The COSPAR Panel on Planetary Protection Role, Structure and Activities

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[The views expressed in this article do not necessarily represent the views of the respective entities and organizations.]

The exploration and use of outer space is the province of all humankind. This principle in Article I of the UN Outer Space Treaty guarantees the freedom to explore outer space, including the Moon and other celestial bodies, without discrimination, and to carry out scientific investigations. This freedom, however, comes with a responsibility described in Article IX of the same Treaty. It states that space activities have to be conducted with due regard to the corresponding interests of all other States Parties to the Treaty. The avoidance of potentially harmful interference with activities of other States Parties is central. The harmful contamination of the Moon and other celestial bodies and the need to ensure safety of the Earth are highlighted in this context. With the entry into force of the Outer Space Treaty in 1967, planetary protection became part of international law. In observance of those treaty obligations, an international standard for planetary protection has been developed by the Committee on Space Research (COSPAR) which provides a forum for international consultation and has formulated a Planetary Protection Policy with associated requirements that are put in place after examination of the most updated relevant scientific studies and recommendations made by the COSPAR Panel on Planetary Protection.

1. Introduction and context

COSPAR is the international scientific COmmittee for SPAce Research of the International Council for Science (ICS), established in 1958. The main objectives of COSPAR are to promote at an international level scientific research in space, with emphasis on the exchange of results, information and opinions, and to provide a forum, open to all scientists and stakeholders in general, enabling discussions and exchanges on problems that could play a role and affect scientific space research. The objectives of COSPAR are mainly achieved through the organization of scientific assemblies and publications. COSPAR's organizational structure consists of scientific commissions representing each and every scientific discipline involved in space research and of panels designed to deal with crosscutting issues that can affect particular segments of the international space research community, and often for which there is an urgent need for input.

In its first years of existence COSPAR, as an apolitical scientific body, played an important role as an open bridge between East and West for cooperation in space. When this role became less prominent with the decline in rivalry between the east and west, COSPAR, as an interdisciplinary scientific organization, focused its objectives on the progress of all kinds of research carried out in space (including balloons). COSPAR has eight scientific commissions and ten technical panels on a variety of topics, from planetary exploration and planetary protection to space weather, scientific ballooning, satellite dynamics, radiation belts, and capacity building (with a fellowship sub-Panel).

One element of the COSPAR activities is to maintain a planetary protection policy for spacefaring nations, both as an international standard to avoid organic and biological contamination in the exploration and use of space, and to guide compliance with the Outer Space Treaty (OST). The treaty was opened for signature in the United States, the United Kingdom, and the Soviet Union on 27 January 1967, and entered into force on 10 October 1967. As of January 2019, 109 countries are parties to the treaty, while another 23 have signed the treaty but have not completed ratification.

The Outer Space Treaty contains the fundamental principles of international space law. Article VI of the Outer Space Treaty is important to all activities in the exploration and use of outer space, including the Moon and other celestial bodies, and describes the international responsibility of States: *"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."* In implementing the requirements under Article IX of the treaty, it is important to keep this central provision of responsibility in mind. This overarching responsibility is fundamental for the principles of "due-regard", "harmful contamination" and "harmful interference" set out in Article IX of the treaty. There is a complex legal connection between those principles, and they are subject to legal interpretation. Moreover, the 1968 Rescue and Return Agreement (ARRA), in its Article 5(4) introduces the concept of returning space objects of "hazardous and deleterious nature".

Space agencies globally have maintained compliance with the Outer Space Treaty by following the COSPAR Planetary Protection Policy. Furthermore, the important role of COSPAR in setting up and promoting planetary protection policy guidelines for the benefit of spacefaring nations has been recognized also by the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) at its sixtieth session in 2017. This is an important element for consideration because it clearly establishes the role of the COSPAR Planetary Protection Policy in ensuring the compliance with the Outer Space Treaty despite its non-legally binding aspect under international law, as will be further described below in detail.

