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Notes
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UNEARTHLY MICROBES AND THE LAWS DESIGNED TO RESIST THEM

***1356** I. Introduction

Dr. John D. Rummel, a sane and intelligent man, takes his job of protecting Earth from space aliens very seriously. [1] And that is only half of his job. An employee of NASA, Dr. Rummel's first duty is to ensure that extraterrestrial microbes, [2] if they exist, do not enter Earth's atmosphere by latching onto spacecraft destined to return to our planet. [3] His second duty is to prevent Earthly microbes from hitching rides aboard spacecraft bound for other planets. [4] Dr. Rummel's job title is "Planetary Protection Officer," and the scope of his task is as broad as our knowledge of the cosmos. [5]

The arrival of microbes from one planet on the surface of another could be bad for two principal reasons. First, if microorganisms from another planet arrived on Earth, they could create the same problems that invasive species cause when they arrive on new continents. [6] The extraterrestrial microbes could multiply prodigiously in the absence of the factors that kept their population in check on the planet from which they came, and the microbes could disrupt the ecological balance of Earth. [7] That ecological disruption could conceivably involve Homo sapiens, one species about which policymakers are consistently concerned. [8]

Second, if the biological contamination involved shipping microorganisms from Earth to a new planet, that planet could lose ***1357** much of its scientific value as a world wholly unaffected by Earth life. [9] Once tainted by life from Earth, conditions on a foreign planet would not be pristine and would no longer represent the culmination of entirely extraterrestrial planetary evolution. [10]

In the United States, NASA seeks to avoid interplanetary contamination by decontaminating spacecraft bound for biologically sensitive planets before launching them. [11] No NASA probe leaves Earth without Dr. Rummel's approval. [12] " 'I often imagine myself strapped to a booster somewhere,' Rummel says in a comic voice, 'Now, you won't launch this unless you get my signature.' " [13]

But Dr. Rummel alone cannot protect the planets. He is an employee of NASA and wields no formal authority in any space agency outside the United States. [14] The threat of interplanetary contamination, however, is international in origin. [15] The space agencies of many foreign nations, unconstrained by Dr. Rummel and NASA's procedural safeguards, have joined the United States in launching objects into outer space. [16] In fact, "the international community is witnessing a revitalization of interest in space exploration," [17] and many countries that have never participated in ***1358** space exploration are now building new programs. [18] The European Space Agency (ESA) has launched orbiters to Venus and Mars. [19] The Japanese Aerospace Exploration Agency (JAXA) has sent orbiters to the moon and is planning a Venusian orbiter, [20] the Chinese National Space Administration (CNSA) has already put a man in orbit and has aspirations of industrial activity in space, [21] and Russia "is still launching more spacecraft than any other space power in the world."[22] These countries may or may not be sterilizing their spacecraft.[23] International cooperation is now a prerequisite to planetary protection.[24]

To ensure that all spacefaring nations decontaminate their spacecraft, the international community needs binding law.[25] Unfortunately, none exists.[26] The founding document of international space law, the 1967 Outer Space Treaty (the OST), does not explicitly address biological planetary contamination.[27] ***1359** Although it instructs states to treat celestial bodies as international commons, its provisions addressing contamination are vague to the point of irrelevance.[28] A subsequent treaty, the Moon Agreement,[29] attempted to address some of the OST's shortcomings, but too few nations ratified it.[30] International environmental law, particularly as articulated in the UN's Stockholm[31] and Rio[32] Declarations, contains some promising principles but is probably inapplicable to activities in outer space.[33]

The most comprehensive international guide to planetary protection comes from the Committee on Space Research (COSPAR), which has promulgated a Planetary Protection Policy (COSPAR Policy).[34] COSPAR overhauled its policy in 2002, and it now provides detailed anticontamination measures calibrated to the nature and destination of every space mission.[35] For instance, spacecraft designed to land on another planet must be cleaner than spacecraft designed to orbit,[36] and missions to bodies which may support life must conform to stricter standards than missions targeting barren celestial bodies like the Moon.[37]

***1360** Unfortunately, the COSPAR Policy lacks legal force.[38] No law binds spacefaring nations to its edicts, so their application depends on the voluntary compliance of those the COSPAR Policy seeks to regulate.[39] This poses a problem because the history of space exploration provides "several examples of failures of operators to comply with recommendations of a non-binding nature."[40]

The international community has a strong interest in planetary protection.[41] Keeping outer space, described as "the province of all mankind" by the OST,[42] free from contamination preserves the ability of future scientists to investigate the existence of extraterrestrial life.[43] Keeping Earth safe from extraterrestrial microbes preserves the integrity of our own planet.[44] To serve these two goals, the international community needs a treaty, ratified by all major space powers, that specifically addresses planetary protection and endorses the COSPAR Policy.[45] Infusing the Policy with legal force will ensure that spacecraft bound for biologically sensitive planets are appropriately decontaminated before they depart.[46]

This Note first discusses the risks that a foreign microbe could pose to a new planet and hypothesizes about the probability of microbial travel between celestial bodies.[47] The Note next turns to current law bearing on planetary protection, describing in some detail the corpus juris spatialis[48] and the international ***1361** environmental law which some believe governs activity in outer space.[49] The Note next addresses the potential for spacefaring states to skimp on planetary protection measures[50] and, finally, proposes a solution to the inadequacies of existing law.[51]

II. The Status Quo

A. SCIENCE AND HISTORY: THE SCOPE OF THE PROBLEM

No one knows exactly how risky or how likely interplanetary contamination is. Although neither science nor history can provide certain answers, both fields offer clues about the dangers that could accompany foreign microbes and the probability of their interplanetary transport. This Part discusses those clues by first addressing the potential consequences of a microbial invasion and then contemplating the probability that microbes could travel between planets.

1. The Risks of Interplanetary Microbial Travel. In the eyes of planetary protectionists, microbes can travel in two directions: to Earth and from Earth.[52] Scientists try to avoid both.[53] Each direction of travel has its own term-the concept of microbes traveling from an extraterrestrial environment to Earth is termed "backward contamination" or "back contamination," while microbes traveling from Earth to another planet would constitute "forward contamination."[54] Either form of contamination

could portend environmental or ecological disaster for the receiving planet, but the risks associated with each vary in severity and type. [55]

***1362** a. Back Contamination. “For the public, the truly hair-raising danger comes from bringing alien material to Earth.” [56] Although the scientific record is devoid of any proven example of backward interplanetary contamination, history does contain useful analogies for the arrival on Earth of extraterrestrial microbes. Intercontinental invasive species provide one parallel. [57]

One of Earth's most infamous invasive species was Variola major, the virus [58] responsible for smallpox. [59] When European explorers crossed the Atlantic to reach North America in the fifteenth and sixteenth centuries, they brought the European cadre of microbial pathogens with them, including Variola major, which had long been common in Europe but was new to North America. [60] Variola major and the other microbes proved devastating. [61] Some scientists believe that smallpox and other illnesses caused by European microbes killed as much as 95% of North America's indigenous human population. [62] What made Variola major so deadly was the absence of local defenses against it. [63] In Europe, where the microbe had evolved alongside its host species for millenia, the hosts had evolved defenses to limit its deadliness. [64] Native Americas, however, had no defenses, and Variola major cut through them like a scythe. [65]

***1363** If a microbe from another planet arrived on Earth, the results could be as devastating to Earth's life forms as Variola major was to Native Americans. [66] If the newly-arrived interplanetary microbe proved parasitic, no life form on Earth would have developed defenses against it. [67] The microbe could then proliferate at the expense of native species-possibly humans or another species on which humans depend. [68]

The effects of an extraterrestrial microbe might be even more devastating than Variola major's arrival in the Americas. [69] The almost supernatural potency of Variola major, an intercontinental microbe, was at least limited to the area outside of the region in which the pathogen evolved-i.e., Europe-because putative European hosts to the virus had evolved defenses to it. [70] A parasitic microbe arriving from a foreign planet might not be so restricted. A space-traveling microbe could conceivably wipe out an entire species or group of species, because no organism on the planet would have evolved defenses to the invader. In the words of one scholar, “[w]hat if bizarre forms of pathogens exist on planets like Mars? Are we really prepared to bring them home?” [71]

Even if an extraterrestrial microbe did not affect humans directly, its effects could be deleterious to the environment. [72] Some scientists who consider it more likely that a foreign microbe could damage Earth's environment than act as a human pathogen have ***1364** described the specter of widespread environmental damage as the “graver concern.” [73] Again, the historical record of invasive species on Earth furnishes an example. American chestnut trees once dominated North America's eastern forests, shading the earth all along the Appalacians with their broad deciduous canopies. [74] A squirrel, it was said, could travel from Maine to Georgia without touching the ground by hopping from one American chestnut to another. [75] Today, the American chestnut has been “virtually exterminated.” [76] The exterminator was a fungus called “chestnut blight,” an invasive species from Asia against which the huge trees had no defenses. [77] Just as chestnut blight annihilated the American chestnut, an alien microbe could decimate the population of any living thing susceptible to it.

Conversely, some scientists suggest that the arrival of alien microbes would be nothing new. [78] Scientists generally accept that when meteors or asteroids strike planets, the tremendous impact force can fling chunks of rock and other debris into outer space. [79] These rocks can travel between planets and plunk down someplace new. [80] Some scientists speculate that the space-traveling rocks could have contained microbial life and may have naturally facilitated the interplanetary travel of microbes. [81] Scientists also generally accept that “solar wind ions”-i.e., winds of charged particles emanating from the sun [82] -could have brought foreign ***1365** material into Earth's atmosphere, although the likelihood of “contamination” from solar winds is low. [83]

Despite suspicions that extraterrestrial microbes have previously arrived on Earth, there is a strong scientific consensus that spacefaring nations should take careful precautions to avoid back contamination. [84] Even if an extraterrestrial microbe has previously arrived on Earth without causing damage, a subsequently arriving microbe could produce very different results.

The example of Variola major is again illustrative. Although their arrival precipitated the death of most then-living American natives, the European explorers of the fifteenth and sixteenth centuries who carried Variola major were not the first Europeans to visit the Americas. Historians have revealed that Norse sailors reached and explored coastal areas of northern North America almost 500 years before Christopher Columbus made his famous voyage. [85] Although these early Norse sailors had contact with Native Americans through battle and trade, exposing the natives to European germs, the natives experienced no massive dieoff-in fact, they remained strong enough to expel the Norse from the continent. [86]

The death wave that rocked the Americas' native population came several centuries later. [87] Although Native Americans' first exposure to European germs seemed innocuous, a subsequent exposure to European explorers and conquistadors like Columbus and Cortez would kill 95% of the Native American population. [88] Similarly, even if Earth's ecosystems have already been exposed to an extraterrestrial microbe, a second exposure could prove deadly.

