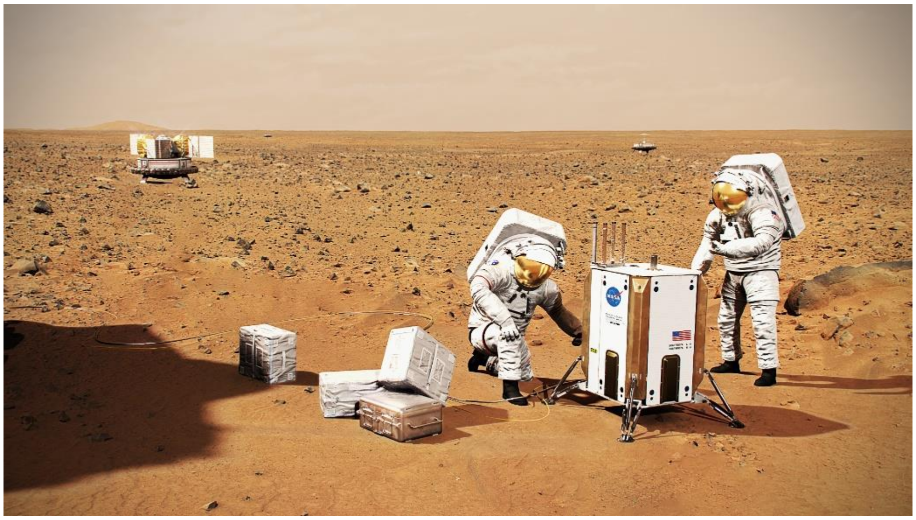
MISSION DESCRIPTION

NASA Spacesuit User Interface Technologies for Students

2023-2024

INSPIRE - ENGAGE - EDUCATE - EMPLOY
The Next Generation of Explorers

Contents



1. Background

NASA Spacesuit User Interface Technologies for Students (NASA SUITS) is a design challenge in which college students from across the country help design solutions for future spaceflight needs. NASA's Artemis missions seek to land the first woman and first person on the moon and build towards a sustained human presence on the Moon and ultimately, Mars. This means engineers are actively developing technologies needed to assure successful completion of science and exploration missions. Created as a collaboration between the Extravehicular Activity (EVA) and Human Surface Mobility Program and the Office of STEM Engagement, NASA SUITS is entering its seventh year of connecting students to authentic engineering challenges.

Humans living and working in deep space will require increased autonomy from Earth. A Mars mission can expect communications delays of up to 20-minutes each way requiring a reimagining of how spacewalks are conducted. This reimagining includes both an augmented reality display in the spacesuit, and more localized center for running some mission operations.

In NASA SUITS, teams are expected to design user interfaces (UI), and the underlying software for spacesuits, and new for this year, a mission control console for use on the surface of Mars. The spacesuit UI will be deployed to a commercially available head-mounted passthrough AR device, or HMD, such as the Microsoft HoloLens 2 or Magic Leap. The new Local Mission Control Console (LMCC) will work on a standard dual monitor setup and provides teams the opportunity to create their own interpretation on what will be needed in a Martian outpost.

Student teams submitting top proposals will be selected to develop their software, be mentored by NASA experts, and test their devices in a mock EVA scenario at NASA's Johnson Space Center in Houston in May 2024 where they will showcase their work to NASA engineers.

2. Mission Concept

NASA SUITS is creating a Mars EVA scenario for 2024. Teams are responsible for the HMD and the LMCC interfaces and software. The testing will take place at the JSC Rock Yard during the daytime; therefore, teams will need to accommodate for lighting factors in the display systems, especially the HMD. The Mars section of the rockyard conists of a pulverized granite base with scoria boulders ranging in size up to 1m.

