IAC-06-E.6.5.04

THE FUTURE OF PLANETARY PROTECTION: IS THERE REASON FOR OPTIMISM?

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ABSTRACT

The search for extraterrestrial life has been a primary focus for interplanetary spacecraft. The integrity of scientific investigations for evidence of indigenous life is dependent upon the presence of a pristine extraterrestrial environment, free from Earth-based organic contaminants carried by the very spacecraft sent to conduct exploratory missions. Policies to protect planetary environments have been adopted by the international scientific and legal communities, however, the policies are not static, and can never be assumed to be adequate to the task. Recent discoveries that water may be more plentiful in the solar system than previously envisioned underscore the need for regular review and re-evaluation of the effectiveness of planetary protection policies. This paper examines recent developments in the evolution of planetary protection, and questions whether there is reason for optimism.

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INTRODUCTION

Planetary Protection
All of the Planets All of the Time. . . .

This simple statement by NASA summarizes the essence of the policy of planetary protection: the pristine celestial environments must be protected from contamination by Earth based exploratory missions. This is a lofty goal in the abstract, but an absolutely essential goal in practice. The international scientific community, acting through COSPAR, has adopted specific policy guidelines and requirements, which have been modified in practice based largely on recommendations developed by the Space Studies Board of the National Research Council for NASA.[1]

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1. *See, e.g., Outbound Spacecraft Basic Policy Relating to Lunar and Planetary Quarantine Control*, NASA Policy Directive 8020.7 (1967); *Outbound Planetary Biological and Organic Contamination Control*, NASA Policy Directive 8020.10A (1972); *Quarantine Provisions for Unmanned Extraterrestrial Missions*, NASA Hand Book 8020.12A (1976); *Biological Contamination Control for Outbound and Inbound Planetary Spacecraft*, NASA Management Instruction 8020.7A (1988), *Biological Contamination Control for Outbound and Inbound Planetary Spacecraft*, NASA Policy Directive 8020.7F (1999).

The planetary protection policy (PPP) developed by the scientific community is the implementation of the mandate contained in the Outer Space Treaty, which provides that:

> 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. . . .[2]

The protection of celestial environments acts to enhance the scientific integrity of experiments conducted on celestial bodies, especially in relation to the search for the presence of extent or past life or the precursors thereof. The planetary protection policy also has important implications for the rights of all states to participate in the exploration of outer space, including the Moon and other celestial bodies.[3]

DEVELOPMENT OF THE PLANETARY PROTECTION POLICY

A. *Trans-science and Risk Assessment*

The application of the planetary protection policy necessarily involves an analysis of risks and probabilities. In basic terms, the risk that a spacecraft may cause forward contamination of a celestial body is dependent upon the initial microbial burden of the craft at launch, the ability of the organisms to survive launch, transit and deposition into an alien environment, and the receptivity of the alien environment to support and sustain the terran life forms.[4] The assessment of these risks

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2. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *opened for signature* January 27, 1967, art. IX, 18 U.S.T. 2410, T.I.A.S. No. 6347, 610 U.N.T.S. 205, *text reproduced in* UNITED NATIONS TREATIES AND PRINCIPLES ON OUTER SPACE 3 (2002) [hereinafter referred to as the "Outer Space Treaty"]; see also Treaty on Principles Governing the Activities of States on the Moon and Other Celestial Bodies, art. 7, *entered into force* July 11, 1984, *text reprinted in* Report, Committee on Peaceful Uses of Outer Space, 34 U.N. GAOR Supp. (No. 20), U.N. Doc. A/RES/34/68 (1979); UNITED NATIONS TREATIES ON OUTER SPACE 27 (2002); *and* 18 I.L.M. 1434 (1979).

3. There are three basic interests which are sought to be safeguarded by the planetary protection policy: first, the prevention of contamination of pristine celestial environments by terrestrial sources, that is forward contamination; second, the prevention of the contamination of the Earth by the return of extraterrestrial materials, *i.e.* back contamination; and third, the prevention of interference with the activities of states in the peaceful exploration and use of outer space. All three of these interests are expressly mentioned in article IX of the Outer Space Treaty. *See* Tennen, *Evolution of the Planetary Protection Policy: Conflict of Science and Jurisprudence?*, PROCEEDINGS OF THE 45TH COLLOQUIUM ON THE LAW OF OUTER SPACE 466 (2003), and 34 ADV. S. RES. 2354 (2003).

