COSPAR Policy on Planetary Protection

Prepared by the COSPAR Panel on Planetary Protection and approved by the COSPAR Bureau on 17 June 2020.

Preamble

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

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

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

therefore, COSPAR maintains and promulgates this policy on planetary protection for the reference of spacefaring nations, both as an international standard on procedures to avoid organic-constituent and biological contamination in space exploration, and to provide accepted guidelines in this area to guide compliance with the wording of the UN Outer Space Treaty and other relevant international agreements.

Policy

COSPAR,

Referring to COSPAR Resolutions 26.5 and 26.7 of 1964 [2], 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 [3],

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

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

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

The five categories for target body/mission type combinations and their respective suggested ranges of requirements are described as follows, and in Table 1. Assignment of categories for specific mission/body combinations is to be determined by the best multidisciplinary scientific advice. For new determinations not covered by this policy, such advice should be obtained through the auspices of the Member National Scientific Institutions of COSPAR. In case such advice is not available, COSPAR will consider providing such advice through its Panel on Planetary Protection, or when needed, an *ad hoc* multidisciplinary committee formed in consultation with its Member National Scientific Institutions and International Scientific Unions:

Category I includes any mission to a target body which is not of direct interest for understanding the process of chemical evolution or the origin of life. No protection of such bodies is warranted, and no planetary protection requirements are imposed by this 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 the origin of life, but where there is only a remote[1] chance that contamination carried by a spacecraft could compromise future investigations. The requirements are for simple documentation only. 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 Annex to this document.

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 which could compromise future investigations. Requirements 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 Annex to this document. Solar system bodies considered to be classified as Category III also are listed in the Annex.

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[2] chance of contamination which could compromise future investigations. Requirements 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. Generally, the requirements and compliance are similar to those on *Viking*, with the exception of complete lander/probe sterilization. Category IV specifications for selected solar system bodies are set forth in the Annex to this document. Solar system bodies considered to be classified as Category IV also are listed in the Annex.

Category V missions comprise all Earth-return missions. The concern for these missions is the protection of the terrestrial system, the Earth and the Moon. (The Moon must be protected from back 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. Missions in this subcategory have planetary protection requirements on the outbound phase only, corresponding to the category of that phase (typically Category I or II). For all other Category V missions, in a subcategory defined as "restricted Earth return," 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

[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.

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 must remain contained unless treated by an effective sterilizing procedure. Category V concerns are reflected in requirements that encompass those of Category IV plus a continuing monitoring of project activities, studies and research (i.e., in sterilization procedures and containment techniques).

Further, COSPAR

Recommends that COSPAR members inform COSPAR when establishing planetary protection requirements for planetary missions, and

recommends that COSPAR members provide information to COSPAR within a reasonable time not to exceed six months after launch about the procedures and computations used for planetary protection for each flight and again within one year after the end of a solar-system exploration mission about the areas of the target(s) which may have been subject to contamination. COSPAR will maintain a repository of these reports, make them available to the public, and annually deliver a record of these reports to the Secretary General of the United Nations. For multinational missions, it is suggested that the lead partner should take the lead in submitting these reports.

Reports should include, but not be limited to, the following information associated to applicable requirements (see annex) for bioburden (points 1-3), organic inventory (point 4), and/or probability of impact (points 5 and 6):

1. 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.
2. The probable composition (identification) of the bioburden for Category IV missions, and for Category V "restricted Earth return" missions.
3. Methods used to control the bioburden, decontaminate and/or sterilize the space flight hardware.
4. The organic inventory of all impacting or landed spacecraft or spacecraft-components, for quantities exceeding 1 kg.
5. Intended minimum distance from the surface of the target body for launched components, for those vehicles not intended to land on the body.
6. Approximate orbital parameters, expected or realized, for any vehicle which is intended to be placed in orbit around a solar system body.
7. 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.

