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THE SCIENTIFIC/LEGAL IMPLICATIONS OF PLANETARY PROTECTION AND EXOBIOLOGY

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ABSTRACT

Missions planned in the next decade to celestial bodies of the solar system have focused renewed attention on the issues of planetary protection and exobiology. Questions of forward contamination of bodies such as Mars and Europa, as well as the potential for back contamination by the return of extraterrestrial samples, raise significant legal implications. Similarly, the role and regulatory authority of international organizations must be re-evaluated, with attendant legal consequences. This paper examines these issues with particular emphasis on the current status of the law of outer space. Mission planning must ensure the resolution of these issues, with ultimate consideration for protection of the Earth and its beings, as well as the protection of pristine celestial environs of extraterrestrial bodies.

INTRODUCTION

Scientific exploration of the cosmos has yielded a wealth of data and insights into the formation of planetary systems and celestial bodies. The fundamental questions of cosmology and philosophy, however, have yet to be answered: How did life on Earth begin, and are we alone in the universe? It has been hoped that examination of our neighbors in the solar system will provide clues leading to the answers to these mysteries. Ever since mankind has had the technological capability to plan and conduct missions of interplanetary exploration, it has been recognized that maintaining the integrity of scientific investigation mandates that measures be taken to prevent the biological contamination of pristine celestial environs. Accordingly, both the international scientific and legal communities have adopted measures for this purpose.

The focus of planetary protection policies has been on the prevention of contaminating celestial environments by the introduction of biological agents from Earth, and the protection of the environment of the Earth from the return of potentially harmful extraterrestrial materials. Environmental contamination can occur by means other than biological, however. Exploratory space craft have ejected a variety of materials on celestial bodies, and soft landed or crashed robotic explorers on their surfaces. The international legal community has addressed the issue of

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protecting celestial environments in broadly phrased terms, but the law in this regard is not well developed. Furthermore, the scientific community has substantially relaxed and revised the self-imposed planetary protection requirements several times, most recently in 1999. As a result, the integrity of both scientific investigation and pristine celestial environments may be called into question.

SCIENTIFIC SELF-REGULATION: PLANETARY QUARANTINE REQUIREMENTS

The protection of planetary environments has been the subject of serious consideration since the beginning of the space age. As a matter of policy, it was determined that the maintenance of pristine celestial environs, including that of Earth, during scientific interplanetary investigations, was of utmost importance.[1] The Committee on Space Research (COSPAR) of the International Council of Scientific Unions conducted extensive studies, and called for the imposition of international controls to prevent back contamination of the Earth's environment by the return of extraterrestrial materials.[2] Further, in 1964, COSPAR approved recommended planetary quarantine requirements (PQR) regarding forward contamination of celestial bodies. Pursuant to these PQR, the probability of contamination:

> of a single viable organism aboard any spacecraft intended for planetary landing or atmospheric penetration would be less than 1×10^{-4}, and a probability limit for accidental planetary impact by unsterilized flyby or orbiting spacecraft of 3×10^{-5} or less.[3]

The PQR obligated states to take active measures to reduce the initial microbial burden of an interplanetary craft at launch. At a minimum, fly-by craft were subjected to clean room assembly. Landing craft, including Viking, were sterilized by various methods, such as heat, gas or radiation. Mission profiles were developed which minimized the risk of unintentional and accidental contact between orbiting vehicles and celestial bodies. The PQR were applied to all interplanetary missions, and any deviation from the policy constituted a specific exception.

Each space active nation was assigned a percentage of the total permitted probability of contamination, which was then allocated to specific missions. Within the United States, the PQR were implemented pursuant to a series of NASA Management Instructions and NASA Policy Directives.[4] In 1978, the PQR were substantially revised by a reduction in the total probability of contamination by a full order of magnitude. This revision was based on the establishment by the Space Science Board of the National Research Council of specific values for the probability of growth (P(g)) factor. The use of these specific values eliminated the need to employ any decontamination techniques whatsoever in order to comply with the revised planetary protection policy for exploratory craft to Jupiter, Saturn, Uranus or Neptune.[5]