Guided by this international legal framework, planetary protection processes and requirements have been developed at the national level to meet the requirements of the treaty obligations. In addition, the COSPAR Planetary Protection Policy is the only international science-based guidance and standard framework, founded on two rationales:

The conduct of scientific investigations of possible extraterrestrial life forms, precursors, and remnants must not be jeopardized.

The Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from another planet.

As a consequence, for certain space missions or planet-targeted combinations, requirements to control terrestrial biological contamination are imposed in accordance with these rationales. As explained below, the correct implementation of these requirements is the responsibility of the various space agencies.

Planetary protection is a definition for agreed international practices applied in the exploration of the solar system in order to avoid contamination of the Earth and the other planets. It is promulgated by the Committee on Space Research (COSPAR) which provides guidelines to be considered in the design of space missions, with the goal to protect investigated solar system bodies from biological contamination and to ensure the same for the Earth in the case of sample-return missions. Planetary protection is critical for enabling scientists to study the natural environments of foreign bodies without interfering with lifeforms that could possibly emerge and develop there. Most importantly, it also helps to protect Earth from possible contamination by extraterrestrial imported material.

Perhaps the best way to consider the scope and importance of planetary protection, however, is to consider case studies involving current or near-term mission architectures:

Hypothetical case 1: After more than a decade of work a robotic explorer on Mars detects evidence for life. The sophisticated science package can look for life in different ways and all the lights are green. This would arguably be the most important scientific discovery ever made. The consequences would be dramatic in terms of basic understanding of the origin and distribution of life in our solar system and in the universe in general. It would also affect very much how future robotic and human missions to Mars would need to be designed and managed. However, how do we know that the life found by our robotic explorer is actually martian life and not terrestrial life that hitchhiked a ride to Mars?

Hypothetical case 2: A university research laboratory announces that they have been selected as part of the initial examination team for samples from Mars. Soon after the samples are received, a number of the researchers examining them develop influenza-like symptoms. After a few weeks, an increased number of these researchers exhibit similar symptoms and, although not incompatible with the winter season in a university environment, these cases are noted by the local public health officials and eventually make their way into the media. Are the symptoms the result of the trailing edge of a typical flu season, or are they instead linked to the initial investigations of the extraterrestrial samples? Has there be a sufficient level of scrutiny of the space activities from public authorities and do we really know whether the extraterrestrial material brought to Earth is not dangerous?

Hypothetical case 3: After several decades of international cooperation for sample return from Mars, a research laboratory detects signatures of recent metabolic activity on the external surface of one of the samples. Are those signatures indigenous from Mars? or were they produced during the manipulation? or are they signatures produced on Earth by microbial activity that was preserved dormant in the samples and was activated once on Earth?

These hypothetical examples provide glimpse into the importance of planetary protection. We have had planetary protection measures in place for more than half a century to avoid cases like 1 and 2. Planetary Protection is an enabling element in the exploration and use of space and the reason why COSPAR has a dedicated panel of experts to make educated recommendations, based on community input, for implementation of the planetary protection guidelines. The guidelines are also there to prevent false positives for life or biomarker detection in samples returned by missions by guaranteeing the safe, isolated, manipulation of samples.

2. Context and basic elements of planetary protection

With planetary protection, it is important to understand the legal and policy background. Article IX of the Outer Space Treaty addresses three major areas:

the provision of cooperation and mutual assistance and due regard to the corresponding interests of all other States Parties;

the provision for the avoidance of harmful contamination of solar system bodies (forward contamination) and avoidance of changes in the environment of the Earth (back contamination) resulting from the introduction of extraterrestrial matter and

the provision that when there is a reason to believe that space activities or experiments planned would cause potentially harmful interference with activities of other states parties, appropriate international consultations shall be undertaken.

There exists a correlation between those three core provisions given the inherent nature of protecting the interest of all States Parties to the Treaty. The provisions of due regard and harmful interference were covered by the 1963 Declaration of Legal Principles Governing the Activities of States in the Exploration and Uses of Outer Space. The dedicated component on planetary protection in Article IX states: *"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"*. Considering the evolution of planetary protection measures at the international level, through the studies and recommendations made by COSPAR since the early 1960s, today COSPAR Planetary Protection Policy is the only international instrument of this type that enforces the procedures for planetary protection based on scientific arguments.

