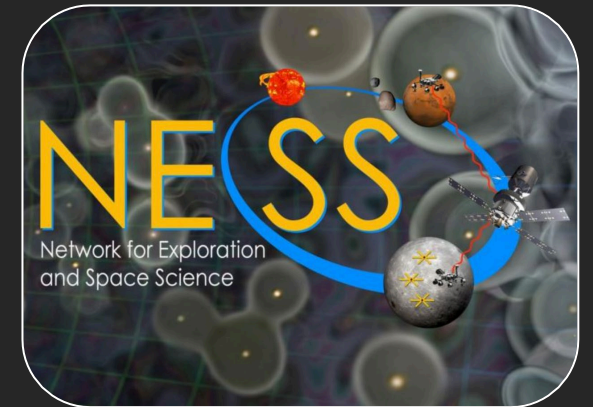




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# Mixed Reality Interfaces for Lunar Robot Supervision and Teleoperation



Michael Walker, Jack Burns, and Daniel Szafir

CU Boulder NESS Team & IRON Laboratory

# Traditional Robot Teleoperation Interfaces





# Virtual Reality Headsets



# VR Headsets and Robots

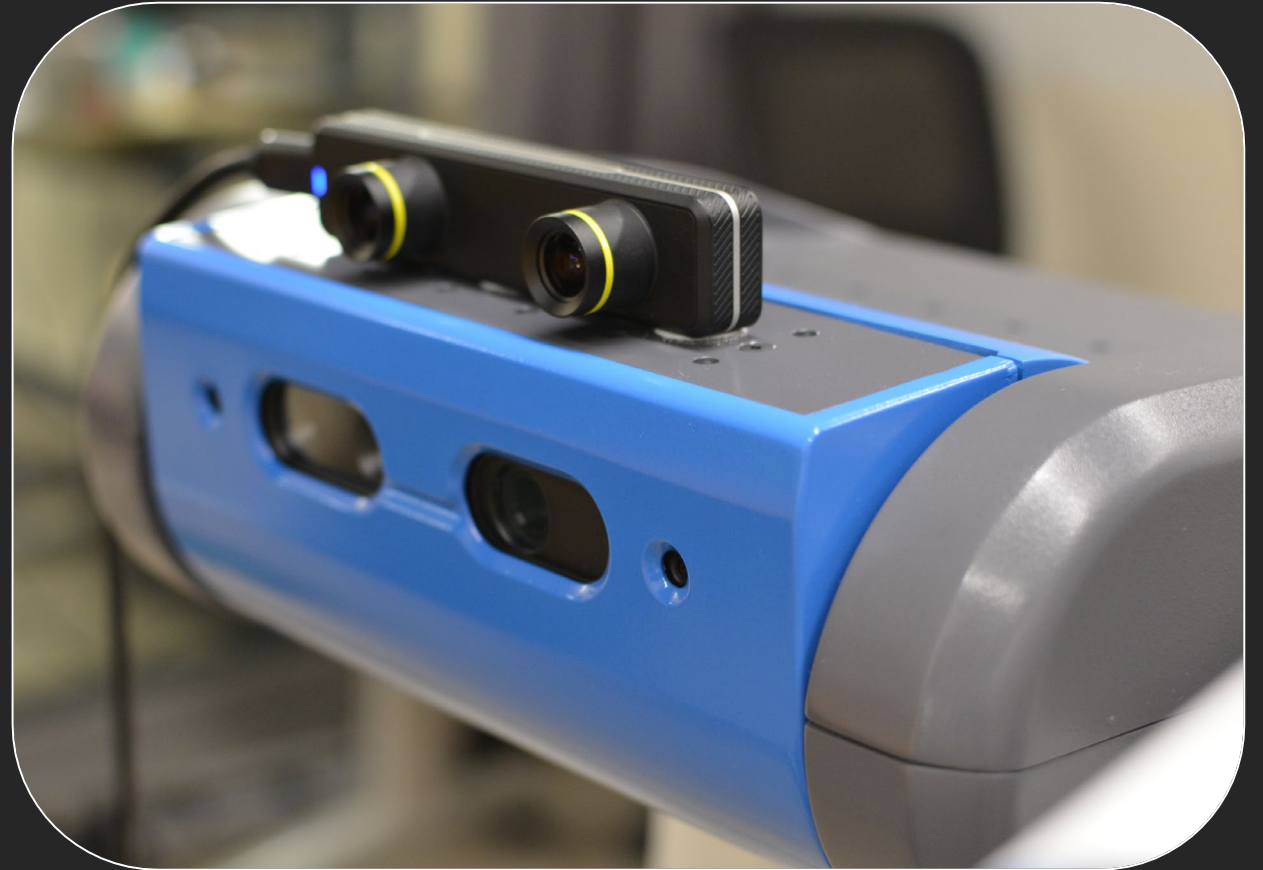
Stereoscopic 3D

Wide field-of-view

Immersion

Robot embodiment

