Planetary Protection

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NASA Forensics Summit

April 2023

Overview

- PP Background
  - What is planetary protection?
  - Why should I care?
  - Mission Categorization
- PP Policy
  - NASA Policy Update
  - Policy Update Process
  - New Lunar NASA Policy
  - Future Mars NASA Policy
- PP and Crewed Mission Activities
  - Crewed Lunar Missions
  - Crewed Mars Missions
  - Discussion Item

What is Planetary Protection? Why should I care? What are the Requirements? How do I verify the Requirements?

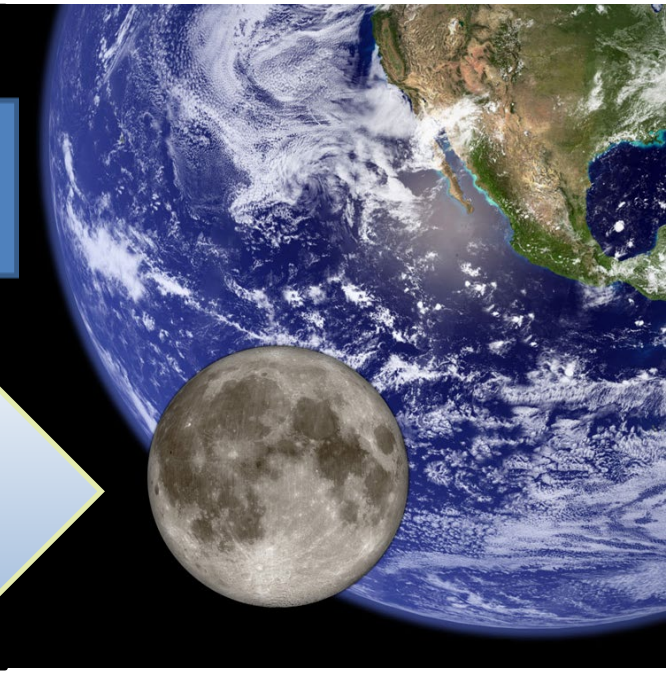
PLANETARY PROTECTION OVERVIEW

Planetary Protection Objective

Protect current and future scientific investigations by limiting biological and relevant molecular contamination of other solar system bodies through exploration activities and protecting the Earth's biosphere from adverse effects from contamination carried on returning spacecraft, as described in the Outer Space Treaty.

Forward PP - Understand and control harmful contamination of other worlds by terrestrial organisms, organic materials, and volatiles from spacecraft

Backward PP - prevent adverse effects on the Earth-Moon system from potential extraterrestrial life and bioactive molecules in returned samples



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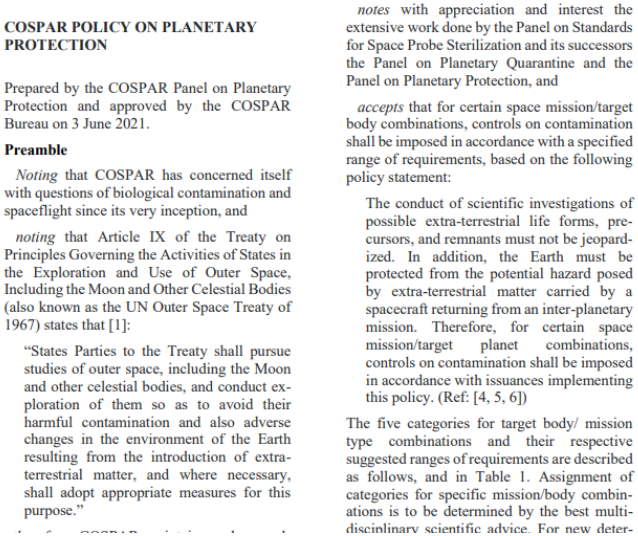
Over 60 Years of Planetary Protection…

- Committee on Space Research (COSPAR) – first code of conduct and responsibility for Planetary Protection (October 1958)
- The UN Outer Space Treaty of 1967 "*Article IX. States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter…*"



COSPAR POLICY ON PLANETARY PROTECTION

Prepared by the COSPAR Panel on Planetary Protection and approved by the COSPAR Bureau on 3 June 2021.

Preamble

Noting that COSPAR has concerned itself with questions of biological contamination and spaceflight since its very inception, and

noting that Article IX of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (also known as the UN Outer Space Treaty of 1967) states that [1]:

"States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extra-terrestrial matter, and where necessary, shall adopt appropriate measures for this purpose."

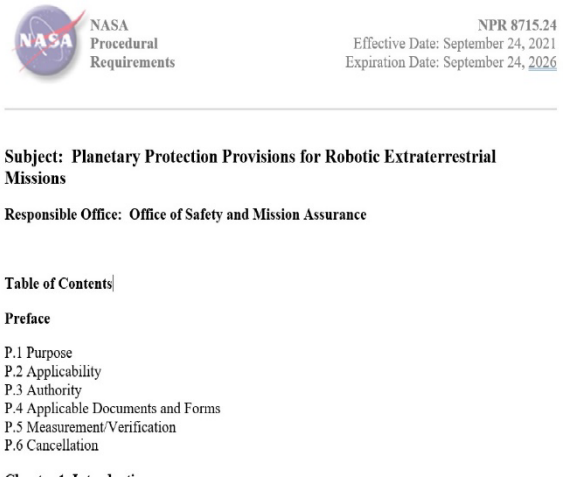
notes with appreciation and interest the extensive work done by the Panel on Standards for Space Probe Sterilization and its successors the Panel on Planetary Quarantine and the Panel on Planetary Protection, and

accepts that for certain space mission/target body combinations, controls on contamination shall be imposed in accordance with a specified range of requirements, based on the following policy statement:

The conduct of scientific investigations of possible extra-terrestrial life forms, precursors, and remnants must not be jeopardized. In addition, the Earth must be protected from the potential hazard posed by extra-terrestrial matter carried by a spacecraft returning from an inter-planetary mission. Therefore, for certain space mission/target planet combinations, controls on contamination shall be imposed in accordance with issuances implementing this policy. (Ref: [4, 5, 6])

