



Review



Cite this article: Hedman N *et al.* 2026 The COSPAR Panel on Planetary Protection and the COSPAR Policy on Planetary Protection: an overview of governance and activities. *Phil. Trans. R. Soc. A* **384**: 20240429. <https://doi.org/10.1098/rsta.2024.0429>

Received: 18 March 2025

Accepted: 28 May 2025

One contribution of 10 to a theme issue
'Planetary Protection for sustainable space
exploration'.

Subject Areas:

astrobiology, Solar System, space exploration

Keywords:

planetary protection, space law, space
exploration, contamination

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The COSPAR Panel on Planetary Protection and the COSPAR Policy on Planetary Protection: an overview of governance and activities

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The search for both extant and extinct life within our Solar System and beyond has been a primary motivation for space exploration since its inception. Mars has long been a focal point for exploration, and it continues to be, while the moons of the gas giants, Jupiter and Saturn, are increasingly seen as possible habitats. To ensure safe and sustainable scientific exploration of these bodies, the COSPAR Policy on Planetary Protection aims at ensuring adherence to the 1967 Outer Space Treaty. Although not legally binding, the guidelines set forth by the Policy are globally supported, with implementation instructions provided. The primary goal of the Committee on Space Research (COSPAR) Panel on Planetary Protection is to safeguard against the harmful effects of both forward and backward contamination. It focuses on the biological exchange that may occur during Solar System exploration, which could negatively affect the study of chemical evolution as well as the origin of life. The Policy is regularly reviewed and revised to incorporate the latest scientific discoveries, alongside the rapidly advancing requirements of space exploration. The Panel's work addresses the specific needs of each space mission, while ensuring the application of relevant expertise to promote the sustainable exploration of the Solar System.

This article is part of the theme issue 'Planetary Protection for sustainable space exploration'.

1. Introduction

The search for habitable and possibly inhabited environments in the Solar System and beyond has been one of the drivers for space exploration from its beginnings. The investigations have targeted particular bodies located in the 'habitable zone', an area at a certain distance from a star where it is theoretically possible for a celestial body with sufficient atmospheric pressure to maintain liquid water on its surface [1]. In the case of our Solar System, the Earth is located in the centre of this habitable zone, at the correct distance from our Sun to possess water in liquid form. Further, the Earth affords a magnetic field to protect life from the detrimental effects of the solar flux and the cosmic particles [2]. Life, as we know it, also requires the assembly of complex organic molecules, and energy sources to sustain metabolism over long periods of time. The energy provided by our star is geothermal, which supports plate tectonic activity and local geological features like hydrothermal vents in extreme environments in our Solar System.

Exploration beyond the Earth has focused on neighbouring planets, which could have benefited from favourable habitable conditions in the past, e.g. Venus and Mars. It has been demonstrated, however, that a runaway greenhouse effect has destroyed any viable environment on Venus today (e.g. [3] and references therein). Mars, on the other hand, because of the interest in finding past life there, is a prime target with currently orbiting spacecraft like Mars Express, ExoMars Orbiter, Al-Hamal and lander missions, such as Mars2020/Perseverance and Tianwen-1 (e.g. [4] and references therein).

Beyond the snow line (the minimum distance from the Sun to where the temperature is low enough for volatile compounds to condense and form planetesimals), the large satellites of the gas giants Jupiter and Saturn, are seen as an ideal target in the Solar System to explore for a potential second genesis of life even though they are beyond the traditional habitable zone. Missions, such as Galileo, Cassini–Huygens and Juno, have identified plausible conditions for habitability (subsurface oceans of liquid water with physiochemical conditions favourable for the emergence and maintenance of life) [5].

Data suggest that some of the moons of gas giants harbour water oceans under their icy crusts, which, in the case of Europa, may be in direct contact with a silicate mantle floor and kept warm through time by tidally generated heat. The Icy Worlds of Titan and Enceladus have organic chemistries with complex organic compounds detected in the plumes of Enceladus and in Titan's thick atmosphere, suggesting potential conditions for prebiotic chemistry and the building blocks for life [6]. Hence, the icy satellites thus provide a conceptual basis within which new theories for understanding habitability and the emergence of life can be constructed.

Future exploration missions are planned to Mars, for example ExoMars 2028 including a Mars Sample Return mission by both ESA/NASA, and one by China, and to the icy moons around the giant planets, which include ESA's JUpiter ICy moons Explorer (JUICE) (launched in 2023) and NASA's Europa Clipper mission (launched in 2024). For a return to Titan, NASA has also recently selected the Dragonfly mission for launch in 2028 and other concepts are being studied. The interest in investigating the icy moons around the giant planets and potentially habitable worlds in the Solar System is showcased in recent programmes such as those established by the studies of NASA's Decadal Planetary Survey [7] and ESA's Voyage 2050 (<https://www.cosmos.esa.int/web/voyage-2050>). For the current missions to the outer Solar System, the measures applied conform to categorization already in place (see Tobie *et al.* [8] and Lorenz *et al.* [9]: this issue). Other celestial bodies like dwarf planets, trans-Neptunian Objects or Kuiper-belt objects may present astrobiological potential and collectively under the term 'Icy Worlds' require specific categorizations in future exploration to avoid their contamination (e.g. Doran *et al.*, [10,11]).

It is the role of the COSPAR Panel on Planetary Protection to establish guidelines and best practices to ensure sustainable space exploration, with the aim to protect the integrity of scientific investigations within the Solar System, which can provide valuable insights into the origin and evolution of our own planet.

2. COSPAR

In 1958, the International Council of Scientific Unions (ICSU), now the International Science Council (ISC) (see <https://council.science/>), established an ad hoc Committee on Contamination by Extraterrestrial Exploration (CETEX), which in turn recommended formulating a code of conduct for space missions and research. In accepting the CETEX-recommendations, ICSU established the Committee on Space Research (COSPAR) during an international meeting in London (1958) to coordinate worldwide space research. COSPAR's first Space Science Symposium was organized in Nice, France, in January 1960 (see <https://cosparhq.cnes.fr/about/>).