The scenario takes place with one of your team members seated at the LMCC to act as flight controller, this role is sometimes labeled the Intra-vehicular activity (IVA) crewmember. Meanwhile, a design evaluator (DE) from NASA will wear your HMD to conduct the EVA. NASA will provide a Telemetry

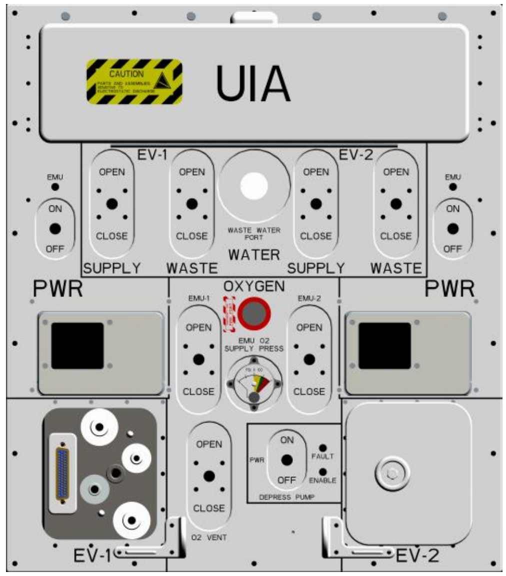
Stream Server (TSS) to handle the transfer of data in a uniform way between the various assets in use. Your team is developing software for both an HMD and LMCC.

During an EVA the crewmembers are commonly referred to as EV1 and EV2. In this document the terms EV, EV1, EV2, DE, and HMD are somewhat interchangeable.

The order of the elements below is arbitrary and subject to change.

2a. Egress

Egress occurs when the crewmembers exit the airlock to begin the EVA. Several steps must take place inside the airlock to ensure the crewmember can safely egress.



The goal of this task is to demonstrate effective and efficient methods for completing the Umbilical Interface Assembly (UIA) procedures used to initiate an EVA by preparing and checking the spacesuit's portable life support systems.

The DE will use information from the HMD and or LMCC to complete procedures for the UIA. The DE will interface with tactile switches on the UIA in accordance with provided procedures. Upon successful completion of egress task, DE will move on to the navigation portion of the EVA.

You decide the most effective method for communicating and accomplishing these procedures, this can be a text checklist, computer vision, voice commands from LMCC, or none of, or a combination of, those listed. The UIA will provide data to the TSS which will be accessible for teams to use as they see fit. Teams shall display the UIA data in at least the LMCC UI. A sample of procedures is in Appendix A but is subject to change as we approach test week.

2b. Navigation

The purpose of navigation is to ensure the crewmember can traverse between stations safely and efficiently. Your goal is to implement a software system for tracking crew and scientific assets in the field, and aid crew members as they navigate the Martian surface.

Upon completion of each task the DE will walk from their current station to the next designated station. The DE will use information displayed via the HMD to physically navigate between these stations. The LMCC console will use the LMCC UI to monitor and assist crewmembers as they move during the EVA.

You will design a navigation solution that is effective and non-obtrusive. The TSS can transfer GPS data between the LMCC and the HMD. This navigation solution needs to allow for flexibility in the EVA as destinations can change. For the HMD UI, teams shall design a 2D mini-map type navigation aid and may include a 3D map and computer vision destination waypoints and/or path indicators. For the LMCC UI, teams shall design a 2D mini-map for monitoring all human and scientific field assets.

2c. Utility Airlock

The purpose of an EVA is for crewmembers to complete science and maintenance tasks. For this portion of the EVA the crewmember will complete a maintenance task for one of the communication towers in the field. The goal of this task is teams exploring methods for accomplishing tasks safely, efficiently, and effectively, while reducing the cognitive load on the DE.

The DE will arrive at the utility airlock. The crew member will complete a set of procedures to safely open an airlock to access equipment inside. This equipment will be used in a later task.

You decide the most effective method for communicating and accomplishing these procedures, this can be a text checklist, computer vision, voice commands from LMCC, or none of, or a combination of, those listed. More details on these procedures will be provided to selected teams. They will include manipulating clamps to physically open the airlock.

2d. Equipment Diagnosis and Repair

The purpose of this task is real time communication between the crew members and LMCC. When diagnosing issues, it is important to have clear and efficient communication between crewmembers in the field and LMCC. The goal is to provide a team approach to problem solving between the DE and LMCC. LMCC should be able to assist, almost, as though they were in the field with the crewmember.

