Evolving, Enabling and Ensuring Safety of Terrestrial, Orbital and Planetary Environments: Planetary Protection's Lunar Policy Evolution and Implications for Future Policy Needs

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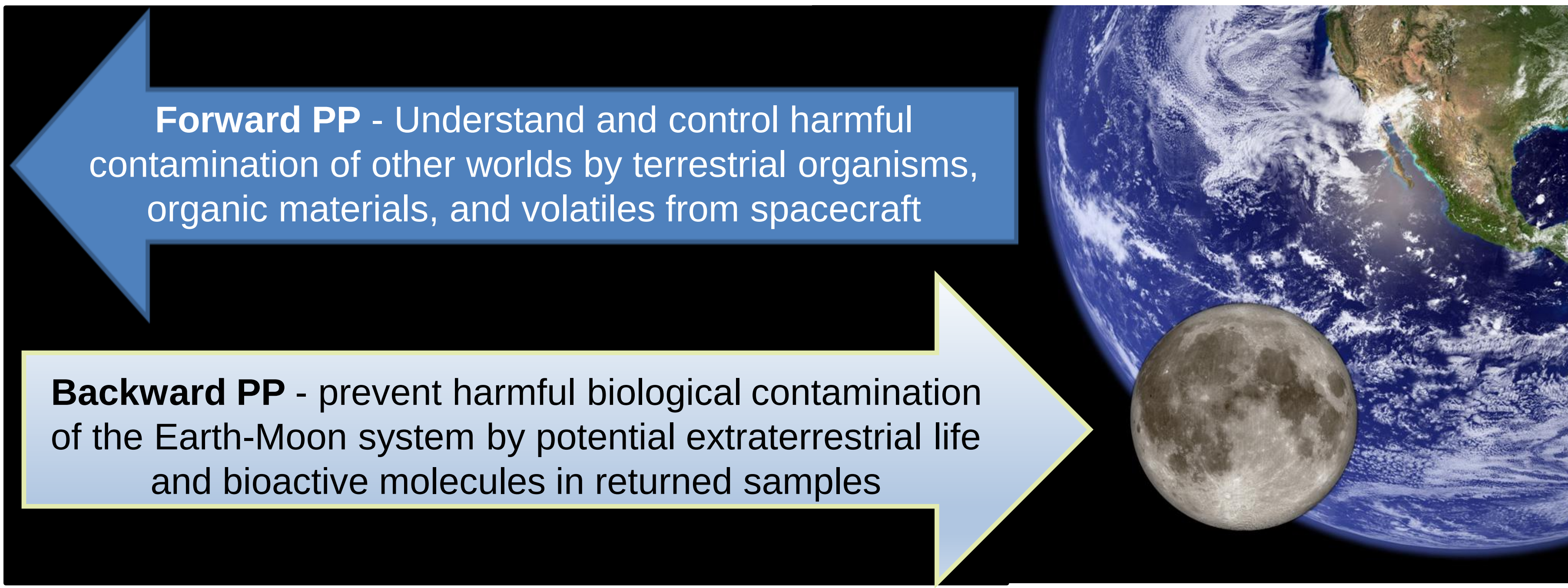
TRISMAC 2024

