C O M M E N T

# REGULATING BIOLOGICAL CONTAMINATION AT THE FINAL FRONTIER

by Cynthia R. Harris

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*United Federation of Planets Department of Conservation Proposes Listing the Tribble* (Tribleustes ventricosus) *as Endangered; Klingon Attorney General Threatens to Bring Suit.*

—*Galactic Times*

Could this be a headline from the future? Pessimists believe space exploration stalled after December 1972, when humans last visited the moon. But the lunar surface is hot real estate now, with no fewer than seven missions slated to launch over the next two years, from the United States' $93-billion Artemis program to China's next sample return mission, Chang'e-6.[1] And the moon is just the gateway to Mars and the icy ocean planets in the outer solar system.

Yet, space is no longer the domain of nation-states. A robust and growing commercial space sector is moving ahead at warp speed. The so-called New Space Economy was valued at $469 billion in 2021.[2] Private-sector funding reached $10 billion in 2021, and the number of space-related start-ups is accelerating. While the industry today primarily offers satellite and launch services, tomorrow will bring manufacturing, research and development, resource extraction, and space tourism.[3]

What do these developments mean for the earth's biosphere, as well as for the environments of other celestial bodies finally within humanity's reach? This is the role of *planetary protection*, the principle of safeguarding both terrestrial and extraterrestrial environments from humanity's propensity for introducing pollution into any habitat. In the domain of space exploration, the primary contaminants of concern are biological, those pernicious organisms whose mere presence could—in true sci-fi thriller fashion—threaten the extremes, from interfering with scientific investigations of far-flung worlds to introducing a novel infectious disease to earth.

Planetary protection's goals remain constant, but the methodology is undergoing an evolution. Proponents of these changes argue simultaneously for fewer restrictions and wider application: loosening stringent protective measures while expanding the regulatory net to cover more actors in this (literal) space. We are witnessing a move beyond a prophylactic approach to planetary protection analogous to the precautionary principle, to one based in the type of cost-benefit analysis so familiar to legal practitioners in the United States. This shift is informed by expediency and advances in technology and scientific understanding, as well as growing realization that the regulatory gap—which private commercial actors slip through—must be addressed.

## I. Planetary Protection 101

*Planetary protection* is distinct from *planetary defense*, which involves monitoring and mitigating the potential risks near-earth objects (NEOs) pose to earth.[4] Planetary protection controls the risk of human activity resulting in harmful biological contamination in two cases: forward contamination and backward contamination.

*Forward contamination* refers to biological material from earth compromising investigation into chemical evolution and the origin, distribution, and character of

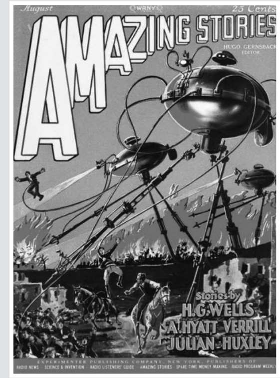
1. John Pickrell, *These Six Countries Are About to Go to the Moon—Here's Why*, Nature (May 11, 2022), https://www.nature.com/articles/d41586-022-01252-7.
2. Press Release, Space Foundation, Space Foundation Releases the Space Report 2022 Q2 Showing Growth of Global Space Economy (July 27, 2022), https://www.spacefoundation.org/2022/07/27/the-space-report-2022-q2/.
3. Ryan Brukardt, *How Will the Space Economy Change the World?*, McKinsey & Co. (Nov. 28, 2022), https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/how-will-the-space-economy-change-the-world (the trend of new entrants contributing to the growth of a robust commercial space sector has been dubbed collectively the New Space Economy).
4. Planetary defense is a common plot device in science fiction disaster films, such as *Armageddon* (Touchstone Pictures 1998) and *Deep Impact* (Paramount Pictures 1998), and served as an allegory for inaction on climate change in *Don't Look Up* (Netflix 2021). Government agencies nevertheless are taking measures to address the real risk of an NEO's serious collision with earth, including the recent successful Double Asteroid Redirection Test (DART) mission. *See* National Aeronautics and Space Administration (NASA), *DART*, https://www.nasa.gov/planetarydefense/dart (last visited Feb. 9, 2023).

life on other planetary bodies. The concern is primarily scientific rather than based in ethical, environmental, or conservation considerations.[5] An early exploratory mission could feasibly contaminate the target body with terrestrial material, making suspect potential evidence of life during subsequent missions.[6]

*Backward contamination* is more directly pragmatic, and concerns potentially harmful consequences that returning spacecraft carrying extraterrestrial material could pose to humans and earth's biosphere.[7]

The concept strongly parallels the "precautionary principle" of environmental protection, though supporters emphasize that the goal is to enable rather than hamstring human exploration of our solar system.[8]

**Planetary Protection and Popular Culture**




Extraterrestrial life-forms wreaking havoc on humanity is a common trope in science fiction cinema, radio, and literature. Beyond the familiar "alien invasion" plot device, less intentionally malignant but just as catastrophic examples of backward contamination include *The Andromeda Strain* and—more humorously—*Star Trek*'s "The Trouble With Tribbles." Less typical are instances of forward contamination, such as *Avatar*'s Eywa reacting to humanity as akin to a virus.

## II. It Came From the Outer Space Treaty

Planetary protection is a legal obligation as well as a goal. Article IX of the Outer Space Treaty (OST) establishes the legal basis, providing:

> States Parties to the Treaty shall pursue studies of outer space including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose.[9]

States, and not private actors, carry this responsibility, although the OST does not require environmental review of proposed extraterrestrial missions. The Committee on Space Research (COSPAR) Planetary Protection Policy (discussed below) is the primary set of voluntary international guidelines for compliance.[10]

Numerous international and soft law instruments expand on the scope of this obligation. Article 7 of the Moon Agreement charges States Parties to "take measures to prevent the disruption of the existing balance of [the moon's] environment, whether by introducing adverse changes in that environment, by its harmful contamination through the introduction of extra-environmental matter or otherwise." It also requires parties to report areas of the moon with "special scientific interest," to advance the possible designation of "international scientific preserves" meriting more protective measures.[11] Hague Building Block 10 includes the "harmful contamination" of celestial bodies as a reason for cautioning avoidance and mitigation of adverse impacts from space resource activities, and recommends that spacefaring actors consider multilateral agreements setting out planetary protection protocols.[12] Similarly, the Moon Village Association's Best Practices for Sustainable Lunar Activities encourages adopting policies for avoiding harmful contamination of the moon.[13]

These instruments also address backward contamination. States Parties to the Moon Agreement agree to "take measures to avoid harmfully affecting the environment of the earth through the introduction of extraterrestrial matter or otherwise."[14] Hague Building Block 10 likewise cautions against "adverse changes in the environment of the Earth."[15] The United Nations Office for Outer Space Affairs (UNOOSA) guidelines advise consideration of "appropriate safety measures to protect the Earth and the space environment from harmful contamination."[16] Domesti-

5. National Academies of Sciences, Engineering, and Medicine, Planetary Protection Considerations for Missions to Solar System Small Bodies: Report Series—Committee on Planetary Protection 1-1 n.1 (2022) [hereinafter NAS 2022].
6. *Id.* at 4-2.
7. Fengna Xu et al., *A Re-Examination of Fundamental Principles of International Space Law at the Dawn of Space Mining*, 44 J. Space L. 1, 35-36 (2020).
8. Athena Coustenis et al., COSPAR Panel on Planetary Protection, Briefing on the Role of the COSPAR Panel on Planetary Protection, Presentation 7 (Sept. 23, 2020), https://www.nationalacademies.org/documents/embed/link/LF2255DA3DD1C41C0A42D3BEF0989ACAECE3053A6A9B/file/D7FE378522F26E6B0FABCE92020359D7DC1180628D30.
9. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies art. IX, Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 (1966) [hereinafter OST]. The OST entered into force in 1967, with 112 States Parties as of the end of 2022.
10. Gerhard Kminek et al., The International Planetary Protection Handbook 31 (2019), https://cosparhq.cnes.fr/assets/uploads/2021/02/PPOSS_International-Planetary-Protection-Handbook_2019_Space-Research-Today.pdf [hereinafter IPPH].
11. Agreement Governing the Activities of States on the Moon and Other Celestial Bodies art. 7, Dec. 18, 1979, 1363 U.N.T.S. 22 [hereinafter Moon Agreement]. Only 18 States are party to the Moon Agreement; the United States is not.
12. Hague International Space Resources Governance Working Group, Building Blocks for the Development of an International Framework on Space Resource Activities (2019) [hereinafter Hague Building Blocks]. The Hague International Space Resources Governance Working Group, established in 2016, adopted the 21 Building Blocks as a governance framework for space resources.
13. Moon Village Association, Best Practices for Sustainable Lunar Activities 5 (2020), https://moonvillageassociation.org/download/best-practices-for-sustainable-lunar-activities-issue-1/.
14. Moon Agreement, *supra* note 11, art. 7.
15. Hague Building Blocks, *supra* note 12, Building Block 10.
16. Chair of the Working Group on Long-Term Sustainability of Outer Space Activities, Committee on the Peaceful Uses of Outer Space, *Guidelines for the Long-Term Sustainability of Outer Space Activities*, U.N. Doc. A/

cally, the United States Space Priorities Framework maintains a commitment to protecting earth's biosphere from biological contamination,[17] and the National Aeronautics and Space Administration (NASA) promulgates planetary protection policies and technical guidance applicable to space missions.[18]