User can “see” from robot point-of-view



# Virtual Reality Lunar Simulator

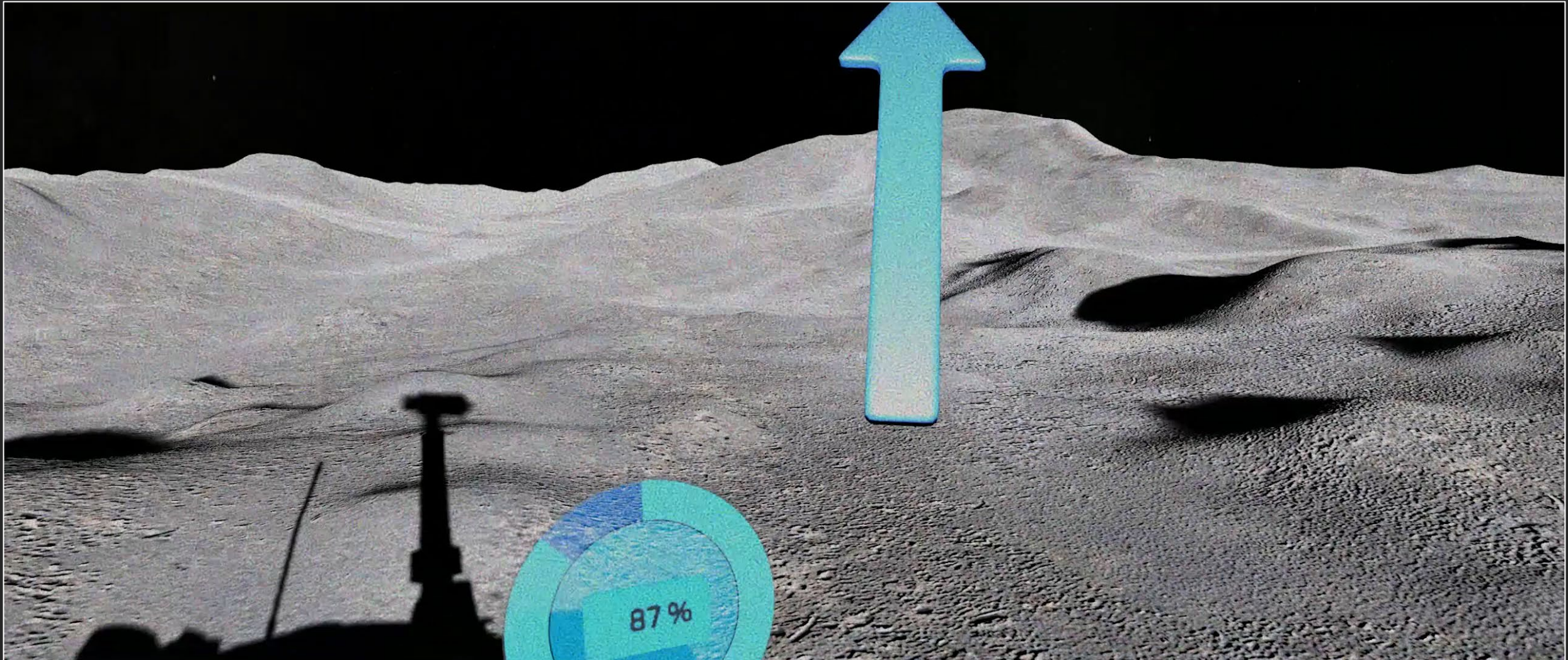
Prototyping and Experiment Testbed

# Virtual Reality Teleoperation Simulator



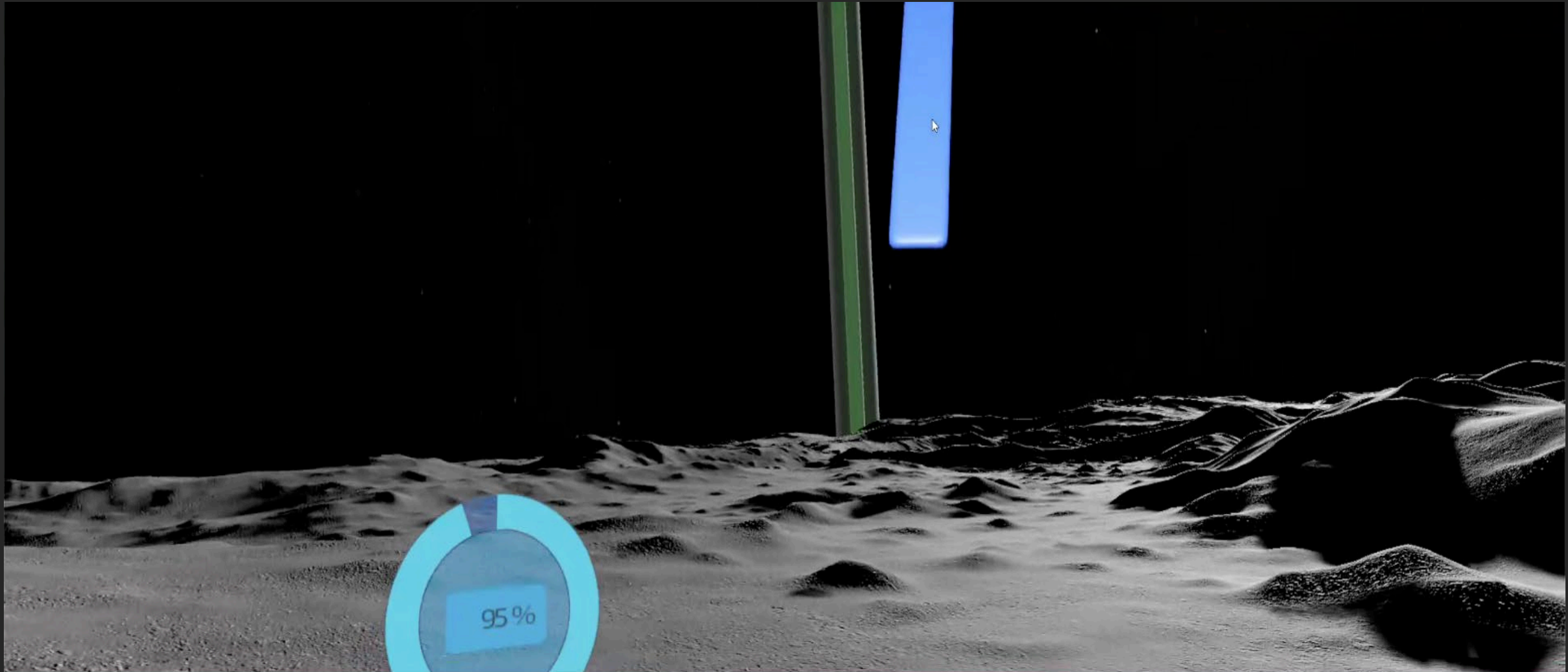


