How NASA Is Using Simulations and Game Engine Technologies to Help Get Us Back to the Moon

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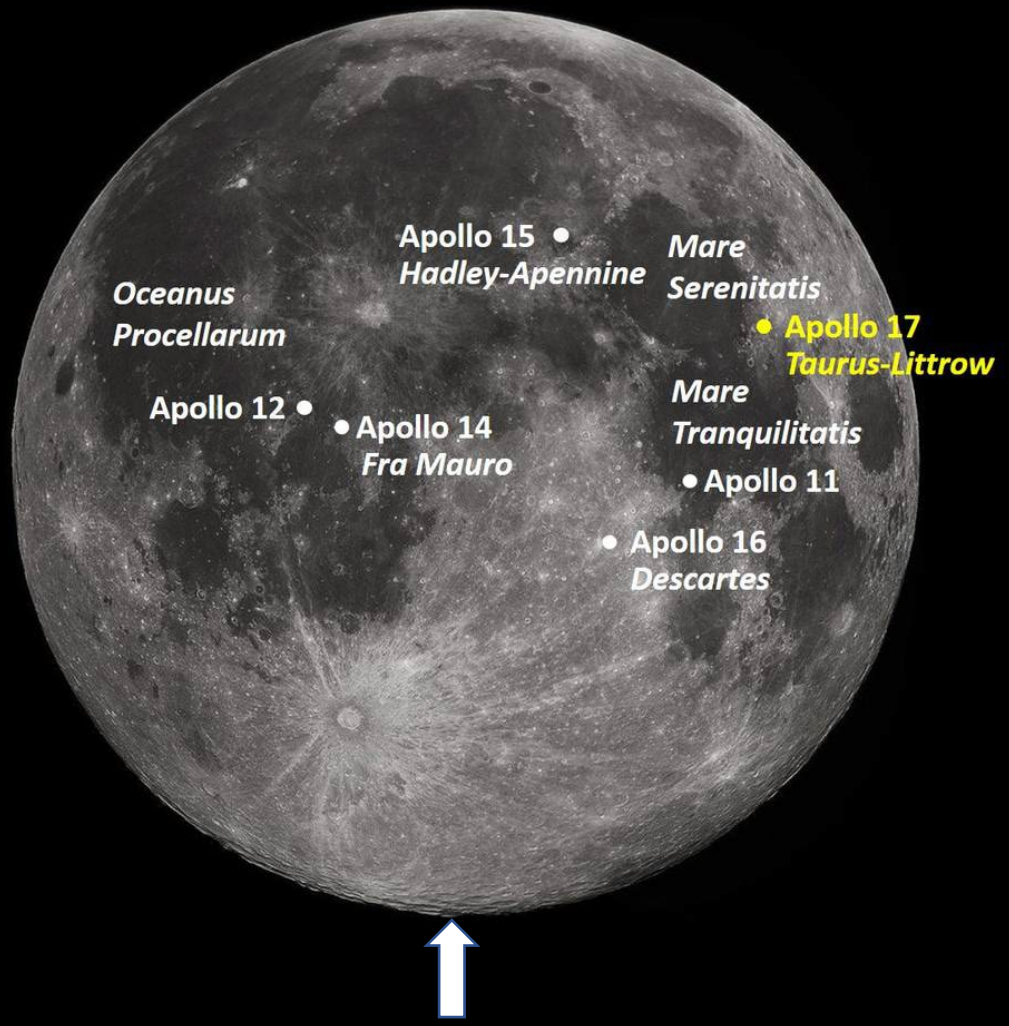
Agenda

- Purpose:
  - Overview of How NASA Is Using Simulations and Game Engine Technologies to Help Get Us Back to the Moon

- This presentation is:
  - ❑ Decisional
  - ❑ Directional
  - ✓ Informational
  - ❑ Action Item Closure / Status (Provide action number)

- Topics:
  - NASA is Going Back to the Moon
  - Lunar Simulation and Visualization Software in Support of Artemis Mission Analysis and Training
  - Overview of Lunar Visualization
  - Unreal Engine Simulation Products and Capabilities
  - Questions

NASA is Going back to the Moon to find Water Ice on South Pole



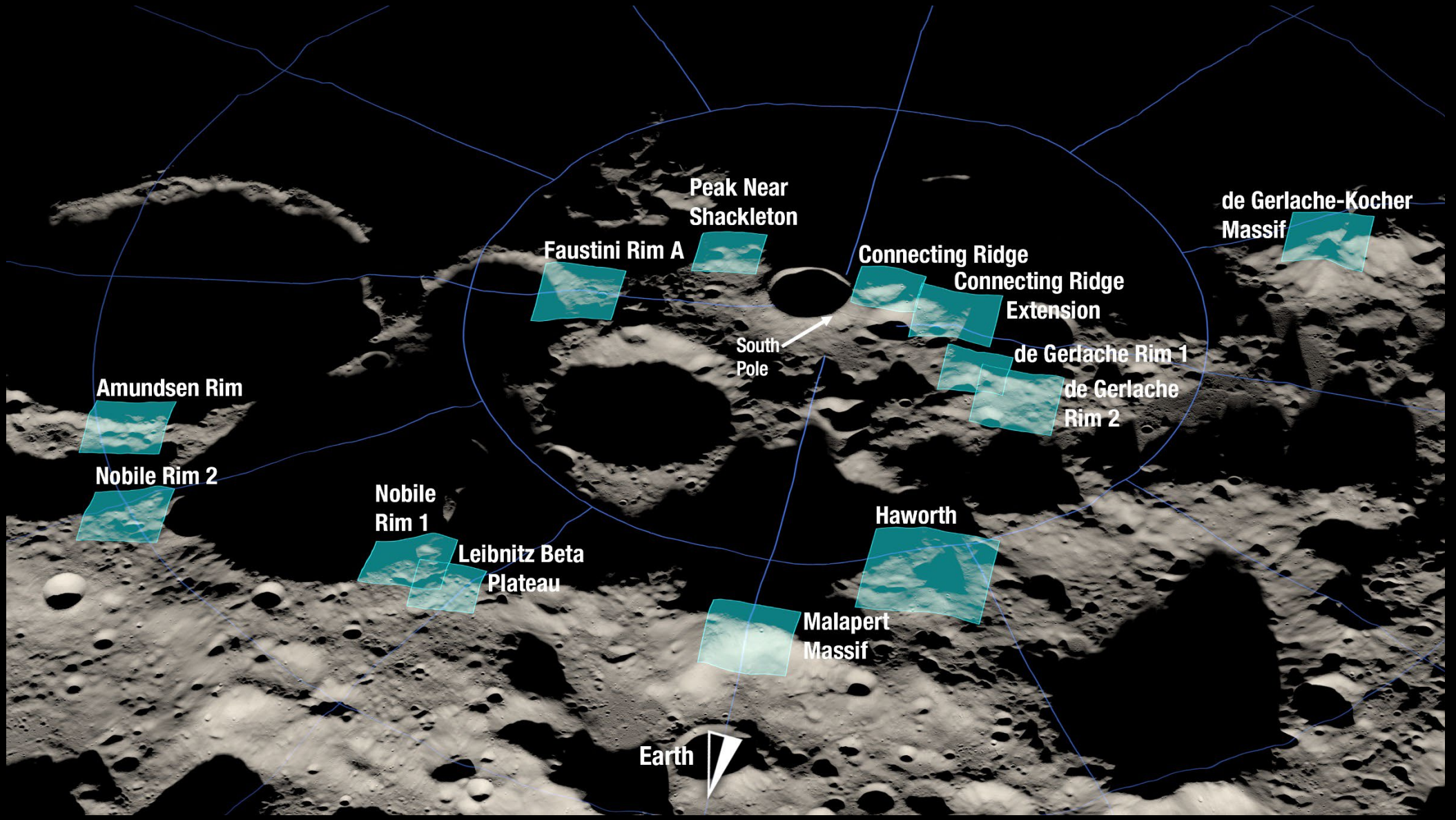
Artemis III, no earlier than Nov. 2025 landing at South Pole near Shackleton Crater

