NASA Office of Planetary Protection Update and Status

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December 4, 2024

SAFELY EXPLORING SAFELY PROTECTING

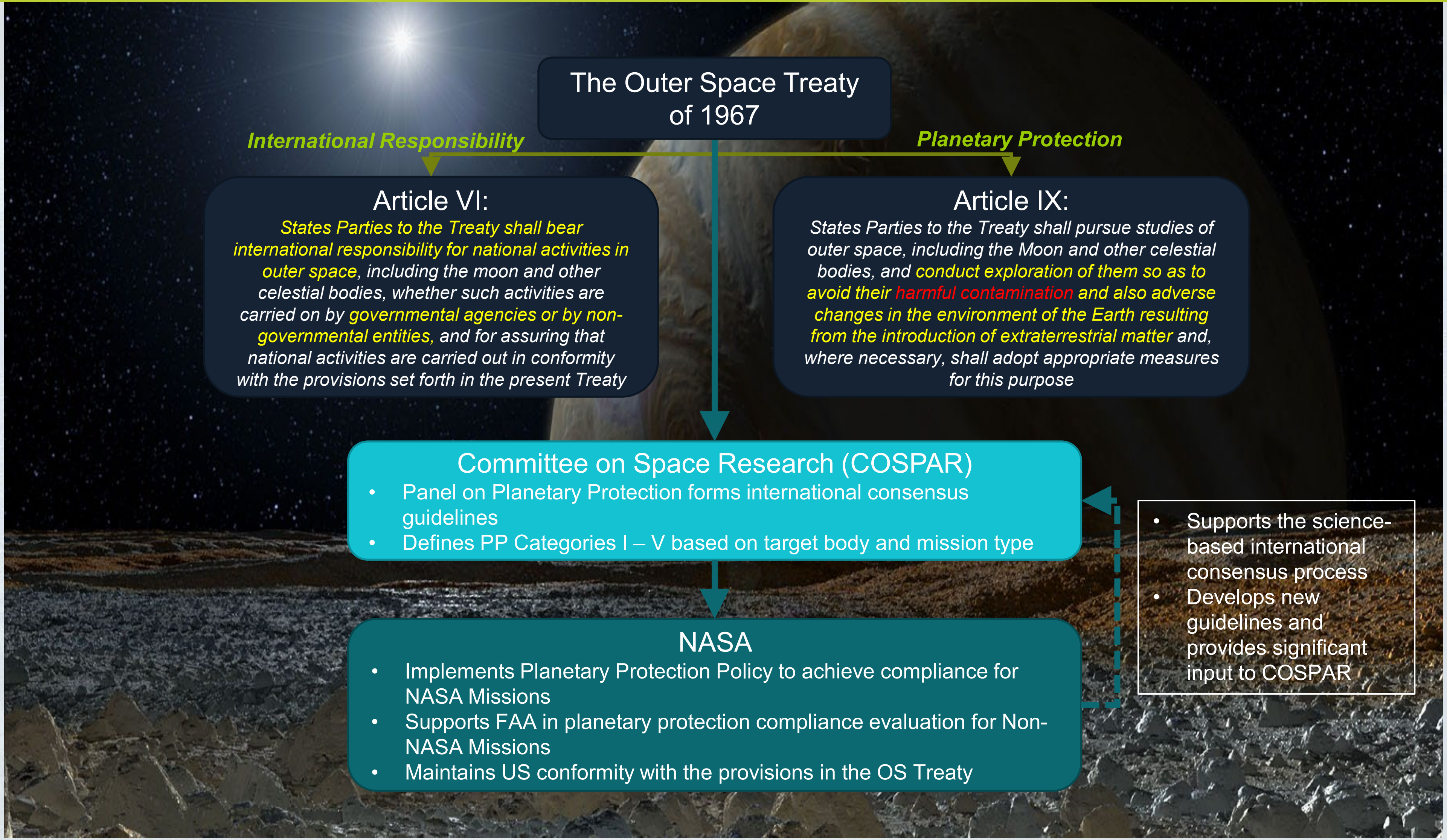
PLANETARY PROTECTION

ENABLING SCIENCE THROUGH SAFETY IN SPACE

Overview

- Policy Status
- Handbook Update
- Crew Policy Update
  - *Policy Knowledge Gap Mitigation and Strategy*
    - *Socialization of KGs*
- Workshops
- Technology and Research Developments

International Planetary Protection Process



OPP Document Tree

Link to NASA Planetary Protection policy and guidance documents at www.sma.nasa.gov

NPD 8700.1F
NASA Policy for Safety and Mission Success
Effective Date July 28, 2022
Expiration Date: July 28, 2028

NASA Policy Directives (NPDs)
- Documents Agency policy statements
- Describe what is required by NASA management to achieve NASA's vision, mission, and external mandates

NPR 8715.24
Planetary Protection Provisions for Robotic Extraterrestrial Missions
Effective Date September 24, 2021
Expiration Date: September 24, 2026

NASA Procedural Requirements (NPRs)
- Provide detailed procedural requirements to implement policy
- Guide how policy directives are implemented in the context of specific missions

NID 8715.129 ("Mars NID")
Biological Planetary Protection for Human Missions to Mars
Effective Date: July 9, 2020
Expiration Date: Sept 30, 2025

NASA Interim Directives (NIDs)
- Documents an immediate, short-term statement of the Agency's policies, requirements, and identifies responsibilities for implementation
- Temporarily modify policy directives or implementation requirements

NASA Standards
- Provide technical requirements
- Each NASA Technical Standard is assigned to a Technical Discipline

NASA-STD-8719.27
Implementing Planetary Protection Requirements for Space Flight
Effective Date: August 30, 2022

NASA-HDBK-6022
Handbook for the Microbial Examination of Space Hardware
Expiration Date: N/A
Status: Revision planned. Last draft revision released Aug 17, 2010

NASA Handbooks
- Companion documents to NPRs and NASA Standards
- Provide supporting material such as guidelines, lessons learned, procedures, and recommendations

All published documents found in NODIS: https://nodis3.gsfc.nasa.gov/ or the OPP website: https://sma.nasa.gov/sma-disciplines/planetary-protection#PolicyGuidance

= Document being updated

NASA NID 8715.129 Conversion Strategy

- NID 8715.129 ("Mars NID") Biological Planetary Protection for Human Missions to Mars
  - *Effective Date: July 9, 2020*
  - *Expiration Date: Sept 30, 2025*
- Working now with internal stakeholders to develop a path forward:
  - *Finalizing survey to NASA Centers and stakeholders*
  - *Next steps*
    - *Evaluate survey comments and develop plan*
    - *Establish working group of internal stakeholders*
- Solution space includes – canceling existing NID, folding key objectives into NPR 8715.24 (2026 expiration), critical design considerations into the NASA Human Rating Standard and capturing guidance and assumptions in Moon to Mars Architecture Concept Review White Papers.

OPP Document Tree

Link to NASA Planetary Protection policy and guidance documents at www.sma.nasa.gov

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= Document being updated

Overview of *Planetary Protection for Space Flight Handbook*

Replaces NASA-HDBK-6022, *Handbook for the Microbial Examination of Space Hardware*.

Aligns to NASA's PP policy and technical standards.

Provides significant updates in PP approaches and implementation.