Frascati, Italy

June 25, 2024

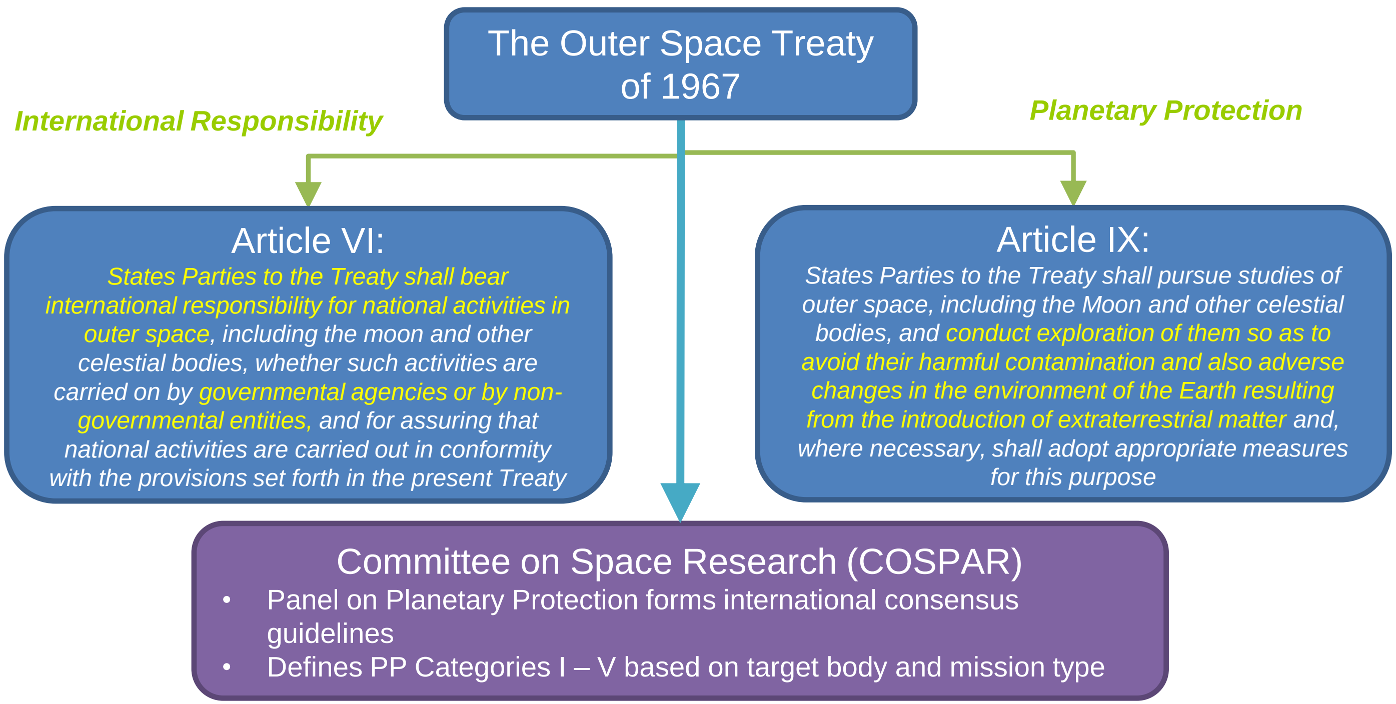
Planetary Protection Objective

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 by avoiding harmful biological contamination carried on returning spacecraft, as described in the Outer Space Treaty.

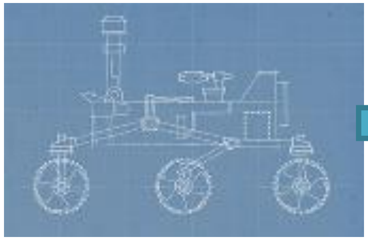


COSPAR PP Policy

- Serves as the international consensus standard as an accepted means of compliance with the OST.
- March 2024 - COSPAR has an updated PP Policy that is an administrative and editorial update to enable future updates to the policy.



Control of Forward Contamination – Lunar



Mission Design & Categorization

- Information to be included in the PP Mission Categorization Proposal
- Mission operations – orbiter or lander. Landing location – PSR, shadowed region or other.

Spacecraft Assembly, Test, Transport, Launch, and Operations

- Biological and organic contamination knowledge inventory materials
- Documentation requirements and communication of data/analysis updates

Avoiding Contamination following Inadvertent Impact

- Avoiding inadvertent impact of solar system bodies by spacecraft and launch elements during flyby, gravity assist, or orbital insertion
  - Mars (Cat III-IV)
- Secondary and auxiliary payloads

End of Mission Disposition

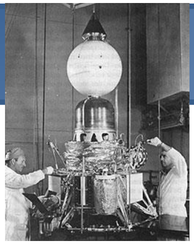
- Documentation of final disposition of hardware
- Updates to organic, biological, and combustion product inventories
- Information to be included in End of Mission PP Report

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 III*



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*

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*

July 1969 – Interagency Agreement on Back PP. Quarantine Provisions.

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

PP Category V Restricted*

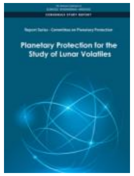
Apollo 15-17
PP Category I*
PP Category V Unrestricted*

1983 – COSPAR Post-Apollo
PP Category I
PP Category V Unrestricted

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

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

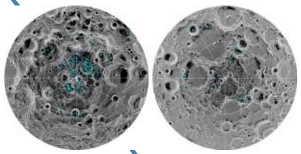
Sept – Oct 2020 NASEM Study



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



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**

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: <u>material inventory limited to organic products that may be released into the lunar environment by the propulsion system</u>.
  - 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: <u>full organic inventory (solid and volatiles).</u>

* 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.

Exploration Planetary Protection Comparison: Moon vs Mars

Moon

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."

Categorization (Outbound):
II/IIa/IIb

Implication:
- Documentation

Categorization (Return):
V(unrestricted)

Implication:
- No further constraints

Mars

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):
III/IVa/IVb/IVc

Implication:
- Documentation
- Avoidance of Impact and/or Cleanliness Requirements

Categorization (Return):
V(restricted)

Implication:
- Documentation
- Rigorous containment of unsterilized material to protect Earth's biosphere
- Quarantine of crew

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

- Mission Guidance from Office of Planetary Protection
  - Streamline reporting of pre-launch, post-launch and end-of-mission
  - 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].