Apollo 17 – Last Time on the Moon (1972)

Lunar South Pole

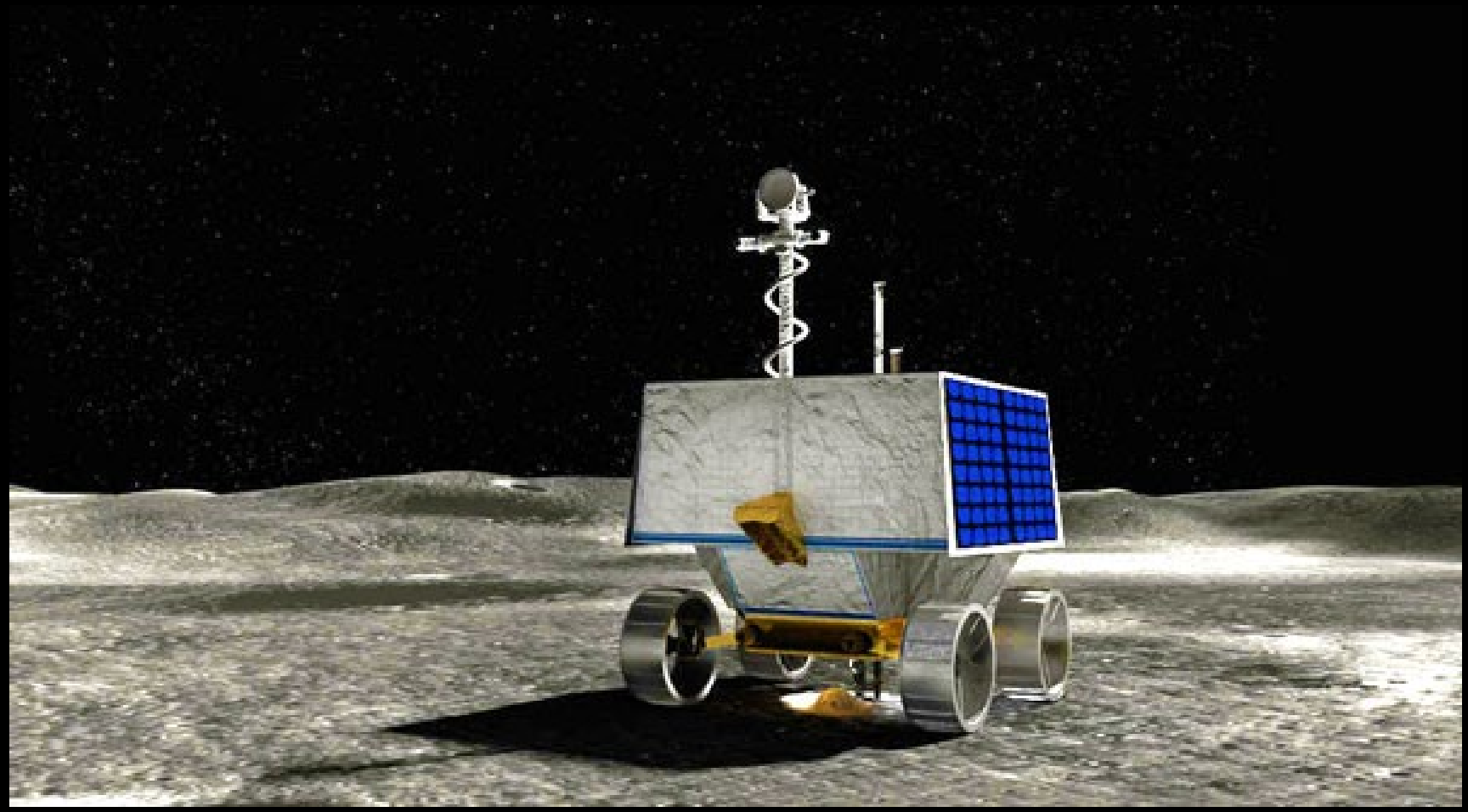
- Lunar South Pole has harsh lighting conditions
  - Moon axis is near vertical (1.5 degrees)
    - Best lighting conditions at exact South Pole are with Sun at 1.5 degrees above horizon
    - Time of year and surrounding terrain impacts lighting conditions dramatically
  - 1 lunar cycle = 29.5 Earth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

13 South Pole (84 South Latitude) Landing Sites Being Considered



NASA's VIPER (Volatiles Investigating Polar Exploration Rover) Mission

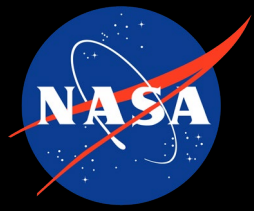
- Unmanned science rover planned to land on South Pole west of Nobile Crater in late 2024
  - Resource mapping mission to find water ice



VIPER Landing Site (West of Nobile Crater) Lighting Study Video

Developed in Unreal5
1mpp Shape From Shading (SFS) terrain plus added small craters & rocks (upscaled to 20 cm per pixel)
With Global Illuminations/Reflections

How Simulation and Visualization Applications are Helping NASA Get Back to the Moon



- NASA is using simulation and visualization software to create Lunar South Pole virtual environments for early navigation and lighting studies/analysis, mission planning and training
  - Desktop visualization applications – Digital Lunar Exploration Sites (DLES) Unreal Simulation Tool, or DUST
  - Lander Human-In-The-Loop (HITL) real-time simulations
  - VR for Lunar surface Extra-Vehicular Activities (EVAs)
  - Lunar Terrain Vehicle (LTV) rover HITL real-time simulations
- Trick based dynamic simulations
  - Trick is a NASA built Open-Source C++ simulation architecture tool
- Unreal5 visualization software

