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

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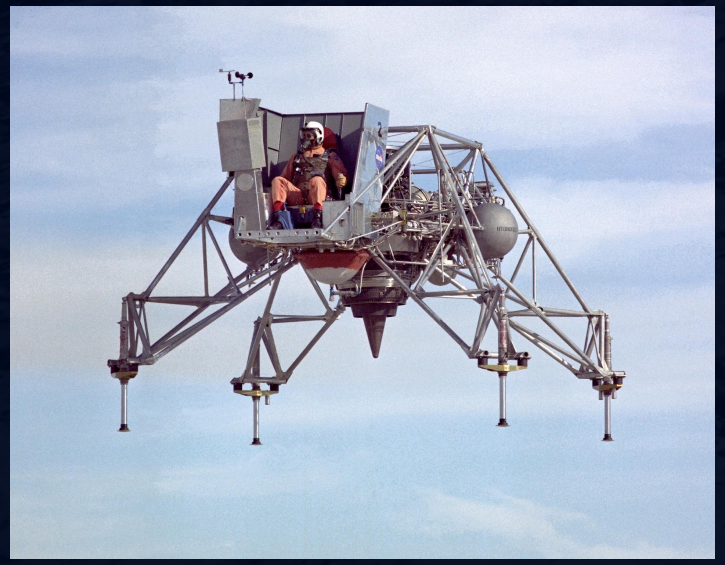
Presentation Overview

- Purpose:
  - Dive into the ways Johnson Space Center's Simulation and Graphics Branch is using Immersive technologies for different Human-In-The-Loop Studies to prepare for the Artemis missions.

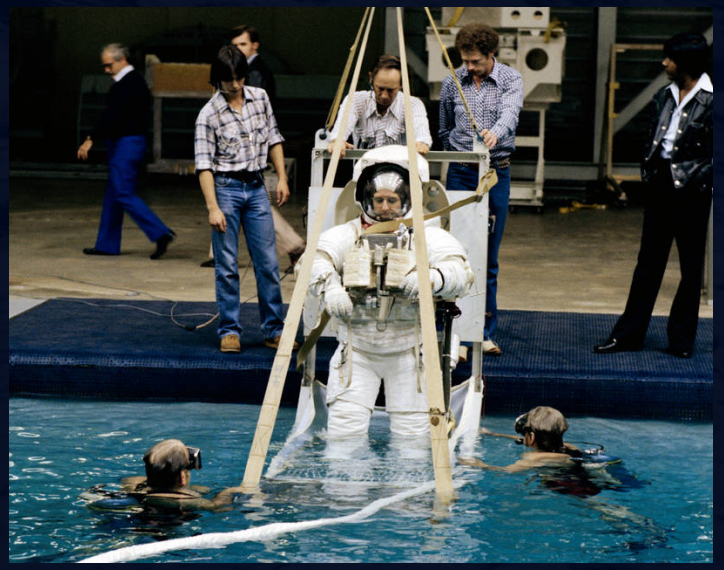
- Topics:
  - Introduction and Mission Challenges
  - Overview of our Immersive Technologies
  - Human-In-The Loop Studies
  - Future Work
  - Questions

Introduction and Historic Human in the Loop Testing



1967 NASA Flight Research Center Lunar Landing Research Vehicle (LLRV)

1979 and 1980 Winglet Flight Research led to flight tests on a KC-135 Stratotanker



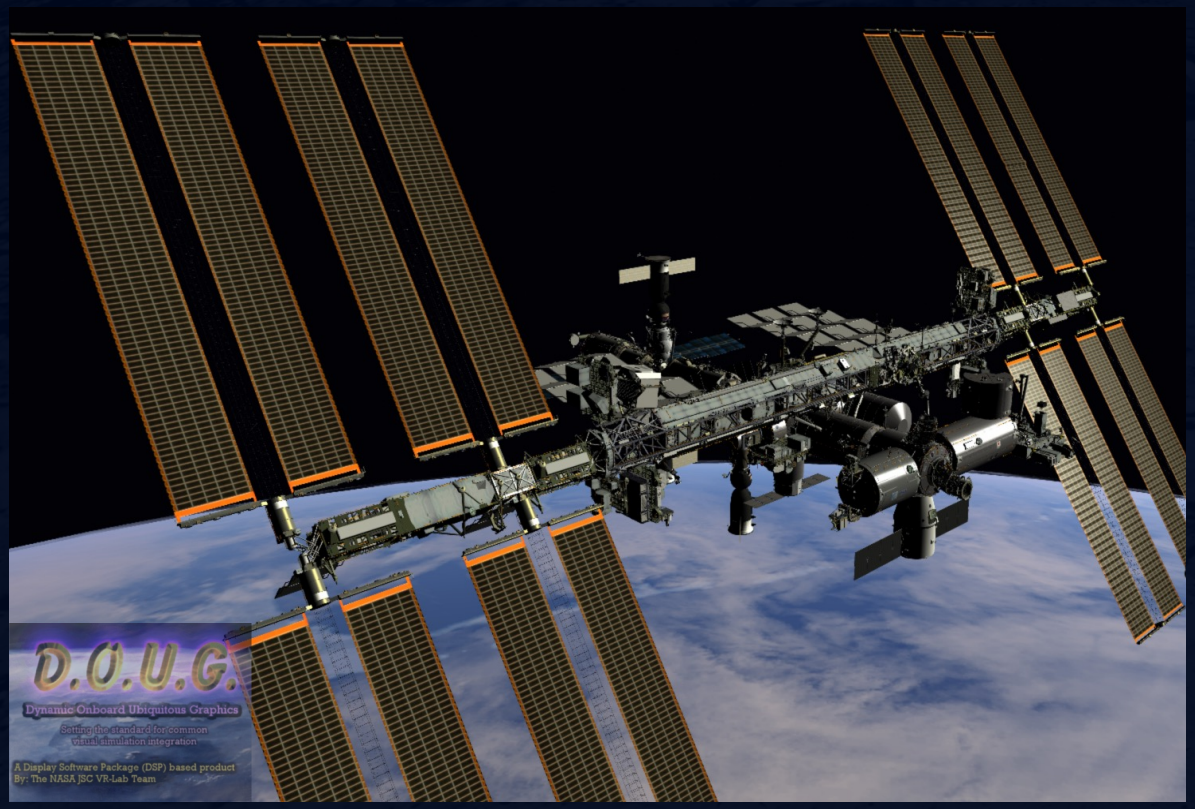
WETF – Weightless Environment Training Facility July 1980

Lunar South Pole

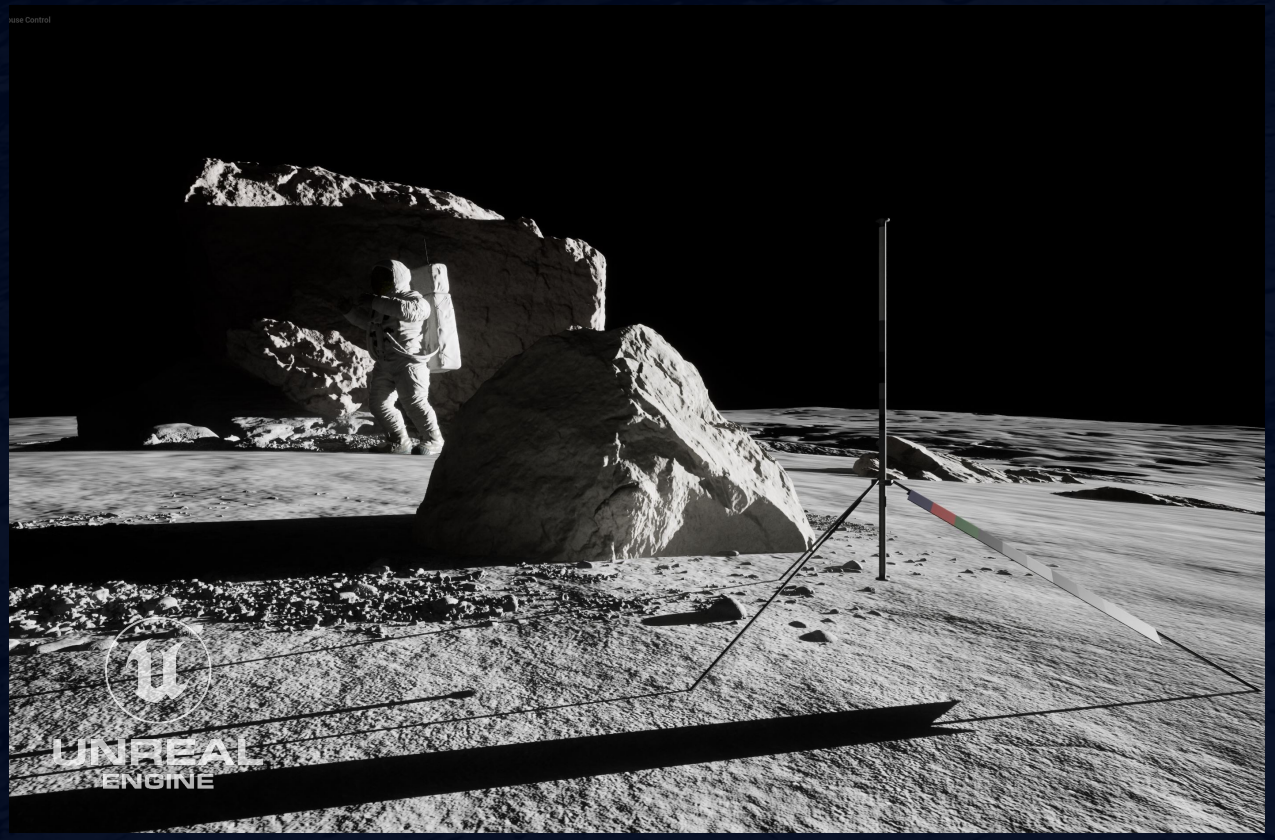
- Lunar South Pole has harsh lighting conditions
  - Moon axis is near vertical (1.5 degrees)
    - Best lighting conditions at exact South Pole are with the Sun at 1.5 degrees above the horizon
    - Time of year and surrounding terrain impacts lighting conditions dramatically
  - 1 lunar cycle = 29.5 Earth days
- Simulations with correct visuals of the South Pole are critical for early navigation and lighting studies/analysis, mission planning and training