## III. A Brief History of Planetary Protection: COSPAR Through Time and Space

COSPAR originated at the dawn of the Space Age. The International Astronautical Federation and the U.S. National Academy of Sciences started discussions over the risk of contaminating other planetary bodies in the late 1950s and, in February 1958, the International Council of Scientific Unions (today the International Scientific Council) established the ad hoc Committee on Contamination by Extraterrestrial Exploration (CETEX).[19]

CETEX set to work developing its Code-of-Conduct, applied to the 1961 Ranger missions.[20] CETEX's mandate was transferred to COSPAR, which established the Consultative Group on Potentially Harmful Effects of Space Experiments.[21] COSPAR developed its initial interim regulatory framework in 1964, replaced in 1969; its international guidelines and NASA's own guidance followed from methods and protocols pioneered for the Viking program, NASA's first Mars lander mission.[22]

COSPAR's Planetary Protection Policy and associated implementation requirements are considered the international standard for planetary protection and guide for complying with OST's Article IX.[23] The policy continues to evolve, having undergone substantial revision in 1984 to delineate specific categories of protection based on target characteristics, mission type, and contamination risk, and again in 1994 to account for Mars orbiters and landers.[24] COSPAR's Panel on Planetary Protection (PPP) updated the policy in 2020 to include revised organic contamination control requirements for missions to Mars and the icy moons in the outer solar system (specifically Europa and Enceladus), and again in 2021 to add new sub-designations for different regions of the moon.[25]

## IV. Close Encounters: Planetary Protection in the United States

COSPAR's guidance is not legally enforceable, but is a widely accepted mechanism for establishing compliance with Article IX.[26] Space agencies typically follow the Planetary Protection Policy, supplemented by their own protocols, in mission planning.[27] The United States, a State Party to the OST, is no exception, and NASA and COSPAR planetary protection policies often evolve in tandem.[28] NASA has also adopted its own planetary protection policies, procedural requirements, and technical standards.[29]

Presidential administrations have proved generally consistent in supporting planetary protection as a policy. Most recently, the Joseph Biden Administration included planetary protection in the United States Space Priorities Framework, issued in 2021. The framework states that "the United States will work with other nations to minimize the impact of space activities on the outer space environment, including avoiding harmful contamination of other planetary bodies."[30]

NASA's Planetary Protection Office is located within the Office of Safety and Mission Assurance (OSMA).[31] The Office ensures that NASA complies with international and domestic planetary protection objectives. Key roles

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AC.105/2018/CRP.20, at 19 (2018), https://www.unoosa.org/res/oosadoc/data/documents/2018/aac_1052018crp/aac_1052018crp_20_0_html/AC105_2018_CRP20E.pdf.

17. The White House, United States Space Priorities Framework 7 (2021), https://www.whitehouse.gov/wp-content/uploads/2021/12/United-States-Space-Priorities-Framework-_-December-1-2021.pdf.
18. *See, e.g.*, NASA Procedural Requirement NPR 8715.24, Planetary Protection Provisions for Robotic Extraterrestrial Missions 3.4.2 (Sept. 24, 2021), https://nodis3.gsfc.nasa.gov/npg_img/N_PR_8715_0024_/N_PR_8715_0024_.pdf [hereinafter NPR 8715.24] (calling for sample return missions to "establish and implement a strategy and design concepts to break the chain of contact with the target body, isolate, and robustly contain restricted samples").
19. National Academies of Sciences, Engineering, and Medicine, Report Series—Committee on Planetary Protection: Evaluation of Bioburden Requirements for Mars Missions 5 (2021), https://www.nationalacademies.org/ocgta/briefings-to-congress/evaluation-of-bioburden-requirements-for-mars-missions [hereinafter NAS Mars 2021].
20. NASA Office of Safety and Mission Assurance, *Planetary Protection*, https://sma.nasa.gov/sma-disciplines/planetary-protection (last visited Feb. 9, 2023) (select "Planetary Protection History" button). The Ranger missions were the first U.S. attempt to launch probes at the moon, beginning with Ranger 1 (launched August 23, 1961) and concluding with Ranger 9 (launched March 21, 1965). Rangers 1-6 experienced a series of technical mishaps, but Rangers 7-9 were successful. NASA Jet Propulsion Laboratory, *Past Missions—Ranger 1-9*, https://www2.jpl.nasa.gov/missions/past/ranger.html (last visited Feb. 9, 2023).
21. IPPH, *supra* note 10, at 15.
22. NASA Planetary Protection Independent Review Board (PPIRB), Report to NASA/SMD Final Report 4 (2019) [hereinafter PPIRB 2019]. The Viking Project was NASA's first success in safely landing a spacecraft on the surface of Mars (Viking 1 on July 20, 1976, and Viking 2 on September 3, 1976) and returning images of the surface. NASA Science Mars Exploration Program, *Viking 1 & 2*, https://mars.nasa.gov/mars-exploration/missions/viking-1-2/ (last visited Feb. 9, 2023); IPPH, *supra* note 10, at 30.
23. PPIRB 2019, *supra* note 22, at 31.
24. National Academies of Sciences, Engineering, and Medicine, Review and Assessment of Planetary Protection Policy Development Processes 19 (2018), https://nap.nationalacademies.org/catalog/25172/review-and-assessment-of-planetary-protection-policy-development-processes.
25. Athena Coustenis et al., Recent Updates in the COSPAR Planetary Protection Policy, Presentation at 44th COSPAR Scientific Assembly (July 16-24, 2022), https://ui.adsabs.harvard.edu/abs/2022cosp...44.3242C/abstract; COSPAR PPP, COSPAR Policy on Planetary Protection (2021) [hereinafter COSPAR PP 2021]; IPPH, *supra* note 10, at 29. Membership of the PPP, chartered in 1999, includes representatives appointed by the major space agencies as well as scientists nominated by other COSPAR commissions. *Id*. at 38.
26. PPIRB 2019, *supra* note 22, at 10.
27. Tanja Masson-Zwaan & Mark J. Sundahl, *The Lunar Legal Landscape: Challenges and Opportunities*, 46 Air & Space L. 29, 35 (2021).
28. NAS Mars 2021, *supra* note 19, at 5. For example, NASA adopted in 1982 a classification system for increasingly stringent planetary protection requirements based on the mission and target solar system body, which COSPAR embraced in 1984. *Id*. at 6.
29. IPPH, *supra* note 10, at 114-15.
30. The White House, *supra* note 17, at 7.
31. Thomas H. Zurbuchen, Associated Administrator, NASA Science Mission Directorate, NASA Response to Planetary Protection Independent Review Board Recommendations (Oct. 17, 2019).

include the mission directorate association administrator (MDAA), NASA project managers, and the planetary protection officer. The planetary protection officer advances planetary protection goals across the agency, assigns planetary protection categories to missions in coordination with the project manager and MDAA, advises individual projects, and generally oversees execution of planetary protection requirements at both the project and agency levels.[32]

Fundamentally, however, all these planetary protection policies and technical standards *apply only to government actors*. The private sector is not regulated in this arena, arguably save for NASA contractors. NASA's procedural requirements provide that while compliance is mandatory for agency employees, entities receiving NASA resources for non-NASA missions need only "use[ ] reasonable efforts to implement planetary protection measures generally consistent with the COSPAR Planetary Protection Policy and Guidelines or the planetary protection measures NASA would take for like missions."[33]

This is not to suggest the space industry is unregulated *in general*. The Federal Communications Commission (FCC) issues licenses to operators of commercial satellites, assigning spectrum for nonfederal use and authorizing satellite transmissions, under the Communications Act of 1934, and the Federal Aviation Administration (FAA) grants licenses to launch vehicles that are in turn used to launch satellites.[34] The United States is taking small steps—and hopefully soon, giant leaps—to address orbital debris. For example, FCC in September 2022 adopted a new rule shortening the time frame required for satellite post-mission disposal from 25 to five years, and is evaluating additional measures, such as maneuverability requirements, and specifically addressing large constellations.[35]

Another example is the transfer of space situational awareness (SSA) functions from the U.S. Department of Defense (DOD) to the U.S. Department of Commerce's Office of Space Commerce in 2018,[36] followed by the Biden Administration proposing a $87.7-million budget for fiscal year 2023 "in order to improve real-time tracking and reporting of objects and debris, helping the space industry safely navigate a congested space environment" (although SSA ultimately was not explicitly incorporated in the Consolidated Appropriations Act of 2023).[37] Yet, planetary protection in the private sector remains off elected officials' radar.