The five categories for target body/ mission type combinations and their respective suggested ranges of requirements are described as follows, and in Table 1. Assignment of categories for specific mission/body combinations is to be determined by the best multi-disciplinary scientific advice. For new deter-

COSPAR Policy, Panel on Planetary Protection June 3, 2021



NASA Procedural Requirements

NPR 8715.24
Effective Date: September 24, 2021
Expiration Date: September 24, 2026

Subject: Planetary Protection Provisions for Robotic Extraterrestrial Missions

Responsible Office: Office of Safety and Mission Assurance

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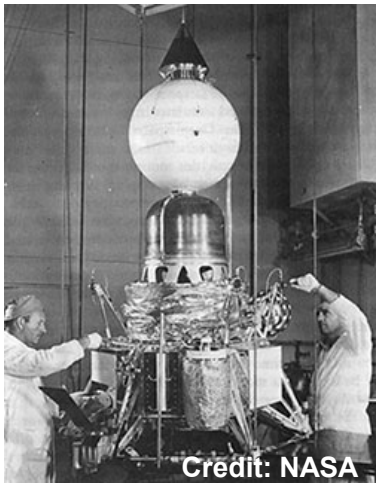
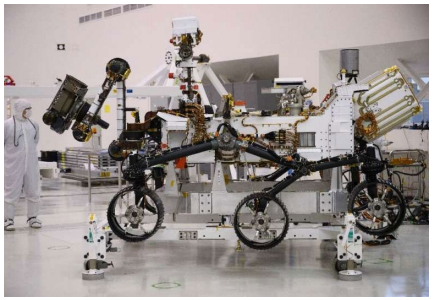
NPR 8715.24 Planetary Protection Provisions for Robotic Extraterrestrial Missions



1961 – Ranger Project 1st to Implement PP



2020 – Mars 2020 last launch of a bioburden controlled mission

Planetary Protection Categorization – Outbound + Inbound

Planetary Target Priority	Mission Type	Planetary Protection Category	Example Target Bodies
Not of direct interest for understanding the process of chemical evolution or where exploration will not be jeopardized by terrestrial contamination.	Any (Flyby, Orbiter, Lander)	I	Undifferentiated, metamorphosed asteroids, Io
Of significant interest relative to the process of chemical evolution but only a remote chance that contamination by spacecraft could compromise future investigations.	Any (Flyby, Orbiter, Lander)	II	Earth's Moon (Cat. IIa & IIb), Venus, Comets, Asteroids, Jupiter; Jovian Satellites (excluding Io, Ganymede and Europa), Saturn; Saturnian Satellites (excluding Titan and Enceladus), Uranus, Uranian Satellites, Neptune, Neptunian Satellites (excluding Triton), Kuiper-Belt Objects <1/2 the size of Pluto
		II*	Jovian Satellites: Ganymede, Saturnian Satellites: Titan, Neptunian Satellites: Triton, Pluto/Charon
Of significant interest relative to the process of chemical evolution and/or the origin of life and for which scientific opinion provides a significant chance that contamination by spacecraft could compromise future investigations	Flyby, Orbiter	III	Mars, Europa, Enceladus, Others to be determined
	Lander, Probe	IV	Mars (Cat. IVa, IVb & IVc), Europa, Enceladus, Others to be determined
Any Solar System Mission	All Earth Return	V(r): Restricted Earth Return	Restricted Earth Return: • Mars • Europa • Enceladus • Others to be determined
		V(u): Unrestricted Earth Return	Unrestricted Earth Return: • Earth's Moon • Venus • Most asteroids and comets (e.g., Bennu, Ryugu) • Others to be determined

Updates to NASA's Planetary Protection Policy Documents

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

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

NID 8715.129 ("Mars NID")
Biological Planetary Protection for Human Missions to Mars
Effective Date: July 9, 2020
Expiration Date: July 9, 2023

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

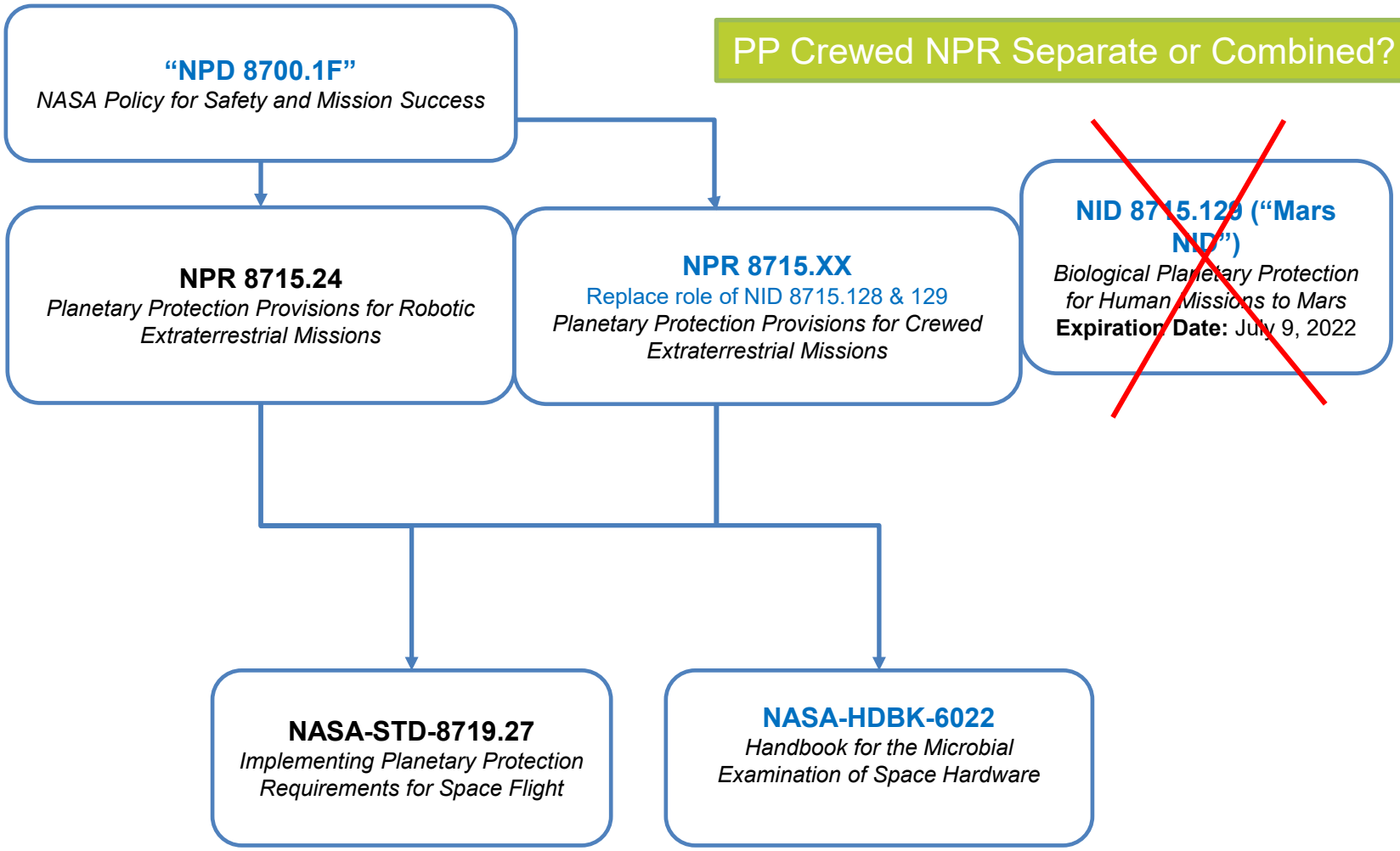
NASA-HDBK-6022
Handbook for the Microbial Examination of Space Hardware
Expiration Date: N/A
Status: Revision planned. Last draft revision released Aug 17, 2010