Lesson learned and lessons lived (1 of 2)

- International coordination of PP policy essential.
- Communication and transparency of changing policy critical with missions that find themselves in the transition.
  - Creates potential last minutes changes to mission requirements. More challenging to implement for partnered missions.
    - Potential SMA opportunity for helping with messaging of partnered missions.
  - Command media essential – articles, common presentations and talking points, response to questions, fact sheets, etc.
  - Working group meetings, town halls, webinars, forums, lunch and learns

Lesson learned and lessons lived (2 of 2)

- Streamline reporting and instructions to NASA and NASA partners
  - Clear and practicable requirements with defined intent.
  - Requirements were broad to allow for flexibility (*e.g.* volatile and organic inventory reporting) but needed more clarification for the end users.
    - Volatiles – what exactly needs reported, how accurate reporting needs to be
    - Organic inventory – what is the reporting threshold, definition of an organic
- Identified flow of reports from NASA partners
  - Payload integration manager served as the single coordination point to collocate reports (Artemis I had 11 projects) and send package to OPP.
  - Office of PP signed reports then flowed back through integration manager

PP Policy “Look Ahead”

- Expansion of current crew guidelines for Mars to matured policy.
- Reporting and consolidation of reports from multiple missions.
- Organic inventory and archiving requirement evaluation.
- Icy worlds update to consider expansion of target bodies and further refining limits of life constraints (e.g., temps and water availability).

Thinking more about how we implement policy updates

- Establishing a process - science vs. policy makers driving change
- First principle: PP's goal is to protect current and future science.

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.

Thank You!

The latest policy changes, mission implications for Artemis I and II, and continued conversations with the science and engineering community ensure current and future science is enabled by PP policy. These lessons learned from the Lunar policy process can help provide a critical perspective as we continue to work in a collaborative environment to continue to evolve, enable, and ensure safety of terrestrial, orbital and planetary environments.

Abstract

Planetary protection (PP) as a discipline focuses on the safety of terrestrial, orbital and planetary environments as well as the safety of the public due to potential harm from a sample returned from other solar system bodies. The COSPAR Planetary Protection policy is leveraged by agencies as the international consensus standard. This international standard is developed and managed by a panel of space agency representatives and selected members of the science community. Technical objectives and guidance within this standard are updated by achieving scientific consensus through a series of agency level assessments, peer reviewed publications, workshops, open and closed panel meeting discussions, and consensus by the panel.

The evolution of lunar planetary protection policy from the 1960s to present day demonstrates the responsiveness of policy to scientific consensus. In 1960 the risk posture was conservative with the absence of scientific data, resulting in what would be considered a decontaminated and sterilized bioburden-controlled spacecraft today (i.e., PP Category IV for landers) for forward planetary protection. Backward planetary protection required the need to contain and quarantine astronauts and lunar samples (i.e., PP Category V(r), restricted Earth return). As more science data came in from Apollo in terms of orbital science, quarantine, and sample safety assessments, PP requirements changed to PP Category I and Category V(u) (unrestricted Earth return) missions starting with Apollo 15. In the early 2000s, more orbital and impacting assets provided data to substantiate that permanently shadowed regions and poles of Earth's Moon were recognized as needing protection for future science; thus, changing to a Category II in 2008. Finally in 2002-2021, further scientific consensus was achieved by the National Academies of Science, Engineering, and Medicine (NASEM) Committee of Planetary Protection and COSPAR. The resulting change of lunar categories expanded to Category II, IIa, and IIb to reflect the level of risk/documentation required for missions orbiting and landing on the lunar surface.

Here we will further showcase the latest policy changes, mission implications for recent NASA missions, and continued conversations with the science and engineering community to ensure current and future science is enabled by PP policy. Lessons from the Lunar policy process can help provide a critical perspective as we continue to work in a collaborative environment to continue to evolve, enable, and ensure safety of terrestrial, orbital and planetary environments.

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 Implications – IIa vs. IIb

- Lunar surface area 3.79 x 10^7 km^2
  - $A = 4\pi r^2$
  - 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) over**
  - 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

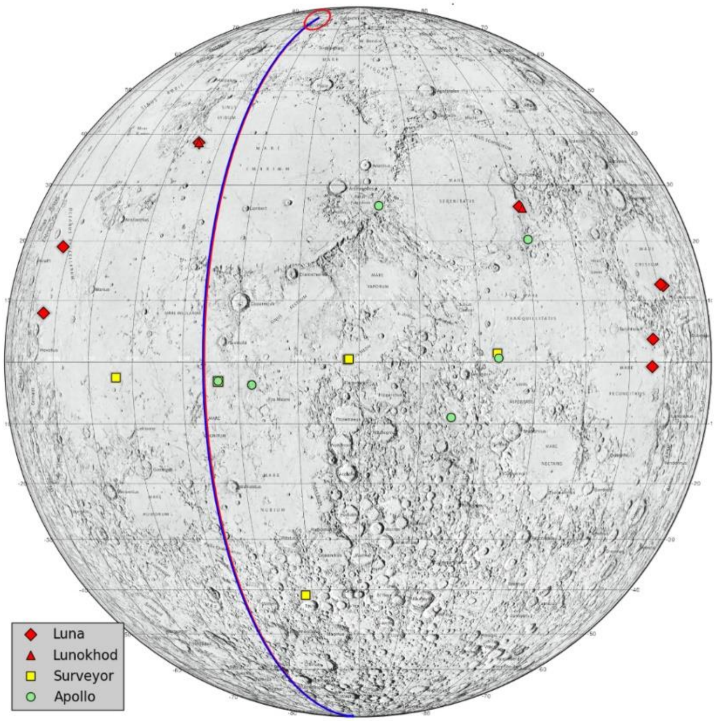


Image Credit: NASA/JPL-Caltech