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Lacuna in the updated planetary protection policy and international law

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ABSTRACT

The Planetary Protection Policy (PPP) has proclaimed the lofty ideal "All the planets, all the time." Originally formulated as Planetary Quarantine Requirements (PQR), the planetary protection policy imposed strict decontamination standards for spacecraft during the initial period of interplanetary exploration. The policy properly has been seen as a work in progress, continuously open to consideration of new data, and subject to periodic re-examination and question with a view toward improvement to better meet the goals of science. This process has led to several revisions of the PPP to improve, simplify and clarify the standards.

In keeping with past practice, the policy was recently revised in light of new data and experience, and the current update is pending before the COSPAR Bureau and Council for review and approval. Specific changes to the PPP add Enceladus to the group of target bodies within the solar system subject to heightened protective measures, and modify the provisions regarding the establishment of special regions on Mars.

These new updates mark another important development in the evolution of the PPP. The PQR and the PPP were based on the precept that outbound spacecraft to celestial bodies should not contaminate natural celestial environments with Earth organisms. Therefore, the policy generally requires that certain missions, particularly to target bodies that could harbor evidence of past or current alien life, take active measures to decontaminate the spacecraft. Nevertheless, recent and proposed missions demonstrate that significant gaps remain in the policy. Instead of enhancing decontamination the policy actually promotes purposely and intentionally enlarging the number of potentially contaminating Earth organisms carried by a spacecraft that could reach celestial bodies, including those bodies which are subject to active decontamination requirements. Thus, even with the new updates, the PPP may not be fully consistent with the international obligations of the Outer Space Treaty, and the continued existence of the entire PPP policy could be in jeopardy.

This article discusses the flight characteristics of two specific missions, one launched and one in development, which are consistent with the PPP but nonetheless pose a substantial risk of biological contamination of celestial bodies. The manner in which the risks can be reduced is identified, and suggestions are made to close some of the gaps that remain in the PPP to comply with international law.

1. Introduction

The 2017 revisions to the COSPAR Planetary Protection Policy added Enceladus to the group of solar system celestial bodies which are subject to heightened protective measures, and modified the provisions regarding establishment of special regions on Mars.[1] We commend the recognition that Enceladus should receive heightened protections, and the clarifications to the criteria for special regions on Mars. The concern remains, however, that these revisions do not go far enough, and that there are significant gaps that continue to exist in the policy that increase the risk of contaminating celestial environments of interest in understanding the process of chemical evolution or the origins of life.

The current revisions illustrate the process of development of the planetary protection policy, which has considered and adapted to increases in scientific knowledge. Numerous issues are emerging which place additional pressure for appropriate and effective measures to protect extraterrestrial environments. There is an expansion of scientific investigations, as more nations achieve the technical competence to conduct missions to celestial bodies. New participants conducting operations in space also include the private sector, which rapidly is developing the expertise to plan and implement a variety of activities ranging from publicity stunts to extensive explorations. In addition,

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[1] COSPAR, 2017. *COSPAR's Planetary Protection Policy*. [pdf] Available at: <https://cosparhq.cnes.fr/sites/default/files/pppolicydecember_2017.pdf> (Accessed 28 February 2019).

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both states and commercial entities are moving toward the establishment of facilities for the extraction and utilization of extraterrestrial resources for scientific or commercial purposes, with tourism being a major focus. While not intended to be exhaustive, the foregoing list raises significant concerns from a planetary protection perspective.[2] Moreover, the current PPP has significant lacuna which allow for the intentional transportation of colonies of extremophile bacteria to our celestial neighbors in an apparent contradiction to the fundamental purposes of the policy.

2. Development of the planetary protection policy

The policy of protecting natural celestial environments was first discussed at an international level prior to Sputnik, at the International Astronautical Congress in Rome in 1956 under the foresight of Andrew Haley. The policy is comprised of both scientific and legal aspects, which have taken parallel but divergent paths. The legal approach has been consistent, in that it established basic standards of protection which have been expanded over time, and which have been incorporated into binding treaty provisions. By contrast, the scientific approach was comprehensive in its initial articulation, but gradually has been transformed to relax and limit the scope of its application.

2.1. Legal regulation

In 1957 the United Nations General Scientific Assembly created the Ad Hoc Committee on the Peaceful Uses of Outer Space (COPUOS), which became a permanent committee the following year.[3] COPUOS operates by consensus, and through its technical and legal sub-committees, examines the issues presented by the movement of mankind into space. The diplomatic community considered the issue of planetary protection early in the space age, but the focus was not on the intrinsic value of preserving pristine natural environments. In March 1962, Chairman Khrushchev wrote to President Kennedy on what he termed “heavenly matters”:

> in carrying out experiments in outer space, no one should create obstacles to the study and use of space for peaceful purposes by other States . . . any experiments in outer space which may hinder the exploration of space by other countries should be the subject of preliminary discussion and of an agreement. . . .[4]

By this letter Khrushchev asserted a right to prior consent over the activities of other states.[5] In addition, he articulated the nexus between protection of celestial environments and the right of states to conduct activities in the exploration and use of space. This right of states to conduct activities was the driving force behind the initial regulation of activities in celestial environments.

On November 22, 1963, COPUOS unanimously approved the Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space, which subsequently was adopted by the United Nations as General Assembly Resolution 1962. Paragraph 6 set forth the first legal planetary protection standard approved by the community of nations:

> In the exploration and use of outer space, States shall be guided by the principle of co-operation and mutual assistance and shall conduct all their activities in outer space with *due regard for the corresponding interests of other States* (emphasis added).

This paragraph also provided for states to engage in consultations if an outer space activity or experiment could cause harmful interference with the activities of other states. COPUOS noted there was urgency to the problem of preventing potentially harmful interference in the peaceful uses of outer space.

The Declaration of Principles, as a General Assembly resolution, is not binding international law, and it was recognized there was a need to elevate the legal principles to the level of a formal treaty. In June 1966, both the U.S. and U.S.S.R. submitted texts of a proposed treaty, and in 1967, COPUOS reached consensus on the text of the Outer Space Treaty.[6] The considerations of planetary protection were expressed in Article IX which provides as follows:

> In the exploration and use of outer space, including the Moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of co-operation and mutual assistance and shall conduct all their activities in outer space, including the Moon and other celestial bodies, *with due regard to the corresponding* interests of all other States Parties to the Treaty. 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 (emphasis added).

The concepts of “due regard” to the interests of other states, and “avoid harmful contamination” are intertwined. However, there is no international consensus on what constitutes harmful contamination or the interests of other states that shall receive due regard that extend beyond harmful contamination. Nevertheless, this article provides for states to engage in consultations in the event an activity may interfere with the activity of other states.

The protection of celestial environments[7] subsequently was addressed in Article 7.1 of the Moon Agreement:

> In exploring and using the moon, States Parties *shall take measures to prevent the disruption of the existing balance of its environment* whether by introducing adverse changes in that environment, by its harmful contamination through the introduction of extra-environmental matter or otherwise. States Parties shall also take measures to avoid harmfully affecting the environment of the earth through the introduction of extraterrestrial matter or otherwise (emphasis added).

The legal obligations in the Moon Agreement are more extensive than the provisions of the Outer Space Treaty. The Moon Agreement prohibits harmful contamination as well as disruption of the existing balance of the lunar environment. Harmful contamination can occur by the introduction of extra-environmental matter as well as by other means, and harmful contamination is one but not the only manner in which the existing balance of the environment can be disrupted.

The Outer Space Treaty was opened for signature in 1967 and entered into force later that same year. It has been signed or ratified by more than 130 states. By comparison, the Moon Agreement has not received the same level of widespread acceptance by the community of nations. The Moon Agreement was opened for signature in 1979, but took five years to receive

[2] *See generally* Hofmann, M., Retberg, P. and Williamson, M., eds. 2010. *Protecting the environment of celestial bodies: the need for policy and guidelines,* Paris: International Academy of Astronautics [hereinafter “IAA Cosmic Study”].

[3] G.A. Res. 1348 (13 December 1958).

[4] Letter dated 21 March 1962 transmitting letter of 20 March 1962 from Chairman Khrushchev to President Kennedy, U.N. Doc. A/AC.105/2, 21 March 1962, p. 5.

[5] There is no indication that the Soviet Union either sought or obtained this consent prior to conducting the Luna missions, including Luna 2, which impacted the Moon on 14 September 1959, and scattered various pennants on the lunar surface.

[6] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *entered into force* 10 October 1967, 610 U.N.T.S. 205 [hereinafter Outer Space Treaty].