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

= New Documents

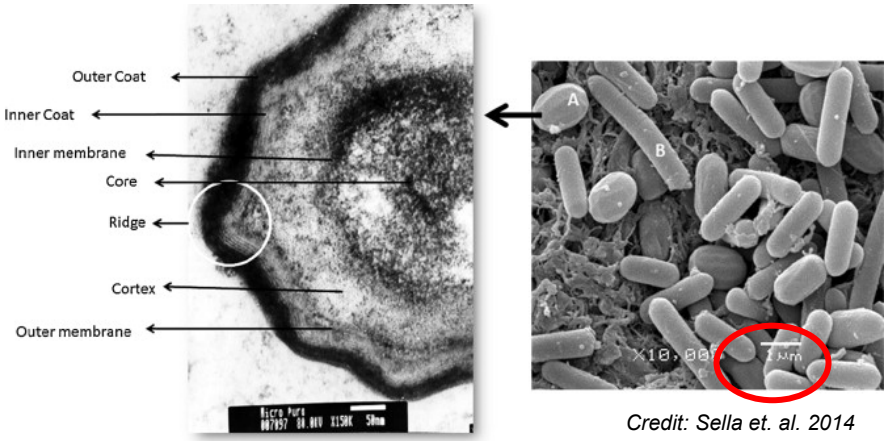
NASA's Planetary Protection Policy Documents (Medium Term)



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

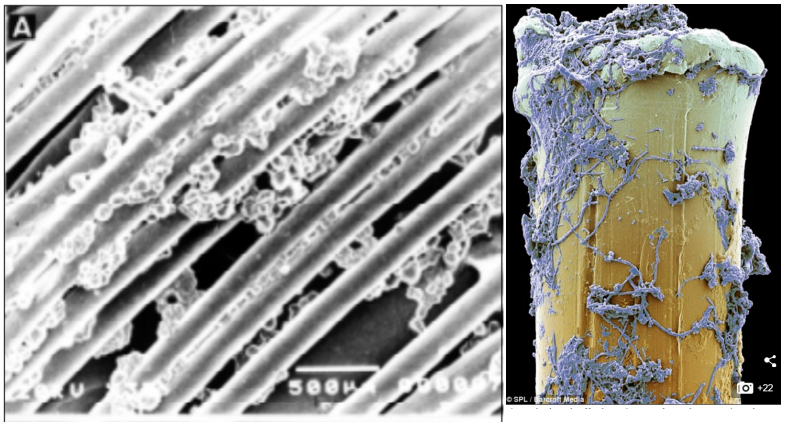
= Revised Documents

Examples of Biological and Relevant Molecular Contamination



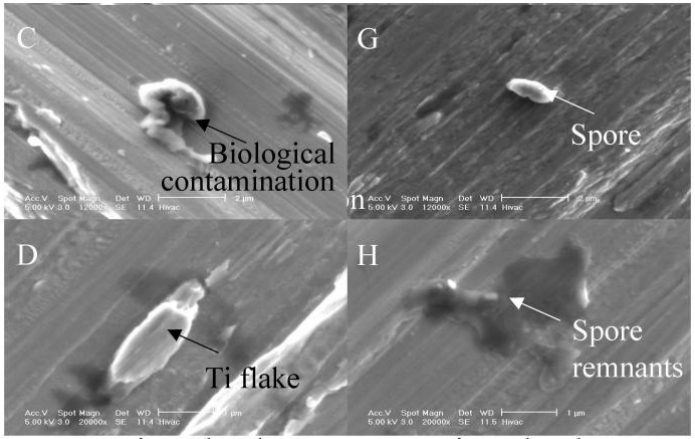
Credit: Sella et. al. 2014

Bacterial Spore



Credit: Filho et. al. 2000

Bacteria on a toothbrush fiber



Credit: Venkateswaran et. al. 2004

Titanium Spacecraft Coupon

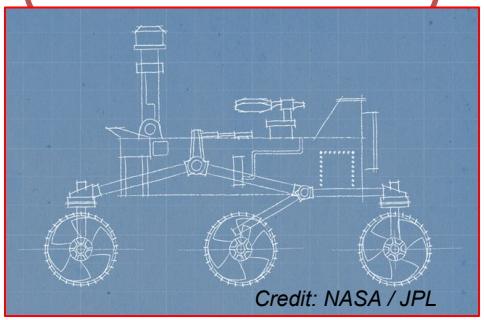
TABLE 1. MAXIMUM AMOUNTS OF CONTAMINATION THAT CAN BE TRANSFERRED TO ORGANIC AND MOLECULAR ANALYSIS EXPERIMENTS, AS PROPOSED BY THE OCSSG (TABLE 2 IN MAHAFFY *ET AL.*, 2004)