# Mixed Reality Support for HMD Teleoperation





# AI Trust Experiment: Navigation Goal & Directions

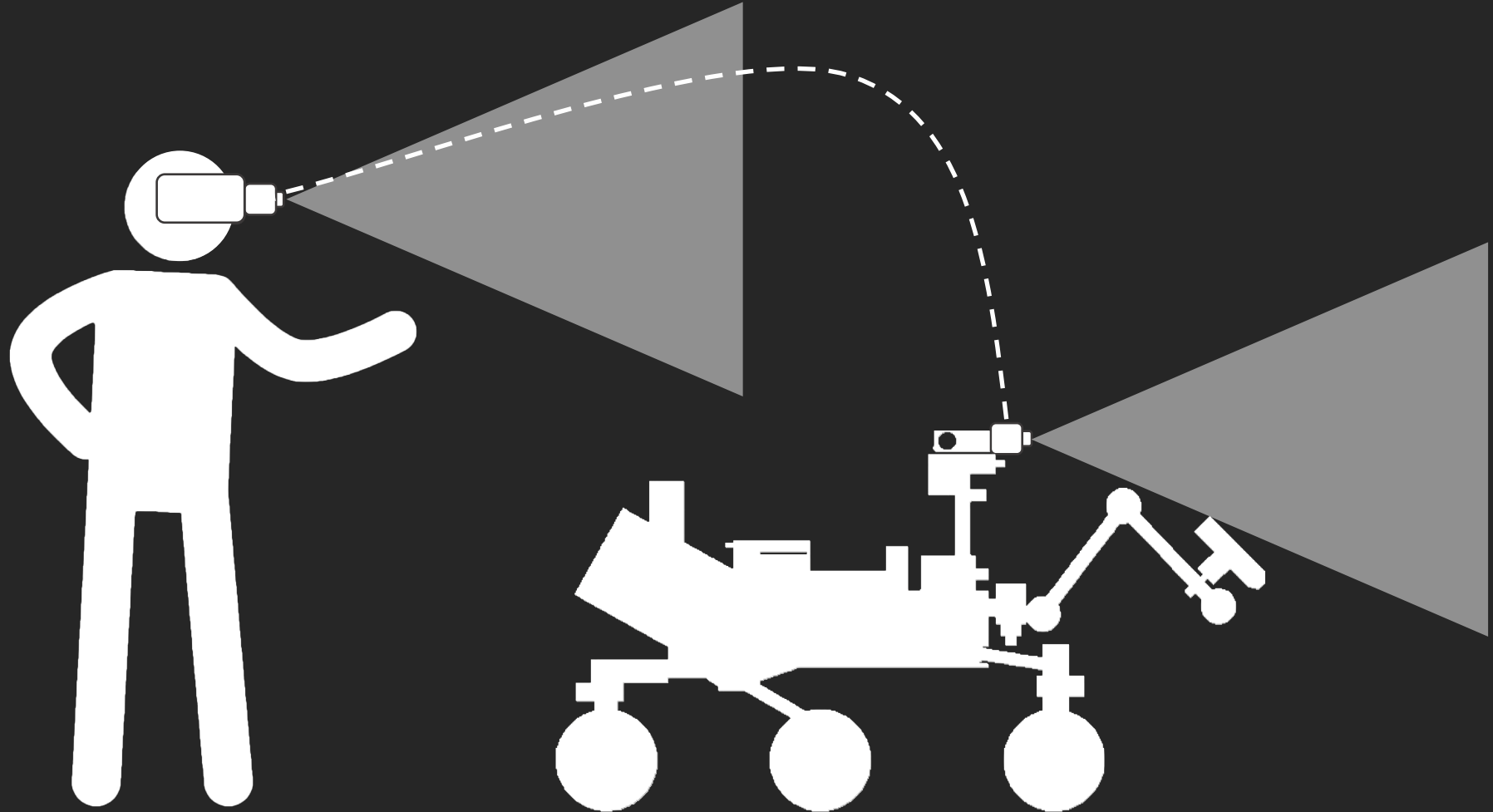




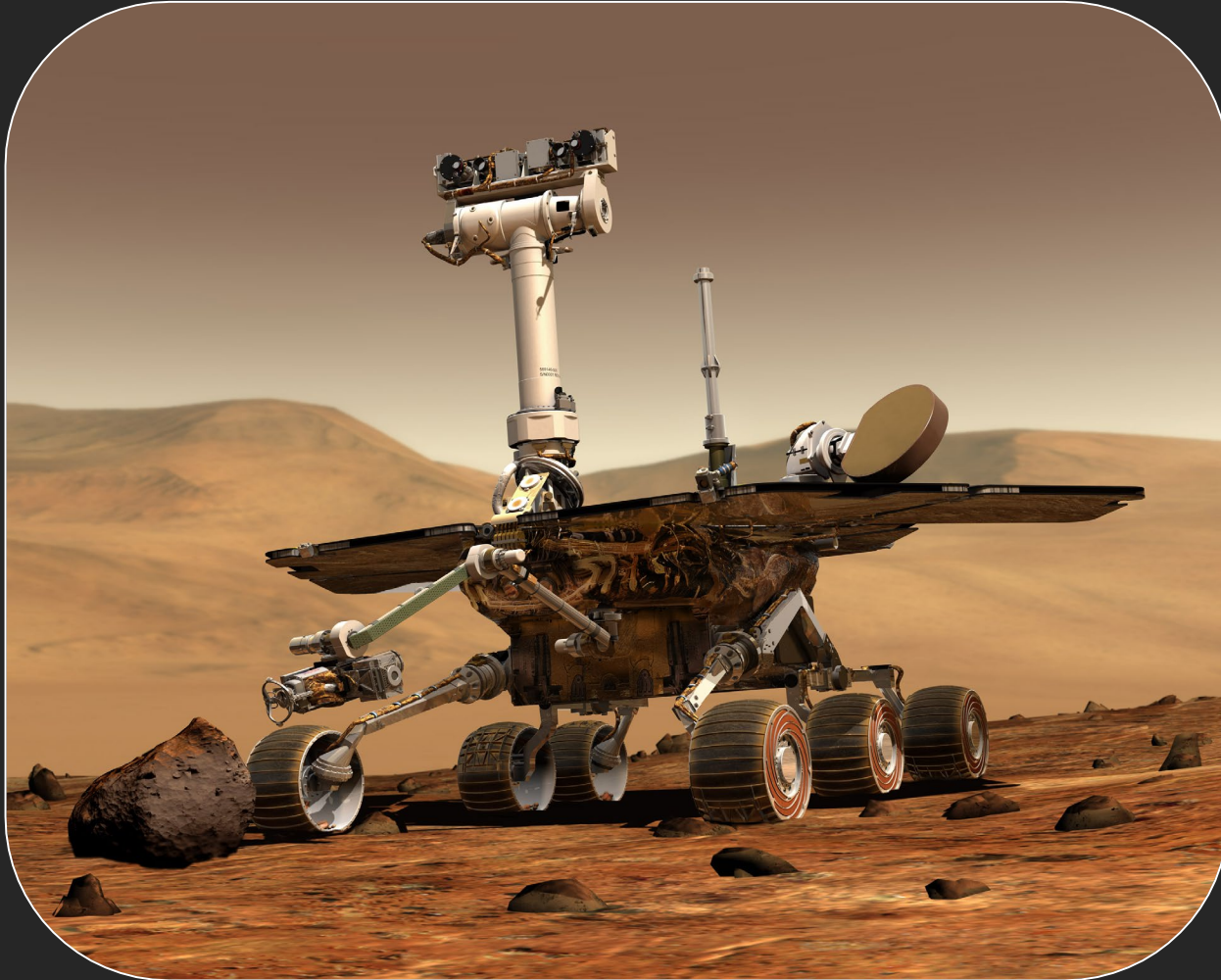
# Stereo Camera HMD Teleoperation Interfaces