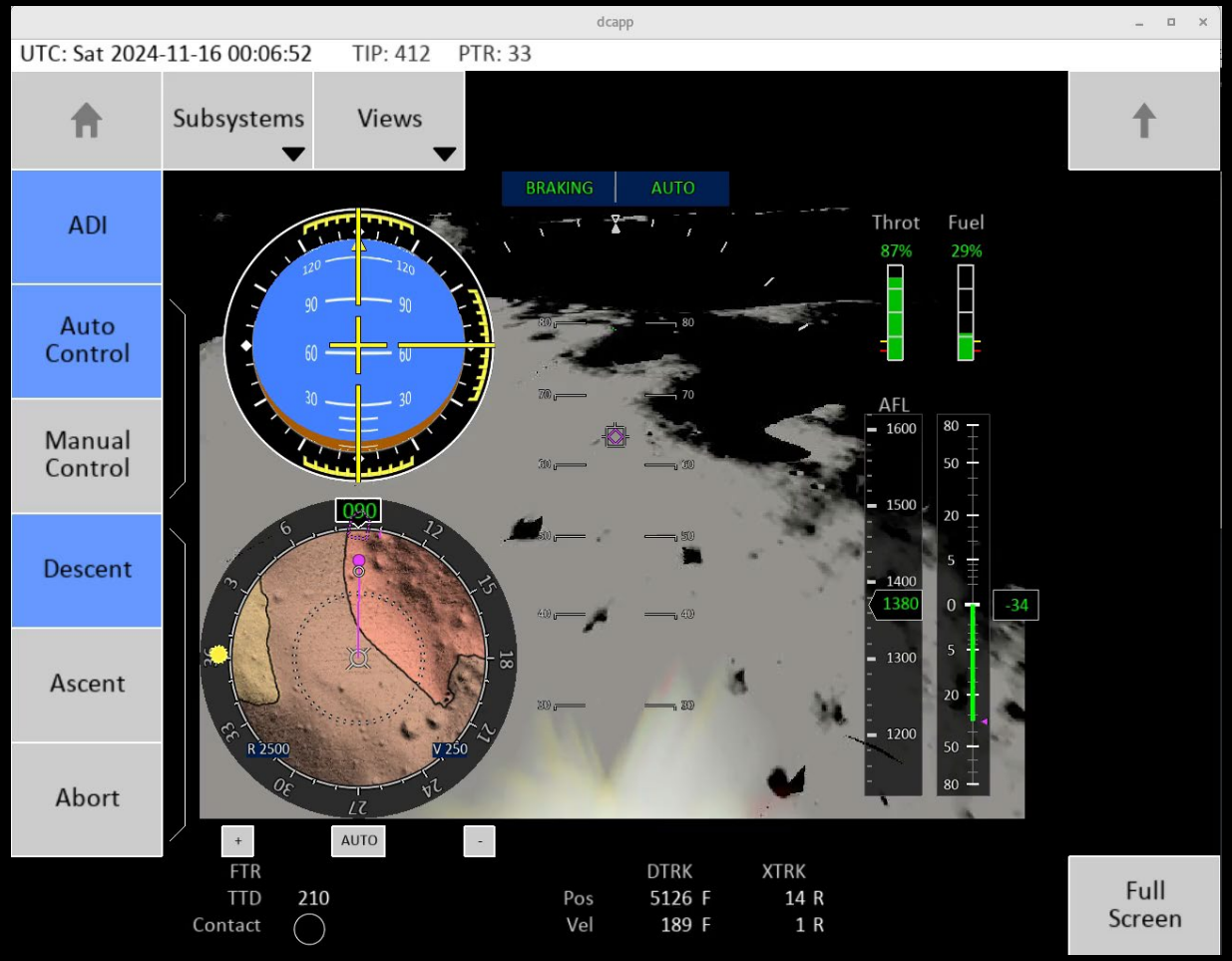
Unreal5's Important Visualization Capabilities

- Double precision
- Rendering real-time performance
- Lighting and reflections
- Terrain rendering from Digital Elevation Maps (DEM)
  - Real-Time rendering from LRO (Lunar Reconnaissance Orbiter) collected DEM data available at Goddard's PGDA website
    - Available at up to 5 meters per pixel for 84 South Latitude and Artemis landing sites
  - Upscaled synthetic terrain to 20 centimeters resolution with added craters and rock distributions
- Multi-player VR with networked state management

NASA Unreal5 Lunar Visualization

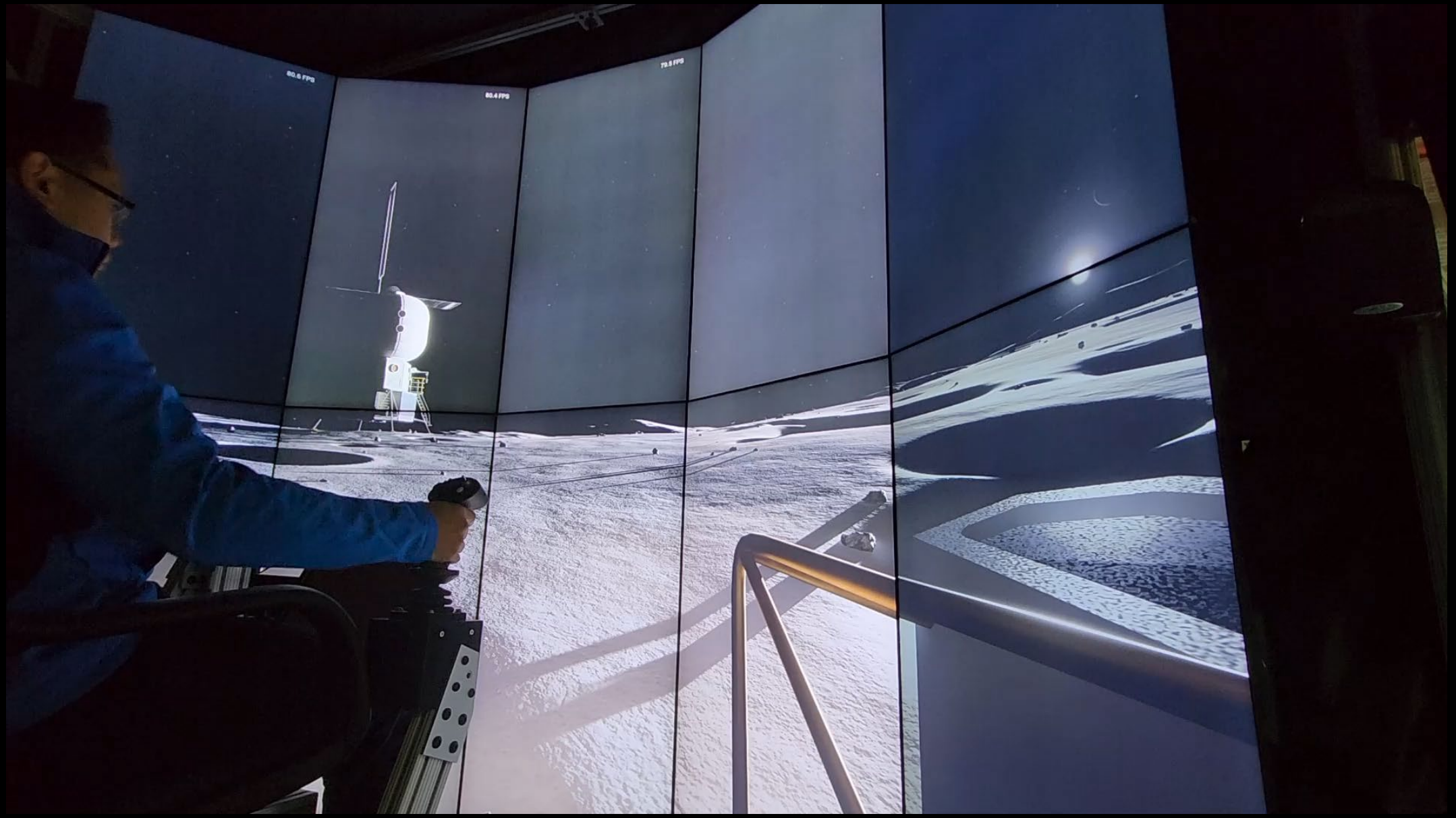
- Desktop tools/trainers with out-the-window, camera and birds-eye views
- Video Walls and projectors with Unreal nDisplay
- Virtual Reality for HITL EVA navigation traverse studies
- Mixed Reality – Varjo XR3 HMD