4. The formula for determining the Probability of contamination (P(c)) is

$$P(c) = m(i)(o) \cdot P(vt) \cdot P(uv) \cdot P(a) \cdot P(sa) \cdot P(r) \cdot P(g)$$

where:

m(i)(o) = initial microbial burden at launch, after decontamination
P(vt) = probability of surviving space vacuum-temperature
P(uv) = probability of surviving ultra-violet space radiation
P(a) = probability of arriving at

is a function of determining and accumulating individual factors.

The outcome of the risk assessment can vary widely, based on the values assigned to the individual variables, and even the identification and definition of the particular factors can influence the ultimate quantification of the risk. Moreover, the analysis of the risk factors requires the placement of quantitative values to criteria which largely are unknown. As a result, there is an intrinsic and significant element of uncertainty, in which the issue of the assessment of risk contains a substantial grey area between scientific resolution and political choice.[5] Even when all available scientific data is considered, a residual level

> [of] uncertainty means that decisionmakers cannot determine policy on purely scientific grounds. At this point uncertainty itself becomes an aspect of the factual picture, and the question of what level of risk is acceptable in light of the uncertainty becomes a question of value, requiring political determination. . . . Failure to recognize the trans-scientific character of such questions too often lends 'scientific' credibility and authority as well as an air of 'factuality' to assertions or determinations that are at least as dependent on value choices as they are on 'scientific fact.'[6]

It is open to question whether the evolution of the planetary protection policy has adequately considered these ˜trans-scientific™elements, or whether political value choices have overshadowed scientific fact.

B. Planetary Quarantine Requirements

The inherent difficulties of assigning quantitative values to unknown qualitative factors can be seen in the evolution of the COSPAR planetary protection requirements. Following the lead of the International Astronautical Federation, and studies by competent international fora,[7] COSPAR adopted strict planetary quarantine requirements (PQR)

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celestial body
P(sa) = probability of surviving atmospheric entry
P(r) = probability of release
P(g) = probability of growth

C.R. PHILLIPS, THE PLANETARY QUARANTINE PROGRAM: ORIGINS AND ACHIEVEMENTS 38 (1975), NASA Pub. No. SP-4902, U.S. GPO Stock No. 3300-00578.

5. Allen, *The Current Federal Regulatory Framework for Release of Genetically Altered Organisms into the Environment*, 42 FLORIDA L. REV. 531, 537 (1990), *citing* Weinberg, *Science and Trans-Science*, 10 MINERVA 209 (1972).

6. Allen, *supra* note 5, at 538-39, *citing* Yellin, *Science, Technology, and Administrative Government: Institutional Designs for Environmental Decisionmaking*, 92 YALE L.J. 1300 (1983).

7. Early studies were conducted by the *Ad Hoc* Committee on Contamination by Extraterrestrial Exploration (CETEX) of the National Academy of Sciences, and the COSPAR Consultive Group on Potentially Harmful Effects of Space Experiments. *See generally* Phillips, *supra* note 4, at 3; H.S. LAY & H.J. TAUBENFELD, THE LAW RELATING TO THE ACTIVITIES OF MAN IN SPACE, AN AMERICAN BAR FOUNDATION REPORT 189, n. 7 (1970); W.C. JENKS, SPACE LAW 34 (1965).

in 1964.[8] These initial COSPAR standards required that decontamination techniques were to be employed to reduce the probability of contamination of a celestial environment by a single viable terrestrial organism aboard any spacecraft intended for planetary landing or atmospheric penetration to less than 1×10^{-4}. COSPAR also set a probability limit for an accidental planetary impact by an unsterilized fly-by or orbiting spacecraft of 3×10^{-5} or less.

The COSPAR planetary quarantine requirements created bright line obligations for mission planners to ensure that interplanetary spacecraft, essentially, were sterilized. These planetary quarantine requirements were to apply to all missions for the initial period of planetary exploration of ten years.[9] Nations were allocated specific fractions of the overall probability limits, which were apportioned by the recipient state among the missions planned to be conducted under its jurisdiction.[10]

The PQR applied to interplanetary spacecraft through the Viking mission in 1976, including Mariner Mars in 1971; Pioneer to Jupiter; and Mariner to Venus and Mercury in 1973. In accordance with the PQR, the probability of contamination allocation for each of these missions, that is, the probability that a single viable organism would contaminate the celestial body subject of the mission, was as follows:[11]

