NASA Planetary Protection: Technical Oversight in Practice

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March 20, 2024
NASEM CoPP Space Sciences Week
Washington DC

NASA's Planetary Protection Policy & Guidance

NPD 8700.1F
Replaced NPD 8020.7G
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

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

NPR 8715.24
Replaced NPR 8020.12D/NID 8020.109A
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

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

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

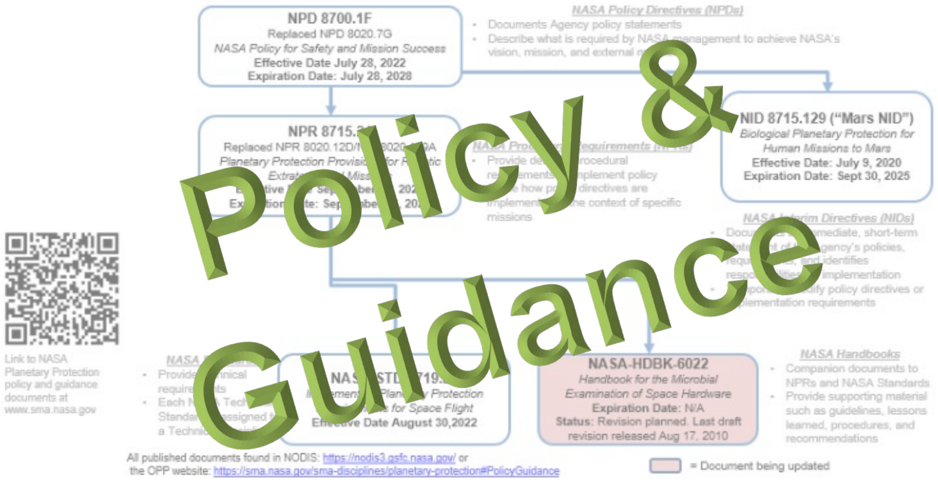
NASA-HDBK-6022
Handbook for the Microbial Examination of Space Hardware
Expiration Date: N/A
Status: Revision planned. Last draft revision released Aug 17, 2010

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

After policy & guidance are released: The work has just begun.



- **Communication**
  - Knowing policy and guidance exist!
- **Understanding**
  - Intent & what the words on the page mean
  - Clearing up confusion
- **Practice**
  - Implementation
  - Exploring options
  - Overcoming issues & problems
  - Documentation
- **Change**
  - How do we keep it relevant?
  - How do we do better?
- **Culture**
  - Supportive & collaborative

Anchoring to Guiding Principles (NPD 8700.1F)

Objectives-Driven	Risk Informed	Case Assured

• Objectives are substantiated, monitored, and independently evaluated throughout the lifecycle based on systematic argumentation, explicit assumptions, and objective evidence.	• Risks are understood, documented, and consistent with the established risk posture.
	• Consider the potential benefits and strategic importance of the mission(s) and consequences of failure, to inform decisions regarding:
	  • Formulation
	  • Implementation
	  • Assurance of the mission.
		• Comprehensive and logical claims made with sufficient argument(s) & objective evidence.

How do technical standard requirements change?

Building the case for change

Defining the Objectives: Organic Inventory & Organic Archiving

- Revisiting legacy requirements in NASA-STD-8719.27 for organic inventory and organic archiving:
  - **Organic Inventory:** List of organic materials present on a spacecraft in amounts greater than 1.0 kg for PP Category II, IIb (Lunar), III, and IV missions. Lunar PP Category IIa limited to propulsion products.
  - **Organic Archive:** Archiving a sample of all organic materials that are present on a spacecraft in amounts greater than 25 kg and would be present through the end of the mission for PP Category III and IV missions.

Simply Put – Do we have the right requirements? If not, what would be value-added to enable current and future science?

Engaging the Community: Organic Inventory Workshop – February 27-28, 2024

- **Goal**

  To establish the current science and engineering approaches and begin to assess whether the current PP requirements address the needs to enable current and future science investigations.