***1366** b. Forward Contamination Generally. Although it is less likely to threaten humans as a species, forward contamination is another evil that planetary protectionists seek to avoid. [89] It poses at least two serious threats. First, forward contamination could impede our ability to determine whether a planet originally held indigenous life. [90] If humans inadvertently “seeded” a planet with microbes, the possibility of “false positive” results would taint subsequent experiments to determine whether indigenous life existed. [91] If scientists searching for life later discovered the “seeded” microbe, they might not recognize it as an Earth-originating organism, either because the overwhelming majority of earthly microorganisms remain unclassified [92] or because the organism could have changed form through rapid evolution or radiation-induced mutation. [93] To most scientists involved in planetary protection, “preserving the ability to answer high-priority questions” like whether indigenous life exists on a foreign planet is the most important reason to avoid forward contamination. [94] This means that humans should be careful, because as Dr. Rummel put it, ” ‘[t]he best way to find life on Mars . . . is to bring it from Florida.’ “ [95]

***1367** This principal reason for preventing forward contamination only applies until scientists have conducted definitive tests for life on the foreign planet. Scientists refer to the period during which forward contamination should be avoided as the “period of biological exploration.” [96] It is unclear how long this period should last, [97] but sometimes its duration is clearer with respect to specific celestial bodies. [98] Scientists can agree, for instance, that the period of biological exploration has ended for the Moon [99] but not for Mars. [100]

Preserving pristine planets for future experiments is not the only reason to avoid forward contamination. Forward contamination could constitute environmental disaster on a planetary scale. [101] For many, the specter of such an environmental catastrophe raises ethical issues. [102] Some scientists and laypeople believe that humans have already crossed a moral threshold by transforming the surface of our own planet, and therefore oppose the alteration of any others, whether deliberate or accidental. [103] Those who oppose human alteration of other planets, whether by contamination, terraforming, [104] or mining, [105] have sometimes been called ***1368** “astroenvironmentalists.” [106] Proponents of astroenvironmentalism argue that other planets should be treated as wildernesses to be explored, not frontiers to be tamed. [107]

If an extraterrestrial microbe were to hitchhike to a new planet, the effects of that microbe could be drastic-it could adversely affect any local life [108] or impede our attempts to discover indigenous life. [109] It could also alter the atmospheric or geologic makeup of the planet, just as cyanobacteria, a terrestrial microbe, contributed to the oxygenation of Earth's atmosphere and caused the “rusting of the earth” some two billion years ago. [110]

Another possibility is that the new microbe would have no effect at all. The microbe might die immediately. [111] In fact, immediate demise is the fate scientists would predict for most Earth-originated microbes arriving on the surface of Mars. [112] Organisms that have evolved on Earth, even resilient microbes, are generally not adapted to deal with the extreme cold, dryness, and ultraviolet radiation of the Martian surface. [113] It is also noteworthy that microbes of extraterrestrial origin arriving on Earth might find Earth's climate similarly unsuitable on account of its environmental dissimilarity to the microbe's planet of origin. Although some microbes, like Variola major, thrive in environments to which they are introduced, ***1369** many microbes would perish if confronted with environments to which their life cycles were not adapted. [114]

c. Forward Contamination of the Moon and Mars. Whereas suspicions exist that backward contamination has already occurred, it is certain that humans have already perpetuated forward contamination. [115] Spacefaring nations have exposed the Moon, in particular, to earthly microbes. [116] Humans have pummeled the moon by crashing no fewer than thirty-four spacecraft onto the lunar surface. [117]

The wreck parade began in 1959 with the Soviet spacecraft "Luna 2," which "carried a 26 kg sphere, which . . . disintegrated on impact, scattering tiny medallions imprinted with Russia's hammer-and-sickle emblem over the surface of the Moon." [118] The pace of the crashes then increased. [119] "[T]he Moon became a dartboard for early probes from the Soviet Union and United States . . . ." [120] Thirty-three crashes later, in 1999, NASA intentionally smashed the unsterilized craft "Lunar Prospector" into the Moon's south pole with a capsule of cremated human remains on board. [121]

Even if none of these thirty-four crashes put earthly microbes on the Moon's surface, Neil Armstrong and Buzz Aldrin almost certainly exposed the Moon to earthly microorganisms. Because human bodies contain and emit so many microbes-humans have been described as "spewing fountains of bacteria" [122] -it is all but impossible to prevent planetary contamination during a manned mission to a celestial body. [123] Biological contamination of the Moon, ***1370** however, is probably no great loss because the Moon is almost certainly lifeless. [124] Scientists generally no longer advise its protection against biological contamination. [125]

Mars is another matter. Along with Europa, one of Jupiter's moons, [126] Mars is one of the prime candidates for supporting extraterrestrial life in our solar system because, despite the inhospitable Martian surface, scientists suspect that life might be able to survive underground. [127] "[M]icrobial Martians might still be nestled in dark warm recesses," Dennis Overbye of the New York Times has written, "waiting for visitors from another world to read the message written in whatever genomic language has been carved out of chemistry, starlight and time." [128]

Although NASA's Viking spacecraft obtained negative results when they landed on Mars and tested for life in the 1970s, many scientists still believe that life could exist there. [129] Scientists have questioned the Viking missions' results because the spacecraft's detection instruments were insufficiently sensitive and tested only near-surface soil. [130] Others have suggested that the Viking spacecraft actually found Martian life but inadvertently killed it. [131] ***1371** Hopes that life exists on Mars are further buoyed by geologic evidence such as "outflow channels," [132] which can be seen online through Google Mars, and halos in rock coloration, [133] both of which suggest that liquid water may flow in the Martian subsurface. [134] The period of biological exploration on Mars, therefore, has not yet ended. [135]

The potential for life on Mars, however, was insufficient to stave off the barrage of Earth-originating spacecraft. Although crashing spacecraft have not thumped Mars as regularly as they have struck the moon, several orbiters and landers not sterilized to Viking levels have crashed on Martian soil. [136]

The first suspected crash occurred in 1964, when certain deep-space tracking stations indicated that the Russian spacecraft Zond 2, which had not been sterilized at all, crashed onto the Martian surface. [137] The fate of Zond 2 remains uncertain, however, because Soviet authorities, who lost contact with the probe before it reached Mars, refused to provide full information. [138] Scientists know more about subsequent crashes. [139] Between 1971 and 2003, the USSR's Mars 2 and Mars 6 landers and the United Kingdom's Beagle 2 lander all collided with Mars, although these spacecraft were more likely to have been sterilized. [140] In 1999, NASA's Mars Polar Lander, which had not been subjected to the full sterilization ***1372** procedures like those used in the Viking missions, failed and crashed on Mars. [141] As a result of these and other impacts, the National Research Council concluded that "past missions that have landed or crashed on Mars . . . have virtually certainly delivered some viable microorganisms to the martian surface." [142]

Nevertheless, at least two strong reasons remain for sterilizing spacecraft bound for the Red Planet. First, any contamination that has already occurred is likely to be "at most local" unless the microorganisms were delivered to an environment that granted them access to the Martian subsurface. [143] Mars's surface environment is harsh and not conducive to microbial transport. [144] Although some scientists have argued that Mars's regular planet-wide dust storms would globalize any contamination, other evidence suggests that microbial travel during a dust storm would be difficult. [145]

Second, because the probability that any organism from Earth could survive on Mars is low, the past delivery of microbes to Mars does not necessarily imply that Mars has been contaminated. [146] The planet is probably still pristine. [147] But the hypothetical good fortune of past missions, whose microbial deliveries may not have contaminated Mars, does not assure that future errors in planetary protection will not have more adverse results. [148] Future crashes could still contaminate Mars. [149] As exobiological pioneer Carl Sagan wrote, "[i]f the individual in front of us throws a lighted match into ***1373** the forest, it does not follow that we may throw large numbers of lighted matches as well." [150]

2. The Probability of Interplanetary Microbial Travel. Although scientists once doubted that microbes were tough enough to withstand the rigors of space travel, recent discoveries have indicated that microbial life can be hardier than scientists once recognized. [151] Discoveries of "extremophiles," organisms adapted to live in conditions of extreme temperature, salinity, or pressure, [152] have opened scientists' eyes to the variety of environments that life can tolerate. [153] Some archaebacteria, for instance, thrive in the anaerobic world of deep-sea hydrothermal vents at 230 degrees Fahrenheit. [154] Other microbes have been found living in rocks three thousand feet below the Earth's surface, [155] in soil frozen for three million years [156] and at the core of nuclear reactors. [157] "[W]e've found life in extreme environments on Earth, that are completely different from anything you or I would be comfortable living in," Dr. Rummel told one interviewer. [158] "I don't want to live in a boiling pool in the middle of Yellowstone Park, but there are microbes that just love it." [159]

Some scientific data specifically suggest that some terrestrial microbes could survive in outer space. [160] In one instance, bacteria survived for two years on the Moon in the housing of a camera left ***1374** behind by U.S. astronauts. [161] "The 50-100 organisms survived launch, space vacuum, 3 years of radiation exposure, deep-freeze at an average temperature of only 20 degrees above absolute zero, and no nutrient, water, or energy source." [162]

The ability of extremophiles to survive in environments scientists once considered inhospitable to life raises questions about where scientists might find life and what journeys life forms could survive. [163] While the rigors of hitchhiking between planets once seemed prohibitive to life, interplanetary microbial travel now seems possible. [164] While the hostility of foreign planets once seemed to preclude life there, scientists are beginning to find extraterrestrial nooks and crannies where life could exist. [165] It is also important to remember that scientists' past discoveries of extremophiles do not necessarily define life's outer limits. [166] Life forms still unknown to science, whether terrestrial or extraterrestrial, might well be tougher than anything yet discovered.

B. LAW: LEGAL RESPONSES TO THE PROBLEM

Current international law does little to prevent interplanetary contamination. [167] Planetary protectionists have scoured the treaties and policies of the corpus juris spatialis and combed through the ***1375** annals of international environmental law searching for a legal hook from which to hang a binding international planetary protection policy, but have found nothing satisfactory. [168] The OST is too vague to compel protective measures, [169] the Moon Agreement is too unpopular, [170] international environmental law is too terrestrial, [171] and COSPAR's Planetary Protection Policy does not have enough bite. [172] This Part of the Note will take up each of these four sources of law in turn.

