ADVANCING THE COSPAR POLICY ON PLANETARY PROTECTION MEASURES FOR A SAFE AND SUSTAINABLE EXPLORATION. Athena Coustenis[1], Niklas Hedman[2], Peter Doran[3], and the COSPAR Panel on Planetary protection[4],
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Introduction: Searching for life in the Solar system and beyond has been one of the drivers for space exploration which has targeted particular bodies harboring potentially habitable conditions. Mars, therefore has been and still remains under extensive exploration, but the satellites of the gas giants Jupiter and Saturn, show astrobiological potential and promising conditions for the current or past development and/or maintenance of life.

In order to ensure a safe and sustainable scientific exploration of such bodies, the Outer Space Treaty of 1967, in its article IX, targets harmful contamination. On that basis, the Committee on Space Research (COSPAR) has established planetary protection guidelines which aim to guide compliance with the Treaty to protect against the harmful effects of forward and backward contamination so that a) The conduct of scientific investigations of possible extraterrestrial life forms, precursors and remnants must not be jeopardized and b) the Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from an interplanetary mission.

The COSPAR Planetary Protection Policy: A Planetary Protection Policy has been developed by COSPAR, which provides an instrument for international consultation in the area of space research. The international standards for planetary protection have been developed through consultation and discussion between COSPAR's Panel on Planetary Protection (PPP) and the scientific community and the national space agencies. The resulting COSPAR Policy has non-binding status, which has allowed for a flexible and organic development, enabling the Policy to be updated as scientific understanding has developed. Although not legally binding, the guidelines in the planetary protection Policy established and promoted by the COSPAR Panel [1] are internationally endorsed and implemented by the national authority responsible for compliance with the OST (cosparhq.cnes.fr/scientific-structure/panels/panel-on-planetary-protection-ppp/). It is the only international standard on planetary protection for reference of space-faring nations to guide compliance with Article IX of the United Nations Outer Space Treaty of 1967 that stipulates against harmful contamination [1,2,3]. Under Article VI, States Parties to the Outer Space Treaty bear international responsibility for national activities (both governmental agencies and non-governmental entities) in outer space, including the Moon and other celestial bodies.

The COSPAR PPP: The COSPAR Panel on Planetary Protection (PPP) is currently composed of 24 international members with 12 members appointed by space agencies and another 12 members who are scientists with a broad scientific and engineering expertise (https://cosparhq.cnes.fr/scientific-structure/ppp). The Panel has also ex-officio members and invites the private sector to contribute to its meetings.

The primary objective of the COSPAR PPP is to develop, maintain, and promote the COSPAR policy and associated requirements for the reference of spacefaring nations and to guide compliance with the Outer Space Treaty. This policy must be based upon the most current, peer-reviewed scientific knowledge, and should enable the exploration of the solar system, not prohibit it [2]. The Panel has several meetings a year and invites all stakeholders including the private sector.

It is not the purpose of the Panel to specify the means by which adherence to the COSPAR Planetary Protection Policy and associated guidelines is achieved; this is reserved to the engineering judgment of the organization responsible for the planetary mission. But States are responsible for their national space activities, whether governmental or non-governmental.

Recent activities of the Panel [1] were based on considerations involving different solar system objects. While no changes were required for the missions to small bodies, after the PPP took into account the 3d NASEM SBB/CoPP report on Planetary Protection for missions to small bodies (https://nap.nationalacademies.org/download/26714), and it was decided that the findings were compatible with the current policy, other categories required some evolution to the Policy, such as the one for the Moon with new subcategories for landers [4] and a review of the Policy for the exploration of Venus [5]. New findings and recommendations are an on-going activity for the Icy Worlds of the outer solar system e.g. moons and dwarf planets like Pluto) have become among the highest priority targets for spacecraft missions. Doran et al. (2024, [6]) summarizes the current knowledge and the history of planetary protection considerations for Icy Worlds as well as suggesting ways forward.

Mars: Missions to Mars fall under categories III or IV.

