Background

As NASA pursues Artemis – landing American astronauts on the Moon by 2024, the agency will accelerate investing in surface architecture and technology development. For exploration, it is essential that crewmembers on extravehicular activities (EVA) are equipped with the appropriate human-autonomy enabling technologies necessary for the elevated demands of lunar surface exploration and extreme terrestrial access. The next-generation lunar spacesuit, the Exploration Extravehicular Activity Mobility Unit (xEMU), defines requirements for a visual display system. In future missions, a dynamic visual display system would optimize the effectiveness of astronaut surface operations. Displays like augmented reality (AR) are a tool to enable interfacing with lunar payloads, support science work, visualize consumables, streamline crew-to-crew communication, bolster Mission Control Center (MCC) interaction methods, and navigate terrain. NASA is exploring AR technology, or virtual user interfaces to adapt to an astronaut's needs in space, making EVA missions more efficient and effective.

Mission Objectives

Develop a user interface for an HMD in an augmented/mixed reality device which assists astronauts with their responsibilities during a lunar mission by providing instructions and other vital information for EVAs in a non-obstructive way. This may include optional supporting hardware (i.e. hand controls, secondary indicators, an app, virtual reality component, etc.). The test scenario will provide specific environments and resources for interacting with said environments, making it possible to design for certain lunar exploration tasks. These tasks include:

- Interact with a suit port (i.e. - UIA, DCU, intervehicular spacesuit prep)
- Display suit vitals in an unobtrusive way
- Navigate between the lunar lander/moon base, a pressurized rover, and a designated excavation site
- Complete a rover repair task (i.e.- interact with rover displays, use instructions to inform repair, etc.)
- Conduct science sampling task at a designated geology site
- Have a functional HMD to accomodate in areas of high contrast between bright and shadowed regions as is present on the Moon

In addition, in the testing environment the astronaut will communicate with a mission control component.

Teams are not limited to designing features for the above tasks. Your HMD will be more successful if it perfectly meets the need of some objectives instead of partially meeting all of them.

Below are specific requirements for some objectives.

Suit Vitals

In this use case, an astronaut on the lunar surface will interface with a display and control unit (DCU) during EVA and suit prep. Suit vitals convey crucial information to an astronaut such as informing them of when to return to a pressurized environment. Your HMD should be able to display all the information associated with these factors. All data will be communicated through a telemetry stream on a local network; therefore, your HMD should be able to receive this data from the stream.

Rover

Quick rover repairs are expected as we move to sustainable moon missions. In this use case, the EVA astronaut will follow a series of steps to repair a tire:

- Display rover repair instructions
- Identify the tire to be removed
- Interface with the rover to raise tire
- Identify the bolt that controls the elevation of the tire.
- Use and identify tools to change tire

All tools will be provided and meet the peripheral device requirements.

Science Sampling

Every lunar mission is an opportunity to take back samples of the Moon for geological research. The geology sampling site will be clearly marked and tools will be provided. In order to collect specific samples types students can utilize their HMD to correctly guide them through the following steps:

- Display science sampling instructions
- Interact with sample bags, tongs, rake, and other miscellaneous lunar tools.
- Locate/navigate to the correct site
- Provide a unique method for taking field notes
- Take pictures of the excavation site and geology samples
- Collect samples

Reference for moon sampling tools:
https://www.lpi.usra.edu/lunar/samples/apollo/tools/index.shtml

Lights and Shadows

The Moon's landscape is both well-illuminated and encased in shadows from its dynamic topography and craters. Lighting is a necessity, especially for mapping with mixed reality. Your astronaut may want to prepare a solution that allows their HMD to remain functional in dark environments. NOTE: Not accomplishing this will not prevent you from completing the other objectives.

Assumptions

- The astronaut will not have had extensive training on any EVA
- Spacesuit and/or communication anomalies can arise at any time
- There will be a latency in communication between the astronaut and mission control
- The astronaut will wear EVA like gloves but no other restrictive garments

Requirements

1	EVA task instructions shall be displayed
2	The astronaut must be able to access the status of the spacesuit at any time
3	The astronaut shall be able to communicate with ground control at any time
4	A caution and warning system must be implemented to inform the astronaut about a spacesuit anomaly
5	In case of an interruption, the astronaut must be able to continue the task on hand seamlessly
6	The user interface shall not permanently impede the astronaut's ability to perform
7	All hand gestures must be operable with EVA gloved hands (like heavy ski gloves)
8	The user interface shall take field notes for lunar sampling

Augmented/Mixed Reality Device Suggestions

This is not an exhaustive list; you are welcome to use something different.

