A Preliminary Assessment of Physical Demand during Simulated Lunar Surface Extravehicular Activities

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Returning to the moon requires many advances in current space technology. One major aspect of this development is a new exploration spacesuit (xEMU). Taking lessons learned from Apollo era suits and the Extravehicular Mobility Unit (EMU) used on the International Space Station (ISS), xEMU will have increased mobility, dust mitigation, headspace, glove fit, and life support capabilities. Artemis astronauts in xEMU will complete a far more rigorous Extravehicular Activity (EVA) schedule than Apollo and ISS. Notably, metabolic rates during Apollo lunar EVA tasks were observed to be up to 50% lower than similar tasks performed in a ground analog environment under simulated partial gravity with newer suits. Therefore, understanding the physical demands of lunar surface exploration operations is critical to ensuring best outcomes operating within the constraints of xEMU and planning for exploration EVA activities.

This study utilized the Active Response Gravity Offload System (ARGOS) to simulate the lunar environment and continuously offload subjects to lunar gravity. Two male subjects completed two days of EVAs wearing the pressurized Mark III spacesuit, completing suit fit and mobility checks, as well as simulated lander operations, cable routing, crew rescue, geology, payload relocation, and traverse tasks in an end-to-end EVA (E2E) task block and standalone (SA) task blocks. We recorded continuous values of metabolic rate (MR) and heart rate (HR) to assess physical demand. During the E2E task block, subjects did not rest between tasks to simulate continuous effort from task to task, as in real EVAs. In comparison, subjects had a 5-minute break after each SA task block to allow for the metabolic rate and heart rate to return to baseline.

MR values were categorized as low (≤ 700 BTU/hr), medium (700-1000 BTU/HR), and high (≥ 1000 BTU/hr), while HR values were categorized as low (≤150) and high (>150). During the 16 tasks in the E2E block, subjects averaged low MR in 6% of tasks, medium MR in 47% of tasks, and high MR in 47% of tasks. While MR was consistent between subjects, Subject 1 averaged low HR for 100% of these tasks, while Subject 2 averaged low HR in 44% of tasks. During the 23 tasks in the SA task blocks, subjects averaged low MR in 26% of tasks, medium MR in 52% of tasks, and high MR in 22% of tasks. Again, HR was different between subjects, with subject 1 averaging low HR in 100% of these tasks while subject 2 averaged low HR in 70%. Across all tasks in this study, subjects reached maximum MR and HR values during a 500m traverse at 30% grade in the E2E block (subject 1: 1747 BTU/hr, 150 BPM; subject 2: 1656 BTU/hr, 177 BPM).

Understanding the physical demand to complete exploration EVA tasks will be instrumental to the future success of exploration spacesuit designs and missions. Further work in this study will be needed to characterize MR during exploration EVA tasks, including expanding the subject pool and testing new suit designs.