The DE will arrive to the worksite. They will inspect the communications tower for any signs of damage. When any potential issues are discovered, the DE will communicate this to the LMCC. LMCC will provide the DE with appropriate procedures to correct the issue. Using the procedures, the DE will complete the repair. LMCC will then confirm if the repair was successful.

You will determine the most effective method for accomplishing this task. The procedures must be sent to the crewmember for this task. The procedure data will be provided, and it is up to the team to determine how this data is displayed to the crewmember. The crewmember's camera feed will also be provided to LMCC. The problem can be anything from a disconnected or frayed cable to dust covered components needing clearing. More information will be provided to selected teams.

2e. Geologic Sampling

The other component of an EVA is to meet science objectives. When we arrive on Mars we want to learn as much as possible about the Martian terrain. We will achieve this by collecting samples with both human and robotic assets. The goal of this task is to show how humans, robotics in the field, and LMCC can work in tandem to gather information about the surface of Mars.

The DE will use a simulated XRF spectroscopy sensor to scan the chemical make-up of rock samples for potential collection. The DE will scan several samples, information about theses samples will be sent to LMCC. LMCC will use the XRF data to determine which samples are of greatest interest and inform DE when sample collection is complete.

This mock XRF sensor uses RFID of selected samples sent to the TSS, which then sends XRF data to the LMCC and HMD. Teams should access and display this data as they see fit. Teams should research field geology techniques and integrate them into your concept. One example is "Look ODD" or look, observe, describe, and document.

2f. Rover

Rovers have provided us with a large portion of what we know about Mars. When arrive on Mars, we will continue to use rovers and robotics to assist us with meeting our scientific objectives. The goal of this task is to command a rover that will collect samples in the field.

The rover will be piloted by LMCC to explore and collect samples of the Martian terrain. LMCC will pilot the rover to designated points of interest, collect a sample at that area, and drop the sample. The DE will collect these samples for further study.

The LMCC will include a rover telemetry and control component. Teams should be able to view data from the rover provided by the TSS including Realsense D425i and camera views. LMCC shall also control the rover to navigate from place to place and trigger other functions such as dropping a collected sample. LMCC shall be able to drop GPS pins based upon rover location or other factors, such as where a sample is collected and/or dropped. The HMD shall receive these pins in the AR environment. The rover is from LeoRover and uses ROSS.

2g. Ingress Procedure

An EVA is not complete until the crewmember has arrived safely back inside their spacecraft or habitat. Ingress is the process of returning to the airlock. Once the crewmember has completed all EVA tasks, they will begin the ingress portion of the EVA. The goal of this task is to ensure the crewmember arrives back to the airlock safely and efficiently.

Upon completion of the final task of the EVA or when instructed by LMCC, the DE will begin ingress. Using the HMD, the DE will follow navigation cues and instructions from LMCC to return to the airlock. The DE will conduct final procedures with UIA when they arrive to the airlock.

You decide the most effective method for navigating back to the airlock. The HMD shall provide a "breadcrumbs" feature for retracing a path. The ideal implementation would provide the shortest safe path back to the airlock.

****See Section 4 for full list of design requirements****

3. NASA Provided Systems and Equipment

3a. TSS

The telemetry stream is provided via a Unity Library, which teams will import into their project. Teams are placed in rooms with data isolated in each room. Each room has a shared state. Devices must be capable of accessing data from the telemetry stream and displaying the states of the following assets at any time:

- ROVER telemetry
- Location data logger: VISION student kit and rover positional data
    - World position floats
        - Latitude and longitude
        - Altitude
        - Bearing
    - Local position and speed floats: X, Y, Z coordinates with respect to a calibration point
- Spectrometer
- UIA- Booleans representing the position of the switches
- Team head-mounted display data stream
    - Floats and strings representing values of suit telemetry and simulated biometric data
    - Correct ranges are provided for anomaly detection

3b. VISION Kit

NASA provides the Virtual Instrument for Simulating Inertial Objects (VISION) kits which will simulate lunar vehicles, various EVA equipment, and points of interest. The crew member wearing the HMD is required to have a VISION kit on them. The VISION kit contains a Raspberry Pi with global positioning system hardware, an inertial measurement unit, an external antenna, and a power supply. Data streamed from the kit includes inertial measurement and location data. For example, the provided data could include its current position, in world and local coordinates, its local speed, and its bearing. The team is responsible for displaying the information given to them via the telemetry stream.