The involvement of COPUOS in the evolution of the international planetary protection framework is noteworthy in this context. The five United Nations treaties and five sets of principles on outer space, thus including the 1963 Declaration and 1967 Outer Space Treaty, have been negotiated within the framework of COPUOS. Contamination concerns were raised, *inter alia*, in the report of the Ad Hoc Committee on the Peaceful Uses of Outer Space in 1959, and in the 1964 COPUOS report the COSPAR planetary quarantine requirements recommended by the Consultative Group on Potentially Harmful Effects of Space Experiments were given important consideration by the re-print in that report of the full COSPAR resolution of May 1964. It is in this context important to note the development of scientific measures on planetary protection and the way such considerations found their way into the legal and policy framework of international cooperation in the peaceful uses of outer space, with the provision of Article IX of the Outer Space Treaty as the legal framework for planetary protection. COPUOS in its report in 2017 noted the long-standing role of COSPAR in maintaining Planetary Protection Policy as a reference standard for spacefaring nations and in guiding compliance with Article IX of the Outer Space Treaty. There is an on-going and close link between COSPAR and COPUOS since the late 1950s, which is evident by the history of the work of COPUOS which goes back to 1958–the same year as the creation of COSPAR. For more information on the historical aspects of the development of the Planetary Protection see:

https://planetaryprotection.nasa.gov/history/

With the status given to planetary protection measures through Article IX of the Outer Space Treaty, the issue of application and implementation must be addressed. According to Article VI of the Outer Space Treaty, state responsibility for national space activities performed also by non-governmental entities (including among other private research institutes, industry and private sector) is subject to application by various nations and its implementation through continuous help in building safe planetary missions. Article VI makes the national implementation requirement clear by stating that *"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"*.

The COSPAR Planetary Protection Policy is a scientific guidance framework and not a legal instrument binding under international law, but the observation by COPUOS in 2017 is important as an indication of the role of the Planetary Protection Policy in the compliance of the Outer Space Treaty. It must be clearly noted that it is the prerogative of States Parties to implement the obligations under Article VI, including the activities of non-governmental entities. It is the State that ultimately will be held responsible for wrongful acts committed by its jurisdictional subjects. The Outer Space Treaty does not require States Parties to use the COSPAR guidance framework on planetary protection in fulfilling Article IX obligations. However, States Parties have for fifty years implemented Article IX by using COSPAR and following its planetary protection guidance framework. It is true that this long-standing commitment to the COSPAR process has helped in developing and upholding the only international standard on planetary protection. Therefore, for certain space mission/target planet combinations, requirements to control terrestrial biological contamination are imposed in accordance with these rationales. As explained below, the correct implementation of these requirements is the responsibility of the various space agencies. This strategy has led so far to the categorization of certain combinations of mission types and solar system objects as described for instance in https://planetaryprotection.nasa.gov/about-categories/. Categorizations are continuously examined in light of new scientific results of relevance (like for instance those discussed below having to do with sample return and habitable worlds in the solar system).

Within the scope of the COSPAR Planetary Protection Policy, the breadth of planetary protection constraints applied to specific missions depends on the targeted celestial object of the mission (e.g., Moon, Mars, planets, satellites, asteroids, etc.) and the type of mission (e.g., orbiter, lander, gravity assist, sample return, etc). With respect to the target body, missions aimed to investigate solar system objects that have a high astrobiological potential and afford habitable conditions for the emergence of life will be subject to more stringent constraints– at the present time such objects are limited to Mars, Jupiter's satellite Europa and Saturn's satellite Enceladus. As for type of mission, the most stringent constraints will be in place for sample return missions from Mars, Europa and Enceladus to Earth.