[7] Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, *entered into force* 11 July 1984, 1363 U.N.T.S. 3 [hereinafter Moon Agreement]. Article 1.1 provides that the Moon Agreement applies to other celestial bodies in the solar system except to the extent specific legal norms enter into force for any particular bodies.

the requisite number of five ratifications to enter into force in 1984. Since then, thirteen more states have ratified the instrument,[8] and four additional states have signed but not ratified the treaty. Significantly, neither the United States nor Russia has become a party to the treaty. Nevertheless, despite the limited acceptance of the Moon Agreement, it must be considered as a part of the body of international law.

The Moon Agreement, just as all four of the predecessor space treaties,[9] was drafted, negotiated and concluded through the auspices of the United Nations acting through COPUOS. It is a recognized multilateral international instrument that was signed and ratified by its constituent nations according to their local processes. The treaty has entered into force according to its terms and consistent with the Vienna Convention on the Law of Treaties and customary procedures. The Moon Agreement is binding upon all states that have completed a formal ratification process as well as those which have signed the document.[10]

The Preamble to Moon Agreement takes into account that the treaty was formulated, in part, to define and develop the provisions of the Outer Space Treaty and the other space treaties with regard to further progress in the exploration and use of outer space. The text of the treaty was approved by consensus at COPUOS, and was adopted by the General Assembly without a vote. The environmental protection provisions in Article 7 were not contentious issues when considered by COPUOS, and due to the negotiating history can be "taken to express the international will on such matters."[11]

The signatories to the Moon Agreement include space active states such as India, which currently is conducting missions to both the Moon and Mars. Moreover, parties and other signatories to the treaty include member states of ESA, including Belgium, France, the Netherlands, and Austria. These states must ensure that any mission in which they participate is conducted in compliance with their international obligations, including the Moon Agreement.[12]

A state which launches a spacecraft is internationally responsible for the mission, and would have the duty to comply with the COSPAR PPP as well as the international legal obligations incumbent on the state.[13] The approval of more than one state may be necessary where such other states are participating in a mission or experiment, either directly or indirectly through their nationals.

2.2. Evolution of scientific regulation of planetary protection

The PPP was developed in recognition of the need to scrutinize experiments that may introduce contaminants to planetary environments. The COSPAR policy expressly acknowledges that it is promulgated to establish international standards of procedure and to guide compliance with the obligations contained in article IX of the Outer Space Treaty to avoid harmful contamination in the exploration of celestial environments. However, the initial planetary protection policy predates the Outer Space Treaty, and initially was formulated as a means of scientific self-regulation before there was any binding international law.[14] Nevertheless, the COSPAR PPP is limited to the prevention of biological contamination, while the international law is more comprehensive in scope.

The International Council of Scientific Unions formed the Ad Hoc Committee on Contamination by Extraterrestrial Exploration (CETEX), which as early as 1958 considered celestial bodies to be *scientific preserves*. This was followed in 1961 by the formation of the COSPAR Consultive Group on Potentially Harmful Effects of Space Experiments. During this period, the Space Studies Board conducted extensive research and reported to NASA, which developed a probability based standard of protection.[15]

In 1964 the COSPAR Consultive Group published a planetary protection policy, in the form of comprehensive planetary quarantine requirements (PQR), which adopted the probabilistic approach developed by NASA. The PQR established limitations on the probability that a spacecraft could contaminate a celestial environment, and a detailed calculation of specific factors was employed to determine the probability of contamination (P(c)) by any mission.[16] A distinction was made between missions intended to land a craft on a celestial body and missions which were to fly-by the target. Consistent with the NASA parameters, the probability of contamination of a celestial environment by a single viable terrestrial organism aboard any spacecraft intended for planetary landing or atmospheric penetration was to be less than 1×10^{-4}. The probability limit for an accidental planetary impact by an unsterilized fly-by or orbiting spacecraft was to be 3×10^{-5} or less.

These P(c) limits were to apply to the initial period of planetary exploration of ten years, which later was extended. In 1966, COSPAR reduced the P(c) limit to 1×10^{-3}.[17] Nations were allocated specific fractions of the overall probability limits, and the recipient state apportioned its share among the various missions it conducted. The overall P(c) limits were divided as follows:[18]

USA	4.4×10^{-4}
USSR	4.4×10^{-4}
All others	1.2×10^{-4}
Total	1×10^{-3}

The United States apportioned its share among the following missions :[19]

Mariner Mars	7.1×10^{-5}
Pioneer Jupiter	6.4×10^{-5}
Mariner Venus	7×10^{-5}
Viking	2×10^{-4} (divided between the Viking 1 and 2 landers and orbiters)

The probabilistic approach reflected in the PQR was criticized for the inherent difficulty and uncertainty of assigning values to factors which largely were unknown in order to determine the P(c) for a mission. COSPAR changed the application of the quarantine requirements so as to be limited

[8] Armenia became the 18th state party to the Moon Agreement on 19 January 2018.

[9] In addition to the Outer Space Treaty are the Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space, *entered into force* 3 December 1968, 672 UNTS 119; the Convention on International Liability for Damages Caused by Space Objects, *entered into force* 1 September 1972, 961 UNTS 187; and the Convention on Registration of Objects Launched Into Outer Space, *entered into force* 15 September 1976, 1975, 1023 U.N.T.S. 15.

[10] States are obligated to act in a manner that does not defeat the object and purpose of international agreements they have signed pending any required ratification process. Vienna Convention on the Law of Treaties, art. 18, *entered into force* 27 January 1980, 1155 U.N.T.S. 331.

[11] IAA Cosmic Study, *supra* note 2, p. 39, § 5.1.3.3.

[12] Jakhu, R.S. and Pelton, J.N., eds., 2017. *Global space governance: an international study*. Cham: Springer, pp. 389, 392 [hereinafter referred to as "GSG Study"].

[13] Outer Space Treaty, arts. VI, VII; *see also* Registration Convention.

[14] For a detailed history of the development of the planetary protection policy, *see generally* Meltzer, M., 2012. *When biospheres collide: a history of NASA's planetary protection programs*. [e-book] Washington, D.C.: U.S. Government Printing Office. Available through: NASA website <http://www.nasa.gov/connect/ebooks/when_biospheres_collide_detail.html> (Accessed 1 March 2019).

[15] *Id.* pp. 78-81.

[16] The calculations considered factors including the initial microbial burden at launch, and the probabilities of such microbes surviving the launch, transit, arrival at the target body, and survival and replication in the celestial environment.

[17] Meltzer, *supra* note 14, p. 82.

[18] *Id.* at p. 84.

[19] NASA, 1973. *Specification sheet for U.S. planetary quarantine program, Control No. 005*. (Prepared for COSPAR Meeting Constanz, FRG, May 1973).

to Mars and other planets *deemed important* in the search for extraterrestrial life. Subsequent revisions to the PPP occurred in 1978 when the probability of growth of terrestrial organisms in extraterrestrial environments was deemed to be sufficiently low so as to negate the necessity of engaging in any active decontamination techniques for most celestial bodies.

These modifications transformed planetary protection from quarantine requirements as the norm to the exception. Under the revised PPP, active decontamination techniques would be required only for certain mission type and target body combinations. This approach has continued with subsequent modifications to the policy. Beginning in the 1980′s the policy provided that missions to target bodies deemed not to be of biological interest in the search for life, including the Moon, did not require any planetary protection techniques to be utilized, nor any specific documentation. Revisions in the 1990′s tied utilization of active planetary protection controls to whether mission objectives included life-detection experiments.

The current policy defines five categories of target bodies. The Moon is classified as Category II, which is comprised of celestial bodies of "significant interest relative to the process of chemical evolution and the origin of life, but where there is only a remote chance that contamination carried by a spacecraft could compromise future investigations." The term "remote" in this context, "implies the absence of environments where terrestrial organisms could ***survive and replicate*** . . . (emphasis added)." The current PPP does not mandate that any active decontamination techniques be applied to lunar spacecraft, rather only simple documentation is required, consisting of:

> a short planetary protection plan . . . primarily to outline intended or potential impact targets, brief Pre- and Post-launch analyses detailing impact strategies, and a Post encounter and End-of-Mission Report which will provide the location of impact if such an event occurs.

The development of environmental regulation in the law of outer space has been to expand the protections afforded to celestial bodies, and extends beyond matters of biological contamination. The historical trend of the revisions to the scientific policy for planetary protection generally has operated to reduce the number of missions which were required to be subject to active decontamination techniques. An exception to this trend is the introduction of the classification of "special regions" on Mars, which are defined based on temperature and the presence of water. Special regions are subject to a higher level of protection, even where the spacecraft is not intended to conduct life detection experiments. Certain other bodies, namely Europa, and now Enceladus, also are deemed worthy of special protection.