Mariner Mars	7.1×10^{-5}
Pioneer Jupiter	6.4×10^{-5}
Mariner Venus	7×10^{-5}
Viking	1×10^{-4}

In 1969, COSPAR revised the planetary quarantine requirements, and stated:

> as the basic objective for planetary quarantine of Mars and other planets deemed important for the investigation of extraterrestrial life, or precursors or remnants thereof, a probability of no more than 1×10^{-3} that a planet will be contaminated during the period of biological exploration . . . ending in 1988.[12]

This decision by COSPAR made two significant alterations to the planetary quarantine requirements: first, it reduced the probability of contamination limit by a full order of magnitude; second, it limited the application of the quarantine requirements to ˜**Mars and**

8. COSPAR Res. 26, 20 COSPAR INFO. BULL. at Annex 4 (1964).

9. Report, Committee on the Peaceful Uses of Outer Space, at 13, U.N. Doc. A/5785 (November 13, 1964). *See* Committee on Planetary Biology and Chemical Evolution, Space Science Board, RECOMMENDATIONS ON QUARANTINE POLICY FOR MARS, JUPITER, SATURN, URANUS, NEPTUNE AND TITAN 27 (1978).

10. Sterns & Tennen, *Protection of Celestial Environments Through Planetary Quarantine Requirements*, in PROCEEDINGS OF THE 23RD COLLOQUIUM ON THE LAW OF OUTER SPACE 107 (1981).

11. NASA, Specification Sheets for U.S. Planetary Quarantine Program, Control No. 005 (1973) (prepared for COSPAR Meeting, Constanz, FRG, May, 1973).

12. COSPAR Decision No. 16, 50 COSPAR INFO. BULL. 15-16 (July, 1969), *quoted by* Stabekis, *History and Processing of Changes*, in REPORT, COSPAR/IAU WORKSHOP ON PLANETARY PROTECTION, Appendix C (2002).

other planets deemed important™ inlte search for extraterrestrial life.

The planetary protection policy was subject to continued re-examination as new data was obtained. However, criticisms to the policy grew within the scientific community. A primary criticism was that the assignment of numerical values to factors, such as the probability of growth, entailed inherent scientific uncertainty. Nevertheless, studies conducted by interplanetary spacecraft did not indicate the presence of extraterrestrial life or the ability of terran organisms to propagate. Thus, it was argued that the logic underlying the original policy was weakened, and that there were occasional inconsistencies in its application.[13]

C. Transformation of the PPP

In 1978, following studies by the Space Studies Board, the probability of growth factor was assigned a value sufficiently low so as to negate the necessity of engaging in any active decontamination techniques for most celestial bodies.[14] As a matter of policy, the assignment of negligible values to the probability of growth factors transformed the PQR from the norm to the exception.[15] In addition, active decontamination techniques were required only for certain mission type and target body combinations. The term PQR no longer was accurate to describe the circumstances, but was replaced with the phrase ˜planetary protection policy.™

In the early 1980's, the structure of planetary protection was transformed, such that planetary protection requirements could be imposed, depending upon the nature of the mission and the target body or bodies to be explored. Pursuant to this policy, missions to target bodies which were 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 was any specific documentation required. The classification of missions to other target bodies was to be determined on a case by case basis.[16]

In 1994, the planetary protection policy was revisited, particularly in relation to missions to Mars. The 1994 policy revisions tied the utilization of active planetary protection controls to whether the mission objectives included life-detection experiments. That is, craft landing on Mars which carried life detection instruments were subject to Viking level sterilization, but landing craft without such life detection instruments were subject to substantially less stringent decontamination techniques.[17]

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13. DeVincenzi & Stabekis, *Revised Planetary Protection Policy for Solar System Exploration*, 4 Adv. Space Res. 291 (1984).

14. Space Science Board, Recommendations, *supra* note 9, at 27-28 (Appendix C).

15. *Id.* Nevertheless, the SSB continued to recommend that crafts intended for such celestial bodies employ clean room techniques. It justified such recommendation not on planetary protection considerations, but on the basis that the use of clean rooms would reduce the possibility of growth of organisms which might compromise the functioning of the spacecraft or its payload. *Id.* at 15-16.