The different planetary protection categories (I-V) reflect the level of interest and concern that contamination can compromise future investigations or the safety of the Earth; the categories and associated requirements depend on the target body and mission type combinations and are summarized hereafter.

Category I: All types of mission to a target body which is not of direct interest for understanding the process of chemical evolution or the origin of life

Category II: All types of missions (gravity assist, orbiter, lander) to a target body where there is significant interest relative to the process of chemical evolution and the origin of life, but where there is only a remote[1] chance that contamination carried by a spacecraft could compromise future investigations

Category III: Flyby (i.e. gravity assist) and orbiter missions to a target body of chemical evolution and/or origin of life interest and for which scientific opinion provides a significant[2] chance of contamination which could compromise future investigations

Category IV: Lander (and potentially orbiter) missions to a target body of chemical evolution and/or origin of life interest and for which scientific opinion provides a significant[2]

[1] 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] Implies the presence of environments where terrestrial organisms could survive and replicate, and some likelihood of transfer to those places by a plausible mechanism

chance of contamination which could compromise future investigations

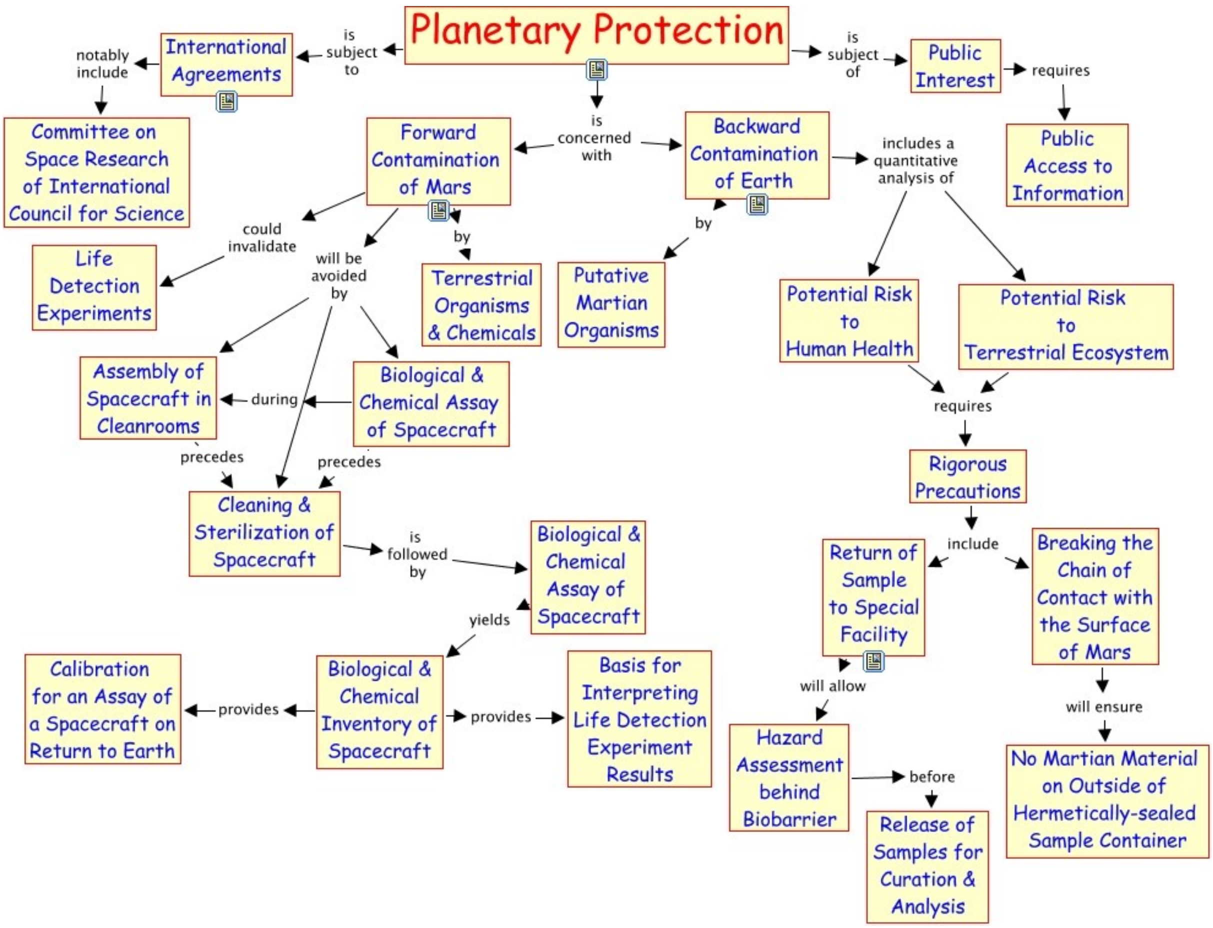
<u>Category V:</u> Two subcategories exist: unrestricted Earth return for solar system bodies deemed by scientific opinion to have no indigenous life forms and restricted Earth return for all others

