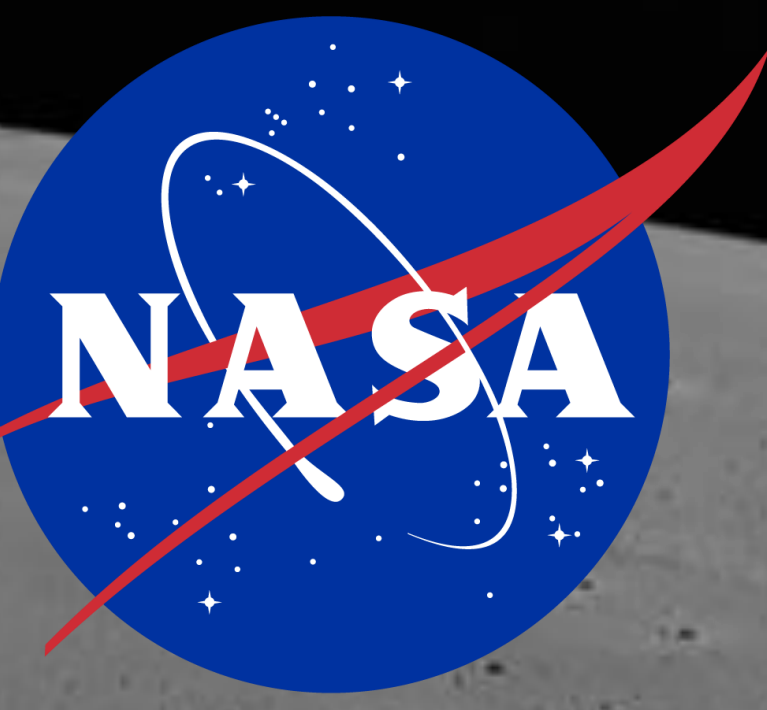


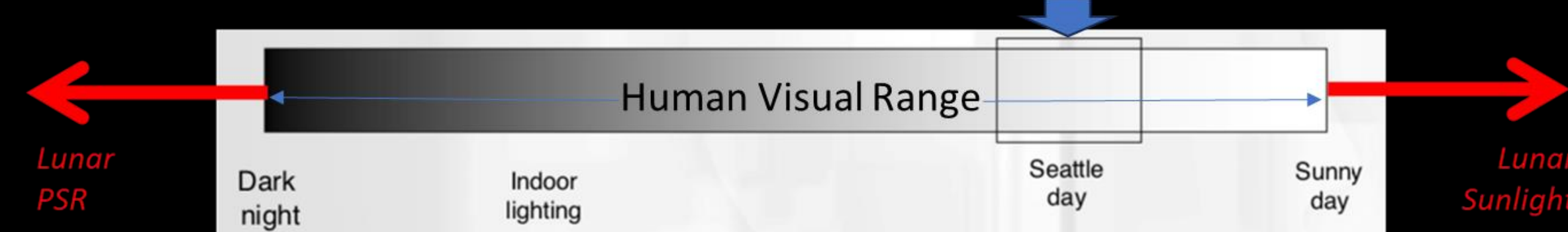
Simulation of Lunar South Pole Lighting Environment For Task Analysis



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INTRODUCTION

- Artemis missions will travel to the lunar south pole (LSP) due to the location's potential for water ice and its suitability for a lunar outpost.
- However, the optical environment of the LSP is very harsh, and difficult for astronauts to function in, due to:
 - A permanent low sun angle** – the sun will never go more than 4-7° above the horizon, resulting in very long shadows
 - The sun orbiting the pole approximately every 28 days – **shadows will move 12.86° per Earth day, which equates to ½° per hour**
 - A lack of atmospheric diffusion** – extremely bright light and dark shadows, creating a large dynamic range in which the human eye needs to function
- Unfortunately, the limitations of human vision in high contrast environments spans about 3 orders of magnitude of brightness at any given accommodation in the visual range.



- This presents a great risk to lunar surface EVA tasks that involve the human-vision of the crew, including but not limited to:

- Lander ingress/egress
- Inspection/monitoring of vehicles and payloads
- Deployment/operation of instruments and payloads
- Observation-based science
- Sample collection
- Ambulatory exploration



"Boy, that sun is bright... It's just like somebody's got a super-bright spotlight." -Pete Conrad, Apollo 12 EVA 1

OBJECTIVES

In order to characterize and explore this problem, this project is developing ways to simulate the optical environment of the lunar surface and complete human task assessments within it.

- 1) Virtual Reality Lunar Environment
- 2) Physical Lunar Environment Mockup
- 3) Human Task Assessments



An astronaut takes a photo of their shadow during a lunar EVA.