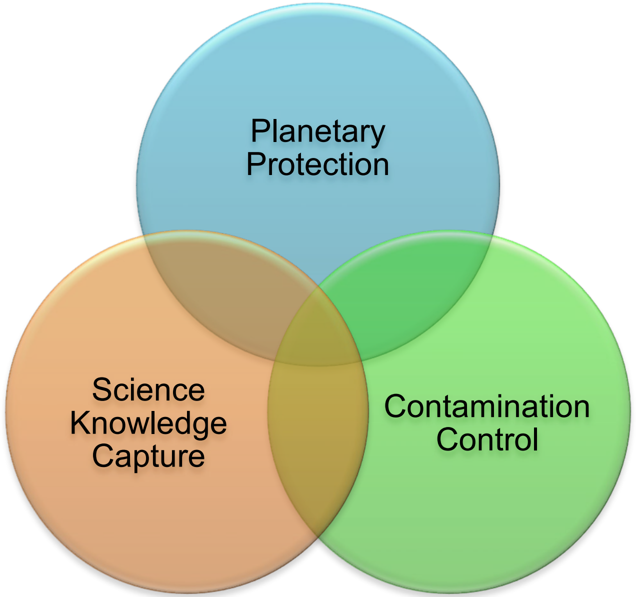
PLANETARY PROTECTION
ORGANIC INVENTORY WORKSHOP
FEBRUARY 27-28, 2024 - NASA HEADQUARTERS

- **Objectives**
  - Evaluate the current organic inventory and archiving requirements in NASA PP Policy.
  - Provide a modernized, updated scientific and engineering balanced rationale and approach to capturing molecular contamination to enable current and future science investigations.
  - Identify knowledge gaps or additional policy inconsistencies that need to be addressed.
- **Workshop**
  - ~60 attendees from AMES, GSFC, HQ, JSC, JPL, KSC, LaRC, MSFC and industry.
  - All presentation files uploaded to the workshop agenda page.
  - Workshop report is planned.

Taking the first step of many to create change.

Workshop Takeaways

- Unique opportunity to bring together a community of practice of engineers, scientists and policy makers.
  - Strengthened the subject matter expertise connections across the discipline.
- Enhanced awareness with the scientific community of the PP-based organic inventory reporting and the organic archiving spacecraft material holdings.
  - Most were unaware.
- Identified the responsible parties for organic contamination interfaces - planetary protection, science, and astromaterials and curation disciplines.
- Understanding “harmful” contamination would involve:
  - Transport analysis from the outgassing of the spacecraft
  - Analysis of changes to the landing environment from thruster plumes
  - Spacecraft operations: in-situ measurements on current, future, & sample return missions



Areas Identified that Need to be Addressed

- Transport modeling is a key to understanding localized and global impacts of spacecraft contamination for consideration of future requirements.
  - Workshop helped to define parameters for FY24 modeling task funded by the Office of Planetary Protection for contamination modeling on the lunar surface.
- Common repository for awareness of knowledge capture activities and science data would be beneficial to enable science analysis.
  - PP publications and archiving could be one of the items captured in the repository.
- Marginal value added with current PP requirements to future science.
  - OPP will be developing a strategy to continue the conversation within NASA and COSPAR to develop a performance-based requirements set for harmful organic contamination.
- Need to establish chain of custody requirements for any archive and a material request process.

Addressing these areas will support exploration of risks and building the case for change.

Supporting the Community: Improving Information Sharing

ELSEVIER

Life Sciences in Space Research
Volume 41, May 2024, Pages 158-165

Report of the 6th (Virtual) Meeting on the Planetary Protection Knowledge Gaps for Human Missions to Mars on June 1–2, 2022

J. Andy Spry [a], Bette Siegel [b], Gerhard Kminek [c], Amy Baker [a], Esther Beltran [d], Michelle Courtney [e], Peter Doran [f], Jennifer Heldmann [g], Aaron Regberg [e], Petra Rettberg [h]

National Academies Reports

The following list represents a selection of the most recent National Academies Reports. Click the button to see the complete list.

