Policies for Scientific Exploration and Environmental Protection: Comparison of the Antarctic and Outer Space Treaties

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INTRODUCTION

The Antarctic Treaty (AT) has been successful by almost any measure. It has dealt effectively with military challenges posed by nuclear weapons, political tensions of sovereignty claims, and the scientific desire for shared access to research sites across vast, unexplored expanses. Over the past 50 years the AT has contributed to global stability, cooperative scientific exploration, and international management for peaceful purposes of nearly 10% of the Earth (Grimaldi, 2009). In similar ways, the UN Outer Space Treaty (OST),[1] which was, in part, modeled on the Antarctic Treaty, has also withstood the test of time, designating outer space as a resource for peaceful uses in the interest of all mankind. In addition to its role in cold war diplomacy and preventing a nuclear space race, the Outer Space Treaty has contributed to productive scientific exploration, international cooperation, and the protection of planets from biological contamination ("planetary protection") for more than four decades.

Although both treaties shared similar priority goals in their early stages, each has responded to quite different challenges, both social and technological, over the last 50 years. As a result, they have diverged over that time, particularly with respect to environmental protection and management. As a guide to the future and to understand the environmental and management challenges of an increased human presence in outer space, it may be instructive to examine the key features of each treaty at the time of negotiation and compare how each was modified over the decades. As both environments will likely face increasing demands for access and use of their relatively hostile, yet fragile, environments, lessons learned from the comparisons can provide insights on how the treaties can respond to future challenges like increased exploration and increased tourism, as well as the more complex decisions about resource management and use brought about by the increased presence of humans in these environments.

For both treaties, sound scientific information has been essential for the establishment and revision of management plans and regulatory guidelines. Looking ahead, ongoing research and new scientific understanding of both Antarctica and outer space will be important to effectively addressing the challenges posed by increased human activities, whether they result from government, scientific, commercial, and industrial or private sector pursuits.

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INITIAL TREATY FRAMEWORKS

As noted by Kerrest (this volume), Antarctica and outer space have a lot in common. Both are hostile environments for humans, both are viewed with the potential for extensive and valuable resources of different types, and both are of intense interest for scientific research and exploration. Likewise, both Antarctica and outer space have potentially high strategic value and were the focus of significant political and military interest during the cold war.

Both treaties were products of the cold war era, developed on the heels of the very successful International Geophysical Year (IGY; 1957–1958) that reflected international scientific cooperation in the post–World War II era. At that time, the Antarctic Treaty deliberations served as a framework to address concerns over possible cold war military expansion as well as conflicting sovereignty claims on Antarctic areas that had been put forward by a handful of nations. Although subsequent discussions about the Outer Space Treaty likewise centered on potential military expansion and national security, they were coupled with a desire to establish the precedent of "freedom of international space," thereby heading off tensions over legal restrictions aimed at orbiting satellites and spacecraft. From a historical perspective, one could argue that scientific activities served as peacekeeping surrogates and cooperative ventures that ensured internationalization and diffused political tensions, that the "political exploitation of scientific goodwill" was used to "achieve essentially political objectives" (Launius, 2009). Regardless, for both treaties, scientific exploration legitimized international control by creating mechanisms for management and goals for continued rational use that continue to this day.

The 17 articles of the Outer Space Treaty have considerable overlap and similarity with the 14 articles of the original Antarctic Treaty. As shown in Table 1, both stipulate exclusively peaceful uses and strict limitations on military activities and the use of nuclear weapons and materials. Both prohibit governments from extending national sovereignty or making new resource claims, and each indicates that states parties are responsible for authorization, supervision, and responsibility over their national activities, whether those activities are undertaken by governmental or nongovernmental entities. Both declare the expectation of freedom of scientific investigations, exchanges of information and personnel, access for observers, and peaceful dispute settlements. In addition, both have provisions for amending, interpreting, and upholding the treaty as well as mechanisms to allow other states to become signatories. Notable differences have to do with the nature of space exploration and the potential for astronauts to come back to the Earth in unplanned ways to unplanned locations. In the Outer Space Treaty, states agree to provide assistance to astronauts in the event of accidents or emergencies; to retain jurisdiction, control, and ownership of their launched objects; and to accept liability for damages caused by objects in their control, whether on Earth or other planets, in air space or outer space.