16. COSPAR Internal Decision 7/84, *quoted by* Stabekis, *supra* note 12, Appendix C, at C-6.

17. *See* AN EXOBIOLOGICAL STRATEGY FOR MARS EXPLORATION 49 (1995), NASA Pub. No.

In 2002, the policy was subject to a comprehensive restatement, which was endorsed by COSPAR at the World Space Congress in Houston. This current statement of the planetary protection policy continues the application of active decontamination techniques based on the mission type and target body combination categories. The policy divides missions into 5 separate classifications of mission type/target body. In relation to bodies which are of "chemical evolution and/or origin of life interest or for which scientific opinion provides a significant chance of contamination which could jeopardize future biological experiments," notably Mars, three sub-classifications are made. These sub-classifications are based on the whether the landing craft is equipped with life detection experiments, or is intended to land in a "special region," where either terrestrial organisms are considered likely to propagate, or *in situ* evidence of extent life is considered to be possible.[18]

It is interesting to note that an Appendix to the current COSPAR policy states that as a numerical guideline, the probability of contamination should be no more than 1 x 10^{-3} for the initial period of exploration of not less than 50 years. However, no particular format is specified for calculating the probability of contamination. Nevertheless, the Appendix further establishes a probability of contamination for Europa flybys, orbiters and landing craft of 1 x 10^{-4}, and states that the "calculation of this probability of contamination should include a conservative estimate of poorly known parameters," the list of which is virtually identical to the factors designated in the original PQR P(c) formula.[19]

THE PLANETARY PROTECTION POLICY IN PRACTICE

A. Survey of Missions

The efficacy of the COSPAR policy can be tested by an examination of its application in practice. A brief review of missions, from a planetary protection perspective, will demonstrate whether the planetary protection policy has lived up to the goal of "all of the planets all of the time." With the exception of the Viking spacecraft, all of the mission listed below have been subject to the planetary protection policy which classifies and categorizes missions by mission type and target body, rather that the more strict planetary quarantine requirements.

The **Viking** mission to Mars soft landed twin spacecraft on the planet's surface in 1976. The landing craft were subject to cleaning to reduce the total surface bioburden to no more than 3 x 10^5 bacterial spores, with no more than 300 spores per square meter space, and a total bioburden for the craft of 5 x 10^5 spores. The craft were then subject to dry-heat sterilization of 111.7 degrees Celsius for 30 hours.[20]

SP-530; *see also* DeVincenzi, *Planetary Protection Issues and the Future Exploration of Mars*, in 12 ADV. S. RES., No. 4, 121 (1992); D.L. DEVINCENZI, H.P. KLEIN & J.R. BAGBY, JR., PLANETARY PROTECTION ISSUES AND FUTURE MARS MISSIONS, NASA Conf. Pub. 10086 (1991).

18. http://www.cosparhq.org/scistr/PPPolicy.htm

19. *Id.* at Appendix, *Implementation Guidelines and Category Specifications for Individual Target Bodies* (Version March 24, 2005).

20. http://planetaryprotection.nasa.gov/pp/missions/past/viking.htm

Mars Observer was launched in 1982, and was classified as a Category III mission. Contact was lost as the craft entered Martian orbit in 1983. NASA acknowledged that debris from the spacecraft "could have inadvertently impacted the surface of Mars, posing a risk of forward contamination."[21]

Mars Global Surveyor entered Martian orbit in 1997. The mission was classified as Category III, and according to NASA, the "orbit may be raised at the end of its mission to ensure against inadvertent entry into the planet's atmosphere."[22]

Mars Pathfinder was launched in late 1996, and carried a small rover named Sojourner. The mission was classified as Category IV-A. Pursuant to this classification, sterilization of the lander and the rover was not required.[23]

Mars Climate Orbiter was launched in 1998, and arrived at Mars in 1999. It was not intended to land on the planet, and was classified as Category III. Contact was lost with the spacecraft upon its arrival at Mars, and according to NASA "most likely inadvertently entered the atmosphere." If the craft did not burn up in the atmosphere, "the debris could pose the possibility of forward contamination."[24]

Mars Polar Lander was launched in 1999, consisting of a lander and two small probes, and was classified as Category IV-A. The spacecraft was assembled in a class 100,000 clean room, and subject to bioburden reduction techniques to meet requirements of "less than 300,000 spores at launch, with a surface distribution of no more than 300 culturable bacterial spores per square meter of surface area." Dry hear processes also were used for some, but not all, of the hardware. Contact was lost with the spacecraft upon arrival at Mars in December, 1999. According to NASA, no "unforeseen risk of contamination" was posed by the likely impact of the lander and probes on the planetary surface, and "fulfillment of planetary protection requirements for this mission was considered to be exemplary. . . ."[25]

