JETT3: A HOLISTIC, INTEGRATED ANALOG FOR ARTEMIS LUNAR SURFACE EXPLORATION.

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Introduction: Since 1972, NASA astronauts have performed hundreds of Extravehicular Activities (EVAs) in support of Skylab, Space Shuttle and International Space Station missions. Not since Apollo, however, have EVAs been driven by discovery-based principles of scientific exploration. Upcoming Artemis missions are challenged to build on lessons learned from Apollo, merging 50 years of EVA experience with the planetary science community's expertise in the remote surface exploration of Mars.

The highest-fidelity preparation for Artemis includes both operational and scientific underpinning to represent the complete, complex picture of lunar surface operations. The Joint EVA & Human Surface Mobility Test Team (JETT) is an interdisciplinary team providing such an environment for collaborative analog testing. JETT builds upon prior analog campaigns (e.g., [1, 2]) to provide high-fidelity environments for hardware and concept of operations development. Sponsored by the NASA EVA & Human Surface Mobility Program (EHP), JETT includes representatives from EHP, NASA Engineering, the Science Mission Directorate (SMD), Human Health & Performance, and the Flight Operations Directorate (FOD). JETT tests evaluate NASA reference designs for EVA (e.g., suits and tools), address gaps and risks for Artemis lunar surface operations, develop capabilities for EVA and science tasks, enable technology maturation, and provide training for Artemis EVA operations.

JETT3, the final JETT field test of FY22, occurred Oct 3-11, 2022 in the San Francisco Volcanic Field north of Flagstaff, AZ. The test focused on developing the Artemis concept of operations and systems, including integrating an Artemis-like Science Team into a NASA Flight Control Team (FCT) to plan and execute a series of simulated lunar EVAs in an environment analogous to Artemis 3.

Test Overview: *Mission Architecture:* Consistent with the current NASA Reference Artemis 3 mission, JETT3 conducted four EVAs over a five-day simulated mission. The traverse area (Fig. 1) was limited to a 2 km-radius surrounding a "lander," which served as base camp for the test team, communications infrastructure, and suit donning/doffing. All EVAs were conducted at night, using high-power LED lighting to simulate low-angle, lunar south polar lighting conditions. The test area included simulated Permanently Shadowed Regions to represent high-priority science targets. A crew of 2 NASA astronauts, both with geologic field experience, performed all four EVAs with the support of a FCT at Johnson Space Center in Houston, Texas.

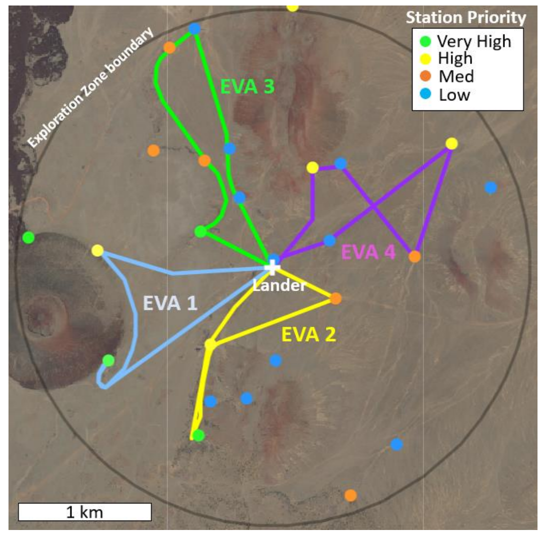

Fig 1: JETT3 Test Area, East of SP Crater in the San Francisco Volcanic Field. Colored lines represent planned EVA routes; dots represent a subset of possible Stations.

Test Hardware: EVAs 1 and 2 utilized the Atlas EXCON suit mockup, which simulates the volume of the Exploration Extravehicular Mobility Unit (xEMU) and includes realistic EVA suit-mounted tool transport (Fig. 2) for higher-fidelity evaluations. EVAs 3 and 4 utilized the Gen. 2 Field Ops Backpack, which is lighter than the Atlas suit but enables fast-paced scientific exploration, which tested the JETT 3 FCT with a high rate of science return from the crew. Both configurations utilized the government reference Artemis Geology Toolkit, including a conceptual Tool Cart, rock hammer, chisel, scoop, rake, tongs, core sampling kit, and hardware for bagging and transporting collected samples [3].