The revisions in the planetary quarantine requirements marked a significant shift in philosophy. Rather than establishing a quarantine requirement as the norm, the 1978 planetary protection policy exempted the application of the quarantine based on the limited knowledge which had been obtained during the initial interplanetary explorations. Further revisions to the planetary protection policy occurred in the 1980's, when the applicable guidelines were relaxed to provide that planetary protection constraints *may* be imposed, depending upon the nature of the mission and the target body or bodies to be explored. For certain missions and/or target bodies, which were deemed to be not biologically interesting, including the Moon, the policy did not require any planetary protection techniques to be utilized, nor was any specific documentation required. For other target bodies, the classification for planetary protection purposes was to be determined on a case by case basis.[6]

The planetary protection policies were revisited again in 1994, particularly in relation to exploratory missions to Mars. Specifically, the 1994 revision to the policy tied the utilization of decontamination and cleanliness 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. However, landing craft without such life detection instruments were subject to substantially less stringent decontamination techniques.[7] A number of robotic exploration programs to Mars are in progress which were subject to this policy.

The most recent revisions by NASA to the planetary protection policy became effective in April, 1999.[8] Pursuant to the newly revised policy, planetary missions will be classified into one of five categories, depending upon the pre-determined "planetary protection status" of the target body, and the mission plan. The categories range from targets which are "not of direct interest for understanding the process of chemical evolution," to missions which involve the return of extraterrestrial samples to Earth.[9] The newly revised policy continues to divide planetary target bodies into those which are or are not deemed to be biologically interesting. A further distinction has been introduced for application to planetary bodies which, while biologically interesting, can be considered to present "only a remote chance that contamination by spacecraft could jeopardize future exploration."[10] The mission categories are described and summarized in Table 1. The "planetary protection status" of target bodies within the solar system are listed in Table 2.

The current NASA policy provides that sterilization is required for all missions designed for the return of extraterrestrial materials to Earth. However, sterilization generally is not required for interplanetary spacecraft with no plans for a return unless the spacecraft is both intended to land on the target body, as well as to conduct life detection experiments. The imposition of planetary protection controls will be determined on a case by case basis pursuant to mandatory written notification and request for classification. Planetary protection controls can range from documentation to active bioburden reduction measures. The policy establishes specific timelines which must be followed by mission planners to accommodate applicable planetary protection concerns. In addition, the policy provides for periodic reviews and the detailed contents of appropriate documentation. Significantly, the policy also establishes procedures and guidelines for the return of extraterrestrial materials to Earth.[11]

ENVIRONMENTAL PROTECTION AND THE LAW OF OUTER SPACE

The Outer Space Treaty[12] contains numerous provisions which relate directly or indirectly to matters of exobiology, particularly concerning forward and back contamination. Specifically, Article IX of the Outer Space Treaty requires 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 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.

This provision applies both to forward as well as back contamination by biological materials. Article IX of the Outer Space Treaty comprised the primary statement of international policy to protect and preserve the environmental integrity of Earth and space during the initial period of interplanetary exploration. However, the provision is unclear as to what constitutes "harmful contamination" or "adverse changes" to the environment. Nevertheless, the introduction of any biological materials to a new environment should be considered as potentially harmful, at least until conclusively demonstrated otherwise.

The Outer Space Treaty contains additional provisions which may be considered applicable to the preservation of natural celestial environments. The protection and preservation of the natural environments of space and celestial bodies properly is considered as an extension of the principle of the common province of mankind as referenced in article I of the Outer Space Treaty. Further, the principle of non-appropriation, as expressed in article II of the Outer Space Treaty, prohibits claims of national sovereignty in space by claim of appropriation, by means of use or occupation, or by any other means. A substantial alteration of a celestial environ would deny other entities the concurrent and future right to use and explore the pristine balance previously existing on that body. Thus, it is urged that biological modification of a natural environment constitutes appropriation prohibited by article II.[13] Biological contamination of a celestial environment also could be considered as an interference with the activities of other states parties.[14]