Compound class	*ng/g of sample*
Benzene or aromatic hydrocarbons	8
Carbonyl and hydroxyl containing compounds	10
Amino acids	1
Amines, or amides	2
Non-aromatic hydrocarbons	8
DNA	1
Total reduced carbon	40

Forward Planetary Protection

Hardware Design (Systems Engineering)

- Establish Driving Requirements
  - 5 x 10^5 spores total
  - 3 x 10^5 spores landed
  - 300 spores / m^2
- Bioburden Allocation
- Organic Inventory
- Implementation Planning



Planetary Protection starts in early mission phases

Hardware Implementation (Clean)

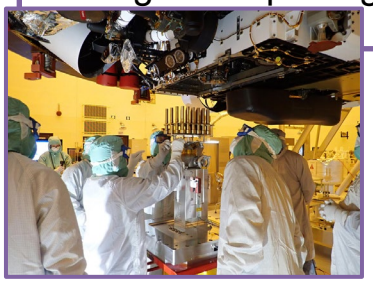
- Microbial Reduction (e.g., heat microbial reduction, etc.)
- Verification of cleanliness (e.g., NASA Standard Assay for spores)

Credit: ESA

Verification – Swab of the ExoMars camera

Recontamination Prevention (Keeping it Clean)

- Cleanroom assembly and test
- Hardware cleaning and covering
- Late critical system installation
- Launch environment cleanliness
- Pre-launch report
  - Bioburden, organic reporting



Credit: NASA / JPL

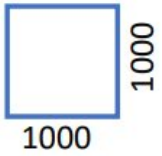
Late integration of the Mars 2020 Sample Tubes

PP Requirements in Perspective (1 of 3)

300 spores per square meter. Here's a square meter..

If a spore is magnified to the size of a poppyseed,
we need to magnify the area – one square meter - $1m^2$ by the same amount

A poppy seed is 1000x the diameter of a spore,
but in cross-section, that's $(1000)^2 = 10^6$ x the area



That's a million square meters, or 1 square kilometer!

PP Requirements in Perspective (2 of 3)

So 300 spores/m^2 scales to 300 poppy seeds/10^6 m^2

Central Park is 4km x 0.8km

PP Requirements in Perspective (3 of 3)

So, 300 spores/m^2 scales to 300 poppy seeds/10^6 m^2

2 poppy seeds per soccer field!

Overview of Process and Current Status

Updated Moon Policy

PLANETARY PROTECTION POLICY

Planetary Protection Requirements Evolve – What it may seem like…

Vashti Cunningham, US, competes in women's high jump final in Tokyo 2020 Olympics.
(AP Photo / David J. Phillip)

https://www.merlijnvanveen.nl/en/study-hall/161-moving-target

Mike Watson Images/Getty Images

Planetary Protection Requirements Evolve – What is actually happening…

Scientific Consensus Drives PP Policy

- Drivers
  - Mission Exploration / Interest – mission enabling
  - New scientific findings – Earth based, Observational Science, or Ground based studies
- Process
  - Scientific Request / Need for Assessment
    - Administration Request, Mission Directorate, Mission
    - NID issued ?
  - National Academics Committee on Planetary Protection
    - Statement of Task from NASA to NASEM
    - Study time ~7 months from start to report
  - Committee on Space Research (COSPAR) – Planetary Protection Panel
    - Symposium on special topic of interest – meets ad hoc, typically 2x's / year
    - Planetary Protection Panel Meeting and Vote
    - General Assembly meeting discussion (occurs every two years)
  - NASA Policy Updates
    - Document lifecycle (five years)

Not just a NASA process. External Factors Impact = National Academies and COSPAR take time (>1 years).

Planetary Requirements Evolve – Moon Case Study…

Sept. 1963 – Policy Change. Relaxed Full Sterilization Requirement. "Required Procedures"

- Clean-room assembly policies be adopted,
- Sporicidal agents be used when "appropriate", and
- Recontamination Prevention for launch processing - covering

PP Category IV*

July 1969 - The crew of Apollo 11 in quarantine after returning to Earth in visited by President Nixon. 21-day quarantine.

PP Category IV*
PP Category V Restricted*

2004 - COSPAR PP Panel Investigate whether the permanently shaded areas near the lunar poles should be "protected" in the sense of imposing the mandatory record-keeping required under.

Proposed PP Category II

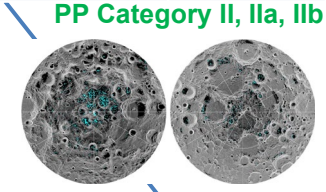
Apr 1971 – Based on Apollo 11-14 data, ICBC recommends lifting quarantine approaches for Apollo 15-17

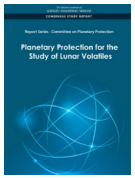
PP Category I*
PP Category V Unrestricted*

June 2021 COSPAR / NASA NPR Update

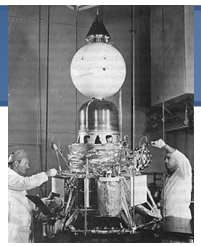
Category	Description	Volatiles Released by Propulsion System	Spacecraft Organic Inventory
II	Orbiter	--	--
IIa	Moon surface not IIb	Required	--
IIb	PSR and lunar poles	Required	Required

PP Category II, IIa, IIb





Sept – Oct 2020 NASEM Study



December 23, 1960
Memo "Decontamination and sterilization procedures for lunar and planetary space vehicles." The memo was signed by Hugh L. Dryden.

PP Category IV*

Apr 1969 – Interagency Committee on Back Contamination (ICBC) Quarantine Provisions.

- Introduction of alien life forms to the Earth's biosphere could be catastrophic.
- Preserve Lunar sample science

PP Category V Restricted*

1983 – COSPAR Post-Apollo

PP Category I
PP Category V Unrestricted

2008 – COSPAR General Meeting
Lunar Reconnaissance Orbiter + LCROSS Impactor
Assign the Earth's Moon to Category II because of the potential for missions to disrupt polar volatile deposits (≥ 70 N & S latitude).