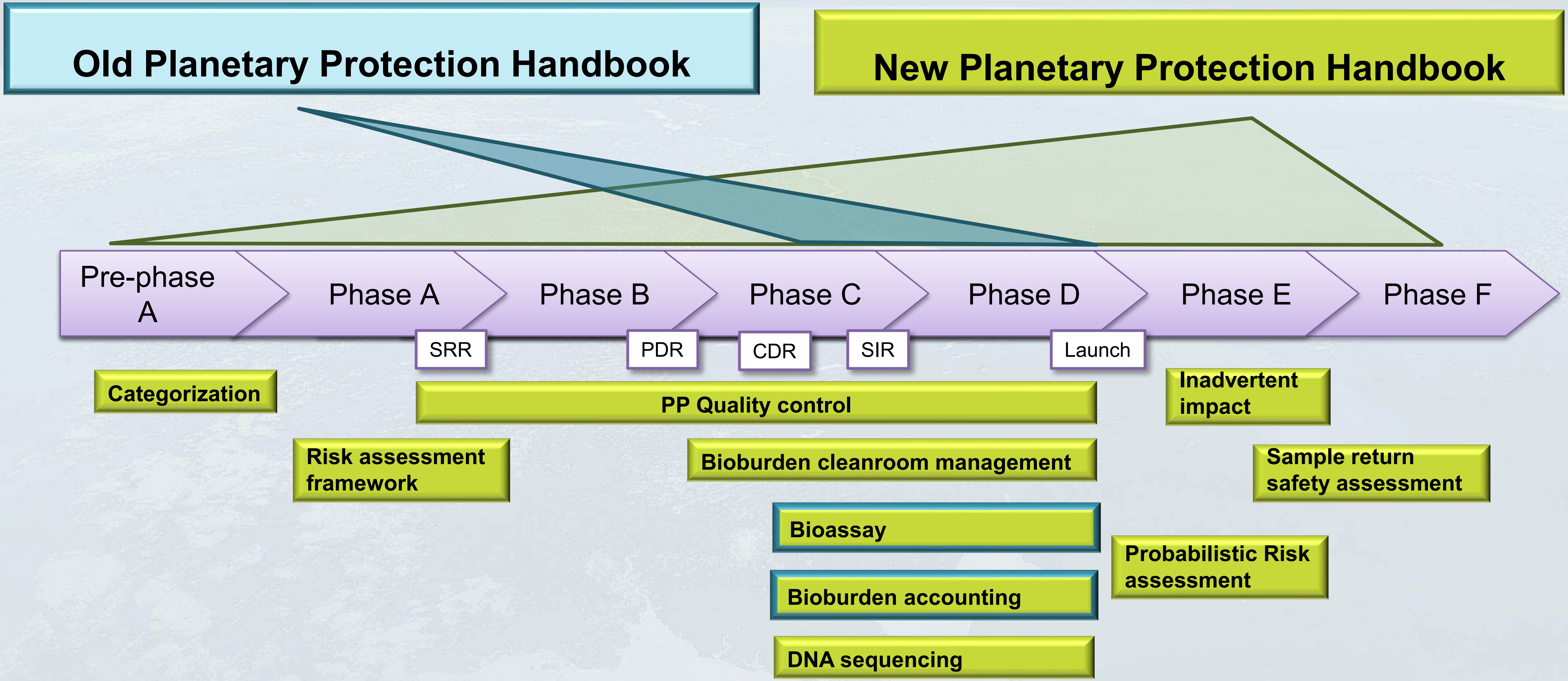
Expands beyond the NASA Spore Assay.

First major update since 2010.

Approx. 180 pages of content.

Reviewed by 20 NASA SMEs.

Modernizing a more useful Planetary Protection Handbook



Handbook Philosophy and Approach

- Provides guidance to Mission providers and Planetary Protection (PP) practitioners on implementing PP measures for both robotic and crewed space Missions.
  - Companion document to NPR 8715.24 and NASA-STD-8719.27.
  - Provides guidance but is not the only approach that can be taken.
- Shifts emphasis from strictly prescriptive requirements to allow performance-based requirements and approaches.
  - Documents guidelines on how to approach a topic as opposed to step-by-step protocols.
  - Leverages and encourages use of peer-reviewed publications and industrial standards.
  - Captures lessons learned and helpful user tips.
- Intended to be a living document and will be frequently updated over time with the latest information.
  - Feedback from the PP practitioner community will support future handbook updates.

Planetary protection laboratory practices.

Handbook Chapters

- 1 - Introduction
- 2 – PP Mission Categorization
- 3 – Guidelines for Forward Contamination Mitigation
- 4 – PP Quality Management System
- 5 – Biologically Controlled Cleanrooms
- 6 – NASA Standard Assay Laboratory Considerations
- 7 – Biological Estimation Techniques
- 8 – Backward PP
- Appendices

- Background
- Spores and Planetary Protection
- Major Handbook Principles
- History of Bioburden Accounting
- Adoption of New Standards and Approaches
- Communication Mechanisms
- A Living Document

Planetary protection samples were collected from the Mars Viking landers to verify biological cleanliness levels.

Handbook Chapters

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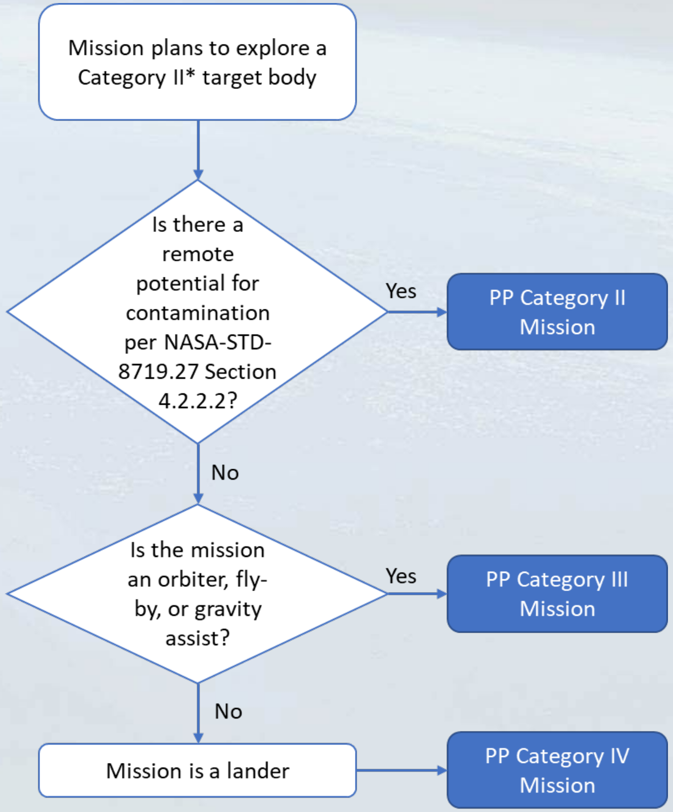
- Appendices

- Overview of the Categories
- Factors to Consider for Categorization
- Key Roles in the Categorization Process
- Updates and Changes to PP Mission Categories
- Sub-Categories
  - Missions to Earth's Moon
  - Category II* Target Bodies
  - Landed Missions on Mars
  - Special Regions (Mars)
  - Sample Return Missions
- Horizontal and Vertical Mobility
- Example Categorization Scenarios
- In-Mission Operations for PP on Interplanetary Missions



Decision process for evaluating Category II target bodies.*

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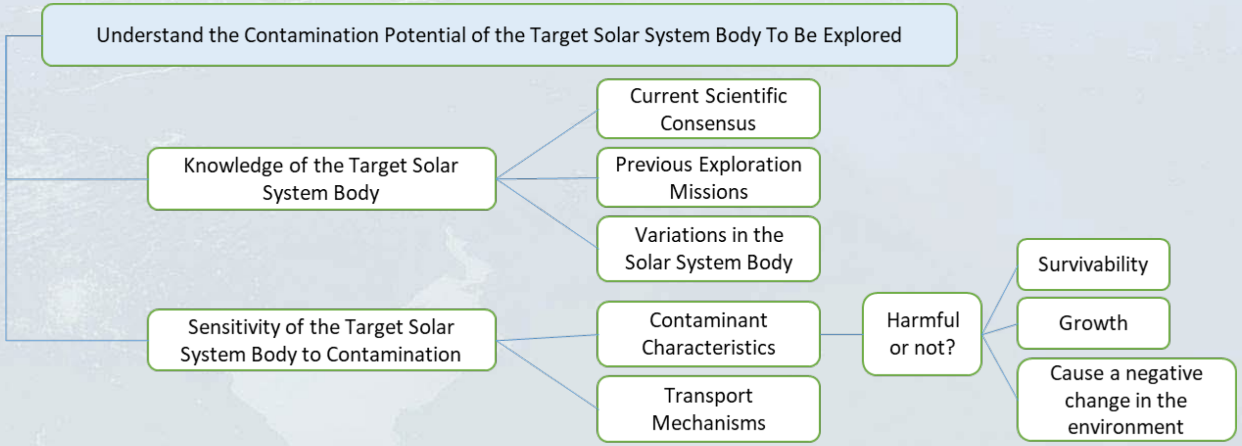
Chapter 3 topics:

- Forward Contamination Risk Assessment Framework
- Mission PP Risk analysis
- Development of an Assurance Case
- Inadvertent Impact at Mars for Lunar (Earth-Moon System) Missions
- Generalized Mars Mission 50-Year Probability of Impact Requirement Compliance
- Breakup and Burnup



Guidelines to understand the contamination potential of the target solar system body to be explored.