1. The Outer Space Treaty. The OST is the Magna Carta of space law. [173] Ratified or acceded to by most states, including most spacefaring nations and almost every country that could realistically consider funding a space program, the provisions of the OST have attained the status of customary international law and therefore bind even the few states that have declined to ratify the treaty. [174] But the drafters of the OST had little to say about planetary protection. [175] Its focus reflects the time at which it was

drafted-of central concern to the drafters were provisions about nuclear weapons in space and the extent to which nations may claim ***1376** property rights in celestial bodies. [176] Concerning contamination of Earth or other planets, the approximately 2,100-word treaty offers only the following language from Article IX: "[countries shall conduct their exploration of space and celestial bodies] 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." [177]

Almost all scholars writing about planetary protection address Article IX's prohibition against "harmful contamination." [178] A few have even pinned their hopes for planetary protection on this provision, contending that its "harmful contamination" language imposes a meaningful legal command on nations with active space programs. [179] But most scholars disagree. [180] The general scholarly consensus holds that while Article IX may provide a springboard for future lawmaking efforts, nothing in the OST compels spacefaring nations to take adequate anticontamination measures. [181]

Article IX is too general to compel any action on the part of a ratifying nation unless that nation passes specific, concrete domestic laws to implement its provisions. [182] This weakness arises from the vagueness of the OST's text-the OST does not define "harmful contamination" or "adverse changes," and Article IX leaves unanswered what "measures" might be "appropriate" for preventing ***1377** contamination. [183] Nowhere in Article IX, or any other part of the treaty, did the drafters specify any means of ensuring that departing spacecraft are sterile, that any extraterrestrial samples brought back to Earth are safely contained, or that ratifying nations comply with the treaty. [184]

While the OST gave the corpus juris spatialis a solid trunk from which other branches of space law could grow, [185] most of its drafters did not fully anticipate, and therefore did not adequately address, planetary protection concerns. [186] Although the Japanese delegation to the treaty's drafting suggested that the OST's planetary protection language was insufficient, its protests went unheeded. [187] As a result, Article IX's language remained cripplingly vague and has had only a minimal effect on the conduct of the nations it purportedly governs. [188]

The problems that the OST's inadequate treatment of planetary contamination created are exacerbated by the lack of enforcement of the contamination provision. Modern problems with "space trash" illustrate this lack of enforcement. [189] Although the OST purports to impose "international responsibility for national activities in outer space," [190] its anticontamination provisions have been insufficient to stop spacefaring nations from leaving their garbage, now termed "space trash," in orbit, a practice most nations have followed since space exploration began. [191] Today, millions of these human- ***1378** deposited objects orbit the Earth, [192] varying in character from tiny paint chips to discarded rocket boosters. [193] Garbage bags, sandwich bags, lint, a piece of a peanut, and human feces have all been found whizzing around the globe in Earth orbit. [194]

At least facially, these items should come under the purview of the OST's prohibition against "harmful contamination." [195] Space trash undoubtedly constitutes "contamination"-the definition of "contaminate" includes "to make inferior or impure by admixture," a definition that clearly encompasses dumping garbage into what was, until recently, a pristine environment. [196] Space trash is also "harmful." Earth-orbiting material, including space trash, travels at about 20,000 feet per second [197] and becomes a collision risk to operational spacecraft. [198] In 1983, a paint chip measuring 0.2 millimeters across struck Challenger's window, requiring NASA to replace the window at a cost of $50,000. [199] And in 1999, a discarded Russian booster rocket very nearly struck and destroyed the International Space Station, missing it by only five miles-a narrow margin in the vast reaches of outer space. [200] Space trash "is now widely accepted as a cause for concern." [201]

Although space trash probably constitutes prima facie "harmful contamination," the OST has failed to stop countries from jettisoning their garbage in orbit. [202] If the OST cannot prevent astronauts from leaving trash bags and peanut hulls in space, there ***1379** is little reason to think that its provisions, standing alone, can induce nations to take the much more difficult step of sterilizing their spacecraft against microbes. [203]

2. The Moon Agreement. The Moon Agreement's language concerning planetary protection is more specific than the OST's Article IX. [204] Unfortunately, however, the Moon Agreement has been ratified by so few nations that its effect on the spacefaring community has been slight. [205]

Opened for signature in 1979, the Moon Agreement specifically contemplates the prevention of forward or backward contamination, [206] stating:

> 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. [207]

Although the Moon Agreement resembles the OST in that it omits definitions of "harmful" and "adverse," the treaties differ in that the text of the Moon Agreement reflects its drafters' sensitivity to environmental and planetary protection concerns. [208] The first ***1380** paragraph of Article 7, quoted in its entirety above, addresses planetary contamination in much greater detail than any provision in the OST. [209] Its prohibition against introducing extra-environmental matter to the Moon forbids forward contamination, and the provision prohibiting the harmful introduction of extraterrestrial matter to Earth squarely addresses back contamination. [210] Furthermore, by decreeing that ratifying nations "shall take measures" to protect planets from foreign material, the drafters imposed an affirmative duty to take anticontamination steps on parties to the treaty. [211]

The Moon Agreement has an egalitarian twist that also sets it apart from the OST. [212] The Agreement borrowed the phrase "province of all mankind" [213] from the OST, but added the new and far-flung phrase "common heritage of mankind." [214] The Agreement then took celestial egalitarianism one step further by contemplating an "international regime" to regulate the exploitation of lunar resources. [215] Among that regime's "main purposes," the agreement declares, is the "equitable sharing by all States Parties in the benefits derived from [lunar] resources." [216]

In two ways, "Moon Agreement" is a misnomer. First, the treaty reaches far beyond our Moon. [217] Pursuant to Article 1, its anticontamination provisions apply to "other celestial bodies within ***1381** the solar system," [218] a scope-setting clause which probably includes other planets, like Mars, and their moons, like Europa. [219] The scope of the Moon Agreement, therefore, is adequate for planetary protection.

"Moon Agreement" is also a misnomer because there was very little "agreement." As of 2005, the treaty had been ratified by only eleven nations and signed by another five. [220] Most of the major spacefaring nations declined to sign. [221] The provisions of the Moon Agreement have not become customary international law and, despite its unprecedented concern for preventing interplanetary contamination, "[the Moon Agreement] is considered to be little more than a dead letter." [222] Even when considered together, most scholars agree that the Moon Agreement and the OST provide little legal protection against interplanetary contamination. [223]

3. International Environmental Law. Some scholars have contended that current international environmental law could protect the space environment. [224] Closer inspection, however, reveals that this body of law probably applies only on Earth. [225]

Most authors contending that international environmental law can be used to prevent interplanetary contamination rely principally on the UN's Stockholm and Rio Declarations. [226] Principle 21 of the 1972 Stockholm Declaration, repeated almost verbatim as Principle 2 of the 1992 Rio Declaration, declares that:

> ***1382** States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the

> responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction. [227]

Many scholars have claimed that this language is facially applicable to planetary protection. [228] These proponents suggest that Principle 21 can be read to prohibit forward contamination because the contamination of a foreign planet would cause damage to an "area[] beyond the limits of national jurisdiction." [229] The text of the OST seems to support this argument for facial applicability by confirming that outer space is beyond the reach of claims of state sovereignty. [230] On its face, Principle 21 may also prohibit back contamination if the extraterrestrial microbe "cause[s] damage to the environment of other States or of areas beyond the limits of national jurisdiction"-i.e., to the territory of any state not responsible for the contamination or to an international commons like the high seas. [231] [232]

Despite the facial applicability of Stockholm Principle 21 and Rio Principle 2, and although Article III of the OST requires that states ***1383** explore outer space "in accordance with international law," [233] the Stockholm and Rio Declarations fail to provide any significant safeguard against interplanetary contamination for two reasons discussed below. First, the declarations probably have no application to activities in outer space, and second, the declarations have demonstrably failed to protect the outer space environment.

The declarations probably apply only on Earth. Although several respected scholars assert that general international environmental law could apply to space exploration, no author can point to any past application of terrestrial environmental law to activities away form our own planet. [234] Legal scholars Goh and Kazeminejad conclude their argument that Principle 21 applies to outer space by pointing to two decisions by the International Court of Justice said to illustrate the "international obligation to protect the environment from contamination." [235] Neither of the cases involves space exploration, even tangentially. Respectively, the cases involve the terrestrial use of nuclear weapons and a water rights dispute between Hungary and Czechoslovakia. [236]

The texts of the Stockholm and Rio Declarations evince no intent to control outer space activity. In fact, textual clues in both declarations suggest that the conceptions of the drafters were limited to the planet on which they sat. Neither document refers to outer space or even uses the word "space." [237] In contrast, language that tends to limit the scope of the declarations to terrestrial affairs abounds in both. The full title of the Stockholm Declaration is "Declaration of the United Nations Conference on the Human ***1384** Environment," [238] which necessarily refers to the earthly environment, since humans are known to live nowhere else. Furthermore, the preamble to the Stockholm Declaration notes the "long and tortuous evolution of the human race on this planet," the "growing evidence of man-made harm in many regions of the earth," and humankind's ability to cause "massive and irreversible harm to the earthly environment." [239] References to Earth are not confined to the preamble. Principle 21 itself refers to nations' "sovereign right[s] to exploit their own resources," which again suggests a terrestrial focus-any nation's "own resources" necessarily exist on Earth, because the OST precludes state sovereignty in outer space. [240]

The text of the Rio Declaration also evinces a terrestrial focus. Its preamble refers to the conference's "goal of establishing a new and equitable global partnership" and the delegates' "[r]ecogni[tion of] the integral and interdependent nature of the Earth, our home." [241] Additionally, Principle 2, a restatement of the Stockholm Declaration's Principle 21, shares Principle 21's focus on a nation's "own resources." [242] Despite the high hopes of some scholars, [243] it is unlikely that the tenets of international environmental law can prevent interplanetary contamination.

4. COSPAR's "Planetary Protection Policy." COSPAR's Policy has won the praise of planetary protection critics for its soundness, comprehensiveness, and coherence. [244] However, it is not internationally binding. [245]

The Policy offers guidelines aimed at preventing planetary contamination. [246] COSPAR was created in 1958 by the International Council for Science, [247] and since its inception has ***1385** continually updated its Planetary Protection Policy, amending it most recently in 2005.[248] Dr. Rummel has called the Policy "the focal point of international activities relating to planetary protection."[249]

The Policy is the finely-wrought result of rigorous scientific inquiry.[250] It divides all space missions into five categories based upon the degree of planetary contact involved and the celestial body targeted.[251] Missions in Category I merit the least concern, and include missions that target the Moon or Venus, which are considered sterile, and that do not involve returning to Earth.[252] Like Category I, Category II excludes Earth return missions, but Category II includes missions targeting comets, some asteroids, and most of the planets in our solar system.[253] Category III missions target bodies on which scientists speculate that life could exist, such as Mars[254] or Europa, but do not involve any "direct contact" with the planet, as with a lander or rover.[255] Category IVa, IVb, and IVc missions involve direct contact with a planet suspected of being capable of supporting life, and Category V missions comprise those contemplating a return to Earth.[256]

The Planetary Protection Policy prescribes different anticontamination measures for each official category.[257] Those measures generally aim to accomplish one of six goals: (1) reducing the spacecraft's bioburden,[258] (2) reducing the chance that the spacecraft will crash onto the planet, (3) ensuring reliable assay ***1386** methods evaluating the bioburden, (4) documenting the maintenance of sterile conditions from construction until launch, (5) developing and maintaining bioburden inventories, or (6) documenting mission events from launch until termination.[259]

The Policy's recommendations do not last indefinitely. COSPAR recognizes a limited period of biological exploration during which its recommendations are active and after which planetary protection measures can be relaxed or abandoned.[260] The length of the period is flexible.[261] Its endpoint can be defined either as a calendar year or as the time by which adequate robotic tests for life have been conducted.[262] In either case, however, the period is unlikely to end soon; one current estimate puts the endpoint at fifty years from the present.[263]

COSPAR's Planetary Protection Policy may be persuasive to many nations, but it binds none.[264] Although COSPAR's highest body, the Council, includes members from most nations with active space programs,[265] and although the world's best-funded space-exploring entity, NASA, "generally follows the COSPAR policy,"[266] the Policy constitutes only "soft law"[267] -its edicts impose only "a moral kind of obligation" on spacefaring nations.[268]

This "moral kind of obligation" is not sufficient. As more nations join in the exploration of outer space, hopes reposing in a voluntary system of self-regulation seem more and more misplaced.[269] International dependence on voluntary compliance has proved futile in at least two areas of space regulation. First, despite Article XX of the UN's Registration Convention, which directs nations to ***1387** register the objects they launch into space, 30% of the objects launched in 2000 were unregistered.[270] Second, despite the International Telecommunication Union's recommendation that satellites nearing the end of their active lives be removed from geostationary orbit, only two of fourteen satellites that expired in 2004 were so removed.[271] Although COSPAR's Policy has been an important step in planetary protection, it is clear that regulating space exploration will require a body of law with a harsher bite.