Building upon the scientific cooperation programme of the International Geophysical Year in 1957–1958, the United Nations General Assembly, in its resolution 1348 (XIII), of 13 December 1958, established the intergovernmental Ad Hoc Committee on the Peaceful Uses of Outer Space, which received its permanent status as the Committee on the Peaceful Uses of Outer Space (COPUOS) by General Assembly resolution 1472 (XIV) of 12 December 1959. This intergovernmental body started out with 18 States members in 1958 and currently counts 104 States members (as of December 2024). Observer status is granted to international intergovernmental and non-governmental organizations, currently counting 56 organizations (as of December 2024). COSPAR became the first observer organization to COPUOS in 1962 and the

relationship between COSPAR and COPUOS has continuously been close since the beginning [12].

Today, COSPAR is composed of eight Scientific Commissions, 15 Panels, five Task Groups, a Committee on Industry Relations and a new structure of Centres of Excellence that unites a global network of more than 14 000 space scientists. More details can be found at: <https://cosparhq.cnes.fr/scientific-structure/>.

COSPAR's objectives are to promote, at the international level, scientific research in outer space with emphasis on the exchange of results, information and opinions, and to provide a forum, open to all scientists, for the discussion of challenges that may affect scientific space research. These objectives are achieved through the organization of Scientific Assemblies, Symposia, publications, and other means, with substantial contributions from most countries engaged in space research. The Scientific Assemblies allow for the presentation of the latest scientific results, the exchange of knowledge and the discussion of challenges facing space research. Over several decades the COSPAR Scientific Assemblies have been recognized as a prime forum for space research and a focal point for international collaboration in space research. In this regard, it should be observed that COSPAR has played a central role in the development of disciplines such as life sciences or fundamental physics in space, by facilitating the interaction between scientists in emergent space fields and senior space researchers.

Since its inception COSPAR has played an important role as an open bridge between East and West for cooperation in space. During the ensuing decades, COSPAR has focused its objectives on the progress of research carried out using space instruments (including balloons) at an international level. Indeed, today, there are even more promising opportunities for COSPAR to be of service to space scientists worldwide. In an era when the capabilities to pursue scientific space research are spreading throughout the world, stakeholders should continue to cooperate to maximize resources; to pursue ever more complex and challenging projects; to share the development of technology with all nations; and to contribute to understand the wealth of data that national and international space missions have delivered.

3. The COSPAR Panel on Planetary Protection

A special case among the Commissions and Panels in the COSPAR structure is the Panel on Planetary Protection, which was established in 1999 [13], building upon its predecessors the Panel on Standards for Space Probe Sterilization and the Panel on Planetary Quarantine, and which serves an important function for space agencies pursuing planetary exploration. Planetary protection aims to guide compliance with the Outer Space Treaty to protect against the harmful effects of forward and backward contamination by planetary missions. The primary objective of the Panel is to develop, maintain and promote the COSPAR Policy on Planetary Protection and associated guidelines for the reference of spacefaring nations (e.g. [5]).

The Panel is currently composed of 26 international members with 12 members appointed by space agencies and another 14 independent members that have scientific and engineering expertise. The space agencies represented in the Panel are ASI (Italy), CNES (France), CNSA (China), CSA (Canada), DLR (Germany), ISRO (India), JAXA (Japan), NASA (USA), ROSCOSMOS (Russian Federation), UAE Space Agency (United Arab Emirates), UKSA (UK) and ESA (European Space Agency). The Panel has also ex-officio members, including the National Academies of Sciences, Engineering and Medicine of the United States (NASEM) and the COSPAR Committee on Industry Relations. Representatives from industry and the private sector are routinely invited to contribute to its proceedings, for example Airbus Defence and Space, Blue Origin, Lockheed Martin, SpaceX, and Thales Alenia Space.

The primary aims of the Panel are to develop guidelines to avoid:

- (1) possible effects of contamination of planets other than the Earth, and of planetary satellites within the Solar System by terrestrial organisms (forward contamination); and

- (2) contamination of the Earth by materials returned from outer space carrying potential extraterrestrial organisms (backward contamination).

This will ensure that scientific investigations of possible extraterrestrial life forms, precursors and remnants will not be jeopardized and similarly the Earth will be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from an interplanetary mission.

The Panel develops, maintains and provides a delineated Policy (see §4a for detail) that provides specific requirements as to the standards that must be achieved to protect against the harmful effects of contamination. The requirements are based upon the most current, peer-reviewed scientific knowledge to enable the exploration of the Solar System [5,14,15]. It is not the purpose of the Panel to specify how to adhere to the COSPAR Policy on Planetary Protection and associated guidelines; this is reserved to the engineering judgement of the entities responsible for the missions.

4. The COSPAR Policy on Planetary Protection and the governance of outer space activities

(a) The COSPAR Policy on Planetary Protection and the Outer Space Treaty

To ensure that the exploration of all types of bodies, in particular the ones with astrobiological potential, is done safely and responsibly, COSPAR has over time established guidelines for planetary protection in the form of the COSPAR Policy on Planetary Protection. The Policy was first consolidated into a single document in 2002 [16] and provides a mechanism for international consultation in space research. The international standards for planetary protection have been developed through consultation and discussion between the COSPAR Panel on Planetary Protection and the scientific community and the national space agencies (<https://cosparhq.cnes.fr/scientific-structure/panels/panel-on-planetary-protection-ppp/>).

The resulting COSPAR Policy has non-legally binding status, which has allowed for a flexible and organic development, enabling the Policy to be updated as scientific understanding has developed. It is the only international standard on planetary protection for reference of space-faring nations to guide compliance with 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 (Outer Space Treaty) that pronounces against harmful contamination [14,15,17]. Under Article VI of the Outer Space Treaty, States Parties to the Treaty bear international responsibility for national activities (carried out by governmental agencies as well as non-governmental entities) in outer space, including the Moon and other celestial bodies.

