COSPAR BUSINESS

Editorial to the New Restructured and Edited COSPAR Policy on Planetary Protection

The COSPAR Panel on Planetary Protection established a subcommittee in 2023 to propose a new version of the COSPAR Policy on Planetary Protection. Upon endorsement of the new version of the Policy by Panel members on 1 March 2024, the text was submitted to the COSPAR Bureau for validation and was approved by the Bureau on 20 March 2024. Below follows a brief explanation to the new version of the Policy, which is published hereafter in the *Space Research Today* journal.

Chapters 1 and 2 – Preamble and Policy Statement

The previous 2021 version of the COSPAR Policy[1], represented a Policy document which had undergone occasional modifications after gradual evolution without always safeguarding the coherence and readability of the text. This new version builds on the 2021 text and reflects editorial and structural adjustments to achieve consistency and better understanding of the Policy and all its components. The content of the respective substantive guidelines in this document has not been altered beyond what has been agreed by the Panel and validated by the Bureau previously.

Compared to the 2021 version, the Preamble and Policy chapters (1 and 2) 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 (vs. prescriptive) approach to the formulation and implementation of planetary protection controls. The new restructured version explicitly calls these two chapters out to delineate between the policy statement and the technical guidelines.

The preamble references the relevant articles of the Outer Space Treaty of 1967. The previous 2021 version only referenced Article IX which require State Parties to avoid harmful contamination during planetary missions (forward contamination) and avoiding adverse changes to Earth's environment during sample return (backward contamination). The new version adds Article VI to address the roles and responsibilities for all national activities to include both governmental agencies and non-governmental entities.

The document now explicitly describes the Policy as an "international voluntary and non-legally binding standard" for reference by spacefaring nations, to preclude any descriptions as mandatory for meeting Article IX. It defines that contamination controls should be imposed consistent with guidelines (vs. "requirements").

The policy objective describes the actual intent of the planetary protection policy more precisely, and resolves inconsistencies (e.g., "compromise" vs. "jeopardize") in the language. The document explicitly states that guidelines for such controls may be tailored while still meeting planetary protection objectives. This reference to tailoring is new and is based on the discussion in the Panel's 2023 Mars paper [Olsson et. al[2]] which addresses the need to allow planetary protection practices to evolve and adapt when there's a scientific basis for doing so.

Chapter 3 – Role of the COSPAR Panel on Planetary Protection

Chapter 3 in the new version describes the functions of the COSPAR Panel on Planetary Protection. This is an entirely new chapter which focuses on the development of the policy and associated guidance and assistance with implementation. It was deemed important to introduce in the document this close link to the responsibilities of the Panel in maintaining and promoting the Policy.

Chapter 4 – Key Assumptions

The Key Assumption chapter is also a new chapter that is added to highlight the key assumptions that form the basis for the technical guidelines. No new assumptions have been added at this time, but additional rationale and background references have been added to each assumption. These are the foundational first principles from which the categorization and technical guidelines are derived. The objective of this chapter is to present these principles so that the intent is better understood by the end user. For example, one area that is expanded upon is the bioburden constraint chapter 4.3, in which the new version expands on the technical growth conditions to include the rationale for selecting the aerobic spore as a proxy for cleanliness.

Chapter 5 – Categorization

The Categorization chapter is new and is added to capture the rationale and assemble all the categorization considerations into one chapter. Notably, there are no new technical considerations or directions provided this time. An overview diagram has been 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 is also added to map the guidelines that may be considered based on the categorization. Minor language cleanup on those categories has been made to provide further clarification.

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

[2] Olsson-Francis, K. et al., 2023. The COSPAR Planetary Protection Policy for missions to Mars: ways forward based on current science and knowledge gaps. *Life Sciences in Space Research*, Vol. 36, p. 27-35. https://doi.org/10.1016/j.lssr.2022.12.001

Chapter 6 – Guidelines

There are no changes in the technical content or mission implications in this chapter. An objective/ intent paragraph is added to the beginning of each of the sub-chapters to provide additional context for the benefit of the end user.

Chapter 7 – Reporting on Mission Activities

The Reporting on Mission Activities chapter is a new chapter and clarifies clauses related to the reporting of planetary protection activities. Detailed examples are given in Appendix B and C. The 2021 version recommended that COSPAR members provide information about procedures and computations to COSPAR. The new version recommends that entities conducting activities in outer space provide a reasoned argument that planetary protection objectives will be or have been satisfied to the authorizing entity of the mission. The recommendation to share information with COSPAR remains and the recommended elements for such reporting are covered in Appendix B. This new chapter seeks to limit the perception of COSPAR as a regulator and avoids concerns regarding the retention of non-public and/or controlled information by COSPAR.

Chapter 8 – References

The Reference chapter has undergone an extensive overhaul. Additional references have been added to capture recent, peer-reviewed manuscripts on which the Panel's recommendations are based.

Appendix A – Terms and Definitions

The Terms and Definitions appendix is a new section and was added to enhance the understanding of the Policy. Definitions have been taken predominately from the existing and agreed-upon definitions from NASA and ESA policies.

