EXTRAVEHICULAR ACTIVITY AND PLANETARY PROTECTION.

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Introduction: The first human mission to Mars will be the farthest distance that humans have traveled from Earth and the first human boots on Martian soil in the Exploration EVA Suit. The primary functions of the Exploration EVA Suit are to provide a habitable, anthropometric, pressurized environment for up to eight hours that allows crewmembers to perform autonomous and robotically assisted extravehicular exploration, science/research, construction, servicing, and repair operations on the exterior of the vehicle, in hazardous external conditions of the Mars local environment. The Exploration EVA Suit has the capability to structurally interface with exploration vehicles via next generation ingress/egress systems. Operational concepts and requirements are dependent on the mission profile, surface assets, and the Mars environment. [1] This paper will discuss the effects and dependencies of the EVA system design with the local Mars environment and Planetary Protection. Of the three study areas listed for the workshop, EVA identifies most strongly with technology and operations for contamination control.

Study Area 1, Microbial and Human Health Monitoring: It is assumed that most of the microbial and human health monitoring related to particulates and backward contamination will be provided by the vehicle Environmental Control and Life Support System (ECLSS) and external tools, such as a detection kit. The suit includes sensors for pressure regulation, O2 pressure, CO2, and humidity levels. Other contaminants such as dust would not easily get inside the suit during an EVA with the bladder underneath the suit restraints being air tight, and the suit at an ambient pressure greater than the Martian atmosphere. Operations such as ingress, suit maintenance, etc. have potential to result in external dust contamination also within the vehicle/facility, not just the suit, as discussed under Study Area 2. This is where technology and operations for contamination control fit in.

Study Area 2, Technology and Operations for Contamination Control: Dust contamination and Planetary Protection must be treated with increased sensitivity on Mars. EVA is essential for exploration and a primary method for the efficacy of exploration mission success, research, and the goal of human pioneering. Each EVA performed on the surface of Mars allows dust to come into contact with the suits. Boots, gloves, elbows and knees will likely see the most accumulation of dust.

Layered Engineering Defense Plan: A Layered Engineering Defense Plan, which includes 6 layers, should be utilized to help mitigate the effect of dust on the suit materials, the transfer of dust on the suits, forward and backward contamination to the crew and habitation, cleaning and protection (interior and exterior) and the use of air quality contamination zones. [2]

The 1st layer includes materials and engineering design. Fabrication of an EVA suit with resistance to impact and abrasion from the Martian dust poses a significant engineering challenge. Technology advances are required for the material layup for both space and planet environments, and can include material exposure to dust, abrasion, punctures, cuts, hypervelocity impacts (micrometeoroids and secondary ejecta), and general vehicle materials compatibility without compromising suit mobility. [3] Dust tolerant mechanisms, seals, bearings, and electrical connectors are necessary to prevent connector shorts, and mechanical failure of connector. These particulate tolerant mechanisms should also be maintainable so that any dust/dirt/particulates can be periodically cleaned out. Pockets and folds should be minimized such that they do not collect particulates and sensitive equipment should include dust impermeable covers.

The 2nd Layer deals with operational controls, which includes eliminating, to the extent possible, suit ingress to the habitable volumes; however, EVA space suit components have a limited life duration and must be maintained during a long duration human mission. The space suits need to be brought inside a habitable volume for nominal and contingency maintenance, which will introduce some amount of dust into the habitable volume. The operations of the removal of dust from the suits will be a multi-phase operation to limit dust introduction into the suits and into the crew cabin.