Handbook Chapters

1 - Introduction

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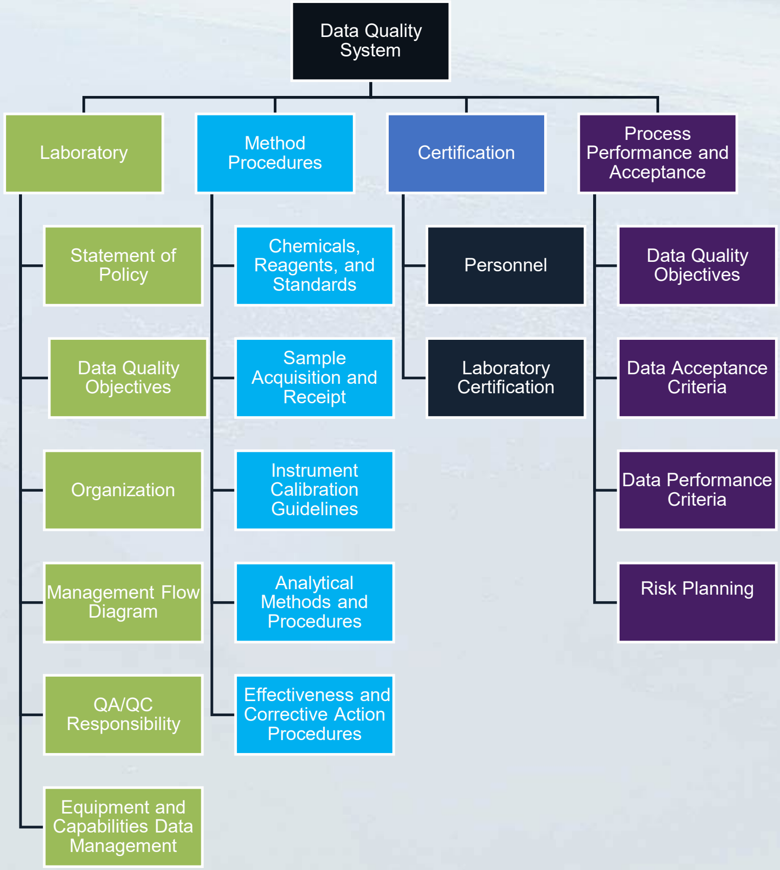
Appendices

- Process Validation
- Data Quality Objectives
- Data Performance and Acceptance Criteria
- Quality Management System
- Laboratory QA Plan
- Laboratory Methods
- Risk Management
- Proficiency Testing
- Oversight and Concurrence Activities



General topics addressed by a Data Quality System.

Handbook Chapters

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- Appendices

- Cleanroom Entry
  - Personnel Entry
  - Ground Support Equipment Cleaning & Entry
  - Hardware Entry
- Aseptic Operations in Cleanroom Environments
- Macroorganisms

The InSight spacecraft has been removed from its shipping container and is being moved for removal of protective wrapping.

Mars 2020 lift activities in the Payload Hazardous Servicing Facility (PHSF) cleanroom.

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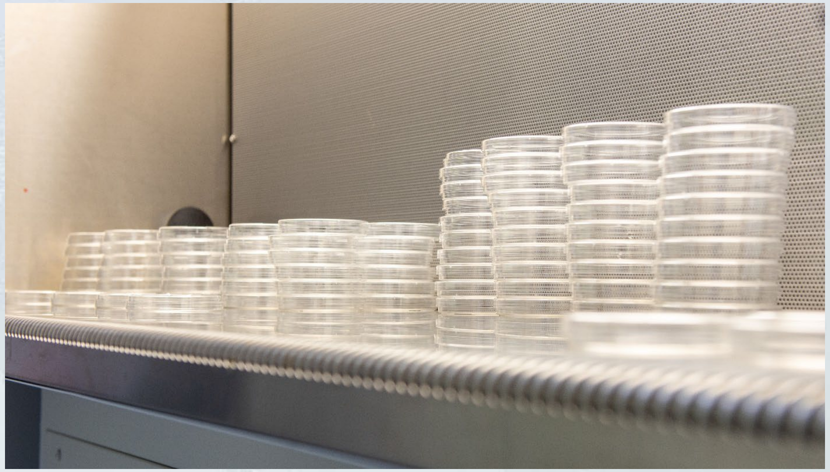
- Use of Bacterial Endospores
- Laboratory Equipment
- Aseptic Technique in Processing NSA Samples
- Barriers
- Method Implementation and Process Validation
- Environmental Biological Contamination Assessment
- Rapid Biological Contamination Assessments
- PP Sequencing Protocol



NASA Standard Assay

Handbook Chapters

1 - Introduction

2 – PP Mission Categorization

3 – Guidelines for Forward Contamination Mitigation

4 – PP Quality Management System

5 – Biologically Controlled Cleanrooms

6 – NASA Standard Assay Laboratory Considerations

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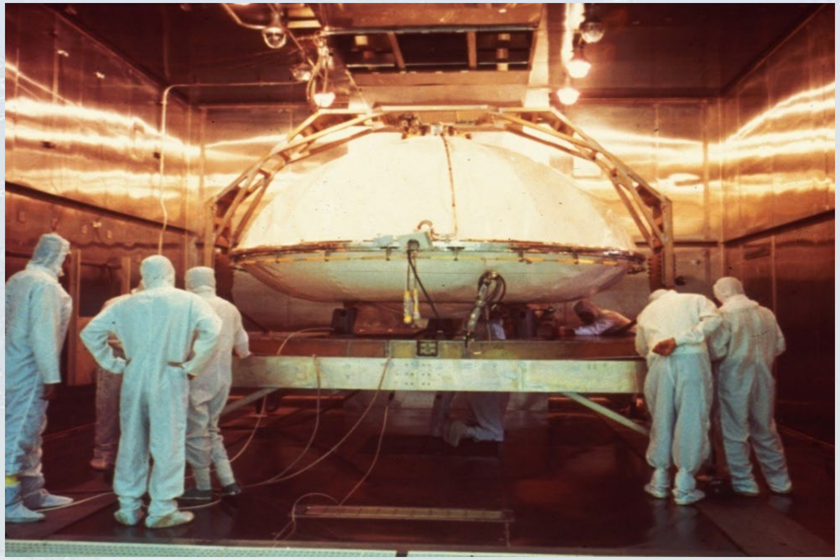
8 – Backward PP

Appendices

- Organic Inventory, Biological Inventory, and Organic Archiving
  - Historical Background of Requirements
  - Reporting of Inventories and Archives
  - Current Limitations, Challenges, and Opportunities for Improvement
- Bioburden Accounting Parameters



Mars Viking Landers were part of the historical background of requirements.

Handbook Chapters

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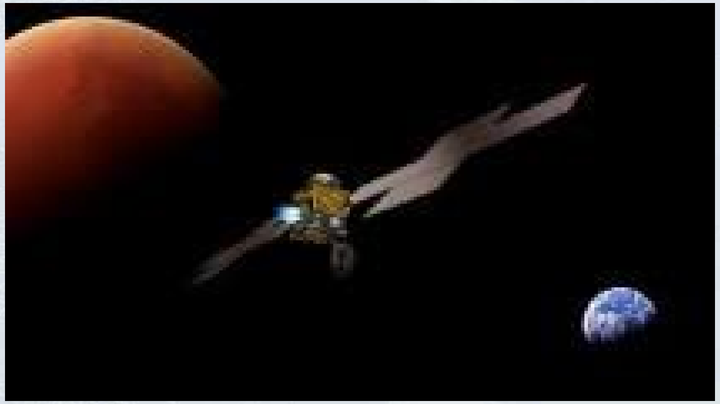
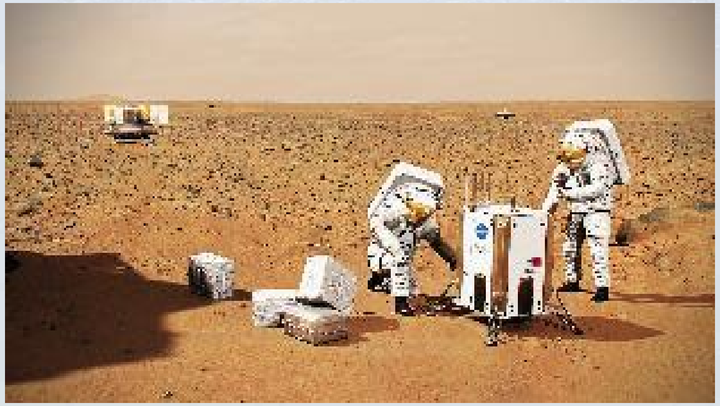
Appendices

- Backward PP Overview
- Sample Safety Assessment Protocol Concepts
- PP Knowledge Gaps for Crewed Missions to Mars





Planning for Mars Sample Return and future crewed missions to Mars.

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- Appendices

- 1 – Definitions
- 2 – Abbreviations
- 3 – National Academies Reports
- 4 – Modeling the Probability of Contamination for NASA Missions
- 5 – PP Cat II Mission Organic Inventory Template
- 6 – Generalized Mars Mission 50-Year Probability of Impact Requirement Compliance
- 7 – Example Laboratory Standard Operating Procedures

Appendix 5: PP Category II Mission Organic Inventory Template

Organic Inventory	Mission Name:

The Mission provides an itemized list of **bulk organic materials** [defined as all carbon-containing compounds, *including* payload biological materials but *excluding* carbides, carbonates, cyanides, and simple oxides of carbon (i.e., CO and CO_2)] presented at the same level as the materials identification and usage list (MIUL)/materials list, as used on the flight hardware, estimated actual (in kg) for organic materials present in amounts larger than 1kg; “small amounts” for organic materials present in amounts between 1kg and 0.1kg; and “traces” for identifiable organic materials present in amounts less than 0.1kg. (Add more lines as needed for each line entry.)