Category III missions at Mars, conducting Mars flybys and Mars gravity assist manoeuvres should demonstrate contamination avoidance of Mars through one of the following approaches [4].

• A probability of impact on Mars by any part of a spacecraft of $\leq 5x10^{2}$ for the first 20 years

after launch and $\leq 5x10^{2}$ for the time period from 20 to 50 years after launch, for nominal and non-nominal flight conditions, OR

• Bioburden constraints for a Category IVa mission Category IV for Mars is subdivided into IVa, IVb, and IVc [4]:

• Category IVa. Lander systems not carrying

instruments for the investigations of extant Martian life.

• Category IVb. For lander systems designed to investigate extant Martian life.

• Category IVc. For missions which investigate Mars Special Regions (see definition below), even if they do not include life detection experiments.

Guidelines imposed include rather detailed documentation than for Category III, including bioassays to enumerate the bioburden, a probability of contamination analysis, an inventory of the bulk constituent organics and an increased number of implementing procedures. The implementing procedures required may include trajectory biasing, cleanrooms, bioburden reduction, possible partial sterilization of the direct contact hardware and a bioshield for that hardware.

In the past years, the PPP has examined the case of JAXA's Martian Moon Explorer (MMX) mission and after taking into account several studies assigned planetary protection category outbound Cat III and inbound Cat V unrestricted Earth return. The full studies can be found in [7].

Robotic exploration of Mar knowledge gapss. Another finding in the current Mars categorization was that planetary protection protocols aimed at avoiding contamination remain necessary to prevent compromising future investigations of extraterrestrial life. In addition, despite the increase in scientific information about Mars, much about its surface and subsurface remains underexplored, creating the need for future in situ missions conducted with caution [8].

Human exploration of Mars. COSPAR has further co-sponsored with NASA a series of Workshops on interdisciplinary meetings considered the next steps in addressing knowledge gaps for planetary protection in the context of future human missions to Mars. The meetings aimed to identify, refine, and prioritize the knowledge gaps that are needed to be addressed for planetary protection for crewed missions to Mars, and describes where and how needed data can be obtained. The findings were published in [9].

Way forward: In 2024, the Policy was updated again with mainly editorial improvements [10] and will continue to be updated as needed. We give thorough consideration to all arguments and scientific inputs in order to make informed decisions.

In the meantime, there is need for community input on science findings and research reserves or recent reports. We are keen to participate and co-sponsor studies, surveys, workshop and focused conferences. COSPAR General Assemblies and dedicated Planetary Protection Meetings are scheduled regularly where all stakeholders are invited to attend and exchange with the Panel.

References: Use the brief numbered style common in many abstracts, e.g., [1], [2], etc. References should then appear in numerical order in the reference list, and should use the following abbreviated style:

[1] Coustenis, A. et al. (2023). *Front. Astron. Space Sci. 10*:1172546. doi: 10.3389/fspas.2023.1172546

[2] Coustenis A., Kminek G., Hedman, N. (2019a) ROOM Journal, June 2019, 44-48. https://room.eu.com/article/the-challenge-of-planetary-protection

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[7] Raulin, F., Coustenis, A., Kminek, G., Hedman, N., eds (2019). Special issue "Planetary protection: New aspects of policy and requirements". *Life Sci. Space Res. 23*, 1-2.

[8] Olsson-Francis, K., et al. (2022). *Life Sci. Space Res., 36*, p. 27-35. DOI: 10.1016/j.lssr.2022.12.001

[9] Spry, A. et al., (2024). Planetary Protection Knowledge Gap Closure Enabling Crewed Missions to Mars. *Astrobiology, 24(3)*:230-274. doi: 10.1089/ast.2023.0092)

[10] Editorial to the New Restructured and Edited COSPAR Policy on Planetary Protection. Ehrenfreund, P., Worms, J.-C., Coustenis, A., Doran, P., Hedman, N., et al. (2024). *Space Research Today 220*, July 2024, 10-13.https://issuu.com/cosparspaceresearchtoday/docs/space_research_today_220 ; pp/ 14-36.