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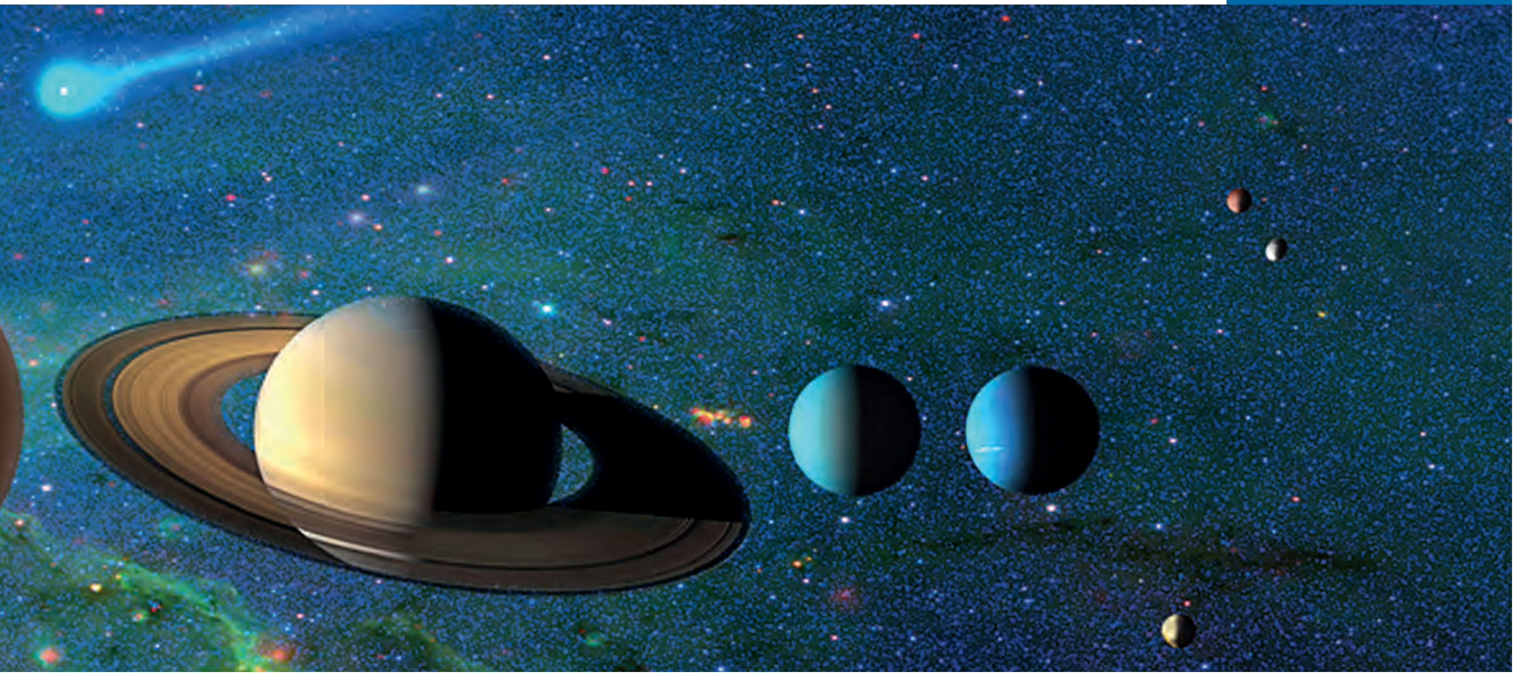
The challenge of planetary protection

Scientists and engineers are keen to explore our universe, carry out scientific investigations and make use of space resources. In the 60 or so years of robotic exploration of the solar system, this urge has pushed humanity forward and given us, among other things, a considerably enhanced understanding of our neighbourhood and of the origin of life on our planet. It comes, however, with a responsibility to avoid harmful contamination of outer space and the need to ensure safety of the Earth. The authors address the concerns and challenges of 'planetary protection'.

Planetary protection is a system of agreed international guidelines applied in the exploration and use of space in order to avoid contamination of the Earth or compromise the search for extraterrestrial life in the solar system.