Article VIII of the Outer Space Treaty may have applicability to the issue of back contamination, in regard to the imposition of international liability for damages to another state party, or its natural or juridical persons, caused by contamination from exposure to or release of harmful extraterrestrial biological contaminants.[15] Additionally, the Liability Convention obligates states to examine the possibility of rendering appropriate and rapid assistance upon request where damage caused by a "space object presents a large scale danger to human life or interferes with the living conditions of the population or the functioning of vital centers."[16] The release of exobiological materials conceivably could present such a large scale danger to life or interference with living conditions. It should be noted, however, that these provisions of the *corpus juris spatialis* may not have any applicability to forward contamination. Damage to celestial environs is not the same as compensable damage to a state.[17]

Article V of the Outer Space Treaty,[18] and the Return and Rescue Agreement generally, obligate states to recover and return astronauts and space objects to the launching state.[19] Questions exist, however, as to whether the independent duties to return personnel or space objects to the launching state would be applicable if the object or astronauts had become exposed to or infected with some type of harmful exobiological contamination, particularly if the mere handling and transportation of the objects or persons would pose a hazard to the rescuing state party. Clearly, however, a distinction should be drawn between astronauts and objects in this regard, as astronauts are declared to be envoys of mankind,[20] and thereby constitute a special and protected class of personnel. Moreover, humanitarian considerations would dictate that nations render aid to and return contaminated personnel, in a manner consistent with the overall protection of the Earth's environment.[21]

States are required to maintain registries and disclose information regarding objects launched into space,[22] which may assist in the imposition of international responsibility and liability in the event of damage by aiding in the identification of the responsible state. The Registration Convention provides that, where a state party is unable to identify the state of registry of a space object which "caused damage to it or to any of its natural or juridical persons, or which may be of a hazardous or deleterious nature," other states parties shall render assistance to the greatest extent feasible, on request.[23] This provision could encompass the hazards presented by contamination from exobiological materials, and could include circumstances both where damage has already occurred, as well as situations which pose a risk of harm.

The Moon Treaty expands the environmental protection provisions in the *corpus juris spatialis*. Article 7, paragraph 1, of the Moon Treaty provides as follows:

> 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.

Pursuant to this provision, states are required to *prevent* the disruption of natural celestial environments. Furthermore, the Moon Treaty, in Article 7, paragraph 2, imposes an affirmative obligation on states to report to the Secretary-General the measures taken to comply with the Treaty. The expression of this obligation implies that it is incumbent upon states to take precautions for *all* missions to prevent forward and back contamination. Moreover, article 7, paragraph 3, of the Moon Treaty, provides for the establishment of areas with special scientific interest as "international scientific preserves." Presumably, areas containing evidence of organic life will be designated as "international scientific preserves," and be subject to more rigorous standards of environmental protection.[24]

The primary focus of environmental protection policies has been on issues of biological contamination. Disruption of natural environments, however, can occur from a variety of sources. The initial interplanetary missions were conducted as much for political prestige as for scientific merit. As such, little consideration was given to the ramifications that a craft would have on the surface of a target body, whether by soft landing or by intentional or unintentional crash. Early missions scattered medallions, planted flags, or left plaques as symbols of national pride on the surface of the Moon and planets. Robotic craft continue to be intentionally impacted onto planetary bodies, and other remnants of missions litter the surface of our celestial neighbors.

The Outer Space Treaty, as well as the Moon Treaty, expressly permit states to conduct a variety of activities on the surface or subsurface of the Moon and other celestial bodies. These activities include the establishment of facilities and installations for scientific and other purposes. The pristine celestial environs necessarily will be disrupted by the conduct of such activities. Thus, the law of outer space does not prohibit all disruption of pristine celestial environments, but only that disruption which is deemed "harmful." As a matter of policy, however, any disruption should be considered as potentially harmful, and therefore limited to the greatest extent possible.

The formulation of planetary protection policies involves issues of both science and politics.[25] A substantial grey area exists between the two, and political issues overlap onto areas of scientific uncertainty. Although all available scientific data must be considered, a residual level of uncertainty will remain, and policy cannot be determined 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. . . . "[26] Therefore, it may be questioned whether the relaxation in the planetary protection policies over the past three decades is prudent.

The utilization of decontamination controls undoubtedly is expensive, and adds to the cost and complexity of missions. The policies should be subject to continuous review and re-evaluation, based on the most current scientific data. Nevertheless, the revisions in policy have occurred in a virtual scientific vacuum, especially in relation to Mars, as no new data have been collected *in situ* in the span of more than twenty years since Viking. Further, the life detection examinations conducted by the Viking landers were inconclusive.[27] The risk of harm presented by biological contamination necessarily is unknown and difficult to quantify, and should not be determined solely with reference to limited data.