This categorisation is revisited and changes considered when new scientific results challenge the current perception and indicate the necessity for updates (for instance with the discovery of new habitats in the solar system among the icy moons of the giant planets) and when challenges appear from new players in the space field or from new requests by sample return missions from Mars and its moons.

The COSPAR Planetary Protection Policy has evolved since its inception and follows carefully the development of scientific knowledge. The rationale being that planetary protection requirements are constantly developing along with new and updated scientific knowledge. In this context, it is important to point out that today no technical planetary protection requirements under the COSPAR Planetary Protection Policy apply to missions (one way and sample return) to the Moon (documentation requirement only) and to the majority of the asteroids. Nor do any planetary protection constraints apply to missions operating in Earth's orbit. Similarly, protecting solar system bodies for their own sake, protecting unique solar system environments or historical sites are specifically not included in the COSPAR Planetary Protection Policy. Protecting Earth from man-made space objects (i.e. space debris), and the objectives of planetary defense (i.e. protecting Earth from the impact of large asteroids or comets), are not covered in the COSPAR Planetary Protection Policy either.

As indicated above, even one-way missions to Mars, Europa and Enceladus have to adhere to stringent planetary protection measures to abide by the first rationale for planetary protection to not interfere with *"scientific investigations of possible extraterrestrial life forms, precursors, and remnants"* and not to impose terrestrial biological contamination to these objects of high astrobiological interest. In the case of investigations with an orbiter, it is important to ensure through a secure trajectory planning and mission design that the spacecraft will not impact the body. In the case of landers and rovers, the only way to avoid a possible terrestrial biological contamination is to control and limit the contamination on the spacecraft itself via extensive bioburden control processes. This constraint is taken on board at the level of the mission development where a set of measures is assumed: technicians using full-body garments in biologically controlled cleanrooms, various solvents, dry heat bioburden reduction, plasma and ionizing radiation to reduce the contamination and barrier systems (purging, filters, seals) to avoid the re-contamination on the spacecraft.

Missions that acquire and return samples from Mars, Europa or Enceladus to Earth have to meet not only stringent planetary protection constraints for the outgoing part of the journey, but to comply with the second rationale (*"the Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from another planet."*) and therefore establish additional strict controls of any possible contamination on the way back. These additional controls are complex and involve a careful containment or sterilization of the extraterrestrial material and a scientific analysis up front of the samples to find out what they are made of and if there is potential danger for the Earth's biosphere. All these measures are part of the protocol applied in sample return handling facilities or sample receiving facilities which follow the recommendation of the SSB (1997) for *"rigorous physical, chemical, and biological analyses [should] confirm that there is no indication of the presence of any exogenous biological entity."* And act to ensure proper quarantine of the samples as well as the protection of the samples from any chemical or biological contamination. The principles of the such functions are described in the *Draft test protocol for detecting possible biohazards in Martian Samples returned to Earth* which is evolving as needed to take into account the



From https://doctorlinda.wordpress.com/2018/11/20/planetary-protection-dont-mess-with-it/

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most recent developments in science instrumentation and scientific results.