Real-World Prototyping and Experimentation

# Remote HMD Video Passthrough for Telerobotics

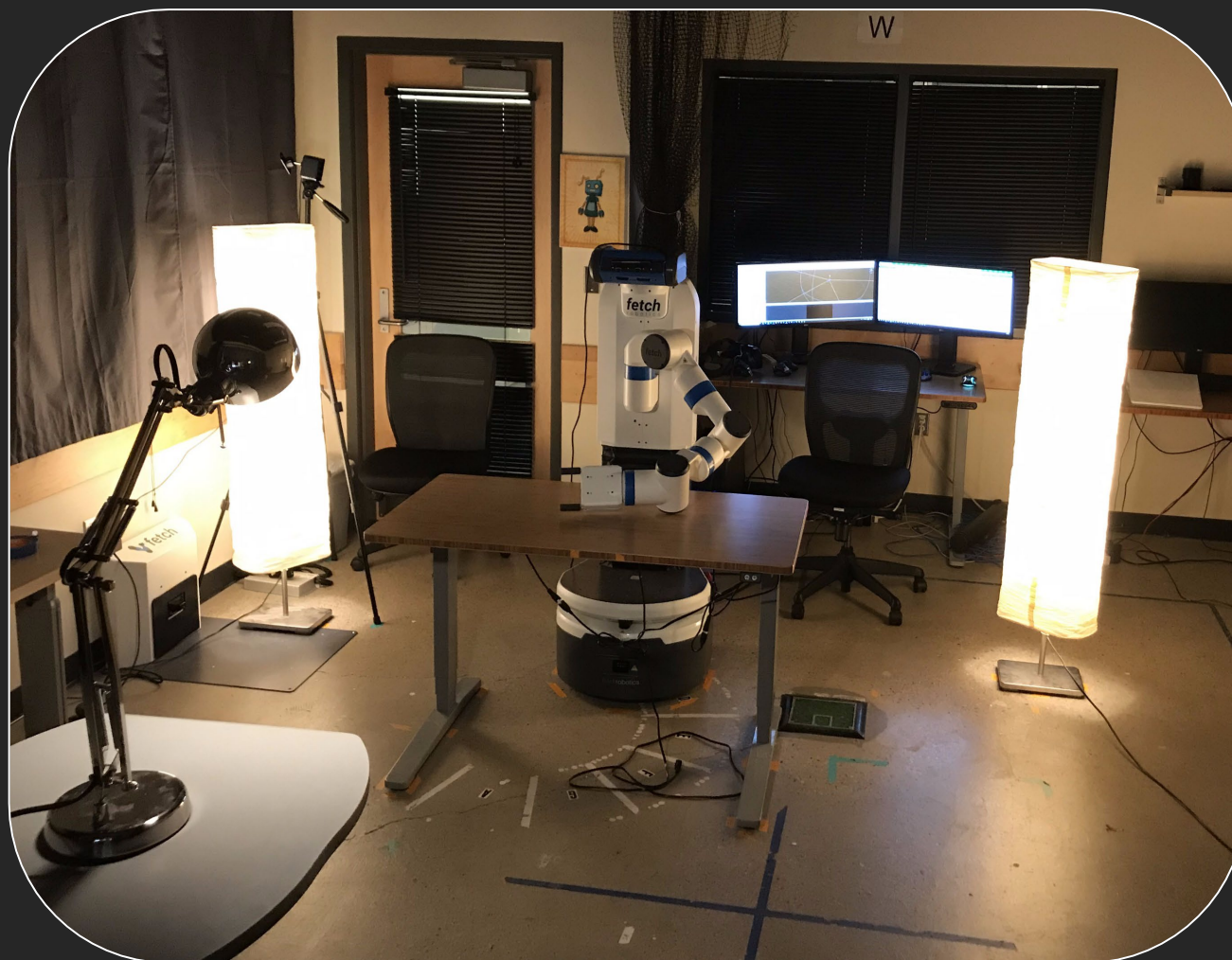