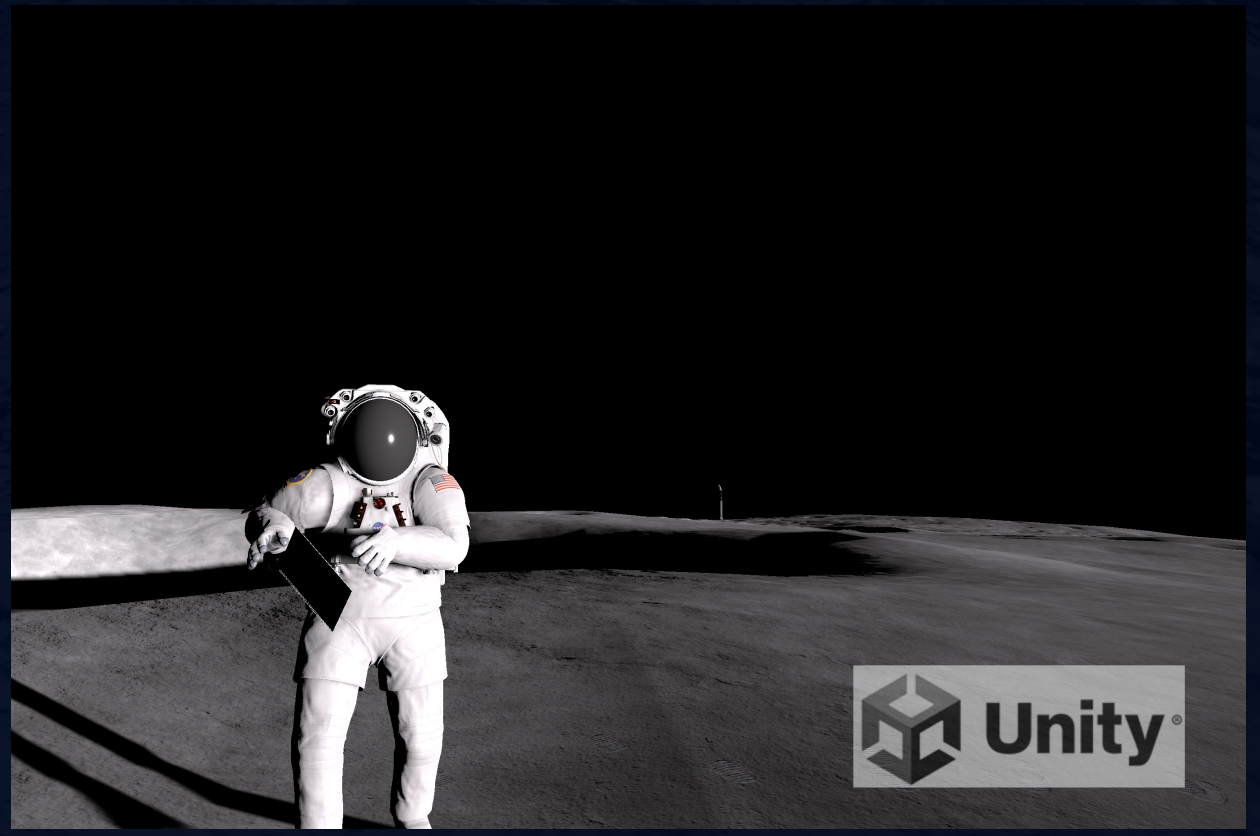
Immersive Technology Overview – Tools

Immersive Technology – Graphics Tools

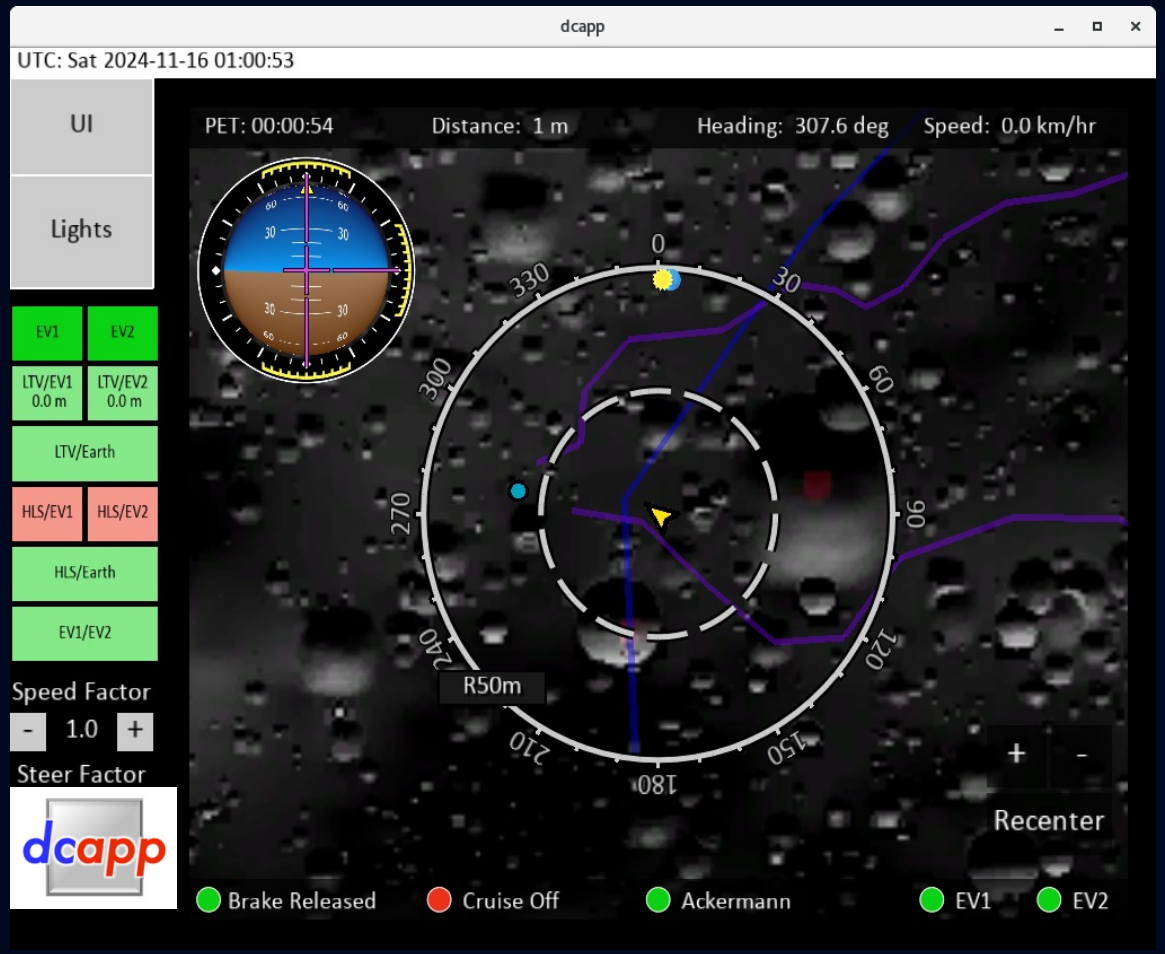


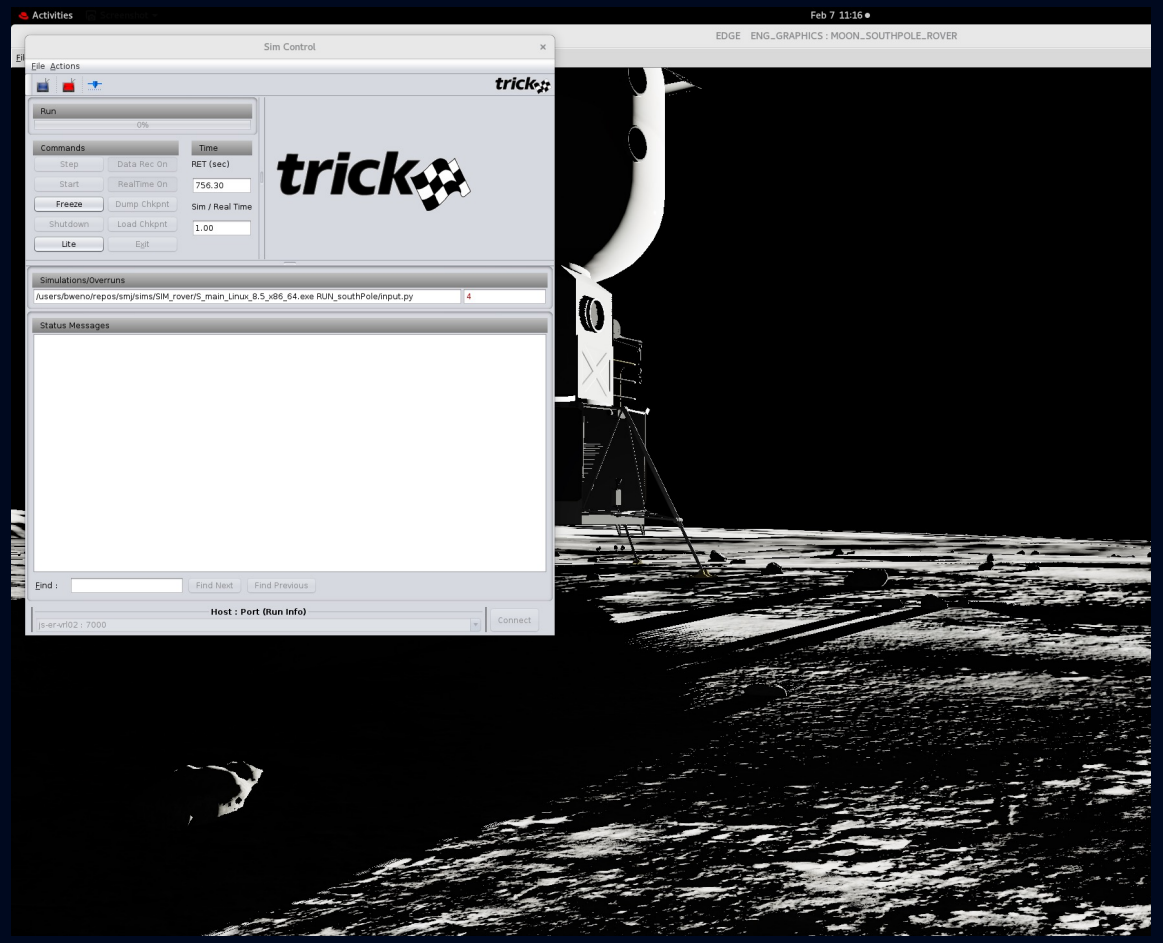
Immersive Technology – Graphics Tools



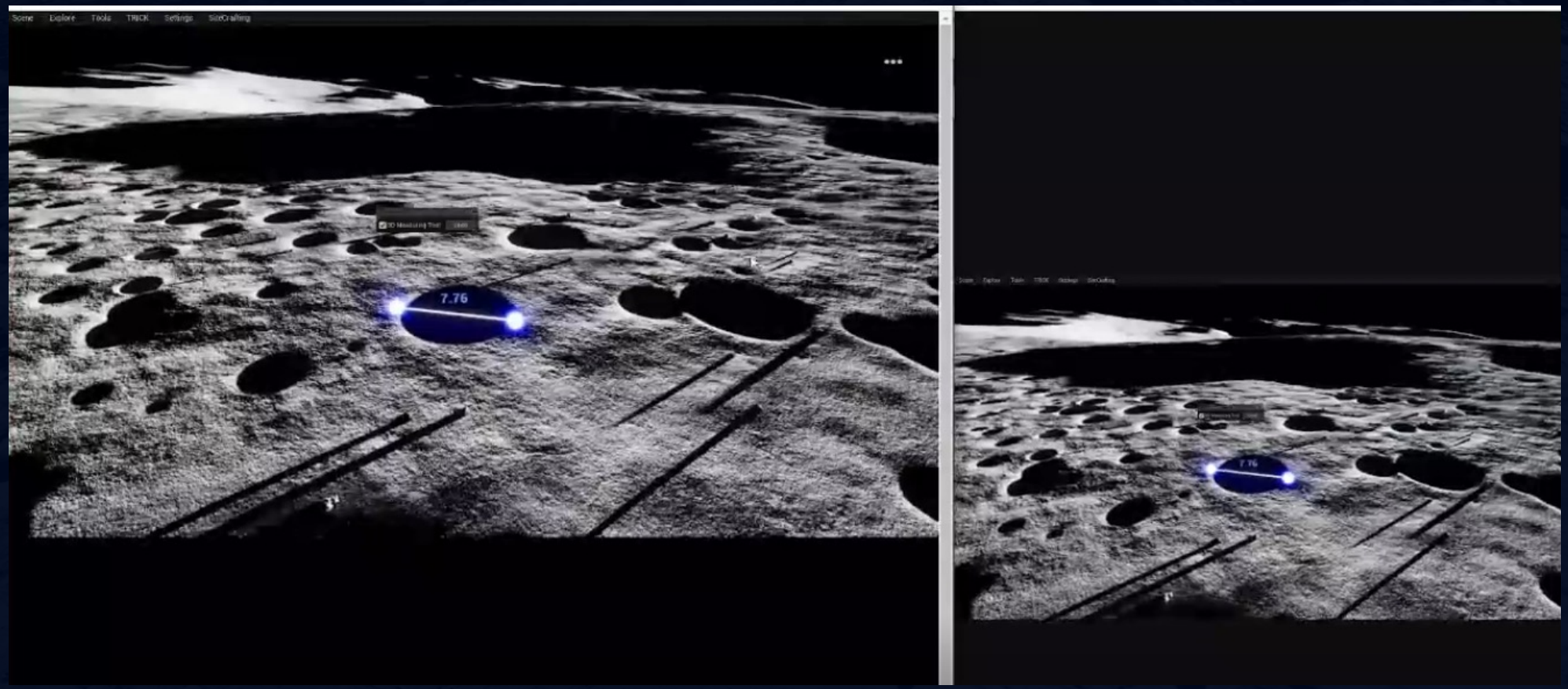


Immersive Technology – Simulation Tools





Immersive Technology – Simulation Tools



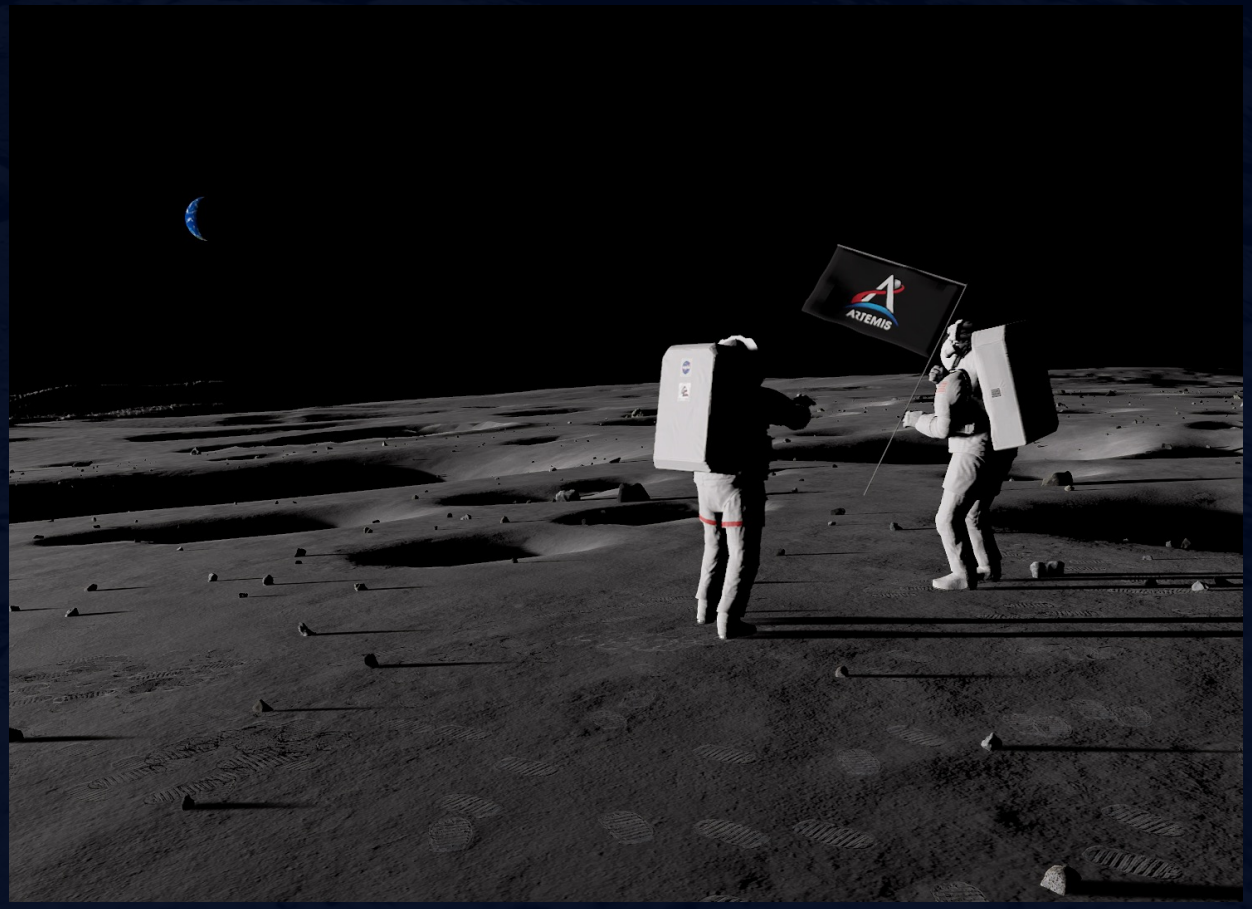
RE-STREAMER

NASA Lunar Terrain | Digital Lunar Exploration Sites (DLES)

Immersive Technology Overview - Applications

Lunar Assessment for Virtual Reality Assets (LAVA)

- An application which supports extra vehicular mission planning, analysis, operations and visualization.