In general, space mission concepts that come forward for guidance on planetary protection items appreciate the attention and help from the COSPAR Panel on Planetary Protection, even though implementing the related planetary protection constraints comes with a cost in time and funding. From a practical point of view, this requires: 1) having access to technologies and products that can be used to bioburden control the materials, hardware and spacecraft components; 2) manipulating the flight model within a "clean room" environment (which is any way a requirement for any space mission, to avoid particulate contamination of the hardware, optical and electrical components); and 3) having contact with a microbiological laboratory that can analyse a set of samples taken in-situ for detection of microbes, that are used to certificate that the clean-level requirement is met. Additionally, planetary protection requires documenting the full procedure and undergoing some reviews, as happens to all other procedures related to space missions. Planetary protection may require some previous planning in the design phase to select or design spacecrafts components and parts that can be easily sterilised. But again, this is standard practice for space mission design, where other constraints like electromagnetic compatibility, vibration and shock resistance, outgassing levels, thermal vacuum and radiation response, etc have to be tested, documented and reviewed and the designs has to be based on elements and components that guarantee that these requirements will be met

Suggesting changes and adaptations to take new developments into account and to help future missions construct a robust and safe architecture, is the purpose of the COSPAR Panel on Planetary Protection (COSPAR PPP).

3. The COSPAR Panel on Planetary Protection

One important purpose of the COSPAR activities is to maintain the Planetary Protection Policy at an international level. Guidelines are put in place with the view to enable space exploration in a mature and safe way and not to prevent any kind of investigations that would enhance our understanding of the Solar System in accordance with the OST. The Policy is therefore by necessity based on the most up-to-date and comprehensive scientific information available. This mandate is covered by the COSPAR Panel on Planetary Protection which includes a number of experts in various space-related scientific fields attached to planetary protection such as (astro)biology, planetary sciences, geology and geophysics, microbiology, sample treatment, space law and ethics, among other, and relies on information brought forward by the various communities though workshops and studies.

The current COSPAR Panel on Planetary Protection is therefore a group of thematic experts from the science community of different countries (e.g. China, France, Germany, India, Italy, Japan, the Russian Federation and the United States) and representatives from their national space agencies and other stakeholders for a total of 19 members (co-authors of this article). The structure and composition of the panel can be found at the COSPAR web site dedicated page: https://cosparhq.cnes.fr/scientific-structure/ppp. The COSPAR Panel on Planetary Protection maintains and updates the COSPAR Planetary Protection Policy regularly in various ways. For instance when a space mission is being developed, the project team may present a request to the PPP with a specific combination of mission architecture or targets. Or scientific results have come forward showing that there is a need for a change or an adaptation/update of some part of the policy. In both cases, the Panel will review all available scientific knowledge through existing or commandeered studies performed by a group or committees of experts who review the information and make a recommendation to the Panel. Workshops, dedicated scientific and technical meetings and independent peer review are all integral part in updating the COSPAR Planetary Protection Policy. Taking these documented inputs into account, the Panel will recommend (or not) to the COSPAR Bureau and Council possible modifications to the policy. Such updates are done in a careful and balanced way to ensure that the right measures are envisaged to fulfill the rationales for planetary protection. The purpose obviously is to respond to the needs of space mission teams, while applying due diligence and expertise in the process. At the end the updated Policy is published.

This method has been a long process in time in the past. But, in the modern era, new challenging mission goals and scientific findings have required the panel to react more swiftly and to encompass additional expertise from the different scientific fields. The new reconstituted Panel is in itself a big step, but the working method will always be founded on scientific expertise and thorough understanding of the celestial bodies as well as of our own planet and its specificities. The Panel is now meeting in person more regularly and having more regular communication via email and telecons. The meeting structure now also has an open public session for transparency and information exchange vis a vis all interested parties, and a closed session gives the panel the necessary structure get work done and decisions made more expeditiously in the interest of the broader scientific community (Terms of Reference for the new panel can be found at https://cosparhq.cnes.fr/scientific-structure/ppp). The new panel's first meeting occurred in January 2019 in Vienna at the United Nations, with a large attendance for the open session and almost full membership attending in person or via telecon during the closed session.