1) Adhesives and Potting Compounds

[e.g., RTV/Silicones (DOW, Nusil, Hysol); polyurethanes such as arathane/solithane conformal coatings; epoxies such as Scotchweld, CFRP resin]

Material Name and Usage	Actual Amount (kg)	Small Amount	Traces
	0.0	❑	❑
	0.0	❑	❑

2) Primers, Paints, and Inks

(e.g., Aeroglaze, Chemglaze, etc.)

Material Name and Usage	Actual Amount (kg)	Small Amount	Traces
	0.0	❑	❑
	0.0	❑	❑

3) Thermal Control Films

(e.g., Kapton, FEP Teflon, Betacloth)

Material Name and Usage	Actual Amount (kg)	Small Amount	Traces
	0.0	❑	❑
	0.0	❑	❑

Example Organic Inventory Template

Review & Release Process

- [x] Material Complied by OPP Handbook Team

↓

- [x] Technical Edits by NASA Safety Center (NSC)

↓

- [x] NASA SME Reviews & Handbook Updates

↓

Special Publications Review & Release:
- [x] Technical Edits by NSC
- Graphical Design Work
- [ ] 508 Accessibility Review
- Public Release Review Process

Current Effort

On track for Early 2025 release!

- Institute of Environmental Sciences and Technology session being coordinated at ESTECH 2025 – May 5-8, 2025 @ Orlando, FL
- ASTM Subcommittee newly forming

ASTM E21.09 is the new Planetary Protection Subcommittee under E21

- E21 is the Committee on Space Simulation and Applications of Space Technology
  - Other Subcommittees under E21:
    - *E21.04 Space Simulation Test Methods*
    - *E21.05 Contamination*
    - *E21.08 Thermal Protection*

Eagerly calling for participation from practitioners in the field to participate as a subcommittee member:

https://www.astm.org/get-involved/membership.html

Direct questions regarding the subcommittee, access, equity or other questions to the subcommittee chair:
Betsy Pugel/NASA, Betsy.Pugel@nasa.gov

ASTM INTERNATIONAL
Helping our world work better

E21.09 Scope: To develop standards and best practices for the identification, quantification, and mitigation of terrestrial contamination from biological organisms, organic materials and organic volatiles carried or released by spacecraft (forward contamination) and for the prevention of harmful biological contamination of the Earth-Moon system by spaceflight hardware, spacecraft, and samples returning from sensitive solar system bodies (backward contamination). This includes the development of protocols and processes central to protecting the integrity of the scientific search and study of processes of chemical evolution or origin of life in the solar system, such as: identification and inventory of organics, use of existing standards for cleanroom practices, bioburden assaying and accounting of spaceflight hardware, reduction of bioburden on hardware, sample containment and risk analysis and other forward and backward contamination-relevant protocols and practices.

Tech Dev – Crew KG Mitigation – Gap Identification

- Andy Spry will present on detailed Knoweldge Gap Identification and Process

Microbial & Human Health Monitoring
1A. Microbial monitoring of the environment
1B. Microbial monitoring of humans
1C. Mitigation of microbial growth in spacecraft systems
1D. Operational guidelines for planetary protection and crew health
Technology & Operations for Contamination Control
2A. Bioburden/transport/operations during short vs. long stays
2B. Microbial/organic releases from humans and support systems
2C. Protocols for decontamination & verification procedures
2D. Design of quarantine facilities/methodologies at different mission phases
2E. Martian environmental conditions variation over time with respect to growth of Earth microorganisms
2F. Research needed to make ISRU & planetary protection goals compatible
2G. Acceptable contamination level from wastes left behind, including constraints on vented materials
ORIGINAL 2H. DELETED (merged with 2B.)
2I. Approaches to achieve 'Break the chain" requirements
2J. Global distribution/depth of subsurface ice and evidence of extant life
2K. Evolution of planetary protection requirements/goals from robotic precursor through to human missions & exploration zones
Natural Transport of Contamination on Mars
3A. Measurements/models needed to determine atmospheric transport of contaminants
3B. Measurements/models for subsurface transport of contaminants
3C. Effect of biocidal factors on survival/growth/adaptation of microorganisms
3D. Determination of acceptable contamination rates & thresholds
3E. Protection mechanisms for organisms on Mars
3F. Degradation of landed materials by Martian environment
3G. Induced environmental conditions around structures
3H. Sensitivity of non-culturable species to biocidal factors

Spry et al, 2024.

Tech Dev – Crew Knowledge Policy Gap Mitigation

- How do we engage the community on large scale R&TD coordination?
  - *COSPAR Panel on PP – limited to ~15 agencies with members only engaged on PP Policy*
  - *International Mars Exploration Working Group (IMEWG)*
  - *Peer-reviewed publications*

ELSEVIER
Life Sciences in Space Research
Volume 36, February 2023, Pages 27-35

The COSPAR Planetary Protection Policy for robotic missions to Mars: A review of current scientific knowledge and future perspectives

Karen Olsson-Francis [a], Peter T. Doran [b], Vyacheslav Ilyin [c], Francois Raulin [d], Petra Rettberg [e], Gerhard Kminek [f], María-Paz Zorzano Mier [g], Athena Coustenis [h], Niklas Hedman [i], Omar Al Shehhi [j], Eleonora Ammannito [k], James Bernardini [l], Masaki Fujimoto [m], Olivier Grasset [n], Frank Groen [l], Alex Hayes [o], Sarah Gallagher [p], Praveen Kumar K [q], Christian Mustin [r], Akiko Nakamura [s]...Maxim Zaitsev [v]

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News & Views

Open camera or QR reader and scan code to access this article and other resources online.

Planetary Protection Knowledge Gap Closure Enabling Crewed Missions to Mars

James A. Spry,[1] Bette Siegel,[2] Corien Bakermans,[3] David W. Beaty,[4] Mary-Sue Bell,[5] James N. Benardini,[2] Rosalba Bonaccorsi,[1,6] Sarah L. Castro-Wallace,[5] David A. Coil,[7] Athena Coustenis,[8] Peter T. Doran,[9] Lori Fenton,[1] David P. Fidler,[10] Brian Glass,[6] Stephen J. Hoffman,[11] Fathi Karouia,[6] Joel S. Levine,[12] Mark L. Lupisella,[13] Javier Martin-Torres,[14,15] Rakesh Mogul,[16] Karen Olsson-Francis,[17] Sandra Ortega-Ugalde,[18] Manish R. Patel,[17] David A. Pearce,[19] Margaret S. Race,[1] Aaron B. Regberg,[5] Petra Rettberg,[20] John D. Rummel,[21] Kevin Y. Sato,[2] Andrew C. Schuerger,[22] Elliot Sefton-Nash,[18] Matthew Sharkey,[23] Nitin K. Singh,[4] Silvio Sinibaldi,[18] Perry Stabekis,[1] Carol R. Stoker,[6] Kasthuri J. Venkateswaran,[4] Robert R. Zimmerman,[24] and Maria-Paz Zorzano-Mier[25]