Although discussions of both treaties began around the same time, the Antarctic Treaty was developed by a group of just 12 countries, led by the United States and the United Kingdom.[2] Treaty deliberations and modifications occur through Antarctic Treaty Consultative Meetings (ATCM), which are now held annually. In contrast, the Outer Space Treaty was negotiated as a United Nations treaty.[3] The UN Committee on the Peaceful Uses of Outer Space (COPUOS), which was established by the General Assembly in 1959, was designated as the focal point of international cooperation and deliberations regarding peaceful exploration and use of outer space. Originally, COPUOS had 24 members but has since grown to 69 members, making it one of the largest committees in the United Nations.

Interestingly, both treaties are supported by strong, active, international scientific panels that grew out of IGY research efforts and which predate the signing of their respective treaties. The Scientific Committee for Antarctic Research (SCAR) and the Committee on Space Research (COSPAR) were established by the International Council of Scientific Unions (now the International Council for Science, ICSU) in 1957 and 1958, respectively, to provide independent scientific advice on matters related to their respective treaties, as well as information on emerging issues. The COSPAR, as a nongovernmental organization, was granted permanent observer status to the UN COPUOS in 1962.[4] The SCAR is similarly a third-party, nongovernmental organization that functions as a permanent observer and advisor to the Antarctic Treaty through the ATCM.[5]

In considering the initial makeup of the treaties, two features are linked to later expansion in areas of environmental and science management.

1. *Science reserves for exploration versus science and use*: Although both treaties stipulate scientific exploration for peaceful purposes for the benefit of mankind, the Antarctic Treaty designated the continent as a natural reserve devoted to science, whereas the Outer Space Treaty specifically mentioned science, cooperation, and use for mankind, keeping the door open for all types of activities, not just scientific exploration on celestial bodies and in outer space.

TABLE 1. Key features of the Antarctic and Outer Space treaties at ratification.

Features	Antarctic Treaty[a] Article	Outer Space Treaty[b] Article
Peaceful Uses for Mankind	I	I, III, IV
No Military Activities or Bases	I	IV
Science Investigation and Cooperation	II	Science Exploration, Cooperation and Use I
No Sovereign Claims	IV	II
No Nuclear Explosives/Waste Disposal	V	No Nuclear Weapons or WMDs in Orbit IV
Jurisdiction and Responsibility for National Activities	VIII	VI
Freedom of Access	III	I
Share Information on Science/Activities	III	XI
Freedom of Personnel and Observers	III	I, X, XII
Peaceful Settlement of Issues and Discourage Contrary Activities	X, XI	Practical Questions Resolved by Consultations XIII, IX
Procedures for Accession	XIII	XIV
Amendment Provisions	XII	XV
Consultative Meetings	IX	—
	—	Avoid Harmful Contamination of Celestial Bodies and Adverse Changes to Earth IX
	—	Assist Astronauts V
	—	Liability for Launched Items VII
	—	Retain Jurisdiction, Ownership of Items VIII
Scientific Advisory Group (independent, 3rd party NGOs)	Sci. Committee on Antarctic Research (SCAR) (1958)	Committee on Space Research (COSPAR) (1958)

[a] Signed in 1959; in force 1961.
[b] Signed in 1967; in force 1967.

2. *Environmental oversight*: The Outer Space Treaty stipulates that states should conduct exploration of celestial bodies in ways "so as to avoid their harmful contamination and also adverse changes in the environment of the Earth caused by the introduction of extraterrestrial matter." The initial version of the Antarctic Treaty made no specific mention of contamination, biological or otherwise, although it does indicate that preservation and conservation of living resources are within the scope of its Consultative Meetings.

