NASA SBIR 2022 Phase I Solicitation

Z13.03 Technologies for Spacesuits in Extreme Surface Environments

Lead Center: JSC

Scope Title

Portable Life Support System (PLSS) Dust Protection

Scope Description

For spacesuits, challenges presented by lunar dust include damage from abrasion, the effects of dust's electrostatic charge on the suit system, and dust intrusion to the suit system. Regarding the effects of dust intrusion, there is a need to protect components that must be exposed to, operate in, or operate after exposure to the lunar dust environment. There are multiple spacesuit components that require access to the environment for gas flow, both in nominal and off-nominal operations. Some of these components require specialized covers that prevent dust intrusion while at the same time allowing for sufficient gas flow. These components are:

1. PLSS Cover Vapor Vent Ports: The PLSS Cover has two ports to allow evaporated water from the Spacesuit Water Membrane Evaporator (SWME) and its backup, the Mini-Membrane Evaporator (Mini-ME), to vent to the surrounding vacuum. The operation of these components is dependent on a low backpressure, and each of the vent ports must have an effective flowthrough area of at least 7 in.$^2$ to maintain the appropriate pressure for evaporation within the PLSS cover. The vents (two total, symmetrically located on each side of the PLSS cover) need to accommodate a water-vapor mass flow of at least 2.6 lb/hr. The total area available for the vent ports is approximately 10 by 2.5 in. on either side.

2. PLSS Vacuum Access Pigtail Umbilical: The Rapid Cycle Amine (RCA) is a component that resides in the Exploration Extravehicular Mobility Unit (xEMU) PLSS. The responsibility of the RCA unit is to remove carbon dioxide (CO$_2$) and water (H$_2$O) from the PLSS ventilation loop. The RCA unit functions in a swing-bed regenerative manner to adsorb CO$_2$ and H$_2$O in one bed and desorb to vacuum in another bed. The PLSS Vacuum Access Pigtail Umbilical provides the vent path to vacuum for the RCA desorption cycle. This umbilical is 3 ft long with a diameter of 1.25 in. and is equipped with a free-flowing quick disconnect (QD) on the end. A specialized dust cover is needed for this umbilical to prevent dust intrusion. For efficient desorption, the pressure in the vacuum access line needs to decrease quickly and allow the flow of 0.65 L of ullage gas to the vacuum environment. The ullage gas can be assumed to be 100% oxygen (O$_2$) at 2.15 psi. Without a specialized cover, this gas dissipates within about 2 sec. After the ullage gas has dissipated, the desorbed gas consists of CO$_2$ and water (H$_2$O) with a mass flow of 325 to 360 g/min, depending on the bed loading and metabolic rate of the crewmember. Between 210 and 230 g/min of that flow is CO$_2$. For efficient operation of the RCA, the rapid decompression of the vacuum line is essential, as is the subsequent diffusion of desorbed gas away from the absorber beds. The specialized dust cover must not impede either of these processes.

3. Purge Valves: The xEMU is equipped with two purge valves to perform pre-extravehicular activity (EVA) denitrogenation purge or to convert the closed-loop ventilation operation into an open-loop operation as a contingency life-support function during the termination of an EVA resultant from a system failure. The
Display and Control Unit (DCU) Purge Valve is located on top of the DCU on the chest of the spacesuit, such that the crew can visually observe the valve as well as reach/activate it with either hand. This is the primary valve. A secondary valve, available in the event of a primary valve failure, is the Hard Upper Torso (HUT) Purge Valve, which is located over the crewmember’s right shoulder. This is a blind operation, accessible with only the right hand. Both valves will be exposed to the lunar dust environment and must be able to be activated and vent while operating in that environment. Both valves have a similar flow capability and function, providing an O₂ flow rate of 1.55 to 1.69 lb/hr at 3.5 psi. Both valves include a two-motion activation that can be performed with EV-gloved hands: pinch and lift.

4. Positive Pressure Relief Valve (PPRV): The PPRV prevents overpressurization of the suit in the event of a failed open primary or secondary oxygen regulator. The xEMU has two PPRVs, both located on the HUT on the crewmember’s lower right side below the shoulder. The two valves do not function under nominal circumstances during EVA but depending on the vehicle pressure schedule and depress rate, could actuate during airlock depress. Current vehicle pressure schedules for human landing systems would make this unlikely with the current 8.6- to 8.8-psid cracking/reseat pressure. The full-open flow rate requirement for the PPRV is 7.49 lb/hr of dry O₂ at 70 °F with suit internal pressure of 10.1 psia and vacuum as the external reference. The valve includes an inlet filter inside the suit and requires a venting protective cover on the outside of the suit that minimizes backpressure on the valve during venting operations.

5. Negative Pressure Relief Valve (NPRV): The NPRV prevents the suit from becoming too negatively pressurized during a rapid airlock repress such as that performed in the event of a suit emergency. Under this circumstance, the valve is designed to maintain the suit pressure at no more than a negative 0.5 psid. The requirement for the NPRV is 49 lb/hr of dry air at 70 °F, with the airlock pressure at 6.5 psia and a suit pressure at 6.0 psia. The NPRV is not used under nominal EVA operations but is exposed to the environment as it is located on the outside of the HUT, under the crewmember’s left shoulder. It must be capable of being exposed to dust with subsequent function if needed in this contingency.