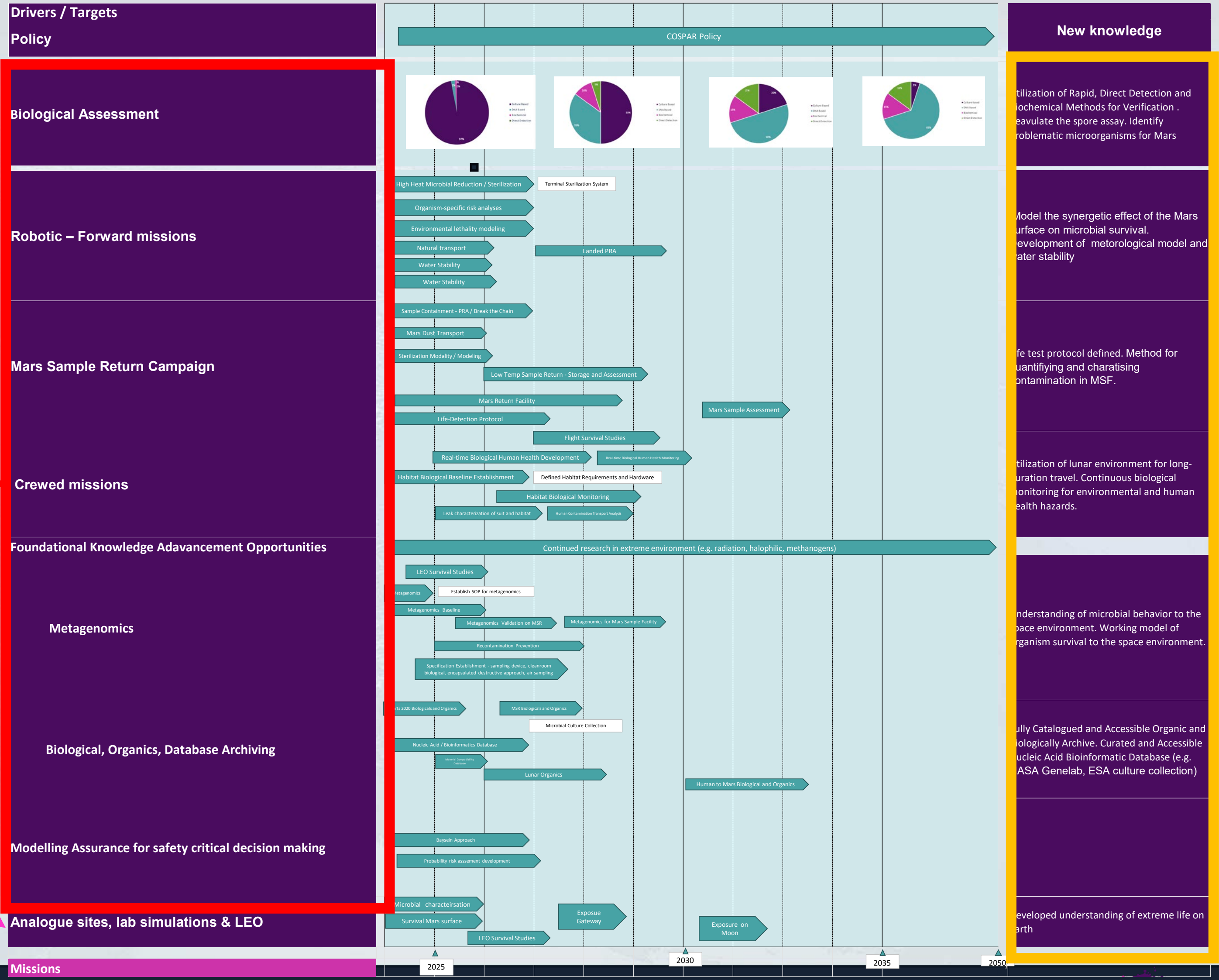
IMEWG on Mars?

Tech Dev – Crew KG Mitigation - Pathway Overview

Policy Drivers

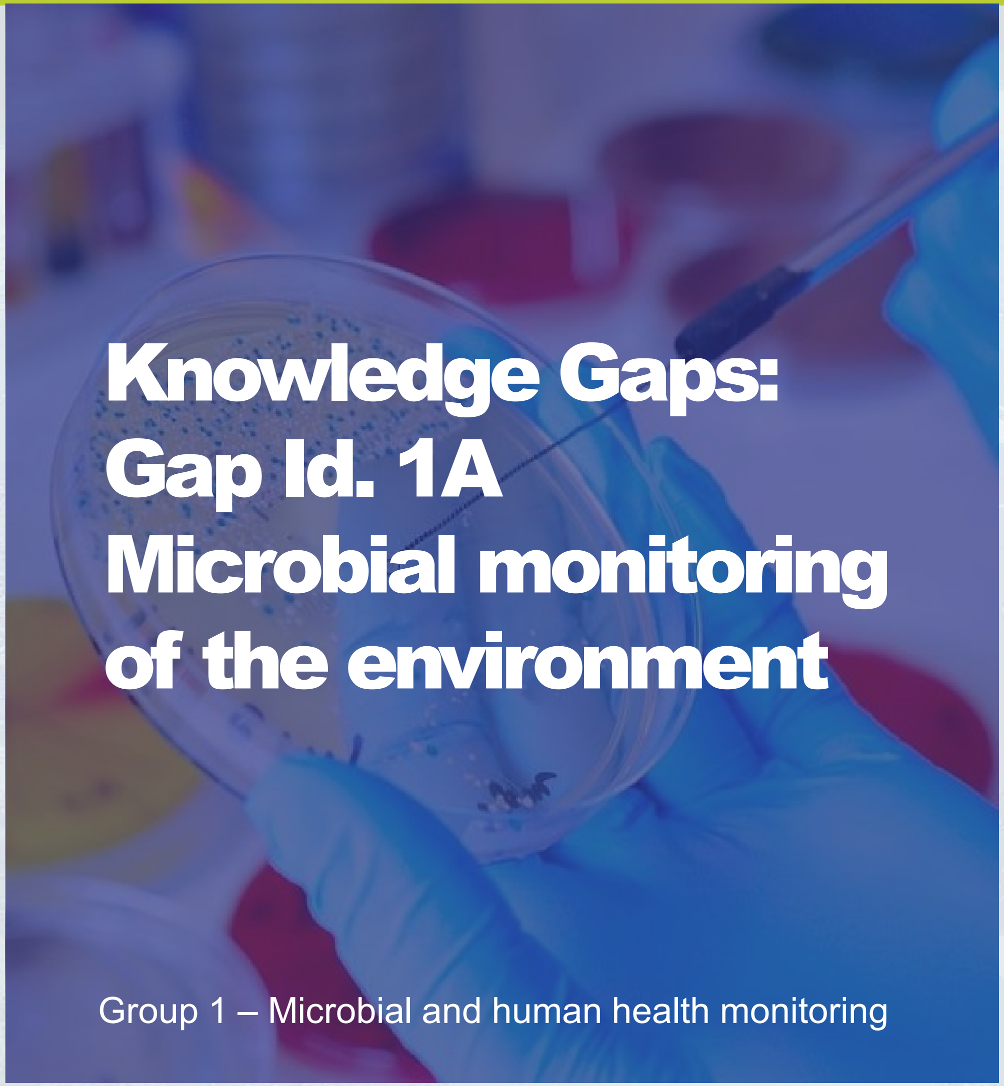
Technical Drivers

Programmatic Drivers (input needed!)



End goal / desire

COSPAR
COMMITTEE ON SPACE RESEARCH



Knowledge Gaps: Gap Id. 1A Microbial monitoring of the environment

Group 1 – Microbial and human health monitoring

COSPAR
COMMITTEE ON SPACE RESEARCH

1. What systematic microbial monitoring is required ?
2. What monitoring is required on human missions ?
3. What is the mutation rate in flight ?

Knowledge Gaps: Gap Id. 1A Microbial monitoring of the environment

Group 1 – Microbial and human health monitoring

MORE SPECIFIC QUESTIONS

- Where is the right spot to monitor?
- How clean is clean enough?
- Can one be too clean?
- Have we overlooked back contamination?
- How much knowledge is enough? 95%? 98%?
- How does one decide?
- How does one characterize the material that the crew is bringing back?
- How long do we need to treat returned samples as a biohazard?
- What if mutated Earth microbes are more dangerous than anything we find on Mars?
- Is there potential to use the Deep Space Gateway as a stopover point for Mars Sample Return and returning astronauts?

Tasks: Gap Id. 1A
Microbial monitoring of the environment

1
Take samples from spacecraft facilities and systems at higher frequency than currently taken (including air filters within the International Space Station)

2
Take contained microorganisms on missions (or simulated mission environments) to determine the mutation rate in the space environment (through comparative genomics)

3
Laboratory test to improve the understanding of microbial persistence in the space environment using targeted simulations (on Earth and on future missions)

4
Define the hazards in human health of introducing new organisms into a system

5
Tackle molecular biology gaps (low biomass, ketone, etc.) and standardise the method

6
Determine which organic materials might be dangerous for human health and develop VOC sensor technologies to monitor levels

7
Develop use of machine learning and AI to determine

Group 1 – Microbial and human health monitoring

Envisioned Resources – Biology, space environmental, reliability, contamination control, chemistry lab, material and processing, digital twin, AI

Workshops and Seminars

SCIENCE MISSION DIRECTORATE

SCIENCE AND PLANETARY PROTECTION IN ADVANCE OF HUMAN MISSIONS SEMINAR

OCTOBER 30 - NOVEMBER 1, 2024

PLANETARY PROTECTION

METAGENOMICS IN SPACEFLIGHT:

ESTABLISHING AN IMPLEMENTATION ROADMAP

NASA AMES | NOVEMBER 19-22

SCIENCE MISSION DIRECTORATE

SCIENCE AND PLANETARY PROTECTION IN ADVANCE OF HUMAN MISSIONS

Seminar - Jul 31 and Aug. 1, 2024

- 4-hours / day
  - 20 min *invited* talks followed by:
  - ~1.5h breakout session; ~30min report outs from each breakout group
- Topics included
  - Overview of PP, MEPAG Goals, NASEM Science Objectives for Human Surface Missions
  - Microbial survivability on Mars
  - Transport on Mars
  - Target locations for the search for life
  - Potential human impacts to Mars
  - Tools and Operations to Monitor Human Health and Impacts

