

IEEE 2024 Paper Abstract

Immersive Technologies for Human-in-the-Loop Lunar Surface Simulations

NASA, the National Aeronautics and Space Administration, continually seeks innovative solutions to enhance its operations, particularly in the realms of testing, evaluation, and training for future missions. Immersive technologies, such as virtual, augmented, and mixed reality have proven to be powerful tools for realistic, interactive, and engaging environments. This paper explores how the Simulation and Graphics Branch at NASA's Johnson Space Center (JSC) leverages immersive technology, modern commercial rendering engines, and physics-based systems simulations to develop human-in-the-loop systems for humanity's return to the Moon through the Artemis program.

When NASA returns to the Moon, astronauts will travel to the Moon's South Pole where lighting conditions will cause a more complex operational environment. Human-in-the-loop testing plays a crucial role in NASA's mission planning, spacecraft and space systems development, and evaluation of operational scenarios. The development of immersive environments such as a lunar rover mockup at a video wall enables engineers and astronauts to simulate and experience mission scenarios, integrated spacecraft systems, and operational procedures in a relevant environment before deployment. By integrating realistic virtual environments, immersive technology allows for the visualization and interaction with virtual spacecraft models, mission landscapes, and complex operational tasks. This approach helps identify potential design flaws, operational challenges, and safety considerations. It also provides valuable insights for risk reduction and helps improve mission efficiency and effectiveness.

With advanced motion tracking systems and custom virtual environments data can be gathered and evaluated to help NASA refine training protocols, develop specialized training procedures and optimize human-robotic interactions for future space missions.

Furthermore, immersive technology offers opportunities for future training initiatives at NASA. The Virtual Reality Laboratory at JSC has pioneered training with Virtual Reality (VR) since the Hubble Space Telescope repair missions in the early 1990's. Extended Reality (XR) simulations enable astronauts to rehearse complex spacewalks, spacecraft maneuvers, and extravehicular activities in a safe and controlled environment. By replicating the physical and cognitive challenges of space missions, immersive training experiences enhance astronauts' situational awareness, decision-making abilities, and adaptability to unexpected scenarios. Additionally, immersive technology facilitates collaborative training, allowing geographically dispersed crew and mission control personnel to engage in synchronized simulations, fostering teamwork and effective communication.

The adoption of immersive technology in NASA's testing, evaluation, and future training programs has yielded significant benefits. By incorporating human-in-the-loop testing for studies involving Extra Vehicular Activities (EVA), surface mobility and landing systems, NASA can identify and mitigate risks, optimize operational procedures, and enhance mission success. Ultimately, immersive training experiences can empower astronauts to better navigate the complexities of space missions, ensuring their safety, productivity, and success in the dynamic and challenging environments they will experience at the Lunar South Pole.