Planetary Protection for Planetary Science and Exploration

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This white paper suggest the following elements and recommendations for inclusion in the Planetary Sciences Decadal Survey (hereinafter, “the Survey”):

1) A summary of planetary protection recommendations, or specific recommendations pertinent to the goals and missions recommended in the Survey, should be included in the Survey.
2) It is essential that planetary protection implementation measures be derived from the latest data on planetary environments, as well as the latest data on the adaptability of Earth life to extreme environments and varied energy sources on this planet.
3) NASA should exercise its capabilities to develop and launch fully sterilized spacecraft for use in planetary exploration in environments where Earth life might grown and thrive. Likewise, to meet future challenges NASA should continue and expand the vigorous pursuit of advanced and less invasive technologies capable of sterilizing spacecraft without the drawbacks of current spacecraft preparation methods (dry heat, radiation, peroxides, etc.).
4) Although the SMD AA is responsible for planetary protection in NASA, planetary protection requirements may affect the development and operations of both human and robotic missions, no matter where the responsibility for those missions is lodged. NASA should ensure that its internal (NAC) advisory committee for planetary protection both meets regularly, and reports to the NAC in such a way that the other Mission Directorates and their advisors are engaged and knowledgeable about those requirements and why they are important to NASA missions. The inclusion of other-agency representatives on the committee is both appropriate and useful.

<u>Biological and Organic Contamination: an Issue in Scientific Exploration</u>

From the earliest days of the space program, concerns have been raised about the prevention of human-caused biological cross-contamination that could occur due to travel between Earth and other bodies in the solar system. If the search for life and the study of life-related chemistry in the solar system are scientific goals to be pursued through space travel, then protecting the evidence and preventing the introduction of contaminants are important and enabling goals for the conduct of planetary science. In 1957, for example, scientists cautioned about the possibility of contaminating other places in the solar system with microbes from Earth, which might cause irreversible changes on other planets and also interfere with scientific exploration. Likewise, it was felt that spacecraft carrying extraterrestrial samples or contaminants returned from space (especially from other planets) might harm Earth’s inhabitants and ecosystems.

The response to these concerns was first given the name “planetary quarantine,” but because of the human-disease-related roots of that name, the term “planetary protection” was coined in the mid-1980s as a broader replacement, to include the potential for other sorts of contamination (e.g., environmental) that might be spread by interplanetary interchange of material.

In part as a reflection of those wider concerns, Article IX of the Outer Space Treaty of 1967 (United Nations 1967), in its lawyerly way, requires that parties pursuing studies of outer space and other celestial bodies "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." In practical terms, these concerns are twofold: avoiding 1) "forward contamination," the transport of terrestrial microbes and uncharacterized organic compounds by outbound spacecraft, and 2) back contamination," the introduction to Earth of living organisms or other biological forms that could be returned from space.

Planetary Protection Policies

The subsequent segment of Article IX of the Outer Space Treaty states that parties to the treaty "where necessary, shall adopt appropriate measures" for the purpose of avoiding harmful contamination and changes to the Earth's environment. As a result, a number of space agencies (e.g., NASA, ESA, CNES) have established their own planetary protection policies to guide their efforts in this area when conducting interplanetary missions. The Treaty also provides that "if a State Party to the Treaty has reason to believe that an activity or experiment planned by *it or its nationals* in outer space...would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space..., it shall undertake appropriate international consultations before proceeding with any such activity or experiment." Likewise, there is a provision for a state to request consultation if it "has reason to believe that an activity or experiment planned by *another* State Party in outer space...would cause potentially harmful interference with activities in the peaceful exploration and use of outer space." [italics added.] Consequently, it has become important for space agencies to coordinate and collaborate on the development of their planetary protection policies.