In hindsight, neither treaty provided much in the way of initial guidance for later expansion into regimes that would address concerns about environmental management and protection. Over time, each has dealt with these issues quite differently, as described below.

EVOLUTION AND IMPLEMENTATION OF THE TREATIES OVER THE DECADES

Antarctic Treaty System

When the Antarctic Treaty went into force in 1961, it was a mere shadow of what it is today regarding environmental and science protection. It is now a treaty system, comprising ~200 agreements and measures that have been developed and ratified via the ATCM process, with considerable multidisciplinary input through SCAR. The system's extensive environmental oversight and protections are an outgrowth of international deliberations and sound science that have been translated incrementally into precautionary, multispecies, and ecosystem-based approaches

TABLE 2. Comparison of the Antarctic Treaty (after 50 years) and the Outer Space Treaty (after 40 years).

Features	**Antarctic Treaty, 1959**	**Outer Space Treaty, 1967**
Agreements/legal instruments	Conservation of Antarctic Fauna and Flora (1964; in force 1982) Conservation of Antarctic Seals (1972; in force 1978) Conservation of Antarctic Marine Living Resources (1980; in force 1982) Protocol on Environmental Protection (1991; in force 1998) Regulation of Antarctic Mineral Resource Activities (1988; later rejected)	Agreement on the Rescue and Return of Astronauts and Objects (1968) Convention on International Liability for Damage by Space Objects (1972) Convention on Registration of Objects Launched into Outer Space (1975; in force1976) Agreement Governing Activities of States on the Moon and Other Celestial Bodies (1979; in force 1984) Guidelines on Space Debris Mitigation (COPUOS- IADC; 2010)
Annexes	Environmental Impact Assessments 1991 (1998) Fauna and Flora 1991 (1998) Waste Management 1991 (1998) Marine Pollution 1991 (1998) Special Protected Areas (& moratorium on mineral activities 1991 (2002) Liability arising for environmental emergencies (2005) (not in force yet)	Declaration on Activities in Exploration and Uses of Outer Space (adopted 1963) Use of Artificial Earth Satellites for International Direct TV Broadcasting (1982) Remote Sensing of Earth from outer Space (1986) Use of Nuclear Power Sources in Outer Space (1992) International Cooperation in Exploration and Use for the Benefit of all States, and Needs of Developing Countries (1996)
Governance framework	AT Consultative Meetings (ATCM), 1961 AT Secretariat, 2004 Scientific Committee for Antarctic Research (SCAR), 1958	Governance framework UN Committee on Peaceful Uses of Outer Space (COPUOS), 1959 UN Office for Outer Space Affairs (UNOOSA), 1958 Committee On Space Research (COSPAR), 1958

to management. As summarized in Table 2, the Antarctic Treaty System is now an amalgam of five main agreements, six annexes, and various legally binding measures relating to protection of Antarctic environments and resources. Most additions to the original treaty were developed from the 1970s through the 1990s, but changes are continuing. As a treaty system, the Antarctic Treaty System is a dynamic entity, considerably more effective and stronger than when originally ratified. What began as a treaty built around cold war diplomacy, military and nuclear limitations, and peaceful science exploration has evolved into a remarkable instrument of environmental protection, international science cooperation, and stewardship for the benefit of humankind, all the while maintaining its important geopolitical and security objectives.

Although the early conventions and agreements on flora and fauna, living resources, and seals were noteworthy, perhaps the most important elements of the Antarctic Treaty for protection of the environment and dependent ecosystems were developed in the 1990s with the Protocol on Environmental Protection and its associated annexes. In addition to preventing development and providing protection for the Antarctic environment, this protocol established a set of binding mandates related to prevention of marine pollution, conservation of flora and fauna, waste disposal and management, special area protection and management, and environmental impact assessments. The result is a clear, comprehensive framework that outlines a code of conduct for expeditions and station activities, along with procedures for international review in advance of proposals likely to have significant environmental impacts. Activities with anticipated minor or transitory impacts fall under the oversight and jurisdiction of national authorities. Ongoing participation and input by SCAR to the ATCM, as well as to the Committee for Environmental Protection (CEP), provide opportunities to update relevant scientific information, identify emerging issues or concerns, and make recommendations for revisions related to stewardship or those intending to minimize the adverse impacts of human activities.[6]