Appendix B – Reporting to COSPAR Recommended Elements

The Reporting to COSPAR Recommended Elements appendix is a new section that was added to capture the detailed mission activities that were examples from the previous Policy. Aside from being reorganized, no additional text has been added in this section with respect to the 2021 version.

Appendix C – Mission Documentation Expected Elements

The Mission Documentation Expected Elements appendix is a new section that provides guidance as to the types of internal mission documentation and topics covered for each document. Table 3, the suggested documentation table, has been retained from the 2021 version. Background text is also added to this section to provide additional guidance and reinforcement to the Policy reporting statement regarding COSPAR reporting obligations vs. mission specific activities. In essence, COSPAR needs to be informed of the high-level activities occurring but the detailed reporting from the missions may contain sensitive or proprietary information not suitable for an international audience. An additional table has been added to this section to further describe to the end user what topics might be covered under each mission documentation.

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COSPAR Policy on Planetary Protection

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1. Preamble

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

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 Outer Space Treaty of 1967) states that [Ref. United Nations 1967]:

"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."

noting that Article VI 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 Outer Space Treaty of 1967) states that [Ref. United Nations 1967]:

"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."

therefore, to guide compliance with the Outer Space Treaty, COSPAR maintains this Policy on Planetary Protection (hereafter referred to as the COSPAR PP Policy) for the reference of spacefaring nations as an international voluntary and non-legally binding standard for the avoidance of organic-constituent and biological contamination introduced by planetary missions.

2. Policy Statement

COSPAR,

Referring to COSPAR Resolutions 26.5 and 26.7 of 1964 [Ref. COSPAR 1964], the Report of the Consultative Group on Potentially Harmful Effects of Space Experiments of 1966, the Report of the same Group of 1967, and the Report of the COSPAR/IAU Workshop of 2002 [Ref. Rummel et al. 2009],

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

accepts that for certain missions, controls on contamination should be imposed in accordance with a specified range of guidelines, based on the following policy objectives:

The scientific investigation of the process of chemical evolution and/or the origin of life must not be compromised. In addition, the Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from a planetary mission.

emphasises, therefore, that all entities conducting space activities beyond Earth orbit must implement controls commensurate with the mission type and targeted body's significance for understanding the process of chemical evolution and/or the origin of life and the potential for adverse impacts to the Earth's biosphere.

recognizes that, for specific missions, controls can be tailored allowing the mission to accomplish its science objectives while still meeting planetary protection objectives.

3. Role of the COSPAR Panel on Planetary Protection

COSPAR has established the Panel on Planetary Protection (hereafter referred to as the COSPAR PPP) to develop, maintain, and promote the COSPAR PP Policy and associated guidelines for the reference of spacefaring nations and to assist them with compliance with the Outer Space Treaty, specifically with respect to protecting against the harmful effects of forward and backward contamination. The COSPAR PPP includes a number of experts in various fields attached to planetary protection such as (astro)biology, planetary sciences, geology and geophysics, microbiology, sample treatment, aerospace engineering and operations, space law and space policy, among other, and relies on information brought forward by the various communities though workshops and studies [Ref. Coustenis et al. 2019].

COSPAR PPP's main function is to regularly review the latest available, peer-reviewed scientific knowledge that is provided by external groups or by a subcommittee of the COSPAR PPP. Based on this information, the COSPAR PPP will produce recommendations to the COSPAR Bureau and Council as to whether a change in the COSPAR PP Policy is required.

To increase transparency and promote inclusion, the activities and reports from the COSPAR PPP such as meeting minutes, presentations, subcommittee reports, panel peer-reviewed journal articles are made available on the COSPAR PPP's website as appropriate.

COSPAR PPP encourages the entities conducting activities in outer space to seek guidance/assistance from the COSPAR PPP on the interpretation of this COSPAR PP Policy as necessary.

COSPAR PPP also supports States, on their voluntary request, in performing mission-specific review and assessment to encourage international cooperation in planetary protection matters.

4. Key Assumptions

4.1 Exploration Assumptions

To meet the objective of protecting the future search for life, the preferred approach is to limit the probability of contamination when that contamination could be harmful for understanding of the process of chemical evolution and/or the origin of life.

The probabilities of growth of contaminating terrestrial micro-organisms are extremely low during the exploration of the outer planets which directly reflects the fact that the environments of these planets appear hostile to all known biological processes,

These environments do not preclude the possibility of *indigenous* life forms,

The search for life is a valid objective in the exploration of the outer solar system,

The organic chemistry of these bodies remains of paramount importance to our understanding of the process of chemical evolution and its relationship to the origin of life,

The study of the processes of the pre-biotic organic syntheses under natural conditions should not be compromised.

4.2 Environmental Conditions for Replication

Given current understanding, the limiting physical environmental parameters in terms of water activity and temperature thresholds that should be satisfied at the same time to allow the replication of terrestrial microorganisms are [Ref: Rummel et al. 2014, Kminek et al. 2016 and Doran et al. 2024]:

- Lower limit for water activity: 0.5
- Lower limit for temperature: -28 ˚C

4.3 Bioburden Constraints

All bioburden constraints for Mars missions are defined with respect to the number of aerobic microorganisms that survive a heat shock of 80°C for 15 minutes (hereinafter "spores") and are cultured on TSA (Tryptic-Soy-Agar) at 32°C for 72 hours [Ref. National Academies of Sciences, Engineering, and Medicine 2021 and Olsson-Francis et al. 2023].

