NASA'S INTERNATIONAL SPACE STATION: A TESTBED FOR PLANETARY PROTECTION PROTOCOL DEVELOPMENT. Bell, M.S.[1], Rucker, M.[2], Love, S.[2], Johnson, J.[2], Chambliss, J.[2], Pierson, D.[2], Ott, M.[2], Mary, N.[3], Glass, B.[4], Lupisella, M.[5], Scheuger, A.[6], Race, M.[7], [1]Jacobs, NASA Johnson Space Center, Mail Code XI3, Houston, TX 77058, USA, mary.s.bell@nasa.gov, [2]NASA Johnson Space Center, [3]Booz Allen & Hamilton, NASA Johnson Space Center, [4] NASA Ames Research Center, [5]NASA Goddard Space Flight Center, [6]University of Florida, [7]SETI Institute.

Introduction: Wherever humans go, they inevitably carry along the critters that live in and on them. Conventional wisdom has long held that it is unlikely those critters could survive the space environment, but in 2007 some microscopic aquatic animals called Tardigrades survived exposure to space [1] and in 2008 Cyanobacteria lived for 548 days outside the ISS [2]. Unlike the Mars rovers that were cleaned once and sent on their way, crew members will provide a constantly regenerating contaminant source. Are we prepared to certify that we can meet forward contamination protocols as we search for life at new destinations? What about the organisms we might reasonably expect a crewed spacecraft to leak or vent? Do we even know what they are? How long might our tiny hitch-hikers survive in close proximity to a warm spacecraft that periodically leaks/vents water or oxygen and how might they mutate with long-duration exposure [3, 4]? How will these contaminants migrate from their source in conditions encountered in space or on other planetary surfaces? This project aims to answer some of these questions by bringing together key stakeholder communities to develop a human forward contamination test, analysis, and integration plan. A system engineering approach to identify the experiments, analysis, and modeling needed to develop the contamination control protocols required will be used as a roadmap to integrate the many different parts of this problem – from launch to landing, living, and working on another planetary surface (Fig. 1).

Implementation: The focus of this road-mapping effort will be "what can we do now with what we have?" For example, the micro-organisms *inside* the International Space Station (ISS) are well-characterized but no one has ever swabbed an ISS external vent to find out what (if anything) has managed to get *outside*. We can swab ISS vents now, without having to wait for program direction or an Orion or a new rocket. If we take a sample and find nothing, that's good news! It means that our environmental control and life support (ECLS) vent filters may already meet forward contamination requirements. If we do find organisms *outside* the ISS, it will be interesting to see how they compare with what we typically find *inside*. Are they the same? Or have they mutated? What corrective measures can we take to prevent external contamination? Once we know what manages to escape a typical spaceship, we can expose it to various destination environments and see how it's likely to behave. Then we can go one step further, and test those organisms in a spacecraft-induced environment to understand whether proximity to a warm, venting spaceship makes a difference. That will tell us how far away we must land from a sensitive area to mitigate forward contamination. We could also bring the modeling community into play and overlay destination weather models onto bacterial growth models to estimate how far microbes could be transported by, say, a small dust storm on Mars. Another opportunity might be to take a sample from an Exploration Extra-Vehicular Activity (EVA) Suit during development testing and follow similar steps as outlined above: what organisms come out of a suit vent or leak from the suit? How close can EVA crew be to a sensitive site without compromising the science objectives? Data would tell us what modifications might be required to the suit *now*, early in the development phase, and avoid an expensive redesign later.

Technical Objectives and Outcomes: This project has four technical objectives:

1. Develop a detailed test plan to leverage existing equipment (i.e. ISS) to characterize the kinds of organisms we can reasonably expect pressurized, crewed volumes to vent or leak overboard;
2. Develop an analysis plan to study those organisms in relevant destination environments, including spacecraft-induced conditions;
3. Develop a modeling plan to model organism transport mechanisms in relevant destination environments;
4. Develop a plan to disseminate findings and integrate recommendations into exploration requirements & operations (Ops).

Technology Readiness Level (TRL): There will be different TRLs for different aspects of this project but because the emphasis is on utilizing what we currently have, TRLs are expected to be fairly high (ISS utilization, for example).

Alignment to NASA and Johnson Space Center Strategic Objectives: This work will influence exploration-class life support and EVA suit design (including whether closed loop is required to meet planetary protection), and aid in developing crew health protection strategies. This work also supports one of NASA's Strategic Knowledge Gaps: Microbial survival, Mars conditions [5].This project supports JSC Strategic Plan Goal #1: Lead Human Exploration, specifically Strategy 1.3 (Extend human exploration beyond LEO) by providing a roadmap to characterize human forward contamination. With that piece of the puzzle in place, we can better understand hardware and operational implications at various destinations beyond LEO. This work also aligns to NASA's strategic goals for exploration as designated in *NASA's Space Technologies Roadmaps and Priorities* [6] specifically Technology Area Breakdown numbers 6.0: *Human Health, Life Support and Habitation Systems,* and 7.0: *Human Exploration Destination Systems Roadmap* [7].

Project Infusion Path: This project's primary deliverable is a JSC-numbered document that will serve as the roadmap for many spin-off efforts, such as ISS utilization tests, advanced EVA and ECLSS development, and crewed operational procedures. This work will link JSC's hardware developers with scientific communities across the Agency, and will provide information and guidance to commercial hardware developers planning crewed exploration missions.

Fig.1. This project will provide a roadmap to integrate planetary protection requirements into the design of engineering systems necessary for human exploration of a variety of destinations.

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