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EXTENDED REALITY LUNARES EXPERIMENT (XRLE): A FRAMEWORK FOR HUMAN-SYSTEM INTEGRATION TESTING USING IMMERSIVE TECHNOLOGIES

Abstract

As humanity prepares for lunar surface operations and sustainable exploration of the Solar System, it is crucial to understand the psychological impacts of confined and isolated environments on astronaut performance. The Extended Reality LunAres Experiment (XRLE) is a collaborative effort between the Sasakawa International Center for Space Architecture (SICSA) and analog astronauts in the Lunares Research Base (M1.24 Pluto Mission) to study these effects through an innovative testing framework.

The XRLE crew utilized biosensors, Virtual Reality (VR) headsets, and Extended Reality (AR) technologies within an analog lunar habitat's Extravehicular and Intraveicular Activity (EVA IVA) area. They performed a hardware manipulation simulation with different levels of difficulty which involved an analog astronaut during simulated EVA, an experiment coordinator, and an analog mission control operator. A suite of biosensors was used to collect data on stress levels, focus, and task effectiveness. This research aims to validate a novel triple-layer human-system integration testing methodology developed at SICSA, incorporating survey-based assessments (NASA TLX, mSUS) and a biofeedback control layer using compact biosensor suites.

Integrating Extended Reality (XR) technologies into traditional space testing platforms offers enhanced immersivity and real-time event generation capabilities. By combining physical hardware interactions with virtual simulations, this framework enables a more comprehensive evaluation of human factors and ergonomics during design iterations. The study will generate quantitative data from biofeedback monitoring, timed imagery, and video recordings, as well as qualitative insights from adapted usability surveys. This multifaceted approach allows for in-depth user performance analysis, stress levels, and hardware effectiveness.

The XRLE experiment proposes an innovative framework for human-system integration testing using relatively inexpensive commercial off-the-shelf (COTS) immersive technologies. By validating this methodology, the space industry can optimize design processes, reduce research and development timelines, and unlock new capabilities for human-rated hardware development. Establishing industry standards for leveraging XR technologies in space applications is crucial as their utilization is projected to grow exponentially with new exploration endeavors like the Artemis program. This paper presents the results of the experiment, including its methodologies and the data collected.