Workshop - Oct 30 – Nov 1, 2024

- 4-hours / day
  - 3 sessions; ~1hr of 20 min talks based on *submitted* abstracts
  - 3 panels; ~1 hr panel discussion, with Q&A from audience on topics based on *submitted* abstracts
  - Scenario Exercise – ~1.5hr all participants discuss a crew mission scenario in breakouts, and ~2h of report outs from each breakout group with large group discussion
- Topics included
  - Life detection in context to PP
  - Analogue environments and future exploration
  - Mars environments and terrestrial biology
  - Risk mitigation for PP
  - Instrument and technology development
  - Science investigations prior to crew
  - An astronaut reality check

SCIENCE MISSION DIRECTORATE
SCIENCE AND PLANETARY PROTECTION IN ADVANCE OF HUMAN MISSIONS

Seminar Key Questions

- What are the priority knowledge gaps in our understanding of survival of terrestrial microbes, building on the existing literature (Final Report of the COSPAR Planetary Protection Knowledge Gaps for Human Mars Missions Workshop Series and Paths to Knowledge Gap Closure).
- What measurements do we want to prioritize and what research can we conduct in advance of human arrival on Mars to ensure future science integrity?
- What tools (incl. crew-robot interface) could crew utilize on the surface to preserve scientific integrity of samples?
- What aspects of guidance for crewed science missions could use further discussion, are missing, and/or work well?
- What are the prioritized science tasks to achieve before humans arrive?
- What scientific research is desired to be conducted before humans arrive and will it inform the activities of the human explorers once they are on the surface?
- What research will the crew themselves be doing, and how will forward and backward contamination control be incorporated into those research (e.g. science and engineering) activities?

Science Seminar Key Takeaways

- **Understanding the survival of terrestrial microbes under Martian conditions:** This includes studying a wider range of organisms, focusing on extremophiles, and understanding the effects of Martian environmental factors on microbial survival.
- **Developing robust sample collection and analysis methods**: This includes minimizing contamination from humans and spacecraft, using sterile tools, and developing efficient and effective decontamination procedures.
- **Prioritizing research before human arrival:** This includes conducting detailed surveys of potential landing sites, studying the survival of microbes in unique environments, and developing models to predict the spread of contamination.
- **Creating a framework for collaboration and interdisciplinary work:** This includes sharing knowledge across different fields, such as astrobiology, life support, and planetary protection, to develop more comprehensive solutions for future missions.

SCIENCE MISSION DIRECTORATE
SCIENCE AND PLANETARY PROTECTION IN ADVANCE OF HUMAN MISSIONS

Workshop Key Questions

- Are there key analogue environments that we should be focusing on to help drive decision making?
- What analogue extreme environmental variables would you consider and why? Is there a “must-have”?
- What are the key technology development needs that we need to enable key measurements before humans arrive? (Should be achievable and realistic in the next 5 years etc...)
- If you had to choose 1-3 technology developments in the near-term, what would they be? What about the longer-term?
- What’s your “non-starter”, we must understand “this” science before we send humans, and why?
- How would you delineate the line between robotic and crew activities? Are there specific activities that you would bin one way or another?
- With MEPAG Goals (from Goals Documents) in mind, what investigations/science campaigns would you conduct on a first crewed Mars mission? What does this campaign need to look like (recon., early experiments, EVAs, returned samples)?
- What does planning the crewed mission science reveal about what is needed from earlier robotic missions?

**Note: Key takeaways based on AI summary of breakout notes and human-created content

Science Workshop Key Takeaways

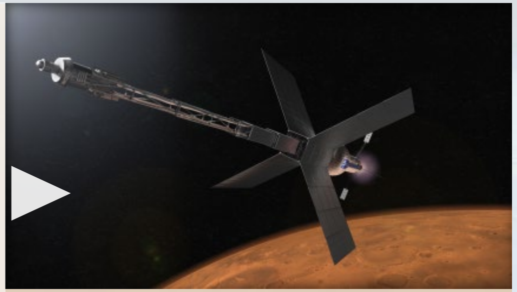
- **Multi-faceted Approach:** Need for a multi-faceted approach to Mars exploration, integrating geology, biology, human factors, and technological advancements.
- **Collaboration and Communication:** Collaboration among scientists, engineers, and industry partners to address the complex challenges of human exploration.
- **Planetary Protection as a Priority:** Planetary protection protocols are paramount to protect both the Martian environment and Earth from potential contamination.
- **Investing in Technology:** Develop advanced technologies, particularly in the areas of life detection, sample return, and robotic capabilities.
- **Preparing for Human Presence:** Understand human adaptation to Martian conditions and mitigating risks to human health and safety.

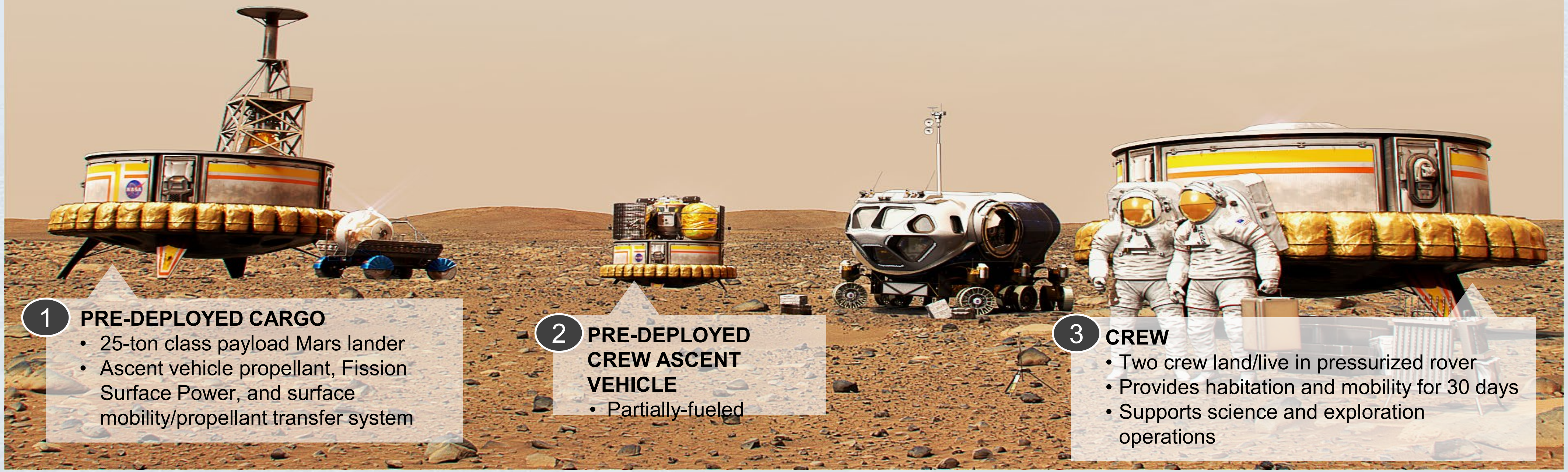
Scenario Exercise Guidelines

- Target landing site is at Jezero Crater; no ISRU requirements
- A Zone of Minimum Biological Risk (ZMBR) is established where crew have no PP-based operational constraints
- Three science sorties of 5 days each, are planned beyond the limit of the ZMBR.
- A notional 8hr science workday, which includes EVAs (max 16)
- COSPAR guidelines for crewed missions continue apply

TRANSIT HABITAT (TH) AND HYBRID NUCLEAR ELECTRIC PROPULSION (NEP) / CHEMICAL STAGE

- Supports four crew on the long mission to Mars
- Two crew remain in orbit while two crew visit the Mars surface





1 PRE-DEPLOYED CARGO

- 25-ton class payload Mars lander
- Ascent vehicle propellant, Fission Surface Power, and surface mobility/propellant transfer system

2 PRE-DEPLOYED CREW ASCENT VEHICLE

- Partially-fueled

3 CREW

- Two crew land/live in pressurized rover
- Provides habitation and mobility for 30 days
- Supports science and exploration operations

NASA HEOMD-415

Reference architecture for *analysis purposes only.* Should not be considered “the plan”

Workshop Key Scenario Exercise Discussion

The breakout rooms engaged in a lively discussion about the scientific goals, logistical challenges, and critical considerations for a first crewed mission to Mars, specifically targeting Jezero Crater. While each room explored different aspects of the scenario, a common thread emerged: the need for a balanced, multi-faceted approach that prioritizes science, technology, and human factors.