Another regulatory gap is the unbalanced application of the National Environmental Policy Act (NEPA).[38] NEPA arguably is the most suitable instrument presently available for implementing the United States' obligations under Article IX of the OST. But NEPA's scope extends only to *backward* contamination and not to *forward* contamination.

First, NEPA's text is undeniably human-centric and—at least at the current state of technological advancement—focused on earth: the "detailed statement"—generally an environmental impact statement (EIS)—accompanies proposed federal actions "significantly affecting the quality of the *human* environment."[39] Second, NEPA's environmental review requirements presumably apply only to federal actions, and their concomitant impacts, within the jurisdiction of the United States. They do not encompass environmental impacts in foreign countries nor, by implication, other planetary bodies.[40]

Presidential action nevertheless obliges NASA to undertake more expansive environmental review, following both Presidential Directive No. 25, Scientific or Technological Experiments With Possible Large-Scale Adverse Environmental Effects and Launch of Nuclear Systems Into Space (President Jimmy Carter, 1977), and Executive Order No. 12114 (President Carter, 1979). The Presidential Directive, broadly interpreted, requires NASA to prepare an EIS for extraterrestrial sample return missions with the potential to significantly impact the earth's physical or biological environment.[41] Executive Order No. 12114 further extends NEPA's purpose to agency actions with potential impacts to the environment beyond U.S. jurisdiction.[42]

32. NPR 8715.24, *supra* note 18, 3.1.
33. *Id.* 1.3.
34. U.S. Government Accountability Office, Satellite Licensing: FCC Should Reexamine Its Environmental Review Process for Large Constellations of Satellites 8 (2022) (GAO-23-105005), https://www.gao.gov/assets/gao-23-105005.pdf. FAA licenses encompass both the launch into space and planned reentry.
35. FCC, Second Report and Order, In the Matter of Space Innovation Mitigation of Orbital Debris in the New Space Age, FCC 22-74 (Sept. 29, 2022), https://www.fcc.gov/document/fcc-adopts-new-5-year-rule-deorbiting-satellites; Fact Sheet, FCC, Space Innovation; Mitigation of Orbital Debris in the New Space Age—Second Report and Order, IB Docket Nos. 22-271 and 18-313 (Sept. 8, 2022), https://www.fcc.gov/document/mitigating-orbital-debris-shortening-time-satellite-disposal.
36. Presidential Memoranda, Space Policy Directive-3, National Space Traffic Management Policy §5(a) (June 18, 2018), https://trumpwhitehouse.archives.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/.
37. Office of Management and Budget, Budget of the U.S. Government Fiscal Year 2023, at 50, https://www.whitehouse.gov/wp-content/uploads/2022/03/budget_fy2023.pdf; Consolidated Appropriations Act, 2023, H.R. 2617, 117th Cong. §2, div. B, tit. III (2022), https://www.govinfo.gov/content/pkg/BILLS-117hr2617enr/pdf/BILLS-117hr2617enr.pdf; House Committee on Appropriations, Consolidated Appropriations Act, 2023: Summary of Appropriations Provisions by Subcommittee 5 (2023), https://appropriations.house.gov/sites/democrats.appropriations.house.gov/files/FY23%20Summary%20of%20Appropriations%20Provisions.pdf.
38. 42 U.S.C. §§4321-4370h, ELR Stat. NEPA §§2-209.
39. NEPA §102(C) (codified at 42 U.S.C. §4332(C)) (emphasis added).
40. Nonetheless, NEPA obliges federal agencies to "recognize the worldwide and long-range character of environmental problems." NEPA §102(F). Note also that Article II of the OST plainly states that "[o]uter space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means." OST, *supra* note 9, art. II.
41. NASA, Draft Mars Sample Return (MSR) Campaign Programmatic Environmental Impact Statement 1-5 (2022) [hereinafter MSR PEIS]; Presidential Directive No. 25, Scientific or Technological Experiments With Possible Large-Scale Adverse Environmental Effects and Launch of Nuclear Systems Into Space 2 (Dec. 14, 1977) ("Where such experiments constitute major action either licensed or funded by Federal Agencies that significantly affect the quality of the human environment, an environmental impact statement will be prepared.").
42. MSR PEIS, *supra* note 41, at 2-7; Exec. Order No. 12114, Environmental Effects Abroad of Major Federal Actions, 44 Fed. Reg. 1957, §1 (Jan. 9, 1979), *available at* https://www.archives.gov/federal-register/codification/executive-order/12114.html.

**Planetary Protection Procedures**

Spacefaring nations around the world have implemented their own planetary protection procedures. An example is Japan, where the **Japan Aerospace Exploration Agency (JAXA)** is responsible for planetary protection, the **Department of Safety and Mission Assurance (S&MA)** develops planetary protection standards, the **International Space Exploration Team** establishes the planetary protection strategy, and the **Institute of Space and Astronautical Science (ISAS)** proposes, develops, and operates missions potentially relating to planetary protection. Another important body is the **Planetary Protection Review Board**.*

**See* Gerhard Kminek et al., The International Planetary Protection Handbook 116-17 (2019).

NASA procedures for applying NEPA to sample return missions are available at 14 C.F.R. §1216.305 (Unrestricted Earth Return, requiring an environmental assessment (EA)) and 14 C.F.R. §1216.306 (Restricted Earth Return, requiring an EIS).[43] Yet, while NASA adheres to planetary protection protocols for both forward and backward contamination, only missions with backward contamination implications undergo environmental review.

## V. COSPAR's Guide to Protecting the Galaxy

Space agencies like NASA generally adopt COSPAR's Planetary Protection Policy. The policy distinguishes five categories of space missions, according to the type of mission (e.g., flyby, orbiter, lander, sample return) and the degree to which the target body (e.g., planet, moon, asteroid, or comet) has the potential for informing science about the origin of life or chemical evolution of the solar system. Table 1 below lays out the different categories and their respective requirements. The objective is to minimize the probability of impact (e.g., by a flyby or orbiter) and risk of contamination, within a stringent set of parameters established for each of the five categories.

This necessitates spacecraft and protocols that can meet both the *bioburden requirements* (the population of viable organisms, or pre-launch spore count measurements) for the target body, and *control requirements* needed to avoid compromising scientific measurements.[44] The planetary protection category assigned to missions approaching multiple solar system bodies is based on the most stringent category applicable to a planetary body included in the mission.[45]

Protective measures range from documentation to stringent sterilization requirements for reducing bioburden transported in or on spacecraft.[46] The policy recommends COSPAR Members report to the organization twice: first, within six months of launch with information on the planetary protection procedures and computations, and again within one year following mission conclusion, about the areas of the target planetary bodies potentially subjected to contamination.[47] Each organization responsible for a planetary mission, as certified by the relevant national/international authority, determines "the best and most cost effective means" to meet the COSPAR requirements.[48]

## VI. Strange New Worlds: The Future of Planetary Protection

Planetary protection fundamentals developed when interplanetary travel was purely aspirational, spacefaring entities were limited to nation-states, and both human and sample-return missions were confined to the earth-moon system. The context today is vastly different, with both government agencies and the commercial sector implementing plans for human exploration of Mars and looking to more extensive exploration of the icy moons of the outer planets.[49]

Efforts are already underway to bring extraterrestrial material to earth for scientific investigation. The upcoming Mars Sample Return (MSR) is one such example. This NASA-European Space Agency (ESA) venture will return one pound of samples that the Perseverance rover is presently collecting from Mars' Jezero Crater. A sample retrieval lander (SRL) will retrieve the material, launch from the surface, and be captured by the Earth Return Orbiter (ERO).