Despite its lack of legal force, however, the COSPAR Policy has given planetary protectionists an invaluable model for procedures that may one day be backed by the force of law.[272] The endorsement of the Policy by COSPAR's nationally diverse Council attests to the potential for international consensus,[273] and the high international regard for the Council's conclusions illustrates the deference that an august body of international scientists may command.[274] The ability of COSPAR to update the Policy when necessary suggests that a scientifically generated list of prescribed protection procedures can adapt itself to changes in technology and circumstance.[275] In many ways, the COSPAR Policy has laid the groundwork for a binding agreement on international planetary protection.

III. Temptation to Skimp

Lured by international prestige and the promise of technological innovation, many nations new to spacefaring have joined mankind's exploration of the final frontier.[276] In some cases they seek to ***1388** collaborate with NASA, the world's most accomplished space program.[277] In other cases they seek to become independent.[278] Without exception, however, other countries' new space programs must rely on coffers that are significantly shallower than NASA's.[279] As these nascent space programs struggle to join the new millennium's space race, it is easy to foresee the temptation to cut corners.

Planetary protection could be one such corner. Even NASA, the world's best-funded space program and a modern adherent to COSPAR's Planetary Protection Policy, relaxed its planetary protection measures in the late 1970s and throughout the 1980s for budgetary reasons.[280] Scholar Mark Williamson has written, "[i]t seems fair to conclude that [NASA's] limitation of decontamination measures was a result of financial concerns rather than an application of the scientific method."[281]

Space programs with less money than NASA, but visions nearly as grand, may be strongly tempted to skimp on planetary protection. Russia's Federal Space Program, for instance, is contemplating missions to the Moon and to Mars.[282] Colonel-General Vladimir Popovkin, commander of Russia's space troops, has spoken of other countries' preparations for "manned flights to the Moon and Mars and also for their subsequent conquest."[283] The Colonel-General then added, "Russia, as the premier world space power, cannot remain aloof."[284] Russia's annual space budget of $500 million ***1389** constitutes approximately one-thirty-second of NASA's $16 billion annual budget.[285]

China's growing space program has made it the third nation, after Russia and the United States, to send a human into orbit, and Chinese aspirations remain high.[286] A Chinese Moon landing appears imminent, and the Chinese National Space Administration is considering launching a Martian probe and facilitating private space tourism.[287] China's space budget, at approximately $2 billion,[288] is about one-eighth the size of NASA's, but Sun Laiyan, head of the CNSA, remains undaunted.[289] In a 2006 interview, he noted that Bejing was spending far less on space exploration than NASA, then added, "[i]n fact, we spend quite little on what we need to do."[290] Foregoing protection measures would allow space programs to cut costs by 5-10% on high-risk missions.[291] As nations like Russia and China clamor to compete with NASA on comparatively tiny budgets, it is far from certain that, in the absence of express requirements to do so, either nation will prioritize planetary protection.

IV. Proposed Solution

The corpus juris spatialis needs a new treaty.[292] Because existing law cannot prevent interplanetary contamination, ensuring that spacefaring nations follow appropriate planetary protection will require binding international law.[293] Many of the tools necessary for the creation of a planetary protection treaty already exist. Drafters ***1390** of such a treaty could turn to the Moon Agreement as a guide,[294] draw upon COSPAR's Policy for technical expertise, and point to COSPAR-compliant programs like NASA and ESA to illustrate the practicality of Policy compliance. This Part first argues that the Moon Agreement could be a model for a new treaty in two ways.[295] It then describes two ways in which the new treaty should differ from the Moon Agreement,[296] and finally, it discusses the feasibility of creating such a treaty.[297]

In two ways, the Moon Agreement could serve as a model for a planetary protection treaty. First, the Agreement confronts interplanetary contamination directly by expressly forbidding forward and backward contamination.[298] The new treaty should do the same. The vagueness that has haunted the OST's Article IX should be replaced by concreteness. The new treaty could, and should, make great strides toward coherence and specificity by endorsing COSPAR's Policy. Once infused with the force of law, the already respected Policy would make national responsibilities regarding planetary protection abundantly clear.

Second, the new treaty should follow the Moon Agreement by including a review clause. Unlike the OST, the Moon Agreement provides for its own review every ten years in light of "past application of the Agreement" or "any relevant technological developments."[299] The review clause, which allows for some revision, lends the Moon Agreement flexibility. Such a review clause would be especially important in a planetary protection treaty because the available methods of spacecraft sterilization can change rapidly.[300] The review clause should be tied to COSPAR, an internationally representative organization already experienced in updating its Policy. [301] The reconvening parties could be obligated to consider and accord deference to any revisions to the Policy by ***1391** COSPAR or could even be required to consult directly with COSPAR's Council.

The problem with the Moon Agreement, of course, is that it is a "dead letter." [302] To avoid the same fate, the new treaty should differ from its predecessor in two ways.

First, the new treaty should not apply to the Moon. Many powerful spacefaring nations harbor lunar ambitions that would be thwarted by prohibitions against forward contamination of the Moon. The United States, for instance, hopes to build a permanent international base on the Moon by 2024, [303] Russia and China are planning manned missions to the Moon, [304] and some parties are aspiring to mine the Moon for its natural resources. [305] A prohibition of forward contamination of the Moon would preclude any of these activities. None of the foregoing countries have signed the Moon Agreement, [306] and they would probably refuse, again, to sign any protection-minded agreement that would frustrate their lunar ambitions. Because the United States, Russia, and China are major actors on the space exploration scene, and because a planetary protection treaty without their accession would lose much of its value, the Moon should be excluded from the purview of the new treaty to make it more palatable to them.

Excluding the Moon from protection is an acceptable sacrifice. The primary reason for preventing forward contamination, assuring the viability of future life detection experiments, does not apply to the Moon because the Moon is lifeless-"by all accounts a dead cinder." [307] COSPAR has acknowledged the acceptability of contaminating the Moon in its Policy, which recommends no anticontamination measures for lunar missions. [308] Furthermore, to ***1392** a greater extent than Mars or any other celestial body, the Moon has already been pounded by unsterilized human spacecraft. [309] The sterility of the Moon and its lengthy history of contamination make lunar anticontamination measures unnecessary.

Second, the new treaty should be less egalitarian than the Moon Agreement. It should eschew the "common heritage of mankind" [310] concept because, as one scholar has noted, the common heritage concept was "popular in the 1970s, but subsequently largely unacceptable to the international community at large." [311] Nor should the new treaty insist on the "equitable sharing" of all benefits derived from lunar resources. [312] Such a requirement would probably deter developed nations, which may intend to profit from lunar exploration, [313] from signing the treaty. [314] A retreat from the egalitarianism of the Moon Agreement would not detract from the effectiveness of the treaty's planetary protection provisions because the treaty would still endorse COSPAR's Policy.

A planetary protection treaty is probably feasible. Recent history shows that the international community recognizes the importance of planetary protection. [315] In 2003, for instance, when NASA's nuclear-powered Galileo spacecraft seemed likely to collide with Jupiter's moon Europa, which is considered a good candidate for hosting extraterrestrial life, international pressures to implement anticontamination measures induced NASA to deliberately destroy the orbiter. [316]

Nations with nascent space programs would be especially likely to support a planetary protection treaty because the Policy, which ***1393** only requires anticontamination measures for missions venturing beyond the Moon, would leave most of their current activities unaffected. The aspirations of most young space programs to explore beyond the Moon are generally several years into the future. [317] The support of now-nascent space programs for a planetary protection treaty, however, may wane in future years as technological and institutional advances make deep space exploration a more immediate possibility. Once a nation has begun exploring deep space without complying with the COSPAR Policy, convincing that nation to change its habits could be difficult.

The space agency with the most experience in deep space exploration, NASA, already has a history of general compliance and holds itself out as Policy-observant. [318] ESA also complies with COSPAR's recommendations. [319] The model conduct of these two organizations not only illustrates the feasibility of meeting the COSPAR Policy's standards, but suggests that NASA and ESA would support a planetary protection treaty. Support by these established agencies would be especially significant because it would encourage support by nations with less developed space programs, many of which seek exploration partnerships with NASA or ESA. [320]

V. Conclusion

The stakes are high. The scope of the risks posed by interplanetary contamination could not be broader and could scarcely be more severe.[321] Forward contamination threatens what ***1394** could be the most important discovery in the history of biology, and back contamination could threaten the existence of any species on Earth. Clearly, planetary protection merits some attention.

Current law is inadequate. Neither the OST, the Moon Agreement, COSPAR's Policy, nor international environmental law can prevent interplanetary contamination.[322] If the corpus juris spatialis is a vehicle, there are leaks in all four tires. "[A]ll . . . the space environment has going for it, in terms of protection," Mark Williamson has written, "is a catalog of analogies."[323] The corpus juris spatialis needs to shore up its protection laws.

The solution is within our grasp, and the time to act is now. COSPAR, the Moon Agreement, and even the OST have laid the appropriate groundwork. NASA and ESA, two of the world's biggest space programs, have already lent their support to the COSPAR Policy, and younger space programs are at the right stage to support a new treaty-they are old enough to recognize the importance of planetary protection, but young enough to be largely unaffected by a legal endorsement of the Policy.

Dr. Rummel has designed a bumper sticker that, excluding the moon, sums it up well: "Planetary Protection: All of the Planets, All of the Time."[324]

Footnotes

1 See Ryder W. Miller, Millennial Fever, Extremophiles, NASA, Astroenvironmentalism, and Planetary Protection, Electronic Green J., Winter 2005, http://egj.lib.uidaho.edu/egj22/miller1.html (discussing Rummel's position at NASA).