3c. UIA

The Umbilical Interface Assembly (UIA) features multiple switches teams will manipulate to match the desired configuration for egress. These switches feed into the telemetry stream, allowing teams to receive real-time feedback on their position. LMCC shall be able to send real-time procedures to the crewmember on EVA. Teams are encouraged to explore solutions such as AR procedure displays, computer vision, and telemetry representation to assist in completing the procedures.

3d. Spectrometer

NASA provides the simulated XRF spectrometer, which selects simulated geological data from a database when a rock with an RFID tag is scanned. The geological data is then sent via the telemetry stream back to the user. The team will display the geological data of each rock with the LMCC and if the team chooses the head-mounted display.

3e. Rover

NASA will provide the rover and framework for the rover to move through the terrain of the test site. It is up to the team to control the rover from their LMCC via the telemetry stream. The team is responsible for designing the UI/UX for their LMCC rover control.

3f. Display and Control Unit

The Display and Control Unit (DCU) features multiple switches which allow the DE to interact with different systems of the space suit. These switches feed into the telemetry stream, allowing teams to receive real-time feedback on their position. The DCU also allows the DE to handle any errors related to these systems. The version provided does not have any displays, rather your HMD will handle this information via the TSS.

The systems controlled by the DCU include:

- Power
- Oxygen
- Fan
- Thermal Control
- Oxygen Ventilation

4. Requirements

Please read and follow the requirements thoroughly.

Note: In the requirements sections below

Shall = required for minimally viable product

Should = requested features, but secondary priority

May = potential stretch goals for development

4a. LMCC Requirements

1) EV Telemetry
   a) The UI shall display crewmember biomedical data. This data shall be easily accessible.
   b) The UI shall display spacesuit system state data. This data shall be easily accessible.
   c) The UI shall display crewmember camera feed from HMD.
2) Rover Telemetry
   a) Camera feed
      i) UI shall display the Rover native camera feed
      ii) UI shall display the Rover Realsense D425i camera feed
   b) The UI shall display the Rover system state data. This data shall be easily accessible.
3) Rover Commanding
   a) LMCC console occupant shall remotely pilot the Rover.
4) Task Procedures
   a) The UI shall display procedures for each EVA task. All procedures shall be easily accessible.

   b) The UI shall allow for easily accessing and sending procedures from LMCC to the HMD as needed.
5) Scientific Data
   a) The UI shall display XRF sensor data when the data has been collected by the DE in the field.
   b) The UI should store this data.
6) Map
   a) The LMCC UI shall include a live 2D map for tracking human and scientific assets
   b) DE location
      i) The map shall track crewmembers' locations live for the duration of the EVA.
      ii) The map may draw the DE's path
   c) Rover location
      i) The map shall track the rover's location for the duration of the EVA.
      ii) The map may draw the rover's path.
   d) Points of interest
      i) The map shall display all designated point of interest
      ii) The map shall update to show any added points of interest by the DE or LMCC
   e) Pins
      i) Shall implement feature for dropping pins on map
      ii) Dropped pins shall sync across interfaces (LMCC, HMD)
      iii) Pin labels should be customizable
   f) Data format
      i) GPS data shall use GeoJSON format (goal is to be accurate to 1m)
7) Caution and Warning
   a) The UI shall feature a caution and warning system.
   b) The caution and warning system shall alert LMCC when any EV suit or biometric telemetry enter off nominal ranges
8) Display Mission Timers
   a) The UI shall display the mission elapsed time
   b) The UI shall display the elapsed time at each station throughout the EVA
   c) All mission timers shall adhere to standards and constraints provided to selected teams.

4b. HMD Requirements

1. EV Telemetry
   a. The UI shall display DE's own suit and biomedical data
   b. The UI shall display accompanied DE's suit and biomedical data
2. Map
   a. The UI shall display a 2-dimensional map
   b. The map shall display points of interest, both predefined and live from LMCC
   c. The map should display location of live assets including rover and other crew members
   d. The UI may display 3D map of the environment.
3. Procedure list
   a. The UI shall display correct procedures for each station of the EVA.