Rationale: This microorganism has been selected for its capacity to withstand typical Martian environmental conditions. The international scientific community has chosen a bacteria representative of thermally resistant spores that would typically contaminate space hardware as a "proxy" to measure the effectiveness of sterilization approaches, in particular dry heat microbial reduction.

4.4 Biological Exploration Period

The biological exploration period for Europa and Enceladus is defined to be 1000 years; this period should start at the beginning of the 21st century [Ref. National Research Council 2012, The International Planetary Protection Handbook 2019 and COSPAR 2020].

The biological exploration period for Mars is defined to be 50 years [Ref. Meltzer 2011].

4.5 Life Detection and Sample Return "False Positives"

A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigour in the guidelines for all later missions.

4.6 Crewed Missions to Mars

The intent of planetary protection is the same whether a mission to Mars is conducted robotically or with human explorers. Accordingly, planetary protection goals should not be relaxed to accommodate a human mission to Mars. Rather, they become even more directly relevant to such missions - even if specific implementation guidelines should differ [Ref. Spry et al. 2024]. General principles include:

- 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.
- For a landed mission conducting surface operations, it will not be possible for all human-associated processes and mission operations to be conducted within entirely closed systems.
- Crewmembers exploring Mars, or their support systems, will inevitably be exposed to Martian materials.

5. Categorization

There are five categories for target body/mission type combinations and the assignment of categories for specific mission/body combinations is to be determined by the best multidisciplinary scientific advice. Planetary protection categorization is a risk-informed decision-making process involving scientific consensus to assess the risk of exploration activities introducing harmful contamination during exploration or the possibility that extraterrestrial materials returning to Earth could have adverse impacts on the biosphere (Refer to **Figure 1**). The type of mission and the target body type are the key parameters to establish a mission category. The type of mission includes flyby/orbiters where there is less likelihood for the scientific investigation of the process of 1) chemical evolution and 2) the origin of life becoming compromised compared to a probe/lander coming into direct contact with the target body. The target body type is evaluated on the potential for indigenous life and the significance that the scientific investigation of the process of 1) chemical evolution and 2) the origin of life would be compromised. Planetary protection guidelines and reporting to COSPAR recommendations can then be identified through the categorization process.

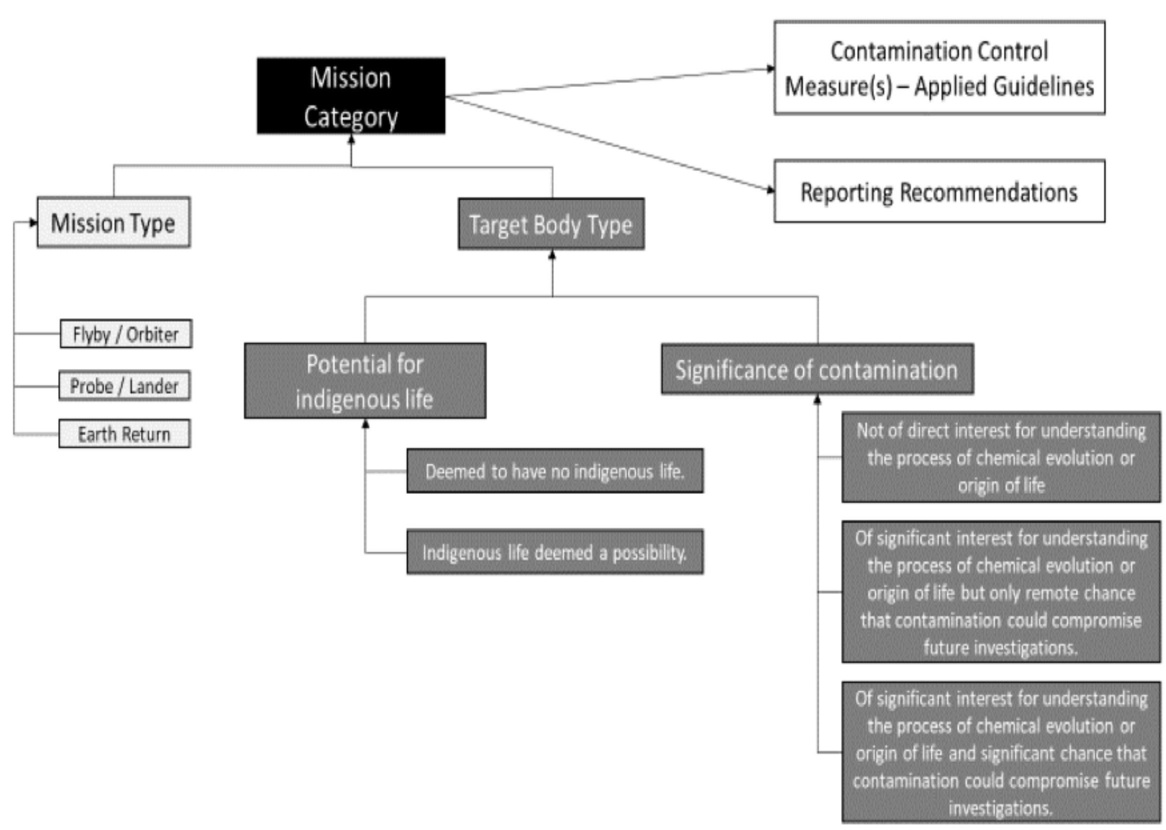

Figure 1: *Planetary protection process overview in establishing the planetary protection categorization and resulting guideline and mission documentation definition.*

Category I missions comprise all types of missions to a target body which is not of direct interest for understanding the process of chemical evolution and/or the origin of life.