Outer Space Treaty

In contrast to the dynamically evolving Antarctic Treaty System, the Outer Space Treaty has remained unchanged over the decades. As shown in Table 2, the OST has been joined by four additional international treaties. Three of these (rescue and return of astronauts, liability, and registration) elaborate on principles included in the original treaty. The fourth, The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (also called the Moon Agreement; accepted by the General Assembly in 1973; nominally in force in 1984) designated "the Moon and its natural resources as the common heritage of mankind." The Moon Agreegment has been ratified by only 13 States and signed by only 4 others,[7] despite repeated calls by the General Assembly (Tuerk, 2009). Among other things, the Moon Agreement embraces nonappropriation of property while asserting the right of states to collect and remove samples of the Moon's minerals and other substances in quantities appropriate for the support of their missions. In addition to these four legal instruments, there is a fifth document that complements the Outer Space Treaty. Recently, after more than a decade of deliberative work by the Inter-Agency Space Debris Coordination Committee (IADC),[8] both COPOUS (2007) and the General Assembly (2008) endorsed the set of voluntary space debris mitigation guidelines and encouraged their implementation through national mechanisms.[9]

During the past four decades, neither the OST nor any of the subsequent agreements have established specific regulations for activities related to the commercialization, exploitation, or use of any natural resources of the Moon or other celestial bodies by either public or private entities. Deliberations by COPUOS have focused largely on activities in Earth orbit or those that might impact Earth (e.g., missions with astronauts, space debris, satellites, liability for damages, ownership of objects, launch registration, nuclear power sources in space, remote sensing of Earth, defense against hazardous asteroids, etc.).[10] Only one article of the OST addresses protection of the Earth and contamination avoidance in space. In Article IX, the OST stipulates avoidance of harmful contamination, protection of exploration, and prevention of "adverse" changes on Earth from the return of extraterrestrial materials.

Despite the lack of development of other OST provisions, the implementation of Article IX has resulted in a long and successful history of planetary protection (from living or organic contamination) of celestial bodies during space exploration. True to its consultative role with COPUOS, COSPAR has played a strong role in developing international policies and guidelines to avoid forward contamination (transport of hitchhiker organisms on spacecraft launched from Earth) and back contamination (uncontained return of extraterrestrial samples or materials that could be biohazardous to Earth). Early efforts in spacecraft decontamination began during the first decade of space exploration beyond Earth, and planetary protection controls have been updated repeatedly to reflect advances in science and technology ever since.[11]

In recent years, the increasing pace of astrobiology research and space missions has contributed to a new understanding of planetary environments, cosmological processes, biological potential, and life in extreme environments. Accordingly, COSPAR and the scientific community have continued to refine planetary protection policies associated with one-way, round-trip, robotic and human missions to solar system bodies.[12] The focus on *biological* and *organic* contamination means there are no specific policies addressing other sorts of environmental management or protection needed to protect physical environments and natural resources beyond the Earth. As a nongovernmental organization without institutional authority, COSPAR's recommendations are not internationally legally binding, except through consultation with and interpretation by COPUOS and the voluntary adoption of COSPAR standards by spacefaring nations in separate, multiparty agreements. Nonetheless, planetary protection provisions have been voluntarily adopted by launching nations over the decades, thereby affording indirect environmental protection to target bodies with possible habitable conditions.