Despite the current revisions to strengthen the protections for Enceladus and special regions, there have been reports of a growing movement to modify the PPP to relax the protective standards, including consideration of acceptable levels of contamination for exploration of several of the most habitable spots on Mars.[20] Nevertheless, further modifications to expand protections may need to be considered in the near future to respond to advances in scientific knowledge. Eight potential celestial oceans have been identified where evidence of alien life may exist: Enceladus, Titan, Europa, Ganymede, Triton, Dione, Calisto, and Pluto. Moreover, there are reports that Venus may have been a habitable planet for much of the history of the solar system, and may harbor life today in the clouds.[21] In addition, ice has been discovered in the craters of Mercury.[22] These discoveries all indicate that Mars is only one of many potential environments which is of interest in the understanding of the process of chemical evolution or the origin of life in the solar system. If it is possible that life could have been present, or may be present today, in environments heretofore believed to be completely inhospitable, even antithetical to life, then it is not possible to rule out any celestial body as a potential home to past or present living organisms until specific and thorough scientific investigations of such body are conducted.

The concerns underlying the PPP are directed toward life as we know it, and that is as it must be, as that is our frame of reference. Nevertheless, extremophiles have expanded the definition of life and our understanding of the extreme conditions in which life may not just exist, but may flourish. The habitable zone is not necessarily limited to the biosphere of Goldilocks where it is not too hot and not too cold, but can extend to almost anywhere in the Solar System. The PPP must anticipate and be prepared for an encounter with life as we do not know it, or that we may not even be able to recognize.

Where active decontamination techniques are implemented, the focus on planetary protection has been to reduce the number of potentially contaminating organisms carried by a spacecraft. Two missions, one flown and one planned, have taken the exact opposite approach, and are designed to intentionally carry payloads comprised of colonies of bacteria to celestial bodies. However, both of these missions can be conducted without violating the PPP as it currently exists.

3. Planetary society LIFE project

The Planetary Society conceived and implemented the Living Interplanetary Flight Experiment - LIFE Project - which was incorporated into the Russian Phobos-Grunt interplanetary sample return mission.[23] The Phobos-Grunt mission was conducted by the Russian Space Agency, and was intended to land a spacecraft on Phobos, collect samples of dirt and rocks from its surface, and return the samples to Earth. The mission would include 34 months in space. The purpose of the Planetary Society's LIFE Project was to investigate the transpermia hypothesis, that is, whether a living organism might survive a journey through space to Earth inside a meteorite. The Project would seek to answer the question "Can life naturally transfer from planet to planet?"

The Planetary Society created a specially designed "biomodule" to hold 11 types of organisms carried on the Phobos-Grunt lander. Inside along with a larger soil sample container were thirty tubes, each measuring three millimeters across. Each tube contained millions of non-pathogenic organisms from all three domains of life: bacteria, archaea, and eukaryota. These organisms ranged from the "mundane" to the "bizarre," and included extremophiles that could survive or even thrive in environments that are toxic for other complex organisms. In addition, these extremophiles were resistant to radiation, desiccation, salt, and/or heat.

The Planetary Society conducted vibration and impact tests on the biomodule, and reported the results on its website. An air cannon was used to shoot a projectile of rolled-up corkboard and duct tape into a foam target, with the LIFE Project biomodule attached to the tip of projectile. The projectile impacted the target at more than 150 ft/sec. According to the report, "***miracle of miracles*** – the capsules survived intact! (emphasis added)"[24]

[20] See Foust, J., 2018. New NASA planetary protection officer seeks greater cooperation with human and commercial missions. *Space News.* [online] 26 February. Available at: <https://spacenews.com/new-nasa-planetary-protection-officer-seeks-greater-cooperation-with-human-and-commercial-missions/> (Accessed 6 February 2019).

[21] Wall, M., 2018. Life on Venus? Why its not an absurd thought. *space.com*. [online] 16 April <https://www.space.com/40304-venus-clouds-alien-life-search.html> (Accessed 6 February 2019); *see also* NASA, 2016. *NASA climate modeling suggests Venus may have been habitable*. [online] Available through: NASA website <https://www.nasa.gov/feature/goddard/2016/nasa-climate-modeling-suggests-venus-may-have-been-habitable> (Accessed 6 February 2019).

[22] NASA, 2012. *MESSENGER finds new evidence for water ice at Mercury's poles*. [online] Available through: NASA website <https://www.nasa.gov/mission_pages/messenger/media/PressConf20121129.html> (Accessed 6 February 2019).

[23] Except as otherwise noted, the information in the text was obtained from the Planetary Society websites, especially Planetary Society, 2019. <http://planetary.org/explore/projects/life/> (Accessed 1 March 2019).

[24] Gelfand, M., 2008. *LIFE Experiment module passes vibration and impact tests.* [online] Available through: Planetary Society website <http://www.planetary.org/blogs/guest-blogs/life_20081015.html> (Accessed 1 March 2019).

The Phobos-Grunt lander was launched on a Zenit rocket from the Baikonur Cosmodrome on November 8, 2011. In addition to the return capsule with the LIFE Project biomodule were two similar containers from the Russian Institute of Biological Medical Problems with different micro-organisms, and a Chinese instrument payload, Yinghuo-1. Troubles became apparent a few hours after launch when the spacecraft failed to fire thrusters to take it out of Earth orbit, and it fell back into the atmosphere on January 15, 2012, and disintegrated.

A post-mission report was posted by the Planetary Society on February 6, 2012.[25] The Planetary Society said that Phobos-Grunt was doomed before it launched. They cited cheap parts, including non-space qualified parts that were used in some electronics circuits; design shortcomings; and lack of pre-flight testing. The Planetary Society acknowledged and emphasized the "unforgiving" nature of space exploration, and stated that the system was designed so that the spacecraft was out of communications range after launch, and that the mission personnel had no idea how the spacecraft was behaving. According to the Planetary Society, the Russians repeated the error that had doomed their Mars-96 mission.

4. Space4Life radio shield experiment

The "Radio Shield" experiment was designed by the Italian Space4Life group to test the effectiveness and efficiency of using biomass as a radiation shield.[26] According to the designers, biomass potentially could provide better shielding against radiation than lead, and at a considerable savings in weight. The experiment was accepted for inclusion as a payload in the Team Indus lunar spacecraft which was competing for the Google Lunar X Prize. The spacecraft was to be launched on an Indian rocket.

The biomass was to be comprised of a colony of cyanobacteria, which was described as "primitive photosynthetic prokaryotes, that are able to resist extremely harsh conditions." The mission plan was for the Team Indus lunar spacecraft to carry a hermetically sealed cannister containing the bacteria. The cannister was designed to provide the most optimal living conditions for the bacteria, and the mission planners were considering the possibility of placing the bacteria in hibernation during the trip to the Moon.

The Team Indus spacecraft was to transport an additional quantity of cyanobacteria for a second experiment to be conducted by Lab2Moon, called ZΩI. This experiment was to test for photosynthesis. The Lunar X Prize competition expired before the mission could be conducted, and with the end of the Lunar X Prize the Team Indus launch contract was cancelled.

5. New space challenges to planetary protection

The gaps that exist within the PPP are illustrated by the missions of two New Space companies: the proposed Moon Express MX-1E Lunar Scout, and the recently launched SpaceX Falcon 9 Heavy carrying a Tesla Roadster as a mass simulator.[27] The MX-1E Lunar Scout is intended to soft land on the moon, and to move around on the surface by conducting a series of propulsive "hops." The Tesla automobile was placed in a precessing Earth-Mars elliptical orbit around the sun. Both missions have received authorization from the U.S. government.

The MX-E1 spacecraft will carry several payloads, including "the International Lunar Observatory, 'MoonLight' by the INFN National Laboratories of Frascati and the University of Maryland, and a 'Celestis memorial flight.'"[28] Authorization to conduct the mission was sought from the U.S. government through the Federal Aviation Administration (FAA). The licensing process requires applicants like Moon Express to make certain disclosures, such as the physical dimensions and weight of a payload and intended payload operations. The required disclosures also include the identification of any hazardous materials. The regulations set out several pages of tables listing hazardous materials, which are primarily directed to chemical contaminants. Radioactive materials are separately referenced, and bacteria and microbes are not mentioned.[29] The FAA conducted an interagency review and determined that the launch of the payload would "not jeopardize public health and safety, safety of property, U.S. national security or foreign policy interests, or international obligations of the United States."[30]

The SpaceX Falcon 9 Heavy rocket was launched on February 6, 2018, just four days after receiving authorization from the U.S. government. The original application for a license had a generally defined payload and orbit. Although the request for authorization had been submitted more than a year earlier, SpaceX announced two months before the planned launch that the payload would be the Tesla Roadster, and the destination would be Mars orbit. NASA raised concerns about potential planetary protection, and SpaceX was requested to provide information on how it would address these matters. SpaceX responded that the mission did not include a flyby, orbiter, or lander for a target body. NASA informed the FAA that while it could not confirm the probability of an impact on Mars, SpaceX's information indicated that the mission was consistent with international guidelines on planetary protection. That is, since the spacecraft would not encounter another planetary body, it was not subject to the NASA or COSPAR planetary protection policy.[31]