PP Category II

PPIRB Report Oct 2019
July 2020 NASA NID 8715.128

Table 1. NASA Mission Planetary Protection

Lunar Target Sensitivity	Mission PP Category
Not of direct interest for understanding the process of chemical evolution or where exploration will not be jeopardized by terrestrial contamination. No protection of such regions is warranted.	I-L
Of significant interest relative to the process of chemical evolution but only a remote chance that biological contamination by spacecraft could compromise future investigations. Reporting of biological materials is warranted.	II-L

Proposed PP Category I-L, II-L

*Notional Category

Template Example

- Reporting can be easy as a template to capture (from existing MIUL)
  - Key organic compounds and estimated size bins (if actuals unknown)

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 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	❑	❑

4) Lubricants

Mars and Identification of PP Knowledge Gaps for Crewed Missions

Key knowledge gaps: microbial and human health monitoring, spacecraft technology and operations, and natural transport of contamination at Mars

2015	2016	2018	2018 & beyond
NASA Workshop at Ames ✓	1st COSPAR Meeting at LPI ✓	2nd COSPAR Meeting at LPI ✓	COSPAR Working Meeting on Contamination Transport on Mars at LPI, May 2018 ✓ COSPAR Working Meeting on Microbial Monitoring & Health at LPI, May 2019 ✓ COSPAR Working Meetings on Spacecraft Systems (virtual) May 2020 and June 2022 ✓
Identification of Planetary Protection Knowledge Gaps for human missions to Mars	Refinement and prioritization of Planetary Protection Knowledge Gaps for human missions to Mars	Mission Opportunity identification for addressing Planetary Protection Knowledge Gaps for human missions to Mars	Measurements and Payload/Operation Concepts for addressing Planetary Protection Knowledge Gaps for human missions to Mars
What Knowledge Gaps…	…in what order…	…using what missions…	…to make what measurements…

…to establish the <u>right</u> quantitative and implementable planetary protection requirements for safe and sustainable exploration and utilization of Mars.

Knowledge-Based Robotic to Crewed Transition Assumptions*

- Human spaceflight hardware leaks (in nominal and off-nominal operation), so the old robotic paradigm of managing a fixed bioload is inappropriate.
- The introduction of a maintained temperate terrestrial environment at the Martian surface affords the opportunity for many more organisms (in type and quantity) to escape into the Martian environment.
- This exploration is taking place in a post-Mars Sample Return (MSR) context where Martian life was NOT (yet?) discovered at the Martian surface/shallow subsurface in returned Mars material, but we know a lot more about Mars from those samples.
- Knowledge gaps need to be understood and preferably closed before launch to protect science return and the Earth.

Robotic Planetary Protection focus is controlling bioburden
Crewed Planetary Protection shift to managing bioburden

* Developed as ground rules for the 2020 COSPAR "4th Workshop on Refining Planetary Protection Requirements for Human Missions" – see the Conference Documents section at https://sma.nasa.gov/sma-disciplines/planetary-protection

Considerations for Lunar and Mars Missions

PLANETARY PROTECTION AND CREWED MISSION ACTIVITIES

Crewed Exploration Planetary Protection Comparison: Moon vs Mars

Moon	Mars
COSPAR Assessment: "of significant interest relative to the process of chemical evolution and the origin of life, but where there is only a remote chance that contamination carried by a spacecraft could compromise future investigations."	COSPAR Assessment: "a target body of chemical evolution and/or origin of life interest and for which scientific opinion provides a significant chance of contamination which could compromise future investigations."
Categorization (Outbound): II/IIa/IIb	Categorization (Outbound): III/IVa/IVb/IVc
Implication: • Documentation	Implication: • Documentation • Avoidance of Impact and/or Cleanliness Requirements
Categorization (Return): V(unrestricted)	Categorization (Return): V(restricted)
Implication: • No further constraints	Implication: • Documentation • Rigorous containment of unsterilized material to protect Earth's biosphere • Quarantine of crew
Organics/Biologicals: • Record keeping for organics only	Organics/Biologicals: • Record keeping for organics • Management of bioburden for Mars contamination • Safeguarding "Earth's biosphere" • Safeguarding crew

Crewed Exploration Planetary Protection: Moon vs "Anticipated" Mars Requirements

Activity	Moon (Current)	Mars (Anticipated)
Venting of Volatiles	Documentation	Documentation; Filtration, other mitigations likely
Trash Disposal	Documentation of organics	Documentation; Containment/ filtered venting likely
Water Generation	No Requirement*	In hab: No Requirement* Ex hab: Microbial management likely
Water Storage	No Requirement*	In hab: No Requirement* Ex hab: Microbial management likely
Crew Waste Disposal	Documentation	Documentation; Containment, other mitigations likely

*No planetary protection requirement, though other responsibilities (e.g., crew health and performance) may have their own requirements on this topic

Expect refinement and increased fidelity on anticipated Mars planetary protection requirements as mission concepts mature and knowledge gaps are closed.

NASA PP Policy for the Moon – Status

- Volatile/Organic Inventory Reporting Requirements
  - Anticipated reporting at pre-launch (estimate) and end of mission (actual update from model).
- No additional requirements or reporting required for planetary protection.
  - No anticipated return to Apollo-era quarantine approaches!

NASA PP Policy for Mars – Status

- NID 8715.129 to be updated as policy is developed
- Joint Workshop Series with COSPAR developed a series of perspectives and metrics, and the following three specific recommendations:
  - The crew should be considered as a unit, meaning if one individual gets sick it will be impractical for them to be isolated from the other crew member(s) (this differs from the current COSPAR Planetary Protection Policy language).
  - Pristine life detection/subsurface samples should be kept separate from the crew during the return trip, both to keep them pristine and to protect the crew. (If there are time sensitive measurement that need to be made during the return trip they could be made on a dedicated non-pristine set of samples)
  - An approach to break the chain of contact between Mars and the Earth is still needed to protect the broader biosphere, even if crew exposed on Mars appear unharmed.

