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The challenge of planetary protection

Athena Coustenis¹, Gerhard Kminek², Niklas Hedman³

Chair and Vice-Chairs of the bureau of the COSPAR Panel on Planetary Protection

*1: Laboratoire d'Etudes Spatiales et d'Instrumentation en Astrophysique (LESIA), Observatoire de Paris, CNRS, UPMC Univ. Paris 06, Univ. Paris-Diderot, 92195 Meudon Cedex, France ;
athena.coustenis@obspm.fr*

2: European Space Agency, Noordwijk, The Netherlands ;

3: Committee, Policy and Legal Affairs Section, Office for Outer Space Affairs, United Nations Office at Vienna

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Scientists and engineers, supported by space agencies and the public are keen to explore our Universe, carry out scientific investigations and make use of space resources. This urge has pushed humanity forward and given us, among other, a considerably enhanced understanding of our neighborhood and of the origin of life on our planet during the 60 or so years of robotic exploration of the solar system. It comes, however, with a responsibility to avoid harmful contamination of outer space and the need to ensure safety of the Earth. Who pays attention to this and how do we ensure that what we call “planetary protection” is applied?

What is planetary protection

Let's imagine that a research laboratory, selected as part of the preliminary examination team for samples from Mars, finds that a number of its researchers dealing with the samples develop flu-like symptoms which start as uncomfortable but then develop to more serious. After a few weeks more and more people show symptoms and this now gets the attention of the local public health officials and the media. It is late winter and symptoms like that are not uncommon, in particular in a campus-like environment. Are the first investigations on the extraterrestrial samples and the trailing edge of an atypical flu season a coincidence? Has there been 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?

The hypothetical example above gives an understanding of the seriousness of what planetary protection stands for. It is exactly to avoid a case like this why we have had planetary protection measures in place for more than half a century as an enabling element in the exploration and use of space and why COSPAR has a dedicated panel of experts put in place to make educated recommendations for the maintenance and updating of these measures.

Planetary protection is a definition for agreed international practices applied in the exploration and use of the solar system in order to avoid contamination of the Earth and compromising the search for extraterrestrial life in the solar system.. It is promulgated by the COmmittee on SPace Research (COSPAR), which provides guidelines to be taken into account 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 possible life forms that may have developed there. Most importantly, it also helps to preserve the terrestrial biosphere from possible contamination by alien material.

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 from 1967 addresses the avoidance of harmful contamination of celestial bodies (forward contamination) and avoidance of changes in the environment of the Earth (back contamination). The specific element of planetary protection in Article IX reads *“States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose”*. Taking into account the evolution of planetary protection measures at the international level, through the studies and recommendations made by COSPAR since the early 1960s, today the COSPAR Planetary Protection Policy is the only international mechanism of this type that outlines a scientifically justified framework for planetary protection.

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. The United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) in its report in 2017 noted the long-standing role of COSPAR in maintaining a Planetary Protection Policy as a reference standard for spacefaring nations and in guiding compliance with Article IX of the Outer Space Treaty. There is a continuous 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.

In terms of application and implementation of planetary protection, article VI of the Outer Space Treaty stipulates that *“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”*. Accordingly, national compliance with the provision of planetary protection under Article IX is here covered. 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 national application and implementation through authorization and continuous supervision of 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 set of internationally agreed guidelines and not a legal instrument binding under international law, and the observation by COPUOS in 2017 is important as an indication on the role of the COSPAR Planetary Protection Policy in the compliance of the Outer Space Treaty.

COSPAR’s Planetary Protection Policy is based on two rationales:

- Ensure that 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 an interplanetary mission.

Therefore, for certain space mission/target planet combinations, requirements to control terrestrial biological contamination are imposed in accordance with these rationales. The range of planetary protection constraints applied to a mission depend on the target body of a specific mission (e.g., Moon, asteroids, planets, etc.) and the type of mission (e.g., gravity assist, orbiter, lander, sample return). With respect to the target body, more stringent constraints are applied for missions to solar system bodies where there is significant scientific interest to search for extraterrestrial life – currently this applies only to Mars, Europa (moon of Jupiter) and Enceladus (moon of Saturn) with most stringent constraints for sample return missions from these bodies to Earth. 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://cosparhq.cnes.fr/sites/default/files/pppolicypolicydecember_2017.pdf. This categorization is continuously examined when new scientific results point to the need for updates and when challenges appear from recent solar system exploration, with the emergence for instance of new habitable worlds (such as some of the icy moons) or the all-the-more-actual sample return missions from Mars and its moons for instance.

It is important to point out that no technical planetary protection constraints apply to missions (one way and sample return) to the Moon and to most of the asteroids. Nor do any planetary protection constraints apply to mission in Earth 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. By the same token, protecting Earth from man-made space objects, i.e. space debris, and planetary defense, i.e. protecting Earth from the impact of large asteroids or comets, are not covered in the COSPAR Planetary Protection Policy either.

The COSPAR Panel on Planetary Protection

COSPAR is a committee of the International Council for Science (ICS). The purpose of COSPAR is to provide a forum, open to all stakeholders, enabling discussions and exchanges of problems that may affect scientific space research. One element of the COSPAR activities is to maintain a Planetary Protection Policy for the reference of spacefaring nations, as an international standard to avoid organic constituent and biological contamination in the exploration and use of space, and to guide compliance with the wording of the Outer Space Treaty. The COSPAR Planetary

Protection Policy is based upon the most current, peer-reviewed scientific knowledge, and on the principle to enable the exploration and use of the solar system in line with the Outer Space Treaty. Updating the COSPAR Planetary Protection Policy is a process that includes and relies on the scientific community. This mandate is covered by the Panel on Planetary Protection.