- HoloLens 1: No longer in development. Free emulator available at https://docs.microsoft.com/en-us/windows/mixed-reality/using-the-hololens-emulator
- HoloLens 2: https://www.microsoft.com/en-us/hololens
- Magic Leap One: https://www.magicleap.com/

Peripheral Device Requirements

These requirements only apply to the development of peripheral device.

1	Any external or additional device must be approved by NASA prior to the test week
2	The device shall communicate with the HMD
3	Any removable components shall have a tether attachment point
4	All tools must be operable with EVA gloved hands (like heavy ski gloves)
5	Devices must not have holes or openings which would allow/cause entrapment of fingers
6	There shall be no sharp edges on any tool
7	Pinch points should be minimized and labeled

Peripheral Device Examples

- Photosensor
- Microcontroller/Raspberry Pi
- Controller device to substitute hand/voice controls
- Augmented lighting
- Geology tool
- Camera interface

Test Environment

The testing environment will contain a real pressurized rover, a station to replicate the Moon's terrain for science sampling, and other mockups and obstacles.
Teams are expected to implement support for interfacing with the physical environment. Designs which would be feasible in a real lunar exploration are preferred (i.e. - object recognition, navigation, etc.); however, QR codes will be provided on primary objects in the environment as a backup option for teams.

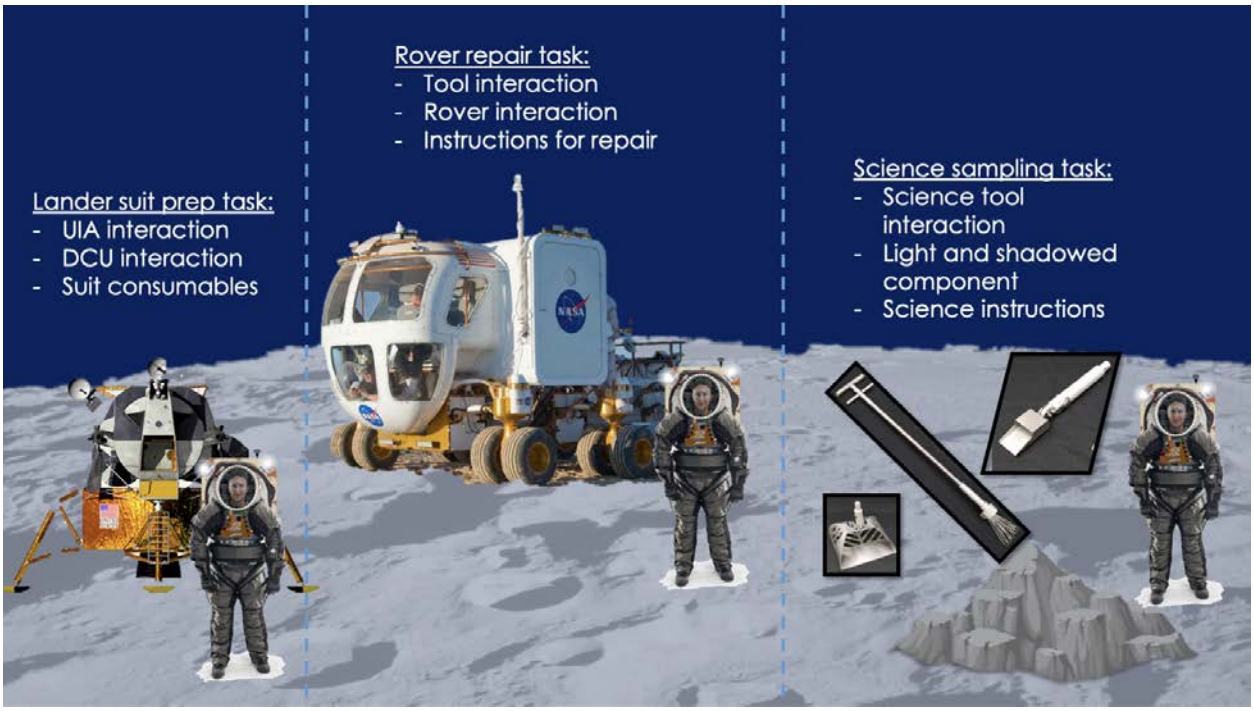

Figure 1: Test scenario con-ops

Figure 2: Pressurized moon rover

Figure 3: Closeup of wheel in lowered position on rover

Figure 4: Control panels inside the rover

Technical Authors

Paromita Mitra,
Human Interface Engineer
xEMU Spacesuit Informatics – Displays and Controls Lead
NASA Johnson Space Center
nasa-suits@mail.nasa.gov

Emily Liu
SUITS Intern 2019
NASA Johnson Space Center

Tanner Gesell
SUITS Intern 2019
NASA Johnson Space Center