See Complete Reports List

Date	Title	General	Mars	Icy Worlds	Other	
2023	Planetary Protection Considerations for Missions to Solar System Small Bodies: Report Series—Committee on Planetary Protection				X	See Paper
2021	Report Series: Committee on Planetary Protection: Evaluation of Bioburden Requirements for Mars Missions		X			See Paper
2020	Report Series: Committee on Planetary Protection: Planetary Protection for the Study of Lunar Volatiles				X	See Paper
2020	Assessment of the Report of NASA's Planetary Protection Independent Review Board				X	See Paper
2019	Planetary Protection Classification of Sample Return Missions from the Martian Moons				X	See Paper

OPP website capture of relevant PP NASEM reports from 1965 - 2023.

How does policy change happen?

Building the case for change

Establishing / Influencing a Process for Policy Change – Science Driving Change

Updated Science Input	• Science identifies updated science input. • Scientific consensus obtained (e.g., peer-reviewed publications, workshops etc.). • Science identifies potential policy implications
Policy Implication Assessment	• Policy engagement to develop policy implications into existing framework. • Policy to work with science to confirm intent is met in proposed language.
Agency Level Assessment	• Engineering feasibility assessment. • Mission Directorate impact assessment of assets and equities – current and planned. • NASEM Committee on PP Studies to help guide Agency position.
Revised Policy Proposal	• Policy is updated with all stakeholders and proposed language can be adopted.

Establishing / Influencing a Process for Policy Change – Policy Driving Change

Policy Implication Assessment

- Policy engagement to identifies policy gaps or parameters to be updated.
- Policy engagement to seek science and engineering consensus (e.g., NASA OCS, workshops, etc).

Science Input

- Science identifies updated science input.
- Scientific consensus obtained (e.g., peer-reviewed publications, workshops etc.).
- Science identifies potential policy implications

Agency Level Assessment

- Engineering feasibility assessment.
- Mission Directorate impact assessment of assets and equities – current and planned.
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Revised Policy Proposal

- Policy is updated with all stakeholders and proposed language can be adopted.

Building Scientific Consensus to Support Decision-Making

Assurance Case Framework

Claim
Statement about a success criteria property of the system/subsystem

Sub-claim

Sub-claim

Argument
Links the Evidence to the Claim

Deterministic

Quantitative

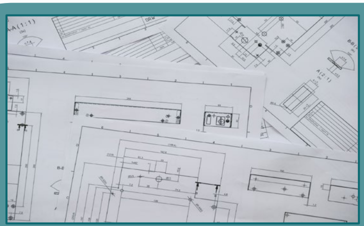
Qualitative

Evidence
Information that demonstrates validity of argument

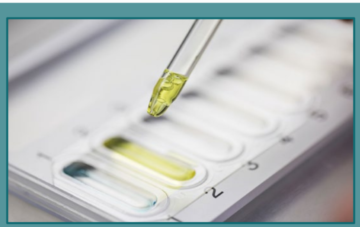
Scientific Consensus

Claim supporting an objective for change

Arguments to support achieving scientific consensus



Design of Experiments & Experimental Plans



Scientific Studies

Community Engagement

Reports & Publications

Evaluation: Back to the Anchoring Principles

Objectives-Driven

- Are the objectives clearly defined?
  - Can non-experts understand the objectives?
- Can the objectives be feasibly achieved?

Risk Informed

- Have potential risks been identified and discussed by a diverse set of communities?
- Has a risk assessment been performed?
- What actions/alternative approaches can help overcome barriers?

Case-Assured

- Does the evidence support the arguments that the objectives can be achieved?
- Is there enough evidence to support the arguments?
- Are the arguments clear and understandable to non-experts?
- Have the criteria to meet the objectives been satisfied?

Questions?