For a variety of reasons, the OST has not developed a comprehensive framework of mandated environmental protections similar to that afforded by the Antarctic Treaty System. Part of the difference is based on the nature and extent of scientific information available about Earth versus outer space, and this lack of knowledge (of the environments, of the capabilities of Earth organisms in those environments, and of the possible existence of extraterrestrial life) has meant that the implementation of the OST's "no harmful contamination" article has focused on biological contamination avoidance, rather than on environmental protection, per se. Although an understanding of Antarctic microbes and ecosystems has only recently developed, our understanding about flora, fauna, and environments on Earth is extensive and can be applied to Antarctica for developing environmental and resource protections. In contrast, our knowledge about planetary environments and the uncertainty about possible associated biota and dependent ecosystems in outer space make it more difficult to establish appropriate levels of protection drawn directly from scientific analogies or legal precedents on Earth. When one celestial body is deemed to be lifeless (like the Moon or some asteroids) compared to another that could potentially harbor extraterrestrial life (like Mars or Europa), one can debate the merits and justifications for developing varied environmental management and planetary protection policies for each, but such designations are subject to change as new knowledge becomes available. Scientists are continuing to deliberate on how to update planetary protection policies and control measures that will protect the various bodies of the solar system even as new launching nations add to a growing number of science missions to diverse target bodies.

Although voluntary adherence to biological contamination controls has translated into protection of science exploration over the years, there is still nothing that provides a framework around the OST similar to the AT's protocol of environmental protection, code of conduct, special area designations,[13] or environmental impact assessments for proposed activities. This lack of a framework has implications for space missions both now and in the future. For example, a number of missions have deliberately impacted the Moon with spacecraft to detect and analyze subsurface ice (e.g., Lunar Prospector, Lunar Crater Observation and Sensing Satellite [LCROSS], etc.), yielding significant information for researchers interested in potential water reserves on the Moon. Nonetheless, other researchers interested in studying the lunar atmosphere or who might want to study the record of past cometary impact on the Moon have expressed concerns that repeated landings, deliberate impacts, or other volatile-rich lunar surface activities could contaminate the fragile atmosphere in ways that could interfere with future scientific study and interpretation of the lunar record. Unlike the Antarctic Treaty, the Outer Space Treaty has no internationally accepted framework or process that requires states parties to assess, in advance, the effects of various science mission proposals or to evaluate their relative merits or cumulative impacts on other science efforts. Concerns about this lack of a review process are likely to grow and become more complicated in the future, with the anticipated increase of commercial, industrial, and private sector activities on the Moon and other planetary surfaces.

LOOKING AHEAD

The Antarctic and Outer Space treaties have each performed well for many decades and, barring any unfortunate geopolitical crises, will presumably maintain their important roles in cooperative science exploration, nonappropriation, prevention of military and nuclear activities, and peaceful uses of their respective territories. However, when it comes to environmental protection and resource management, the Antarctic Treaty framework is currently better prepared to tackle likely future challenges, as detailed in the following comparison.

Antarctic Treaty

On the basis of the original treaty and subsequent revisions, the Antarctic Treaty System outlines clear statements about its prohibitions, regulations, and objectives and has evolved regulatory and procedural frameworks effective for environmental management and changing scenarios. It is a streamlined legal instrument, overseen by a relatively limited number of acceding states whose highly involved user communities rely on the ATCM and up-to-date information to manage the continent as a reserve for scientific research. The existing framework provides an established means to tackle emerging challenges such as the growing interest in bioprospecting, increasing demand for tourism, and continued interest in mineral exploitation, oil and gas extraction, and expansion of economic activities.[14] Other complications may arise from tensions between science preservation and perceived national interests, particularly in regard to pollution control, marine resources, or rights at the intersection of other treaties (e.g., the UN Convention on the Law of the Sea). All in all, the Antarctic Treaty has grown into a strong environmental treaty over time and has contributed to five decades of peaceful scientific exploration and cooperative stewardship, even though historians suggest that science was manipulated in the beginning to achieve Western geopolitical aims during the cold war era (cf. Launius, 2009). From today's perspective, the treaty can provide valuable lessons and useful analogues on how to approach the management of sensitive international resources for the benefit of humankind.