COPUOS, with its Scientific and Technical Subcommittee and Legal Subcommittee, is the body in the United Nations system where international space law as a branch of public international law has been negotiated and established, with five treaties, principles, guidelines and resolutions (International Space Law: [18]). In 2022, the COPUOS Legal Subcommittee agreed to a report provided by the United Nations Office for Outer Space Affairs (UNOOSA), in its capacity as secretariat to COPUOS and its Subcommittees, explaining elements to assess when becoming party to the United Nations treaties on outer space. This includes their interrelationship, perspectives on the development of national space policy, strategy and regulatory frameworks and elements for consideration in international cooperation (see [19]).

As referred to above, the treaty directly related to planetary protection is the first of the United Nations treaties on outer space, namely, the Outer Space Treaty, which was negotiated by COPUOS and adopted by the General Assembly on 19 December 1966 under resolution 2222 (XXI). It entered into force on 10 October 1967. As of 1 January 2025, 116 States are

parties to the Treaty, while another 23 have signed, but not ratified (UNOOSA website at <https://www.unoosa.org>)[20].

The Outer Space Treaty contains several fundamental legal principles for the exploration and use of outer space briefly summarized as follows (non-exhaustive):

- Exploration and use of outer space—‘province of all mankind’ (*Article I*),
- Principle of non-appropriation (*Article II*),
- Carrying activities in accordance with international law and UN Charter (*Article III*),
- Prohibitions concerning weapons of mass destruction/the Moon and other celestial bodies to be used exclusively for peaceful purposes (*Article IV*),
- Astronauts as ‘envoys of mankind’, phenomena constituting danger to astronauts (*Article V*),
- International responsibility for national activities in outer space (*Article VI*),
- International liability for damage (*Article VII*),
- Jurisdiction and control over objects launched into outer space (*Article VIII*),
- Cooperation and mutual assistance, due regard, harmful contamination and harmful interference (*Article IX*),
- Opportunity for observation of flight of space objects (*Article X*),
- Information and notification (*Article XI*),
- Stations, installation, equipment and space vehicles on the Moon and other celestial bodies open on the basis of reciprocity (*Article XII*).

In the implementation of the rights and obligations under the Treaty, it is important to observe the Treaty as a whole, given that the respective provisions are interrelated. As for space exploration and scientific investigation, it should be noted that Article I of the Outer Space Treaty provides the fundamental principle from which subsequent treaty provisions are derived. As such, in quoting Article I,

‘[t]he exploration and use of outer space, including the Moon and other celestial bodies, shall be carried out for the benefit and in the interest of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind. Outer space, including the Moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies. There shall be freedom of scientific investigation in outer space, including the Moon and other celestial bodies, and States shall facilitate and encourage international cooperation in such investigation’.

The legal basis and the goal for planetary protection is established in Article IX of the Outer Space Treaty, which is a complex provision addressing three separate, but interconnected, key principles, namely, ‘due regard’, ‘harmful contamination’ and ‘harmful interference’. The Treaty does not give a clear definition of the terms ‘contamination’ and ‘interference’. The planetary protection element in Article IX reads

‘[...] 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 and, where necessary, shall adopt appropriate measures for this purpose [...]’.

The harmful contamination element connects with the general duty in Article IX for States Parties to conduct space activities ‘with due regard to the corresponding interests of all other States Parties to the Treaty’. This due-regard obligation balances the principle in Article I that space ‘shall be free for exploration and use by all States’, including ‘free access to all areas of celestial bodies’. In broad terms, States Parties are to ensure that exercising their rights and freedoms in outer space does not interfere with or compromise the safety of space activities and operations of other States Parties [21]. With the consultation requirement on potentially

harmful interference, by Article IX as a whole, States Parties when implementing their treaty obligations on planetary protection, are required to consider the interests of other States Parties in the exploration and use of outer space and consult with other States Parties where these interests may be seriously affected [22].

As can be seen, the scientific definition of planetary protection objectives in the COSPAR Policy on Planetary Protection derives from the elements in Article IX classified as forward and backward contamination. The obligation to adopt ‘appropriate measures for this purpose’ is effectively met at the international level by the cooperation and coordination of planetary protection measures among nations represented by space agencies under the framework of the COSPAR Panel on Planetary Protection, and at the national level (as well as ESA as an international intergovernmental organization) by planetary protection regulations, standards and protocols.

Given the status of the COSPAR Policy on Planetary Protection as a voluntary non-legally binding international standard for guiding spacefaring nations in the avoidance of organic-constituent and biological contamination introduced by planetary missions, the provision in Article VI of the Outer Space Treaty becomes central in implementing planetary protection measures, and reads

‘States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The activities of non-governmental entities in outer space, including the Moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty [...]’.

Thus, it is the prerogative of States to regulate their national space activities. For planetary protection purposes, the conjunction of Article IX and Article VI of the Treaty coupled with the cooperation and coordination mechanism provided by the COSPAR Panel on Planetary Protection, has contributed significantly to the protection against biological contamination and has evolved over the past 60 years into a well-established international framework.

A reference to Article VI of the Outer Space Treaty was added to the 2024 revised version of the COSPAR Policy on Planetary Protection (see further in §6) to mark this relationship between the obligations laid down in Article IX and Article VI, respectively. With an increase in space activities and missions by industry and private sector entities it was important for the Panel to introduce this distinction into the Policy in order to avoid confusion in the application and implementation of the planetary protection guidelines.

The Outer Space Treaty is a treaty of ‘principles’, as elaborated in its title, and its provisions are general and hardly provide any legal definitions. When studying Article IX of the Outer Space Treaty, it must be taken into consideration that according to its Article III, space activities shall be carried on ‘in accordance with international law, including the Charter of the United Nations’. Thus, general principles of international law apply, and for the purpose of Article IX, international environmental law principles are to be observed in the exploration and use of outer space, including the Moon and other celestial bodies (see further discussion on environmental perspectives of outer space activities in [21,23,24]).