As early as 2033, the ERO will release the Earth Entry System (EES) to land in Utah, where a recovery team will transport the EES in a biocontained "vault" to a sample retrieval facility (SRF) rated biosafety level 4 (BSL-4) for safety assessment and containment, followed by curation and scientific analysis.[50] NASA released a programmatic environmental impact statement (PEIS) in late 2022, which details the agency's application of Planetary Protection Category V—Restricted Earth Return at each step of the

43. *See, e.g.*, 14 C.F.R. §1216.306(d), *available at* https://www.govinfo.gov/content/pkg/CFR-2022-title14-vol5/pdf/CFR-2022-title14-vol5-part1216-subpart1216-3.pdf:

> Typical NASA actions normally requiring an EIS include . . . [d]evelopment and operation of a space flight project/program which would return samples to Earth from solar system bodies (such as asteroids, comets, planets, dwarf planets, and planetary moons), which would likely receive a Restricted Earth Return categorization (as defined in Appendix A to this subpart) from the NASA Planetary Protection Office or the NASA Planetary Protection Subcommittee.

44. National Academies of Sciences, Engineering, and Medicine, Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032, at 21-21 (2022) [hereinafter NAS Decadal Strategy].
45. NASA Technical Standard NASA-STD-8719.27, Implementing Planetary Protection Requirements for Space Flight 46 (2022) [hereinafter NASA-STD-8719.27].
46. COSPAR PP 2021, *supra* note 25. *See, e.g.*, NASA-STD-8719.27, *supra* note 45, at 39.
47. COSPAR PP 2021, *supra* note 25.
48. Coustenis et al., *supra* note 8, at 8.
49. PPIRB 2019, *supra* note 22, at 5, 9; NAS Mars 2021, *supra* note 19, at ix, 1, 41.
50. *See generally* MSR PEIS, *supra* note 41.

## Table 1. Planetary Protection Categories

| CATEGORY | MISSION TYPE | TARGET | REQUIREMENTS |
|---|---|---|---|
| I | Flyby, orbiter, lander | Bodies not of direct interest for understanding the process of chemical evolution or the origin of life* | None |
| II (a-c) | Flyby, orbiter, lander | Bodies of significant interest relative to the process of chemical evolution and origin of life, but only a remote chance that contamination could compromise future investigations**<br>IIa: orbital and flyby to moon<br>IIb: landing on moon<br>IIc: landing/surface operations on moon within permanently shadowed regions (PSRs) and lunar poles | Brief documentation (planetary protection plan; pre-launch, post-launch, post-encounter, and end-of-mission reports, e.g., final disposition of the spacecraft); moon requires inventory of all organic compounds > 1 kilogram. NASA may require trajectory analysis demonstrating sufficiently low impact risk to other solar system bodies, especially Mars and Europa*** |
| III | Flyby, orbiter (no direct contact) | Bodies of significant interest to the process of chemical evolution and/or life and where scientific opinion provides a significant chance that contamination could compromise future investigations♦ | Category II plus documentation on contamination control and organics inventory, and trajectory biasing, cleanroom, bioburden reduction, impact probability analysis for Mars, Europa, and Enceladus |
| IV (a-c) | Lander, probe (direct contact) | Bodies of significant interest to the process of chemical evolution and/or life and where scientific opinion provides a significant chance that contamination could compromise future investigations♦<br>IVa: *not* investigating extant Martian life<br>IVb: investigating extant Martian life<br>IVc: investigating Martian special regions | Documentation (same as for Category III) plus microbial reduction plan, Category III procedures plus partial sterilization and bioassay monitoring♦♦<br>IVa: category III *plus* lander systems restricted to a surface bioburden level of ≤ 3 x $10^5$ spores, and an average of ≤ 300 spores per square meter<br>IVb: category IVa *plus* lander systems restricted to a surface bioburden level of ≤ 30 spores or sterilization to these levels and method of preventing recontamination<br>IVc: category IVa *plus* either surface bioburden level of ≤ 30 spores or sterilization to these levels and method of preventing recontamination |
| V<br>*UNRESTRICTED*<br>EARTH RETURN | Earth-return missions after contact with bodies deemed by scientific opinion to have no indigenous life-forms,♦♦♦ scientific evidence mission will not cause harmful biological contamination of earth's biosphere° | | Requirements for outbound phase same for a category of target body/outbound mission<br><br>Inbound: None |
| V<br>*RESTRICTED*<br>EARTH<br>RETURN°° | Earth-return missions after contact with bodies deemed by scientific opinion to be of significant interest to the process of chemical evolution and/or origin of life°°° | | Requirements for outbound phase same for a category of target body/outbound mission<br><br>Inbound: Category IV requirements plus sterile or contained hardware, procedures to "break the chain" of contact with target body, isolate and contain samples, and continual monitoring of project activities (e.g., biosafety level 4-plus sample receiving facility (SRF), sample safety assessment)°°°° |

Sources: COSPAR PPP, COSPAR Policy on Planetary Protection (2021); Gerhard Kminek et al., The International Planetary Protection Handbook 31 (2019); NASA Technical Standard NASA-STD-8719.27, Implementing Planetary Protection Requirements for Space Flight (2022); National Academies of Sciences, Engineering, and Medicine, Report Series—Committee on Planetary Protection: Evaluation of Bioburden Requirements for Mars Missions 6 (2021); National Academies of Sciences, Engineering, and Medicine, Planetary Protection Considerations for Missions to Solar System Small Bodies: Report Series—Committee on Planetary Protection 4-1 (2022); The White House National Space Council, National Strategy for Planetary Protection (2020).

* *E.g.*, undifferentiated, metamorphosed asteroids.

** *E.g.*, moon, comets, carbonaceous chondite asteroids, Jupiter, Saturn, Uranus, Neptune, Ganymede, Titan, Triton, Pluto/Charon, Ceres, Kuiper Belt objects.

*** National Academies of Sciences, Engineering, and Medicine, Planetary Protection Considerations for Missions to Solar System Small Bodies: Report Series—Committee on Planetary Protection 4-2 (2022).

♦ *E.g.*, Mars, Europa, Enceladus.

♦♦ "Category IV missions landing or accessing the subsurface on Europa, Enceladus, or other sensitive icy worlds demonstrate contamination avoidance at a probability of occurrence less than 1.0 x 10-4 for a biological inoculation event into a potentially habitable aqueous environment (e.g., liquid water body, brine) for 1,000 years." NASA Technical Standard NASA-STD-8719.27, Implementing Planetary Protection Requirements for Space Flight 56 (2022).

♦♦♦ "Special regions" are defined as regions where there is a high potential for extant life to exist or for terrestrial organisms to replicate, such as places with sufficiently warm temperatures and sufficient water activity. *Id.* at 21, 47.

♦♦♦♦ *E.g.*, Venus, moon. *See* The White House National Space Council, National Strategy for Planetary Protection 1 (2020) ("samples from Earth's Moon have been deemed non-hazardous and their return to Earth has been deemed unrestricted since 1971").

° Currently the only category applicable to crewed missions.

°°Three prior NASA missions were designated Restricted Earth Return: Apollo 11, 12, and 14. NASA, Draft Mars Sample Return (MSR) Campaign Programmatic Environmental Impact Statement 1-8 (2022).

°°° *E.g.*, Mars, Europa.

°°°° "RER [Restricted Earth Return] missions have requirements to break the chain of contact with the target body as well as isolate and robustly contain restricted samples during all mission phases through safe receipt and containment on Earth." NASA, Draft Mars Sample Return (MSR) Campaign Programmatic Environmental Impact Statement 1-6 (2022).

**Thinking Light Years Ahead**

*Recent reports proposed to NASA recommendations for meeting tomorrow's planetary protection challenges*

**NASA Planetary Protection Independent Review Board (PPIRB), Report to NASA/SMD Final Report (2019)**
NASA chartered the PPIRB to evaluate opportunities for improving and streamlining its planetary protection policies, as well as adapt to new entrants and potential planetary missions.

**National Academies of Sciences, Engineering, and Medicine, Report Series—Committee on Planetary Protection: Evaluation of Bioburden Requirements for Mars Missions (2021)**
NASA's Science Mission Directorate and OSMA requested that the Committee on Planetary Protection (CoPP) propose criteria for identifying locations on the Martian surface suitable for a lower spacecraft bioburden requirement than under COSPAR policy.

**National Academies of Sciences, Engineering, and Medicine, Planetary Protection Considerations for Missions to Solar System Small Bodies: Report Series—Committee on Planetary Protection (2022)**
NASA's Science Mission Directorate and OSMA leadership requested CoPP to evaluate the appropriateness of relieving from planetary protection considerations outbound missions to small bodies in the solar system in order to streamline requirements for future exploratory and commercial endeavors.

**National Academies of Sciences, Engineering, and Medicine, Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032 (2022)**
Pinpoints priorities over the next decade of space exploration, including missions and areas of scientific investigation.

complex mission. More detail is provided in the case study following this Comment.