To do this, and since the beginning of the space age (resulting in its first published policy in 1963), spacefaring nations have depended on the Committee on Space Research (COSPAR) of the International Council for Science (ICSU) to maintain an international-consensus planetary protection policy (COSPAR 2008) for joint reference and implementation. To develop this policy, COSPAR reviews the latest scientific information and considers recommendations from its member National scientific institutions and the International Scientific Unions, and secures the approval of the COSPAR Bureau and Council before making any changes. These changes may then be considered by space agencies for inclusion in their own planetary protection policies, although joint international missions generally use the COSPAR policy, itself, as the basis for mission implementation—which allows international partners to avoid getting bogged down in questions about whose policy will govern a particular mission.

It should be noted that assigning planetary protection measures to a particular mission and target requires synthesis of information about biological systems and extraterrestrial environments, while acknowledging uncertainties about the conditions that exist in those locations and the ability of microbes to inhabit them. Because scientific discovery about both microbiology and about other planetary bodies is ongoing, planetary protection policies must take into account such uncertainties. Nonetheless, policies must also acknowledge the need to be conservative to prevent exploration, itself, from disrupting or interfering with evidence pertaining to extraterrestrial life. COSPAR's policy suggests that space agencies should obtain advice on how to deal with these uncertainties by consulting with their National scientific institutions, or with COSPAR itself. It is in this consultative role that (in the US) NASA often turns to the National Research Council's Space Studies Board (SSB) to provide top-level recommendations on how to apply and or implement its policy, and on the policy itself. The SSB is the primary *external* advisory group assisting NASA in understanding the appropriate measures to be applied to each mission and target. Specific application of the NASA planetary protection policy has been subject to advice by a committee, subcommittee, or task force of the NASA Advisory Council (NAC) since 1999, in accordance with previous SSB recommendations (Space Studies Board 1997, 1998).

It should also be noted that the recommendations of the SSB may find their way into COSPAR policy both through the SSB's role as the National scientific institution that represents the United States on the COSPAR Council and Bureau, and due to NASA's participation in the activities of the COSPAR Panel on Planetary Protection (which maintains the COSPAR policy within COSPAR). For example, COSPAR has adopted the SSB recommendations on the forward contamination of Mars (SSB 1992 and SSB 2006b), on the return of Mars samples (SSB 1997) and on the return of samples from small solar system bodies (SSB 1998). COSPAR has also adopted the SSB's recommendations on preventing the forward contamination of Europa (SSB 2000) and on the requirements for the exploration of Venus (SSB 2006a). More specific recommendations associated with sample return missions (SSB 2002, SSB 2009) may not be incorporated into COSPAR policy because the policy is not written at the level-of-detail of those reports—which, however, will still form the basis of both NASA and ESA's work on such missions.

Planetary Protection Controls

Controls to implement planetary protection policies vary depending on the solar system body that will be explored, both for its interest with respect to astrobiological studies, and whether it is thought that its environment could harbor living organisms or support Earth life. Controls may include both operational and spacecraft-preparation measures. For example, spacecraft trajectories are designed to avoid unintended impacts on other bodies, and spacecraft may be restricted from approaching certain areas without special preparation. Accordingly, spacecraft may be assembled in clean rooms and their scientific instruments, or even the whole spacecraft, may be heat treated or specially packaged to reduce the number of microbes they carry. For round-trip missions to places such as Mars, returned samples are treated as potentially hazardous until proven otherwise, whereas other sample-return missions may not require any planetary protection controls at all.

In addition to extensive cleaning and decontamination of the outbound spacecraft, the return portion of a mission to a body that may be capable of supporting indigenous life requires a fail-safe, durable, container that can be remotely and effectively sealed, ensured to be free of external contamination, safely launched from the planet, monitored en route, and opened in an appropriate quarantine facility. If containment cannot be verified during the return flight to Earth, the sample and any spacecraft components that have been exposed to the extraterrestrial environment will be sterilized in space or not returned. Pristine sample materials will not be removed from containment until they are sterilized or certified as nonhazardous, using a rigorous battery of life detection and biohazard tests. Although the likelihood of releasing and spreading a contained living organism is low, special equipment, personnel, and handling are warranted to minimize harmful effects in case a life-form is discovered.