6. Policy considerations

Experiments such as Space4Life biomass Radio Shield, and the Planetary Society Phobos-Grunt LIFE Project, present questions regarding the propriety of introducing a colony of living bacteria into or within the proximity of a natural celestial environment, especially where such celestial environment may contain water ice or otherwise is of significant interest relative to understanding the process of chemical evolution or the origin of life. The Phobos-Grunt mission was launched with the tacit if not express approval of three states, namely Russia, the U.S., and China, each of which apparently was satisfied that it was permissible in accordance with the current COSPAR Planetary Protection Policy to send a colony of extremophile bacteria to Phobos at an orbit of 6000 km (3700 miles) above the surface of Mars. Similarly, although the Team Indus spacecraft did not complete the authorization process prior to the cancellation of the Google Lunar X Prize, the PPP would not seem to prohibit the Space4Life Radio Shield experiment. This conclusion is bolstered by the fact that unlike Mars, which is of

[25] Friedman, L.D., 2012. *Phobos-Grunt failure report released*. Available through: Planetary Society website <http://www.planetary.org/blogs/guest-blogs/lou-friedman/3361.html> (Accessed 1 March 2019).

[26] The information in the text was obtained from the Space4Life website. Space4Life, 2017. *Facebook page*. [online] Available at: <https://www.facebook.com/TeamSpace4Life/> (last accessed 1 March 2019).

[27] SpaceX, 2018. *Falcon Heavy demonstration mission.* [press release] Available at: <https://www.spacex.com/sites/spacex/files/falconheavypresskit_v1.pdf> (Accessed 6 February 2019).

[28] Moon Express, 2018. *Moon Express*. [online] Available through: Moon Express website <http://moonexpress.com/expeditions/> (Accessed 1 March 2019).

[29] 14 CFR §§ 401.5, 415.59; 49 CFR § 172.101.

[30] Federal Aviation Administration, 2016. *Fact Sheet – Moon Express payload review determination.* [online] 3 August. Available at: <https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=20595> (Accessed February 6, 2019).

[31] Statement issued by NASA's Office of Planetary Protection, *reprinted in* National Academies of Sciences, Engineering and Medicine, 2018. Review and assessment of planetary protection policy. Washington, D.C.: The National Academies Press, Appendix H, Interagency deliberations concerning initial launch of the Falcon 9 Heavy, development processes [hereinafter referred to as "National Academies Report"]. [online] Available at: <https://www.nap.edu/read/25172/chapter/17> (Accessed 1 March 2019).

direct interest in the search for extraterrestrial life or the precursors thereof, the PPP classifies the Moon as a Category II target body, and considers the presence of biological materials to be incidental to the mission spacecraft, and not as an integral part thereof. Phobos is not expressly listed in any of the COSPAR categories, but would be classified either as Category I or Category II. Category I bodies are not entitled to any protection and no planetary protection requirements are imposed by the PPP.[32]

The emergence of New Space companies conducting of commercial activities on celestial bodies raises broad challenges to environmental protection, from robotic landing craft to resource extraction to tourism. The risk of contamination by a scientific mission is deemed to be outweighed by the data sought to be obtained, which will inure to the benefit of all humanity. The goal sought by a private venture, however, is the opportunity to generate a profit that will inure to the benefit of a small group of investors. Although the private sector can make significant advances in creating and developing innovative and economically efficient solutions to technical problems, which can include spacecraft bioburden reduction and decontamination techniques, this is only one factor to be considered for any particular activity, and not every commercial mission will push the envelope of understanding and capability. The challenges to planetary protection carry an element of urgency with the announcements by SpaceX of plans to send humans around the moon and to Mars, and by Moon Express to send the Lunar Outpost spacecraft to the south pole to prospect for water.

The purpose of the COSPAR PPP is to preserve scientific integrity in the search for evidence of extraterrestrial life. Toward this end, the PPP has established guidelines and standards of conduct which are the minimum requirements from a scientific perspective. The COSPAR PPP focus is on biological contamination, which is only one aspect of the protection of celestial environments. The obligations of states in international law in regard to protecting and preserving natural celestial environments extend beyond the COSPAR policy, and the absence of a violation of the COSPAR policy does not necessarily mean that a state has complied with the applicable legal standards.

States must consider not just the legal standards of the Outer Space Treaty and the Moon Agreement but also must determine as a matter of policy whether a particular mission or experiment should be authorized and conducted. This determination requires a balancing of the benefits sought to be attained by the mission with the risk of potential contamination to the natural celestial environment.

Articles IX of the Outer Space Treaty, and 7.1 of the Moon Agreement, may prohibit the intentional placement of a cannister containing cyanobacteria on the lunar surface. The presence of such a cannister could be considered as harmful contamination by the introduction of extra-environmental matter or otherwise a disruption to the existing balance of the environment of the Moon. Similarly, sending a biomodule filled with extremophile bacteria in proximity to Mars or another celestial body important for the search for life carries a significant risk of causing environmental disruption by harmful contamination or the introduction of extra-environmental matter, or otherwise interfering with the activities of other states *in situ*. Nevertheless, to the extent that all of the bacteria are successfully contained within their enclosures it can be asserted that the activity does not contaminate or disrupt the natural celestial environment.

There are several factors which favor approval of missions such as the LIFE Project or Space4Life Radio Shield: first and foremost is that the experiments could lead to important scientific discoveries. Ultimately, this is the fundamental justification to conduct any experiment. Second, conducting the experiments is an exercise of the right of states to explore and use outer space, the Moon and other celestial bodies recognized by article I of the Outer Space Treaty. Third, the experiments are not expressly prohibited by the current COSPAR Planetary Protection Policy, and fourth, state practice has permitted this type of experiment, in that the Phobos-Grunt mission launched with the participation of three states and without any formal objections being raised at the international level. Finally, the experiments do not explicitly contravene the imprecise standards of article IX of the Outer Space Treaty nor article 7.1 of the Moon Agreement.

Countervailing factors which do not favor approving the missions include that while attainment of scientific knowledge is at the heart of the LIFE Project and Space4Life Radio Shield experiments, that is not a sufficient justification, in and of itself, for the missions to be approved and conducted. Second, the right of states to explore and use outer space is not unlimited, and missions must consider and give due regard to the rights of other states to explore and use a target celestial body. States also must conduct activities so as to prevent the harmful contamination or other disruption of the natural celestial environments.

Third, the COSPAR policy establishes only a minimum baseline standard of conduct, and for Category II target bodies, including the Moon, requires only minimal bare-bones documentation. The policy does not impose any obligation to employ decontamination or bioburden reduction techniques to the spacecraft whatsoever. The Moon and other bodies are classified as Category II based in large part on the presumption that there is the absence of an environment where terrestrial organisms could survive and replicate. The Space4Life Radio Shield experiment was specifically intended to transport a live colony of bacteria that was extremely resistant, able to survive harsh conditions, and capable of explosive replication. The colony was to be housed in a habitat precisely designed to promote survival and stimulate that explosive growth. The LIFE Project cannister also was designed to transport extremely resistant bacteria in a hospitable and nurturing habitat. It is known from the camera recovered from the Surveyor lunar lander and returned to Earth that Streptococcus mitis bacteria potentially can survive in the lunar environment without any special protections.[33] Further, the heat resistant microbe Microbispora survived the ill-fated re-entry of Columbia charred but intact.[34]

The rationale for classifying a body as Category II - that there is only a remote chance for terrestrial organisms to survive and replicate - is completely inapplicable and inapposite where experiments specifically are designed to ensure the survival and replication of a colony of bacteria in that environment. Moreover, the PPP classifications are based on the physical properties of the body itself, that is, whether the body is of interest *vis-a vis* understanding the process of chemical evolution or the origin of life. However, the planetary protection concerns of missions such as the LIFE Project are not limited to the target body of Phobos, but must also consider that the experiment was to be conducted within 6000 km of the surface of Mars if everything went as planned.

Missions which target a Category II body and which also orbit, fly by, or otherwise encounter another celestial object with a higher PPP categorization are subject to certain requirements applicable to the latter body. The outbound segment of Phobos-Grunt was classified as a Category III mission and thereby was subject to impact probability limitations that apply to Mars. Specifically, the mission was required to demonstrate that it had a 99% probability of avoiding impact with Mars for 20 years, and a 95% probability of avoiding impact with the planet for 50 years. The calculations resulted in a probability of successfully avoiding impact of 99.79%.[35]

The impact probability analysis conducted by the Russians took a

[32] Babb, R.J., Erb, H. and Howard, D., 2018. Cost reduction solutions in regard to planetary protection for commercial companies. In: *69th International Astronautical Congress*, Bremen, Germany, 1–5 October 2018. IAF Paper No. IAC-18-F1.2.3. Paris: International Astronautical Federation.