No protection of such bodies is warranted, and no planetary protection guidelines are imposed by this COSPAR PP Policy.

Category II missions comprise all types of missions to those target bodies where there is significant interest relative to the process of chemical evolution and/or the origin of life, but where scientific opinion provides a remote[1] chance of contamination by organic or biological materials which could compromise future investigations of the process of chemical evolution and/or the origin of life.

Category II for Earth's Moon is subdivided into II, IIa, and IIb [Ref. National Academies of Sciences, Engineering, and Medicine 2020 and COSPAR 2021].

- Category II. For orbital and flyby missions.
- Category IIa. Landed missions not going to a Permanently Shadowed Region (PSRs) and/or the lunar poles which are defined as locations in particular south of 79°S latitude and north of 86°N latitude.
- Category IIb. Landed missions going to a Permanently Shadowed Region (PSRs) and/or the lunar poles which are defined as locations in particular south of 79°S latitude and north of 86°N latitude.

The guidelines are for documentation of the mission´s organics and trajectory, as applicable. Preparation of a short planetary protection plan is required for these flight projects primarily to outline intended or potential impact targets, brief Pre- and Post-launch analyses detailing impact strategies, and a Post-encounter and End-of-Mission Report which will provide the location of impact if such an event occurs. Solar system bodies considered to be classified as Category II are listed in the Category specific planetary protection guidelines.

NOTE: The small bodies of the solar system not elsewhere discussed in this COSPAR PP Policy represent a very large class of objects. 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.

Category III missions comprise certain types of missions (mostly flyby and orbiter) to a target body of chemical evolution and/or origin of life interest and for which scientific opinion provides a significant[2] chance of contamination by organic or biological materials which could compromise future investigations of the process of chemical evolution and/or the origin of life.

Guidelines will consist of documentation (more involved than Category II) and some implementing procedures, including trajectory biasing, the use of cleanrooms during spacecraft assembly and testing, and possibly bioburden reduction. Although no impact is intended for Category III missions, an inventory of bulk constituent organics is required if the probability of impact is significant. Category III specifications for selected solar system bodies are set forth in the Category specific planetary protection guidelines. Solar system bodies considered to be classified as Category III also are listed in the Category specific planetary protection guidelines.

[1] "Remote" here implies the absence of environments where terrestrial organisms could survive and replicate, or a very low likelihood of transfer to environments where terrestrial organisms could survive and replicate.

[2] "Significant" here implies the presence of environments where terrestrial organisms could survive and replicate, and some likelihood of transfer to those places by a plausible mechanism.

Category IV missions comprise certain types of missions (mostly probe and lander) to a target body of chemical evolution and/or origin of life interest and for which scientific opinion provides a significant chance of contamination by organic or biological materials which could compromise future investigations of the process of chemical evolution and/or the origin of life.

Category IV for Mars is subdivided into IVa, IVb, and IVc [Ref. COSPAR 2021]:

- 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 (more involved than 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.

Category V missions comprise all Earth-return missions and is given in addition to the outbound (I-IV) categorization. The concern for these missions is the protection of the terrestrial system, the Earth and the Moon. (The Moon should be protected from backward contamination of other celestial bodies to ensure unrestricted Earth-Moon travel.) For solar system bodies deemed by scientific opinion to have no indigenous life forms, a subcategory "unrestricted Earth return" is defined. For all other Category V missions, a subcategory is defined as "restricted Earth return".

For "unrestricted Earth Return missions" planetary protection guidelines are on the outbound phase only, corresponding to the category of that phase (typically Category I or II).

For "restricted Earth Return missions" the highest degree of concern is expressed by the absolute prohibition of destructive impact upon return, the need for containment throughout the return phase of all returned hardware which directly contacted the target body or unsterilized material from the body, and the need for containment of any unsterilized sample collected and returned to Earth. Post-mission, there is a need to conduct timely analyses of any unsterilized sample collected and returned to Earth, under strict containment, and using the most sensitive techniques. If any sign of the existence of a non-terrestrial replicating entity is found, the returned sample should remain contained unless treated by an effective sterilizing procedure. Category V concerns are reflected in guidelines that encompass those of Category IV plus a continuing monitoring of project activities, studies and research (i.e., in sterilization procedures and containment techniques).

Table 1. Planetary Protection Categories in relation to target bodies.