2 "Microbe" is another word for microorganism. Merriam-Webster's Collegiate Dictionary 783 (11th ed. 2003). The two words will be used interchangeably throughout this Note.

3 Clive Thompson, A Galactic Warrior, with Hypothetical Enemies, N.Y. Times, Apr. 24, 2004, at B9.

4 Id.

5 Id.

6 See Mark Williamson, Space: The Fragile Frontier 114 (2006) (comparing planetary contamination to movement of invasive, disease-causing pathogens to "isolated societies" on Earth).

7 See Miller, supra note 1 (comparing planetary contamination to movement of "harmful non-indigenous species around the globe").

8 See Barry E. DiGregorio, The Dilemma of Mars Sample Return, 31(8) Chemical Innovation 18, 20 (2001), available at http:// pubs.acs.org/subscribe/journals/ci/31/special/digreg/08digregorio.html (noting that foreign planets could hold "bizarre forms of pathogens").

9 See Committee on Space Research [COSPAR], Planetary Protection Policy, at app. (amended Mar. 24, 2005) (Sample Return Missions from Mars, Category V), available at http://parhq.cnes.fr/Scistr/Pppolicy.htm (articulating concerns about false positives in life-detection test).

10 See Williamson, supra note 6, at 160 (noting that forward contamination could "invalidate the science data collected by [a] spacecraft or, worse still, damage indigenous life-forms").

11 See id. at 122, 123 (stating that both NASA and ESA comply with COSPAR's policy).

12 Laura Woodmansee, Planetary Protection: Saying Hello to Alien Life, Safely, Space Daily, Sept. 20, 2001, http:// www.spacedaily.com/news/life-01zg.html.

13 Id.

14 See Planetary Protection Advisory Comm., NASA, Meeting Report 10 (June 10-11, 2004), available at http:// science.hq.nasa.gov/strategy/ppac/minutes/PPACmin0406.pdf ("[Rummel] noted that the current NASA standard [for planetary protection] is not established by international treaty.").

15 Nat'l Research Council of the Nat'l Acads., Preventing the Forward Contamination of Mars 14 (2006) ("[P]lanetary protection is inherently international.").

16 J.D. Rummel & L. Billings, Issues in Planetary Protection: Policy, Protocol and Implementation, 20 Space Pol'y 49, 52 (2004), available at http:// www.medicine.mcgill.ca/mnmsmi/Rummel%20and%C20Billings%202004.pdf ("[T]he number of nations engaging in solar system exploration is rising."); Jeremy L. Zell, Putting a Mine on the Moon: Creating an International Authority to Regulate Mining Rights in Space, 15 Minn. J. Int'l L. 489, 494-95 (2006) (noting increase in space exploration).

17 Zell, supra note 16, at 494-95; see also Rummel & Billings, supra note 16, at 50 (noting "accelerating pace of solar system exploration").

18 Rummel & Billings, supra note 16, at 52; see also Audra T. Leath, Space Programs of Other Countries; Culture Change at NASA, FYI: The AIP Bulletin of Science Policy News, May 17, 2004, http:// www.aip.org/fyi/2004/063.html (noting that Japan, India, Russia, China and Europe are contemplating or planning launches into space); Zell, supra note 16, at 495 (stating that China has sent two sets of astronauts in two years into space).

19 Williamson, supra note 6, at 103-04 tbl.4 (providing table of orbital spacecraft).

20 Id.

21 Tracy Quek, China's Moon Mission on Track, Straits Times (Singapore), Oct. 13, 2006, available at 2006 WLNR 17729007 ("In 2003, China became the third country . . . to put a man in space."); Info. Office of the State Council of the People's Republic of China, China's Space Activities in 2006, at IV (2006), available at http://www.chinadaily.com.cn/china/2006-10/12/content_706670.htm (setting forth goal of "accelerat[ing] the industrialization of space activities").

22 ESA, Discovery and Competitiveness: The Keywords in Europe's Policies and Programmes for Space (2005), http:// www.esa.int/esaCP/Pr_2_2005_i_ EN.html.

23 See Woodmansee, supra note 12 (noting Rummel's doubts about decontamination measures taken on certain Russian spacecraft and writing, "Rummel says that Russia's Mars '96 mission followed NASA's planetary protection rules, but only because the French, who were partners on the project, insisted").

24 See Nat'l Research Council of the Nat'l Acads., supra note 15, at 14 ("[P]lanetary protection is inherently international and a matter of concern for all existing and future spacefaring nations.").

25 See Williamson, supra note 6, at 178-79 (highlighting need for treaty); see also E. Fasan, Planetary Protection - Some Legal Questions, 45 L. of Outer Space 443, 446 (2002) (noting that current laws are "not sufficient" to protect against biological planetary contamination).

26 See Williamson, supra note 6, at 178-79 (suggesting that without treaty, existing protection for space environment is inadequate).

27 See generally 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 Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter OST] (focusing on space exploration, rescue and militarization).

28 See Ulrike M. Bohlmann, Planetary Protection in Public International Law, 46 L. of Outer Space 18, 19 (2003) (noting that Article IX "heavily lacks specificity" and describing effect of Article IX as "minimal").

29 See generally Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, opened for signature Dec. 5, 1979, 16 I.L.M. 1434, 1363 U.N.T.S. 3 [hereinafter Moon Agreement] (setting forth provisions in space law).

30 See I. Almar, Protection of the Lifeless Environment in the Solar System, 45 L. of Outer Space 438, 441 (2002) (noting that most spacefaring nations declined to sign Moon Agreement).

31 United Nations Conference on the Human Environment, June 5-16, 1972, Declaration on the Human Environment, U.N. Doc. A/CONF.48/14 [hereinafter Stockholm Declaration].

32 United Nations Conference on Environment and Development, June 3-14, 1992, Rio Declaration on Environment and Development, U.N. Doc A/CONF.151/5 (June 14, 1992) [hereinafter Rio Declaration].

33 See infra notes 157-76 and accompanying text (describing shortcomings of international environmental law).

34 See Bohlmann, supra note 28, at 24 ("[COSPAR's Policy] is a very consistent and highly developed system of recommendations by an independent and international body of scientists with a high reputation in the field.").

35 Id.

36 Rummel & Billings, supra note 16, at 52 (noting that for spacecraft unlikely to touch their target bodies, "cleanliness requirements are reduced").

37 Bohlmann, supra note 28, at 24.

38 Id.; Williamson, supra note 6, at 122-23.

39 Bohlmann, supra note 28, at 24.

40 L. Perek, Planetary Protection: Lessons Learned, 45 L. of Outer Space 462, 464 (2002).

41 See Nat'l Research Council of the Nat'l Acads., supra note 15, at 14 (describing planetary protection as “a matter of concern for all existing and future spacefaring nations”).

42 OST, supra note 27, art. I.

43 Williamson, supra note 6, at 160 (noting that forward contamination could compromise validity of future tests for extraterrestrial life).

44 See DiGregorio, supra note 8, at 20 (noting that it is not in the interest of humans to import “bizarre forms of pathogens” to Earth).

45 See Williamson, supra note 6, at 178 (noting need for amendment to OST or new treaty); see also infra notes 216-34 and accompanying text (discussing need for treaty).

46 See infra notes 244-75 and accompanying text.

47 See infra notes 52-166 and accompanying text.

48 “Corpus juris spatialis” refers to the international body of space law. See L.I. Tennen, Evolution of the Planetary Protection Policy: Conflict of Science and Jurisprudence?, 34 Advances in Space Res. 2354, 2359 (2004), available at http://adsabs.harvard.edu/abs/2004adspr..34.2354t (using “corpus juris spatialis” to refer to the international body of space law).

49 See infra notes 167-275 and accompanying text.

50 See infra notes 276-91 and accompanying text.

51 See infra notes 292-324 and accompanying text.

52 Woodmansee, supra note 12 (“NASA divides planetary protection concerns into two categories; forward and backward contamination.”).

53 See Thompson, supra note 3 (noting that NASA is concerned with both backward and forward contamination).

54 Rummel & Billings, supra note 16, at 49; see also Williamson, supra note 6, at 113-14 (defining forward contamination as “the contamination of a planetary body other than the Earth, which may occur as a result of landing a spacecraft on that body”).

55 See Thompson, supra note 3 (describing planetary protection as “an Xtreme form of environmentalism”).

56 Id. Fictional literature illustrates the public's fear of such an event. See generally, e.g., Michael Crichton, The Andromeda Strain (Alfred A. Knopf 1969) (telling fictional story of appearance on Earth of deadly extraterrestrial pathogen).

57 See Williamson, supra note 6, at 114 (comparing planetary contamination to the movement of pathogens on Earth); Miller, supra note 1 (comparing planetary contamination to movement of "harmful non-indigenous species around the globe").

58 Whether Variola major may be called an invasive species is, in a purely technical sense, debatable because viruses are sometimes classified as living, and sometimes as non-living. University of North Carolina-Chapel Hill, Nanoscale Science Education, Viruses, http:// www.cs.unc.edu/Research/nano/ed/virus.html (last visited June 22, 2007). For purposes of this Note, however, whether a virus is technically "alive" is not relevant, and Variola major will be treated as a living organism.

59 Cts. for Disease Control and Prevention, Smallpox Fact Sheet (Dec. 30, 2004), http://www.bt.cdc.gov/agent/smallpox/overview/disease-facts.asp.

60 Jared Diamond, Guns, Germs, and Steel 77-78 (W.W. Norton and Co. 1999) (1997).

61 See id. at 78, 211 (noting that European pathogens killed as much as 95% of North America's indigenous human population).

62 Id.

63 Id. at 211-12.

64 Id. at 357.

65 Id. at 211-12, 357.

66 See Miller, supra note 1 ("Microscopic life brought back to Earth or to another planet from Earth will not necessarily have the population limiting factors that keep them in check elsewhere. . . . We see many similar examples of this with harmful non-indigenous species around the globe.").

67 See Williamson, supra note 6, at 114 (comparing back contamination to human "explorers taking diseases to isolated societies that had no immunity and wiping out their civilizations").

68 See Miller, supra note 1 (stating that extraterrestrial microbes "may also enter the Earth's biosphere as extraterrestrial diseases").

69 See id. ("When organisms [from the same planet] are introduced they can alter ecosystems, and extraterrestrial microbes could possibly alter planets.").

70 Diamond, supra note 60, at 357 (noting that "many Eurasians . . . developed immune or genetic resistance" to many deadly pathogens, including Variola major).

71 DiGregorio, supra note 8, at 20.

72 John D. Rummel & Michael A. Meyer, Where No One Has Gone Before . . . What Is Planetary Protection, Anyway?, Planetary Report, July-Aug. 1994, available at http://calspace.ucsd.edu/Mars99/docs/library/mars_ exploration/

robotic_missions/landers/sample_return/planetary_protection1.html (noting "potential, unanticipated environmental effects of a new form of life on Earth").