[33] NASA, 1998. *Earth microbes on the Moon.* [online] Available through: NASA website <https://science.nasa.gov/science-news/science-at-nasa/1998/ast01sep98_1/> (Accessed 1 March 2019).

[34] McLeana, R.J.C., Welsha, A.K. and Casasanto, V.A., 2006. Microbial survival in space shuttle crash, *Icarus*, 181(1), pp. 323-325.

[35] Conley, C.A., 2011. *Planetary protection for Phobos-Grunt.* [pdf] Powerpoint presentation, 11 May. Available at: <https://smd-prod.s3.amazonaws.com/science-red/s3fs-public/atoms/files/Conley-Phobos-GruntPP_1_TAGGED.pdf> (Accessed 22 February 2019). The sample return segment of the mission was classified as Category V, Restricted Earth Return. *Id*.

different form than that used by NASA or ESA,[36] which could cast some doubt on its accuracy. In addition, the impact probabilities were calculated based on an "extensive assessment of reliability for critical hardware components"[37] which, according to the Planetary Society, were substandard and not space rated. Furthermore, the impact probability limits were derived with reference to spacecraft which may not necessarily have been required to actively reduce the number of bacteria they carried, but not one such as Phobos-Grunt that intentionally was loaded with an increased bioburden housed in a cannister designed to enhance and promote the survivability and replication of that bioburden. This housing was meant to protect and shield the bacteria, which could increase probability of surviving atmospheric re-entry and accidental impact with the Martian surface.

Numerous technological challenges are presented by any mission, all of which carry a risk of failure which could result in the intentional landing of a spacecraft at a location other than originally intended, or the unintentional impact of spacecraft at almost any location on a celestial body. Sample return missions, such as Phobos-Grunt, are among most complex conducted to date. Clearly, the mission carried a significant risk that it would not operate flawlessly on arrival, and every possible malfunction during rendevous, landing, take-off from the surface and transit from Phobos carried a corresponding risk of possible impact or other contamination of Mars. The reasons cited by the Planetary Society for the failure of the Phobos-Grunt mission are particularly troublesome from a planetary protection perspective. Poor oversight, inadequate systems communications, lack of quality control, and the use of non-space rated substandard parts all present unacceptable procedures and processes for conducting space missions of any type.

There is a poor track record for interplanetary spacecraft even if not intended to return a sample of extraterrestrial material. Approximately half of all missions to Mars have ended in failure. The Russians have been particularly unsuccessful in conducting missions to the red planet, and their few spacecraft which actually reached Mars failed shortly after arrival.[38] Missions conducted by other launch authorities which were unsuccessful include:

Mars Observer entered Martian orbit in 1983, when contact was lost. NASA acknowledged that debris from the spacecraft could have inadvertently impacted the surface of Mars.

Mars Climate Orbiter arrived at Mars in 1999 when contact was lost. According to NASA it was likely the spacecraft inadvertently entered the atmosphere.

Mars Polar Lander lost contact with NASA upon arrival at Mars in December 1999.

The Japanese **Nozomi, or Planet B** spacecraft lost contact as it approached Mars in 2003. It is believed to have entered solar orbit, but the exact location and fate are unknown.

Mars Express was launched by the European Space Agency in 2003, and contact with the lander "Beagle" was lost on deployment into the Martian atmosphere.

Ultimately the central planetary protection policy consideration is an assessment of whether the scientific results that are sought to be obtained are outweighed by the risks presented by the experiment. It is not just the direct risks that must be assessed assuming the mission successfully performs within intended parameters, but also the indirect risks which can result from accident or other unplanned or unintentional events and circumstances. Thus, in the case of activities such as the LIFE Project experiment, the review and analysis from a planetary protection perspective should consider not just whether the mission plan is permissible in regard to the environment of Phobos but also whether the mission also poses any risk of contamination of Mars.

An evaluation must be made as to whether the scientific results sought by a mission or experiment can be obtained only by an activity conducted *in situ* on the Moon or other celestial body, or whether the results can be obtained by either an Earth-based experiment or an off-Earth location that does not present a significant risk of contaminating a celestial environment. For both the Space4Life Radio Shield and the LIFE Project the essence of the experiment was the long term exposure of the bacteria to the environment of outer space, which could have been at any distant location. Any exposure to the environment of Phobos or the Moon largely would have been coincidental, irrelevant, and superfluous.

The Planetary Society's LIFE Project squarely presents the issue of whether the planetary protection policy should countenance the intentional introduction of potentially contaminating bacteria or other bioload into or in proximity to Mars. A crewed mission to Mars such as proposed by SpaceX would present further concerns from a planetary protection perspective, as the life support and other systems, as well as the crew members themselves, inevitably will carry innumerable quantities of bacteria and other potential contaminants to the landing site and possibly beyond. The COSPAR policy articulates specific guidelines for human missions to Mars, and recognizes that it will not be possible to conduct all human-associated processes and mission operations within entirely closed systems. The policy concludes:

> Planetary protection requirements for initial human missions should be based on a conservative approach consistent with a lack of knowledge of martian environments and possible life, as well as the performance of human support systems in those environments. Planetary protection requirements for later missions should not be relaxed without scientific review, justification, and consensus.

The policy states that there should not be any crew access to an uncharacterized Martian site prior to evaluation by robotic precursors. In addition to the expansion of understanding of the Martian environment, both the human associated contamination and the capabilities of earth source organisms need to be understood prior to crew access.[39]

The Falcon 9 Heavy flight illustrates that transportation vehicles that are not intended to operate in celestial environments nevertheless may pose a risk of contamination in the event of impact with a celestial body. The COSPAR PPP recognizes this risk in relation to Mars, and provides that the probability of impact on Mars by any part of a launch vehicle "shall be $\leq 1 \times 10^{-4}$ for a time period of 50 years after launch." NASA has incorporated this directive for "all launch vehicle elements leaving Earth orbit. . . ."[40] In addition, "Cruise stages, flyby, and orbiter spacecraft shall meet a probability of impact of 0.99 for twenty years after launch and a probability of impact of 0.95 for the period 20–50 years after launch."[41] These are the same impact probability limits that Phobos-Grunt was said to have met. Spacecraft that do not meet these parameters are required to be decontaminated to reduce the total bioburden to a specified level.[42]

Activities on Mars and other celestial bodies, including the Lunar Outpost mission of Moon Express, can impact the scientific community in two direct ways: one is by disturbing an area of interest; and the second is by a discovery of something of interest. Various surface and subsurface activities, including *in situ* resource utilization, could destroy unique and irreplaceable scientific evidence not just related to the origins of life. In the event something of interest is found, the significance may not be recognized, and even if it is the discovery may not be adequately preserved and the vicinity of the discovery protected

[36] *Id.*
[37] *Id.*
[38] List of Missions to Mars, 2019. *Wikipedia: The Free Encyclopedia*. [online] Available at: <https://en.wikipedia.org/wiki/List_of_missions_to_Mars> (Accessed 2 March 2019).
[39] GSG Study, *supra* note 12, p. 448.
[40] NASA Interim Directive 8020.109A, § 5.3.1.1.
[41] *Id.* § 5.3.1.2.
[42] *Id.* § 5.3.1.4.

from further intrusion pending scientific investigation. This is a matter of concern not just to the scientific community but to all states and the public as well as other stakeholders. The need for cooperation and coordination between scientific concerns and private interests is apparent.