Flight Control Team Support: The integrated JETT3 FCT, consisting of FOD personnel, technical experts, and the JETT3 Science Team, supported EVA planning [4], training, and execution. During EVAs, the FCT

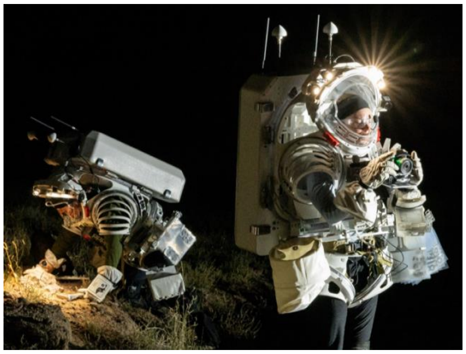

Fig. 2: EV crewmembers perform a JETT 3 traverse wearing the Atlas EXCON mockup suit.

communicated with the astronauts in the field via two-way radio and one-way "helmet cam" video. Flight Controllers alternated support between EVAs (Team A, EVAs 1/3; Team B, EVAs 2/4), while the Science Team supported all four EVAs from the "Science Evaluation Room" (SER; test scope included only a tactical science team). Between shifts, the FCT conducted strategic tasks as needed, such as EVA replanning as required and providing feedback on EVA crew observations.

During EVAs, information flowed between crew and system-level experts through the FCT structure in Fig. 3. In this context, *Front Room* Flight Controllers are the final decision-makers of the operation, *Multi-Purpose Support Room* (MPSR): personnel are operations experts providing information to the Front Room, and *Mission Evaluation Room* personnel are technical experts providing data to the MPSR The MPSR included EVA Task, who monitors the EVA timeline, technical tasks, and tool usage, the EVA Science Officer (ESO), who is the operational authority for execution of the science plan, and EVA Systems, who monitors the health of the space suit.

Simulated Events: Simulated space suit data was provided to the FCT via the model used to train NASA flight controllers on the Extravehicular Mobility Unit (EMU). Suit data, and the associated role of the Systems MPSR, enabled a holistic representation of FCT workload. Simulated malfunctions challenged the FCT by imposing a layer of troubleshooting and communications distinct from science operations.

Test Objectives: JETT3 evaluated multiple aspects of lunar surface EVA concepts of operation, but the objectives most relevant to the planetary science community examined integration of a Science Team into the EVA FCT. These objectives included:

Integrating discovery-based principles into EVA planning. Described in detail in [4], the JETT3 Science Team conducted pre-mission mapping and developed working hypotheses for the landing site, which were distilled to Objectives and associated with prioritized

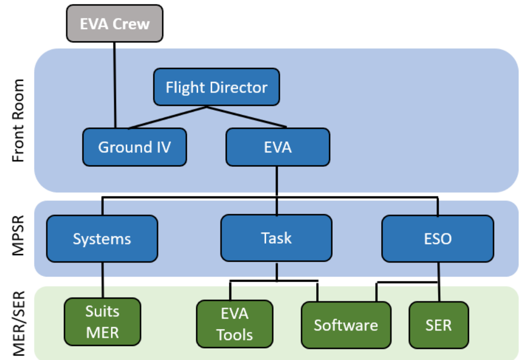

Fig 3: JETT3 FCT structure and information flow (indicated by black lines)

Stations (Fig. 1). The Science Team provided a Science Traceability Matrix to ESO, who designed EVAs iteratively with Task to address the objectives while complying with mission rules for distance, time, and safety. Traverse planning utilized a combination of commercial and prototype software tools to explore what digital capabilities an Artemis FCT will need [5]. This phase focused on when and how to engage the EVA operations team, communicating science priorities in an operational environment, and traverse map iteration between ESO, Task, and the Science Team.

Incorporating science into EVA products. Finalized traverse plans were incorporated into products such as detailed procedures (referenced by the FCT), the EV crew's Map Book (carried on the Tool Cart), and Cuff Checklists worn on EV crewmembers' wrists.

Stressing real-time decision-making with a science team in the loop. Science-driven EVAs create more communication between the crew and FCT as discoveries are made throughout the EVA. Thus, JETT3 examined workload and pace of communications for all consoles, particularly between EVA, ESO, Task, and the SER. Findings will help distribute workload appropriately and enable efficient decision-making in the fast-paced operational environment of Artemis 3.

Conclusion: While it is important to engage science in preparing for Artemis EVA operations, the reverse is also true: integrated analogs in which hardware and operations affect scientific objectives are crucial in providing a holistic picture of the reality of Artemis lunar-surface EVAs. JETT3 provided a comprehensive first look at the form and function of an integrated Artemis 3 Flight Control Team and the end-to-end lunar surface EVA concept of operations.

References: [1] Ross, A. et al (2013) *Acta Astro. 90, 2* [2] Beaton, K. H. et al (2019), *Astrobiology 19, 3* [3] Naids, A, and Bergman, H. R. (2021) *LSSW* [4] Young, K. E. et al (2023) *LPSC 2023* [5] Miller et al. (2021) *LSSW #3022*