The emphasis on the probability of growth factor, as a basis for justifying the relaxation of the planetary protection policies, may be both too restrictive as well as misplaced. The probability of survival in an extraterrestrial environment may be more fundamental, for if an organism can survive, there is no way to know what may be the result of the potential interaction with indigenous life forms, no matter how simple or complex. It is premature to conclude that life does not exist elsewhere in the solar system merely because the scientific community has not been able to identify conclusively any alien organisms from the investigations conducted to date (notwithstanding the controversy surrounding meteorite ALH84001). Our understanding of celestial environments clearly is incomplete. We know with certainty, however, that life is adaptable and resilient, and once it takes hold in an environment, no matter how seemingly inhospitable, life is imbued with a tenacious will to continue to exist.[28] Therefore, prudence dictates that planetary protection policies continue to be developed and enforced pending future scientific investigations.[29]

Recent events underscore the necessity for prudence in the conduct of scientific investigation. On July 31, 1999, the Lunar Prospector craft intentionally was crashed into the south pole of the Moon, in an attempt to induce a plume of water molecules from the previously announced polar ice deposits. It was hoped that the plume would be visible and measurable by observers, and thereby provide confirmation of the existence of lunar ice.[30] In addition, the Lunar Prospector carried a small vial of the cremated remains of Dr. E. Shoemaker for "burial" on the Moon. The spacecraft was not sterilized, nor were active decontamination measures utilized.

The intentional crash of the Lunar Prospector was not a violation of the planetary protection policy, at least as it has existed since 1978. The current policy exempts missions to the Moon, continuing the categorization of our closest neighbor as not "biologically interesting." With all due respect for Dr. Shoemaker and the Lunar Prospector mission planners, the activities utilized to conclude the mission set a terrible precedent and were ill advised.

The intentional crash of the spacecraft was not the only conceivable method which could be utilized to confirm the existence *vel non* of lunar ice. Even if the answer to the question could not be provided by Lunar Prospector in any other way, there was no assurance that the intentional crash would provide the result either. Indeed, no ice was detected as a result of the Lunar Prospector impact.[31] Thus, the crash may have created unnecessary debris and potential contamination of a water source, the well spring of carbon based life, without producing any scientific benefit whatsoever.

It is ironic that the planetary protection policy exempts the Moon from its application, when the Moon Treaty contains the most comprehensive environmental protection provisions in space law. It is further ironic that the current revision of the policy continues to exempt the Moon as not being "of significant interest relative to the process of chemical evolution" at the same time the Lunar Prospector is being intentionally crashed into the surface to prove the presence of lunar ice. Yet, the Lunar Prospector, consistent with the current planetary protection policy, intentionally impacted an unknown quantity of unidentified microbes and other bioburden into what could have been a repository of an important clue to unravel one of the fundamental mysteries of life. If this seems to be an overstatement, it should be recalled that the Lunar Prospector also delivered a capsule of cremated human remains into the pristine lunar polar environment. Unfortunately, the Moon has now been converted into a cemetery.

CONCLUSION

There is no race for interplanetary exploration. The only race is for the preservation of the universe, which is an inverse race for time. Once a pristine environment has been contaminated, there is no avenue for return. The *status quo ante* forever may be lost to scientific investigation and natural evolutionary processes.

Table 1. PLANETARY PROTECTION MISSION CATEGORIES

PLANET PRIORITIES CATEGORY		MISSION TYPE	CATEGORY
A	Not of direct interest for understanding the process of chemical evolution. No protection of such planets is warranted and no requirements are imposed.	Any except Earth return	I
B	Of significant interest relative to the process of chemical evolution but only a remote chance that contamination by spacecraft could jeopardize future exploration.	Any except Earth return	II
C	Of significant interest relative to the process of chemical evolution and/or the origin of life or for which scientific opinion provides a significant chance of contamination which could jeopardize a future biological experiment.	Flyby, Orbiter	III
		Lander, Probe	IV
All	Any Solar System Body	Earth-Return	V