# Remote HMD Video Passthrough for Telerobotics



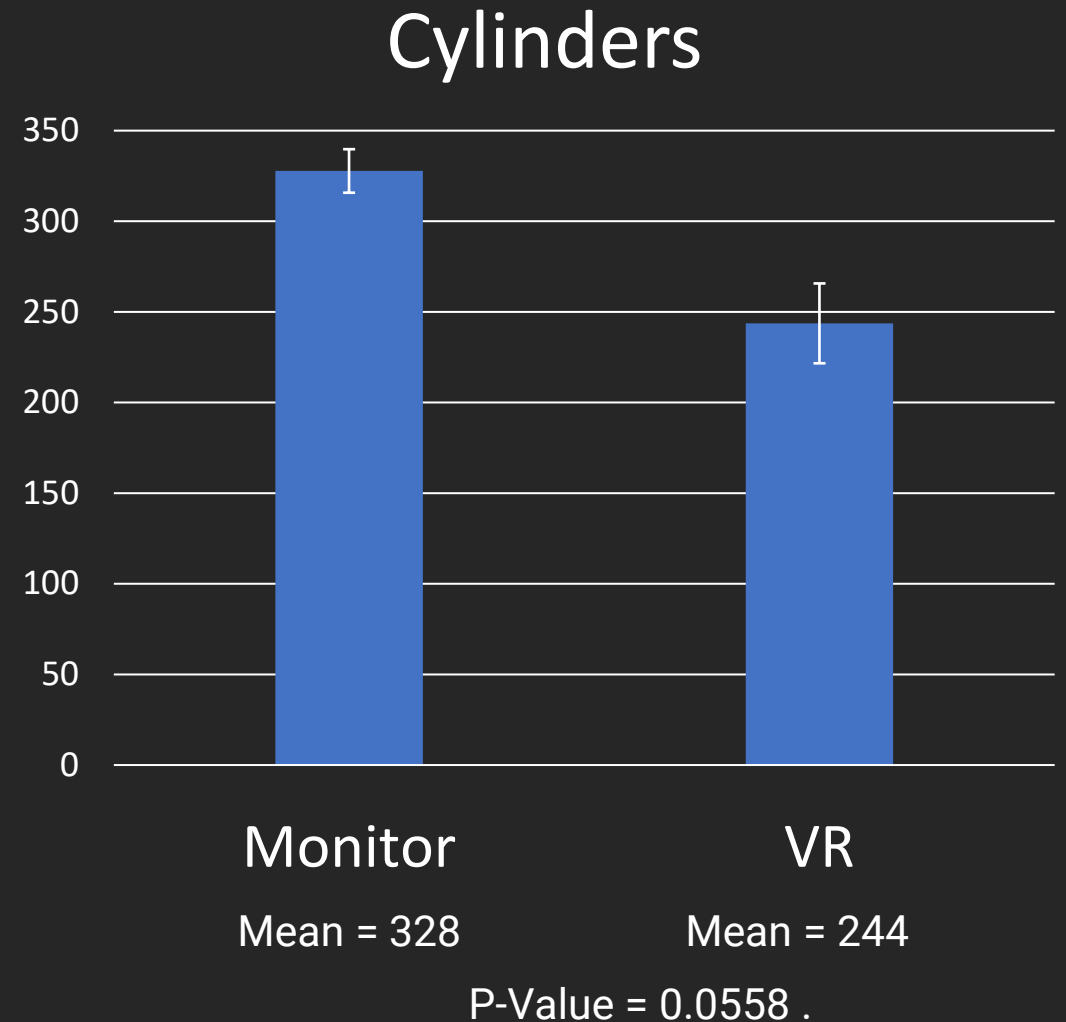
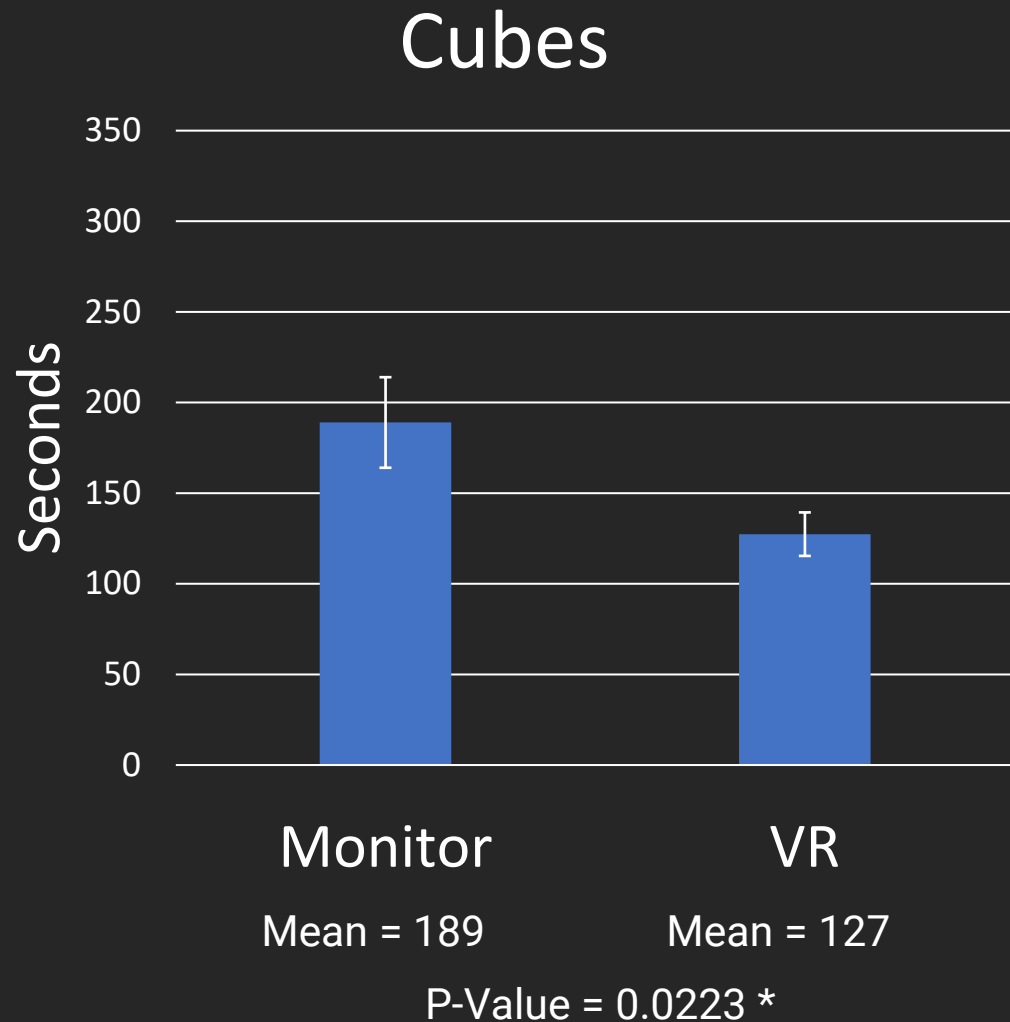