Desktop Trainers – Lunar Lander Simulation

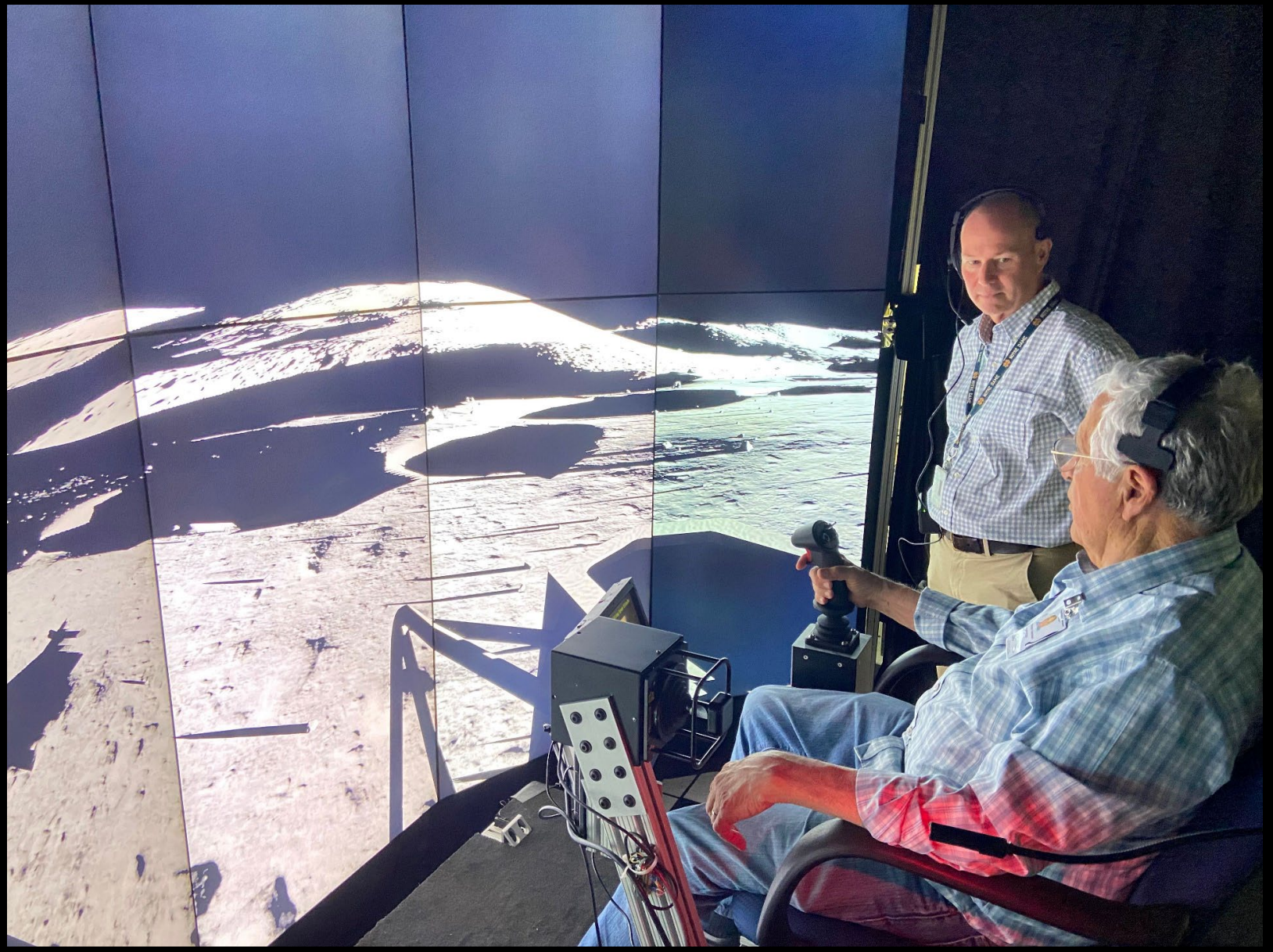


Desktop Trainers – Lunar Lander Simulation

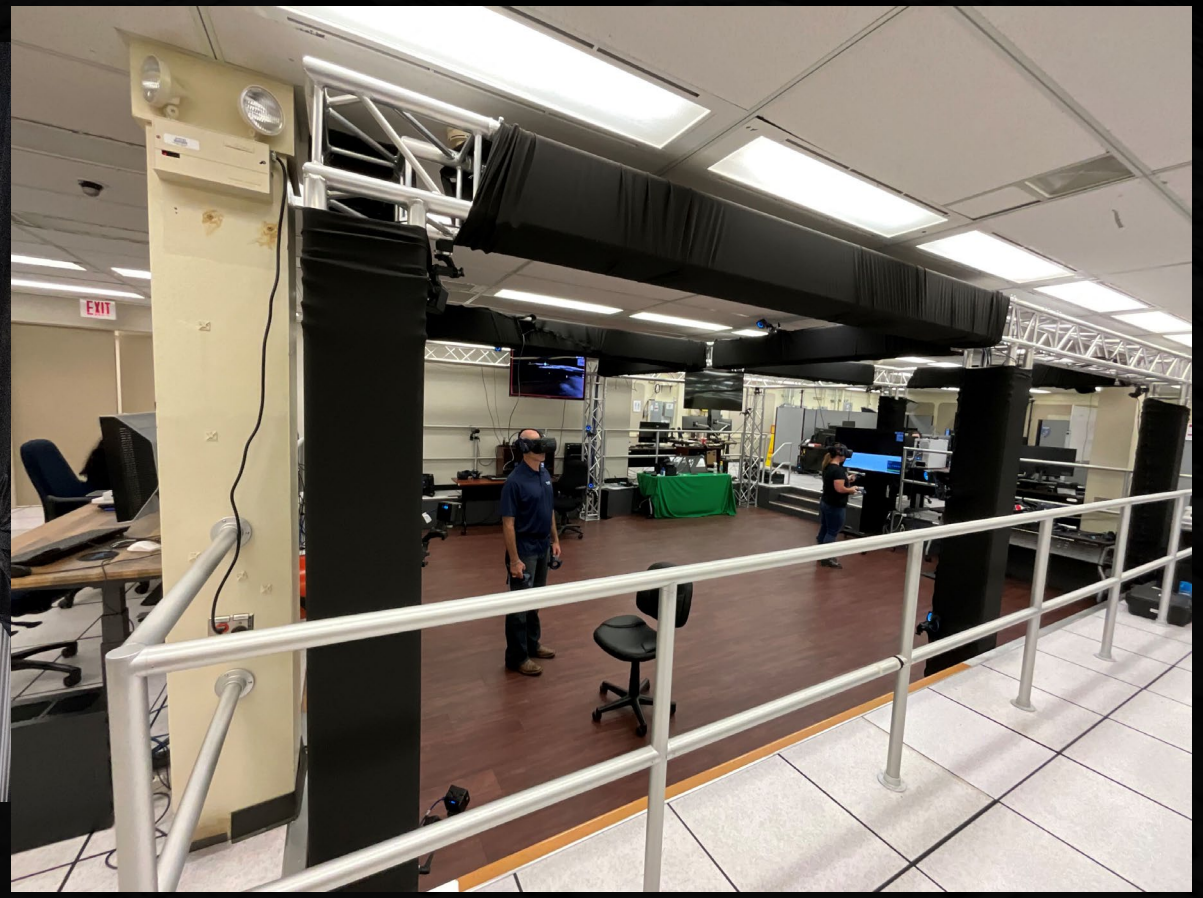
Video Wall – Rover Simulation



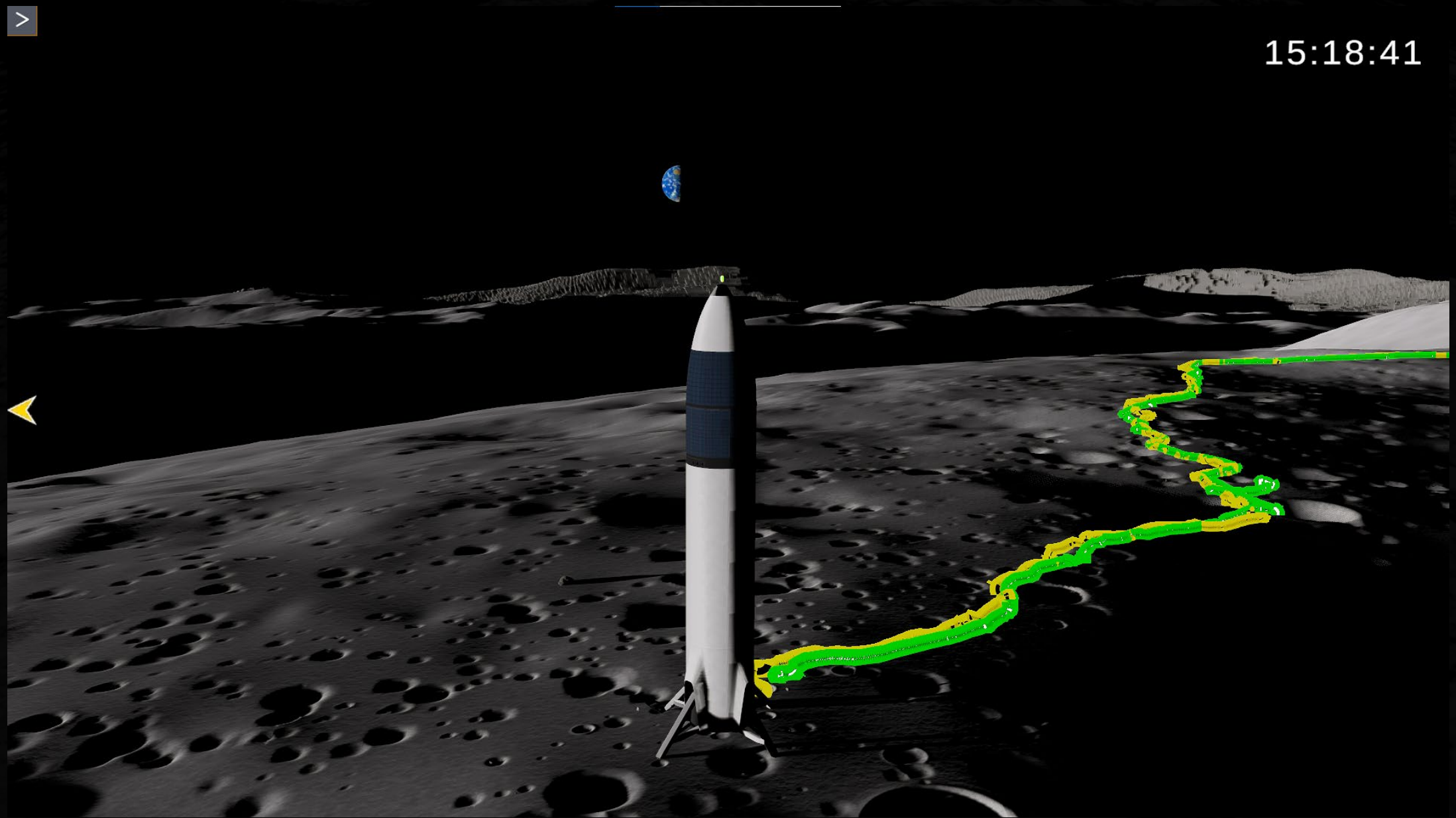
