

Committee on Planetary Protection Concluding Session: Discussion Topics/Q&A

Meeting of the Committee on Planetary Protection

March 24-27, 2026

NASEM Space Science Week

A New Era for U.S. Planetary Protection Policy

- NASA Ignition strategy:
 - Accelerates NASA and commercial missions to establish a permanent U.S. lunar presence; and
 - Announced new Mars robotic missions:
 - Space Reactor-1 Freedom: nuclear propulsion mission; and
 - Skyfall: deployment of helicopters to surface of Mars
- Ignition creates exciting planetary protection (PP) opportunities:
 - Implementing Moon to Mars (M2M) architecture to shape PP approaches for robotic and crewed missions to Mars
 - Applying Category II, IIa, and IIb requirements for more NASA and commercial lunar missions
 - Managing PP challenges for Category III (nuclear propulsion orbiter) and Category IVa (helicopter landers) for Mars

Catalyst for Implementing Planetary Protection Actions in Moon-to-Mars Architecture (1/2)

- Through M2M architecture, NASA has:
 - Integrated PP into objectives of M2M architecture (e.g., NASA, *Moon to Mars Architecture Definition Document (ESDMD-001)—Rev. B* (Dec. 2024))
 - Identified specific PP considerations for M2M architecture (e.g., NASA, *Architecture-Driven Planetary Protection Considerations* (White Paper, Dec. 2025))
- Ignition provides a strategic opportunity to accelerate:
 - Closing PP knowledge gaps relevant to M2M architecture
 - Implementing M2M/PP activities across planning, engineering, and executing of robotic and crewed lunar missions
 - Building “connective tissue” for crafting PP mission approaches and technologies that enable crewed missions to Mars

Catalyst for Implementing Planetary Protection Actions in Moon-to-Mars Architecture (2/2)

- Potential activities include:
 - M2M/PP campaign plan for phases of planned lunar missions that informs development of a similar PP plan for stages of Mars exploration
 - Site utilization plan (e.g., for science, ISRU, etc.) would be helpful in mapping PP needs, with lessons learned fed into Mars exploration
 - Campaign plan activities that enable science on lunar prebiotic chemistry
 - M2M/PP activities in Artemis launches through “win-win” collaborations (e.g., hardware bio-sampling and crew-health monitoring)
 - M2M/PP collaboration with commercial lunar missions with most promise for generating PP insights for crewed missions to Mars
 - PP research funds toward M2M/PP implementation.

Risk Assessments

- Contamination is inevitable with crewed exploration; identifying what constitutes harmful contamination is essential as it must be avoided through, among other measures:
 - Identifying factors that are most relevant to preventing harmful contamination
 - Mitigating effects of contamination on scientific exploration
 - Developing tools for probabilistic risk assessment that include metagenomics
- Continued work on probabilistic risk assessment on forward planetary protection is necessary, as well as expanding this work to backward planetary protection models
- Risk assessment approaches used in medical device and pharmaceutical industries relating to contamination control and sterilization can supplement or inform aspects of these forward and backward probabilistic risk assessments

Bioburden Knowledge and Metagenomics (1/3)

- Bioburden knowledge (internal and external) from prior crewed and uncrewed missions—and changes over time—is important. Culturing assessments in parallel with data from metagenomics (from ISS, cleanroom, and environmental monitoring) are significant advances. Commend investigators in their commitment to publish this work. Would be useful to consolidate data collected to date from across different groups, and with international partners, and draw some conclusions. This would help in better defining research priorities
- Integration of metagenomics across forward and backward contamination PP analyses for crewed missions
- Consideration of benefits of other technologies that may be used in parallel to assess viability of bioburden in these environments. Examples include use of ATP (described within updates at this meeting) and other viability/activity assays. Some of these methods may be crude, but they can inform risk assessments

Bioburden Knowledge and Metagenomics (2/3)