According to the COSPAR Policy on Planetary Protection, planetary protection, specifically, is concerned with biological contamination, and chemical contamination as far as it comprises ‘organic constituent’, and its policy statement specifies the forward contamination objective that ‘the scientific investigation of the process of chemical evolution and/or the origin of life must not be compromised’. The Policy thus targets ‘scientific investigation’ and does not address environmental concerns or other motives of protection of the Moon and other celestial bodies.

(b) COSPAR and COPUOS

The role of the COSPAR planetary protection framework is also recognized by COPUOS, which in its 2017 report noted the long-standing role of COSPAR in maintaining the Planetary Protection Policy as a reference standard for spacefaring nations and in guiding compliance with Article IX of the Outer Space Treaty (A/72/20, para. 332) [25]. Moreover Guideline D.1 of the 2019 COPUOS Guidelines for the Long-term Sustainability of Outer Space Activities [26] recommends that

‘States and international intergovernmental organizations should promote and support research into and the development of sustainable technologies, processes and services and other initiatives for the sustainable exploration and use of outer space, including celestial bodies’.

Guideline D.1 promotes and supports research into and the development of ways to support sustainable exploration and use of outer space. Guideline D1 continues and recommends that

‘States and international intergovernmental organizations should consider appropriate safety measures to protect the Earth and the space environment from harmful contamination, taking advantage of existing measures, practices and guidelines that may apply to those activities, and develop new measures as appropriate’.

The Long-term Sustainability Guidelines are voluntary and non-legally binding and as a whole predominantly deal with the safety of space operations in Earth orbit. However, with Guideline D1 the instrument is broadened to comprise space sustainability beyond Earth orbit, thus also addressing the Moon and other celestial bodies as part of the overall space environment.

Back in the early 1960s, the United Nations General Assembly adopted the ‘Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space’ on 13 December 1963 as resolution 1962 (XVIII), which had been negotiated by COPUOS. This instrument was the precursor to the Outer Space Treaty of 1967 and contains most of the fundamental principles enshrined in the subsequent Treaty. For the discussion on contamination, it should be noted that paragraph 6 of the 1963 Declaration addresses cooperation and mutual assistance, due regard for the corresponding interests of other States, and potentially harmful interference with activities of other States in the peaceful exploration and use of outer space, together with the international consultation mechanism embodied in the 1967 Outer Space Treaty. However, the principle of harmful contamination, as described above, was not included in the 1963 Declaration. For an assessment of the negotiation history of the 1963 Declaration and the 1967 Outer Space Treaty, as part of the evolution of planetary protection, see [27].

The early consideration of ‘potentially harmful effects of space experiments’ is the most striking in the history of the relations of COPUOS and COSPAR, and for which COPUOS in its 1964 report (A/5785) incorporated the full text of the COSPAR Executive Council resolution of May 1964 and its appendices. Before that, in 1963, COPUOS in its report (A/5549) emphasized that certain experiments conducted in space may affect present and future scientific activities in this or other fields, and that humankind, being concerned about potentially harmful effects of such experiments, seeks to be scientifically assured that such experiments will not adversely change the space environment or adversely affect other experiments in space.

The COSPAR Consultative Group on Potentially Harmful Effects of Space Experiments was also noted in the 1963 COPUOS report as being composed by authoritative scientists and specialists on an international basis, and that their assistance was available to the members of COSPAR, the international scientific unions and bodies of the United Nations.

Following its consideration in 1963, in its 1964 report, COPUOS requested the United Nations Secretary-General to circulate to Member States of the United Nations the resolution of COSPAR, the report of the Consultative Group and its four appendices. COPUOS urged that all Member States proposing to carry out experiments in space should give full consideration

to the problem of possible interference with other peaceful uses of outer space, as well as of possible harmful changes in the natural environment caused by space activities. Moreover, Member States were advised, where they would consider it appropriate, to seek a scientific analysis of the qualitative and quantitative aspects of those experiments from the COSPAR Consultative Group on Potentially Harmful Effects of Space Experiments and should give due consideration to the results of this analysis.

The 1964 report of COPUOS contains, as already stated, in its Annex II the resolution adopted by the Executive Council of COSPAR on 20 May 1964, and in Annex III the report of the COSPAR Consultative Group on Potential Harmful Effects of Space Experiments to the COSPAR Executive Council. In Appendices 1–4 the report contains: (i) a statement on upper atmospheric pollution by rocket exhaust and chemical injection experiments; (ii) a statement on belts of orbits; (iii) a statement on potentially harmful effects of space experiments concerning the contamination of planets; and (iv) the report of the Panel on Standards for Space Probe Sterilization, the precursor to the Panel on Planetary Quarantine and the present Panel on Planetary Protection.

The introduction of forward and backward contamination into Article IX of the Outer Space Treaty thus came in a period of active consultations between COSPAR and the intergovernmental body COPUOS. The role of COSPAR as an international non-governmental platform for scientific exchange was acknowledged by COPUOS in the way its proceedings and reports were incorporated into the formal reporting structure of COPUOS. The formulation of international consultations on potentially harmful interference into both the 1963 Declaration and subsequently Article IX of the 1967 Outer Space Treaty should be understood as consent among governments on the consultative power of COSPAR. By way of example, the United States delegate to COPUOS at the 1963 session clarified that the Consultative Group of COSPAR was understood as an appropriate forum for consultations (A/5549 annex verbatim records, and [28]).

This historical overview of the role of COSPAR during the early developments of the governance of outer space activities at the United Nations level clarifies the importance of scientific research as a contribution to the creation of international space law, and for the purpose of planetary protection gives a picture of the introduction of forward contamination and backward contamination into Article IX of the Outer Space Treaty.