# Assembly Robot HMD Teleoperation Experiment



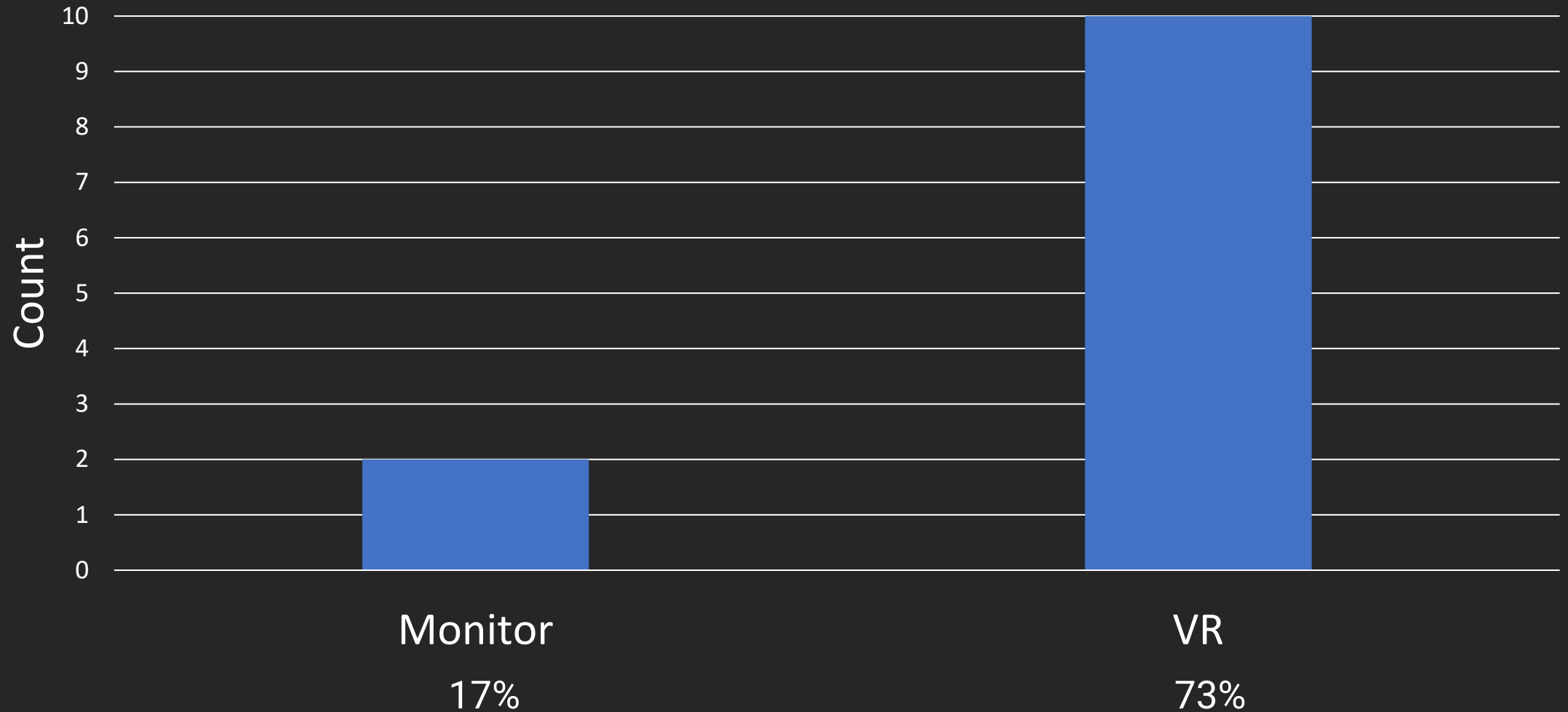


# Stacking: Efficiency (Time to Complete)





# Overall Assembly Interface Preference



# Mixed Reality HMD Teleoperation Interfaces

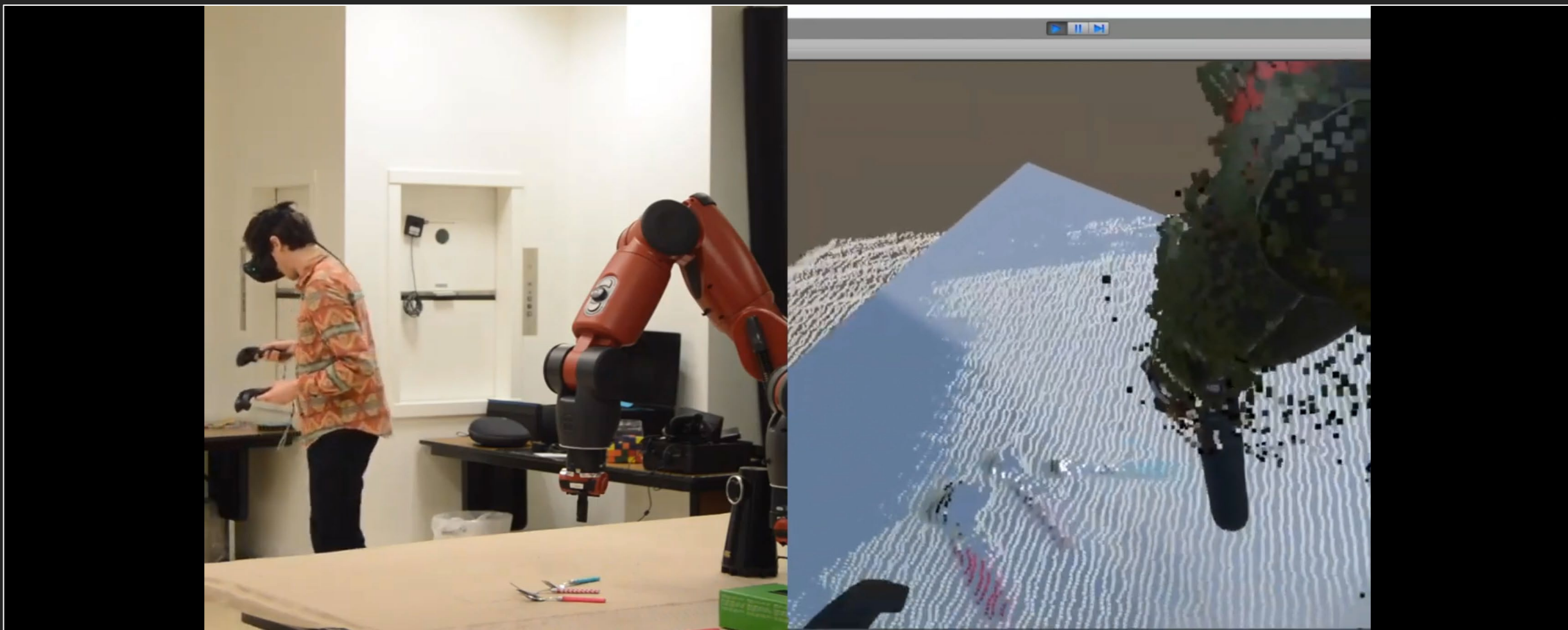
Merging the Real and Digital World

# First-Person (Egocentric) Teleoperation Interfaces





# Third-Person (Exocentric) Teleoperation Interfaces



[Whitney, et al. 2018]

# Future Experiment: Combined Exocentric & Egocentric Teleoperation Interface

A Unified interface that provides both exocentric and egocentric perspectives

Virtual Control Room Interface (*Egocentric*)

Live 3D Video Stream

Immersion and Robot Embodiment