- Utilized for the Orienteering and Navigation HITL simulation for lunar traverse, EVA planning, and evaluation of different lighting conditions.



- Made with Unity
- Networked environment using Photon Unity Networking
  - Supports desktop clients:
    - Birds eye view camera client
    - Astronaut suit camera views
    - Rover Camera Views
    - Lander Cameras
    - Top-down orthographic views of the lunar surface
- Uses DLES terrain generated using the LUTE tool
- Supports full body tracking with HTC VIVE Pucks

Digital Lunar Exploration Sites Unreal Simulation Tool (DUST)

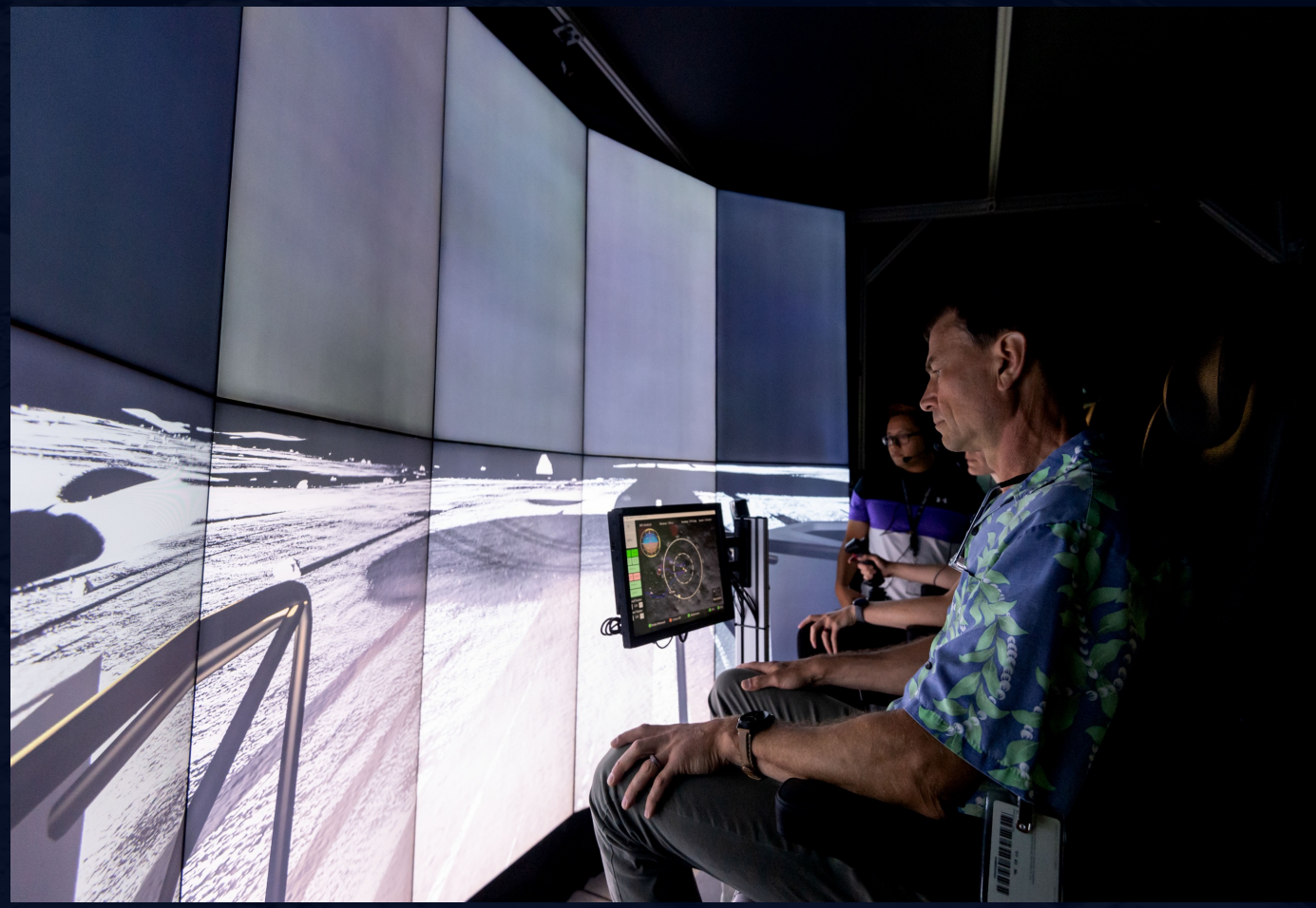
- Designed for use as an early reference to enable candidate vendors to perform initial studies of the lunar terrain and lighting in support of the Strategy and Architecture Office (SAO), Human Landing System (HLS), EVA and Human Surface Mobility Program (EHP), and Moon To Mars (M2M)

- Provides a suite of capabilities for early mission traverse and lunar landing simulation capability assessments in a high-fidelity digital model of the lunar surface

- A generic version of the tool is available publicly through a Software Usage Agreement on NASA's software catalog
  - Digital Lunar Exploration Sites Unreal Simulation Tool (DUST) Products(MSC-27522-1) | NASA Software Catalog