73 Id.

74 Karen Nitkin, The Maryland Chapter of the American Chestnut Foundation's Breeding Program in Columbia Aims to Keep the Blight-Resistant Specimen Blooming: A Rare Tree Grows in MD, Balt. Sun, Sept. 20, 2006, at 1G.

75 See, e.g., id. (reciting adage about squirrel).

76 Jared Diamond, The Third Chimpanzee 358 (Harper Perennial 2006) (1992).

77 Id.

78 See Rummel & Billings, supra note 16, at 50 (noting scientific speculation about "natural interplanetary transfer of micro-organisms by the high-velocity ejection of soil and rock resulting from planetary impacts of comets and other small bodies").

79 See Leslie Mullen, Planetary Uncertainty Principle, Astrobiology Mag., June 21, 2004, http://www.astrobio.net/news/article1029.html (noting possibility of "a large impact event that would take material from Earth to Mars today").

80 Id.

81 See Rummel & Billings, supra note 16, at 50 (discussing possibility that rocks facilitated interplanetary microbial transport).

82 NASA, The Solar Wind at Mars (Jan. 31, 2001), http:// science.nasa.gov/headlines/y2001/ast31jan_1.htm.

83 See Planetary Protection Advisory Comm., NASA, supra note 14, at 13 (stating that certain missions were "assigned COSPAR Category V (unrestricted Earth return) because the material being returned does not pose a biological risk to the Earth environment beyond what occurs naturally (from solar wind ions and interplanetary dust impinging on Earth['s] atmosphere)").

84 See COSPAR, supra note 9 (Policy, Category V) (prescribing strictest sterilization and containment measures for spacecraft returning to Earth after voyage); see also, e.g., Rummel & Billings, supra note 16, at 49 (when returning extraterrestrial samples to Earth, "planetary protection is in order").

85 Jared Diamond, Collapse 205-07 (Penguin Books 2005) (2005).

86 Id. at 208-09.

87 Compare id. at 209 (describing Norse contact with Native Americans), with Diamond, supra note 60, at 77 (describing smallpox epidemic in Americas in early sixteenth century).

88 Diamond, supra note 60, at 78, 211.

89 See, e.g., Rummel & Meyer, supra note 72 (noting that NASA's planetary protection policy addresses "forward contamination, the potential contamination of another solar system body by Earth organisms").

90 See COSPAR, supra note 9 (Policy, Category IV) (contemplating that forward contamination "could jeopardize future biological experiments").

91 Williamson, supra note 6, at 126-27 (noting that deposition of Earth life on foreign planet could jeopardize future exobiological experiments); see also COSPAR, supra note 9, at app. (Sample Return Missions from Mars, Category V) (articulating concerns about false positive "indications" in life-detection test).

92 Planetary Protection Advisory Committee, supra note 14, at 9 (noting that only 1% of microbial species present in soil or water samples can be identified).

93 See Diamond, supra note 60, at 210 (noting rapidity with which microbe responsible for syphilis was able to evolve); Williamson, supra note 6, at 128 (contemplating possibility of "radiation-mutated" microbe).

94 Planetary Protection Advisory Comm., NASA, supra note 14, at 13 (quoting Dr. Norrine E. Noonan); Williamson, supra note 6, at 160 (stating that "most space professionals" oppose forward contamination "because [it] would invalidate the science data collected by [a] spacecraft or, worse still, damage indigenous life-forms"); see Woodmansee, supra note 12 (" 'The [planetary protection] policy is actually based on the desire to preserve extraterrestrial environments for the science opportunities that are there' . . . ." (quoting Dr. John Rummel)).

95 Thompson, supra note 3.

96 Nat'l Research Council of the Nat'l Acads., supra note 15, at 13.

97 Id. at 13 n.7.

98 For instance, scientific consensus holds that the period of biological exploration of the Moon is clearly over. See COSPAR, supra note 9, at app. (Category-Specific Listing of Target Body/Mission Types) (placing missions to Moon in Category I); id. (Policy, Category I) (describing Category I missions as those directed at bodies "not of direct interest for understanding the process of chemical evolution or the origin of life" and stating that "[n]o protection of such bodies is warranted").

99 Id.; see also Dennis Overbye, Back to the Moon! But Why?, N.Y. Times, Dec. 12, 2006, at F1 (describing moon as "dead cinder").

100 See generally Nat'l Research Council of the Nat'l Acads., supra note 15 (arguing that humans should prevent forward contamination of Mars).

101 See Woodmansee, supra note 12 ("[I]f we bring Earth life with us to another planet, there is the chance that we may kill or harm indigenous life.").

102 See Williamson, supra note 6, at 182 ("[S]pace ethics would cover, for example, the impact of our actions in space on . . . the space environment itself."); Bohlmann, supra note 28, at 18 ("Basic ethical considerations lead to the conviction that the protection of the space environment including these potentially existing forms of life is a goal in itself.").

103 See Nat'l Research Council of the Nat'l Acads., supra note 15, at 113 (noting that reasons for avoiding forward contamination “extend into the ethical and philosophical realms”).

104 Terraforming Mars would involve colonizing the planet after releasing greenhouse gases to make the Martian environment more suitable for humans. See generally Robert Zubrin, The Case for Mars: The Plan to Settle the Red Planet and Why We Must (1997) (advising terraforming Mars).

105 Some have seriously proposed the mining of other planets as an economic endeavor. See Zell, supra note 16, at 490-91 (describing controversy over propriety of mining in outer space).

106 See generally Ryder W. Miller, Astroenvironmentalism: The Case for Space Exploration as an Environmental Issue, Electronic Green J., Dec. 2001, http://egj.lib.uidaho.edu/egj15/miller1.html (referring to astroenvironmentalists).

107 See id. (arguing that outer space should be conceived as “wilderness to protect, rather than a ‘frontier’ to exploit”).

108 Woodmansee, supra note 12 (“[I]f we bring Earth life with us to another planet, there is the chance that we may kill or harm indigenous life.”).

109 Williamson, supra note 6, at 160 (stating that forward contamination could “invalidate the science data collected by [a] spacecraft”).

110 Richard Southwood, The Story of Life 22-23 (Oxford University Press 2003) (2003). The “rusting of the earth” produced banded iron deposits, sedimentary geological formations that appear in many parts of the world and constitute humans' principal reserves of iron ore. Id.

111 Press Release, Robert Sanders, Univ. of Cal. - Berkeley, Mars' Dust Storms May Produce Peroxide Snow (July 31, 2006), available at http:// www.berkeley.edu/news/media/releases/2006/07/31_peroxide.shtml.

112 Id.

113 Id.

114 See id. (noting that life from Earth probably could not survive on Martian surface).

115 Nat'l Research Council of the Nat'l Acads., supra note 15, at 16 (“[P]ast missions that have landed or crashed on Mars . . . have virtually certainly delivered some viable microorganisms to the martian surface.”).

116 See Williamson, supra note 6, at 94-96 tbl.3 (providing table of impacts of spacecraft on Moon).

117 Id.

118 Id. at 91.

119 See id. at 94-96 tbl.3 (providing table that lists and dates impacts of spacecraft on Moon).

120 DiGregorio, supra note 8, at 22.

121 Williamson, supra note 6, at 123. The on-board remains were those of Eugene Shoemaker, a lunar geologist. Id.

122 Thompson, supra note 3.

123 Planetary Protection Advisory Comm., NASA, supra note 14, at 9-10 (noting that "human-associated contamination cannot be completely avoided by human space explorers" and that "once humans are on the martian surface, it will be compromised for future investigation of whether there was extant life on Mars").

124 Overbye, supra note 99.

125 See COSPAR, supra note 9, at app. (listing Moon Missions as category I and stating that COSPAR imposes no planetary protection requirements on Category I missions).

126 Woodmansee, supra note 12 (noting that "Europa, the small moon of Jupiter . . . is probably the most likely source of life in our solar system other than Earth").

127 Overbye, supra note 99; see also Nat'l Research Council of the Nat'l Acads., supra note 15, at vii (describing Mars as "one of the most likely repositories for extraterrestrial life" among our solar system's planets); id. at 19 (noting that certain microbes might be able to live under one millimeter of rock); Associated Press, Martian Mistake? Paper Suggests Mission Killed Life, Augusta Chron., Jan. 8, 2007, at A9 (noting signs that Mars may support life); Robert Roy Britt, Mars Underground: The Harsh Reality of Life Below, Space.com, Mar. 8, 2004, http://www.space.com/scienceastronomy/mystery_ monday_040308.html (noting that any life on Mars would probably live underground).

128 Overbye, supra note 99.

129 See Associated Press, supra note 127 (explaining possible errors of Viking missions and noting that life may yet exist there).

130 Nat'l Research Council of the Nat'l Acads., supra note 15, at 42; see also Williamson, supra note 6, at 126 (noting that same equipment would have yielded negative results on Earth if Viking lander had landed in Chile's Atacama Desert, thereby implying that life did not exist on Earth).

131 See Associated Press, supra note 127 (noting that Viking missions may have drowned hydrogen peroxide-based life).

132 Nat'l Research Council of the Nat'l Acads., supra note 15, at 43. These outflow channels can be seen online through Google Mars. Google Mars, http://www.google.com/mars/ (follow "Stories" hyperlink in upper-left corner, then follow "Outflow Channel in Kasei Valles" hyperlink) (last visited June 22, 2007).

133 Randolph E. Schmid, 'Halo' Pattern Called More Evidence of Water on Mars, Chi. Trib., Feb. 16, 2007, at 9.

134 Id.; Nat'l Research Council of the Nat'l Acads., supra note 15, at 43.

135 See Nat'l Research Council of the Nat'l Acads., supra note 15, at 25 n.8 (suggesting that period of biological exploration might end fifty years from present).

136 Id. at 16-17.

137 DiGregorio, supra note 8, at 24.

138 See id. (stating that authorities lost contact with Zond 2); Woodmansee, supra note 12 ("There is no way to confirm that the Russian probes went through any sort of decontamination before launch."); Bruce Murray et al., Planetary Contamination II: Soviet and U.S. Practices and Policies (declaring that "every effort should be made to induce the Soviets to supply additional details on the Zond 2 . . . mission").

139 See Nat'l Research Council of the Nat'l Acads., supra note 15, at 18-19 tbl.1.1 (providing table of known crashes); Williamson, supra note 6, at 97 tbl.3 (same).

140 Nat'l Research Council of the Nat'l Acads., supra note 15, at 18-19 tbl.1.1 (providing table of known crashes); see also Williamson, supra note 6, at 97 tbl.3 (same).

141 Nat'l Research Council of the Nat'l Acads., supra note 15, at 17-18. The final resting sites of most of these spacecraft can be viewed online through Google Mars. Google Mars, supra note 132 (follow "Spacecraft" hyperlink in upper-left corner).

142 Nat'l Research Council of the Nat'l Acads., supra note 15, at 16.

143 Id. at 19.

144 Id.

145 Id.

146 See Press Release, Robert Sanders, supra note 111 (highlighting difficulty terrestrial microbe would have surviving on Mars).