- **Human-Robot Collaboration:** The discussion demonstrated a strong appreciation for the unique combination of human ingenuity and robotic capabilities for achieving scientific goals on Mars.
- **Comprehensive Planning:** Successful mission planning requires a multi-faceted approach, integrating scientific objectives, technology development, crew safety, and planetary protection protocols.
- **Continuous Learning and Adaptation:** Future missions to Mars will benefit from the lessons learned from the first crewed mission, requiring a constant cycle of data gathering, analysis, and adaptation.

Science Seminar and Workshop Next Steps

- Workshop Series Report
  - *Winter 2025 - NASA Technical Reports Server*
    - *Delivery and coordination with NASEM Science Objectives for Human Surface Missions Study Committee*
  - *Summer 2025 - Peer-reviewed Journal Workshop Report*

PLANETARY PROTECTION

METAGENOMICS IN SPACEFLIGHT: ESTABLISHING AN IMPLEMENTATION ROADMAP

NASA AMES | NOVEMBER 19-22

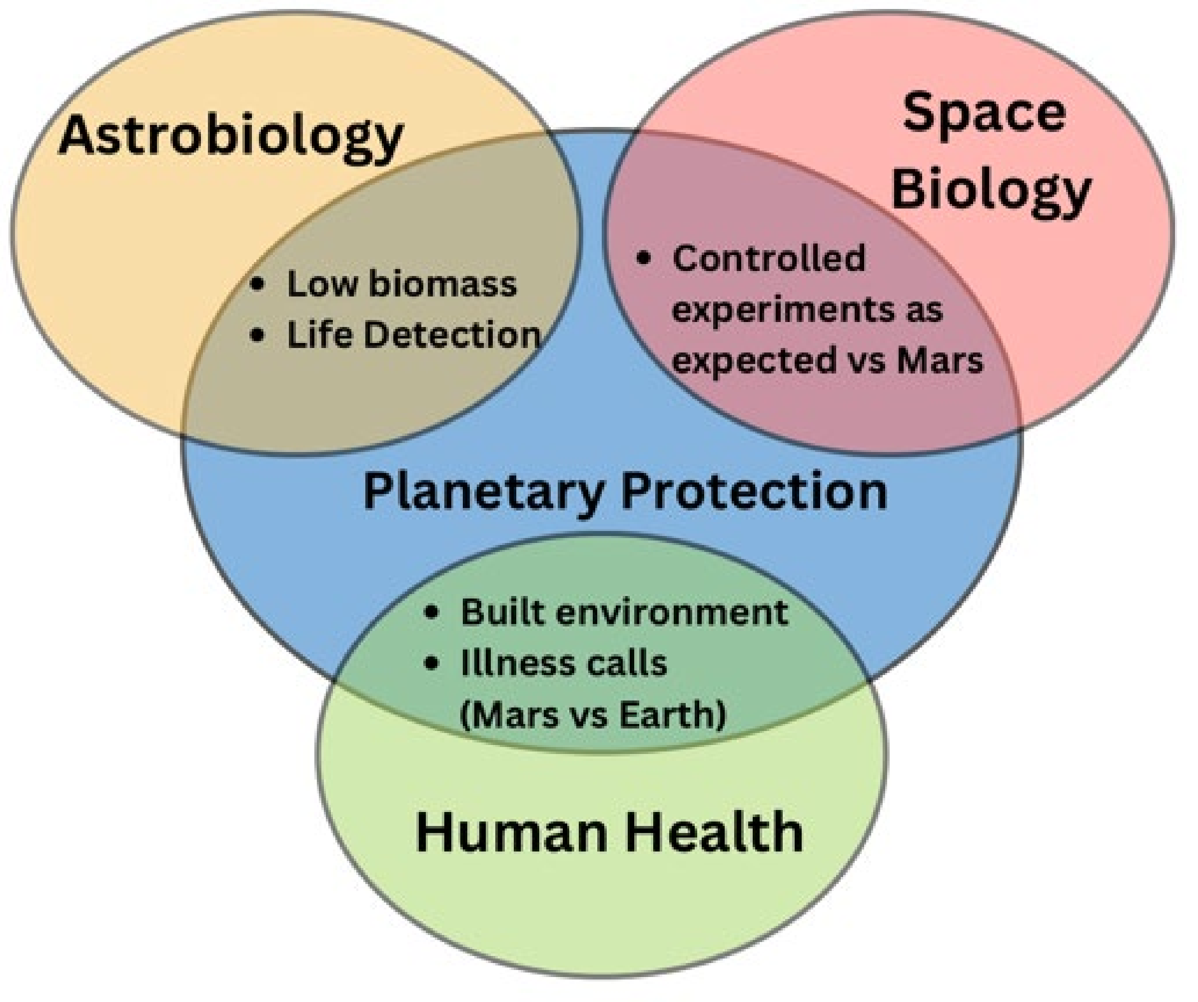
- 3.5 days
  - 20 min *invited* talks followed by:
  - ~1.5h breakout session; ~30min report outs from each breakout group
- Topics included
  - Safety Critical Decision Making
  - Microbial Dark Matter
  - Low Biomass
  - Bioinformatics and Databases
  - Technology Needs
  - Human Health and the Built Environment
  - Roadmap to Implementation
- International participation/sponsorship – ESA, JAXA, COSPAR

Metagenomic Workshop Objectives and Overview

PLANETARY PROTECTION
METAGENOMICS IN SPACEFLIGHT:
ESTABLISHING AN IMPLEMENTATION ROADMAP
NASA AMES | NOVEMBER 19-22

Establish the path forward for <u>what is needed</u> to be able to leverage metagenomics (-omics, nucleic acid based) technologies for in-flight and safety critical decision making.

- Planetary Protection – BPP safety critical, harmful contamination compliance
- Astrobiology – science, life detection/safety critical
- Space Biology – safety critical if sustainability, monitoring of experiments plant pathology etc., microbial performance in the space environment
- Human health – safety critical, built environment, ECLSS and disease diagnostics



Key Workshop Seminar Takeaways and Next Steps

- Establishment a community of practice working group leveraging the NASA Open Science Data Repository Advisory Working Group
- Mock community and metagenomic standards
- International community standard operating protocol
- Highlighted need for interdisciplinary and inter-Agency coordination of technology development with industry partnerships
- Roadmap to implementation
- Next Steps
  - Roadmap to implementation (5-year plan) and report publication

- Coordination of activities include:
  - *SMD's **Research Opportunities in Space and Earth Science Planetary Protection Research (ROSES-PPR) program** David Smith, ROSES-PPR Scientist)*
  - *STMD's **Small Business Innovative Research (SBIR) program** Sub-topic 13.04 Contamination Control and Planetary Protection (JPL/GSFC sub-topic technical managers)*
  - *STEM Engagement's **Established Program to Stimulate Competitive Research (EPSCoR) program** (OSMA/PPO technical manager)*
    - Research Infrastructure Improvement (RII) Track 4: EPSCoR Research Fellows Program
    - *Rapid, Response Research (R3)*
  - *Space Grant*
  - *Directed Center tasks – Office of Planetary Protection, SMD Mars Exploration Program Technology Developments, etc.*
  - *Mission Specific – MSR, Moon to Mars, etc.*

Office of Planetary Protection Metagenomics Study: Characterization of NASA Cleanrooms

- Cross center and international collaboration (NASA/ESA) to develop a standard method for metagenomic analysis of cleanrooms for Planetary Protection
- Background:
  - *Fall '23-Spring '24 Langley intern team developed preliminary protocol, design of experiments*
  - *Timeframe for current study: September 2024 – September 2025*
- Objectives
  - *Develop standard method for metagenomic analysis of cleanrooms for Planetary Protection*
  - *Strengthen the PP SME community and build collaboration*
  - *Collaborate with the international community on an international standard for metagenomic analysis*
  - *Provide updates on metagenomic analysis for PP Handbook revision*
  - *Publish findings/standard process*

Office of Planetary Protection Metagenomics Study: Experimental Scope

Participation

- Generate equipment list to capture capabilities across Centers
- Sampling and analysis locations

Scope

- Define the purpose of this study
- Establish Experimental parameters
- Streamline approach to fit within timeline and budget

Plan

- All centers provide input
- Minimize variance
- Sampling Procedure
- Packaging, shipping, and storage procedures
- Consumables
- Analysis pipeline