(Ref: [3], [7], [8], [9])

Annex: Implementation guidelines and category specifications for individual target bodies

1. Implementation guidelines on the use of clean-room technology for outer-planet missions

COSPAR,

Noting that in the exploration of the outer planets, the probabilities of growth of contaminating terrestrial micro-organisms are extremely low, reflecting the fact that the environments of these planets appear hostile to all known biological processes,

noting also that these environments do not preclude the possibility of *indigenous* life forms in some of these environments,

recognizing that the search for life is a potentially valid objective in the exploration of the outer solar system,

recognizing that 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,

recognizing that study of the processes of the pre-biotic organic syntheses under natural conditions must not be jeopardized,

recommends the use of the best available clean-room technology, comparable with that employed for the *Viking* mission, for all missions to the outer planets and their satellites.

(Ref: [10])

2. Numerical implementation guidelines for forward contamination calculations

To the degree that numerical guidelines are required to support the overall policy objectives of this document, and except where numerical requirements 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 $1x10^{-3}$. 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. No specific format for probability of contamination calculations is specified.

3. Guidelines on the implementation of an organic inventory

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. 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.

4. Trajectory biasing

The probability of impact on Mars by any part of the launch vehicle shall be $\leq 1x10^{-4}$ for a time period of 50 years after launch.

5. Environmental Conditions for Replication

Given current understanding, the physical environmental parameters in terms of water activity and temperature thresholds that must be satisfied at the same time to allow the replication of terrestrial microorganisms are (Ref: [11], [12]):

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

6. Implementation guidelines for Category V missions

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 shall be abandoned, and if already collected the spacecraft carrying the sample must not be allowed to return to the Earth or the Moon.

7. Category-specific listing of target body/mission types

Category I: Flyby, Orbiter, Lander: Undifferentiated, metamorphosed asteroids; Io; others to-be-defined (TBD)

Category II: Flyby, Orbiter, Lander: Venus; Moon (with organic inventory); 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

Category III: Flyby, Orbiters: Mars; Europa; Enceladus; others TBD

Category IV: Lander Missions: Mars; Europa; Enceladus; others TBD

Category V: Any Earth-return mission

"Restricted Earth return": Mars; Europa; others TBD

"Unrestricted Earth return": Venus, Moon; others TBD

*The mission-specific assignment of these bodies to Category II must 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.

8. Category III/IV/V requirements for Mars

8.1. Missions to Mars

All bioburden constraints 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.

Category III. Orbiter systems shall meet one of the following conditions (Ref: [11], [12], [13]):

- The probability of impact on Mars by any part of a spacecraft assembled and maintained in ISO class 8 conditions, or better, is $\leq 1 \times 10^{-2}$ for the first 20 years after launch, and $\leq 5 \times 10^{-2}$ for the time period from 20 to 50 years after launch for nominal and non-nominal flight conditions.
- The total bioburden of the spacecraft on Mars, including surface, mated, and encapsulated bioburden, is $\leq 5 \times 10^{5}$ bacterial spores.

This is not only applicable to orbiter missions around Mars but also for Mars fly-by and Mars gravity assist maneuvers.

Category IV for Mars is subdivided into IVa, IVb, and IVc:

Category IVa. Lander systems not carrying instruments for the investigations of extant martian life are restricted to a surface bioburden level of $\leq 3 \times 10^{5}$ spores, and an average of ≤ 300 spores per square meter.

Category IVb. For lander systems designed to investigate extant martian life, all of the requirements 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 must 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.

Category IVc. For missions which investigate Mars Special Regions (see definition below), even if they do not include life detection experiments, all of the requirements 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 shall be sterilized to these levels, and a method of preventing their recontamination prior

to accessing the special region shall be provided.

If a non-nominal condition (such as a hard landing) could cause a high probability of inadvertent biological contamination of the special region by the spacecraft, the entire landed system must be sterilized to a surface bioburden level of ≤ 30* spores and a total (surface, mated, and encapsulated) bioburden level of $\leq 30 + (2 \times 10^5)$* spores.

*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.