Crew Health & Medical Perspective on Planetary Protection - Takeaways

- Need to balance PP with mission goals and crew health (otherwise, why go?)
- Existing policy will need to evolve to accommodate crewed missions
- Not all answers are available today and data will evolve over time
- Decisions will have a component of risk assessment (e.g., for microbial allowances, sample analysis, quarantine)
- Need a contingency plan in place well before launch
- Planetary Protection goes beyond just the technical, with complex issues and decision making on how to proceed, involving dialogue with multiple stakeholders.

(From 2022 presentation by T McCoy and M Courtney)

NASA PP Policy/Crew Interface for Mars – Considerations

- Sample Containment Discussion
  - Geologic (MSR SSAP provides baseline)
  - Crewed (Nominal vs Non-nominal scenarios)
- Sample Storage Discussion
  - Geologic (Science driven)
  - Crewed (Evidence driven?)
- Stakeholder/Chain of Custody Considerations
  - Who, what and for what purpose?

BACKUP

Considerations on the design of quarantine facilities and methods for use on Mars, returning from Mars, and in the Earth-Moon system

- The consensus of the 2022 COSPAR meeting was the following:
  - There is a continued need to manage terrestrial (forward) biological contamination in the context of crewed Mars exploration.
  - Crew exposure to Martian materials should be minimized to the extent practicable.
  - Monitoring, as well as control and mitigations, is needed for the human crew with regard to microbial health.
  - Crew need to be isolated from the samples, with rigorous isolation from pristine or potentially life-bearing samples (e.g., from Special Regions).
  - Isolation of individuals is not practicable; crew should be quarantined as a unit.
  - Since infection is often dose-based, best effort isolation and containment PPE should be available on the return transit.
  - Quarantine on return to Earth is needed, despite in-space pseudo isolation.

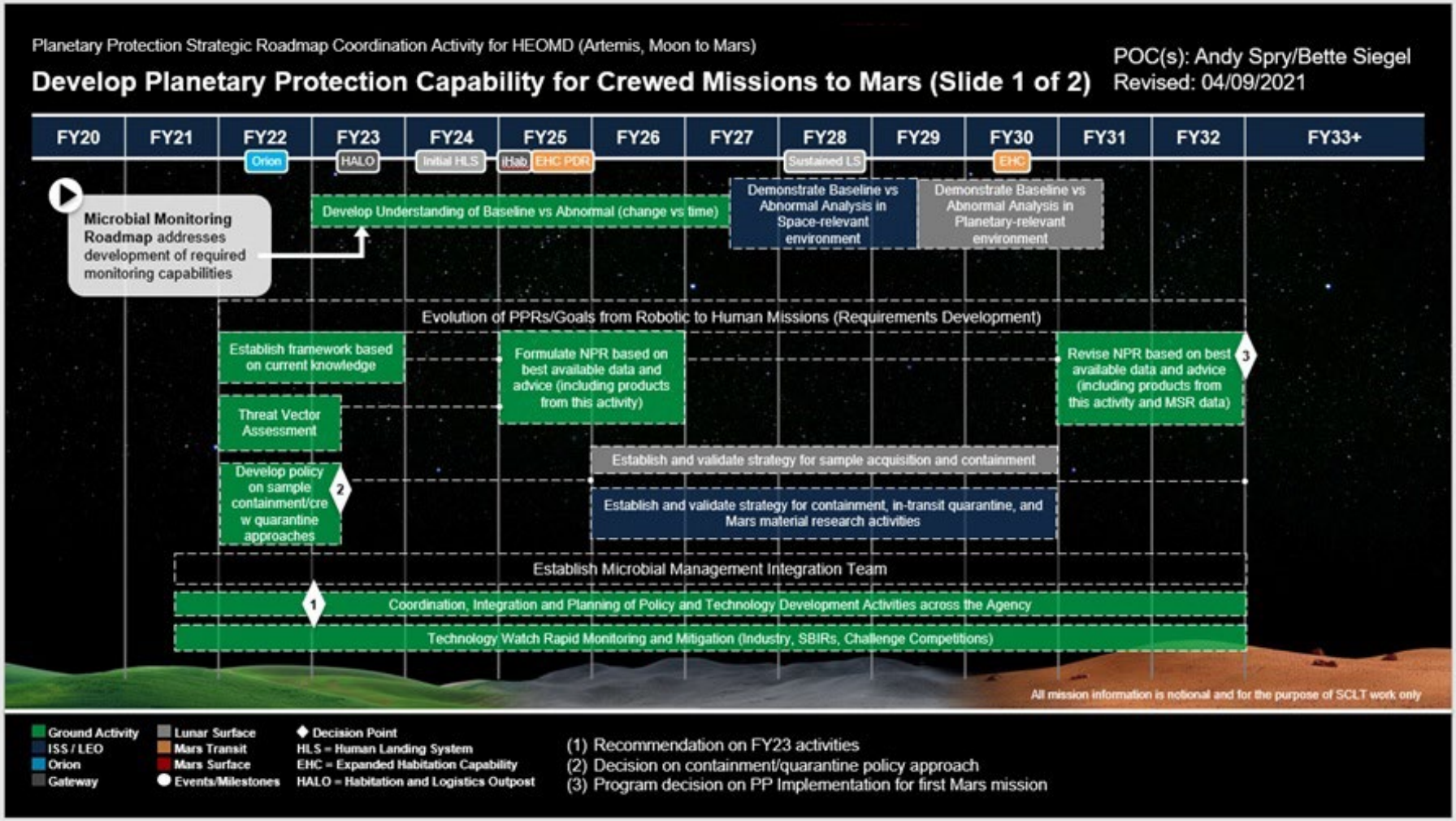
Approaches to be taken to achieve the requirements to "Break the Chain of Contact" with the Martian environment for human missions

- The consensus of the 2022 COSPAR meeting was the following:
  - Crew should do work with samples on the surface, performing analyses to select high value material for return, but with planetary protection in mind as crew safety is paramount in surface activities, utilizing surface vehicle science instrument capabilities to facilitate this work.
  - An appropriate approach to breaking the chain of contact between Mars and Earth is still needed to protect the broader biosphere, even if crew exposed on Mars have shown no harm.
  - Samples should be stored separately from the crew (for planetary protection), but should be monitored (e.g. for temperature exposure, seal integrity) to support correct life detection outcomes (for both science and planetary protection).
  - Containment of all Mars samples should be maintained (from crew and others), even if i) Mars Sample Return (MSR) shows no life, and ii) crew are previously exposed, until samples are demonstrated to be “safe” (by a terrestrial sample safety assessment).
  - Analyses for life detection or biohazard testing is not to be permitted on the return from Mars.
  - Engineering decision making is better informed if more data is available, e.g., if precursor missions/activities are performed to better understand: Martian dust, microbial survival, the presence of life (or its absence, distribution).