The need to preserve a finding of interest is of the highest importance in the event a private mission was to discover evidence of alien life. In such event, the commercial operations should be immediately suspended and the authorizing state notified.[43] The Moon Agreement provides in Article 5.3 that the Secretary-General, the public and the international scientific community shall be promptly informed of the discovery of any indication of organic life. Regulations requiring immediate notification and suspension of activities should apply not just to the discovery of living organisms, but also to any indication of past life or the precursors thereof lest such evidence be irretrievably lost to science. A commercial entity that finds alien life should not be able assert exclusive proprietary rights to the discovery. This principle has been codified in the U.S. Commercial Space Launch Competitiveness Act of 2015 which recognizes certain property rights in a "space resource" which is specifically defined to be abiotic.[44] Thus, a private enterprise would not be able to claim ownership of any living organisms that may be present in minerals or ice extracted from a celestial body.[45]

The landing of any craft on the Moon will inevitably cause some disturbance or change to the lunar surface. States have the right to conduct activities on the Moon and other celestial bodies, therefore the mere landing and presence on the surface of an object does not constitute harmful contamination under Article IX of the Outer Space Treaty, nor disruption of the natural environment pursuant to Article 7 of the Moon Agreement. The activities conducted by states to date on the Moon have left indelible and iconic impressions on the surface, and future missions will add to these marks, and possibly obliterate important scientific evidence. As noted by Rummel & Conley, "It is one thing to process illminite taken from the surface (out of the view of Earth) for oxygen and quite another to destroy the impact record of the Earth-Moon system written in the volatiles in the permanently shaded craters of the lunar poles, without reading it first!"[46]

It is uncertain where the Lunar Scout will make its initial landing, and it is even more uncertain where the relocation "hops" will take spacecraft, as much will depend upon the successful operation of the propulsion and other systems after each jump. As a fundamental question, can private entities be prohibited from conducting activities in areas based on scientific considerations, such as special regions on Mars, or a radio-quiet crater on the lunar far side for SETI?[47] Conversely, can a private entity claim an area off limits to science? Article I of the Outer Space Treaty provides that states have the right to explore and use all areas of celestial bodies. The environmental provisions in Article IX are a limitation on the rights of states expressed in Article I.[48] This does not mean, however, that a state can unilaterally invoke Article IX and declare an area off limits to all other states for commercial or any other purpose. Such a declaration would be tantamount to a claim of national appropriation over the area, which is prohibited by Article II.

In the event that a state believed that an area of the Moon or other celestial body had special scientific interest such that the activities of commercial ventures therein should be limited or restricted, notification could be given to the Secretary-General of the UN pursuant to Article 7.3 of the Moon Agreement. In such circumstance, the Moon Agreement provides that consideration shall be given to the designation of the area as an "international scientific preserve" with "special protective arrangements to be agreed upon in consultation with the competent bodies of the United Nations." The PPP designation of an area as a special region is specifically related to the search for evidence of indigenous life, and not for the protection of the celestial environment for other purposes. Thus, the designation of an area as an international scientific preserve under the Moon Agreement is not the same and is not limited to the purposes of a special region as provided in the PPP.

In view of the scientific motivation for making a notification to the Secretary-General under the circumstances expressed in Article 7.3, it would not be required that the notifying state be a party to the Moon Agreement. Rather, any state should be able to make this notification as a matter of pre-emptory norm, *de lege lata, de lege ferenda*. Moreover, pending any consultative procedures within the UN, states could voluntarily place a moratorium on their authorization of non-scientific activities within the potential international preserve, and seek agreement with other states on interim protective arrangements. In the event a state became aware that a proposed commercial activity could cause interference with the activities of other states, it could request consultations with the state obligated to authorize and supervise the commercial activity. If the states were parties to the Moon Agreement, such consultations would be compulsory under Article 15.2.

There are considerations of history and aesthetics in addition to scientific concerns that can be negatively impacted by disturbing locations such as the Apollo landing sites or unique formations, vistas, and other special areas on celestial bodies.[49] It is noteworthy that in 2010 the California Department of Parks and Recreation received a nomination to add 106 objects located at Apollo 11 Tranquility Base to the Register of Historic Resources.[50] The delivery of the Celestis memorial payload to the lunar surface presents an additional set of policy concerns. According to the Celestis web site, the payload is comprised of cremated human remains and DNA samples, and more than 30 customers have each paid at least $12,500 to send this corporeal material to the Moon.[51] Although the payload itself is presumed to not pose a significant risk of contamination or environmental disruption, it nevertheless must be questioned from philosophical, ethical, moral, and other perspectives whether the Moon should be turned into a cemetery run for profit. If containers with cremated human remains are permissible, why not entire bodies, and what about the ashes of family pets, or the embalmed pets themselves, or favorite possessions no matter the size? And what about the urns, containers, receptacles, or markers or monuments? How much of the Moon should be set aside for vanity purposes? If it is only a matter of the ability to afford the cost, then wealthy individuals and corporations will be able to indulge virtually any whim and the Moon will become a preferred playground of narcissism to the detriment of humanity. The present generation has an obligation to be mindful that the exploration and use of outer space, including the Moon and other celestial bodies, is the province of all mankind,[52] and that the rights of future generations must be respected.[53]

[43] GSG Study, *supra* note 12, p. 406.

[44] § 402(a).

[45] GSG Study, *supra* note 12, p. 406.

[46] Rummel, J.D. and Conley, C., 2014. *Planetary protection considerations and constraints in commercial spaceflight beyond Earth.* In: *65th International Astronautical Congress*, Toronto, Canada, 29 September–3 October 2014. IAF Paper No. IAC-14-A3.1.4. Paris: International Astronautical Federation.

[47] See Maccone, C., ed. *Protected antipode circle on lunar farside.* Paris: International Academy of Astronautics (in preparation).

[48] Marchisio, S., 2009. *Article IX*. In: Hobe, S., Schmidt-Tedd, B. and Schrogl, K-U., eds. 2009. I *Cologne commentary on space law.* Cologne: Carl Heymanns Verlag. § 23 p. 175 [hereinafter referred to as "I CoCoSL"].

[49] IAA Cosmic Study, *supra* note 2, pp. 31-34.

[50] State of California, Office of Historic Preservation, 2010. *Actions taken.* [online] Available at: <http://ohp.parks.ca.gov/?page_id=26509> (Accessed 2 March 2019).

[51] Celestis memorial spaceflights, 2019. [online] Available at: Celestis website <https://www.celestis.com/launch-schedule/luna-02-flight/participants?page=1> (Accessed 2 March 2019); and https://www.celestis.com/experiences-pricing/#service-Luna (Accessed 6 February 2019).

[52] Outer Space Treaty, art. I.

[53] Moon Agreement, art. 4.1 ("due regard shall be paid to the interests of present and future generations"); *see also* IAA Cosmic Study, *supra* note 2, pp. 20-23.

The COSPAR PPP imposes minimal requirements on missions to the moon such as the Lunar Scout. As a Category II target body, the moon is subject only to documentation requirements, and neither the Lunar Scout spacecraft nor the payloads it carries are subject to mandated active microbial decontamination. The approval of the MX-E1 license established a precedent that COSPAR and NASA planetary protection considerations do not impose a significant burden on missions to the moon regarding potential contamination from biological sources.[54] However, the precedent may be stretched too far if it is applied to missions to craters which may contain water at the lunar poles. Nevertheless, the example of Lunar Scout will be cited by commercial missions to other Category II bodies, as well as Category I objects, thereby encompassing both undifferentiated, metamorphosed asteroids and carbonaceous chondrite asteroids. However, missions seeking to return materials from asteroids, or the entire asteroid itself, will require detailed examination, and under the COSPAR PPP may be classified as restricted or unrestricted Earth return based on the "best multidisciplinary scientific advice, using the framework presented in the 1998 report of the U.S. National Research Council's Space Studies Board entitled, Evaluating the Biological Potential in Samples Returned from Planetary Satellites and Small Solar System Bodies: Framework for Decision Making."

The U.S. National Academies of Sciences, Engineering, and Medicine recently issued a report which specifically recommended that "Planetary protection policies and requirements for forward and back contamination should apply equally to both government-sponsored and private-sector missions to Mars."[55] Public agencies, such as NASA and ESA, have implemented mandatory procedures consistent with the COSPAR PPP for missions conducted with government involvement. Article VI of the Outer Space Treaty makes states internationally responsible for national activities in space. National activities are defined by this same article to include activities conducted by both governmental as well as non-governmental entities. This article further obligates states to authorize and continuously supervise the activities of their non-governmental entities in space. Many countries have implemented licensing regimes to perform such authorization and supervision functions.

The national licensing regimes vary from country to country, and each state has its specific procedural and substantive requirements. All licensing regimes review requests for authorization to conduct private missions based on several criteria, including conflicts with the legal obligations of the state.[56] The COSPAR policy is not contained within any treaty or formal agreement between governments, and does not have the force of binding international law. However, governmental agencies have voluntarily adopted policies based on and consistent with the COSPAR standards. Nevertheless, national licensing regimes typically have not included a specific directive for private entities to comply with the COSPAR PPP. This regulatory gap can lead to pressure from commercial interests to diverge from and lessen the requirements to prevent biological contamination which are applicable to public missions, even though the harm that may be caused to a celestial environment does not distinguish between governmental and non-governmental actors.

The opinion has been expressed that the interests of the scientific community and commercial companies largely overlap regarding protection of celestial environments.[57] The rationale for this position on the part of entrepreneurs is to ensure their business case, that is, to preserve the environment for their own continued future use.[58] While there may be some shared interests between the two communities, the purposes to be served for each by preventing contamination are very different, and these differences ultimately may come into conflict. Planetary protection compliance could have significant impact on the design of mission hardware and payloads, and environmental regulation on Earth often is considered as just a cost of doing business, to be minimized and avoided as much as possible.