Test

- Conduct test plan activities

Deliver

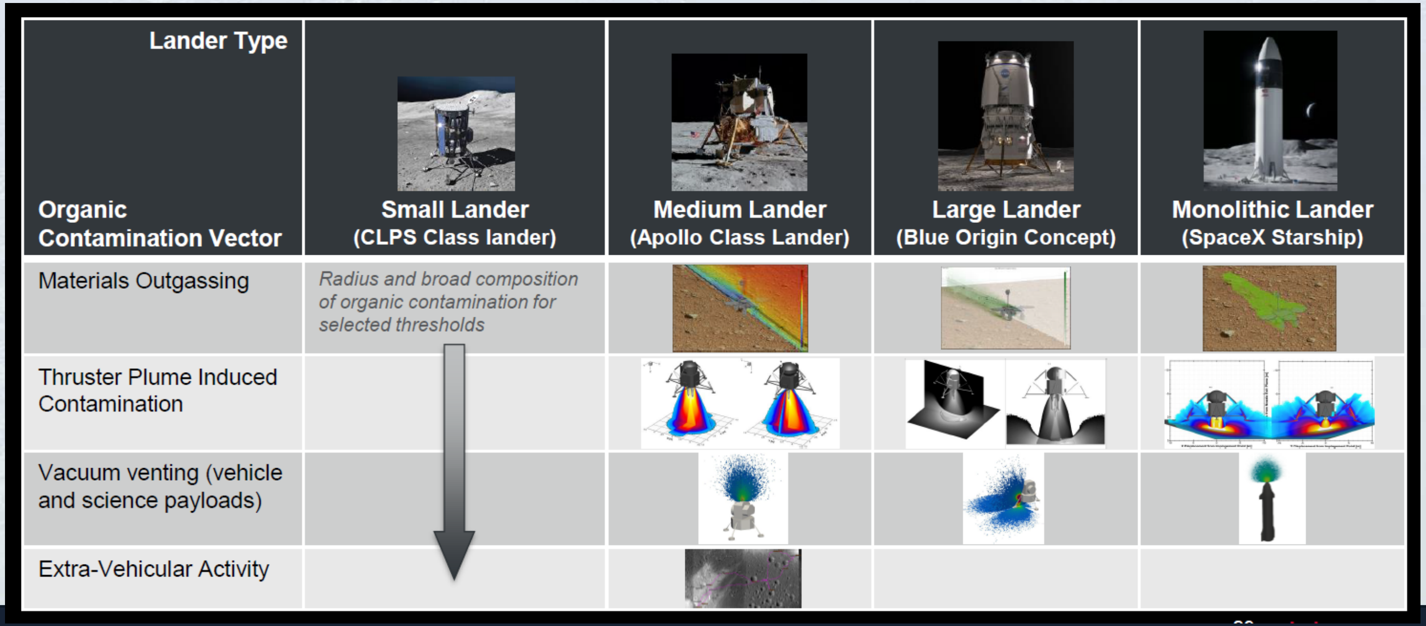
- Revise
- Finalize standard method
- Publish

Office of Planetary Protection Lunar Organic Footprint Modeling

- Organic Inventory Requirements for the Moon

Category	Description	Volatiles Released by Propulsion System	Spacecraft Organic Inventory
II	Orbiter	--	--
IIa	Moon surface not IIb	Required	--
IIb	PSR and lunar poles	Required	Required

- Can modeling help us further refine the implementation of the requirements to enable current and future science?

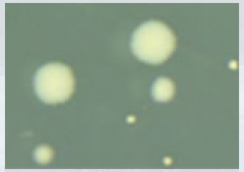


Lander Type / Organic Contamination Vector	Small Lander (CLPS Class lander)	Medium Lander (Apollo Class Lander)	Large Lander (Blue Origin Concept)	Monolithic Lander (SpaceX Starship)
Materials Outgassing	*Radius and broad composition of organic contamination for selected thresholds*			
Thruster Plume Induced Contamination				
Vacuum venting (vehicle and science payloads)				
Extra-Vehicular Activity				

Resources Available Through The OPP Website

PLANETARY PROTECTION
SAFELY EXPLORING SAFELY PROTECTING
ENABLING SCIENCE THROUGH SAFETY IN SPACE

Articles


What Are Spores?


How to Build a Clean Spacecraft


Cleanroom Gowning or How to Dress in the Cleanroom

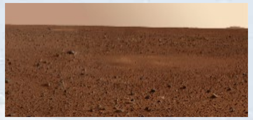

Ground Support Equipment


Protecting the Planet: Planetary Protection vs. Planetary Defense

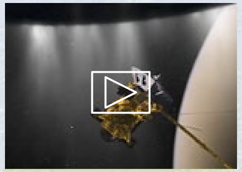

OSIRIS REx Sample Return Doesn't Pose a Risk to Earth's Biosphere

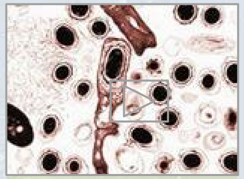

Bioburden Accounting Tool Release

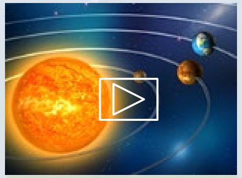
Organic Inventory Workshop

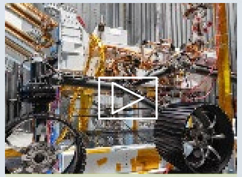

PP Crewed Knowledge Gaps

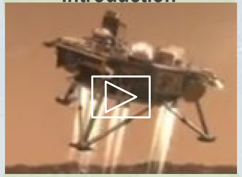
Videos


Planetary Protection: An Introduction

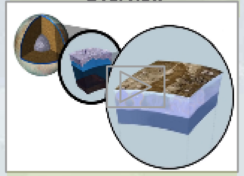

Just How Small is a Spore?

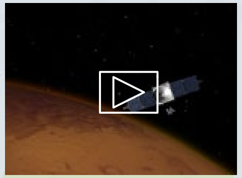

Forward and Backward PP Overview


Behind the Spacecraft Perseverance


Mission Design and PP Categorization


Probability of Impact

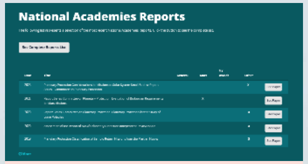

Ocean Worlds


End of Mission Disposition

https://sma.nasa.gov/sma-disciplines/planetary-protection

Missions & Studies

Mission Reports



NASEM Study Reports

Questions?

Feel free to reach out as well!

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Erin Lalime – NASA Deputy Planetary Protection Officer (Acting) - Erin.Lalime@nasa.gov

https://sma.nasa.gov/sma-disciplines/planetary-protection

Science Workshop Key Discussion (1 of 2)

- **Life Detection and Planetary Protection (presentations):**
  - *Challenge of finding signs of life on Mars while ensuring forward and backward contamination control.*
  - *Experts discussed the need to move beyond binary "life/no life" thinking and adopt a spectrum approach to better understand potential Martian biospheres.*
  - *The importance of understanding the biocidal effects of the Martian environment and the potential for human-introduced microbes to survive and evolve.*
- **Analog Sites and Future Exploration (panel):**
  - *Explored the value of analog sites for informing future exploration, emphasizing the need for cross-correlation studies and a more standardized approach to data collection.*
  - *Studying microbial adaptation to multiple stressors and the need for better integration of modeling and lab experiments.*
  - *The creation of an astrobiology sample repository was proposed to enhance accessibility and collaboration.*

Science Workshop Key Discussion (2 of 2)

- **Mars Environmental and Terrestrial Biology/Mitigating Risk for PP (presentations):**
  - *Precursor robotic missions for data gathering, technology validation, and environmental characterization.*
  - *Detailed pre-mission surveys to identify potential refugia and mitigate contamination.*
  - *Advancements in robotic capabilities, particularly in mobility, manipulation, and drilling, were discussed.*
  - *The limitations of current spacesuits in terms of dexterity and contamination control.*
  - *The potential for human-introduced microbes to impact the Martian environment and the need for robust mitigation strategies.*
  - *Understanding the interplay between human health, engineering, and planetary protection.*
  - *Value of conducting human factor experiments, including monitoring of human physiology and psychology.*
- **Instruments and Technology Development (panel):**
  - *More sensitive instruments and multiple orthogonal detection methods for life detection.*
  - *A call for greater collaboration and standard interfaces for instruments was made to improve efficiency and adaptability.*
  - *Concerns were raised about the limitations of current technology, particularly the sensitivity of existing instruments for detecting microbial life.*
  - *The importance of understanding the geochemical context of samples alongside biosignature detection was stressed.*
  - *The need to simulate Martian environmental conditions in laboratory settings was highlighted.*

Workshop Areas of Non-Consensus

- **EVA Limitations:** While some groups accepted the possibility of restricted EVAs, others questioned the value of sending humans if their ability to directly interact with the Martian surface was significantly limited.
- **Sample Triage:** The need for sample triage due to limited return mass generated discussion about prioritization strategies and the potential trade-off between quantity and quality of samples.
- **In-situ Experiments vs. Sample Return:** There was some debate about the relative emphasis on conducting experiments on Mars versus collecting and returning samples for more detailed analysis on Earth.