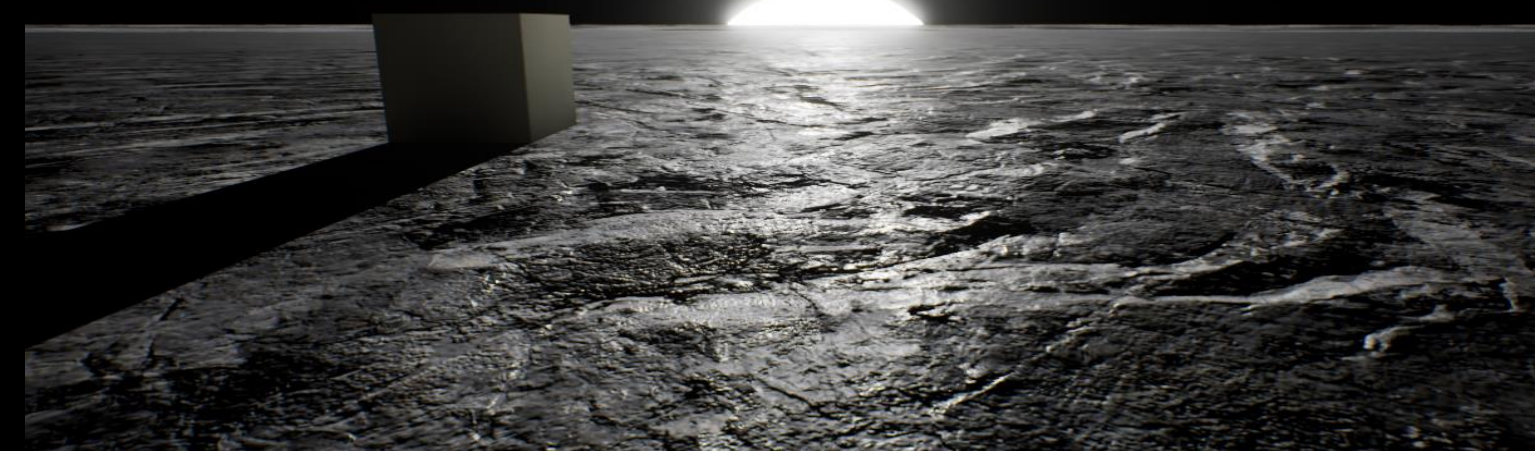
The original lunar environment mockup at the Flat Floor Robotics Lab (FFRL).



METHODS: Virtual Reality

Virtual Lunar Environment

- The VEL, located in 4705, features **VR** and **motion capture (MoCap)** capabilities. Using Unreal Engine 5, VEL engineers are generating a virtual environment of the LSP.
- Assessment participants will wear a VR headset and MoCap suit, which will enable their virtual "presence," complete with casting a shadow.
- Several environmental effects must be taken into consideration and replicated virtually:
 - Sun angle/position
 - Lunar surface terrain
 - Reflectivity of lunar regolith
 - Reflectivity of EVA suits, vehicles, other materials



Screenshot from Lunar Surface Lighting simulation, in development in the VEL (Unreal 5)

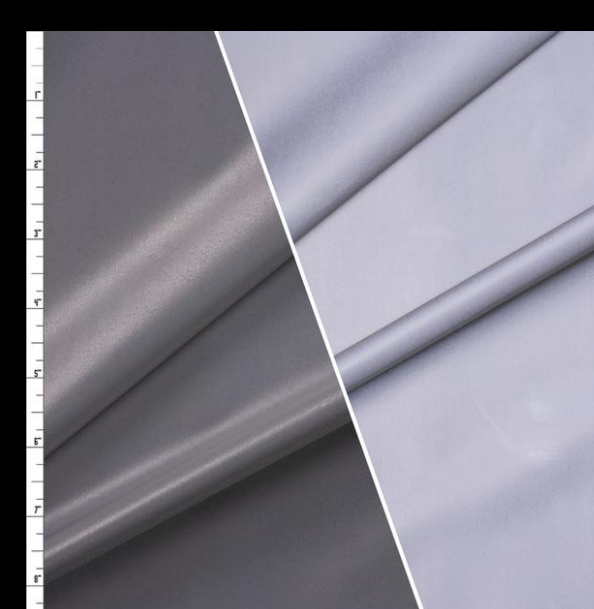
Virtual Assets/Models

- To support task assessment, a 3D model of a lunar lander will be built. This will be imported into the virtual environment with material/reflectivity representative of materials used on lunar lander vehicles.

METHODS: Physical Mockup

Lunar Lander Mockup

- A mockup of a lunar lander will be designed and constructed to enhance the simulation, and for use in the task assessments. It will be illuminated along with the lunar surface mockup.