5. The COSPAR Planetary Protection Policy measures: categories, standards and reporting

(a) Categories

Planetary protection requirements apply to all interplanetary missions, regardless of whether their scientific objectives are relevant to astrobiology. However, specific planetary protection measures vary based on scientific objectives, astrobiological relevance of the target body, expected level of spacecraft contact with extraterrestrial bodies and whether samples will be returned to Earth.

The different planetary protection categories in the Policy (I–V) reflect the level of interest and concern that contamination may compromise future investigations or the safety of the Earth; the categories and associated requirements depend on the target body and mission type combinations:

Category I: All types of mission to a target body which is not of direct interest for understanding the process of chemical evolution and/or the origin of life; *Undifferentiated, metamorphosed asteroids; Io; others to-be-defined (TBD)*.

Category II: All types of missions (gravity assist, orbiter, lander) to a target body where there is significant interest relative to the process of chemical evolution and/or the origin of life, but

where there is only a remote chance that contamination carried by a spacecraft could compromise future investigations; *Venus; Moon*, with organic inventory only for landed missions at the poles and in permanently shadowed regions (PSRs); *Comets; Carbonaceous Chondrite Asteroids; Jupiter; Saturn; Uranus; Neptune; Ganymede; Callisto; Titan; Triton; Pluto/Charon; Ceres; Kuiper-belt objects > 1/2 the size of Pluto; Kuiper-belt objects < 1/2 the size of Pluto; others TBD*.

Category III: Flyby (i.e. gravity assist) and orbiter missions to 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; *Mars; Europa; Enceladus; others TBD*.

Category IV: Lander (and potentially orbiter) missions to 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. Three subcategories exist (IVa,b,c) differentiating instruments, science investigations, Special Regions (a Special Region is defined as a region within which terrestrial organisms are likely to replicate. Any region which is interpreted to have a high potential for the existence of extant Martian life forms is also defined as a Special Region. Spacecraft-induced Special Regions are to be evaluated, consistent with these limits and features, on a case-by-case basis. Identified Mars limits, features, observational evidence and additional case-by-case evaluation considerations are further captured in e.g. [29,30]); *Mars; Europa; Enceladus; others TBD*.

Category V: All Earth return: Two subcategories are defined—unrestricted return for Solar System bodies deemed by scientific opinion to have no indigenous life forms and restricted return for all others.

(b) Standards

The COSPAR Panel on Planetary Protection assists in the application of rules for the construction of sterile (or low biological burden) spacecraft, the development of flight plans that protect planetary bodies of interest, the development of plans to protect the Earth from returned extraterrestrial samples and the formulation and application of policies as they apply to planetary protection.

In addition to standards developed by the International Organization for Standardization [31], examples of standards for such measures include from NASA the NASA-STD-8719.27 and from ESA the ECSS-U-ST-20C (Planetary Protection) as well as the following:

- Materials and hardware compatibility tests for sterilization processes, ECSS-Q-ST-70-53C,
 - Describes how to test hardware compatibility and provides examples;
- Ultra cleaning of flight hardware, ECSS-Q-ST-70-54C,
 - Describes procedures how to clean flight hardware, in particular for life detection;
- Microbial examination of flight hardware and cleanrooms, ECSS-Q-ST-70-55C,
 - Describes procedures how to measure the biological contamination (bioburden and biodiversity). Bioburden is the population of viable organisms on or in spacecraft materials;
- Vapour phase bioburden reduction for flight hardware, ECSS-Q-ST-70-56C,
 - Describes hydrogen peroxide sterilization procedures;
- Dry heat bioburden reduction for flight hardware, ECSS-Q-ST-70-57C,
 - Describes high-temperature sterilization procedures;
- Bioburden control for cleanrooms, ECSS-Q-ST-70-58C.
 - Describes how to set-up and operate bioburden-controlled cleanrooms.

(c) Reporting

It is recommended in the COSPAR Policy on Planetary Protection that spacefaring entities inform COSPAR when establishing planetary protection requirements for planetary missions, and also that they provide information to COSPAR within a reasonable time (not exceeding six months after launch) about the procedures and computations used for planetary protection for each flight and again within 1 year after the end of a planetary mission about the areas of the target(s) which may have been subject to contamination.

Reports should include, but are not limited to, the following information:

- *The estimated bioburden at launch, the methods used to obtain the estimate (e.g. assay techniques applied to spacecraft or a proxy), and the statistical uncertainty in the estimate,*
- *The probable composition (identification) of the bioburden for Category IV missions, and for Category V ‘restricted Earth return’ missions,*
- *Methods used to control the bioburden, decontaminate and/or sterilize the space flight hardware,*
- *The organic inventory of all impacting or landed spacecraft or spacecraft-components, for quantities exceeding 1 kg,*
- *Intended minimum distance from the surface of the target body for launched components, for those vehicles not intended to land on the body,*
- *Approximate orbital parameters, expected or realized, for any vehicle which is intended to be placed in orbit around a solar system body,*
- *For the end-of-mission, the disposition of the spacecraft and all of its major components, either in space or for landed components by position (or estimated position) on a planetary surface.*

It should be noted that such reports and documentation are for information only and that COSPAR is not a repository of any sensitive information, nor can it impart such information to external parties without the consent of the reporting agency.

6. The 2024 restructured version of the COSPAR policy on planetary protection

In 2024, the COSPAR Panel on Planetary Protection developed a new version of the COSPAR Policy on Planetary Protection. The previous version of the Policy, dating from 2021, was an assembly of a basic document which had undergone occasional modifications and updates affecting its readability and coherence after gradual evolution [32]. Consequently, the Panel considered it important to modernize the Policy in this manner to adequately apply to current and future missions, both governmental and non-governmental, and to present the Policy and its corresponding guidelines in a way fit for better understanding by operational decision-makers and national regulatory authorities.

The new version of the Policy published in 2024 reflects editorial and structural adjustments to achieve consistency and an improved comprehension of the Policy and all its components. The content of the respective substantive guidelines in this new document has not been altered beyond what had already been agreed by the Panel previously.