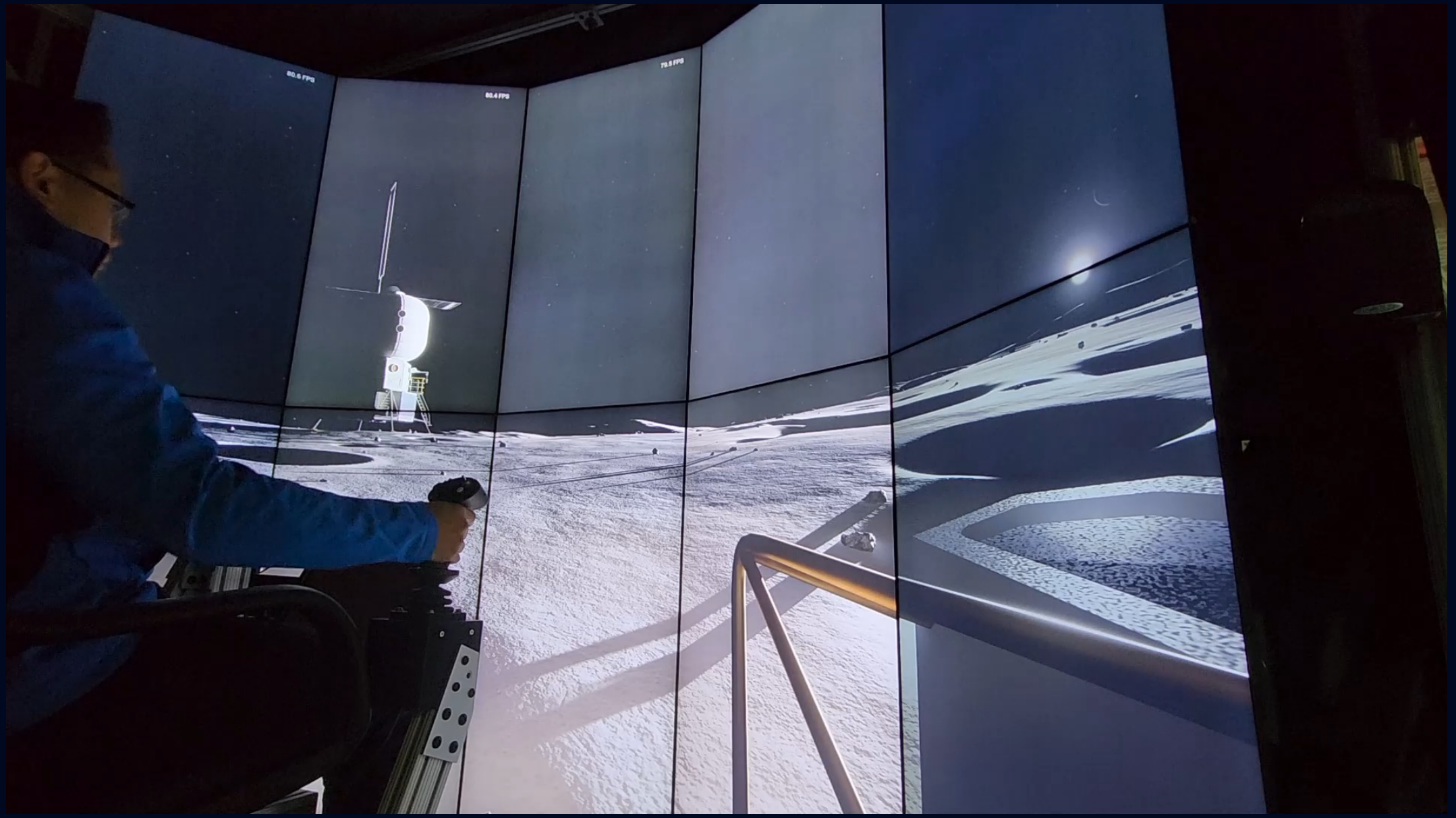
Multi-Unreal Display (MUD) - MUD

- An application which synchronously renders a lunar simulation across multiple monitors using Unreal Engine NDisplay.
- 10 Monitors surround a simulated lunar rover cockpit.
- Utilizes the same set of terrain plugins as DUST for uniformity amongst our simulations.
- Supports different lunar terrain vehicles (LTVs) and hand controller configurations.



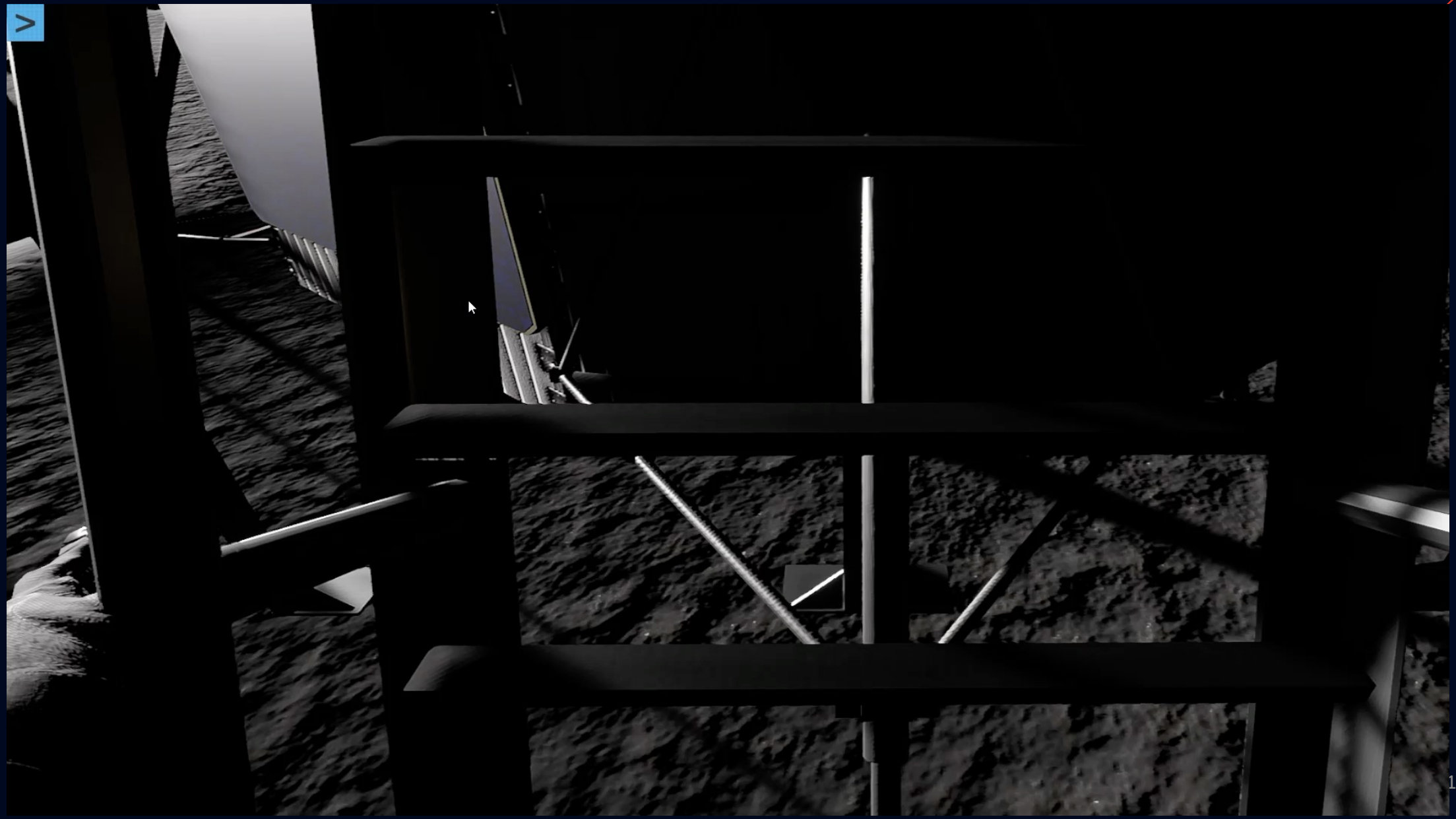
Immersive Technology Overview – Capabilities