Mars Odyssey entered orbit around the planet in late 2001. The spacecraft was classified as a Category III mission for planetary protection purposes, and its orbit may be raised to ensure against inadvertent entry into the Martian atmosphere.[26]

The Japanese **Nozomi, or Planet B** spacecraft, launched by the predecessor to JAXA, was intended to orbit Mars. Contact with the spacecraft was lost as it approached Mars in 2003, and it is believed to have entered solar orbit. The exact location of the craft is unknown.

JAXA has acknowledged the obligation to comply with the COSPAR policy, which

21. http://planetaryprotection.nasa.gov/pp/missions/past/mars_observer.htm

22. http://planetaryprotection.nasa.gov/pp/missions/current/mgs.htm

23. http://planetaryprotection.nasa.gov/pp/missions/past/pathfinder.htm

24. http://planetaryprotection.nasa.gov/pp/missions/past/climate_orbiter.htm

25. http://planetaryprotection.nasa.gov/pp/missions/past/polar_lander.htm

26. http://planetaryprotection.nasa.gov/pp/missions/current/marsodyssey.htm

would have classified the mission as Category III. According to the JAXA website,

> The international organization called "COSPAR" representing worldwide space science organs defines "Planetary Protection Policy" as special protective measure that provides for regulating a percentage possibility below one percent of falling upon Mars, within twenty years after the launch, for Mars orbiting satellites inadequately sterilized. On the other hand, from the standpoint of observing Mars, it is naturally better to get closer to Mars as much as possible, which means, therefore, the closest distance of 894km is marginally and most appropriately set for probe trajectory to take (sic).[27]

Mars Express was a mission conducted by the European Space Agency. Launched in 2003, the craft carried a lander, Beagle, intended to conduct exobiological and geochemical experiments. Contact with Beagle was lost on deployment into the Martian atmosphere. The mission was classified as Category IV-A pursuant to the COSPAR policy, which NASA says, like its own policy, "establishes strict sterilization requirements for Mars landers carrying instruments intended to search for evidence of biological activity."[28]

Mars Exploration Rovers Spirit and Opportunity landed on the planet in early 2004. The mission was classified as Category IV-A. According to NASA, "tests showed that the total spore count on both [rovers] was well below the allowable level." A primary mission objective was to search for evidence of water activity on Mars.[29]

B. Effectiveness of the Planetary Protection Policy

The Mariner Mars and Viking missions were subject to the rigorous PQR, which provided significant protection against forward contamination. However, by any objective standard, the revised planetary protection policy, based on classifications of mission type and target body combinations, has failed to prevent the contamination of Mars. Not less than three separate unsterilized rovers have landed on the surface of the red planet, together with associated mission hardware, and not less than four other unsterilized spacecraft have been lost while approaching the planet and may have impacted the surface. All seven of these unsterilized craft were in compliance with the applicable PPP classifications.

These missions each were classified either as Category III or IV-A, and under the more stringent requirements of the latter, a bioload burden at launch of 300,000 bacteriological spores still was deemed acceptable. Thus, each of the spacecraft can be expected to have carried a significant amount of contaminants to Mars. Moreover, the locations of the contaminated spacecraft are uncertain. While the location of the rovers can be known at the end of their respective missions, the

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27. http://www.jaxa.jp/missions/projects/sat/exploration/nozomi/backnumber_e.html

28. http://planetaryprotection.nasa.gov/pp/missions/current/marsexpress.htm

29. http://planetaryprotection.nasa.gov/pp/missions/current/mer.htm

locations of the missing spacecraft are undetermined. Similarly, the extent of damage to the natural environment also is unknown. Significantly, these missing spacecraft even may have impacted areas that may qualify as "special regions."

The PPP based on mission type/target body classifications suffers from several inherent weaknesses. The PQR were criticized for the uncertainty in the required input parameters, especially the probability of growth factor. This is a valid criticism, and as noted above, focuses attention on the trans-scientific nature of planetary protection. Nevertheless, the probability of growth factor was subject to several downward revisions based on the absence of findings of indigenous life and indirect lines of reasoning. Thus, the PQR was transformed into the PPP as a result of the reduced P(g) values for several celestial target bodies. Nevertheless, there is a certain illogical circularity in criticizing a factor for its uncertainty, and then utilizing that same uncertain factor as the justification for a wholesale reduction in requirements.