Reproduced from NASA Procedures and Guidelines 8020.12B (1999), chap. 1

Table 2. PLANETARY PROTECTION PRIORITY FOR TARGET BODIES

A	B	C
Sun	Venus	Mars
Moon	Jupiter	Europa (tent.)
Mercury	Saturn	
	Uranus	
	Neptune	
	Pluto	
	outer planet satellites (except Europa)	
	comets	
	asteroids	

Reproduced from NASA Procedures and Guidelines 8020.12B (1999), Appendix, p. 45

NOTES

1. *See generally* C.R. PHILLIPS, THE PLANETARY QUARANTINE PROGRAM: ORIGINS AND ACHIEVEMENTS 10 (1975), NASA Pub. No. SP-4902, U.S. GPO Stock No. 3300-00578; M. WERBER, OBJECTIVES AND MODELS OF THE PLANETARY QUARANTINE PROGRAM 4 (1975), NASA Pub. No. SP-344, U.S. GPO Stock No. 3300-00588.

2. *See generally* J.R. BAGBY, JR., BACK CONTAMINATION LESSONS LEARNED DURING THE APOLLO QUARANTINE PROGRAM, JPL Contract No. 560226 (1975).

3. COSPAR Res. 26, COSPAR INFOR. BULL. at Annex 4 (1964), Fifth International Space Science Symposium, Florence, Italy. The determination of the probability of contamination (P(c)) for any mission was based on the application of the following formula:

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

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 celestial body

P(sa) = probability of surviving atmospheric entry

P(r) = probability of release

P(g) = probability of growth

Phillips, *supra* note 1, at 38.

4. *See generally, 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 Handbook 8020.12A (1976); *Biological Contamination Control for Outbound and Inbound Planetary Spacecraft*, NASA Management Instruction 8020.7A (1988).

5. Committee on Planetary Biology and Chemical Evolution, Space Science Board, NATIONAL RESEARCH COUNCIL, RECOMMENDATIONS ON QUARANTINE POLICY FOR MARS, JUPITER, SATURN, URANUS, NEPTUNE AND TITAN 27-28 (Appendix C) (1978). *But see* Sterns & Tennen, *Current U.S. Attitude Concerning Protection Of The Outer Space Environment*, in PROCEEDINGS OF THE 27TH COLLOQUIUM ON THE LAW OF OUTER SPACE 398 (1985). Further reductions in the probability of growth factor have been made over the years. The "evolution" of the probability of growth factor for Mars has been summarized as follows:

1963: $P(g) = 1$
1964: $P(g) = 10^{-3}$
1967: $P(g) = 10^{-4}$
1971: $P(g) = 10^{-6}$
1978: $P(g) = 10^{-10}$ (10^{-7} for the polar caps, 10^{-8} for the subsurface below 6 cm).

Debus, Runavot, Rogovsky, Bogomolov, Khamidullina & Trofimov, *Mars 96 Planetary Protection Program and Implications for Mars Environment Preservation*, in PROCEEDINGS OF THE 40TH COLLOQUIUM ON THE LAW OF OUTER SPACE 220, 221 (1998).

6. NASA Management Instruction 8020.7A (1988), *supra* note 4.

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

8. *Planetary Protection Provisions for Robotic Extraterrestrial Missions*, NASA Procedures and Guidelines 8020.12B (1999).

9. *Id.* at chap. 1.

10. *Id.*

11. *Id.* at chap. 2, ¶¶ 2.2.5, *et seq.*

12. 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, 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 (1999)[hereinafter referred to as the "Outer Space Treaty"].

13. *See* Sterns & Tennen, *Exobiology and the Outer Space Treaty: From Planetary Protection to the Search for Extraterrestrial Life*, in PROCEEDINGS OF THE 40TH COLLOQUIUM ON THE LAW OF OUTER SPACE 141 (1998).

14. *See* Outer Space Treaty, *supra* note 12, at art. IX; *see also* Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, *entered into force* July 11, 1984, art. 8, ¶ 3, 1363 U.N.T.S. 3, *text reproduced in* UNITED NATIONS TREATIES AND PRINCIPLES ON OUTER SPACE 22 (1999), *and* 18 I.L.M. 1434 (1979)[hereinafter referred to as the "Moon Treaty"].