- Metagenomics can help (1) fill knowledge gaps that inform probability models; and (2) recognize false positives—but other approaches are still needed because:
 - Metagenomics relies on successful DNA extractions and can miss active metabolic processes
 - To model probability and track changes in microbial function effectively, metagenomics needs to be combined with biochemical and organic molecule analyses, functional assays, functional annotation, and broader ‘-omics’ techniques, like transcriptomics and proteomics
 - Traditional spore assay remains essential because it provides a continuous 50-year baseline dataset, is highly accessible, and can successfully detect organisms when DNA recovery fails
 - Assays that target biofilms, measure cellular viability, and accurately distinguish between active microbial replication and dormant persistence are needed

Bioburden Knowledge and Metagenomics (3/3)

- Artemis is a critical PP proving ground:
 - Integrating PP sampling into Artemis missions is an essential prerequisite for Mars exploration
 - Artemis is necessary testbed to optimize and validate sample collection tools, internal standards (NIST), decontamination protocols, and metagenomic workflows
- Addressing backward contamination knowledge gaps in parallel with, and informed by, forward contamination workflows
- Good efforts to (1) create working groups, such as Planetary Protection—Analysis Working Group; and (2) incorporate standards and connect and disseminate work on metagenomics and other data analyzed across PP-science communities
- For sampling and metagenomic methods, more work is needed to understand limitations of methods used—such as sample collection, recovery efficiencies (in low biomass environments), and DNA extraction efficiency. Utilizing prior knowledge from industry and academia would be useful to accelerate and limit investigations

Focusing Planetary Protection Research on Closing Knowledge Gaps (1/2)

- Experimental design and impactful results that Cassily and Servetas reported on using metagenomics for assessment of biological cleanliness is impressive. This project demonstrates value of directed research to narrow PP knowledge gaps
- Concerns about 2025 ROSES structure, which places PP within Solar System Science and provides minimal information about research priorities related to crewed missions to Mars. Are alternative funding mechanisms possible? How can OPP provide more guidance to potential proposers?

Focusing Planetary Protection Research on Closing Knowledge Gaps (2/2)

- Opportunity exists for consolidation of spore and metagenomic data from multiple projects (published and internal) to inform OPP research needs. Increased research collaboration could facilitate multiple state-of-art measurements on low -biomass samples from spacecraft and assembly facilities
- NASA has established Space Microbial Culture Collection (SMCC) at Ames. Look forward to hearing about addition of isolates from Artemis missions and other activities in M2M architecture

Additional Research Needs (1/2)

- Consolidation of research knowledge by:
 - Combining bioburden (culturing) assessments with metagenomic data (from ISS, cleanroom, and environmental monitoring) across multiple sites to define conclusions, including diversity changes over time in space missions
 - Streamlining and **prioritizing** former list of research opportunities (Spry et al, 2024)
- Examples of needed research include:
 - Changes in microbial populations in crewed missions (e.g., sensitivity to inactivation by natural or applied antimicrobial factors at the lunar and martian surface)
 - Resolving understanding of detection of microorganisms on ISS's external surfaces and ruling out false positives (or negatives) because information to date suggests unexpected survival. Simulations may help to accelerate this work

Additional Research Needs (2/2)

- Examples of research needs (continued):
 - Molecular signatures that are present for typical terrestrial contaminants, and what we can expect to occur with contaminants based on prior knowledge
 - Method optimization, limitations, and validation
 - Survival profiles of detected bioburden—based on prior art and simulant studies under conditions representing lunar and Martian environments—to help inform non-linear survival risk modelling and improve confidence in risks to lunar and Martian missions
 - Impact of planet environmental conditions on high bioburden wastes

Evolving Lunar PP Knowledge

- Modeling and knowledge gaps on prebiotic chemistry: How to improve modeling of organic contamination transport on lunar surface?
- Utility of PP organic and propellant document inventories: How are these inventories helpful in identifying “harmful contamination” for lunar prebiotic chemistry in absence of “ground truth” data?
- PSRs: Need for preserving select lunar areas of prebiotic interest be considered in near- and long-term. Considering NASA's emphasis on transparency, any implicit “keep out” zones that NASA is using in selection and approval of Category IIb landing sites and surface missions need to be publicly defined. Critical need for analyses to decide objectively if any “keep out” zones around PSRs are required with respect to propellants as well as actual sampling and science requirements