Let's imagine that a research laboratory, selected to make preliminary examinations of samples from Mars, finds that a number of its researchers begin developing flu-like symptoms. It is late winter and this is not uncommon, in particular in a campus-like environment, but after a few weeks more and more people show symptoms and this attracts the attention of local public health officials and the media. Are the first investigations of the extraterrestrial samples and the trailing edge of an atypical flu season a coincidence? Has there been sufficient scrutiny of the lab's activities by public authorities and do we really know that the extraterrestrial material brought to Earth is not dangerous?

This hypothetical scenario provides an understanding of the seriousness of what planetary protection stands for. It is precisely why planetary protection measures have been in place for more than half a century and why the COmmittee on SPAce Research (COSPAR) has a dedicated panel of experts who make recommendations for the maintenance and updating of these measures.



The guidelines promulgated by COSPAR are used in the design of space missions with the goal of protecting solar system bodies from biological contamination, so that scientists can study the natural environments of these extraterrestrial bodies. Most importantly, the guidelines also help to preserve the terrestrial biosphere from possible contamination by alien material brought back by sample-return missions.

Basic elements

It is important to understand the legal and policy background. Article IX of the Outer Space Treaty (OST) of 1967 addresses the avoidance of harmful contamination of celestial bodies (forward contamination) and the 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”.

Planetary protection measures have evolved since the early 1960s through the studies and recommendations made by COSPAR at an international level, and today the COSPAR Planetary Protection Policy is the only international mechanism that outlines a scientifically justified framework for planetary protection. Indeed, the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) noted, in its report in 2017,

Planetary protection is a system of agreed international practices or guidelines to avoid contamination of Earth or compromise the search for extraterrestrial life

▼ Artist impression of the MMX spacecraft around Phobos and Deimos.

Measures have evolved since the early 1960s through studies and recommendations made by COSPAR at an international level

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.

In terms of application and implementation of planetary protection, Article VI of the OST 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". So this covers national compliance with the provision of planetary protection under Article IX.

Importantly, state responsibility for national space activities performed by non-governmental entities (including private research institutes and the private industry sector) is also subject to national application and implementation. Article VI is very specific in this respect, "The activities of non-governmental entities in outer space, including the Moon and other celestial bodies, shall require authorisation and continuing supervision by the appropriate State Party to the Treaty".

It is worth noting that the COSPAR Planetary Protection Policy is a set of internationally agreed guidelines and not a legal instrument binding under international law, but the above-mentioned observation by COPUOS in 2017 is important as an indication of the role of the COSPAR Planetary Protection Policy in the compliance of the OST.

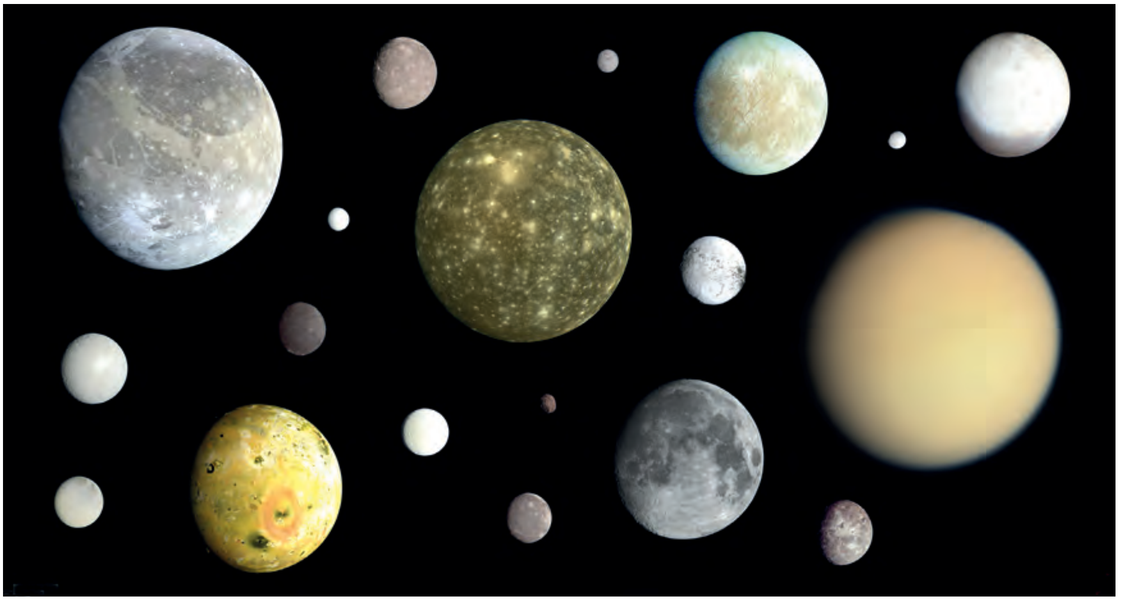
COSPAR's Planetary Protection Policy is based on two rationales:

1. Ensure that the conduct of scientific investigations of possible extraterrestrial lifeforms, precursors and remnants must not be jeopardised

2. 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 depends 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 in searching for extraterrestrial life: currently this applies only to Mars, Jupiter's moon Europa and Saturn's Enceladus, with most stringent constraints for sample return missions from these bodies.



▶ Major moons of our solar system.

This strategy has led so far to the categorisation of certain combinations of mission types and solar system objects as described in detail in COSPAR's Planetary Protection Policy document.

This categorisation is re-examined when new scientific results point to the need for updates and when challenges appear from recent solar system exploration, for example with the emergence of new habitable worlds (such as the icy moons) or sample return missions from Mars and its moons.

It is important to point out that no technical planetary protection constraints apply to one-way or sample-return missions to the Moon and to most of the asteroids. Nor do any planetary protection constraints apply to missions in Earth orbit.

Similarly, the COSPAR Planetary Protection Policy does not seek to protect solar system bodies for their own sake, does not protect unique solar system environments or historical sites, and does not protect Earth from man-made space objects (i.e. space debris) or from the impact of large asteroids or comets (i.e. planetary defence).

COSPAR Panel

As a committee of the International Council for Science (ICS), the purpose of COSPAR is to provide a forum, open to all stakeholders, which enables the discussion of problems that may affect scientific space research. COSPAR's Planetary Protection Policy is based on the most current, peer-reviewed scientific knowledge, so updating the Policy is a process that relies on the scientific community. This mandate is covered by the Panel on Planetary Protection.

The COSPAR Panel on Planetary Protection is a group of experts and representatives from space agencies, the science community and other stakeholders. It currently has 19 members, including national and international space agency representatives and science experts in fields related to planetary protection (such as planetary sciences, geology and geophysics, astrobiology, microbiology and sample-return). 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 categorisation 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. The most recent meeting of the Panel took place at the Vienna International Centre - the United Nations' premises in Austria - on 23-25 January 2019, where several items were discussed and examined pertaining to planetary protection.

▲ Members of the COSPAR Panel on Planetary Protection (see - https://cosparhq.cnes.fr/scientific-structure/ppp).

Because new scientific results appear in a regular fashion, the guidelines and requirements need to be adapted regularly. Indeed, recent scientific discoveries point to many new possible habitats and highlight extra astrobiological potential in the solar system, while also trailblazing new exploration targets and concepts. Some of these aspects concern the Martian moons, potential habitats in the subsurfaces of the icy moons of the outer solar system, Earth return missions and human exploration.

As mentioned above, most of the one-way missions leaving Earth have no technical planetary protection constraints although missions to Mars, Europa and Enceladus 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 of these solar system objects. The best approach in this context is, of course, not to impact them, so careful trajectory planning and reliable spacecraft design is paramount.

This is typically the case for spacecraft that study planets from orbit using 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 meet the first rational for planetary protection in such a case is to limit and control contamination on the spacecraft. This is achieved by assembling the spacecraft in biologically controlled cleanrooms, using heat, plasma and ionising radiation to reduce the bilogical contamination, and barrier systems (e.g. purging, filters and seals) to control the re-contamination of the spacecraft.