Additionally, private companies are emerging as major players, propelled by greater investment and new, affordable technology.[51] The possibility—and associated profitability—of extracting basic elements, such as water and carbon for producing propellant, has renewed private-sector interest in mining small bodies.[52] In situ utilization of resources like water ice by crewed missions increases the potential for biological contamination of Martian subsurface areas,[53] and the nascent space tourism industry raises its own set of planetary protection questions.[54]

Both NASA and the National Academies of Science, Engineering, and Medicine recently issued independent reports assessing NASA's planetary protection policies and protocols in light of these developments and outlining recommendations for the federal government. Two areas of focus are (1) clear planetary policy regulations applicable to the private sector; and (2) streamlining bioburden requirements for greater flexibility, lowering mission costs, and avoiding schedule delays, without compromising public safety and the integrity of scientific investigation.[55]

### *A. Closing the Regulatory Gap for the Commercial Space Industry*

All three reports highlight the lack of consensus as to the OST's application to nongovernment entities.[56] NASA theoretically could make the agency's business or other support contingent on compliance with planetary protection measures. But NASA is not a regulatory agency—as contrasted to, for example, FCC (satellite transmissions) and FAA (launches)—and does not oversee commercial space flight.

51. Small satellites (e.g., "CubeSats") prove an ultra-low cost option, using off-the-shelf technologies, for carrying out planetary missions. *See, e.g.*, NASA Jet Propulsion Laboratory, *Mars Cube One—MarCO*, https://www.jpl.nasa.gov/missions/mars-cube-one-marco (last visited Feb. 9, 2023). The two communications-relay CubeSats launched May 5, 2018, and successfully monitored the entry, descent, and landing of the InSight Mars Lander as well as conducted communications and navigation experiments.
52. NAS 2022, *supra* note 5, at 5-1. As of late 2021, scientists identified in our solar system 1.2 million known small bodies, 27,196 NEOs, 1.1 million Main-Belt asteroids, and 4,429 comets, and approximately 9,800 Jupiter Trojans. *Id.* at 2-1, 2-9. Astronomers heading a major new 10-year astronomy project at Chile's Vera C. Rubin Observatory anticipate the number of known comets may grow to approxiately 10,000 as a result. Duane Bonifer, *Monmouth's Michael Solontoi Publishes Paper as Part of Multinational Astronomy Project That Will Capture "Ten-Year Digital Movie of The Sky"*, River Cities' Reader, Mar. 14, 2023, at https://www.rcreader.com/news-releases/monmouths-michael-solontoi-publishes-paper-part-multinational-astronomy-project-will
53. NAS Mars 2021, *supra* note 19, at 49.
54. *See, e.g.*, Marcia Dunn, *World's 1st Space Tourist Signs Up for Flight Around Moon*, AP (Oct. 21, 2022), https://apnews.com/article/elon-musk-spacex-science-travel-ee385c4d9f39519c59602b40af1b5dd9. Current tourist destinations are limited to the International Space Station and orbiting the moon (rendering the term "honeymoon" literal rather than a mere colloquialism).
55. *See generally* PPIRB 2019, *supra* note 22; NAS Mars 2021, *supra* note 19; NAS 2022, *supra* note 5.
56. PPIRB 2019, *supra* note 22, at 10.

**"I'm Sorry Dave, I'm Afraid I Can't Do That"**

The National Academies of Sciences, Engineering, and Medicine's CoPP issued a report in 2022 weighing the merits of reassessing planetary protection categorizations. CoPP focused on Categories I and II, as applied to outbound-only missions to small bodies.

CoPP settled on target composition as the primary factor for making categorization decisions, and volatile-/organic-rich small bodies as more astrobiologically significant.* CoPP determined information about the size of any subclass of planetary bodies was limited, and that no assumptions could be made about the likelihood of revisiting a target body, with respect to preserving scientific integrity for future missions.** CoPP noted that larger targets are generally considered to be primordial, rather than comprising collisional fragments, and therefore hold more astrobiological interest.*** CoPP further deemed it "highly improbable" that small bodies host life (extinct or extant), or that terrestrial microbes transported to a small body would proliferate on arrival because they would be quickly inactivated by ultraviolet C (UVC) radiation.****

CoPP found no reason to change the current categorization of missions to small bodies, and it remains appropriate to apply Category II to missions to relatively primitive, volatile-rich, and organic-bearing small bodies with astrobiological importance (e.g., C-complex, P-type, and D-type Main-Belt asteroids (MBAs) and NEOs, Trojans, comets, Kuiper Belt objects (KBOs), and Centaurs).***** Category I would apply to missions to mine metals, volatiles, and other materials from S- or M-type bodies.******

* NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE, PLANETARY PROTECTION CONSIDERATIONS FOR MISSIONS TO SOLAR SYSTEM SMALL BODIES: REPORT SERIES—COMMITTEE ON PLANETARY PROTECTION 3-3, 3-4 (2022).
** *Id.* at 3-1 to 3-2.
*** *Id.* at 3-3.
**** *Id.* at 2-17.
***** *Id.* at ES-2, 3-4.
****** *Id.* at 5-1.

The current state of affairs brings consequences. First, the United States arguably is failing its obligations under Article IX of the OST by not effectively supervising private-sector activities.[57] Second is the lack of regulatory certainty. The National Academies found private-sector actors confused about the federal government's regulatory authority, and that many perceived planetary protection requirements as more stringent than they are in reality.[58] Commercial space representatives even suggested designating a regulatory agency to provide clarification.[59] Both NASA's Planetary Protection Independent Review Board (PPIRB) and the National Academies reports recommended the U.S. Congress identify and grant jurisdiction to such an agency to supervise nongovernmental space actors, including implementing and overseeing compliance with planetary protection measures.[60]

### B. *Streamlining and Updating Overly Stringent Planetary Protection Standards*

The reports describe current planetary policy scientific cleanliness requirements as outdated and unrealistic, even needlessly conservative, and claim existing policies for robotic return missions from Mars—which are Category V—Restricted Earth Return—are "unachievable" for human planetary missions.[61]

NASA and COSPAR planetary protection guidelines for Mars include specific thresholds for spacecraft bioburden and approaches to meet those standards. Proponents of modernization concede they were "appropriately conservative" when little was known about the likelihood of potentially habitable regions on Mars. Today, however, they regard the guidelines as insufficiently flexible to account for evolving scientific understanding about Mars' habitability, the growing number and types of future missions, the potential for extremophiles (organisms able to exist in "extreme" environments, see box titled "Conan the Bacterium"), and mission-specific opportunities for reducing the risk of contamination.[62] The reports offer four overarching recommendations.

*First* is moving beyond the exclusive reliance on bioburden, with its strict numerical spore count limits, as the key

57. NAS 2022, *supra* note 5, at 5-3.
58. *Id.* at ES-3, 5-2.
59. *Id.* at 5-3 to 5-4. Representatives proposed this at a joint NASA/White House Office of Science and Technology Policy round table in 2021.
60. PPIRB 2019, *supra* note 22, at 18; NAS Mars 2021, *supra* note 19, at 3; NAS 2022, *supra* note 5, at 5-3. A related recommendation is to establish a centralized data repository, with NASA's Planetary Data System as a model. The National Academies stated: "The future, however, is likely to bring many more small-body missions, including those initiated by new entrants to space exploration, such as private-sector entities with unknown archival standards." *Id.* at 4-3.
61. PPIRB 2019, *supra* note 22, at 9, 11, 15.
62. NAS Mars 2021, *supra* note 19, at 39.

**Real-Life Sci-Fi Villains?**

There is irony in the amount of effort expended on developing planetary protection protocols, when evidence suggests that bad actors acting intentionally can easily introduce biological materials to other planetary bodies. One example is Beresheet (SpaceIL and Israel Aerospace Industries), a private Israeli lunar lander that carried thousands of dormant tardigrades in its payload. The lander crashed into the moon on April 11, 2019, and was destroyed.* The PPIRB highlighted the need for a legal enforcement tool, such as sanctions, to hold such perpetrators accountable—bringing new meaning to the term "spacesuit."**

* Daniel Oberhaus, *A Crashed Israeli Lunar Lander Spilled Tardigrades on the Moon*, *WIRED* (Aug. 5, 2019), https://www.wired.com/story/a-crashed-israeli-lunar-lander-spilled-tardigrades-on-the-moon.
** Nasa Planetary Protection Independent Review Board (Ppirb), Report to Nasa/Smd Final Report 12 (2019).

indicator of the risk of forward contamination.[63] Alternative techniques include genomic tools for monitoring and characterizing bioburden, probabilistic models of the risk of adverse forward contamination, crediting for the time a spacecraft spends in a harsh space or planetary environment, new sterilization technologies,[64] and more accurate methods for detecting life.[65]