Video Wall – Rover Simulation – Jack Schmitt (Apollo 17 Astro)



Virtual Reality for Human-in-the-Loop Studies



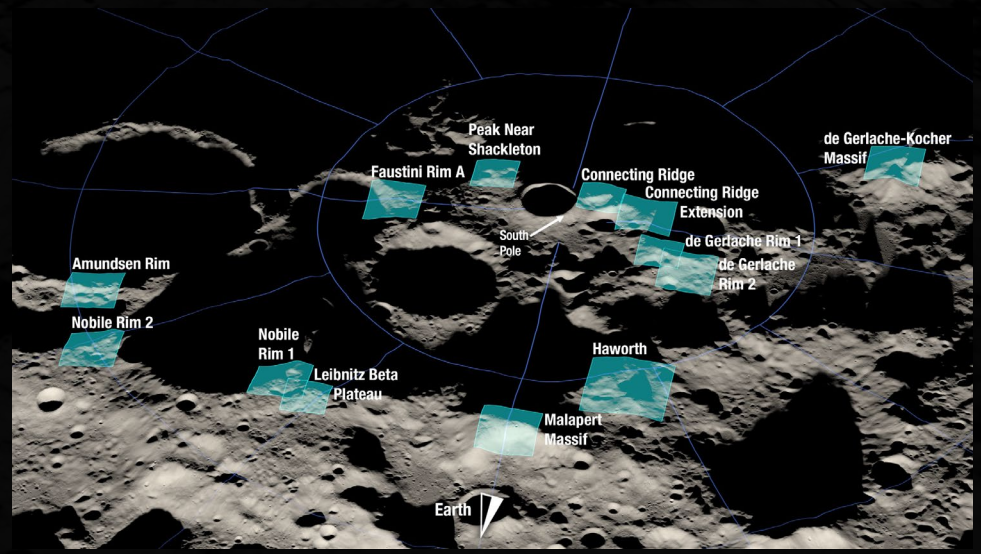
Virtual Reality for Human-in-the-Loop Studies – EVA Traverse