Outer Space Treaty

Although the original Outer Space Treaty and its subsequent agreements likewise outline clear statements about prohibitions, guidelines, and objectives, its implementation through COPUOS over the past four decades has focused predominantly on launches and activities in Earth orbit (issues related to astronauts, ownership, liability, sustainability and protection of orbital assets, handling of space debris, and equipment at end-of-life, etc.). At the same time, COSPAR and the international scientific community have concentrated on the only element of the treaty that specifically mentions contamination or protection beyond Earth orbit. So far, COSPAR has incrementally developed planetary protection "rules of the road" that represent "detailed and very specific non-binding, standards and guidelines that amount to soft law instruments applicable to extraterrestrial space exploration" (Bohlmann, 2009:192. According to Bohlmann (2009:193), this evolution of policies and law governing space protection reflects the increased influence of the science community and a shift of political motivations for space exploration initiatives away from "the early hard power arguments to the quest for scientific knowledge perceived as a cultural imperative."

Already, we can anticipate the kinds of pressures likely to arise in the coming decades. For example, planned human activities may contribute to a variety of direct, indirect, and cumulative impacts, including base infrastructure construction, waste handling and disposal, exploration, road building, mining, in situ resource utilization, traffic management of orbital assets, end-of-mission debris handling, placement of large radio telescopes, use and disposal of nuclear power sources, and eventual settlement and associated development. Concerns about potential impacts on historical sites or special areas have been raised by proposals for novel private or commercial activities like aerospace prize competitions, space tourism, and even astroburials on the lunar surface. Although many of these scenarios have analogues on Earth or in Earth orbit, they present unusual complications as the pace of activities increases.

Although a predominantly science-based approach has worked well in Antarctica to develop a framework for environmental protection, resource management, and prevention of harmful contamination, there are some distinctively different issues associated with this type of approach in space.[15] Given the wide variety of different environments found in outer space, even the conceptual basis for such a framework will need reconsideration. Notions like environmental stewardship, sustainability, preservation, resource use, exploitation, or adverse impacts on, under, or above celestial bodies have yet to be defined and discussed in detail because in many cases hostile space environments are incapable of sustaining life. Accordingly, there are no general guidelines for how to address the protection of lifeless environments in the solar system.

Other possibly unique complications could arise if and when verified extraterrestrial life is discovered since all legal and ethical systems on Earth are based on life as we know it. Recently, scientists have even suggested the need to discuss whether ethical considerations should be integrated into planetary protection policy along with protection of science (National Research Council [NRC], 2006:111–114). The recommendation for an international workshop on the topic was endorsed by COSPAR in 2008, and a workshop on ethical issues in planetary protection was held in June 2010 and discussed at the COSPAR General Assembly in Bremen, Germany (July 2010). With so many different environmental situations possible in "outer space," some of which are distinctly different from those encountered in terrestrial situations, questions about a treaty regime that will ensure the appropriate protection of unique natural and physical systems are sure to persist. Clearly, there is a long road ahead before we can develop a consensus system for balancing science exploration, environmental protection, and diverse, peaceful uses of outer space for human benefit (to say nothing about benefiting "all mankind").