Video Wall – (MUD) Rover Simulation



Motion-base Simulator and VR Video

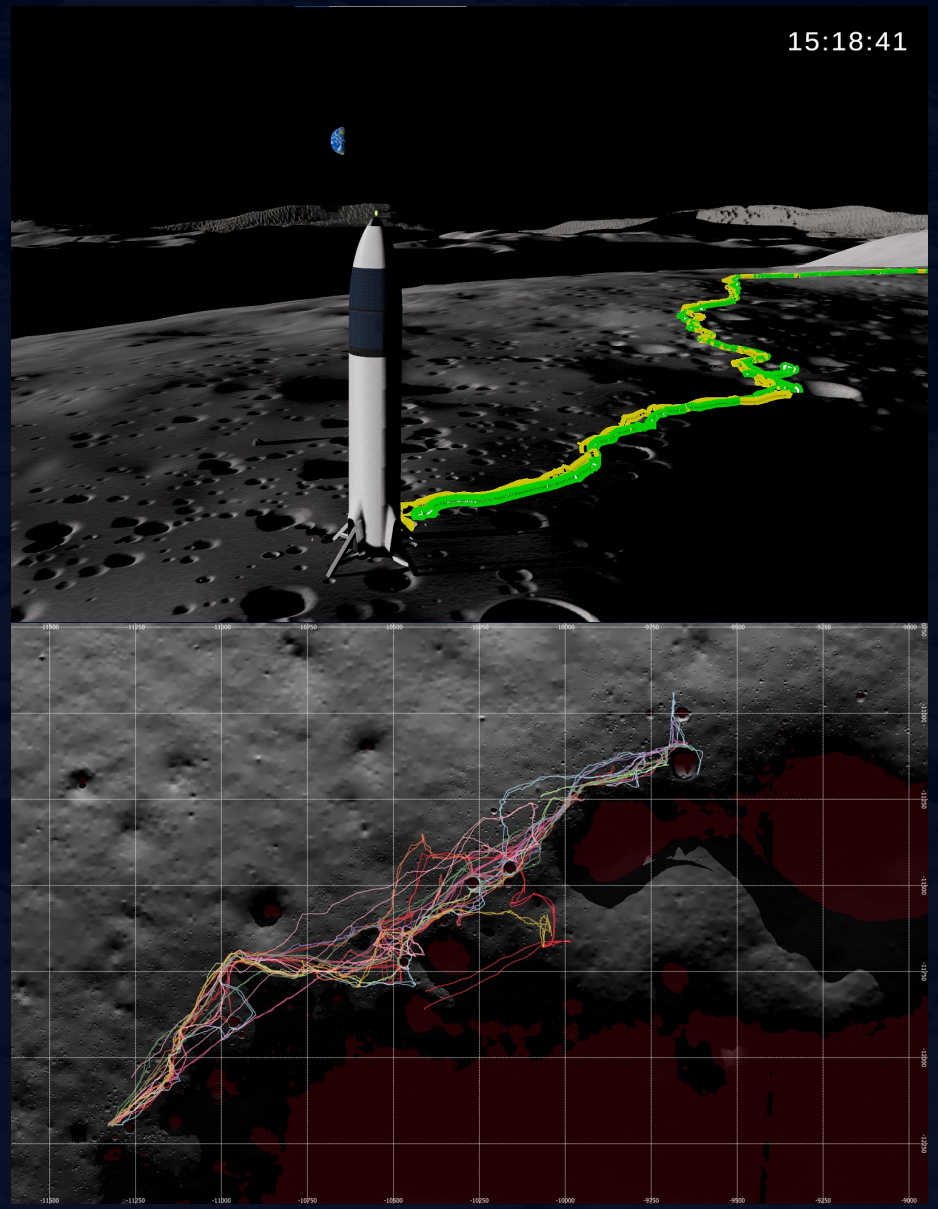
Active Response Gravity Offload System (ARGOS) Mixed Reality



Human in the Loop Studies

Lunar Navigation and Orienteering

- This studies simulates a series of Extravehicular Activity (EVA) navigation operations on the lunar south pole using limited navigation aids and realistic lighting conditions.
- Two Participants complete a specific EVA traverse wearing HTC VIVE Pro 2 VR headsets.
- Virtual maps in LAVA for navigation -- slope and shadow information.
- Participants communicate with a Ground IV Monitor in a separate Mock-Mission Control Center.
- The data collected in this study including comparisons of the crew's location estimates and their actual locations, traverse duration, and idle times will help inform NASA and improve planning for Lunar EVAs during future Artemis Missions.



Lunar Navigation and Orienteering

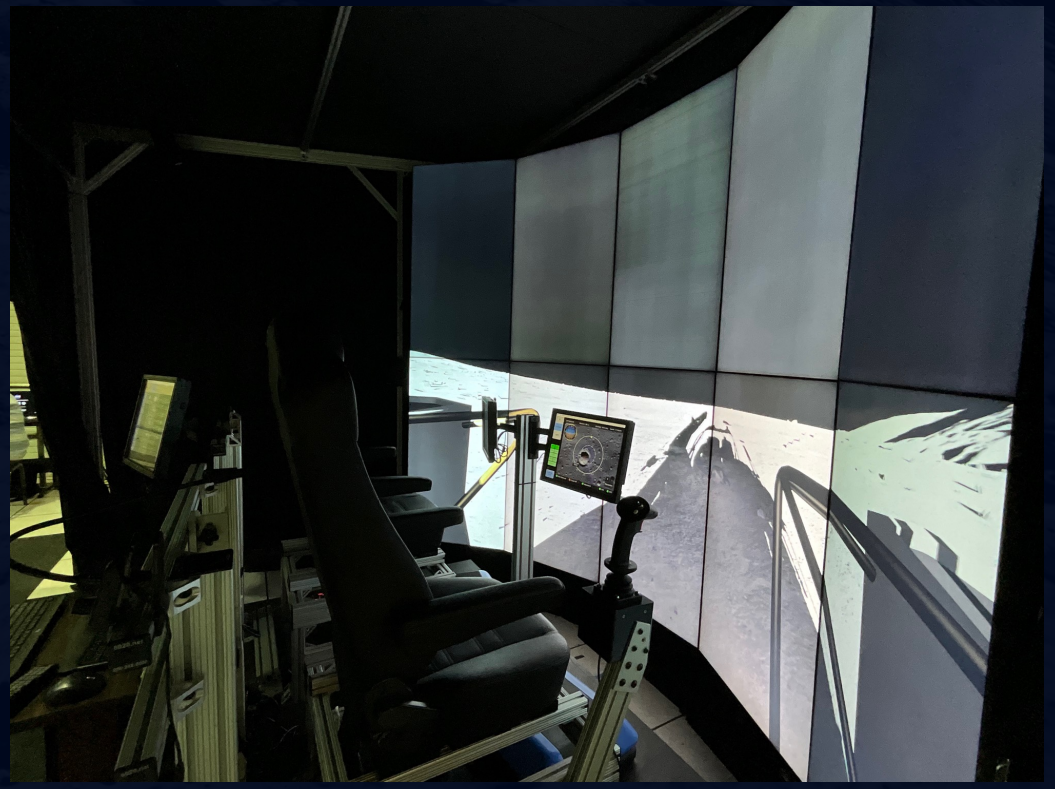
LTV Hand Controller Study

- The LTV Hand Controller Study was conducted in the spring of 2022 in conjunction with the EVA and Human Surface Mobility Program (EHP).
  - Video Wall Facility
  - Trick based rover simulation

- The purpose was to test different LTV hand controller design concepts.
  - T-Handle Implementation
  - Custom Tri-Rotor design

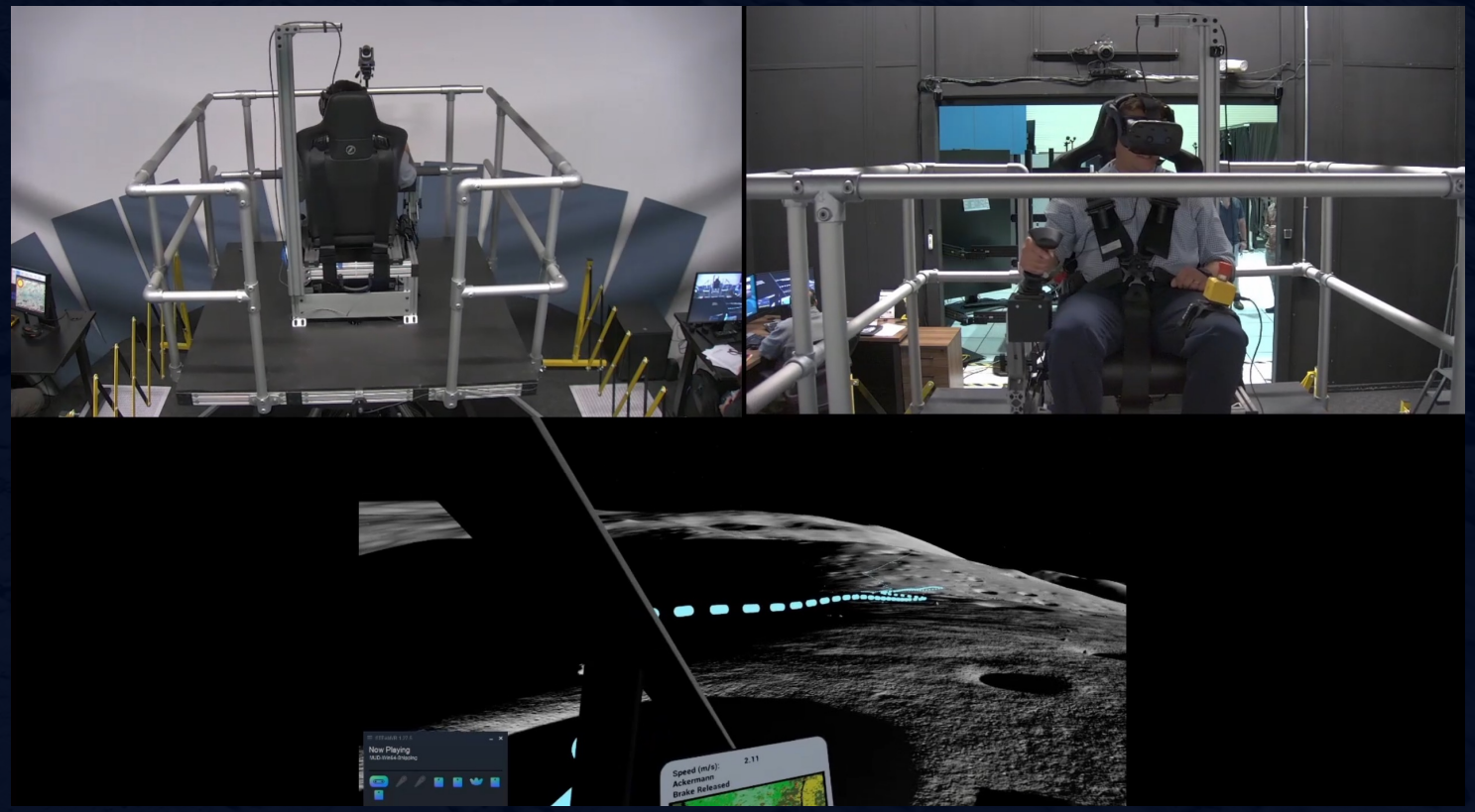
- Participants performed driving tasks and followed pre-planned traverses.