Planned 3-sigma pre-launch landing ellipses must be evaluated on a case-by-case basis as part of the (landing) site selection process, to determine whether the mission would land or come within contamination range of areas or volumes meeting the parameter definition for Mars Special Regions or would impinge on already described features that must be treated as Mars Special Regions. The evaluation must be based on the latest scientific evidence and in particular include an assessment of the extent to which the temperature and water activity values specified for Mars Special Regions are separated in time. The evaluation must be updated during the mission whenever new evidence indicates that the landing ellipse and/or the operational environment contain or are in contamination range of areas or volumes meeting the parameter definition for Mars Special Regions or already described features that must be treated as Mars Special Regions [14].

Definition of "Special Region"

A Special Region is defined as a region within which terrestrial organisms are likely to replicate (for parameter definition see paragraph 5). 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.

Observed features to be treated as Special Regions until demonstrated otherwise [14]:

- Gullies (taxon 2-4)[†], and bright streaks associated with gullies
- Subsurface cavities
- Subsurface below 5 meters
- Confirmed and partially confirmed Recurrent Slope Lineae (RSL)[‡]

Features, if found, to be treated as a Special Region until demonstrated otherwise [14]:

- Groundwater
- Source of methane
- Geothermal activity
- Modern outflow channel

Observed features that require a case-by-case evaluation before being classified as a Special Region [14]:

- Dark streaks
- Pasted-on terrain
- Candidate RSL[‡]

[†]Description for Gully taxon [15]

[‡]Observational evidence for Recurrent Slope Lineae (RSL), adapted from [16]:

- Confirmed: observed simultaneous incremental growth of flows on a warm slope, fading, and recurrence of this sequence in multiple Mars years
- Partially confirmed: observed either incremental growth or recurrence
- Candidate: slope lineae that resemble RSL but where observations needed for partial confirmation are currently lacking

Spacecraft-induced Special Regions are to be evaluated, consistent with these limits and features, on a case-by-case basis.

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 [17].

8.2. Sample Return Missions from Mars

Category V. The Earth return mission is classified, "Restricted Earth return."

- Unless specifically exempted, the outbound leg of the mission shall meet Category IVb requirements. 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. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all later Mars missions.
- Unless the samples to be returned from Mars are subjected to an accepted and approved sterilization process, the canister(s) holding the samples returned from Mars shall be closed, with an appropriate verification process, and the samples shall remain contained during all mission phases through transport to a receiving facility where it (they) can be opened under containment.
- The mission and the spacecraft design must provide a method to "break the chain of contact" with Mars. No uncontained hardware that contacted Mars, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the Mars environment shall be provided during sample container loading into the containment system, launch from Mars, and any in-flight transfer operations required by the mission.
- Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving Mars for return to Earth; and 3) prior to commitment to Earth re-entry.
- For unsterilized samples returned to Earth, a program of life detection and biohazard testing, or a proven sterilization process, shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample.

8.3. Principles and Guidelines for Human Missions to Mars

The intent of this planetary protection policy 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 requirements must differ. 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.

In accordance with these principles, specific 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 shall 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 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 requirements 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 requirements for later missions should not be relaxed without scientific review, justification, and consensus.

9. Category III/IV/V requirements for Europa and Enceladus [13]

9.1. Missions to Europa and Enceladus (Ref: [13], [18], [19], [20])

Category III and IV. 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. 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 Europan or Enceladan subsurface liquid water to less than $1x10^{-4}$ per mission. The probability of inadvertent contamination of a Europan or Enceladan ocean of $1x10^{-4}$ applies to all mission phases including the duration that spacecraft introduced terrestrial organisms remain viable and could reach a sub-surface liquid water environment. The calculation of this probability 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 Enceladian 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.

9.2. Sample Return Missions from Europa and Enceladus

Category V. The Earth return mission is classified, "Restricted Earth return."