Category	Mission Type	Target Body
I	Flyby, Orbiter, Lander	Undifferentiated, metamorphosed asteroids; Io; others to-be-defined (TBD)
II	Flyby, Orbiter, Lander	Venus; Moon (Cat. II, IIa & IIb); Comets; Carbonaceous Chondrite Asteroids; Jupiter; Saturn; Uranus; Neptune; Ganymede*; Callisto; Titan*; Triton*; Pluto/Charon*; Ceres; Kuiper-belt objects > ½ the size of Pluto*; Kuiper-belt objects < ½ the size of Pluto; others TBD
III	Flyby, Orbiters	Mars; Europa; Enceladus; others TBD
IV	Landers	Mars (Cat. IVa, IVb, & IVc); Europa; Enceladus; others TBD
V "Restricted Earth return"	-	Mars; Europa; Enceladus; others TBD
V "Unrestricted Earth return"	-	Venus, Moon; others TBD

*The mission-specific assignment of these bodies to Category II should be supported by an analysis of the "remote" potential for contamination of the liquid-water environments that may exist beneath their surfaces (a probability of introducing a single viable terrestrial organism of $< 1 \times 10^{-4}$), addressing both the existence of such environments and the prospects of accessing them.

Table 2. An example of the guidelines that may be considered based on planetary protection categories.

	Guidelines					
Category	Mission Documentation	Cleanroom	Trajectory Biasing	Inadvertent Impact	Organic Inventory	Biological Control
I	Yes	-	Yes	-	-	-
II (II,IIa, & IIb)	Yes	Only outer planets and their satellites; refer to Section 6.3	Yes	-	IIb only	-
III	Yes	Yes	Yes	Yes	Yes	Yes
IV (IV,IVa, IVb, IVc)	Yes	Yes	Yes	Yes	Yes	Yes
V "Restricted Earth return"	Yes	Yes	Yes	-	Yes	Yes
V "Unrestricted Earth return"	Yes	-	Yes	-	-	-

6. Guidelines

6.1 Biological Control

The objective for biological control of missions is to demonstrate a means of reducing the probability of contamination that might harm future scientific investigations. Biological control for a mission can either be addressed through a probability of contamination calculation or direct measurement of biological cleanliness of an outbound mission.

6.1.1 Numerical Implementation for Forward Contamination Calculations

To the degree that numerical guidelines are used to support the overall policy objectives of this document, and except where numerical guidelines are otherwise specified, the guideline to be used is that the probability that a planetary body will be contaminated during the period of exploration should be no more than 1×10^{-3}. The period of exploration can be assumed to be no less than 50 years after a Category III or IV mission arrives at its protected target. While there is no specific format for probability of contamination calculations, a performance based, risk-informed, safety case assured approach such as probabilistic risk assessments or assurances cases may be considered [Ref: National Academies of Sciences, Engineering, and Medicine 2021 and Olsson-Francis et al. 2023].

6.1.2 Category III and IV Missions

The objective for missions considering inadvertent impact is to delineate from operations that pose a lower risk of contamination to the target body. This guideline defines that probability threshold and where bioburden constraints are recommended to control as well as deliberate contact with a low probability of harmful contamination.

6.1.2.1 Missions to Icy Worlds

Guidelines for Europa and Enceladus flybys, orbiters and landers, including bioburden reduction, should be applied in order to reduce the probability of inadvertent contamination of Europan or Enceladan subsurface liquid water to less than 1×10^{-4} per mission to include all mission phases including the duration that spacecraft introduced terrestrial organisms remain viable and could reach a sub-surface liquid water environment.

For Icy Worlds the calculation of the probability of inadvertent contamination should include a conservative estimate of poorly known parameters, and address the following factors, at a minimum:

- Bioburden at launch
- Cruise survival for contaminating organisms
- Organism survival in the radiation environment adjacent to Europa or Enceladus
- Probability of landing on Europa or Enceladus
- The mechanisms and timescales of transport to a Europan or Enceladan subsurface liquid water environment
- Organism survival and proliferation before, during, and after subsurface transfer

The Preliminary calculations of the probability of contamination suggest that bioburden reduction will likely be necessary even for Europa and Enceladus orbiters (Category III) as well as for landers, requiring the use of cleanroom technology and the cleanliness of all parts before assembly, and the monitoring of spacecraft assembly facilities to understand the bioburden and its microbial diversity, including specific relevant organisms. Relevant organisms are Earth organisms potentially present on the spacecraft that can survive the spaceflight environment, the environment at the icy moon and replicate in icy moons subsurface liquid water. Specific methods should be developed to identify, enumerate and eradicate problematic species.

6.1.2.2 Missions to Mars

6.1.2.2.1 Category III for Mars

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 (Ref: DeVincenzi et al. 1996, ECSS 2019, and COSPAR Aug 2019]:

- A probability of impact on Mars by any part of a spacecraft of ≤ $5x10^2$ for the first 20 years after launch and ≤ $5x10^2$ 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 detailed in Section 6.1.2.

Note 1: In addition to Mars-targeted missions, inadvertent impact calculations/considerations as described in this section are also applicable to any mission (Category I, II, III, IV) where the primary target is not Mars, but with risk to unintentionally introduce parts of the flight system into the Mars environment (as a result of Mars gravity assist manoeuvres or flybys in nominal and non-nominal flight conditions).