Reflective Fabric

- Reflective fabric will be used to line the floor of the simulation, as well as foam rocks, to simulate both the optical properties and the geometry of lunar regolith.

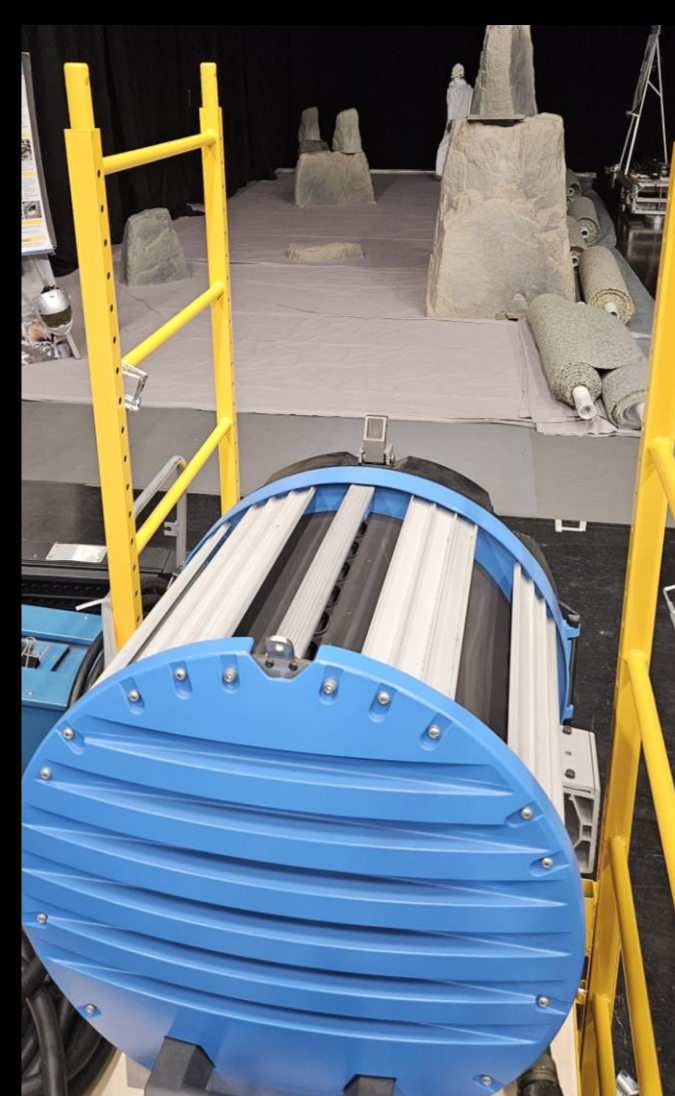
Space Suit Mockups

- Participants in the human task assessments will be outfitted with space suit mockups, provided by the University of North Dakota, to simulate what astronauts on a lunar EVA will be experiencing



Solar Simulator

- The FFRL is outfitted with an array of 12 kW movie lights that will be used to simulate the harsh lighting from the sun. The array can also be translated the length of the lunar mockup to simulate the sun's movement in the sky, and the subsequent change in shadow location within the mockup.



ANALYSES

Functional Task Analysis

- When the virtual and physical lighting environment simulations are complete, functional task analyses will be conducted. This will involve participants of varying age, size, etc. entering these environments and walking through a collection of tasks.
- These assessments will focus on vision-based inspection tasks the crew will need to perform near the lander, such as:
 - Inspecting landing struts for damage
 - Inspection lander hull for damage, some of which could be located above their heads
 - Climbing up and down the bottom ladder portion present in Blue Origin's HLS lander concept
- This analysis will inform lighting and task requirements for future Artemis missions.

Physical vs. Virtual Lighting Simulation

- Physical and virtual lighting simulations have both been used throughout the Agency for analysis of lunar surface lighting conditions and their impacts on architecture, operations, etc.
- There are pros and cons to each method;
 - Virtual simulations can be easily re-configured and adapted to different conditions; generally, they are not limited by space and available facilities
 - Physical lighting of proper brightness can better replicate real-world experience for human vision; computer displays cannot get close to the light levels that arc lamps, plasma lights, and other bulbs can
- Conducting task assessments with both methods will allow for detailed documentation of comparisons, and insight gained from both methodologies.

FUTURE WORK

- Once developed, the virtual and physical lighting simulations will be used to address other concerns related to the lunar lighting environment. A VR environment can be used for surface architecture development through the use of digital assets. Both VR and physical lighting simulations can support similar task analyses for space habitats, which MSFC is the lead center for.
- The lander mockup, with fidelity limited by available data, can be improved as more design details come to life. The size of the FFRL facility allows for support of large-scale mockups for other lunar surface assets, such as rovers and payloads.

Acknowledgements

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