The COSPAR Panel on Planetary Protection (<https://cosparhq.cnes.fr/scientific-structure/ppp>) is a group of experts and representatives from space agencies, the science community and other stakeholders. The Panel currently in place has 19 members including national and international space agency representatives and scientific experts in fields related to planetary protection such as planetary sciences, geology and geophysics, astrobiology, microbiology, samples, and more. This enables the Panel to evaluate and properly assess the requests and scientific studies that are presented in order to recommend to the COSPAR Bureau the appropriate categorization and measures for space missions ..

The way the Panel works is to study all the scientific information available, look at the available studies and outcomes of workshops and make a recommendation to the COSPAR Bureau and Council to be considered at their annual meetings. In view of new scientific results appearing and requesting rapid attention, the guidelines and requirements need to adapt in a faster and more flexible way and so the panel works more swiftly. Indeed, recent scientific discoveries point to many new possible habitats and highlight extra astrobiological potential in the Solar System, but also trailblaze new exploration targets and concepts. Some of these aspects concern the Martian moons, potential habitats in the subsurfaces of the icy moons in the outer Solar System, Earth return missions and human exploration.

The most recent meeting of the Panel with a large attendance took place at the Vienna International Centre - the United Nations premises - in Vienna, Austria, on 23-25 January 2019, where several items were discussed and examined pertaining to planetary protection. A couple of the points raised at that meeting are described hereafter.

Most of the one-way missions leaving Earth have no technical planetary protection constraints. Missions to Mars, Europa and Enceladus on the other hand have to adhere to stringent planetary protection measures to meet the first rationale for planetary protection. These measures are in place to control and limit the terrestrial biological contamination we would bring to these solar system objects. The best approach in this context is of course not to impact them. Therefore, a careful trajectory planning and a robust and reliable spacecraft design is paramount. This is typically used for spacecraft that study these planets from orbit (remote sensing). On the other hand, we also have to consider spacecraft that land and operate on the surface or subsurface. The only way to control the terrestrial biological contamination for such missions is to limit and control the contamination on the spacecraft. This is achieved by assembling the spacecraft with technicians using full-body garments (so called bunny-suits) in biologically controlled cleanrooms, use of various solvents, heat, plasma and ionizing radiation to reduce the contamination and barrier systems (purging, filters, seals) to control the re-contamination on the spacecraft.

Missions that come back to Earth with samples from Mars, Europa or Enceladus have to meet not only stringent planetary protection constraints for the outgoing part of the trip but in line with the second rationale for planetary protection also stringent constraints on the way back. The approach followed is quite simple – contain or sterilize the extraterrestrial material and through the careful

scientific analysis of the material find out what the samples are made off and if there is any danger for Earth. All these measures need to be independently verified to ensure they are adequate and not biased.

In particular, at its Vienna meeting, the Panel as a whole has been presented with the most recent and up-to-date evidence for scientific and technical aspects of such missions and have made recommendations on the Phobos/Deimos sample return categorization for example regarding the International JAXA-led Martian Moons eXploration mission (MMX: <http://mmx.isas.jaxa.jp/en/>), a very ambitious project that will travel to Mars and survey the red planet's two moons, Phobos and Deimos in view of bringing new information on these objects and also collecting a sample from one of the moons to bring back to Earth.

Implementing planetary protection constraints cost time and money but in general they make a mission more robust and provide a better overall return of investment. The credo here is responding to the needs of the user, applying due diligence and visibility in the process. At the end the updated Policy is published.

Future plans for facing planetary protection challenges in the future

Through COSPAR, the Panel on Planetary Protection intends to inform the international community, e.g., COPUOS, as well as various other bilateral and multilateral organizations, of policy consensus in this area. However, it needs to be noted again that the COSPAR Planetary Protection Policy does not describe how to implement the requirements nor does it define or require a certain organizational structure for the implementing entity (i.e. space agency); both aspects are under the discretion of the user. The best and most cost effective means to adhere to the COSPAR planetary protection requirements is reserved to the engineering judgment of the national entity of international organization responsible for the planetary mission, subject to certification of compliance with the COSPAR planetary protection requirements by the appropriate national or international authority.

Besides the concerns expressed above, planetary protection will be facing in the future a few additional challenges. One has to do with the increased interest in space exploration and utilisation of non-governmental entities which may entail a closer examination of regulatory aspects perhaps not properly covered by some States that are signatories of the UN Outer Space Treaty. Another, not completely unrelated, is the need to formulate quantitative planetary protection constraints for human missions to Mars. This addresses 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. The latter one is an integral aspect of protecting astronauts and Earth. Human missions are different from robotic missions. NASA and other space agencies are actively addressing this issue already for several years and it becomes clear that in order to have safe (for astronauts and the general public) and productive human endeavors to Mars we need to know more about the processes how contamination is transported on Mars, i.e. atmospheric circulations models with high spatial and temporal resolution. We know a lot about Mars already but we do not have all the basic information we need to better characterize these processes.

The Panel thus intends to help in the above concerns. It 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 whole chain of activities leading to planetary missions, thus confirming that COSPAR is a reliable and essential actor to count on.