15. *See also* Convention on International Liability for Damages Caused by Space Objects, *opened for signature* March 29, 1972, arts. II, III, 24 U.S.T. 2389, T.I.A.S. No. 7762, 961 U.N.T.S. 187, *text reproduced in* UNITED NATIONS TREATIES AND PRINCIPLES ON OUTER SPACE 11 (1999).

16. *Id.* at art. XXI.

17. *See* Lyall, *Protection of the Space Environment and Law*, IAF Paper No. IAA-99-IAA.7.1.05 (1999); *but c.f.* 42 U.S.C. §§ 4321 *et seq.* (National Environmental Policy Act).

18. Outer Space Treaty, *supra* note 12, at art. VIII.

19. Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched Into Outer Space, *opened for signature* April 22, 1968, art. V, ¶ 2, 19 U.S.T. 7570, T.I.A.S. No. 6599, 672 U.N.T.S. 119, *text reproduced in* UNITED NATIONS TREATIES AND PRINCIPLES ON OUTER SPACE 8 (1999).

20. *Id.* at Preamble; *see also* Outer Space Treaty, *supra* note 12, at art. V; Moon Treaty, *supra* note 14, at art. 10, ¶ 1.

21. *See* Sterns & Tennen, *supra* note 13, at 146.

22. Outer Space Treaty, *supra* note 12, at arts. V, VIII; Convention on Registration of Objects Launched Into Outer Space, *opened for signature* January 14, 1975, 28 U.S.T. 695, T.I.A.S. No. 8480, 1023 U.N.T.S. 15, *text reproduced in* UNITED NATIONS TREATIES AND PRINCIPLES ON OUTER SPACE 18 (1999).

23. *Id.* at art. VI.

24. *See* DeVincenzi, Klein & Bagby, *supra* note 7, at 18. Article 5, paragraph 3 of the Moon Treaty further provides that states shall inform the Secretary-General of the United Nations of the discovery of any indication of organic life on celestial bodies.

25. *See* Race, *Planetary Protection: Legal Ambiguity and the Decision Making Process for Mars Sample Return*, 18 ADV. S. RES., No. 1/2, 345 (1996).

26. Allen, *The Current Federal Regulatory Framework for Release of Genetically Altered Organisms into the Environment*, 42 FLORIDA L. REV. 531, 538-39 (1990); *see also* Sterns & Tennen, *Regulation of Space Activities and Trans-Science: Public Perceptions and Policy Considerations*, 11 SPACE POLICY 181 (1995).

27. *See generally* ORBITING QUARANTINE FACILITY: THE ANTAEUS REPORT 39-40, (D. DeVincenzi & J.R. Bagby, Jr., eds. 1981) NASA SP-454.

28. *See* Sterns & Tennen, *Preserving Pristine Celestial Environments: The Planetary Protection Policy*, 77 SCIENCE AND TECHNOLOGY SERIES, SPACE SAFETY & RESCUE 1988-1989 399 (1990); *see also* Phillips, *supra* note 1, at 36-7, (discussing the discovery of alpha hemolytic *Streptococcus mitis* bacteria in a camera from Surveyor 3 returned from the lunar surface by Apollo 12); Kushner, *Life in High Salt and Solute Concentrations: Halophilic Bacteria*, in MICROBIAL LIFE IN EXTREME ENVIRONMENTS 318 (D.J. Kushner, ed. 1978); NASA Ames Research Center, NASA NEWS RELEASE 99-54, *NASA Seeks Odd Organisms Living at the Upper Heat Limit of Life*, September 16, 1999.

29. *See* DeVincenzi, *supra* note 7; DeVincenzi, Klein & Bagby, *supra* note 7; Sterns & Tennen, *Legal Aspects of Planetary Protection for Mars Missions*, 15 ADV. S. RES., No. 3, 281 (1995).

30. NASA Ames Research Center, *Lunar Prospector Mission Update*, July 31, 1999.

31. NASA Ames Research Center, NASA NEWS RELEASE 99-63, *No Water Ice Detected from Lunar Prospector Impact*, October 13, 1999.