Note 2: Inadvertent impact calculations/ considerations should be made for missions to Icy Worlds as applicable, as these will feed into the final probability of contamination described in Section 6.1.

6.1.2.2.2 Category IVa for Mars

Category IVa missions to Mars should demonstrate compliance with the following bioburden cleanliness constraints:

- A total bioburden of the spacecraft on Mars, including surface, mated, and encapsulated bioburden, is ≤ $5x10^{-5}$ bacterial spores,
- The surface bioburden level is ≤ 3×10^{-5} spores, and
- An average of ≤ 300 spores per square meter.

Note: the values indicated in this section for spore density and total number of spores are a result of the evolution of a probability-based approach over the years to ascertain a probability of $1x10^{-4}$ of suitable growth conditions in the target body [Ref: National Research Council 1992].

6.1.2.2.3 Category IVb Life Detection and Sample Return Missions for Mars

All of the guidelines of Category IVa apply, along with the following requirement:

- The entire landed system is restricted to a surface bioburden level of ≤ 30* spores, or to levels of bioburden reduction driven by the nature and sensitivity of the particular life-detection experiments, OR
- The subsystems which are involved in the acquisition, delivery, and analysis of samples used for life detection should be sterilized to these levels, and a method of preventing recontamination of the sterilized subsystems and the contamination of the material to be analyzed is in place.

6.1.2.2.4 Category IVc Special Region Access for Mars

All of the guidelines of Category IVa apply, along with the following requirement:

- **Case 1.** If the landing site is within the special region, the entire landed system is restricted to a surface bioburden level of ≤ 30* spores.

- **Case 2.** If the special region is accessed through horizontal or vertical mobility, either the entire landed system is restricted to a surface bioburden level of ≤ 30* spores, OR the subsystems which directly contact the special region should be sterilized to these levels, and a method of preventing their recontamination prior to accessing the special region should be provided.

NOTE: *This value takes into account the occurrence of hardy organisms with respect to the sterilization modality. This specification assumes attainment of Category IVa surface cleanliness, followed by at least a four order-of-magnitude reduction in viable organisms. Verification of bioburden level is based on pre-sterilization bioburden assessment and knowledge of reduction factor of the sterilization modality.

6.2 Organics Inventory

The objective for an organic inventory from hardware is to capture knowledge of the hardware materials for use by future scientific investigators as a reference. While these guidelines don't preclude organic constituents for planetary protection, they do identify mission documentation parameters where organics may be perceived as a potential risk of harmful contamination.

An organic inventory should be provided for Category II, III & IV missions. For missions to the Moon, some exceptions apply (see Section 6.2.1).

6.2.1 Category II, IIa and IIb Missions to the Moon

Category II. Orbiter and flyby missions to the Moon should provide the planetary protection documentation. There is no need to provide an organic inventory.

Category IIa. All missions to the surface of the Moon whose nominal mission profile does not access areas defined in Category IIb should provide the planetary protection documentation 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 accesses Permanently Shadowed Regions (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 in line with Section 7 [Ref. National Academies of Science, Engineering and Medicine 2020 and COSPAR 2021].

Note: Category IIb applies to all PSRs, irrespective of latitude, and non-PSR regions within the latitude limits south of 79°S and north of 86°N.

6.2.2 Category III and IV Missions

A spacecraft organic inventory includes a listing of all organic materials carried by a spacecraft which are present in a total mass greater than 1 kg.

6.3 Cleanroom

The objective of utilizing a cleanroom during hardware assembly and integration is to manage contamination and recontamination thereby minimizing the potential risk of harmful contamination.

To manage contamination of hardware COSPAR recommends the use of cleanroom technology (ISO 8 or better) for all missions to the outer planets and their satellites [Ref. International Organization for Standardization, 2004].

6.4 Trajectory Biasing

The objective of trajectory biasing through mission design considerations is to prevent unwanted contamination of launch vehicle components. Launch vehicle end of mission disposal should be considered by each mission as to not be an additional source of harmful contamination.

The probability of impact on Mars by any part of the launch vehicle should be $\leq 1\text{x}10^{-4}$ for a time period of 50 years after launch.

6.5 Category V: Restricted Earth Return

The objective of the restricted Earth return guidelines for missions are to ensure missions have a means of managing higher risk extraterrestrial samples decreasing adverse impacts to the Earth's biosphere.

6.5.1 Sample Return Missions

- Unless specifically exempted, the outbound leg of the mission should meet contamination control (or Category IVb for Mars) guidelines. This provision is intended to avoid "false positive" indications in a life-detection and hazard-determination protocol, or in the search for life in the sample after it is returned.
- The mission and the spacecraft design should provide a method to "break the chain of contact" with the target body.
- For unsterilized samples returned to Earth, a program of life detection and biohazard testing, or a proven sterilization process, should be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

Note: determination of universal biohazard testing, proven sterilization processes or general risk management measures might not be credible without evaluating evidence of extinct or extant life on the samples. More realistic and tailored protocols can be developed once specific studies are performed on detected extraterrestrial life form [Ref. Kminek et al. 2022].