147 See Woodmansee, supra note 12 (" 'The likelihood of any significant amount of contamination from the Viking spacecraft being circulated around the Mars [atmosphere] is very low . . . it is a miniscule concern.' " (quoting Karen Buxbaum)).

148 See Nat'l Research Council of the Nat'l Acads., supra note 15, at 17 (stating that possible past delivery of microbes to Mars "does not vitiate ongoing planetary protection measures").

149 Id.

150 Carl Sagan et al., Contamination of Mars, 159 Science 1191 (1967), available at http://profiles.nlm.nih.gov/BB/A/B/J/H/_/bbabjh.pdf.

151 See SETI Institute, About Us, Voices - Featuring Roger Mancinelli, http://www.seti.org/site/pp.asp?c=ktJ2J9MMIsE&b=179065 (last visited June 22, 2007) (noting that although most of the microbes tested in "early days of space travel . . . died nearly instantly," recently discovered halophiles "could be good candidates for surviving a space flight").

152 University of Bath, Center for Extremophile Research, Extremophiles (2005), http://www.bath.ac.uk/cer/extremophiles.htm.

153 See Miller, supra note 1 ("The discovery of extremophiles has changed the previous paradigm that life can only be found on pleasant Earth-like planets.").

154 Southwood, supra note 110, at 20; Rummel & Meyer, supra note 72.

155 Rummel & Meyer, supra note 72.

156 Id.

157 Woodmansee, supra note 12.

158 Id.

159 Id.

160 NASA, Earth Microbes on the Moon (Sept. 1, 1998), http:// science.nasa.gov/NEWHOME/headlines/ast01sep98_1.htm (discussing microbes believed to have survived for years in a camera left on the lunar surface); see also Williamson, supra note 6, at 116-17 (same).

161 Id.

162 NASA, supra note 160. But see Planetary Protection Advisory Comm., NASA, supra note 14, at 9 (noting that camera may have been "contaminated during return, storage and inspection activities" that occurred after it was retrieved).

163 Miller, supra note 1 (noting that scientists now believe life could survive in wider range of environments than once imagined).

164 Rummel & Billings, supra note 16, at 50 ("Researchers have examined the potential for a natural interplanetary transfer of micro-organisms by the high-velocity ejection of soil and rock resulting from planetary impacts of comets and other small bodies.").

165 Id. at 49 ("[N]ow scientists are beginning to learn about locations on or beneath the surface of other planets and moons where Earth life, at least, might thrive.").

166 See William J. Broad, From Scum, Perhaps the Tiniest Form of Life, N.Y. Times, Dec. 23, 2006, at A1 (describing recent discovery of extremophile that may necessitate " 'reconsider[ing] existing paradigms for the minimum requirements for life' ").

167 Fasan, supra note 25, at 446 (describing existing space law as "not sufficient"); see also Williamson, supra note 6, at 175 ("Even a cursory analysis of international space law . . . shows that, although in general it is well meaning, it provides insufficient protection for the space environment.").

168 See, e.g., Philippe Achilleas, Planetary Protection - Legal Issues, 46 L. of Outer Space 214, 215 (2003) (surveying existing law and then concluding that "the over-all effect of [the OST and Moon Agreement] is minimal since they provide no specific standards and no official method for clarifying issues and monitoring activities"); Fasan, supra note 25, at 446 (surveying corpus juris spatialis and international law, then describing existing law as "not sufficient").

169 See Bohlmann, supra note 28, at 19 (noting that Article IX "heavily lacks specificity" and describing effect of Article IX as "minimal").

170 See Almar, supra note 30, at 441 (noting that most spacefaring nations declined to sign Moon Agreement).

171 See infra notes 224-43 and accompanying text (describing shortcomings of international environmental law).

172 Williamson, supra note 6, at 122-23.

173 Gerardine Meishan Goh & Bobby Kazeminejad, Mars Through the Looking Glass: An Interdisciplinary Analysis of Forward and Backward Contamination, 20 Space Pol'y 217, 220 (2004), available at http:// adsabs.harvard.edu/abs/2004SpPol..20..217G.

174 Id. at 220 (noting that OST has become customary international law); see also OST, supra note 27, at list of signatories (listing most nations which do, or could, support space program). Of twenty-five states which constitute the EU, which is closely linked to ESA, only seven have not ratified the OST, and those seven countries are generally unlikely to invest in space exploration. Id. They are Estonia, Latvia, Lithuania, Malta, Portugal, Slovakia and Slovenia. Id. Because the OST was ratified by virtually all spacefaring nations, its provisions regarding space exploration would be binding even if they had not become customary international law.

175 See Goh & Kazeminejad, supra note 173, at 219 ("Damage to the environment caused by . . . contamination did not figure in the drafters' considerations.").

176 See id. at 219 (noting that drafters showed little concern for outer space environment); see OST, supra note 27, art. I (proclaiming that space "shall be the province of all mankind"); id. art. IV (declaring that no nuclear weapons may be placed in orbit).

177 OST, supra note 27, art. IX.

178 Id.; see, e.g., Bohlmann, supra note 28, at 19 (describing Article IX as "most important provision" of OST regarding planetary protection); see also Nat'l Research Council of the Nat'l Acads., supra note 15, at 13-14 (discussing OST).

179 See Tennen, supra note 48, at 2359 (describing corpus juris spatialis as "consistent in both its philosophy and its expression"); id. at 2360 (suggesting that COSPAR's Planetary Protection policy "may be deficient vis-a-vis international treaty commitments" like Article IX).

180 See, e.g., Bohlmann, supra note 28, at 19 (describing effect of Article IX as "minimal").

181 Id.; Achilleas, supra note 168, at 215 (describing effect of OST and Moon Agreement as "minimal").

182 Bohlmann, supra note 28, at 19; Goh & Kazeminejad, supra note 173, at 219. "Self-executing" means "effective immediately without the need of any type of implementing action." Black's Law Dictionary 1391 (8th ed. 2004).

183 Bohlmann, supra note 28, at 19; Goh & Kazeminejad, supra note 173, at 219.

184 See Williamson, supra note 6, at 176-79 (noting that "the current body of space law can offer little protection to the space environment" because of the "vagueness of [OST's] terminology" and because "compliance mechanisms or procedures based on [the OST] would also have to be developed").

185 See id. at 149 (describing several other major treaties in copus juris spatialis as "elaborations" on OST).

186 See Goh & Kazeminejad, supra note 173, at 219 (noting that drafters of OST did not consider environmental damage that contamination would cause).

187 Tennen, supra note 48, at 2258.

188 Bohlmann, supra note 28, at 19.

189 See Williamson, supra note 6, at 176 (noting that treaties of corpus juris spatialis "do not even help with the well-recognized problem of orbital debris").

190 OST, supra note 27, art. VI.

191 See generally Daria Diaz, Trashing the Final Frontier: An Examination of Space Debris from a Legal Perspective, 6 Tul. Envtl. L.J. 369 (describing dumping of trash in outer space).

192 Id. at 370-71.

193 W.L. Rathje, Archaeology of Space Garbage: We're Loading the Final Frontier with Technology's Trash, 1(5) Discovering Archaeology 108, 108-09 (1999), available at http://www.kenlarson.net/code/scienc01.htm.

194 Diaz, supra note 191, at 371-72.

195 OST, supra note 27, art. IX.

196 Merriam-Webster's Collegiate Dictionary, supra note 2, at 283.

197 Twenty thousand feet per second is approximately equal to 13,636 miles per hour. U.S. Coast Guard, Chemical Hazard Response Information System Conversion Factors (Mar. 1999), http://www.chrismanual.com/Intro/convfact.htm.

198 Rathje, supra note 193, at 110.

199 Diaz, supra note 191, at 372.

200 Rathje, supra note 193, at 108.

201 Mark Williamson, Protection of the Space Environment: The First Small Steps, 45 L. of Outer Space 456, 457 (2002).

202 Williamson, supra note 6, at 176 (noting that existing space treaties do not deal with space trash); see also Williamson, supra note 201, at 457 ("Some have concluded that certain low Earth orbits may become unusable by the middle of the century [because of space trash].").

203 Williamson, supra note 6, at 176 (reasoning that because current space treaties "do not even help with the well-recognized problem of orbital debris, [i]t would be surprising, therefore, if they provided for the protection of the planetary bodies").

204 See Tennen, supra note 48, at 2359 (noting that Moon Agreement prescribed specific disclosures by launching nation, "including the specific measures taken to control the number of micro-organisms on and in a spacecraft").

205 See Goh & Kazeminejad, supra note 173, at 219-20 (noting that Moon Agreement is considered "dead letter").

206 Williamson, supra note 6, at 151 (stating that Moon Agreement was opened for signature in 1979); Bohlmann, supra note 28, at 20-21 (noting that Moon Agreement contemplates forward and backward contamination).

207 Moon Agreement, supra note 29, art. 7(1) (emphasis added).

208 See Bohlmann, supra note 28, at 20 (suggesting that Moon Agreement shows environmental consciousness because it was written in late 1970s, when "environmental considerations were becoming a global concern").

209 Achilleas, supra note 168, at 216 (observing that Moon Agreement does not define "harmful"); Goh & Kazeminejad, supra note 173, at 219 (noting absence of definitions for "harmful" or "adverse").

210 Moon Agreement, supra note 29, art. 7.1; see also Bohlmann, supra note 28, at 20-21 (noting that "issues of forward and backward contamination are addressed" in Moon Agreement).

211 Tennen, supra note 48, at 2359.

212 See P.P.C. Haanappel, The Law and Policy of Air Space and Outer Space 61 (2003) (noting that "[t]he major stumbling block, mostly for developed nations, is the 'equitable sharing by all States Parties in the benefits derived from . . . resources' ").

213 OST, supra note 27, art. I; Moon Agreement, supra note 29, art. 11(1). The phrase referred to the exploration of outer space. Id.

214 See Moon Agreement, supra note 29, art. 11(1) ("The Moon and its natural resources are the common heritage of mankind . . . .").

215 Id. art. 11(5); Haanappel, supra note 212, at 61.

216 Moon Agreement, supra note 29, art. 11(7); Haanappel, supra note 212, at 61.

217 Bohlmann, supra note 28, at 20 (noting that Moon Agreement applies to other solar system bodies).

218 Moon Agreement, supra note 29, art. 1(1).

219 Bohlmann, supra note 28, at 20 (noting that the Moon Agreement "appl[ies] to other celestial bodies within the solar system other than the Earth, and the respective orbits or trajectories around them").

220 Williamson, supra note 6, at 151.

221 Almar, supra note 30, at 441.

222 Goh & Kazeminejad, supra note 173, at 219-20; see also Bohlmann, supra note 28, at 21 (writing that Moon Agreement has "no customary value").