Human Missions

The basic principles of planetary protection—avoiding forward and backward contamination—are equally pertinent to human missions as to robotic missions. In the words of the COSPAR policy for human missions to Mars (COSPAR 2008), "the greater capability of human explorers can contribute to the astrobiological exploration of Mars only if human-associated contamination is controlled and understood."

For the *Apollo* missions to the Earth's Moon, the major concern was on backward contamination, in case the lunar surface were to hold any infectious organisms that could contaminate the astronauts or the lunar samples. This yielded a quarantine program for the first several lunar missions (*Apollo*s 11, 12 & 14) developed by an Interagency Committee on Back Contamination (ICBC) of the US Government that was formed to coordinate requirements for the quarantine of the astronauts, spacecraft, and samples. Quarantine ended with *Apollo* 14 because lunar samples were determined to be lifeless and not biohazardous. There were a variety of problems in implementing the *Apollo* quarantine—problems that, in hindsight, were sufficiently large to have made the quarantine ineffective should there actually had been environmental or even pathological hazards in the lunar dust. Nonetheless, it was a start.

A more robust program of planetary protection, including forward contamination control, medical monitoring, spatial planning for human exploration, and precautions against back contamination, has been described in NASA and ESA-led studies (Race et al. 2008). Basic principles for future human missions have been adopted by COSPAR as part of its planetary protection policy in 2008 (COSPAR 2008). Effectively these principles involve "defense in depth" and continuous evaluation through a mission of the contamination status of the crew and the planetary surface (and subsurface) that they will explore.

Future Missions

Both outer planet and Mars missions of the future present challenges in implementing planetary protection policy. Give the nature of the icy outer planet satellites, any mission with a perennial heat source onboard (e.g., a radioisotope power supply) presents an opportunity for a warm, watery, environment to be formed, even where temperatures and water activity might normally be too extreme for Earth life to grow. Even without perennial heat sources being involved, round-trip missions to Mars or other extraterrestrial locations that might support indigenous life pose a significant challenge in both planning and execution. Because sample amounts are anticipated to be limited (less than 1 kg of rocks and soils), and because human astronauts are not involved, quarantine procedures and flight operations will be less complex and can be more effective than those associated with the *Apollo* missions. However, a heightened awareness of microbial capabilities and microbe-caused diseases has developed since the time of *Apollo*, with corresponding public concern about the risks of sample-return missions.

As solar system exploration continues, so too will the refinement of specific planetary protection policies. Revisions to planetary protection policies must depend on an improved understanding of extraterrestrial environments and the emerging awareness of the tenacity of life in extreme environments on Earth. It appears increasingly likely that there are extraterrestrial environments that could support Earth organisms, at least for a limited period of time. Even more interestingly, future missions may find distant environments that support their own extraterrestrial life. With such possibilities in mind, planetary protection provisions will be essential to the study and conservation of such environments, and of life-in-the-universe, itself.

Implementing Sound Planetary Protection Measures

General

In the past, the SSB has made significant and lasting recommendations regarding both the goals of NASA's planetary protection policy and the measures used to implement the policy. As it happens, these recommendations are scattered throughout reports specifically targeting planetary protection, and related recommendations are found in reports covering everything from the Astrobiology Institute to "weird life," and all the planets in-between. Unfortunately, this widespread distribution can render these recommendations and their context unavailable to the readers of the Decadal Survey report, or they can be perceived to be of lesser importance. In order to offset this tendency, the first recommendation of this white paper is aimed at the Survey steering committee itself:

> *1) A summary of planetary protection recommendations, or specific recommendations pertinent to the goals and missions recommended in the Survey, should be included in the Survey.*

Knowledge of Planetary Environments

Planetary environments are continually reevaluated as to their past, present, and future state. Future missions are expected either to refine our knowledge of the environments that we have already measured, or those whose characteristics are constrained by measurements made remotely or *in situ*, or conceivably to probe entirely new environments that are not currently known or constrained as to their applicability to the issue of "life." In the face of such possibilities, it is essential to the proper implementation of planetary protection policy that estimates of the habitability of planetary environments be conservatively established, and that measures taken to protect against their contamination be derived accordingly:

> *2a) It is essential that planetary protection implementation measures be derived from the latest data on planetary environments,....*

Knowledge of Microbial Capabilities

A true revolution in our understanding of biology has been afforded by access to the techniques of molecular biology, and has included an appreciation of the tremendous capabilities of microbial life to inhabit environments on Earth that were once thought to be too hot, too cold, too deep, too dark, too dry, etc. Earth life is extraordinarily adaptable, and is found growing actively on this planet essentially everywhere there is water available and the temperature is somewhere between -20C and 121C. The picture is expanding all the time, and microbial life has been seen to use such a wide variety of energy sources that it is not unreasonable to consider it likely that our knowledge of where and how microbes live will continue to expand. Hence:

> *2b) ....as well as the latest data on the adaptability of Earth life to extreme environments and varied energy sources on this planet.*

Preparation of Mission Hardware

Spacecraft used in the pursuit of planetary science discovery are invariably complex, expensive, and in some ways fragile. Orbiters and landers alike have to operate in environments that may include extremes of temperature, natural hazards (dust, radiation, micrometeorites, rocks, etc.), and communications challenges. These challenges are often considered "normal" for space vehicles, but other challenges must be considered in pursuit of the ability to explore environments that may support life, while avoiding biological contamination. NASA has pursued technologies that are robust against space hazards, and is capable of developing spacecraft that are fully compatible with a full suite of sterilization techniques and protection methods. It is also true that NASA needs to exercise this capability, and reacquire and apply the techniques that were used on the successful *Viking* landed missions to Mars:

> *3) NASA should exercise its capabilities to develop and launch fully sterilized spacecraft for use in planetary exploration in environments where Earth life might grown and thrive. Likewise, to meet future challenges NASA should continue and expand the vigourous pursuit of advanced and less invasive technologies capable of sterilizing spacecraft without the drawbacks of current spacecraft preparation methods (dry heat, radiation, peroxides, etc.).*

Access to Knowledgeable, Unconflicted, Advice

Current NASA planetary protection policy (NPD 8020.7G) states NASA shall "take into account current scientific knowledge about the target bodies through recommendations from both internal and external advisory groups, but most notably from the Space Studies Board of the National Academy of Sciences" (NASA 1999). The benefit of receiving both external advice (from the SSB) and internal advice (from an advisory committee run by NASA) has become clear recently, with the SSB addressing implementation *issues* and *recommendations* in an authoritative manner, whereas the internal NAC committee (Planetary Protection Task Force [1999-2001]; Planetary Protection Advisory Committee [2001-2006]; and Planetary Protection Subcommittee [2006-Present]) has been maintained by the NAC and has weighed-in on *implementation* and *management* of NASA planetary protection activities. This separation of roles has been effective.

Unfortunately, the most recent iteration of the NAC has done two things that are regrettable. The first, placing the Planetary Protection Subcommittee (PPS) under the Science Committee of the NAC was/is an obvious conflict-of-interest, but was implemented by upper-level NASA administrators as a part of the means of controlling the various subordinate committees of the NAC. The second is a predictable follow-on from the first—the Science Committee has generally neglected to forward PPS recommendations to the full NAC, and has refused to allow the PPS to meet regularly (the NAC has cancelled or delayed PPS meetings for the last 10 months). Thus:

> *4) Although the SMD AA is responsible for planetary protection in NASA, planetary protection requirements may affect the development and operations of both human and robotic missions, no matter where the responsibility for those missions is lodged. NASA should ensure that its internal (NAC) advisory committee for planetary protection both meets regularly, and reports to the NAC in such a way that the other Mission Directorates and their advisors are engaged and knowledgeable about those requirements and why they are important to NASA missions. The inclusion of other-agency representatives on the committee is both appropriate and useful.*

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