NASA recently constituted an Advisory Council (NAC) which recognized that some representatives of the commercial space sector have begun to express opposition to expanding what planetary protection means in law and policy. The NAC recommended that: "While taking appropriate efforts to prevent harmful contamination of the Earth or other celestial bodies, NASA should not adopt policies that would place unduly onerous and/or unreasonable restrictions and obligations on public or private sector space missions."[59]

This recommendation is consistent with legislation that was approved in 2018 by the U.S. House of Representatives. The American Space Commerce Free Enterprise Act contained the following provision: "Guidelines promulgated by the Committee on Space Research may not be considered international obligations of the United States."[60] Had this legislation become law, the regulatory gap would be been closed by exempting private space companies from the application of any specific planetary protection requirements. If the PPP is declared to not be the obligation of the U.S., a private payload could disregard the policy and not be disqualified on that basis from receiving approval for licensing.

Article IX of the Outer Space Treaty provides that states shall be guided by the principles of cooperation and mutual assistance in the exploration and use of space and celestial bodies, and shall conduct all their activities with due regard to th e corresponding interests of all other states party to the treaty. The obligation to exercise "due regard" is distinguishable from the obligation to prevent harmful contamination even though both are expressed in the same article of the treaty. The Moon Agreement separates these directives into two separate articles. Article 7 directly addresses environmental disruption, while Article 4.2, provides that states shall be guided by the principle of cooperation and mutual assistance, and that "due regard shall be paid to the interests of present and future generations as well as the need to promote higher standards of living and conditions of economic and social progress and development in accordance with the Charter of the United Nations." The beneficiaries of due regard in the Moon Agreement is more expansive than the "states parties" identified in the text of the Outer Space Treaty. The Moon Agreement is consistent with the view that the obligation of due regard extends to all states, whether or not a party to any particular treaty, as a matter of customary international law.[61]

The phrase "due regard" is not defined in either the Outer Space Treaty or the Moon Agreement. The concept "refers to the performance of an act with a certain standard of care, attention or observance," and generally is considered to give rise to duty of due diligence.[62] One commentary has described this as a duty of the state to "prove beyond a reasonable doubt that everything possible was undertaken to prevent a harmful act from occurring."[63] An obligation of due regard is not unique to the law of outer space, as the international community has agreed to abide by the standard in aviation and maritime matters. Article 3 of the Convention on International Civil Aviation (the "Chicago

[54] Babb, Erb & Howard, *supra* note 32.

[55] National Academies Report, *supra* note 31, at Recommendation 6.1, p. 86.

[56] *See generally* Hermida, J., 2004. *Legal basis for a national space legislation.* Dordrecht: Kluwer Academic Publishers; GSG Study, *supra* note 12, § 4.2, pp. 89-107.

[57] Smith, M., 2018. *NASA to form task force to review planetary protection guidelines*. Space Policy Online. [online]12 December, *quoting* statement by Mike Gold, Chair, NAC Regulatory and Policy Committee (RPC). Available at Space Policy Online website <https://spacepolicyonline.com/news/nasa-to-form-task-force-to-review-planetary-protection-guidelines/> (Accessed 6 February 2019).

[58] Babb, Erb & Howard, *supra* note 32.

[59] Smith, *supra* note 57.

[60] HR 8209, April 25, 2018, § 80103(c)(2)(D). Section 80103(c)(2)(C) provided that the obligations of the United States under the Outer Space Treaty were not all to be presumed to be obligations imputed to the private sector.

[61] Lyall, F. and Larsen, P.B., 2009. *Space Law A Treatise*. Surrey: Ashgate pp. 70-80.

[62] I CoCoSL, *supra* note 48, §§ 24, 25, pp. 175-176.

[63] *Id.* § 25.

Convention")[64] provides that state aircraft are exempt from the treaty but are to fly with due regard to the safety of civil aviation. The UN Convention on the Law of the Seas (UNCLOS)[65] imposes a due regard obligation in several articles, including Article 87, paragraph 2, which requires states to exercise their rights under the treaty with due regard to rights of other states to use and conduct activities on the high seas and in areas beyond the continental shelf. Similarly, Article 58(c) requires that ships in the exclusive economic zone give due regard to the coastal state.

The recent South China Sea Arbitration under UNCLOS[66] applied the concepts of due regard and due diligence. The arbitrators observed that the precise scope of the obligation to exercise due diligence may be difficult to determine, and it may be far from obvious what steps a state could realistically have taken to prevent harm. However, China was found to have failed to exercise due diligence and exhibit due regard by tolerating and escorting Chinese fishing vessels in the Philippine's exclusive economic zone. This may be somewhat of an extreme situation, in that Chinese government ships appeared to actively assist the offensive conduct. Nevertheless, the arbitration panel expressed that tolerating as well as actively assisting offending behavior can violate the obligation to exercise due regard.

A state which grants a non-governmental entity authority to conduct an activity that causes harm on a celestial body could be considered to tolerate if not actively assist the detrimental activity. On the other hand, the obligation to exercise due regard is directed to the process employed by the state, not the outcome. As indicated by the arbitral panel in the South China Sea case, the obligation of due regard is not a guarantee. A state could take steps it deemed reasonable to require private entity compliance with planetary protection measures, and therefore claim that it demonstrated due regard, even if a harm was caused to another celestial environment. Similarly, the state could assert that these same steps are sufficient to establish that the activities it authorized were conducted in a manner so as to avoid the harmful contamination pursuant to Article IX of the Outer Space Treaty.

The state practice that has developed by the recognition and implementation of the COSPAR PPP by governmental space agencies has established a baseline standard of conduct regarding the prevention of biological contamination of celestial environments. The practice of states has evolved and adjusted to the various modifications that COSPAR has made to the policy based on advances in knowledge since the PPP was first articulated a half-century ago. The emerging New Space era will require states to focus attention on an entire array of policy issues that did not exist when governments held a virtual monopoly on space activities on celestial bodies. The international community will be called upon to establish appropriate standards of conduct which will give rise to new state practices as private enterprise engages in tourism, the extraction and utilization of extraterrestrial resources, and other commercial activities on celestial bodies. This is similar to the situation that was presented regarding the proliferation of satellite debris in Earth orbit, where new state practices were developed to reduce the creation of debris by both the public and private sectors.[67] The development of appropriate state practices to govern commercial space will be essential to prevent conflict and maintain celestial bodies for peaceful uses only. This is a fundamental purpose and tangible benefit of space law.[68]

NASA has assumed a leading role in addressing these challenges to protecting celestial environments. The above noted NASA Advisory Council, through its Regulatory and Policy Committee (RPG), recently issued several Observations, Findings and Recommendations concerning planetary protection and COSPAR, including that:

> NASA should establish a multi-disciplinary team of experts from industry, the scientific community, and relevant government agencies, to develop U.S. policies that properly balance the legitimate need to protect against the harmful contamination of the Earth or other celestial bodies with the scientific, social, and economic benefits of public and private space missions.

This recommendation was accepted by NASA, and changes proposed by this task force will be reviewed by the NAC committees on Science, Human Exploration and Operations, and the RPG, as well as by the NAC itself. Recommendations on proposed changes will be forwarded to the NASA Administrator, and to the SSB and the Aeronautics and Space Engineering Board (ASEB) for review. After completion of this process, relevant proposals will be submitted to COSPAR for consideration pursuant to customary procedures.[69]

The expertise and resources of organizations such as the International Institute of Space Law, the International Academy of Astronautics, and the International Astronautical Federation should be solicited in the effort to achieve broad participation, support and agreement on new policies. In addition, proposed policies could be presented to the COPUOS and its Legal and Technical Subcommittees for their competence, capabilities and consensus. These actions on an international level would mirror and further the activities of the NASA multi-disciplinary group by involving industry, the scientific community, and governments in the policy-making process.

The international regulation of private sector activities in space could utilize a variety of mechanisms. One proposal is for the creation of a new organization similar to the International Seabed Authority established pursuant to the UN Convention on the Law of the Seas.[70] Another proposal calls for the drafting of a new treaty based on the due diligence standard of the Outer Space Treaty.[71] Suggested provisions of such a new instrument include: states should guarantee that non-governmental entities under their jurisdiction will comply with Outer Space Treaty Article IX and take the COSPAR criteria into account; states should provide the Secretary-General with information on measures taken to protect celestial environments and this information should be made public; states should include PP measures as conditions to licensing authorization; and states in cooperation with COSPAR and the Secretary-General should indicate areas on celestial bodies which should receive special protection as international scientific preserves pursuant to Article 7.3 of the Moon Agreement.[72]

An alternative to a formal treaty would be the adoption of a Code of Conduct similar in concept to the legal regime for Antarctica. The Antarctic Treaty does not have an express provision regarding protection of the natural environmental. Specific rules are provided by supplements to the treaty which comprise Antarctic Treaty System (ATS). These supplements include the Protocol on Environmental Protection,

[64] Convention on International Civil Aviation, *entered into force* 4 April 1947, 15 UNTS 295.