223 See, e.g., Achilleas, supra note 168, at 215 ("[T]he over-all effect of these treaties['] provisions is minimal.").

224 See, e.g., Sergio Marchisio, Protecting the Space Environment, 46 L. of Outer Space 9, 13 (2003) (claiming that international environmental law could "pave the way for identifying the existing legal regime which protects the space environment").

225 See infra notes 226-43 and accompanying text.

226 Bohlmann, supra note 28, at 25 (describing Stockholm and Rio declarations as "the most prominent texts to cite"); see, e.g., Marchisio, supra note 224, at 13 (claiming that international environmental law could legally govern space activities).

227 Stockholm Declaration, supra note 31, at Principle 21. The Rio Declaration's language differs only in that the phrase "their own environmental policies" becomes "their own environmental and developmental policies." Rio Declaration, supra note 32, at Principle 2.

228 See, e.g., Marchisio, supra note 224, at 12 ("This responsibility [described in Principle 21] also covers, indeed, outer space as an area beyond national jurisdiction.").

229 Stockholm Declaration, supra note 31, at Principle 21.

230 OST, supra note 27, arts. I, II (describing outer space as "the province of all mankind" which "is not subject to national appropriation by claim of sovereignty").

231 The high seas constitute an area beyond the jurisdiction of any nation. Black's Law Dictionary, supra note 182, at 1376.

232 While a state accused of biologically contaminating Earth or another planet might dispute allegations under Principle 21 by arguing that space exploration is not an "activit[y] within [its] jurisdiction or control," this argument is likely to fail. Stockholm Declaration, supra note 31, at Principle 21. Article VIII of the OST specifically provides that when a state launches an object into outer space, that state "shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body." OST, supra note 27, art. VIII.

233 Id. art. III.

234 See, e.g., id. at 12 (asserting that Principle 21 applies to outer space); Achilleas, supra note 168, at 218 (asserting that Principle 21 applies to outer space); Bohlmann, supra note 28, at 25 (asserting that Principle 21 applies to outer space); see also Goh & Kazeminejad, supra note 173, at 220 (describing proposition that Principle 21 applies to space exploration as "arguable").

235 Goh & Kazeminejad, supra note 173, at 220.

236 See generally Legality of the Use by a State of Nuclear Weapons in Armed Conflict, Advisory Opinion, 1996 I.C.J. LEXIS 7 (July 8) (addressing use of nuclear weapons in armed conflict); Gabcikovo-Nagymaros Project (Hung. v. Czech and Slovk. Rep.), 37 I.L.M. 168, 168 (Jan. 1998) (addressing legal propriety of Hungary's abandonment of joint project).

237 See generally Stockholm Declaration, supra note 21 (not containing word "space"); Rio Declaration, supra note 32 (not containing word "space").

238 Stockholm Declaration, supra note 31, at title (emphasis added).

239 Id. paras. 1, 3, 6 (all emphasis added).

240 Stockholm Declaration, supra note 31, at Principle 21; OST, supra note 27, art. II.

241 Rio Declaration, supra note 32, para. 3, 5.

242 Id. at Principle 2.

243 See, e.g., Marchisio, supra note 224, at 12 (asserting that Principle 21 applies to outer space).

244 See Bohlmann, supra note 28, at 24 ("Obviously, the COSPAR Planetary Protection Policy is a very consistent and highly developed system of recommendations.").

245 Williamson, supra note 6, at 122-23.

246 Rummel & Billings, supra note 16, at 50.

247 Comm. on Space Research, About COSPAR (Aug. 16, 2006), http:// www.cosparhq.org/About/about.htm.

248 COSPAR, supra note 9; Nat'l Research Council of the Nat'l Acads., supra note 15, at 25, 28.

249 Rummel & Billings, supra note 16, at 50.

250 See Bohlmann, supra note 28, at 24 (praising COSPAR policy).

251 See Nat'l Research Council of the Nat'l Acads., supra note 15, at 26-27 tbl.2.1 (showing chart with COSPAR Categories I, II, III, IV, and V).

252 Id.

253 Id.

254 See Associated Press, supra note 127 (discussing possibility that Mars may harbor life).

255 Id.

256 Id.

257 See COSPAR, supra note 9 (Policy, Categories I-V).

258 "Bioburden" refers to "the number of microorganisms with which an object is contaminated." University of Rochester Medical Center, Sterile and Materials Processing Department, Glossary, http:// www.urmc.rochester.edu/Sterile/glossary.html (last visited June 22, 2007).

259 Nat'l Research Council of the Nat'l Acads., supra note 15, at 29.

260 Id. at 13.

261 See id. at 13 n.7 (noting that period of biological exploration can be defined in multiple ways).

262 Id.

263 Id. at 25 n.8.

264 Williamson, supra note 6, at 122-23.

265 The Council has members from France, the Netherlands, the United States, China, Japan, Argentina, Canada, India, and Russia. Comm. on Space Research, supra note 247.

266 Williamson, supra note 6, at 122, 123; NASA, About Planetary Protection (July 14, 2006), http:// planetaryprotection.nasa.gov/pp/about/index.htm.

267 Achilleas, supra note 168, at 216.

268 Bohlmann, supra note 28, at 24.

269 See Perek, supra note 40, at 464 (noting that if more nations begin exploring outer space, voluntary compliance with planetary protection policy will probably fail).

270 Id.

271 Id.

272 See Rummel & Billings, supra note 16, at 52 (stating that planetary protection policies of COSPAR and NASA "stand as models" for other nations).

273 See Comm. on Space Research, supra note 247 (listing varied national origins of COSPAR Council members); Rummel & Billings, supra note 16, at 50 (noting that COSPAR "became, and still is, the focal point of international activities relating to planetary protection").

274 See Bohlmann, supra note 28, at 24 (describing COSPAR Policy's promulgating body as "independent and international body of scientists with a high reputation in the field").

275 See Nat'l Research Council of the Nat'l Acads., supra note 15, at 22-28 (noting changes to Policy in 1964, 1969, 1984, 1992, and 2002).

276 See Zell, supra note 16, at 494-95 (noting that new nations are venturing into outer space).

277 See, e.g., Adam Aston, NASA's "First Date" with China, Bus. Wk., Oct. 16, 2006, at 18 (noting possibility of collaboration between U.S. and Chinese space programs).

278 See ESA, supra note 22 (noting ESA's goal of "European non-dependence").

279 Leath, supra note 18 ("[Marcia Smith of the Congressional Research Service] estimated that Russia spends approximately $500 million annually on its space program, India spends about $450 million, China about $2 billion, and Europe spends $4.5 billion for civilian space programs and approximately the same amount for military space programs. (NASA's budget request for FY 2005 is $16.2 billion[.])").

280 Williamson, supra note 6, at 119.

281 Id.

282 Nikolay Khorunzhiy, Russia: Space Troops Commander Details Five Years of Achievements, Future Plans: Interview with Vladimir Popovkin, Commander of Space Troops, World News Connection, Oct. 14, 2006.

283 Id.

284 Id.

285 Leath, supra note 18.

286 Quek, supra note 21.

287 Id.; see also Christopher Bodeen, Shanghai Scientists Developing Nuclear-Powered Rover for China's First Mission to Moon, AP DataStream, Apr. 2, 2007 (describing Chinese preparation of lunar rover).

288 Leath, supra note 18.

289 Quek, supra note 21.

290 Id.

291 See Rummel & Billings, supra note 16, at 52 ("The cost of meeting stringent Category V requirements on a Mars sample return mission is estimated at about 5-10 percent of the budget for the project.").

292 See Williamson, supra note 6, at 178 (noting need for amendment to OST or new treaty); Goh & Kazeminejad, supra note 173, at 222 (stating that planetary protection requires "[t]reaty regime").

293 See Perek, supra note 40, at 464 (noting shortcomings of non-binding rules).

294 Id. at 441.

295 See infra notes 298-301 and accompanying text.

296 See infra notes 303-14 and accompanying text.

297 See infra notes 315-20 and accompanying text.

298 Bohlmann, supra note 28, at 20-21.

299 Moon Agreement, supra note 29, art. 18.

300 See Nat'l Research Council of the Nat'l Acads., supra note 15, at 91-102 (describing advances in protection technology in great detail).

301 See id. at 22-28 (noting changes to Policy in 1964, 1969, 1984, 1992, and 2002).

302 Goh & Kazeminejad, supra note 173, at 219-20.

303 Overbye, supra note 99.

304 Bodeen, supra note 287; Khorunkhiy, supra note 282; Quek, supra note 21.

305 See Zell, supra note 16, at 490-91 (describing controversy over propriety of mining in outer space).

306 Williamson, supra note 6, at 151.

307 Overbye, supra note 99.

308 COSPAR, supra note 9, at app. (Category-Specific Listing of Target Body/Mission Types) (placing missions to Moon in Category I); id. (Policy, Category I) (describing Category I missions as those directed at bodies not "of direct interest for understanding the process of chemical evolution or the origin of life" and stating that "[n]o protection of such bodies is warranted").

309 See Williamson, supra note 6, at 94-96 tbl.3 (providing table of impacts of spacecraft on Moon).

310 See Moon Agreement, supra note 29, art. 11(1) ("The Moon and its natural resources are the common heritage of mankind.").

311 Haanappel, supra note 212, at 60.

312 Moon Agreement, supra note 29, art. 11(7)(d).

313 See Zell, supra note 16, at 490 (noting that mining Moon "holds the potential to be a very lucrative endeavor").

314 See Haanappel, supra note 212, at 61 (noting that "[t]he major stumbling block, mostly for developed nations, is the 'equitable sharing by all States Parties in the benefits derived from . . . resources' ").

315 See Marchisio, supra note 224, at 13-14 (noting growing international awareness of planetary protection).

316 Id. at 14.

317 See generally Info. Office of the State Council of the People's Republic of China, supra note 21 (describing in detail mission plans involving Earth and Moon, but mentioning deep space exploration only briefly).

318 Williamson, supra note 6, at 122-23 (stating that NASA and ESA are Policy-compliant); NASA, supra note 266 ("The NASA policy generally follows the COSPAR policy.").

319 Williamson, supra note 6, at 122, 123 (stating that both NASA and ESA are Policy-compliant).

320 Goh & Kazeminejad, supra note 173, at 222 ("NASA has thus far been involved in almost all non-NASA solar system exploration missions. . . ."); see also Info. Office of the State Council of the People's Republic of China, supra note 21, at (II)(Space Science)(1) (describing cooperation with ESA); Aston, supra note 277, at 18 (noting possibility of collaboration between U.S. and Chinese space programs).

321 See supra notes 52-166 and accompanying text (discussing risks of interplanetary contamination).

322 See supra notes 167-275 and accompanying text (discussing shortcomings of existing law).

323 Williamson, supra note 6, at 175.

324 Margaret S. Race, Planetary Protection: An Integral Part of Mission Preparations, Space.com, May 1, 2003, http://www.space.com/searchforlife/seti_ race_protect_0230501.html.

41 GALR 1355