- The data collected will influence design concepts and can be used to assess prototypes before vehicle integration.



LTV Handling Qualities Pilot Study

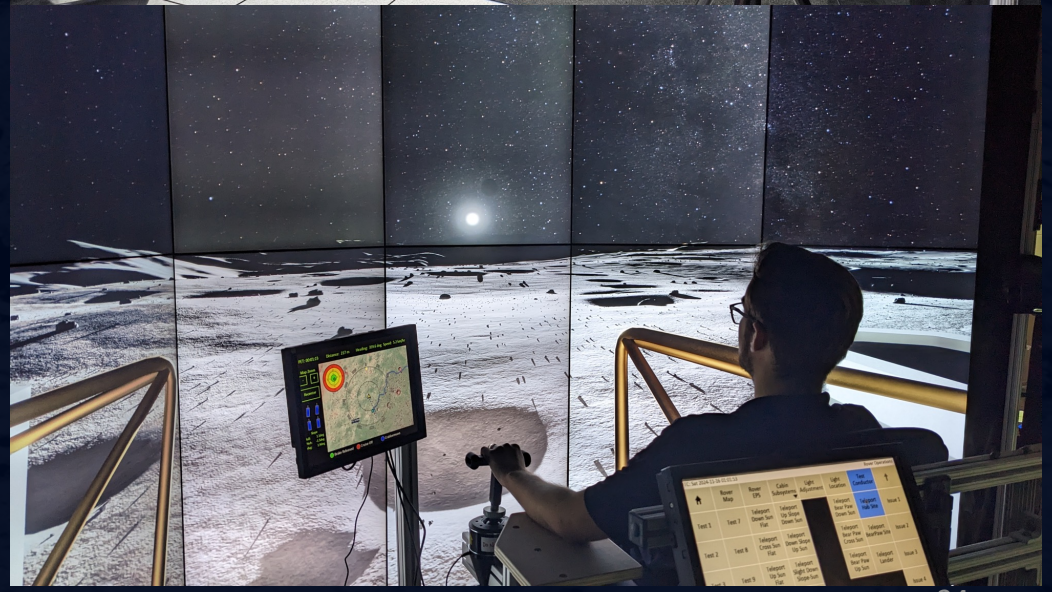
- An Internal Research and Development (IRAD) study to test the usability of the 6-dof motion table for LTV handling analysis.
- Streamed the MUD lunar surface environment into a VIVE Pro 2 VR headset.
- Participants completed tasks and gave feedback on the motion base and the simulation.
- The Conclusion: it's possible for participants to complete multiple hour in length sessions, with short breaks, in VR on the motion-base system.



Human-in-the-Loop LTV-EVA Lighting and Nav Study Phase 1

- Human-in-the-Loop LTV-EVA Lighting and Nav Study Phase 1
  - Video wall implementation of the DUST lunar terrain and Trick LTV simulation integration
  - Virtual Reality EVA Simulation using LAVA

- Focused on studying the effects of different lighting conditions on navigation and science exploration tasks.
  - Participants included astronauts and subject matter experts.
  - Tested procedures included:
    - Driving the LTV on planned traverses using the video wall with various lighting conditions.
    - Walking planned traverses in VR (LAVA) with different lighting conditions.



Human-in-the-Loop LTV-EVA Lighting and Nav Study Phase 2

- Human-in-the-Loop LTV-EVA Lighting and Nav Study Phase 2
  - Video wall implementation of the DUST lunar terrain and Trick LTV simulation integration using the Multi-Unreal Display (MUD) application.
  - Virtual Reality EVA Simulation using LAVA
  - Simulated Mission Control Center

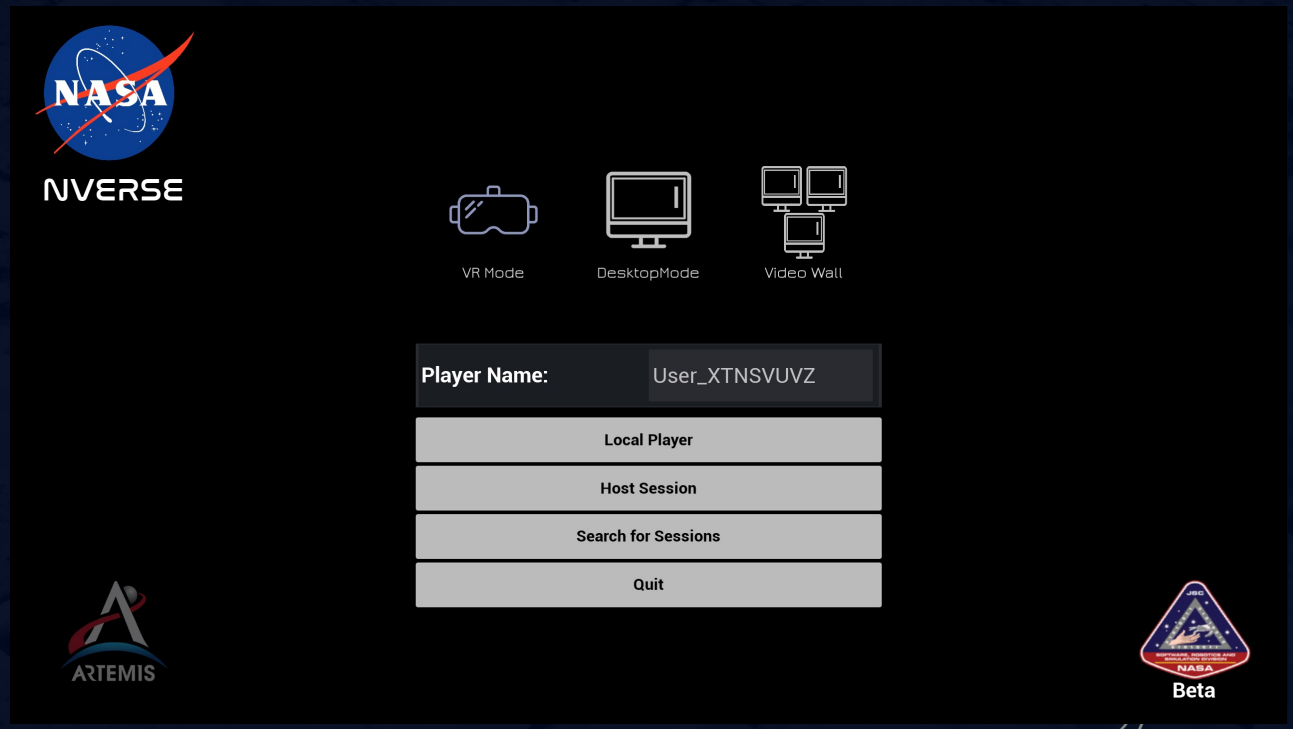
- Focused on studying preliminary Mission Control Center communications and functions during Lunar LTV-EVA operations.
  - Testing and evaluating possibilities of remote rover teleoperations to support Lunar EVA operations.
  - Other scenarios simulated included: communication outages, navigating to specific sites, remote rover operation time delays.

