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**Introduction:** Though we have experience conducting crewed science operations on another planetary body through the six Apollo lunar surface missions, the several decades of technological advancement mean that we have considerable work to do to prepare for the next generation of lunar exploration. As NASA prepares to put astronauts on the lunar surface with the Artemis program, the lunar science and extravehicular activity (EVA) operations communities are starting to develop the concepts of operations (conops) and support infrastructure necessary to execute Artemis EVAs. This submission will outline analog efforts currently ongoing to prepare for the next generation of lunar EVAs as well as discuss areas of advancement and factors to consider for preparing astronauts and flight support personnel for Artemis.

**Ongoing Analog Testing:** There are a number of analog testing environments that are currently being used to advance conops and technology for future lunar exploration. We mention just a couple of these efforts here as representative of the efforts going on across the community to advance sampling protocols and hardware, EVA informatics, and concepts of operation (conops) for future planetary surface exploration.

*NASA Extreme Environment Mission Operations (NEEMO):* NEEMO missions have taken place over the last two decades using the Aquarius underwater habitat, located several miles offshore from Tavernier, FL. Owned and operated by Florida International University, Aquarius is an excellent analog for spaceflight in that crewmembers (astronauts, scientists, and engineers) live in a habitat in an extreme environment and can conduct scientifically motivated EVAs in a mission timeline in an unknown environment. Recent NEEMO missions (NEEMO 20-23) have included robust marine science objectives as an analog for future lunar science EVAs as the sampling protocols and hardware mimic those under consideration for lunar EVAs.

*JSC Facilities:* In addition to field testing in analog environments with projects like NEEMO, there are a number of facilities located at JSC that are being leveraged for the advancement of conops and EVA hardware. These include the Active Response Gravity Offload System (ARGOS), the Neutral Buoyancy Laboratory (NBL), the JSC Rockyard, and numerous Virtual Reality (VR) facilities. While larger-scale operational field tests like NEEMO are critical in that they drive out lessons learned in a higher-fidelity mission environment, these facilities also represent an important resource due to their ability to frequently iterate in the relatively accessible platforms and integrate EVA spacesuits and tools in a 1/6$^{th}$ gravity environment. While no analog environment perfectly approximates operating on the lunar science, combining lessons learned across this portfolio of operational field testing will ensure sufficient preparation for lunar surface missions, both in terms of training crew and flight support personnel as well as in driving out hardware and conops lessons learned in advance of flight.

**Sampling Hardware:** The five decades since Apollo have brought technologic advancements in tools, instrumentation, and materials, all of which will impact the hardware sent to the lunar surface in the Artemis program. Efforts are underway to not only review and update tools that were a success during the Apollo program, but also to design new tools to meet the evolving sampling and curation requirements as we move toward exploration of the South Pole. Types of hardware being tested in analog projects like NEEMO include strategies for astronauts to transport tools, samples, and other equipment while on EVA, sampling systems to obtain core, chip, float, and regolith samples, and advanced strategies for curation. Astronauts serving as crewmembers in operational field tests, such as NEEMO, are able to provide end user feedback early and often throughout the development process, and as these tests include high-fidelity planetary science objectives, we will be well-positioned to understand sampling requirements and identify areas that still require future development.

**Informatics:** As the complexity of science missions increases, so too does the complexity of the procedures and data display capabilities. We are currently working to advance informatics technology to allow crewmembers to access nominal and contingency procedures, navigational/ situation awareness, and instrument data. One such development is the use of EVA cue cards, or a series of hyperlinked data screens showing daily and mission traverse plans, nominal and contingency procedures, and in situ instrument data obtained earlier in the mission. These cue cards were developed for NEEMO missions and have since been implemented across a variety of analog platforms. The cue card concept can be implemented using handheld informatics devices, a heads-up display platform, or even on intravehicular (IV) support infrastructure for astronauts left inside the lander or habitat.

Additionally, NEEMO work has included the testing of a heads-up display capability, meaning that nominal and contingency procedures, *in situ* instrument data, and navigation information is accessible by crewmembers real-time during EVA through the use of glasses worn inside the analog suit helmet. Analog testing of these informatics capabilities is critical as we have no experience testing this type of system in spaceflight.

Informatics can be developed to support EV crewmembers during surface operations, but another important area of informatics development is both IV and Mission Control and Science Support personnel. While not critical for early lunar missions, mission architectures where EV Crew are supported by crew counterparts located either in a surface habitat or on the Gateway platform, IV capabilities are critical to enable EVA support. To that end, we have developed IV Workstation capabilities to allow IV crew to track and assist their crewmates on EVA. Software includes camera feeds from the EV crew, timeline tracking, communications software to both EV crew and Mission Control, cue cards to dictate procedures and any necessary trouble-shooting, science data tracking information, and more, all which will be critical to autonomous (absent of Earth support) missions like manned-missions to Mars. Similar software packages are also being developed to aid Mission Control and Science Team situational awareness of EVA operations. From a purely science perspective, this enhanced situational awareness is critical to maximize efficiency and productivity of science operations.

**Concepts of Operation:** The benefit of operational field tests in a high-fidelity mission environment (including immersion in an extreme environment, a mission timeline that does not deviate due to artificial constraints, and crewmembers supported constantly by a mission-control and science team) is maximizing the applicability of driving out conops for how to conduct scientifically-driven EVAs on another planetary surface. We are in the early stages of defining the relationship between mission control architectures similar to what is currently used to support EVAs on the International Space Station (ISS) and what will need to be changed to support lunar EVAs. Analogs such as NEEMO enable the integration of the science and operations community into one unified team that speaks a common language, which is critical as we build toward Artemis. Additionally, the facilities we test in onsite at JSC enable us to access the Mission Control facilities and simulators used across the human spaceflight community, meaning that we can start to develop an operational flow and the physical infrastructure that will be needed to support lunar EVAs.

While we have experience conducting lunar EVAs during Apollo, and more recent experience conducting EVAs on ISS, future Artemis EVAs will likely include a higher degree of autonomy on the crew's part and fewer timeline and traverse restrictions than we're used to experiencing from Apollo and ISS. A well-trained crew and a confident Mission Control team means that crewmembers will be able to deviate from predetermined traverse plans in a flexible traverse execution methodology, but this takes robust training and conops that can accommodate that flexibility. It is absolutely critical to design a conops and the supporting infrastructure (like an IV Workstation and corresponding Mission Control and Science Support hardware and software) to allow for this new paradigm of science operations, and this work is already underway through a fully integrated Science and Operations community. Future testing should include a broader swath of the community in order to ensure a fully prepared science community that can respond to the rigors of human spaceflight in an operational environment.

**Conclusions and Moving Forward:** Analog testing has so far been critical in advancing sampling protocols and hardware, informatics to aid astronauts in conducting EVA science operations, and operational concepts designed to facilitate scientifically-motived EVAs. Additional benefits include cross-training of scientists and engineers in science operations as well as creating a workforce knowledgeable and experienced on exploration work. As we approach the Artemis lunar surface missions, development in these key areas is critical to enable mission success. This team has been assembled due to its strong interdisciplinary nature, which should continue and even be enhanced as we continue to evolve technology, procedures, and architectures for the next generation of lunar exploration.

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