A corollary to the foregoing weakness of the PPP is that it draws broad conclusions from limited information and extrapolation. The studies which have been conducted *in situ* in celestial environments have been limited in both scale and location. The data set is not well developed, and the experiments conducted to date have not yielded unambiguous, conclusive results. Reliance on limited *in situ* investigations to revise the PPP is premature, as the discovery of water on the Moon and other celestial bodies has demonstrated.

The PPP is directed toward considerations regarding life as we know it, and that is as it must be, as that is our frame of reference. Yet recent discoveries concerning extremeophiles are expanding the definition of life and our understanding of the extreme conditions in which life may not just exist, but may flourish. We must be prepared for an encounter with life as we do not know it, or may not even be able to recognize it.[30] Does red halophilic bacteria bear a sufficient resemblance to a blue footed booby that both would be instantly recognized as indigenous life forms by an alien observer?

We cannot answer, as any answer we give is filtered by the logic and experiences of homo sapiens, and thus may be very different than an answer from any alien we may encounter.[31] That, of course, is the point, we cannot know, but we must allow for the possibility. Perhaps we will know tomorrow, or the next day, or the day after that. In the meantime, we must not take readily avoidable chances of contaminating celestial environments.

This leads to another major weakness of the PPP, the division of celestial bodies into two categories: those which are of "chemical evolution and/or origin of life interest or for which scientific opinion provides a significant chance of contamination which could jeopardize future biological experiments," and all others. This distinction is unnecessarily restrictive and myopic. All celestial bodies are of interest for chemical evolution and/or origin of life issues,

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30. Grinspoon, *The Case for Astrobiological Research of Venus*, SETI INSTITUTE EXPLORER Vol. 1, No. 1, at 4 (2004).

31. Sterns, *SETI and Space Law: Jurisprudential and Philosophical Considerations for Humankind in Relation to Extraterrestrial Life,* 46 ACTA ASTRONAUTICA 759, 761 (2000).

even those bodies which prove to be sterile. This is especially pertinent for celestial bodies which are thought to present environmental conditions which are conducive to life, as the building blocks of life are believed to be abundant throughout the universe. Thus, it is of crucial importance to understand why a sterile body is fundamentally different than Earth now or in past, such that life started here and holds on tenaciously, but failed to gain a toehold in a similar environment. The discovery of such a world would underscore the uniqueness of Earth and how precious is the gift of life.

C. New Optimism?

The COSPAR policy in relation to Mars recently was re-examined by the Space Studies Board. The SSB has recommended that the entire Martian planet be considered as a special region, and thus subject to Viking level sterilization, until designated areas can be exempted for less rigorous decontamination techniques based on further exploration and experimentation. This re-examination was conducted, according to the SSB, in light of current information regarding the science of Mars, the ability of extremeophiles to survive in conditions which have expanded the understanding of the tenacity of life, new technologies and life detection techniques, improvements in methods to decontaminate and sterilize spacecraft, and other factors.[32] Nevertheless, and while not stated by the SSB, perhaps the most significant factor mandating the re-examination is that the application of the COSPAR planetary protection policy has failed to achieve its essential purpose.[33]

CONCLUSION

The new SSB recommendations are an important development in the protection of the Martian environment. Perhaps they signal that the pendulum in planetary protection policies has reached its crest, and is now moving back in the direction of planetary quarantine. Nevertheless, the optimism engendered by this positive development is tempered by the further recommendation by the SSB that the new policy toward Mars is to be implemented over a lengthy ten year period.

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32. Committee on Preventing the Forward Contamination of Mars, Space Studies Board, National Research Council, PREVENTING THE FORWARD CONTAMINATION OF MARS 2 (2006), http://www.nap.edu/catalog/11381.html.

33. Tennen, *Commentary on "Environmentally Sustainable" Space Exploration: Reconciling Challenges of Planetary Protection*, IASL – IISL INTERNATIONAL AND INTERDISCIPLINARY WORKSHOP ON POLICY AND LAW RELATING TO OUTER SPACE RESOURCES: THE EXAMPLE OF THE MOON, MARS & OTHER CELESTIAL BODIES (2006).