4. Navigation
    a. The UI shall implement a "bread crumb" feature for navigational use
        i. This feature will allow the user to follow 3D assets back to the airlock.
    b. The UI may implement a best path return navigation feature
    c. The UI may offer navigation aids to points of interest
5. Drop Pins
    a. The design shall provide the DE the ability to drop a pin within augmented reality environment at any point during the EVA.
    b. Dropped pins shall appear on the UI's 2D map within the HMD and LMCC.
    c. The HMD shall be able to receive and display pins dropped by LMCC in the AR environment and on the 2D map within the UI.
6. Caution and Warning
    a. The UI shall feature a caution and warning system
    b. The caution and warning system shall alert the DE if his/her spacesuit or biometric telemetry enter off nominal ranges
    c. The caution and warning system shall alert the DE if accompanied DE's suit or biometric telemetry enter off nominal ranges
    d. The UI may feature a digital switching solution for the DCU.
7. Scientific Data Reporting
    a. The UI shall alert the DE when a sample is scanned.
    b. The UI shall alert the DE when the sample is being analyzed.
    c. The UI should display spectroscopy analysis to DE when the sample is scanned.
    d. The UI shall alert the DE when the analysis is complete.
    e. The UI shall alert the DE when he/she may proceed to next scan.

4c. Peripheral Requirements

These requirements shall apply to the development of peripheral device.

1. Any external or additional device must be presented at the software design review (SDR) and approved by the NASA SUITS team.
2. The device should communicate with the AR device outside of the TSS, i.e. Bluetooth
3. Any removable components shall have a tether attachment point
4. Devices must not have holes or openings which would allow/cause entrapment of fingers
5. There shall be no sharp edges on the device
6. Pinch points should be minimized and labeled
7. Electrical design must meet the additional requirements

Appendix A: Sample UIA Procedures

0. Ensure that all switches are set to off

1. Power on EMU-1
  1.1. Switch EMU-1 Power to ON
  1.2. When the SUIT is booted (emu1_is_booted), proceed

2. Prepare UIA
  2.1. Switch O2 Vent to OPEN
  2.2. When UIA Supply Pressure (uia_ < 23 psi, proceed
  2.3. Switch O2 Vent to CLOSE

3. Purge N2
  3.1. Switch O2 Supply to OPEN
  3.2. When UIA Supply Pressure is > 3000 psi, proceed
  3.3. Switch O2 Supply to CLOSE

  3.4. Switch O2 Vent to OPEN
  3,5. When UIA Supply Pressure is < 23 psi, proceed
  3.6. Switch O2 Vent to CLOSE

4. Initial O2 Pressurization
  4.1. Switch O2 Supply to OPEN
  4.2. When UIA Supply Pressure is > 1500 psi, proceed
  4.3. Switch O2 Supply to CLOSE

5. Fill EMU Water
  5.1. Dump wastewater
    5.1.1. Switch EV-1 Waste to
    5.1.2. When water level if < 5%, proceed
    5.1.3. Switch EV-1 Waste to CLOSE

  5.2 Refill EMU Water
    5.2.1. Switch EV-1 Supply to OPEN
    5.2.2. When water level is > 95%, proceed
    5.2.3. Switch EV-1 Supply to CLOSE

6. Depressurize Airlock to 10.2 psi
  6.1. Switch Depress Pump to ON
  6.2. IF the pump faults:
    6.2.1. Switch the Depress Pump to OFF
    6.2.2. When the fault goes away, proceed
    6.2.3. Switch the Depress Pump to ON
  6.3 When airlock pressure is < 10.2 psi, proceed

7. Complete EMU Pressurization
  7.1 Switch O2 Supply to OPEN
  7.2 When UIA Supply Pressure > 3000 psi, proceed
  7.2 Switch O2 Supply to CLOSE

8. Complete Airlock Depressurization
  8.1 Switch Depress Pump to ON
  8.2 When airlock pressure is < 0.1 psi, proceed
  8.3 Switch Depress Pump to OFF

9. UIA Procedures are complete, exit the airlock