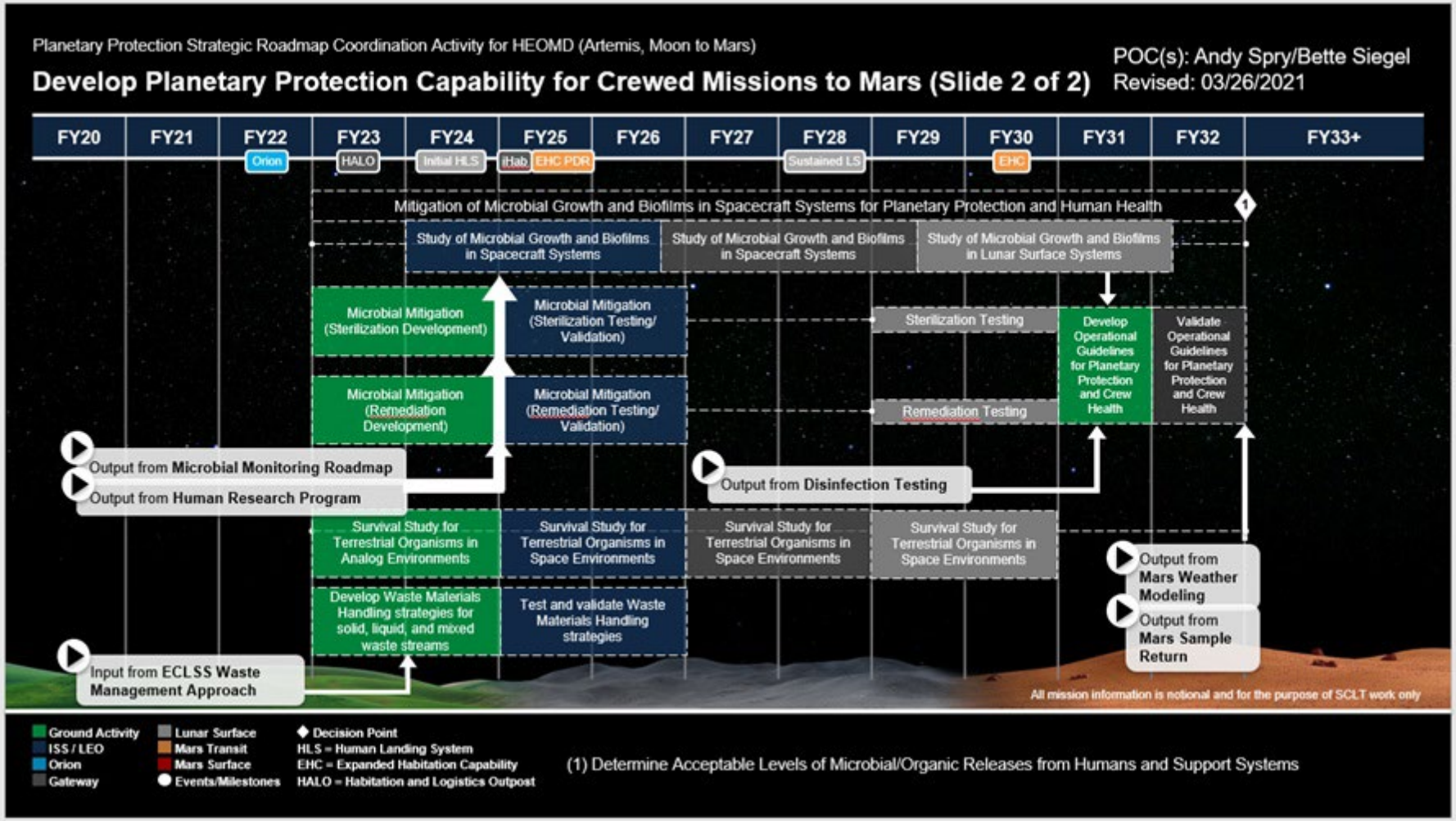
Draft PP Gap Analysis and Requirements for Mars Waste Handling

- Description: Ability to contain all waste products to prevent microbial release for long duration to leave on planetary surface and uphold planetary protection requirements. Wet trash's thermal capacitance will volatize large volumes of water vapor when jettisoned to vacuum. Traditional HEPA filter element bonding agents compatibility with very wide range of surface is not known. Challenges existing with water vapor filming/freezing over filter elements and preventing pressure release which may result in uncontrolled microbial releases.
- Figures of Merit: Passive unheated surface venting/filtering technologies for surface waste disposal compatible with wide range of surface temperatures (-170C to +130C) and high water vapor transfer until waste is dry and prevent microbial release for >50 years.