The good news is that research and analysis during the past 10–15 years have already identified various issues and gaps or inadequacies in outer space policy (e.g., Hargrove, 1986; Lupisella and Logsdon, 1997; Almar, 2002; Race and Randolph, 2002; Tennen, 2003; Cockell and Horneck, 2004; Williamson, 2006; Sterns and Tennen, 2007; Masson-Zwann, 2008), and the COSPAR planetary protection policy has been updated and expanded every two years (at biannual COSPAR Assemblies) since 2002. In addition, recently a number of interdisciplinary groups have begun organized discussions on how to develop environmental management agreements in ways that effectively integrate scientific exploration with potentially expanding commercial and private sector activities. For example, the International Academy of Astronautics (IAA) "Cosmic Study" on Protecting the Environment of Celestial Bodies (PECB) was formed under the auspices of IAA Commission V (Space Policy, Law, and Economy) to examine current planetary protection controls for avoiding biological contamination and consider whether and how protection might extend to geophysical, industrial, and cultural realms. The PECB study report (Hoffman et al., In press) identified a variety of problems related to environmental protection, including the lack of suitable detection methodologies and an insufficient legal framework, a paucity of economic analytical tools, and a shortage of the political will to address the issues ahead. COSPAR's Panel on Exploration (PEX) (COSPAR, In press) undertook a study to provide independent input to support the development of worldwide space exploration programs while safeguarding the scientific assets of solar system objects. The PEX report also outlines how to protect the lunar and Martian environments for scientific research under various legal frameworks. Elsewhere, the European Space Foundation (ESF) co-organized a transdisciplinary conference and dialogue with the European Space Agency (ESA) and the European Space Policy Institute (ESPI) in 2007 to assess issues at different phases in human exploration, first in Earth orbit, then on other bodies, and finally as colonizers off Earth (Codignola and Schrogl, 2009). A subsequent ESF scoping conference (2009) extended discussions to even broader considerations, from philosophy and religion to culture, education, legal, ethical, political, and social frameworks. Ultimately, the conference output will lead to publication of a multidisciplinary research roadmap (ESF, 2011). Finally, COSPAR's Planetary Protection Panel has begun planning a symposium for 2011 that will examine planetary protection policy and environmental protection in outer space as a continuum and determine what revisions in COSPAR policy, if any, may be needed to adapt to the changing face of space exploration.

Viewed collectively, many of the ideas identified as ways to move forward in outer space bear striking similarities to elements of the Antarctic Treaty's framework for environmental management. For example, tentative suggestions have included the need to consider

- designation of special management areas or protected zones to avoid or mitigate impacts in advance (e.g., special scientific regions, historical/cultural/aesthetic reserves, planetary parks, special natural features or formations, developable regions, etc.);
- development of a comprehensive environmental protection protocol (for scientific and other proposals) that outlines procedural approaches for review and assessment of proposed activities that have the potential for significant direct or indirect contamination or exploitation impacts;
- establishment of code(s) of conduct appropriate for different types of celestial bodies and environments (including subsurface and orbital) and an elaboration of how these may apply to various categories of activities and different sectors (scientific, commercial, industrial, private, etc.); and
- development of workable analytical tools and criteria for evaluating considerations such as costs, benefits, reversibility, and varying degrees of impacts from proposed activities, including cumulative impacts.

Although the underlying concepts and principles for environmental management and stewardship will necessarily be drawn from terrestrial analogues and experiences, some issues may require innovative approaches or consideration. For example, there is need to anticipate what complications could arise if and when extraterrestrial life is discovered and verified. Since all current ethical and legal systems are based on life as we know it, such a discovery will likely challenge the bases for management and stewardship in outer space. Likewise, questions about how to determine the balance between scientific exploration and the use of an environment for the benefit of humankind will require discussions of issues like "fair" access and equity among different current users, as well as issues like the long-term sustainability of resources and environments in outer space and consideration of obligations to nonspacefaring nations and future generations. In light of these unusual complications, some observers have suggested the need for a new international consultative body to engage in more coordinated and informed consideration of the complex issues ahead.

Once these discussions start in earnest, multiple "user" communities can enter into deliberations about environmental management that have previously been overseen largely by COSPAR and the rest of the scientific community. It is important to continue the application of existing planetary protection controls and policies as working guidelines for scientific and other users, even as we evaluate how to transition to a more comprehensive set of mandates and regulations covering more than biological and organic contamination. Planetary protection policies, even today, incorporate echoes of the notion of a "period of biological exploration" (set at 50 years), which once suggested that when we know more about planets like Mars and had determined whether extraterrestrial life exists, then we might transition to a more active period of human activity and development. In some ways, this period could function like the moratorium on mineral exploration in Antarctica and provide a suitable cushion of time for a conservative or precautionary approach in the face of scientific uncertainty.