Two issues discussed at that meeting are described below.

3.1 Recommendation on the categorization of the Phobos/Deimos sample return mission

The Panel was presented with the most recent scientific and technical plans of JAXA's Martian Moons eXploration (MMX: http://mmx.isas.jaxa.jp/en/) mission. This mission will travel to Mars and explore the planet's two moons, Phobos and Deimos to enhance our understanding of these objects. Part of this mission will involve sample from one of the Martian moons. The scientific goals of MMX are to investigate the origin of the Martian moons and the formation and evolution of the Martian system. The Panel was asked to comment on the Phobos/Deimos sample return to Earth categorization after considering the findings from three different studies by: 1) JAXA in its capacity as operator for the planned mission; 2) by the Sterilization Limits "SterLim" Team (represented by Open University); and 3) by a joint committee of the National Academies of Science, Engineering and Medicine and the European Science Foundation as an independent review. Large parts of these studies are published in a special issue of Life Sciences in Space Research (2019, Volume 23). Having extensively discussed the findings of the 3 studies presented in the open session, the Panel in its review recommended that samples returned from the Martian moons be designated unrestricted Earth return. The Panel further assessed that the recommendation only relates to this specific MMX mission and does not form a recommendation for other future missions. Discussing safety issues, the panel noted the successful precedent of planetary protection guidelines used for the JAXA Hyabusa mission. The Panel submitted the following recommendations to the COSPAR Bureau for formal consideration at the March 2019 meeting in Paris, where they were adopted and validated for the MMX mission.

- Based on the current COSPAR Planetary Protection Policy, the COSPAR PPP recommends that the outbound portion of the MMX mission be classified Planetary Protection Category III.

- Regarding the inbound portion of the MMX mission, two separate studies using several types of analysis, simulations, and laboratory experiments that incorporated current knowledge of Martian moons, were independently reviewed by a joint US National Academy of Sciences and European Science Foundation committee. Given the evidence presented and the discussion that followed, the Panel recommends that the inbound (Earth return) portion of the MMX mission, as currently planned by JAXA (ref. GNG-2018003A, 15 Jan. 2019), be classified Planetary Protection Category V, unrestricted Earth return.

3.2 Planetary Protection for missions to the outer solar system

The outer solar system is of high interest within the international scientific community with many new findings from missions like Cassini, Galileo and JUNO. Reference was made to the impact of the results from the joint ESA/NASA Cassini-Huygens mission, which had demonstrated that the discoveries a mission can make may be completely different from those expected and therefore the preparation for landing on foreign bodies needs to be done with the outmost care. Cassini-Huygens further demonstrated the importance of international collaboration in such endeavors.

Outer solar system missions are numerous and at various stages of development. The ESA JUICE (Jupiter Icy moons Explorer: http://sci.esa.int/juice/) mission scheduled to launch in 2022, has as a science goal to study the planet and its moons, including flybys of Europa and an extended study of Ganymede. The NASA Europa Clipper mission (https://www.nasa.gov/europa) is expected to be launched in 2023 and will investigate the jovian satellite with several dozen flybys. The next New Frontier mission will either return a sample from comet 67P/Churyumov Gerasimenko to Earth (CAESAR: http://caesar.cornell.edu) or visit Saturn's largest moon, Titan with a quadcopter drone (Dragonfly: http://dragonfly.jhuapl.edu/). A Saturn probe mission is being proposed by the planetary community, and further-on possible missions to Uranus and Neptune and their satellites are being discussed. Finally, a Europa lander mission is being studied at JPL.