[65] Convention on the Law of the Sea, *entered into force* 16 November 1994, 1833 UNTS 3.

[66] Philippines v. China Arbitration (PCA Case Number 2013–19). [pdf] Available at: <https://pca-cpa.org/wp-content/uploads/sites/175/2016/07/PH-CN-20160712-Award.pdf> (Accessed 6 February 2019).

[67] Inter-Agency Space Debris Coordination Committee (IADC), 2007. *Space debris mitigation guidelines.* [online] Available through IADC website <iadc-online.org/index.cgi?item=dpcs_pub> (Accessed 2 March 2019). These guidelines have been approved by the UN General Assembly in Resolution A/RES/62/217, p. 6, ¶ 26. [pdf] <http://www.unoosa.org/pdf/gares/ARES_62_217E.pdf> (Accessed 6 February 2019) and have been incorporated into the national licensing laws of several states. GSG Study, *supra* note 12, p. 281.

[68] GSG Study, *supra* note 12, p. 394.

[69] Smith, *supra* note 57.

[70] Rummel & Conley, *supra* note 46.

[71] IAA Cosmic Study, *supra* note 2, p. 67, Recommendation 4.

[72] Hofmann, M., (2010). *Moon Agreement as a tool of planetary protection.* In: *61st International Astronautical Congress*, Prague, Czech Republic, 27 September–1 October 2010. IAF Paper No. IAC-10.E.7.2.9. Paris: International Astronautical Federation.

the Code of Conduct for Antarctic Expeditions and Station Activities, the Convention on Regulation of Antarctic Mineral Resource Activities, and Recommendations Regarding Antarctic Protected Area System Concerning Specially Protected Areas, Sites of Special Scientific Interest, and Historic Sites and Monuments. These instruments include provisions concerning waste disposal and management, introduction of alien species, and environmental impact assessment. Significantly, the ATS has a mandatory dispute resolution procedure, which is lacking in the space treaties.

National licensing regimes can supplement the international regulations and address the challenges to planetary protection in a number of specific areas. The payload review conducted by the licensing authority could include a scientific review which could examine the proposed mission from the perspective of whether the area of operations was of scientific interest such that it should be explored prior to the initiation of *in situ* commercial operations. The review also could require the preparation of an environmental impact assessment to examine the mission from the perspective of contamination other than from biological sources. This contamination includes the introduction of chemicals into the environment, any disturbances to the surface and/or subsurface, and the distribution of any hardware that will not be removed by the end of the mission. Space objects have been intentionally crashed into the surface and soft landed on celestial bodies since 1959 in pursuit of scientific investigation, and neither the Outer Space Treaty nor the Moon Agreement have any requirement that such be removed. Nevertheless, states will need to determine whether companies should be required to conduct remedial measures at the end of the venture to restore the celestial body to the *status quo ante* as much as possible, feasible and economical.

The licensing process could include a public comment period, which would allow the international scientific community to examine the mission and provide any guidance and advice, and for other states and private entities to express any concerns or objections. While commercial entities seeking authorization could be hesitant about making too detailed of public disclosures of what otherwise could be confidential and proprietary information, a balance will need to be found between corporate privacy and transparency to the global community regarding basic information including the specific locations and activities to be conducted.

7. Conclusion

Experiments such as Space4Life and the Planetary Society's LIFE Project squarely present the issue of whether the planetary protection policy should countenance the intentional introduction of potentially contaminating bacteria or other bioload into or in proximity to a celestial environment during the period of scientific uncertainty as to the existence of indigenous life or the precursors or remnants thereof in such environment. Clearly missions which intentionally introduce potential contaminants into or in proximity to a celestial environment carry an inherent risk of contaminating the environment. As a matter of prudence, any proposed experiment that increases the risk of contaminating a celestial environment should be strictly scrutinized, and at a minimum, the scientific results sought must be of very high significance and not available by any other alternative means. The international scientific community must determine, as a matter of policy, whether the PPP should limit, restrict or prohibit such missions to specific target bodies, e.g. Mars, Enceladus or other ocean worlds. The current policy appears to prohibit such missions to special regions on Mars, and consideration should be given to whether the provisions are in need of revision, strengthening and expansion.

The PPP classification system is based on whether a target body is of direct interest for understanding the process of chemical evolution or the origin of life. However, even if Phobos itself may not be of such direct interest, missions such as the LIFE Project that intentionally places bacteria in close proximity to Mars carry an inherent risk of contaminating the Martian environment. Thus, the planetary protection concerns are not limited to the target body of Phobos, but must include consideration of the risks of contamination of Mars by accident or otherwise. The example of the LIFE Project presents a case for addressing the regulatory gap in the PPP that now allows such experiments to satisfy the approval process of national space agencies.

The PPP seeks to achieve the intertwined goals of protecting scientific integrity in investigations and preventing adverse modification of potential habitats of any indigenous forms of life which may exist. To the extent the PPP considers the Moon and Phobos to be of any interest regarding the understanding of chemical evolution or the origin of life as Category II celestial bodies, such classification is based on the presumption that there is an absence of an environment where terrestrial organisms could survive or replicate. However, both the Radio Shield and the LIFE Project specifically were designed to house the bacteria in enclosures which would provide an extremely hospitable environment conducive to enhance and promote survivability and replication. Thus, the rationale for the classification as Category II is absent.

Experiments such as the Radio Shield and the LIFE Project which intentionally introduce potentially contaminating bacteria in or in proximity to celestial environments where water ice may be present run counter to the purpose and spirit on which the PPP is based. These experiments needlessly increase the risk of contaminating the natural environments, and neither represent the best practices of states nor establish good precedent. Furthermore, these experiments could be contrary to the provisions of the Outer Space Treaty and the Moon Agreement. Reliance on the Phobos-Grunt mission for precedent of state practice to support similar missions would be misplaced. This single mission is an insufficient data set on which to draw broad conclusions on what constitutes an established standard of state practice. Moreover, the mission itself was questionable as a matter of policy, and states should not be bound to follow a dubious precedent.

The burgeoning commercial space industry presents new challenges to planetary protection, and also provides opportunities for states to develop new best practices to meet these challenges. The regulation of private sector activities on celestial bodies will have both international and domestic components, whether in the form of a treaty, code of conduct or other multinational agreement, as well as national authorization and supervision regimes. The development of the appropriate policies and standards of conduct will require the participation of the science community, the government, and industry. NASA has already created an initial task force with representation of each of these stakeholders to examine the existing policies and recommend appropriate changes.

The COSPAR PPP, while not legally binding as a matter of international law, which has provided a framework by which states have adopted internal policies applicable to missions conducted with government participation. However, neither the COSPAR PPP nor national policies have been made applicable to private entities conducting missions to and/or operations on celestial bodies. States will need to address this regulatory gap directly.

The PPP addresses only the issue of potential biological contamination of celestial environments, and the regulation of private sector activities on celestial bodies will need to consider the broader aspects of planetary protection, including:

procedures to announce the discovery of evidence of alien life, or the remnants or precursors thereof, or other discovery of scientific interest;

the preservation and protection of such evidence, together with the area in proximity to the discovery;

the determination of whether certain areas, such as special regions on Mars, historic sites, or other unique locations be declared off limits to commercial activity pending scientific investigation or other justifications;

whether commercial missions should be required to include a scientific component;

whether private spacecraft should be removed from celestial bodies at the end of the venture, and should the surface and subsurface be restored to the condition that existed prior to the commercial operations;

what amount of disturbance of the celestial environment can be tolerated by commercial operations;

procedures for the review of proposed missions by scientific community for planetary protection concerns, as well as by the public;

procedures and requirements for the disclosure of information concerning proposed missions including an inventory of hazardous materials and an environmental impact assessment for activities to be conducted *in situ*;

the criteria to be established for the return to Earth of all or a portion of asteroids; and

the determination of the aesthetic, ethical, moral and philosophical limitations that should apply to commercial activities on celestial bodies.

The protection of celestial environments directly benefits the interests of all humanity: the rights of states to conduct activities are preserved; scientific integrity and advancements in knowledge are enhanced; and the ability of the private sector to operate commercial ventures is maintained. Whether in the form of guidelines from COSPAR or other organizations, national regulations and licensing regimes, or a treaty instrument or international code of conduct, the protection of celestial environments will serve the overarching purpose of international space law of promoting the peaceful exploration and use of outer space, including the Moon and other celestial bodies.