Both the Antarctic and space communities are involved in explorations aimed at understanding extreme environments of interest and importance to humankind. Both communities recognize the need to devise workable plans for environmental stewardship and management that can respond to new challenges posed by human presence, yet which will continue to sustain the resources of these vast areas, now and in the future. It is too early to say what a suitable framework for environmental management in outer space should be, particularly in the face of increasing pressures by diverse user groups. Although these communities continue to protect and sustain science exploration and discovery through existing treaties and policies, we must find ways to allow appropriate technological development and expansion of human activities beyond Earth, presumably borrowing from successful analogues and precedents on Earth. On the basis of lessons learned from the Antarctic experiences, it is clear that the space community has considerable work ahead. Fortunately, the Antarctic Treaty System provides a workable model that may be emulated with some confidence as the exploration of outer space moves ahead.

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NOTES

1. The Treaty on Principles Governing the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies.

2. The Antarctic Treaty was originally signed by 12 parties and now has been ratified by 47 parties, 28 of which are Consultative Parties eligible to vote at ATCMs.

3. The Outer Space Treaty was signed initially by 27 parties; as of 2008, the treaty had been signed and ratified by 98 signatory states (plus 27 additional states not fully ratified).

4. Many other nongovernmental organizations have been granted observer status with the COPUOS in the subsequent decades, including the International Astronautical Federation (IAF), the International Institute of Space Law (IISL), and the International Academy of Astronautics (IAA).

5. Mahlon Kennicutt II, Department of Oceanography, Texas A&M University, personal communication, 2010.

6. For example, questions about the advisability of drilling into pristine subglacial aquatic lakes and environments like Lake Vostok became the subject of extensive discussions by SCAR and the scientific community for over a decade in efforts to minimize harmful contamination. These discussions were undertaken largely within the context of the treaty structure. See NRC (2007) for a historical review of deliberations to develop a sound scientific basis for contamination and cleanliness standards aimed at managing future research and exploration in these sensitive environments.

7. At the time of signing, all 13 were nonspacefaring nations; subsequently, France and India have become launching nations.

8. For information on IADC, see http://www.iadc-online.org/index.cgi?item=home (accessed 18 November 2010).

9. UN Office for Outer Space Affairs, "Space Debris Mitigation Guidelines of COPUOS," (United Nations, Vienna, 2010), http://www.unoosa.org/pdf/publications/st_space_49E.pdf (accessed 18 November 2010).

10. Additional agreements that relate to outer space issues but are not considered part of the treaty include the Nuclear Test Ban Treaty (1963) and the International Telecommunication Union Constitution and Convention (1992) (geostationary orbits) (Williamson, 2006).

11. For historical reviews of planetary protection policies, see NRC (2006: pp. 11–35) and Williamson (2006: pp. 91–148). Depending on the target body and the type of science activities planned for a mission, general planetary protection requirements may include a combination of clean room assembly of parts and spacecraft; cleaning and sterilization of components, subsystems, and whole spacecraft; microbiological reduction and control via use of standard cleaning procedures and assays on hardware; methods to prevent recontamination before launch; calculation of impact probabilities to minimize accidental contamination; and inventories of organic compounds on spacecraft for certain missions categories.

12. See "COSPAR Planetary Protection Policy," http://cosparhq.cnes.fr/Scistr/PPPolicy(20-July-08).pdf (accessed 18 November 2010); and NASA planetary protection Web site, http://www.planetaryprotection.nasa.gov (accessed 18 November 2010).

13. The Moon Treaty, Article 7, par. 3, mentions areas of special scientific interest, but it has never been implemented.

14. Mahlon Kennicutt II, personal communication, March 2010.

15. The interpretation of harmful contamination has been suggested to mean harmful to humans rather than harmful to the environment, especially because Article IX of the Outer Space Treaty mentions causing harmful interference with activities in the peaceful exploration and use of outer space. Some suggest that it relates to avoiding harm to human activities, rather than harm to space environments (Cypser, 1993; Williamson, 2006:160).

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