Technology Roadmap (1 of 2)



Technology Roadmap (2 of 2)



COSPAR Implications – IIa vs. IIb

- **Lunar surface area 3.79 x 107 km2**
  - $A = 4\pi r^2$
  - r = 1,737 km

- **IIb regions – 1.04% of total surface area**
  - North Pole (86°N) – 4.62 x 10^4 km^2
  - South Pole (79°S) – 3.48 x 10^5 km^2

BUT….end of mission disposal / potential consideration

- **Polar orbits with inclinations at 90° - 8.33% of lunar ground track (km)**
  - Inclinations below 70° extremely unlikely to end up in PSR
  - r = 1.09 x 10^4 km lunar ground track
  - N pole arc (8°) – (8/360)2πr – 243 km
  - S pole arc (22°) – (22/360)2πr – 667 km

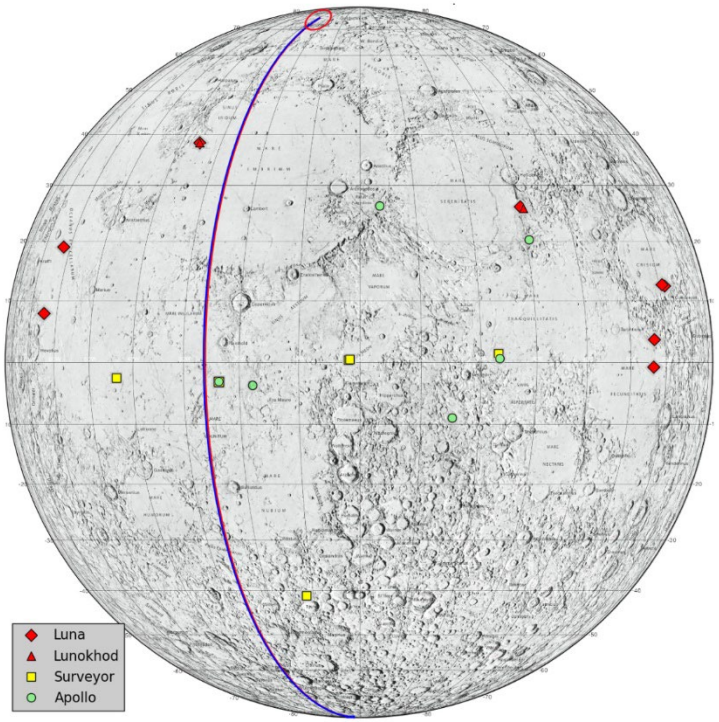


Image Credit: NASA/JPL-Caltech

Current Moon Policy - COSPAR Announcements

- https://cosparhq.cnes.fr/assets/uploads/2021/07/Press-Release_PPP_15July2021_FINAL.pdf

- https://cosparhq.cnes.fr/assets/uploads/2021/07/PPPolicy_2021_3-June.pdf

8. Category II requirements for missions to the Moon

8.1 Orbiter and fly-by missions to the Moon [13]

Category II. Orbiter and fly-by missions to the Moon shall provide the planetary protection documentation described in Table 1. There is no need to provide an organic inventory.

8.2. Lander missions to the Moon [13]

Category II for the Moon is subdivided into IIa and IIb:

Category IIa. All missions to the surface of the Moon whose nominal mission profile does not access areas defined in Category IIb shall provide the planetary protection documentation described in Table 1 and an organic inventory limited to organic products that may be released into the lunar environment by the propulsion system,

Category IIb. All missions to the surface of the Moon whose nominal profile access Permanently Shadowed Regions (PSRs) and the lunar poles, in particular latitudes south of 79°S and north of 86°N shall provide the planetary protection documentation described in Table 1 and an organic inventory in line with chapter 3 [14].

Excerpt from COSPAR PP Policy

COSPAR PP Policy for the Moon – Categorization

WAS

- Orbiter
  - Category II (with organic inventory)
- Surface Mission
  - Category II (with organic inventory)

IS - Recommendation 5/18/21

- Orbiter
  - Category II ~~(with organic inventory)~~
- Surface Mission
  - Cat. IIa: all missions to the surface of the Moon whose nominal mission profile does not access areas defined in Cat IIb: material inventory limited to organic products that may be released into the lunar environment by the propulsion system.
  - Cat. IIb: all missions to the surface of the Moon whose nominal mission profile accesses PSRs* and the lunar poles, in particular latitudes south of 79S and north of 86N: full organic inventory (solid and volatiles).

* PSRs: Permanently Shadowed Regions, regions of the Moon that contain ice deposits potentially holding information about the chemical evolution of the solar system. Latitudinal limits 79S and 86N based on LRO data.

NASA PP Policy for the Moon – Requirements

- Organic Inventory Reporting Requirements

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

- Anticipated reporting at pre-launch (estimate) and end of mission (actual update from model).
- End of mission disposal should be considered. Spacecraft inventory required if [>1 x 10^{-3} probability of landing in a IIb region within 15 years].
- No additional requirements or reporting required for planetary protection.

Reporting - COSPAR Policy vs. NASA Approach

Table 1: Categories for solar system bodies and types of missions

	Category I	Category II	Category III	Category IV	Category V
Type of Mission	Any but Earth Return	Any but Earth Return	No direct contact (flyby, some orbiters)	Direct contact (lander, probe, some orbiters)	Earth Return
Target Body	See Category-specific listing	See Category-specific listing	See Category-specific listing	See Category-specific listing	See Category-specific listing
Degree of Concern	None	Record of planned impact probability and contamination control measures	Limit on impact probability Passive bioburden control	Limit on probability of non-nominal impact Limit on bioburden (active control)	If restricted Earth return: • No impact on Earth or Moon; • Returned hardware sterile; • Containment of any sample.
Representative Range of Requirements	None	Documentation only (all brief): • PP plan • Pre-launch report • Post-launch report • Post-encounter report • End-of-mission report	Documentation (Category II plus): • Contamination control • Organics inventory (as necessary) Implementing procedures such as:	Documentation (Category II plus): • P_c analysis plan • Microbial reduction plan • Microbial assay plan • Organics inventory	Outbound Same category as target body/ outbound mission Inbound If restricted Earth return:

- **COSPAR Policy = Technical Requirements + Documentation Requirements**
- **NASA Approach. Meet COSPAR science requirements (organic inventories + volatile, as required) through a minimal set of Agency tailored documentation requirements.**
- **This approaches seeks to streamline the customer interface, but not necessarily get caught up on the "how-to" documentation requirements of COSPAR. We are not requiring documentation unless there is a need.**
- **Form approach for reporting also an option.**

COSPAR Documentation	NASA Approach
PP Plan	**PP Plan (PP Requirements Document in new NPR – for capture in Project Requirements Tracking System)**
Pre-launch Report	**PP Pre-launch Report - Organic Inventory + Volatile Estimate Reporting**
Post-launch Report	Updates as needed, not required
Post-encounter Report	Updates as needed, not required
End-of-mission Report	**PP End-of-Mission Report - Volatile Actuals**