- Unless specifically exempted, the outbound leg of the mission shall meet the contamination control requirements given above. This provision should 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. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all later Europa or Enceladus missions.
- Unless the samples to be returned from Europa or Enceladus are subjected to an accepted and approved sterilization process, the canister(s) holding the samples returned from Europa or Enceladus shall be closed, with an appropriate verification process, and the samples shall remain contained during all mission phases through transport to a receiving facility where it (they) can be opened under containment.
- The mission and the spacecraft design must provide a method to "break the chain of contact" with Europa or Enceladus. No uncontained hardware that contacted material from Europa, Enceladus or their plumes, shall be returned to the Earth's biosphere or the Moon. Isolation of such hardware from the Europan or Enceladan environment shall be provided during sample container loading into the containment system, launch from Europa or Enceladus, and any in-flight transfer operations required by the mission.
- Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) subsequent to sample collection and prior to a maneuver to enter a biased Earth return trajectory; and 3) prior to commitment to Earth re-entry.
- For unsterilized samples returned to Earth, a program of life detection and biohazard testing, or a proven sterilization process, shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample [18].

10. Category requirements for small solar system bodies

10.1. Missions to Small Solar System Bodies [21, 22]

Category I, II, III, or IV. The small bodies of the solar system not elsewhere discussed in this 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. Further elaboration of this requirement is anticipated.

10.2. Sample Return Missions from Small Solar System Bodies

Category V. Determination as to whether a mission is classified "Restricted Earth return" or not shall 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* [21]. Specifically, such a determination shall 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?

For containment procedures to be necessary ("Restricted Earth return"), an answer of "no" or "uncertain" needs to be returned to all six questions.

For missions determined to be Category V, "Restricted Earth return," the following requirements shall be met:

- Unless specifically exempted, the outbound leg of the mission shall meet contamination control requirements to avoid "false positive" indications in a life-detection and hazard-determination protocol, or in any search for life in the sample after it is returned. A "false positive" could prevent distribution of the sample from containment and could lead to unnecessary increased rigor in the requirements for all later missions to that body.
- Unless the samples to be returned are subjected to an accepted and approved sterilization process, the canister(s) holding the samples shall be closed, with an appropriate verification process, and the samples shall remain contained during all mission phases through transport to a receiving facility where it (they) can be opened under containment.
- The mission and the spacecraft design must provide a method to "break the chain of contact" with the small body. No uncontained hardware that contacted the body, directly or indirectly, shall be returned to Earth. Isolation of such hardware from the body's environment shall be provided during sample container loading into the containment system, launch from the body, and any in-flight transfer operations required by the mission.
- Reviews and approval of the continuation of the flight mission shall be required at three stages: 1) prior to launch from Earth; 2) prior to leaving the body or its environment for return to Earth; and 3) prior to commitment to Earth re-entry.
- For unsterilized samples returned to Earth, a program of life detection and biohazard testing, or a proven sterilization process, shall be undertaken as an absolute precondition for the controlled distribution of any portion of the sample [21].

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

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

(continued)			• Cleanroom • Bioburden reduction (as necessary)	Implementing procedures such as: • Trajectory biasing • Cleanroom • Bioburden reduction • Partial sterilization of contacting hardware (as necessary) • Bioshield • Monitoring of bioburden via bioassay	• 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

References

1. United Nations, Treaty on principles governing the activities of states in the exploration and use of outer space, including the moon and other celestial bodies, Article IX, U.N. Doc. A/RES/2222/(XXI) 25 Jan 1967; TIAS No. 6347, 1967.

2. COSPAR. COSPAR RESOLUTION 26.5, *COSPAR Information Bulletin*, **20**, 25-26, 1964.

3. Rummel, J. D., *et al.* Report of the COSPAR/ IAU Workshop on Planetary Protection, COSPAR, Paris, France, 200

4. DeVincenzi, D. L., P. D. Stabekis, and J. B. Barengoltz, A proposed new policy for planetary protection, *Adv. Space Res*., **3**, #8, 13-21, 1983.

