EXTRAVEHICULAR ACTIVITY CONCEPT OF OPERATIONS FOR INITIAL CREWED LUNAR SURFACE MISSION. D. A. Coan[1], T. J. Lindsey[1], B. K. Alpert[2], A. Kanelakos[2], T. G. Graff[3], K. E. Young[4]; [1]The Aerospace Corporation at NASA JSC, 2101 NASA Pkwy, Houston, TX, 77058; (corresponding author email: david.coan@nasa.gov); [2]NASA Johnson Space Center, 2101 NASA Pkwy, Houston, TX, 77058; [3]Jacobs at NASA JSC, 2101 NASA Pkwy, Houston, TX, 77058; [4]NASA Goddard Space Flight Center, 8800 Greenbelt Rd., Greenbelt, MD, 20771

Introduction: Lunar missions will allow for continued scientific research of the Moon, along with providing a critical test bed for concepts of systems bound for Mars. These missions will progress with a phased approach, starting with smaller short missions and expanding to a long duration presence on the surface. Extravehicular Activity (EVA) operations will involve a variety of engineering-focused and science-focused tasks.

Per "From "Forward to the Moon: NASA's Strategic Plan for Human Exploration", 4 Sept 2019", the Artemis program will have two astronauts land near the lunar South Pole and stay for 6.5 days.

One of the primary purposes for landing on the surface of the Moon will be for science. The Exploration EVA (xEVA) System will enable the science tasks in order to return samples to Earth.

Exploration EVA System Capability Overview: The Exploration EVA (xEVA) System allows crewmembers to conduct excursions outside a habitable vehicle in order to perform exploration, research, construction, servicing, and repair operations.

The system includes the xEVA suit, the Exploration EVA-Vehicle Interface Equipment.

The xEVA surface suit will be rear-entry, operate at a nominal EVA pressure of 4.3 psid, and support EVAs of up to 8 hours in duration. It will allow for science operations of up to 2 hours of continuous exposure in a shadowed area, including Permanently Shadowed Regions (PSRs). Crew wearing the suit will possess the mobility to traverse slopes of up to 20° and on walking excursions of up to 2 km away from the lander (depending on terrain), including into and out of craters, volcanic terrains, and shadowed regions. The xEVA System will have the ability to record communication and video onboard the suit in case of loss of signal with the Mission Control Center (MCC), and there will be lights that support visual sight of suited astronaut boots, ground ahead, partner in a PSR, lander, and the worksite. Crew in the xEVA suit will utilize tools for transportation, construction, geology, and contingencies. The system will operate within a variety of vehicle saturation atmospheres.

During Phase 2 of Artemis, the xEVA suit will include an informatics system with a heads-up display type of capability that will allow for viewing of procedures, imagery, navigation data, suit data, possibly augmented reality cues, etc.

In order to save on mass and conserve volume, the xEVA System is examining utilizing a single suit system architecture for Human Landing System (HLS) operations during descent, EVA, and ascent. For those dynamic flight, the crew will remove the Exploration Primary Life Support System (xPLSS) and install closed-loop umbilical(s) between the Exploration Pressure Garment System (xPGS) and host vehicle for power, data, audio communication, ventilation, and thermal control. This configuration will protect astronauts during lunar ascent/descent for any sort of cabin depress contingency event.

Human Landing System: The Human Landing System (HLS) will bring the astronauts from lunar orbit down to the surface. HLS will have the capability to support up to 5 EVAs during the lunar surface stay, and support EVAs of up to 8 hours (6±2 hours) in duration each. It will have the appropriate volume to don, doff, and maintain the suits, and provide a minimum EVA hatch opening of 1.02 x 1.53 m (40x60 in). The cabin atmosphere will allow for the shortest prebreathe and require the least amount of crew time, while maintaining flammability constraints. HLS will provide a layered engineering defense protocol for lunar dust mitigation, have the volume and mass launch capacity for returning samples collected, and allow for margin to bring back EVA equipment from the lunar surface.

Lunar Surface Environment and Notional Landing Site: Per the direction for Artemis, the next lunar missions will land near the South Pole of the moon. This location enables exploration of regions that may contain volatiles and possibly ice water. There the crew will traverse into craters, PSRs, and volcanic terrain. One of the potential landing sites is on Connecting Ridge, which provided the notional environment for developing a design reference EVA. That area includes a variety of terrain, including PSRs where ice water may possibly be located. Crew will also be able to sample breccias, anorthosites, and basalts.

Phases of Exploration EVA Operations: The EVA System passes through several phases during a mission, from preflight to Earth return.

1. Preflight Testing and Training
2. Earth Launch and Mission Logistics
3. xEVA Suit Assembly and Checkout in Lunar Orbit
4. Descent and Landing
5. Surface Operations Prep ("Road-to EVA")
6. Pre EVA (Prep & Prebreathe)
7. EVA
    a. Egress & Setup
    b. Surface EVA Tasks
    c. Cleanup & Ingress
8. Post EVA
9. Maintenance
10. Ascent Prep
11. Ascent and Docking
12. Post Docking Operations
13. Post Flight Processing and Evaluations

During surface EVAs, the crew will conduct a variety of engineering and science tasks. The engineering tasks will be for preparing equipment, constructing infrastructure, assembling and maintaining equipment, and preparing the ascent vehicle for return. The science tasks will include macro-scale and micro-scale observations, data collection with handheld instruments and geotechnical tools, emplacement of science payloads, and sample acquisition. Those samples will include rock float, rock chip, rock core, bulk regolith, regolith core, regolith surface, volatiles, and atmospheric samples.

Notional Design Reference EVA Scenarios for Development of the xEVA Con Ops: A notional design reference EVA series and example EVA was established to enable development of the xEVA con ops. The reference EVA is an example of a snapshot of the initial Artemis mission. The landing zone for this reference is presumed to be near the South Pole at Connecting Ridge. While this reference EVA is likely oversubscribed for any single EVA, gives the reader an idea of what will need to be performed on the lunar surface via EVA. This reference EVA does not timeline an actual EVA, but only provides a potential example of tasks performed by EVA on the lunar surface, with the goal to help the designers understand the various movements and interfaces for the xEVA suit.

Summary: The Exploration EVA System will enable up to 5 lunar surface excursions outside the lander during a 6.5 day Artemis III mission in 2024.

Crewmembers will be able to conduct EVAs of up to 8 hours in duration (6±2 hours), while walking up to 2 kilometers away from the lander and on terrain of up to a 20° slope. They will perform tasks standing, kneeling, and possibly on hands and knees.

EVA crewmembers will conduct both engineering tasks (construction/maintenance/repair) and science tasks on the surface. They will acquire samples from craters, permanently shadowed regions, volcanic terrain, and ejecta blankets. They will also deploy experiment packages and environmental monitoring stations.

This concept of operations will evolve as the Artemis mission becomes more defined and the design of the xEVA System matures, with updates made to the xEVA System Concept of Operations document to reflect changes.

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