IAF SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations - IAF SPACE EXPLORATION SYMPOSIUM (IP)

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# ADVANCED PLANETARY PROTECTION MEASURES FOR MARS AND BEYOND

**Abstract**

Planetary protection is thus developing into an important challenge as space agencies and private entities ramp up their operations to explore Mars and other celestial bodies. The widely debated issue of preventing contamination of extraterrestrial environments by terrestrial microorganisms while maintaining scientific integrity poses its challenges. Existing sterilization techniques for spacecraft and landers are largely limited to prelaunch decontamination, an area in which further work remains necessary for long-term missions, integration of human presence, and in-situ resource utilization (ISRU). This study proposes novel decontamination protocols for rovers, habitats, and crewed missions beyond Earth. The next-generation sterilization techniques such as plasma-based decontamination, UV-C radiation exposure, self-sanitizing surfaces, and bioactive coatings are examined here to rationale for microbial growth mitigation in space environments. Besides these developments in sterilization techniques, we investigate the possibility of a real-time microbial monitoring system based on an AI-driven biosensor to dynamically detect and mitigate contamination risks. In addition, we assess the potential for crew-mediated contamination control through sealed entry systems, specialized airlocks, and biological containment units for future planetary outposts. The study also relates how greater contamination control could balance science exploration with ethical and environmental responsibility so that possible Martian biosignatures go undisturbed for future astrobiological investigation. The current study, by advancing effective and adaptive sterilization methods with the ability to incorporate real-time observations, aims at informing international planetary protection frameworks and improving mission planning for Mars, Europa, Enceladus, and beyond. Proposed measures would help to reinforce astrobiological integrity and provide a road for safe and sustainable human expansion throughout the solar system.

Keywords: Planetary Protection, Sterilization Techniques, AI-driven Biosensors, Contamination Control, Mars Exploration, Astrobiology, In-Situ Resource Utilization (ISRU), Space Ethics, Microbial Monitoring.