*Second* is more precise matching of planetary protection categories to missions. The PPIRB recommended consideration of redesignating regions of the moon's surface and subsurface as Category I versus Category II, depending on whether areas are deemed higher priority for human exploration as contrasted to being of significant astrobiological interest.[66] The PPIRB also suggested NASA study the "transport, survival, and amplification mechanisms of contamination for each ocean world," presently designated Category IV.[67] Notably, COSPAR did update its Planetary Protection Policy for lunar missions in 2021, creating Category II subdesignations to accommodate missions to different regions, including permanently shadowed regions (PSRs).[68]

*Third* is loosening planetary protection standards for human missions, including developing guidelines specific to Mars in the near term,[69] and *fourth* is periodically reassessing protocols and guidelines to keep up with advances in scientific knowledge. Ceres is a prime example; scientists now recognize Ceres as the most water-rich body in the inner solar system, after earth, and consequently meriting more stringent planetary protection measures than required under its current Category II designation.[70] Indeed, not just forward contamination policies require revision; existing U.S. policy on backward contamination has not been updated since the Apollo missions.[71] The National Academies proposed establishing a standing planetary protection risk management board comprising subject matter experts in the relevant fields of astrobiology, chemistry, mission planning and navigation, and spacecraft engineering.[72]

There may be opportunity to put some of these recommendations to the test in the not-so-far-off future. The 2021 National Academies report advised loosening the bioburden reduction requirements for robotic missions to Mars that interact only with the surface and uppermost subsurface, away from subsurface areas that merit continued protection from forward contamination. The report reasoned that the presence of terrestrial organisms on the surface, and even in disconnected subsurface regions, were unlikely to compromise future scientific investigation, because the Martian environment is not conducive to terrestrial organisms flourishing.[73]

Still, there is some risk of harmful contamination: viable terrestrial organisms delivered to the surface of Mars could survive and be transported by wind or robotic device to potentially habitable subsurface environments. These

63. PPIRB 2019, *supra* note 22, at 11.
64. *See, e.g.*, NAS Decadal Strategy, *supra* note 44, at 21-22:

> Concepts for terminal sterilization—i.e., the complete elimination of all biological contamination at the landing site following the completion of all scientific investigation—are in the formulation phase as part of the Europa Lander mission concept technology efforts. At bodies where the timescales of surface-subsurface transport exceed the 1000-year period of biological exploration, missions might not require such extreme measures, providing significant cost savings. For bodies where surface-subsurface transport is less than 1000 years, further technology development of terminal sterilization, in concert with planetary protection requirements tailored for the specific body and mission science requirements, would provide a robust strategy to minimize the risk of contamination while maximizing unambiguous science return.

Scientists recently released findings indicating that exposure to thermoplastic polyacetal polymer, a potential spacecraft material, unilaterally inactivated bacterial spores of three *Bacillus* species, suggesting possibilities for integrating planetary protection properties into the very design of spacecraft. *See* Andrew C. Schuerger et al., *Microbial Protocols for Spacecraft: 2. Biocidal Effects of Delrin and Nylon in Sealed Compartments May Enhance Bioburden Reductions in Planetary Spacecraft*, Int'l J. Astrobiology (Sept. 29, 2022), https://www.cambridge.org/core/journals/international-journal-of-astrobiology/article/abs/microbial-protocols-for-spacecraft-2-biocidal-effects-of-delrin-and-nylon-in-sealed-compartments-may-enhance-bioburden-reductions-in-planetary-spacecraft/FFD06DCEA72DFB326B15D5367E641F6A.

65. NAS Mars 2021, *supra* note 19, at 39; PPIRB 2019, *supra* note 22, at 11. The NAS Decadal Strategy also pointed out the limited category of organisms used for assessing bioburden. NAS Decadal Strategy, *supra* note 44, at 21-22:

> Attention needs to be given to controlling the possible introduction of contaminants over and above those used for planetary protection bioburden, especially chemical species of astrobiological interest such as amino acids, nucleic acids, carboxylic acids or lipids and molecules that may confound measurements of these (e.g., isobaric species), at concentrations that might interfere with the scientific exploration of planetary bodies.

66. PPIRB 2019, *supra* note 22, at 13.
67. *Id*. at 21. Ocean worlds include Europa, Enceladus, and Titan.
68. PSR-containing polar regions may contain water ice deposits. COSPAR previously upgraded the moon from Category I to II in 2008. Press Release, COSPAR, COSPAR Updates Its Planetary Protection Policy for Missions to the Moon's Surface (July 15, 2021), https://cosparhq.cnes.fr/assets/uploads/2021/07/Press-Release_PPP_15July2021_FINAL.pdf; COSPAR PP 2021, *supra* note 25, at 8.2.
69. PPIRB 2019, *supra* note 22, at 15.
70. NAS 2022, *supra* note 5, at 2-4, 3-4.
71. The White House National Space Council, National Strategy for Planetary Protection 2 (2020).
72. NAS Mars 2021, *supra* note 19, at 45.
73. *Id*. at 2.

**CONAN THE BACTERIUM**

What is the likelihood of life from Mars hitching a ride back to earth and contaminating the terrestrial biosphere? A 2022 study by William H. Horne et al., *Effects of Desiccation and Freezing on Microbial Ionizing Radiation Survivability: Considerations for Mars Sample Return* (2022), suggests our own planet may hold clues in the form of "extremophiles," organisms that can persist in the most extreme environmental conditions.

The Red Planet's surface may once have harbored life but is characterized today by freezing temperatures (210 K, or -63°C), arid conditions, and prolonged exposure to ionizing radiation at incredibly high doses compared to earth.

Scientists typically rely on *Bacillus* spores to calculate bioburden, because they can survive under tough conditions. The research team looked at six other organisms, including polyploid *Deinococcus radiodurans*, dubbed "Conan the Bacterium." The team successfully extended the microbe's already high radiation survival threshold from 25 kilograys (kGy) to 140 kGy through desiccation and freezing—both characteristic of the Mars surface. The researchers postulated that *D. radiodurans* could survive up to 280 million years, if buried desiccated and frozen 10 meters beneath the Martian surface, thanks to robust genomic repair systems.

This suggests that Martian organisms could have survived in a dormant state for millions of years, especially with intermittent periods of melting (such as by meteorite impacts) allowing populations to flourish and disperse. Such hints that life may persist in conditions the scientific community previously considered infeasible has implications not only for backward contamination, but also forward contamination. It reminds us that humanity, without taking cautionary measures, may leave behind a longer-lasting and more pernicious legacy than intended.

include caves (potentially hosting water ice or salt and brine depositions) and the deep subsurface (a possible site of underground aquifers), where indigenous Martian life would most likely inhabit and where terrestrial organisms could grow and proliferate.[74] Notably, a 2022 study identified at least one such potential "viable terrestrial organism," the extremophile *Deinococcus radiodurans*.[75]

The 2021 National Academies report does account for this possibility, pointing out that "[t]ests using genetic assays could better characterize microbial populations, including the presence of extremophiles," better informing "both risk assessments and mitigation techniques that can reduce the risk of harmful contamination."[76] The report proposed more cost-effective protocols, including following such a risk management approach,[77] as well as relaxing bioburden requirements for missions limited to the surface or accessing up to one meter in the subsurface where evidence currently indicates no ice exists,[78] taking advantage of in situ, onboard, and natural bioburden reduction opportunities,[79] and establishing buffer zones around key sites, like subsurface access points and astrobiologically significant areas.[80]

NASA may be responding to these recommendations. The agency recently issued updated and interim planetary protection policies, including for robotic and human missions to the moon and Mars.[81]

## VII. Boldly Going Where No Lawyer Has Gone Before . . .

Planetary protection as a realistic goal will truly be put to the test over the coming decades, as both public and private actors move beyond a handful of robotic missions to more ambitious ventures to explore and potentially exploit the rest of the solar system. Plans encompass sample retrieval for analysis on earth, dispatching human missions, and estab-