The 2024 version of the Policy in its preamble references both Articles IX and VI of the Outer Space Treaty. While the previous 2021 version had only referenced Article IX of the Outer Space Treaty, the new 2024 Policy additionally references Article VI of the Treaty to address the roles and responsibilities for all national activities to include both those carried out by governmental agencies and non-governmental entities.

The preamble of the 2024 version furthermore stipulates that the Policy is an international ‘voluntary and non-legally binding’ standard for the avoidance of organic-constituent and biological contamination introduced by ‘planetary missions’, instead of the more limited reference to ‘space exploration’ in the 2021 version. The 2024 version also addresses actions under its Policy statement by ‘all entities conducting space activities beyond Earth orbit’ and not as previously in its 2021 version by ‘Member National Scientific Institutions of COSPAR’.

Those changes represent a significant modernization of the directions given for the application of the Policy.

Compared with the previous version, Chapter 1 (Preamble) and Chapter 2 (Policy Statement) of the new document were changed to not just improve consistency and clarity of the language, but also to introduce a more objectives-driven and case-adapted (versus prescriptive) approach to the formulation and implementation of planetary protection controls. The restructured version explicitly calls these two chapters out to delineate between the policy statement and the technical guidelines. The document clarifies clauses related to the reporting of planetary protection activities.

Chapter 3 of the new document describes the role and functions of the COSPAR Panel on Planetary Protection. This new chapter focuses on the role of the Panel in developing and promoting the Policy and assistance with its implementation. It was deemed important to introduce in the new version a reference to this close link between the Policy and the responsibilities of the Panel in developing and maintaining it.

Chapter 4 (Key Assumptions) is a new chapter that was added to highlight the key assumptions that form the basis for the technical guidelines. No new assumptions were added, but additional rationale and background references complement each assumption. These are the foundational first principles from which the categorization and technical guidelines are derived. The objective of this chapter was to pull these out of the 2021 version, so that the intent would be better understood by the end user.

Chapter 5 (Categorization) is a new chapter that was added to capture the rationale and assemble all the categorization considerations in the 2021 version into one chapter. Notably, there are no new technical considerations or directions provided. An overview diagram was added to capture the key elements of the categorization process as well as a paragraph detailing the intent behind the categorization process. A summary table was also added to map the guidelines that may be considered based on the categorization.

The new version of the Policy also contains an updated list of references, a table of terms and definitions to enhance the understanding of the Policy and a listing of the recommended reporting elements to COSPAR as well as examples of expected reporting elements as part of the internal mission documentation. Aside from being reorganized, no additional text was added in this section from the 2021 version.

These review and editing efforts were undertaken by a subcommittee established by the Panel in 2023. The new version of the Policy was endorsed by the Panel members in late February 2024 and the COSPAR Bureau approved the new version in March 2024. The document was published in COSPAR's journal *Space Research Today* in July 2024 [33].

The COSPAR Panel has been working on further changes to the COSPAR Policy and consequently a 2026 version of the Policy is being published in *Space Research Today* in early 2026 as volume 224. The main updates apply to Icy Worlds. See further in 7(d).

7. Recent activities of the COSPAR Panel on Planetary Protection

The COSPAR Panel on Planetary Protection was restructured in 2018 and has in the past seven years held several executive meetings (for members only and for decision-making and informative purposes) but, more essentially, many regular open sessions that are advertised on the Panel's website and open to registration by all interested parties. The Panel has a general cadence of two to three meetings per year and numerous other interactions, which means that it takes into consideration the fact that scientific findings are moving fast in the exploration of the Solar System. The COSPAR Scientific Assemblies feature organized Panel sessions and public business meetings and Panel members have delivered lectures at most of the related congresses

and conferences in Europe and around the world. Recent activities of the Panel (e.g. [5,14]) were based on considerations involving different Solar System objects, as explained below.

(a) The Moon

In view of the renewed interest for lunar exploration and the need to protect scientifically interesting regions but also recognizing the need for relaxation of some reporting requirements for the Moon, the COSPAR Panel on Planetary Protection revised the lunar requirements in the COSPAR Policy on Planetary Protection in 2020 based on new findings, stakeholder consultations and studies from different groups like the Lunar Exploration Analysis Group and the NASEM Committee on Planetary Protection (CoPP) [34]. Taking all that on board, the COSPAR Panel formulated new requirements for lunar exploration which were expeditiously implemented in the 2021 COSPAR Policy version [6,32] with the inclusion of two new subcategories for lander missions to the Moon specifying the need to protect certain regions more strongly than before.

Under those new categorization requirements, the COSPAR Policy stipulates that all missions to the surface of the Moon whose nominal mission profile access PSRs and/or the lunar poles, in particular latitudes south of 79°S and north of 86°N, should provide the planetary protection documentation and an organic inventory. This applies to all PSRs, irrespective of latitude. All missions to the surface of the Moon whose nominal profile does not access other areas should provide planetary protection documentation and an organic inventory limited to organic products that may be released into the lunar environment by the propulsion system.

(b) Venus

Based on the existing measurements and studies, the COSPAR Panel on Planetary Protection considered that Venus' clouds are not special regions and possible habitats for Earth life. Owing to the low level of water in the clouds where the temperatures are mild enough, life as we know it, would not be able to replicate there even if there were nutrients available (and protection from radiation, sulfuric acid, etc).

The experts considered that unless there are new measurements that demonstrate a water activity greater than 0.6 (relative humidity greater than 60%), Venus clouds are not a concern for planetary protection because 'life as we know' from Earth would not proliferate there. They are of course extremely interesting for planetary science, including atmospheric chemistry, P cycle, etc. Therefore, the COSPAR Panel has not changed the COSPAR Policy on Planetary Protection categorization for Venus which remains in Category II [3]. This applies for instance to the missions currently planned by ESA and NASA (ENVISION, VERITAS and DAVINCI).