If during the course of a Category V mission there is a change in the circumstances that led to its classification, or a mission failure, e.g.:

- New data or scientific opinion arise that would lead to the reclassification of a mission classified as "Unrestricted Earth return" to "Restricted Earth return," and safe return of the sample cannot be assured, OR
- The sample containment system of a mission classified as "Restricted Earth return" is thought to be compromised, and sample sterilization is impossible,

then the sample to be returned should be abandoned, and if already collected the spacecraft carrying the sample should not be allowed to return to the Earth or the Moon.

6.5.2 Sample Return from Small Solar System Bodies

Missions to small solar system bodies should determine if a mission is classified "Restricted Earth return" or not. This mission assessment should be undertaken with respect to the best multidisciplinary scientific advice, using the framework presented in the 1998 report of the US National Research Council's Space Studies Board entitled, *Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies: Framework for Decision Making* [Ref. National Research Council 1998]. Specifically, such a determination should address the following six questions for each body intended to be sampled:

1. Does the preponderance of scientific evidence indicate that there was never liquid water in or on the target body?

2. Does the preponderance of scientific evidence indicate that metabolically useful energy sources were never present?

3. Does the preponderance of scientific evidence indicate that there was never sufficient organic matter (or CO_2 or carbonates and an appropriate source of reducing equivalents) in or on the target body to support life?

4. Does the preponderance of scientific evidence indicate that subsequent to the disappearance of liquid water, the target body has been subjected to extreme temperatures (i.e., >160°C)?

5. Does the preponderance of scientific evidence indicate that there is or was sufficient radiation for biological sterilization of terrestrial life forms?

6. Does the preponderance of scientific evidence indicate that there has been a natural influx to Earth, e.g., via meteorites, of material equivalent to a sample returned from the target body?

As a result of the above decision-making process, if scientific consensus results in the potential for life to still be present, then a mission should be categorized as a restricted Earth return mission.

6.6 Crewed Mars Missions

Implementation guidelines for human missions to Mars include:

- Human missions will carry microbial populations that will vary in both kind and quantity, and it will not be practicable to specify all aspects of an allowable microbial population or potential contaminants at launch. Once any baseline conditions for launch are established and met, continued monitoring and evaluation of microbes carried by human missions will be required to address both forward and backward contamination concerns.

- A quarantine capability for both the entire crew and for individual crewmembers should be provided during and after the mission, in case potential contact with a Martian life-form occurs.

- A comprehensive planetary protection protocol for human missions should be developed that encompasses both forward and backward contamination concerns and addresses the combined human and robotic aspects of the mission, including subsurface exploration, sample handling, and the return of the samples and crew to Earth.

- Neither robotic systems nor human activities should contaminate "Special Regions" on Mars, as defined by this COSPAR PP Policy.

- Any uncharacterized Martian site should be evaluated by robotic precursors prior to crew access. Information may be obtained by either precursor robotic missions or a robotic component on a human mission.

- Any pristine samples or sampling components from any uncharacterized sites or Special Regions on Mars should be treated according to current planetary protection Category V, restricted Earth return, with the proper handling and testing protocols.

- An onboard crewmember should be given primary responsibility for the implementation of planetary protection provisions affecting the crew during the mission.

- Planetary protection guidelines for initial human missions should be based on a conservative approach consistent with a lack of knowledge of Martian environments and possible life, as well as the performance of human support systems in those environments. Planetary protection guidelines for later missions should not be relaxed without scientific review, justification, and consensus.

7. Reporting on Mission Activities

COSPAR recommends that entities conducting activities in outer space provide to authorizing entities a reasoned argument that planetary protection objectives will be or have been satisfied.

COSPAR further recommends that entities conducting activities in outer space publish and share with the COSPAR PP Panel their approaches, certain mission parameters, and lessons learned for the benefit of future missions.

COSPAR recommends that such entities do so within a reasonable time not to exceed six months after launch and again within one year after the end of a planetary mission.

Reports should include, but not be limited to, information regarding applicable guidelines for bioburden, organic inventory, and probability of impact. Appendix B provides the recommended reporting elements. Reports are made available in an open-source repository for the reference of the COSPAR PPP, mission implementers, and members of the science community.

Appendix C (with Table 3 and 4) refers to mission documentation expected elements. These documents are intended to be captured as part of the internal mission documentation and not necessarily expected to be reported to COSPAR.

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Appendix A –Terms and Definitions

Bioassay. A collection and analysis of biological contamination with a specific procedure.

Bioburden. Population of viable organisms on or in spacecraft materials.

Break the Chain of Contact. Prevent the transfer to the Earth-Moon System of all materials from another habitable world that are not sterilized or contained to Earth's biosphere.

Earth-Moon System. The Earth and the Moon (including artificial objects in orbit around either body) is considered as a single environment for planetary protection purposes in considering sample return from restricted sample return bodies (Mars, Europa, Enceladus, others to be determined) to protect the unrestricted travel within the system.