Future Work

NVERSE – NASA's Virtual Exploration Rendered Simulation Environment

- NVERSE represents the accumulation of our graphics simulation capabilities into a singular product

- Goal is to provide a diverse rendering environment capable of supporting all our current and future simulation environments
  - Virtual Reality
  - Video Wall
  - Domes and Projectors
  - Desktop Clients and Camera Views
  - Motion-base Simulator
  - Simulation Exploration Analysis Lab (SEAL)



Future Work

- Video Wall Improvements
- HITL LTV-EVA Lighting and Navigation Study Phase 3 and 4
- Future Lunar Navigation and Orienteering HITL Studies


Questions?

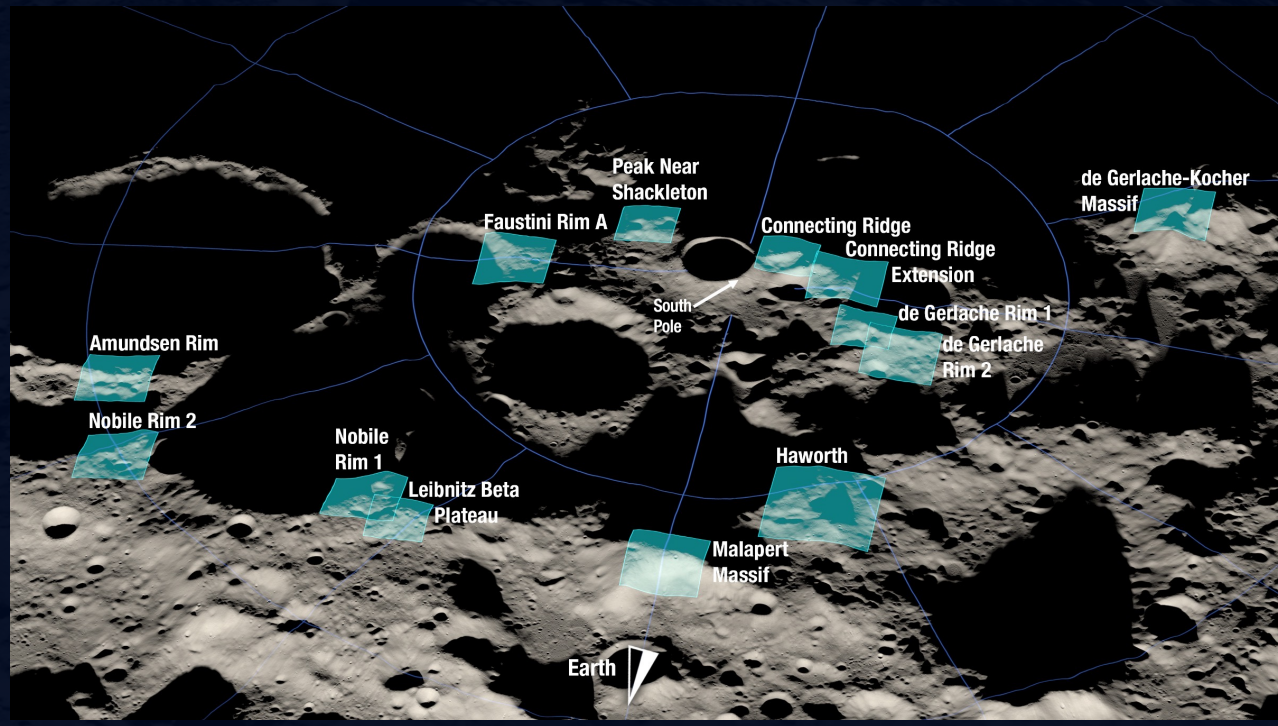
Extra

Resources

- Lunar Landing Research Vehicle https://www.nasa.gov/image-detail/amf-ecn-1606/
- KC-135 Tanker https://www.nasa.gov/image-detail/amf-ec79-11314/
- WIF and WETF https://www.nasa.gov/history/building-on-a-mission-neutral-buoyancy-facilities-for-spacewalk-training/
- One photo on slides 14, and one photo from slide 25, come from NASA Imagery Online Website
- Landing Site Image Slide 32 https://www.nasa.gov/news-release/nasa-identifies-candidate-regions-for-landing-next-americans-on-moon/
- First slide image: https://www.nasa.gov/mission/artemis-iii/

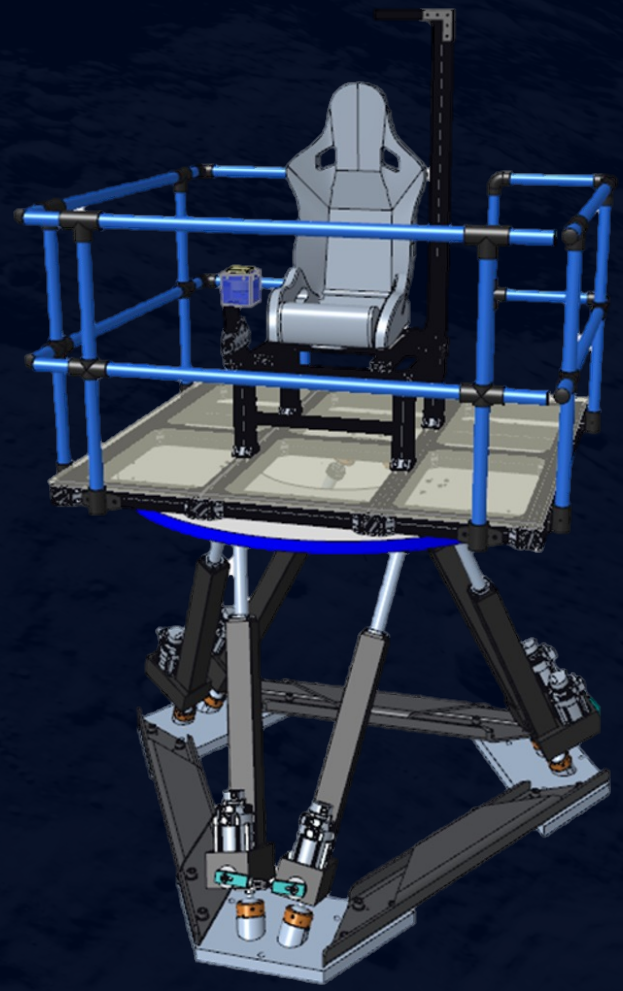
Immersive Technology – DLES

- Digital Lunar Exploration Sites (DLES)
  - An organized collection of Digital Elevation Models (DEM) provided by NASA's Lunar Reconnaissance Orbiter (LRO) and the Lunar Orbiter Laser Altimeter (LOLA)
  - JSC's Astromaterials Research and Exploration Sciences (ARES) team lead by Sam Lawrence removes instrumentation artifacts from the DEM files
  - Most of the data for the Lunar South Pole (LSP) is captured at 5 meters-per-pixel (mpp) resolution
- DLES Unreal Simulation Tool (DUST) MSC-27522-1
  - Provides a suite of capabilities for visualization and analysis in a high-fidelity digital model of the lunar surface
  - Built with the Unreal Engine 5 game engine



Motion-base Simulator and VR

- High performance 6 degree-of-freedom hexapod robot
- 1100kg payload capacity
- 1mm repeatability and accuracy
- Internally developed washout motion program that provides motion cueing and correlated vehicle attitude
- VR rendered to a wired HTC Vive Pro HMD
- Vive Tracker used to feedback table attitude to remove duplicated motion washout
- Trick-based lunar rover simulation



Active Response Gravity Offload System (ARGOS) Mixed Reality

- Integrates the LAVA Simulation with ARGOS to add an additional immersive element of 1/6th lunar gravity.
- Full body tracking with HTC VIVE Tracking Pucks attached to the hands, feet, and waist.
- Finger and hand motion can be tracked using Bebop Haptic Gloves.
- HTC VIVE Pro VR headsets were adapted to a helmet for safety.
- Stair mock-up for the lunar lander matches the stairs within the LAVA simulation and the positioning calibrated to match the lunar environment.

Immersive Technology – Additional Tools

- LURE – Lunar Unreal Replacement for EDGE
  - Bare bones lunar application that will provide the necessary hooks and plugins for visualization of LTV and HLS Lander Trick simulations

- LUTE – Lunar Unreal Terrain Exporter
  - Application that can export a polygonal model (Wavefront *.obj) of areas of the Lunar South Pole
  - Allows you to specify a specific area and the resolution of the terrain export model

- LEE – Lunar ER7 Example Project
  - A distributable Unreal Engine 5 project that utilizes the precompiled binary plugins necessary to render the lunar terrain and connect to a Trick simulation
  - Can be shared with partners (LARC, MSFC, etc.)