74. *Id*. at 2.
75. William H. Horne et al., *Effects of Desiccation and Freezing on Microbial Ionizing Radiation Survivability: Considerations for Mars Sample Return*, 22 Astrobiology 1337 (2022).
76. NAS Mars 2021, *supra* note 19, at 40. Scientists continue devising new methods for tracking forward contamination. For example, a team of biologists investigated changes in microbial diversity in snow samples taken, over a two-year period, at different distances from "extraterrestrial analogue" site, the Concordia Research Station on the Antarctic Plateau ("the ancient, most isolated, stable and coldest icy environment on Earth . . . where liquid water essential for active life is virtually absent"). The team concluded their method, 16S and 18S rRNA gene sequencing, could be effective for planetary protection purposes and noted "other promising techniques under development" (e.g., nanopore- and antibody-body-based techniques). Most samples contained DNA concentrations below the detection limit, and no significant changes were observed based on season or distance from Concordia Base. *See* Alessandro Napoli et al., *Snow Surface Microbial Diversity at the Detection Limit Within the Vicinity of the Concordia Station, Antarctica*, 13 Life 113 (2022). *But see* Keith Cowing, *Away Team Issues: Humans Are Leaving Behind a Frozen Signature of Microbes on Mount Everest,* Astrobiology, Mar. 14, 2023, at https://astrobiology.com/2023/03/away-team-issues-humans-are-leaving-behind-a-frozen-signature-of-microbes-on-mount-everest.html.
77. NAS Mars 2021, *supra* note 19, at 2, 42.
78. *Id*. at 2-3.
79. *Id*. at 3, 46, 48. An example of natural processes is UVC radiation.
80. *Id*. at 2-3.
81. *See, e.g.*, NASA Interim Directive NID 8715.129, Biological Planetary Protection for Human Missions to Mars 1.3.1 (July 9, 2020), https://nodis3.gsfc.nasa.gov/OPD_docs/NID_8715_129_.pdf (to "develop risk-informed decision making implementation strategies for human missions to Mars, which account for and balance the needs of human space exploration, science, commercial activities, and safety"); NPR 8715.24, *supra* note 18, 1.1.3 ("NASA will use risk-informed decision making processes defined in NPR 8000.4 for balancing the needs of scientific discovery, space exploration, commercial activities, and safety"); NASA-STD-8719.27, *supra* note 45 (the technical requirements as an accompaniment to the detailed procedural requirements in NPR 8715.24 and NID 8715.129) (generally applicable to robotic missions with specific sections applicable to crewed missions).

**Mission to Mars**

*MSR*
NASA-ESA joint venture to return samples from Mars' Jezero Crater for scientific investigation (returns to earth 2033)

*ExoMars*
ESA mission to determine whether life ever existed on Mars. Trace Gas Orbiter (launched 2016) and first European rover, the Rosalind Franklin rover, outfitted with drill and laboratory (mission suspended due to Russia's war on Ukraine)

*Mars Life Explorer (MLE)*
NASA mission to determine if life is or ever was present in ice under the surface. Will drill up to two meters/6.5 feet into mid-latitude ice and study samples (landing as early as 2033)

*Tianwen-3*
Chinese mission, including lander/ascent vehicle and orbiter/return module, launching on the Long March 5 and 3B rockets, respectively, to recover samples (launch 2028, land on Mars 2029, return to earth 2031)

lishing long-term outposts and colonies, beginning with Mars. These missions implicate risks of both forward and backward contamination.

The National Academies 2023-2032 Decadal Strategy underscores that NASA has not yet developed strategies tailored to crewed missions. This is concerning, due to the need to protect both human explorers and the earth's own biosphere from harmful organisms.[82]

A pragmatic and viable approach is to explicitly transition from the existing policy embodying the precautionary principle, to one that applies NEPA-like procedures of comprehensive environmental review of public- *and* private-sector activities with implications for both earth and other celestial bodies. The principal virtue of the precautionary principle is that it is simple to understand and apply when environmental damage is merely theoretical. But once humanity has the technological capacity to inflict previously only hypothesized damage, *and* where there are very real economic, social, and cultural reasons for humanity to press forward with space exploration, these serve as powerful arguments to abandon the precautionary principle in favor of cost-benefit analysis.This will require Congress to identify and confer regulatory jurisdiction on a federal agency. Advantages include streamlined requirements, regulatory certainty for the commercial space industry, and recognition that humanity's responsibilities for environmental stewardship should extend beyond the terrestrial. Assignment of this responsibility to a single agency will also leverage a cadre of technical experts competent to apply the latest scientific knowledge to develop appropriate mitigation measures.

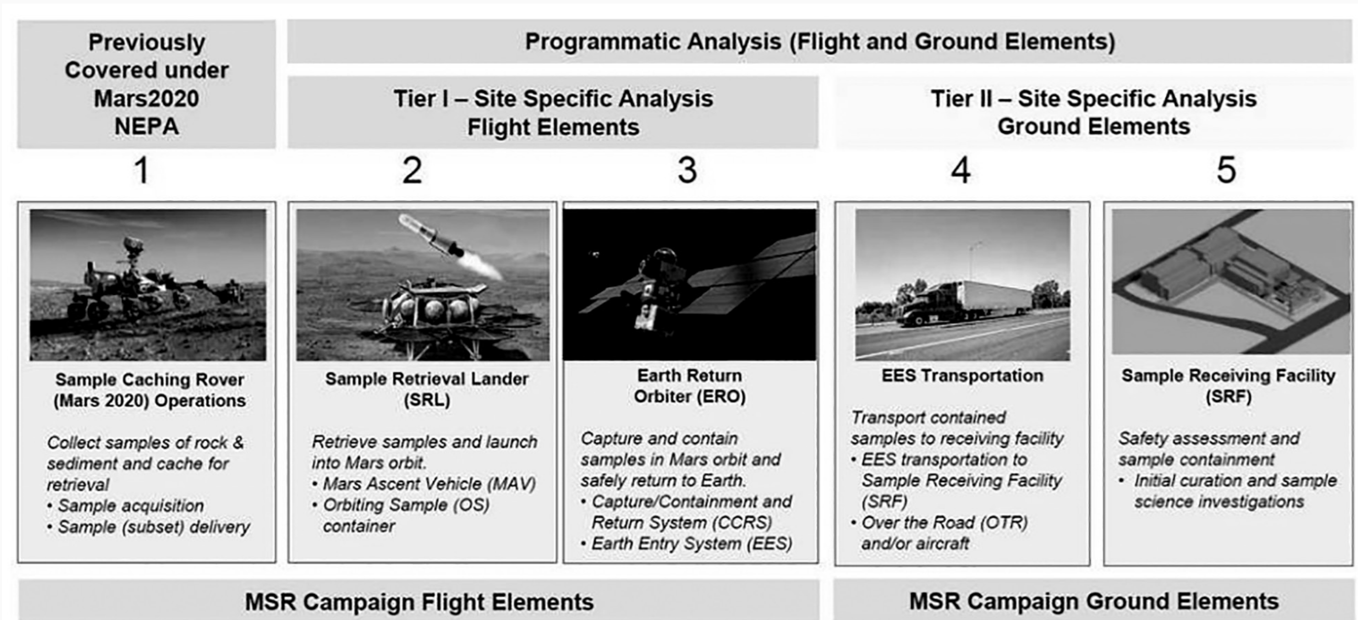
Investment into further research is also advisable, potentially under the aegis of this new regulatory agency. After all, humanity is only beginning to understand how life can persevere under the most extreme conditions of our own planet—to say nothing of forms of life we can barely dream as possible of existing in our vast universe.

82. NAS Decadal Strategy, *supra* note 44, at 19-12.

## Case Study: Mars Sample Return

*The MSR mission will return Mars samples to earth for scientific analysis and research, surmounting the limited scope and detail of the science that can be carried out remotely by robots. Goals are to (1) significantly advance the understanding of the origin and evolution of the Red Planet's geology and climate and derive clues about the other terrestrial planets; (2) amplify the search for evidence of ancient life-forms; and (3) prepare for human exploration of the planet.*[83]

**Figure 1. MSR Campaign Elements**




Source: NASA, Draft Mars Sample Return (MSR) Campaign Programmatic Environmental Impact Statement (2022).

### A. *Mission Description and Timeline*

The MSR is a partnership between NASA and ESA and encompasses five elements: three flight elements and two ground elements.[84]

- *Perseverance rover*, launched in July 2020 and in February 2021, landed in the Jezero Crater, an ancient Martian river delta, and is collecting samples, such as rocks, regolith, and atmosphere.[85] It will cache approximately 450 grams (one pound) within ultraclean and sterile sample tubes.[86]

- *SRL*, launching by NASA in 2028, with backup opportunities in 2030 and 2032, would deliver to the planet's surface the Mars Ascent Vehicle with the orbiting sample container, a sample transfer arm provided by ESA, and up to two sample recovery helicopters (based on the design of the Ingenuity helicopter) as a backup if Perseverance is unable to directly transport its sample tubes to the SRL.[87]

- *ERO*, provided by ESA, will carry a Capture, Containment, and Return System (CCRS), provided by NASA. The CCRS will capture and contain the orbiting sample, and place it inside the earth entry vehicle, creating the EES. The ERO would arrive at earth in 2033, with a backup opportunity in 2035.[88]

83. MSR PEIS, *supra* note 41, at S-1.
84. *Id*. at 1-2.
85. *Id*. at 1-10.
86. *Id*. at 2-5.
87. *Id*. at S-3, 2-2.
88. *Id*. 2-2, S-3 to S-4, 7.