Cyber Physical Interface (*Exocentric*)

Live RGB Point Cloud Streams

3D Remote Environment Reconstructions

Provides a virtual shared workspace for multi-user real-time collaboration



# Mixed Reality Prototype: Cyber-Physical Virtual Control Room Teleoperation Interface





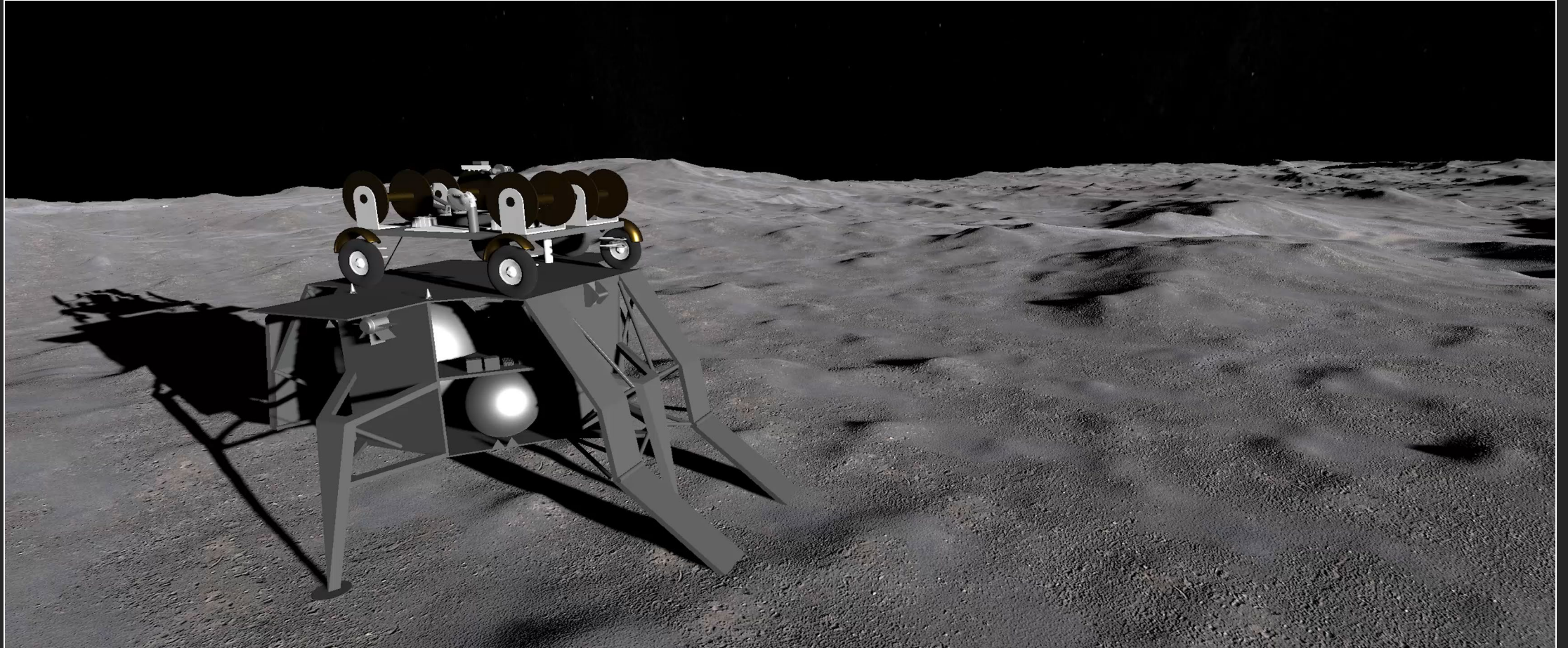
# Mixed Reality Future Work: Cyber-Physical Virtual Control Room with Telepresence Avatar Support





# Use Cases for Teleoperated Lunar Robots:

Deployment of Polyimide Film and Dipole Antennas for Low-Frequency Radio Telescopes





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# Thank You!

## Questions?



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