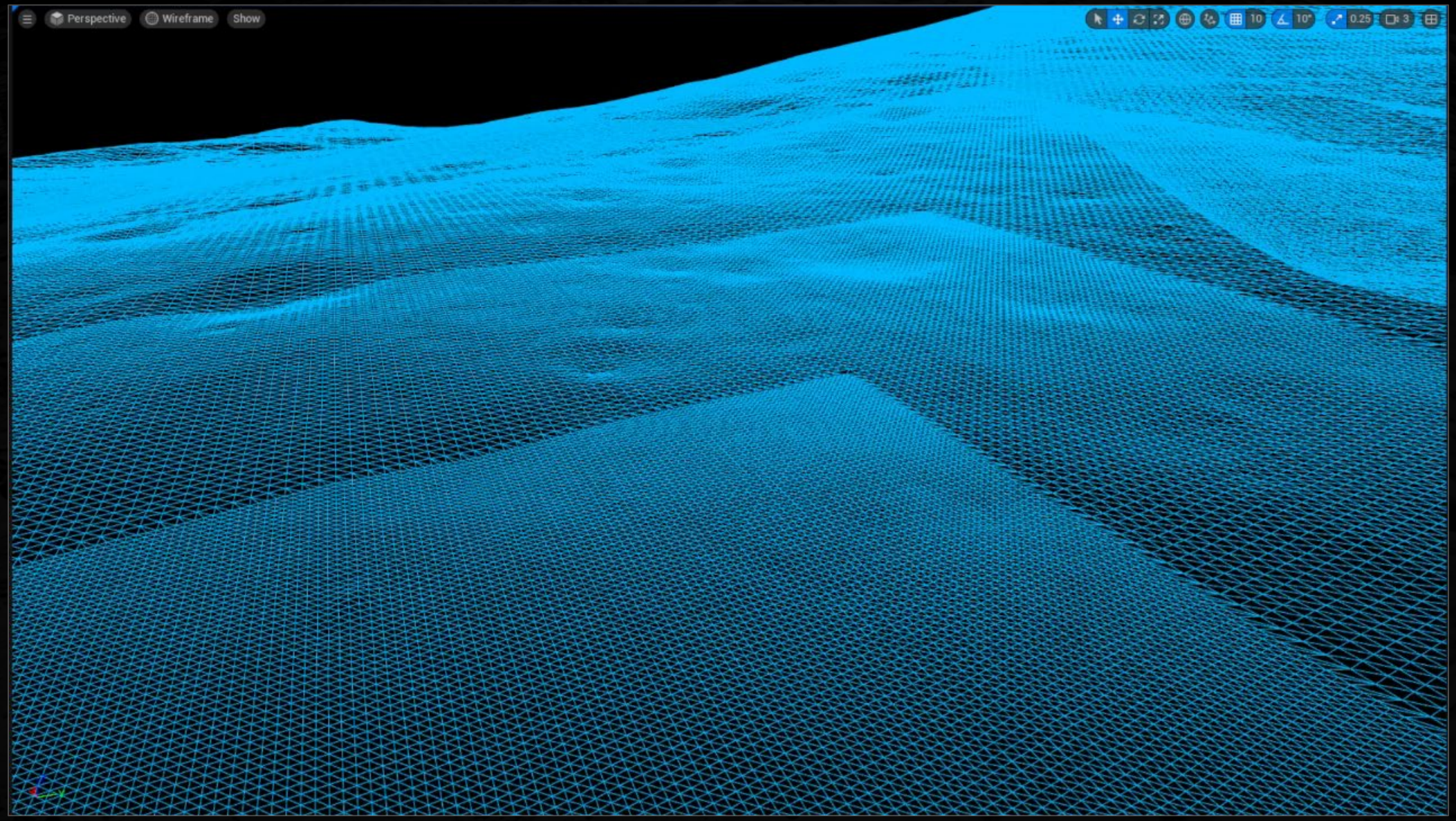
Varjo XR-3 Mixed Reality Lunar Lander Prototype

Overview of Lunar Visualization

- 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)
  - Most of the data for the Lunar South Pole (LSP) is captured at 5 meters-per-pixel (mpp) resolution
  - Upscaled DEM files that include sub-pixel surface features (craters) that are representative of the regions of interest that are not captured by the LOLA instrument
- Persistent Object Database (PODB)
  - Contains a collection of rock models from scanned Apollo rocks
  - Database of rock positions, orientation, and scale crafted to be representative of the regions of exploration
  - Can be extended to track rover tracks, tools, and other surface assets



Overview of Lunar Visualization - Clip Map Terrain



Overview of Lunar Visualization - Lunar Terrain

Developed Plugins and Tools

- CUT – Clip map Unreal Terrain
  - Provides clip map terrain rendering of the Lunar South Pole via loaded DEM files
  - Uses GDAL (Geospatial Data Abstraction Library) function calls to georeference clip map vertices and calculate 3 axis curvature
- TUC – Trick Unreal Connector
  - Unreal Engine plugin that provides a general adapter for connecting with Trick simulations
  - Configurable in Editor to assign simulation state variables to actors in your UE5 scene
- SCP – Site Crafting Plugin
  - Unreal Engine plugin that provides a suite of tools for crafting lunar environments
  - Rock Crafting-PODB rock placement-Procedural rocks for select site crafting-Dynamic runtime procedural rock generation
  - Crater Crafting-PODB crater placement-Procedural select site crafting
  - Model Placement-Accurate placement via in-editor GUI lat/lon selection
- UE5Pixel-Restreamer
  - Provides MJPEG and other codec web streaming of Unreal Engine scene to NASA's Displays and Controls Application (DCApp)

Developed Plugins and Tools cont.

- LUTE – Lunar Unreal Terrain Exporter
  - Application that can export polygonal models (Wavefront *.obj) of areas of the Lunar South Pole
  - Provides the user the ability to specify a specific area and the resolution of the terrain export model
- GAS – Graphical Astrodynamics Simulator
  - Unreal Engine plugin that provides a simple interface for creating orbital dynamics simulations
  - Supports both ephemeris-propagated and integrator-propagated spacecraft simulations
  - Gravitational (spherical and geopotential) force models
- LEE – Lunar Exploration Example
  - Unreal Engine project that includes precompiled plugins for lunar environment terrain rendering
  - Includes the necessary components for lunar surface simulations
  - Distributable to other NASA centers and partners (requires Software Usage Agreement, SUA)

GAS Demo Video

Digital Lunar Exploration Sites Unreal Simulation Tool (DUST)

- Designed for us in site inspection, mission planning, and analysis of lunar landing and traverse sites in support of the Strategy and Architecture Office (SAO), Human Landing System (HLS), EVA and Human System Mobility Program (EHP), and Artemis Base Camp

- Provides a suite of capabilities for simulation, visualization, and analysis in a high-fidelity digital model of the lunar surface

- A generic version of the tool will be available publicly on NASA's software catalog very soon