- *EES* will land within the landing ellipse at the Air Force-managed Utah Test and Training Range (UTTR), about 129 kilometers (80 miles) southwest of Salt Lake City.[89] A recovery team will contain the tire-size EES, first within a small biohazard containment "travel case," and then transport it, via either helicopter or ground, first to a "vault," and then offsite to the SRF.[90]

- *SRF* is a BSL-4-equivalent facility to isolate and secure the unsterilized samples, conduct a sample safety assessment, and finally curate them.[91]

## B. Cooperating Agencies

- *Biosafety:* U.S. Department of Health and Human Services, Centers for Disease Control and Prevention (CDC)[92]

- *Biological select agents and toxins (BSAT) transportation and handling:* U.S. Department of Agriculture, Animal and Plant Health Inspection Service[93]

- *Landing site, EES transport:* U.S. Air Force[94]

- *Biosecurity, EES transport:* U.S. Army[95]

## C. Environmental Review

The MSR mission is categorized as Planetary Protection Category V—Restricted Earth Return, the first sample return mission so classified.[96] NASA prepared a PEIS[97] that covers four of the five mission elements; launch of the lander is considered a routine payload mission, with impacts already reviewed in the *NASA Routine Payload Environmental Assessment* (2011).[98] A future tiered NEPA analysis will address site-specific environmental impacts associated with transporting the samples from the UTTR/Dugway Proving Ground complex to the SRF, the SRF's development and operation, and the risk of the SRF containment systems failing.[99] NASA concluded that the agency did not expect significant adverse impacts associated with transferring the EES to the SRF.[100] Public review included four public meetings and a 45-day public comment period, ending December 19, 2022.

## D. Measures to Prevent Backward Contamination

The PEIS states that the consensus opinion within the astrobiology scientific community is that the Martian surface is currently inhospitable to life, particularly at the location and shallow depth being sampled. The planet's surface is highly oxidizing, bombarded by significant levels of ultraviolet radiation, the average surface temperature (-55°C, -67°F) is too cold, and Mars lacks a magnetic field to shield against galactic cosmic and solar particle radiation.[101] NASA is nevertheless taking a precautionary approach, as follows:

- *Develop detailed protocols and studies*. COSPAR appointed a working group to develop a sample safety assessment protocol in the context of the MSR.[102] NASA convened a Sterilization Working Group to identify, assess, and verify methods for sterilization and inactivation.[103] NASA and ESA both agreed to adhere to COSPAR's Planetary Protection Policy and Implementation

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89. *Id*. at 2-17. NASA utilized the UTTR for the prior 1998 Stardust (comet dust) and 2001 Genesis (solar wind) sample retrieval missions, and the UTTR is the planned landing site for the OSIRIS-Rex mission (dust and rocks from the asteroid Bennu) in 2023. *Id*. at 2-18.
90. *Id*. at 2-13.
91. *Id*. at S-5, 2-16.
92. *Id*. at 1-9; 42 C.F.R. pt. 73, Select Agents and Toxins.
93. Regulates BSAT and non-BSAT-infected material that may pose a severe threat to animal and plant health/products. *See* MSR PEIS, *supra* note 41, at 1-9; 7 C.F.R. pt. 331, Possession, Use, and Transfer of Select Agents and Toxins; 9 C.F.R. pt. 121, Possession, Use, and Transfer of Select Agents and Toxins.
94. MSR PEIS, *supra* note 41, at 1-7 to 1-8.
95. *Id*.
96. *Id*. at 3-15. The Apollo 11, 12, and 14 missions were initially quarantined until assessment of the lunar samples found they posed no hazard. Prior mission sample return missions at the UTTR were classified as Unrestricted Earth Return.
97. 14 C.F.R. §1216.307, Programmatic EAs, and EISs, and tiering.
98. MSR PEIS, *supra* note 41, at 1-3.
99. *Id*. at 1-2, 2-30.
100. *Id*. at 2-30.
101. *Id*. at 2-2 to 3-3. NASA is nevertheless taking a precautionary approach.
102. *Id*. at 2-17.
103. *Id*. at 3-4.

Guidelines and to develop a joint biological planetary protection management plan defining the primary roles and responsibilities for planetary protection activities related to the flight element.[104] NASA is also developing a planetary protection approach and implementation document.[105] ESA will follow the most current versions of its own planetary protection policies.[106] Ongoing NASA studies are evaluating burnup/breakup, atmospheric release, contingency planning, and the risk of Mars material being released outside of the landing site radius.[107]

- *Protect, seal, and shield the orbiting sample container*. The container's enclosure will open only to allow insertion of the sample tubes. The CCRS will seal the orbiting sample container inside a primary containment vessel, heat-sterilizing any remaining Mars dust. A tight seal will form between the inner and outer part, and the container joint sterilized.[108] A Micrometeoroid Protection System will defend the EES from impacts that could damage the Thermal Protection System.[109]

- *EES designed to simultaneously avoid and prepare for off-nominal landing*. The EES has a passive aerodynamic design for entering earth's atmosphere and includes two levels of containment to protect the sample container and tubes on landing.[110]

- *Jettison the CCRS and maneuver the orbiter into an earth-avoiding trajectory*. Both the CCRS and orbiter will be treated as contamination vectors, with the former jettisoned into a stable orbit around Mars, and the latter, after releasing the EES, navigating to a trajectory that would avoid earth for more than 100 years.[111]

- *Rigorous criteria for landing site selection*. These include that the landing site be remote, in a controlled zone with restricted access and controlled airspace, on land, and free of hazardous terrain features. Other factors are slopes less than five degrees, soft landing surfaces, and capacity to track the EES during descent.[112]

- *Treat the landing site as though impacted by a hazardous material release*. The recovery team would wear personal protective equipment, cordon off the landing site, and potentially decontaminate it, with decontamination activities likely aligning with response planning for the U.S. Environmental Protection Agency's chemical, biological, radiological, nuclear, and explosives (CBRNE) strategy and the Air Force's Readiness and Emergency Management Office.[113]

- *Treat EES and Mars samples as potentially hazardous*. NASA would handle the samples consistent with DOD BSAT protocols.[114] Transportation guidelines could follow the U.S. Department of Transportation's Hazardous Materials Regulations (49 C.F.R. Parts 171-180) and/or the Federal Select Agent Program.[115] The "vault" would be a secure, biocontained enclosure rated BSL-4.[116] The SRF would be a BSL-4-equivalent facility; BSL-4 represents the highest level of containment, handling, and transportation standards, applied to highly infectious or unknown materials.[117] Presently, there are only four BSL-4 laboratory sites in the United States. This does not include NASA's existing curation facility at the Johnson Space Center,[118] so NASA would need to modify that facility, construct a new one, or expand an existing facility.[119] NASA would not release the Mars samples until determined safe through analysis or sterilized.[120]

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104. *Id.* at 4-8 to 4-9. *See* Brian Muirhead, NASA Jet Propulsion Laboratory, MSR Joint Planetary Protection Management Plan (JPPMP) 6 (2020) [hereinafter JPPMP].
105. MSR PEIS, *supra* note 41, at 3-9 n.25.
106. JPPMP, *supra* note 104, at 7 (including the *ERO Planetary Protection Requirements* document (ESA-E3P-ERO-RS-001)).
107. MSR PEIS, *supra* note 41, at 2-11.
108. *Id.* at 3-11.
109. *Id.* at 3-12.
110. *Id.* at 2-9.
111. *Id.* at 2-6.
112. *Id.* at 2-27 to 2-28.
113. *Id.* at S-10, S-12, 2-12.
114. *Id.* at 1-7.
115. *Id.* at 2-15.
116. *Id.* at 2-13.
117. *Id.* at 1-7, 2-11 (CDC 2020) (referring to 49 C.F.R. Parts 171-180, 42 C.F.R. §73.11, 7 C.F.R. §331.11, and 9 C.F.R. §121.11).
118. NASA's Johnson Space Center in Houston, Texas, will host the Mars Sample Receiving Project Office, responsible for planning and coordinating the process from sample recovery through scientific investigation. Keith Cowing, *New Mars Sample Receiving Project Office Opening at NASA Johnson*, Astrobiology, https://astrobiology.com/2023/01/new-mars-sample-receiving-project-office-opening-at-nasa-johnson.html (Jan. 23, 2023).
119. MSR PEIS, *supra* note 41, at 2-16.
120. *Id.*

**Figure 2. MSR Concept Illustration**

Source: NASA Science Mars Exploration Program, *Mars Sample Return Concept Illustration*, https://mars.nasa.gov/resources/26895/mars-sample-return-concept-illustration/ (last updated July 27, 2022).