Backup

Contamination vs. Harmful Contamination

Contamination	Harmful Contamination
Contamination* Unwanted material present on or in the spacecraft/spacecraft assembly environment or introduced into the environment of a solar system body.	**Harmful Contamination*** Unwanted material on the surface of a solid material, or incorporated into a solid, liquid, or gas that damages the integrity of the study of chemical evolution and the origin of life at another solar system body, or that has negative consequences for humans and Earth's biosphere.
Expected: There is a non-zero amount of contamination expected for spacecraft.	**To Be Limited and Avoided:** What is the tipping point from "contamination" to "harmful contamination?"
Contamination Control: Practice to control contamination of spacecraft & spacecraft assembly environments to acceptable limits.	**Planetary Protection:** Practice to limit contamination of solar system bodies (Forward PP) and avoid harmful contamination of Earth (Backward PP).
Focuses on: Particulate contamination, molecular contamination, & sometimes biological contamination.	**Focuses on:** Biological contamination & molecular contamination.
Contaminants of Concern: Not all contaminants are the same. Requirements depend on what the contamination is, where it is, and how much.	**Contaminants of Concern:** Biological – Spores & viable terrestrial organisms Molecular - ???

**Definitions from NASA-STD-8719.27*

First Principle: Harmful Contamination – Planetary Protection

SCIENCE Responsibility

- There's a cost of doing business. Exploration comes at "some" cost. All space activities will have some level of contamination. The question is when does it become an issue?
- Day-to-day trade space for the scientific process and the design of experiments (e.g., signal to noise, limit of detection etc.).
  - Ability to interpret analytical results with meaningful conclusions
  - Statistical significance – uncertainty, what defines acceptably low, stable, and well-characterized? (OCP Report 2014)

PP Responsibility

- PP Policy needed to help define objectives and develop performance metrics based on science need. (Assuming this is not a one size fits all answer.)
- PP Policy needs a balanced solution to enable science but does not replace science's role.
- Enables science by defining an internationally agreed upon set of practices.
- What defines this trip wire for science?
  - Limit of detection? Projected limit of detection?
- Is this different for
  - Current mission(s)?
  - Future missions? Is there a time dimension to project?
- What's the balance point for science return vs. barriers to exploration? Can you plan for the unknowns or a bad day?

Contamination

What is the organic material of concern?
Concentration of concern?

Knowns vs. Unknowns?

Harmful

Organic Inventory Models Explored[1]

Pre-Processed Inventories

Model A: The Detailed Listing Model

- Detailed listing of all organic compounds known to have been launched on lunar payloads.
- Identification, amounts, location of payload landing, and application of reasonable dispersion model to the landing site.
- *Estimated to cost $1.3M to create such an inventory for all US spacecraft in 1968 ($11.5M today).*

Model B: The "Like Configuration" Model

- Similar to Model A, but material info limited to detailed accounting of materials for one spacecraft of each configuration launched by the US and USSR programs (a "model spacecraft").
- Assume organic contaminants in locations where each configuration landed.
- *Estimated to take 8 work years to build such a model.*

Model C: The Soft Landing / Hard Impact Model

- Similar to Model B, but a dispersion function applied for each contamination load depending if payload experienced a soft landing or hard impact.

Demand-Processed Inventories

Model D: The Contamination Map Model

- Ignores identity and quantity of organic constituents and applies a dispersion function to landing sites based on the soft landing / hard impact of Model C.
- Result would be a series of lunar charts designating areas expected to be contaminated by terrestrial organic materials.
- But preserve spacecraft build records in the event an individual case arises where the risk of contamination needs to be determined.

No Material Inventory

Model E: The Minimalist Model

- No provision for saving spacecraft documentation from past or future programs. Limited to identifying payload landing sites and dispersion patterns.

[1] Lyle, Robert G. TRSR-68-029: "Planning Study for an Organic Constituents Inventory Program," Exotech Inc., 1968, https://ntrs.nasa.gov/api/citations/19680018443/downloads/19680018443.pdf.