National Aeronautics and Space Administration

Development of Planetary Protection Technologies for Special Region Missions

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Program: Strategic Initiative

Project Objective:

The 3-year goal of our work is to develop aseptic assembly techniques and investigate biobarrier/bioshield implementation to obviate the need for subsystem and system-level heat microbial reduction (HMR). Our work is focused on aseptic assembly techniques and processes considering a variety of sterilization modalities; (e.g., Vapor Hydrogen Peroxide, radiation). We aim to:

1. Determine targets for research augmentation of approved modalities.
2. Evaluate the effectiveness of techniques in view of hardware with complex geometries, size scale up issues, and material compatibility issues.
3. Develop biobarrier/bioshield implementation options for recontamination prevention.
4. Evaluate biobarrier/bioshield options for use both at the subsystem and the system level.

Benefits to NASA and JPL (or significance of results):

A 2006 case study done by the Mars program at JPL has shown that if a "MER-like" mission needed to meet "Viking-like" sterilization requirements using system-level HMR, the project costs would increase by 14%, and ~$25M would be required to update existing JPL and KSC facilities. HMR is also time-consuming, having a significant impact on ATLO critical path schedules. The work we are conducting should provide a low-temperature local sterilization technology for aseptic assembly and integration of S/C parts. Application of this alternative approach is estimated to reduce the cost of "Viking-like" sterilization of the "MER-like" S/C to ~7.5%, since system-level HMR related rework and redesign could be eliminated. Furthermore, the estimated $25M facility cost would also be eliminated, and impacts on ATLO critical path schedule would be reduced. Our work will also develop an aseptic assembly technique for system and subsystem sterilization of S/C for the potential robotic exploration of Martian special regions and other solar system targets such as Europa. We will investigate biobarrier/bioshield implementation approaches to allow the S/C H/W to remain sterile during final ATLO activities, launch decompression, cruise, and EDL (entry, descent, and landing) activities.

The results of this work are expected to enhance JPL's ability to meet Planetary Protection requirements and to obtain significant cost/risk/schedule reduction for flight hardware activities. It will also help JPL to prepare for future life detection and potential sample return missions where stringent biological cleanliness is needed for scientific reasons.

FY16/17 Results:

Objective 1: Performed a literature review and prepared report/paper on the cutting edge sterilization techniques of the last five years and evaluated the advancements in sterilization technologies and their applicability to spacecraft hardware (H/W). Identified γ-radiation as planetary protection (PP) sterilization technology for further investigation.
Objective 2: Designed and built a complex geometry model to simulate flight H/W for sterilization purposes; materials were chosen to be compatible with the selected sterilization modality: Vapor Hydrogen Peroxide (VHP). The complex geometry model was coupled with a modular enclosure we designed to achieve in situ (hi-bay and launch pad) sterilization capability of flight H/W. In our testing campaign we modified various operational parameters of our VHP generator to develop a sterilization cycle capable of processing complex spacecraft (S/C) H/W. Designed and prototyped the hose connector to be used for in situ VHP sterilization. We also initiated evaluation of γ-radiation as a sterilization modality for S/C H/W. Prepared report documenting (work performed in FY16) the development of a complex geometry model to simulate flight hardware for sterilization purposes; a modular enclosure designed to achieve in situ (hi-bay and launch pad) sterilization capability of flight H/W; the testing campaign where various operational parameters of our VHP generator were modified to develop a sterilization cycle capable of processing complex spacecraft hardware; and the results of initial evaluation of γ-radiation as a sterilization modality for spacecraft hardware. The evaluation of γ–radiation was continued in FY17 to determine the doses required for one order-of-magnitude (OoM) reduction in microbial population and overkill (complete sterilization). The one OoM experiments included organisms regularly used as biological indicators for other microbial reduction processes (i.e., HMR and VHP). A procedure for VHP microbial reduction of S/C H/W was expanded/refined. Interviewed hardware Subject Matter Experts (SME) representing the major S/C subsystems and potential instruments (that could be used on notional missions to Mars Special Region) to identify those components with potential issues with HMR and other sterilization modalities. Under the same study, we surveyed PP records for Mars Exploration Rover and Mars Science Laboratory H/W for documented sterilization compatibility. We also developed the structure for a web-based database to compile material and component sterilization compatibilities, beginning the compilation of that data into a spreadsheet for future import into the database.
Objective 3: Preliminary story boards have been developed for various implementation options outlining the use of microbial reduction modalities and biobarriers (BB) through the build, integration, and test process. Alternatives have been identified for some of the problem components. The designs developed in previous biobarrier/bioshield (BB/BS) R&TD tasks and flight projects were reviewed, most significantly the BBs for the Phoenix Robotic Arm and a potential Europa Lander. The team developed multiple concepts for each level of implementation from the entire flight system down to ground support BBs to protect modules during environmental/functional testing after microbial reduction and before integration with the spacecraft.
Objective 4: All of the BB/BS concepts have been evaluated for strengths and weaknesses. BB/BS design work has been initiated, and several of the ground support options have been prototyped and tested.

Fig 1. The enclosure attached to the VHP 1000ARD Biodecontamination unit

Fig 2. The complex geometry model (beige and black) surrounded by the enclosure structure

Fig 3. Complex geometry model with biological and chemical indicators

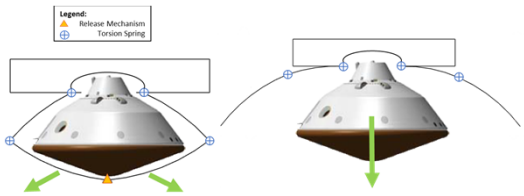

Fig 4. Example biobarrier concept for entry vehicle-level protection from recontam-ination

Publications:

R. Gradini, F. Chen, L. Newlin, "A Summary on Cutting Edge Advancements in Sterilization and Cleaning Technologies in Medical, Food, and Drug Industries, and Its Applicability to Spacecraft Hardware" , to be submitted to Advances in Space Research, 2017, in preparation.

R. Gradini, Z. Dean, L. Newlin, C. Spry, K. Stott, W. Schubert, "Results of the First Testing Campaign for the Validation of Gamma Irradiation for Planetary Protection Purpose", to be submitted to Advances in Space Research, 2017, in preparation.

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