Implementing planetary protection constraints costs time and money, but in general makes a mission more robust and provides a better overall return on investment

Missions that return 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 rational for planetary protection, also stringent constraints on the way back. The approach followed is quite simple: contain or sterilise the extraterrestrial material and, through the careful scientific analysis of the material, find out what the samples are made of and whether they represent a danger to Earth. All these measures need to be independently verified to ensure that they are adequate and unbiased.

For example, at its Vienna meeting, the Panel made recommendations on the Phobos/Deimos sample return categorisation regarding the International JAXA-led Martian Moons eXploration mission (MMX). This is an ambitious project that will travel to Mars and survey the red planet's two moons, Phobos and Deimos, with a view to returning new information and collecting a sample from one of the moons to bring back to Earth.

Implementing planetary protection constraints costs time and money, but in general makes a mission more robust and provides a better overall return on investment. The credo here is responding to the needs of the user, applying due diligence and visibility in the process.

Through COSPAR, the Panel on Planetary Protection aims to inform the international community of policy consensus in this area. However, it should be noted again that the Policy does not describe how to implement the requirements, nor does it define or require a certain organisational structure for the implementing entity (e.g. space agency); both aspects are under the discretion of the user.

Future plans

Besides the concerns expressed above, planetary protection will in future face a number of additional challenges. One has to do with the increased interest in space exploration and utilisation by non-governmental entities, which may to a high degree influence future planetary missions and for which the national implementation of the rights and obligations under OST is becoming increasingly relevant.

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 - protecting the Earth (i.e. humanity) upon return of the astronauts and avoiding compromising the search for extraterrestrial life.

To ensure safe and productive human exploration of Mars, we need to know more about how contamination is transported on Mars

Clearly, human missions are different from robotic missions. NASA and other space agencies have been actively addressing this issue for several years and it has become clear that, in order to ensure safe and productive human exploration of Mars, we need to know more about how contamination is transported on Mars. In other words, we need atmospheric circulation models with high spatial and temporal resolution. We know a lot about Mars already, but we do not have all the necessary information we need to better characterise these processes.

In addition to its regular work, the Panel on Planetary Protection intends to investigate the ways and means of increasing awareness of the COSPAR Planetary Protection Policy and its applications among governments, space agencies, research institutions and other actors in the broader space community. This includes both public and private entities involved in activities where planetary protection is a key consideration. In this way, COSPAR will continue to offer a reliable and essential service to the space community. ■

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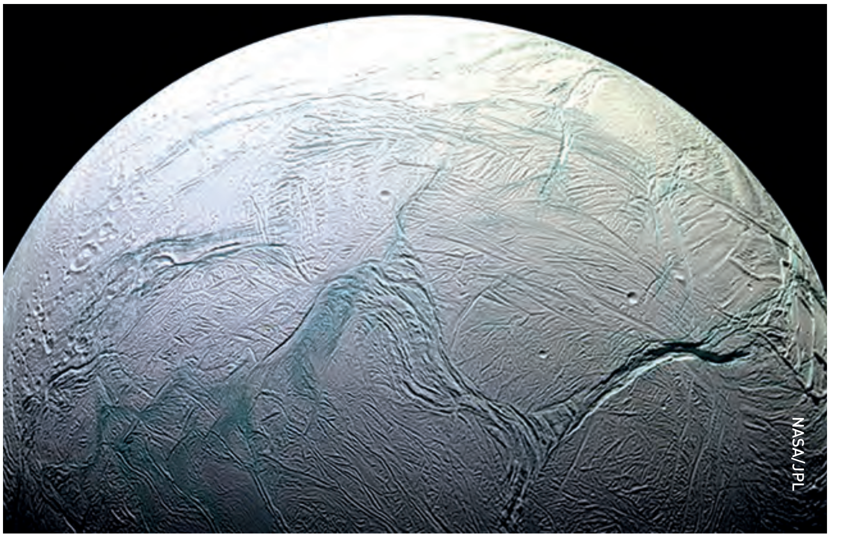
The views expressed in this article do not necessarily represent the views of the respective entities and organisations.

▼ The tortured surface of Saturn's moon Enceladus and its fascinating ongoing geological activity is a prime target for future sample-return missions.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