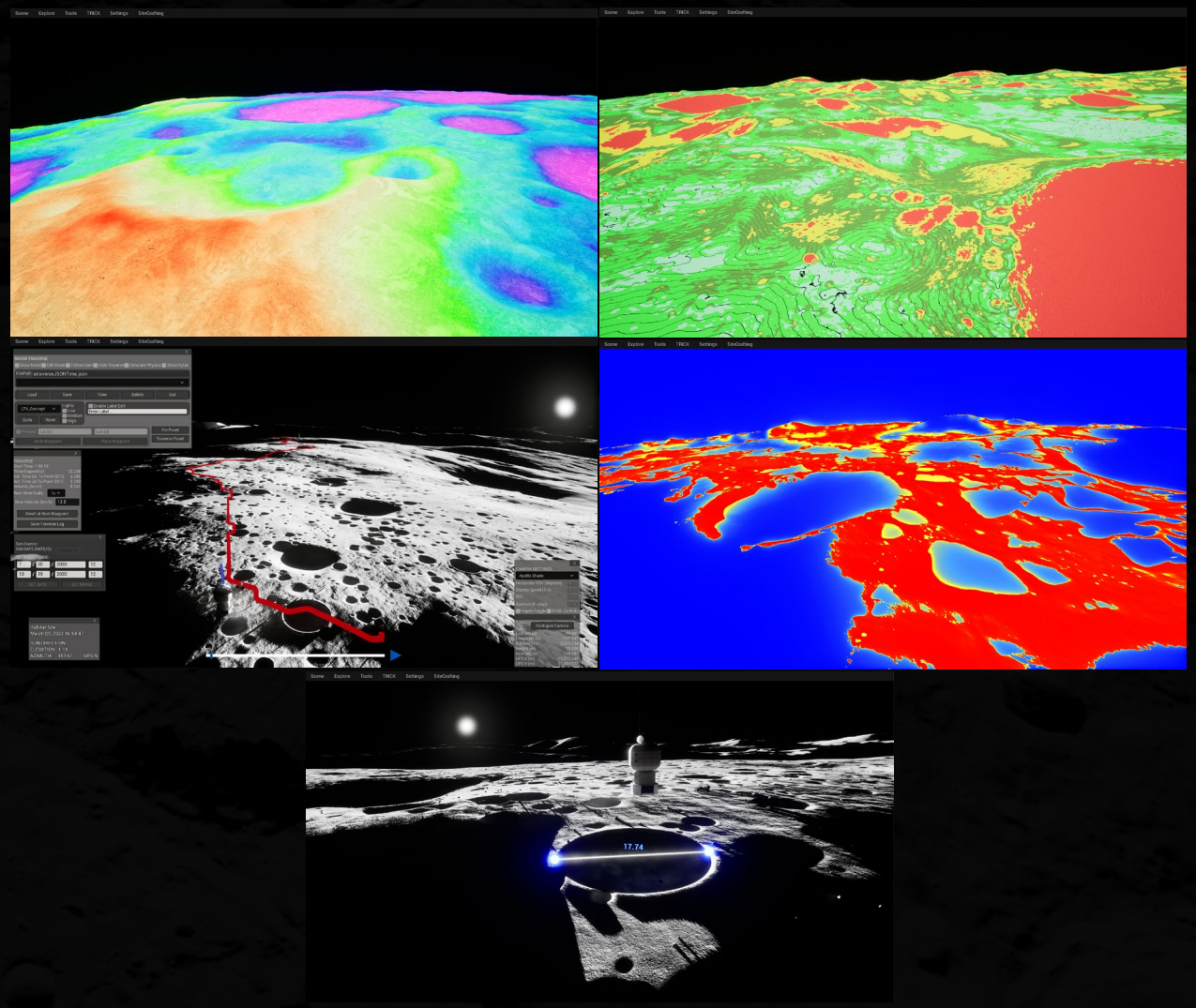
  https://software.nasa.gov

DUST Capabilities Overview

- SPICE Integration
  - A toolkit developed by NASA to track the positions and orientations of planetary bodies and spacecraft
  - Provides an API that reads kernel datasets containing information about the tracked objects over a timeframe
  - Provides the Sun and Earth positions and orientations in DUST with respect to the Moon's planet-fixed coordinate frame
- Trick Integration
  - A NASA developed open-source simulation environment that provides an architecture for simulation development
  - DUST provides an interface to connect to a Trick simulation over a socket and provides a visualization environment of the physics-based simulation (e.g. rover, lander, etc.)
- Persistent Object Data Base (PODB) Integration
  - A NASA generated database with a web API wrapper that stores positional data of persistent synthetically added lunar objects such as rocks and craters
  - The DUST PODB integration tool queries the PODB API for rock data in any designated region and allows you to visualize these rock distributions within the tool

Capabilities Overview cont.

- Rover and EVA Traverse Visualizer
  - DUST can parse rover and EVA traverse data and display it on the simulated lunar surface
  - Waypoints can be edited in real-time and exported
  - Visualize a rover or suited crew person following the traverse with respect to time
- Communication (Line-of-Sight) Visualizer
  - Communication towers can be placed on the surface, and their range and occlusion can be visualized to determine where on the terrain the signal would reach with the specified tower configuration
  - Gateway and Earth LoS
- Topography Visualizer
  - DUST can generate slope map analysis with contour lines overlaid across all rendered lunar terrain
  - Elevation map data can be automatically calculated and displayed in place of slope data
- Measuring Tool
  - Provides 3D measuring capability in meters between user specified locations



DUST – Video

Multi-Unreal Displays (MUD)

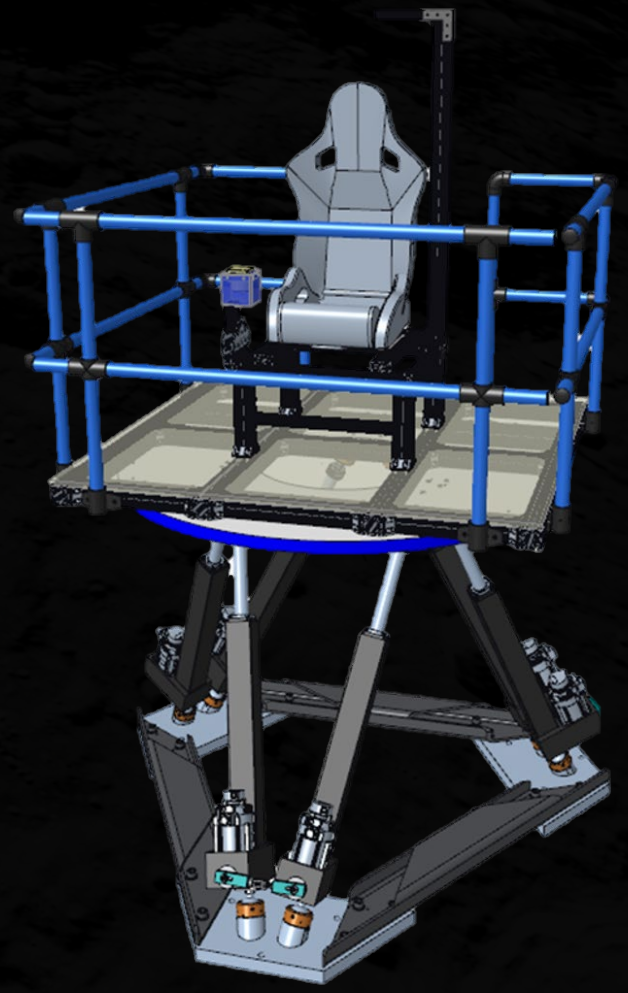
- MUD is a simulation product that integrates Unreal Engine's nDisplay capability and a video wall in support of Human-in-the-loop studies