Operational controls also include ingress/egress methods that will mitigate dust transfer into the cabin, (i.e. rear-entry airlocks, suitport-airlocks, and suitports). Past methods of ingress/egress through airlocks would have the crewmember traversing/translating directly through the dust that was brought in after an EVA both after the crewmembers doff their suits and prior to donning their suits. A next generation airlock is needed to provide high availability EVA, particulate mitigation, and backward and forward planetary protection by donning/doffing the rear-entry EVA suit through a bulkhead, such that the crewmember does not translate through the dust shirtsleeve during vehicle ingress and don/doff. To further prevent backward contamination, it is assumed the EVA space suits will be left behind on the surface and that the crew will ingress the ascent vehicle via a pressurized method, such as a tunnel from the rover to the ascent vehicle. The 3rd Layer includes contamination prevention. Exploration of Mars must be conducted with planetary protection requirements, considering both forward and backward contamination prevention. Space suits inherently have some amount of venting/leakage. Human systems introduce the risk of forward contamination through venting of organics through water vapor with trace contaminants such as gases (CO, methane, etc) and liquids (body oils, ointments, etc) and leakage through flanges and fabric-to-metal attachment points. Some of the next generation airlock methods minimize the volume of consumables being vented from the vehicle; however, there is still gas during depress that is vented to the atmosphere. Vented gas as well as gas contained by reclamation systems can help reduce this with the proper amount of filtration in place in the vehicle's ECLSS. Likewise these same human systems introduce the risk of backward contamination to the crewmembers and to the Earth and need to be evaluated by human health and performance. Despite possible engineered controls designed within the suit and other assets, operational controls for planetary protection are anticipated to establish "keep out zones" or special regions prohibiting human presence in Martian areas deemed to be highly likely to contain life. These zones would probably be established by robotic precursor missions to conduct sensitive analyses before an EVA crewmember arrives. Flight rules and operational concepts need to be understood to work around potential special regions.

To the extent possible, Layers 4 and 5 are directed toward external and internal cleaning and will help minimize the amount of dust brought into a pressurizable area or ingress/egress method and minimize the cleaning of interior zones. Wipes (dry and wet), vacuum/cleaning systems and other potential cleaning tools that can safely remove and contain dust without exceeding the limitation of the space suit materials need to be evaluated. Contamination detection technology should be evaluated via purpose and operational concepts (hand-held vs. inside the ingress/egress method). Containment and cleaning technology needs to be evaluated. If sterilization is considered necessary in the ingress/egress method, it must not exceed the suit material limitations and must be compatible with the vehicle ECLSS and materials inside the ingress/egress method. When ingressing the chamber containing the space suits to perform suit maintenance, the crewmembers don Personal Protective Equipment (PPE) to the extent necessary, along with utilizing floor mats, pressure differentials, dust containment curtains, mud rooms, etc.

Finally, the 6th Layer includes air quality contamination zones. This is linked to engineering and operational design of the ingress/egress method as well as the overall asset architecture. As mentioned above, a conventional airlock would include a single volume for bringing the suit inside a pressurizeable volume for conducting suit maintenance. Next generation airlocks such as rear-entry airlocks/suitlocks and suitport-airlocks could include a secondary chamber or mud room to further contain contamination and increase air quality as the crewmember translates to the cleanest areas of the vehicles, such as habitats, pressurized rovers and ascent vehicles.

Strategic Knowledge Gaps for EVA: Strategic Knowledge Gaps include the need for an agency/program endorsed document that includes the following characteristics of the environment: chemical and physical properties of dust/dirt, particle size, shape, composition, toxicity, static electricity, electrical conductance, dust storms, etc. Guidance for use of dust simulants is needed for testing. If JSC-Mars 1 simulant is not adequate for testing mechanical systems, what is? [4] Do certain corrosive materials need to be added to the simulants for materials testing? What are the mitigation protocols? Do the dust properties change when exposed to a habitable environment (pressure, humidity, increased O2, etc.)? What type of hazards does the dust present to humans? A programmatic requirement for allowable levels of Martian contamination within the habitable volume is needed. Next generation airlock analogs/testing should be demonstrated to study levels of dust mitigation/planetary protection.

Closure of knowledge gaps can significantly increase the fidelity of early development testing of EVA suit materials and will help develop flight rules and operational concepts to enable more efficient human exploration of the Mars surface.

References: [1] Author Stephanie Sipila, Natalie Mary, and David Coan (2013) *Exploration EVA Capabilities and Operational Concepts,* 36-45. [2] Author Sandra Wagner (2014) NASA/TP-2014-217399 *Asteroid, Lunar, and Planetary Regolith Management: A Layered Engineering Defense.* [3] Office of Chief Technologist (April, 2012) *NASA Technology Roadmap TA6 and TA7* [4] National Academy of Sciences. (2002). Safe on Mars: Precursor Measurements Necessary to Support Human Operations on the Martian Surface. National Research Council. Copyright ©

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