Given the strong and growing interest in missions to the outer solar system, particularly the icy moons, it was considered of vital importance by the Panel to re-examine the planetary protection issues for the icy moons because of the possible emergence of habitable worlds around giant planets. A study was commissioned and organized by the European Science Foundation with international experts for studying the Planetary Protection for the Outer Solar System (PPOSS) aspects. The PPOSS Team's main objective was to provide an international forum to consider and approach the specificities of planetary protection for outer Solar system bodies, in the general context of planetary protection guidance and to provide recommendations to the COSPAR Planetary Protection Panel. The PPOSS study team presented a set of recommendations for review by the Panel in the following areas which were endorsed by the Panel after discussion in the open session:

1) The COSPAR Planetary Protection Policy guidelines should include a generic definition of the environmental conditions potentially allowing Earth organisms to replicate;

2) The second paragraph of the Category III/IV/V requirements for Europa and Enceladus text in the COSPAR Planetary Protection Policy's appendix should be more specific on problematic species;

3) The COSPAR Planetary Protection Policy guidelines should be updated to reflect the period of biological exploration of Europa and Enceladus. Requirements for Europa and Enceladus flybys, orbiters and landers, including bioburden reduction, shall be applied in order to reduce the probability of inadvertent contamination of a European or Enceladan ocean to less than $1x10^{-4}$ per mission;

4) The COSPAR Planetary Protection Policy should acknowledge the potential existence of Enhanced Downward Transport Zones at the surface of Europa and Enceladus; these zones should be defined and characterized by further studies.

4. How is the COSPAR Planetary Protection Policy implemented

The COSPAR Panel on Planetary Protection works intently to educate and inform the international space community, e.g. COPUOS, as well as other concerned multilateral organizations, of policy consensus in the area of planetary protection. It is not the job of the COSPAR PPP to suggest ways to implement the requirements. Implementation of the COSPAR Planetary Protection Policy is left to the agencies or organizations planning and executing the missions. The best and most cost-effective means to adhere to the COSPAR planetary protection requirements is subject to certification of compliance with the COSPAR planetary protection requirements by the appropriate national or international authority

5. Plans for facing planetary protection challenges in the future

The panel discussions following the first 2019 meeting will continue in particular on the aspects of planetary protection categorization and guidelines for outer solar system bodies, i.e. the icy moons who are potential habitats, following the PPOSS study described here. But in addition to the items described above, planetary protection will be facing more challenges and needs for new guidelines in the future. One has to do with the interest to return to the Moon, investigate new regions, return more samples and eventually establish a human base. Related to this and part of several international space agencies programs, is the need to develop planetary protection guidelines for robotic and human missions to Mars. Human missions to Mars touch on both rationales for planetary protection – protect the Earth (i.e. astronauts and the humanity upon their return) and avoid compromising the search for extraterrestrial life. When we reach the stage where human missions are developed, very different considerations will apply compared to robotic missions. NASA and other space agencies, along with COSPAR, have been actively addressing this issue for several years and it is clear that in order to have safe (for astronauts and the general human race) and productive human missions to Mars, we need to better characterize the processes of how contamination will be impacted by the natural Mars and environment and how it is transported on Mars. There is need, for example, for additional research on the additive or synergistic biocidal effects of the Mars environment, and collection of new data for atmospheric circulations models with high spatial and temporal resolution.

An additional aspect for consideration by planetary protection experts is the increased interest in space exploration and utilisation by non-governmental entities (e.g. the private and commercial sector). Planetary protection measures could be seen as an "insurance" for long-term investments by commercial and private sector entities. If a harmful contamination should occur, the liability for damage caused might be high and this factor should be considered in the long-term planning of planetary missions by a broader spectrum of space actors.

The Panel thus intends to help in all the above concerns and anything more that will be brought to its attention. The panel is aware of and works in conjunction with various national activities. The Panel will also investigate ways and means to increase awareness of the COSPAR Planetary Protection Policy and its applications, including by Governments, space agencies, research institutions, and other actors in the broader space community, both public and private, involved in activities where planetary protection is a key consideration in the chain of activities leading to planetary missions, thus confirming that COSPAR is a reliable and essential actor to count on.

Further Reading:

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- M. Viso. Mars sample receiving facility or facilities? That is the question.