(c) Mars

Mars is considered to be an object of high scientific value not only owing to its unique features but also because of its proximity to the Earth and the habitable zone, raising the question as to whether life could have emerged there in the past, as it did on Earth. Although living organisms are not expected to exist on Mars today, finding traces of past life and revealing the history of the planet's atmosphere and water content evolution and subsequent disappearance are extremely important elements of the Red Planet's exploration goals. This also explains the large number of missions sent there in the past 60 years (more than 50 and continuing with ascending trend).

Missions to Mars are currently categorized according to mission architecture, instruments, science investigations and Special Regions attained. In the absence of specific information, no

Special Regions are currently identified on the basis of possible Martian life forms. If and when information becomes available on this subject, Special Regions will be further defined on that basis; see [29,30] in Category IV and Category V (if they involve sample return).

During 2018–2019, the COSPAR Panel on Planetary Protection examined the particular case of JAXA's Martian Moon Explorer (MMX) mission (<https://www.mmx.jaxa.jp/en>). After taking into account several studies, the COSPAR Panel assigned planetary protection category outbound Category III and inbound Category V unrestricted Earth return. To support the categorization, ESA initiated an activity with a science consortium to evaluate the level of assurance that no unsterilized Martian material naturally transferred to Phobos (or Deimos) is accessible to a Phobos (or Deimos) sample return mission. NASA supported the activity from the very beginning providing test materials and expert advice, followed by JAXA with their own experimental and modelling work supporting the overall assessment.

The ESA-JAXA-NASA coordinated activities finished with an independent review by the National Academies of Sciences and the European Science Foundation presented to the ESA Planetary Protection Working Group (PPWG) and to COSPAR. The full studies behind this decision can be found in the special issue edited by Raulin *et al.* [35].

One 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 [4].

The COSPAR Panel will continue to work with various national and international space agencies, the scientific community, the International Mars Exploration Working Group and other stakeholders (e.g. the private sector and industry) to develop a roadmap for coordinating research activities addressing the identified knowledge gaps. This will include further characterization of the biocidal effects at the surface of Mars, which needs to be addressed before *in situ* reduction can be considered as an approach for bioburden control for robotic missions. Although the science underpinning the Policy is advancing, as highlighted in more recent reports (e.g. [4,36,37]), there are still several knowledge gaps in robotic and human Martian exploration that need to be addressed before they can be directly applied to accommodate the interest of the user. In brief, these knowledge gaps fall within three main themes, all of which will benefit from more measurements by space missions and ground-based observations: biocidal effects, contamination transport model and Mars environmental conditions.

The COSPAR Panel was also concerned with the question as to whether samples returned from Mars could be harmful to the Earth environment. The COSPAR Sample Safety Assessment Framework (SSAF) was accordingly developed by a working group appointed by COSPAR. The purpose of the SSAF was to evaluate if the presence of Martian life can be excluded in samples returned by a mission to the Red Planet. In case the presence of Martian life cannot be excluded, a 'pause' (or time to consider) is put in place as well as risk management measures that lead to recommendations on how to proceed. The SSAF conducted a series of workshops whose findings were published [38].

COSPAR has further co-sponsored together with NASA and ESA a series of workshops and interdisciplinary meetings considering the next steps in addressing knowledge gaps for planetary protection in the context of future human missions to Mars. These activities aimed to identify, refine and prioritize the knowledge gaps that are needed to be addressed for planetary protection for crewed missions to Mars, and described where and how necessary data can be obtained. The findings are published in Spry *et al.* [37].

The findings of human missions to Mars include:

- The intent of the planetary protection policy is the same whether a mission to Mars is conducted robotically or with human explorers,
- Planetary protection goals should not be relaxed to accommodate a human mission to Mars, i.e. they become even more directly relevant to such missions—even if specific

implementation requirements must differ. Human exploration of Mars will require additional planetary protection considerations to those for robotic missions,

- Safeguarding the Earth from potential back contamination is the highest planetary protection priority in Mars exploration,
- The greater capability of human explorers can contribute to the astrobiological exploration of Mars only if human-associated contamination is controlled and understood.

The purpose is to establish engineering requirements through a series of workshops on planetary protection for human missions to Mars to address knowledge gaps for planetary protection in the context of future human missions to Mars. Reports from these workshops are posted under Conference Documents at <https://sma.nasa.gov/sma-disciplines/planetary-protection/>.

A report was published after the last COSPAR-ESA-NASA Meeting on ‘Planetary Protection Knowledge Gaps for Crewed Mars Missions’ [37] at the completion of the COSPAR series. This report aimed to identify, refine and prioritize the knowledge gaps that are needed to be addressed for planetary protection for crewed missions to Mars, and described where and how necessary data can be obtained. Thus, the knowledge gaps addressed in this meeting series fall into three major themes:

‘1. *Microbial and human health monitoring*; 2. *Technology and operations for biological contamination control*; and 3. *Natural transport of biological contamination on Mars*’ Olsson-Francis *et al.* [4]; Kminek *et al.* [39].

This approach was consistent with current scientific understanding and the COSPAR Policy, considering that the presence of a biological hazard in Martian material cannot be ruled out, and appropriate mitigations need to be in place. The findings were published in Spry *et al.* [37], with COSPAR’s support. The paper highlights the scientific measurements and data needed for knowledge gap closure, updating and completing in more detail the material previously available.

(d) Icy Worlds

The natural satellites of the giant planets offer new tantalizing opportunities to explore dark and cold (far from the Sun) subsurface environments that harbour liquid water, organic chemistry and energy sources, so that a new concept of habitable environments could still be considered. This is the case for satellites of Jupiter and Saturn like Europa, Enceladus, Titan and Ganymede to which future missions like JUICE, Europa Clipper and Dragonfly will go.