Simulated Mission Control Center for Human-in-the-Loop Studies

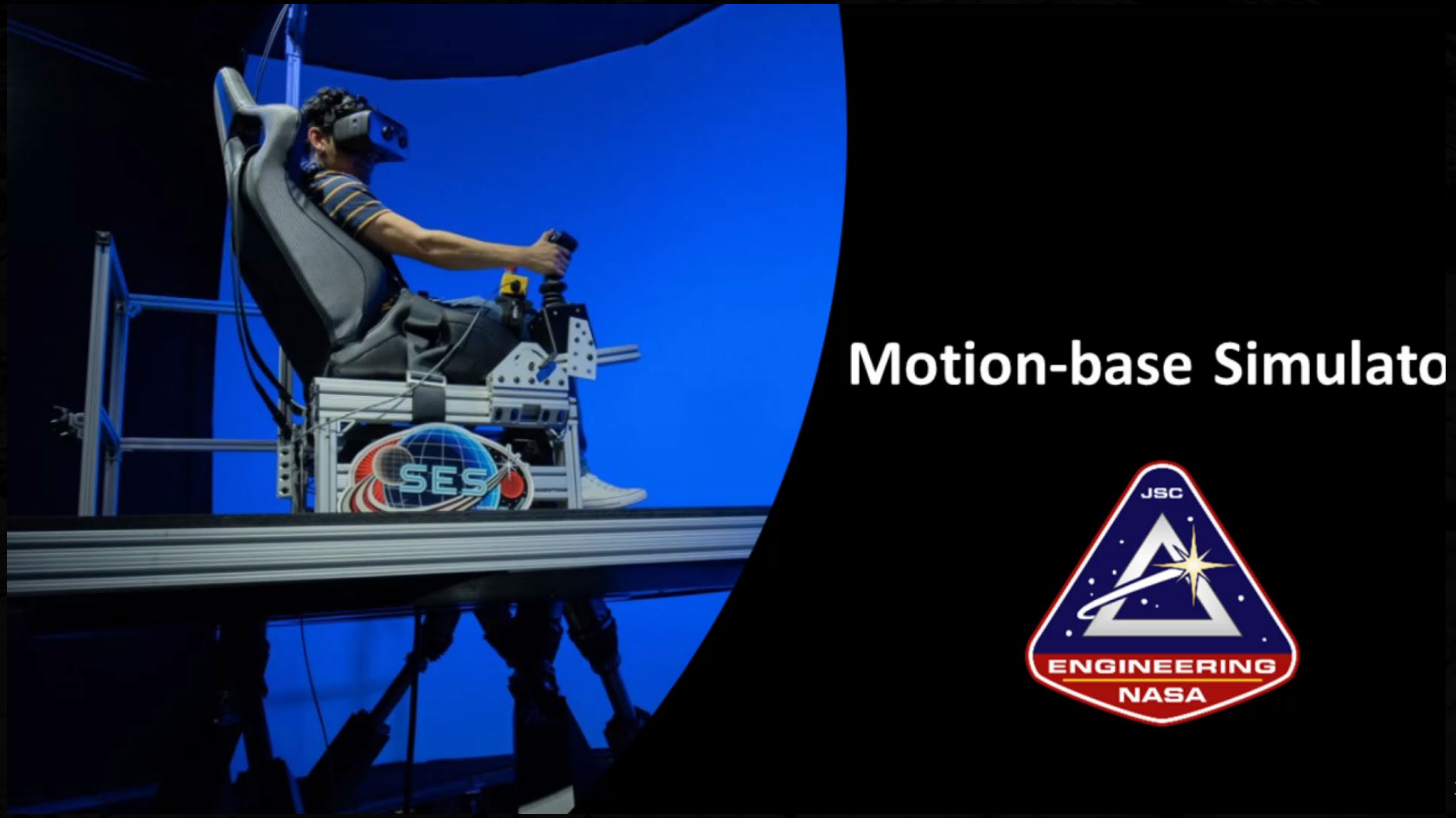
Apollo 16 Astronaut Charlie Duke

Motion-base Simulator and VR

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



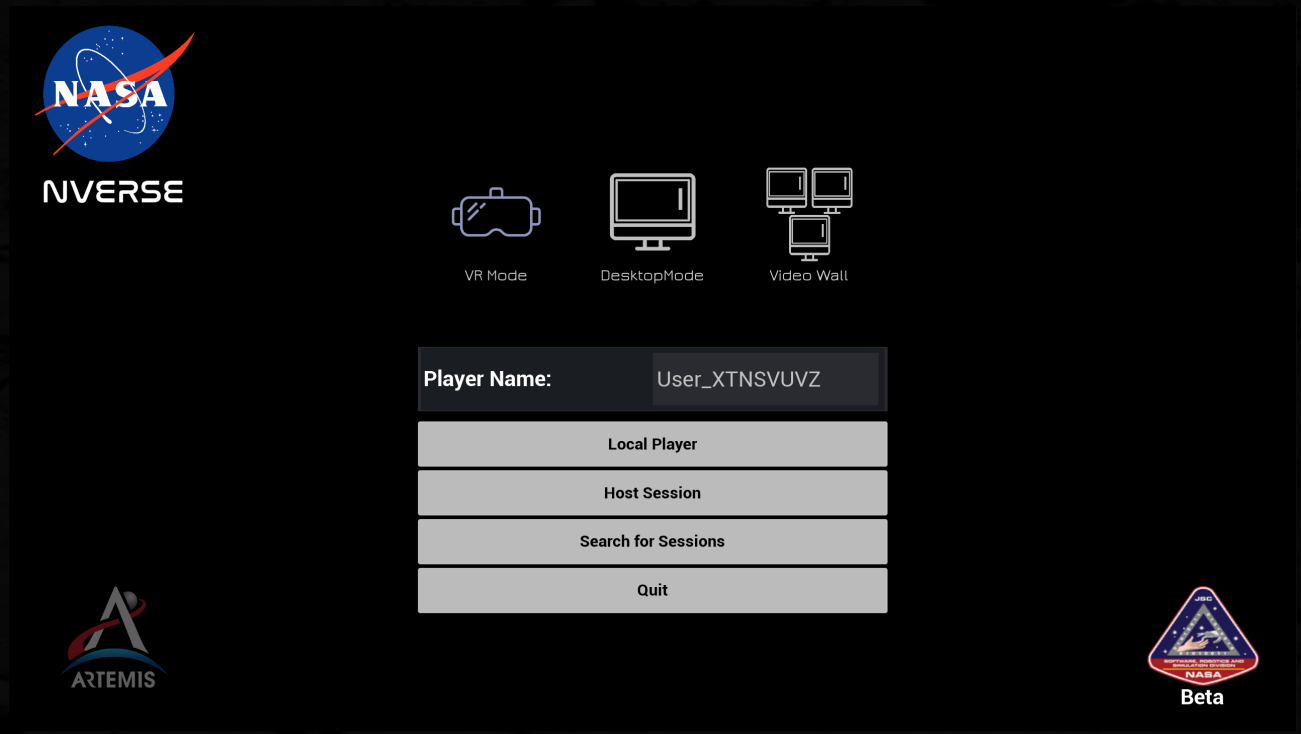
Motion-base Simulator and VR Video



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)



NVERSE EVA VR Video

Questions