6. Service and Cooling Connector (SCC): The SCC serves as the suit's main interface to vehicle services: O₂, H₂O, and power/data. The SCC is disconnected from the vehicle services umbilical at the beginning of an EVA and reconnected at its conclusion. While disconnected, the SCC must be protected from dust intrusion while operating in the dust environment. The protection must then be installed after disconnection and removed or inactivated during reconnection. The SCC includes two 3,000-psi O₂ recharge QDs, three H₂O QDs, and a 54-pin electrical connector ganged together in a single interface. The SCC presents a flat, outward-facing plane that is 2.5 by 4.0 in., located centrally on the DCU on the anterior of the suit.

Expected TRL or TRL Range at completion of the Project

3 to 4

Primary Technology Taxonomy

Level 1

TX 06 Human Health, Life Support, and Habitation Systems

Level 2

TX 06.2 Extravehicular Activity Systems

Desired Deliverables of Phase I and Phase II

- Analysis
- Prototype
- Hardware

Desired Deliverables Description

Phase I Deliverables: Reports demonstrating proof of concept, test data from proof-of-concept studies, and concepts and designs for Phase II. Phase I tasks should answer critical questions focused on reducing development risk prior to entering Phase II.
Phase II Deliverables: Delivery of technologically mature hardware, including components, subsystems, or treatments that demonstrate performance over the range of expected suit conditions. Hardware should be evaluated through parametric testing prior to shipment. Reports should include design drawings, safety evaluation, and test data and analysis. Robustness must be demonstrated with long-term operation and with periods of intermittent dormancy. System should incorporate safety margins and design features to provide safe operation upon delivery to a NASA facility.

State of the Art and Critical Gaps

Good dust-mitigation technologies and strategies are nonexistent for the spacesuit.

Relevance / Science Traceability

This scope is included under the Space Technology Mission Directorate (STMD) for Dust Mitigation. The project customer for this scope is the Exploration Extravehicular Mobility Unit (xEMU) project, which is under the Human Exploration and Operations Mission Directorate (HEOMD). Therefore, this scope has traceability to HEOMD as well.

References

Note to offeror:

- PLSS schematics and hardware drawings shall be provided if offeror is selected for award.
- Dust simulant characteristics shall be provided if offeror is selected for award.


Scope Title

Dust Removal Aids for Spacesuits

Scope Description

The Exploration Extravehicular Mobility Unit (xEMU) Environmental Protection Garment (EPG) is a multilayered softgoods (textile material) system. Its primary function is to protect the xEMU suit system from the extreme extravehicular activity (EVA) environment while enabling suit functionality. The EPG system itself must survive the environment and protect the suit from the environment while enabling xEMU functionality of its three subsystems—the pressure garment system (PGS), portable life support system (PLSS), and informatics system. The EPG shell fabric is the suit's first line of defense as well as the source of regolith introduction back into lunar landers.

NASA is in search of cleaning aids for spacesuits. One part of a lunar dust mitigation solution involves cleaning off as much regolith dust as possible while still in the EVA environment. The more dust a crewmember can leave outside, the less intravehicular cleaning will be required, and less strain put on vehicle-level air filters. Projects currently underway are looking at numerous ways to improve suit cleaning beyond the capabilities used during Apollo. Examples include improved brush materials and geometry and a compressed gas system for forced dust removal.

Ortho-Fabric, the three-fiber shell fabric developed for the space shuttle suit outer layer, was designed for the shuttle airlock oxygen concentration of 30% at 10.2 psi (70.3 kPa) and for durability. While Ortho-Fabric does not support combustion in an exploration environment of 36% oxygen atmosphere at 8.2 psi, it is a woven fabric. The interstices of the weave (gaps between yarns) allow for some amount of lunar dust to penetrate, and therefore it is a poor barrier to dust. In addition, the GORE-TEX® expanded polytetrafluoroethylene (ePTFE) film is easily abraded by the dust. Although GORE-TEX® is a PTFE (Teflon®) and inert, it can accumulate a charge.

In short, NASA is without an adequate solution for removing lunar regolith from the outermost layer of the EPG
system that covers the xEMU suit system. NASA is looking for innovative solutions for cleaning aids to address dust removal from the EPG and other external suit areas prone to dust contamination.

**Expected TRL or TRL Range at completion of the Project**

3 to 4

**Primary Technology Taxonomy**

**Level 1**

TX 06 Human Health, Life Support, and Habitation Systems

**Level 2**

TX 06.2 Extravehicular Activity Systems

**Desired Deliverables of Phase I and Phase II**

- Prototype

**Desired Deliverables Description**

Phase I Deliverables: Reports demonstrating proof of concept, test data from proof-of-concept studies, and concepts and designs for Phase II. Phase I tasks should answer critical questions focused on reducing development risk prior to entering Phase II.

Phase II Deliverables: Delivery of technologically mature hardware, including components, subsystems, or treatments that demonstrate performance over the range of expected suit conditions. Hardware should be evaluated through parametric testing prior to shipment. Reports should include design drawings, safety evaluation, and test data and analysis. Robustness must be demonstrated with long-term operation and with periods of intermittent dormancy. System should incorporate safety margins and design features to provide safe operation upon delivery to NASA.

**State of the Art and Critical Gaps**

Currently, Apollo-like brushes are being used for cleaning off dust on the spacesuits. Also, compressed gases are being assessed.

**Relevance / Science Traceability**

This technology will support the lunar mission where dust is a potential hazard to operating the spacesuit on the lunar surface safely.

This scope is included under the Space Technology Mission Directorate (STMD) for Dust Mitigation. The project customer for this scope is the Exploration Extravehicular Mobility Unit (xEMU) project, which is under the Human Exploration and Operations Mission Directorate (HEOMD). Therefore, this scope has traceability to HEOMD as well.

**References**

None