The COSPAR Panel on Planetary Protection has already updated the Policy requirements and definitions for the icy moons, especially Europa and Enceladus, [40]. This was based on the Planetary Protection for the Outer Solar System (PPOSS) study led by the European Science Foundation and funded by the European Commission along with DLR/Germany, INAF/Italy, Eurospace, Space Technology/Ireland, Imperial College London (UK), China Academy of Space Technology, and the NASEM Space Studies Board (SSB). The PPOSS study recommended a revision of the planetary protection requirements for missions to Europa and Enceladus, based partly on the NASEM-SSB 2012 Icy Bodies Report and on an ESA PPWG recommendation.

COSPAR was involved throughout the multi-year-long process and at the end updated the requirements for missions to Europa and Enceladus:

- *Category III and IV: Requirements for Europa and Enceladus flybys, orbiters and landers, including bioburden reduction, shall be applied in order to reduce the probability of inadvertent contamination of a European or Enceladan ocean to less than 1×10^{-4} per mission.*
- *The probability of inadvertent contamination of a European or Enceladan ocean of 1×10^{-4} applies to all mission phases including the duration that spacecraft introduced terrestrial organisms remain viable and could reach a subsurface liquid water environment.*

PPOSS led to the creation of the International Planetary Protection Handbook [41]. After the PPOSS study, a subcommittee of the COSPAR Panel on Planetary Protection considered the future exploration of Icy Worlds and Ceres. The COSPAR Panel has been working on a thorough review of the current knowledge for Icy Worlds of the outer Solar System. Doran *et al.* [10] represents the products of the subcommittee. The proposals made by Doran *et al.* include:

- Establish a new definition of Icy Worlds for use in the COSPAR Policy on Planetary Protection: *‘Icy Worlds in our Solar System are defined as all bodies with an outermost layer that is believed to be greater than 50% water ice by volume and have enough mass to assume a nearly round shape’*,
- Establish indices for the lower limits of Earth life with regard to water activity (lower limit of water activity (LLAw)) and temperature (lower limit of temperature (LLT)) and apply them into all areas of the COSPAR Planetary Protection Policy (currently 0.5 and -28°C , respectively),
- Establish LLT as a parameter to assign categorization for Icy Worlds missions (subject to 1000 year period of biological exploration),
- Have all missions consider the possibility of impact,
- Restructure or remove Category II* from the policy,
- Establish any sample return from an Icy World as Category V restricted Earth return.

The COSPAR Panel has been seeking community input into the proposals while planning on how these proposals will be worked into Policy changes. Presentations and discussion of the current state of affairs have taken place at NASA’s Outer Planet Advisory Group and other meetings.

(e) Small bodies

The small bodies of the Solar System not elsewhere discussed in the COSPAR Policy on Planetary Protection represent a very large class of objects. The current Policy guidelines for small bodies states that ‘imposing forward contamination controls on these missions is not warranted except on a case-by-case basis, so most such missions should reflect Categories I or II’. The NASEM/SSB CoPP issued its third report on planetary protection for missions to small bodies [42] which was presented to the COSPAR Panel that same year.

The CoPP report found that it is highly unlikely that small Solar System bodies harbour extinct or extant life or that terrestrial life could proliferate there. The Committee concluded that given the importance of some relatively primitive, volatile-rich and organic-bearing small bodies to studies of prebiotic chemistry and the sparsity of current knowledge about them, there is no reason at this time to reduce the current categorizations (from Category II to Category I) for missions to small bodies. The Committee did point out that larger objects like Ceres may be an exception. Knowledge about these larger objects is scant, and they should be assessed further before being visited, but for now, Category II is acceptable until further assessment.

The COSPAR Panel took the CoPP report into account at its meeting in 2022 and noted that the findings were compatible with the current Policy. After thorough considerations and discussion by the Panel experts, it was decided that there was no need currently to change anything in the Policy as concerns small bodies [14].

8. Conclusions

COSPAR has leveraged a process for mission-specific tailoring based on a technical sound and responsible case being made by missions on a case-by-case basis. A recent example, of tailoring the guidelines for a mission is the MMX mission, which identified the need for a

specific category for unrestricted Earth return, based on scientific information from different independent sources that had demonstrated that samples returned from Phobos would not present a threat to Earth. This tailoring process could serve as a predictable, replicable and transparent model to adopt for further developing the COSPAR Policy on Planetary Protection.

The COSPAR Policy, founded in the principles of the Outer Space Treaty, is a living document with elements derived from over 60 years of scientific research, and will continuously be updated but not in a rushed process. The COSPAR Panel on Planetary Protection considers arguments and scientific inputs by all actors concerned, and consequently issues an informed decision. The Panel works in unison with consensus achieved before any amendment to the Policy and its guidelines are made. Publications in scientific peer-reviewed journals (by Panel members and external experts) accompany changes to the Policy.

As we embark on an era of more complex missions, including crewed and sample return, it is essential to obtain input from the scientific community, through studies, surveys, workshops and focused conferences, on future endeavours. This is particularly prudent as we enter an era of increasing space activities and missions to the Moon and other celestial bodies by multiple actors both public and private. The COSPAR Policy on Planetary Protection guidelines aim at ensuring sustainable planetary missions at a reasonable cost [43].

Data accessibility. This article has no additional data.

Declaration of AI use. We have not used AI-assisted technologies in creating this article.

Authors' contributions. N.H.: writing—original draft; A.C.: writing—original draft; P.D.: writing—original draft; J.-C.W.: writing—original draft; O.A.S.: writing—original draft; E.A.: writing—original draft; M.F.: writing—original draft; O.G.: writing—original draft; T.H.: writing—original draft; A.H.: writing—original draft; V.I.: writing—original draft; C.M.: writing—original draft; K.O.-F.: writing—review and editing; J.P.: writing—original draft; K.P.: writing—original draft; O.P.-B.: writing—original draft; F.R.: writing—original draft; P.R.: writing—original draft; E.S.: writing—original draft; M.S.: writing—original draft; S.S.: writing—original draft; Y.S.: writing—original draft; J.T.: writing—original draft; L.W.: writing—original draft; K.X.: writing—original draft; M.Z.: writing—original draft.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Conflict of interest declaration. We declare we have no competing interests.

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