Prioritized Technology: Planetary Protection
Expanded Bioburden Reduction Technique Toolbox

Technical Goal

To enable planetary protection (PP) capabilities to meet the 10^{-4} inadvertent contamination probability for forward planetary protection through expansion of bioburden reduction technique toolbox and materials compatibility:
Near Term: Compatibility and Specifications Expansion - materials compatibility, increased size scale and expanded specifications for **Heat Microbial Reduction** – expanded specs: mated surfaces, embedded organisms ; **Vapor Hydrogen Peroxide** – validate VHP model, dose dependences of dose (e.g. pressure, time, temp, geometry)
Mid Term: - Development of Alternative Approaches: Gamma Radiation –develop specs for in-flight and pre-launch dose condition; **DoD Techniques –** Leverage & tailor existing approaches for spacecraft applications
Long-Term: Scaling and Risk Mitigation: Interrupted microbial reduction processing experimentation (e.g. Does 110C at 20h + 110C at 30h = 110C at 50h?); **Summed bioburden reduction approaches** e.g. VHP+HMR, HMR+VHP

Mission Applications

What is enabled if we achieve the goal?

Forward Contamination Risk Reduction for:

- Europa: Clipper, Lander, Sample Return
- Enceladus: Plume Sample Return, Lander Sample Return
- Ceres, Vesta, Mars, TItan: Landers, Rovers/Boats, Sample Return

Risk mitigation for activities common to the project lifecycle: Current mitigations are conservative implementations, given limited technology development (for example, rework recontamination after integration has not been explored experimentally from a planetary protection POV)

Synergistic impacts : At NASA—human exploration; **Outside NASA**--Department of Defense and National Institutes of Health applications for use with biohazard/bioweapon decontamination activities.

Technical Status

Current NASA Methods for Bioburden Reduction:

A. **Heat Microbial Reduction:** Understood for free surfaces <200C; T >200C not well-characterized for free & mated surfaces and embedded; Hidden compatibilities may exist --MIL-SPEC 810F (High Temperature Compliant) and Automotive (AEC series) parts.
B. **Vapor Hydrogen Peroxide:** parts-level VHP has well-defined V&V, process dependencies not understood as they still require evaluation and bio-indicator verification. Hidden compatibilities & size scalability exist in data from other agencies.

Limited experimental work exists for other techniques (gamma/plasma/e-beam/laser; other Agencies standards for NASA use, interrupted processing, combined credit, cleaning for specific populations).
Forward Contamination Detection: Sample collection and processing efficiencies cover large areas (wipes >1m^2), quantitative metagenomics requires higher resolution (swabs <25 cm^2); Limited experimental work on microbial lethality for space conditions

Development Cost and Schedule