5. Rummel, J. D., *et al*. Report of the COSPAR Workshop on Planetary Protection, COSPAR, Paris, France, 2008.

6. Kminek, G. Minutes of Meeting, ESA Planetary Protection Working Group, June 2008.

7. COSPAR. COSPAR DECISION No. 16, *COSPAR Information Bulletin*, **50**,15-16, 1969.

8. COSPAR. COSPAR INTERNAL DECISION No. 7/84, Promulgated by COSPAR Letter 84/692-5.12.-G. 18 July 1984, 1984.

9. COSPAR. COSPAR DECISION No. 1/94, *COSPAR Information Bulletin*, **131**, 30, 1994.

10. COSPAR. COSPAR DECISION No. 9/76, *COSPAR Information Bulletin*, **76**, 14, 1976.

11. DeVincenzi, D. L., P. D. Stabekis and J. Barengoltz, Refinement of planetary protection policy for Mars missions, *Adv. Space Res*., **18**, #1/2, 311-316, 1996.

12. European Cooperation for Space Standardization. Planetary Protection Standard, ECSS-U-ST-20C, 1 August 2019.

13. COSPAR Panel on Planetary Protection recommendation from Panel's meeting of 3-5 December 2019, Vienna, Austria.

14. Kminek, G., Hipkin, V.J., Anesio, A.M., Barengoltz, J.,Boston, P.J., Clark, B.C., Conley, C.A., Coustenis, A., Detsis, E., Doran, P., Grasset, O., Hand, K., Hajime, Y., Hauber, E., Kolmasová, I., Lindberg, R.E., Meyer, M., Raulin, F., Reitz, G., Rennó, N.O., Rettberg, P., Rummel, J.D., Saunders, M.P., Schwehm, G., Sherwood, B., Smith, D.H., Stabekis, P.E., and Vago, J. COSPAR Panel on Planetary Protection Colloquium Report, *Space Res. Today*, **195**, 2016.

15. Rummel, J.D, Beaty, D.W., Jones, M.A, Bakermans, C., Barlow, N.G., Boston, P.J., Chevrier, V.F., Clark, B.C., de Vera, JP.P., Gough, R.V., Hallsworth, J.E., Head, J.W., Hipkin, V.J., Kieft, T.L., McEwen, A.S., Mellon, M.T., Mikucki, J.A., Nicholson, W.L., Omelon, C.R., Peterson, R., Roden, E.E., Lollar, B.S., Tanaka, K.L., Viola, D., and Wray, J.J., A new Analysis of Mars "Special Regions": Findings of the Second MEPAG Special Regions Science Analysis Group (SR-SAG2), *Astrobiology*, **14**, 887-968, 2014.

16. McEwen, A.S., Dundas, C.M., Mattson, S.S., Toigo, A.D., Ojha, L., Wray, J.J., Chojnacki, M., Byrne, S., Murchie, S.L., and Thomas, N., Recurrent slope lineae in equatorial regions of Mars, *Nature Geosciences*, **7**, 53-58, 2014.

17. Kminek, G., Conley, C., Allen, C.C., Bartlett, D.H., Beaty, D.W., Benning, L.G., Bhartia, R., Boston, P.J., Duchaine, C., Farmer, J.D., Flynn, G.J., Glavin, D.P., Gorby, Y., Hallsworth, J.E., Mogul, R., Moser, D., Buford Price, P., Pukall, R., Fernandez-Remolar, D., Smith, C.L., Stedman, K., Steele, A., Stepanauskas, R., Sun, H., Vago, J.L., Voytek, M.A., Weiss, P.S., Westall, F., Report of the COSPAR Mars Special Regions Colloquium, *Adv. Space Res*., **46**, 811-829, 2010.

18. Space Studies Board, National Research Council (US), Preventing the Forward Contamination of Europa. Task Group on the Forward Contamination of Europa, National Academy of Sciences, Washington, D.C., 2000.

19. COSPAR Panel on Planetary Protection recommendations from Panel's meeting of 23-25 January 2019, Vienna, Austria.

20. The International Planetary Protection Handbook: *Space Research Today* Volume 205, Supplement, Pages e1-e120 (October 2019). DOI: 10.1016/j.srt.2019.09.001

21. Space Studies Board, National Research Council (US), Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies, Task Group on Sample Return From Small Solar System Bodies, National Academy of Sciences, Washington, D.C., 1998.

22. Kminek, G., Conley, C., Hipkin, V., Yano, H., COSPAR's Planetary Protection Policy. *Space Res. Today*, **200**, December 2017.