Encapsulated bioburden. Bioburden inside the bulk non-metallic materials not manufactured with additive layer manufacturing. Examples are bioburden inside paints, conformal coatings, thermal coatings, adhesives, composite materials, closed-cell foam, bulk liquids and bulk gasses.

Extant life. Form of life, or signatures thereof, whether metabolically active or dormant.

Extinct life. Form of life, or signatures thereof, that is unambiguously no longer metabolically active or dormant.

Exposed surfaces. Internal and external surfaces free for gas exchange.

False positive. In a life-detection and/or hazard-determination protocol, it is any unwanted organic contamination introduced to the sampling process. As a consequence of cross contamination in the sample under analysis, validity of the sample and associated scientific results will be affected.

Mated surfaces. Surfaces joined by fasteners rather than by adhesives.

Non-nominal. These scenarios cover cases where some condition could occur that results in the system performing in a way that is different from normal. This includes failures, low performance, unexpected environmental conditions, or operator errors that would affect compliance with the probabilistic guidelines.

Organic archive. A complete inventory should include organic products that may be released into the environment of the protected solar system body by propulsion and life support systems (if present) and include a quantitative and qualitative description of major chemical constituents and the integrated quantity of minor chemical constituents present.

Period of Biological Exploration. The period of time (decades to centuries) during which a solar system body is explored for signs of the origin of life and the history of prebiotic chemistry based on current scientific understanding.

Planetary Protection Category. Category assigned to reflect the interest and concern that terrestrial contamination can compromise future investigations and depends on the target body and mission type.

NOTE Different requirements are associated with the various categories.

Probability of contamination (P_c). Probability of introducing into the environment of a solar system body unwanted material present on or in the spacecraft.

Sample. Any intentionally collected or unintentionally adhering physical material (including solids, liquids, and gasses) that reach the spacecraft returning to the Earth-Moon system from other solar system bodies.

Special Region. 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 Kminek et. al. 2010, McEwen et. al. 2014, and Rummel et. al. 2014.

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 [Kminek et. al. 2010].

Water activity. ratio of the vapour pressure of water in a material to the vapour pressure of pure water at the same temperature.

Appendix B – Reporting to COSPAR Recommended Elements

The following points provide the kind of information that is recommended to be described within a reporting to COSPAR [Ref: COSPAR 1969, COSPAR 1984, COSPAR 1994 and Rummel et al. 2009] detailed in Section 7.

- 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.

Appendix C – Mission Documentation Expected Elements

The following points provide the kind of information that is recommended for each mission to document the identified PP requirements and to capture the missions PP execution throughout the life cycle of the mission. These documents are intended to be captured as part of the internal mission documentation and not necessarily expected to be reported to COSPAR.

Table 3. An example of a mission's documentation and deliverables that may be considered based on a mission's categorization.

	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 End of mission scenario	Limit on impact probability End of mission scenario 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 Mission Documentation and Deliverables	None	Documentation only (all brief): PP plan; Pre-launch report; Post-launch report Post-encounter report End-of-mission report Implementing procedures such as: Cleanroom (only outer planets and their satellites; refer to Section 6.3)	Documentation (Category II plus): Contamination control Organics inventory (as necessary) Implementing procedures such as: Trajectory biasing Cleanroom Bioburden reduction (as necessary)	Documentation (Category II plus): P_c analysis plan Microbial reduction plan Microbial assay plan Organics inventory Implementing procedures such as: Trajectory biasing Cleanroom Bioburden reduction Partial sterilization of contacting hardware (as necessary) Bioshield Monitoring of bioburden via bioassay	Outbound Same category as target body/ outbound mission Inbound If restricted Earth return: Documentation (Category II plus): P_c analysis plan Microbial reduction plan Microbial assay plan Implementing procedures such as: • Trajectory biasing • Sterile or contained returned hardware • Continual monitoring of project activities • Project advanced studies and research If unrestricted Earth return • None

Table 4. An example of the objective and expected elements for a mission's documentation throughout a mission life cycle.

Document type	Objective	Main expected responses
Planetary protection plan	To provide information on planned measures to implement planetary protection programs. It describes the "how"	General mission description, implementation approach, i.e. how planetary protection requirements are intended to be met
Pre-launch planetary protection report	To provide evidence that mission meets planetary protection requirements prior to launch	Results of analysis, probability of impacts / contamination, bioburden & contamination measures, as applicable for a given mission category
Post-launch planetary protection report	To provide information of post launch activities and any potential impact of these on pre-launch planetary protection measures	Description of launch activities and post launch events within the deployment and in orbit commissioning timeframe
Post encounter report	To provide evidence of continued compliance with planetary protection requirements	Updates (if any) on probabilities of impact and contamination (as applicable), deviations (if any) from planetary protection requirements and plan
End-of-mission report	To provide evidence of compliance with planetary protection requirements throughout the complete mission	Disposition of all launched flight hardware either orbiting in space or landed/impacted on target body; any update on probability/analysis as applicable
Organic inventory	To document the organic material on the spacecraft.	Identity; Chemical composition; Usage, with respect to product tree; Mass estimate; Outgassing properties (i.e RML - recovery mass loss, TML - total mass loss, CVCM - collected volatile condensable material); Supplier for each item.