Imaging Lead, Sample Lead, Station Action Tracker/Planner, and Traverse and Mapping Lead. In addition to the SER roles, JETT5 continued to develop the role of the Science Officer – a flight controller position working closely with the Task and EVA Officers to ensure the implementation of science objectives.

Real-Time Image Return: To evaluate the impact of having images returned from the Handheld Universal Lunar Camera (HULC) during EVAs, JETT5 included two EVAs in which a limited number of images could be requested by the SER and downlinked [11]. The workload associated with image tracking and producing image data products necessitated multiple positions. The team found that HULC images returned during the EVA were useful for real-time planning and analysis, and led to modifications and reprioritization of upcoming crew activities to more effectively and efficiently meet science objectives [12-13].

Video Feed: At various times during the JETT5 EVAs, live suit video was unavailable due to simulated line-of-sight obstruction or range limitations of the communications infrastructure. This enabled the Science Team to evaluate the impact of potential loss of live video during Artemis III, while still maintaining crew audio. The SER Execute Shift found that video was crucial for situational awareness, particularly for tracking and analyzing crewmembers' observations and descriptions in real time. When video was not available, the SER had to rely entirely on audio, which led to decreased awareness of crew location, and limited context for crew observations and samples.

SER Tools and Documents: The Science Team developed products to use during mission execution and replanning, and to facilitate handover of information between shifts. These tools and documents were used to record data, track activity and EVA progress, document STM progress and science decisions, and summarize and handover information between shifts. This resulted in the development of sixteen tracking documents across various roles. While each document had a clear intent, the team recommends consolidating information into several key locations. Essential functions of SER tools include a common annotatable digital map, crew transcript, sample tracker, decision log, play-by-play description of crew actions with timestamp, the ability to annotate images, text-based chat for team communication, and display of real-time video feed.

Summary and Future Work: The JETT5 mission simulation was an important test of science planning, integration, and mission operations for early Artemis missions. Lessons learned from JETT5 are already being used by the Artemis III Science Team [12-13]. However, more work is needed to refine the science planning process, SER tools, and operations with a fully staffed Execute and Planning Shift, and to evaluate the science achieved via samples and crew observations from these operations tests.

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