A R T I C L E S

THE DEVELOPMENT OF NATURAL RESOURCES IN OUTER SPACE

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SUMMARY

We are in the first phase of a second space age, building on exploration that led to the 1967 Outer Space Treaty. The year 2020 witnessed 110 orbital launches. Renewed activity in outer space, and new sources of investment and technology, will magnify and accelerate the potential environmental effects of space activities. Those venturing into or investing in space will need to keep abreast of the current applicable legal framework, and also look for ways to improve the law to address concerns related to pollution, contamination, and debris. This Article summarizes the environmental law of outer space; it is adapted from Chapter 28 of *Law of Environmental Protection* (2021), published by ELI Press and available in pdf format for *ELR* subscribers at https://www.elr.info/tools/law-environmental-protection.

On New Year's Eve of 2018, a robot arrived at an asteroid. The Origins, Spectral Interpretation, Resource Identification and Security-Regolith Explorer (OSIRIS-REx) made the two-million-kilometer journey to the asteroid known as 101955 Bennu.[1] After surveying the asteroid, OSIRIS-REx landed in a crater 460 feet in diameter and scooped up about 60 grams of material.[2] As of this writing, that material is on its way back to earth for further analysis, and should arrive in 2023.[3] Bennu contains substantial carbon, and there is some evidence of water coursing over the parent asteroid that broke up to form Bennu.[4] While the mission to Bennu was designed to help determine the origin of the universe, it turns out that the asteroid also contains an estimated $670 million in gold.[5]

The trip to Bennu is not the first time humankind has reached out into the solar system and brought materials back to earth. The Apollo astronauts brought back 842 pounds of samples from the moon, with additional samples collected by several unmanned Russian missions. The Japan Aerospace Exploration Agency's Hayabusa expeditions collected material from the asteroids Itokawa and Ryugu in 2019.[6] We are in the "golden age of space-sample returns."[7]

Humanity, then, has already started to mine the moon and asteroids, albeit on a small, non-commercial scale. But the development of natural resources in outer space won't stop there. National governments and private enterprises are looking at ways to find and use these resources, as described below. While it may be hard to justify bringing these resources back to earth, at least in the near term, natural resources can be developed and deployed in outer space.[8]

The moon is the likely first stop for serious mining activities. Ice exists on the moon, and the water extracted from this ice can be used to generate not just water for drinking,

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1. Keith T. Smith & Kip V. Hodges, *Sampling the Early Solar System*, 370 Science 672 (2020).
2. Chris Thompson, *An Earth Robot Is Taking Soil Samples on an Asteroid Tonight and by God You Will Know About It*, Defector, Oct. 20, 2020, https://defector.com/an-earth-robot-is-taking-soil-samples-on-an-asteroid-tonight-and-by-god-you-will-know-about-it/.
3. Smith & Hodges, *supra* note 1.
4. Hannah Kaplan et al., *Bright Carbonate Veins on Asteroid (101955) Bennu: Implications for Aqueous Alteration History*, 370 Science 676 (2020).
5. Asterank, *101955 Bennu (1999 RQ36)*, http://www.asterank.com/ (last visited Dec. 15, 2020).
6. Smith & Hodges, *supra* note 1; *see also* Tomokatsu Morota et al., *Sample Collection From Asteroid (162173) Ryugu by Hayabusa2: Implications for Surface Evolution*, 368 Science 654-59 (2020).
7. Miriam Kramer, *The Golden Age of Space-Sample Returns*, Axios Space, Dec. 8, 2020, https://www.axios.com/space-samples-solar-system-evolution-9a5832c5-9e0c-48ed-b22a-755c3d2ed1a2.html.
8. Toni Feder, *Prospect of Off-Planet Outposts Spurs Interest in Space Resources*, 72 Physics Today 24 (2019).

but oxygen to breath and hydrogen for rocket fuel. And the extraction and processing of ice on the moon could be an economically viable enterprise.[9] Moon miners could use robots and 3-D printers to convert other materials mined from the moon into homes and vehicles, and form a base for further space exploration. Significantly, the moon is loaded with helium-3, which can be used as fuel for fusion reactions. Not only could helium-3 be used for power on the moon, helium-3 might be capable of economic exportation back to earth as an energy source.[10]

Our imaginations run toward the human settlement of Mars, which will also require the development of Martian resources. We might travel to Mars directly, or via the moon or earth orbit.[11] One privately held company, SpaceX, has announced plans to develop a shuttle system between the earth and Mars, with a target of undertaking initial steps by the mid-2020s.[12]

As with the moon, there is ice on Mars, and perhaps even liquid water.[13] Mars also has useful minerals at or below its surface, capable of use in support of a human settlement.[14] The Mars Society sponsored a contest to design a Martian colony capable of supporting 1,000 people, resulting in a series of analyses showing how a colony may be able to use ice and water and materials from Mars to be largely self-sustaining.[15] In any design for Martian habitation, mining ice and minerals will be crucial for a sustainable presence.

Asteroids 101

Asteroids comprise three general classes: C-, S-, and M-types.[a] *C-type* asteroids are likely made up of clay and silicate rocks. *S-types* consist of silicate rocks and nickel-iron. *M-types* are composed of nickel-iron.

Some asteroids contain platinum and other precious metals.[b] The value of a single platinum-bearing asteroid could be between $25 and $50 billion.[c] The website asterank.com provides valuation for over 600,000 asteroids.

a. NASA, *Asteroids: In Depth*, https://solarsystem.nasa.gov/small-bodies/asteroids/in-depth/ (last visited Dec. 15, 2020).
b. Ian Sample, *Asteroid Mining: US Company Looks to Space for Precious Metal*, Guardian, Jan. 23, 2013, https://www.theguardian.com/science/2013/jan/22/space-mining-gold-asteroids.
c. Jim Edwards, *Goldman Sachs: Space-Mining for Platinum Is "More Realistic Than Perceived,"* Business Insider, Apr. 6, 2017, https://www.businessinsider.com/goldman-sachs-space-mining-asteroid-platinum-2017-4.

Finally, asteroids have potential for mineral development. Over one million asteroids orbit the solar system in the main asteroid belt between Mars and Jupiter.[16] While these asteroids are too far for commercial mining in the near term, opportunities exist to mine near-earth asteroids (NEAs), which are within about 120 million miles of the earth.[17] Scientists have documented about 18,000 NEAs, and that number is growing.[18]

Rather than bringing an asteroid back to earth, or near the earth, asteroids are more likely to be mined and developed in outer space. Robots can mine the asteroid, manufacture products in space, and even use ice from an asteroid for fuel.[19] Asteroids could also support the human exploration of outer space: as one journalist put it, "[o]nce mined, asteroids could be turned into the equivalent of gas stations and lumberyards for outbound spacecraft."[20]

Lumberyards and gas stations are industrial facilities, and mining is an industrial activity. That is as true in outer space as it is on earth. As a result, mining and manufacturing on the moon, on Mars, or of an asteroid will have environmental impacts. As discussed in this Article, there is existing law concerning resource extraction in outer space, and the regulation of the effects of those activities. While that law remains fairly general, it does provide guidance to space miners. As the development of resources in outer space continues to expand, these existing laws will provide the foundation for more detailed laws and regulations into the future.

I. Overview of Environmental Issues That May Attend Space Mining

A. Overview

In most jurisdictions on earth, and certainly in the United States, mining requires extensive consideration and mitigation of the environmental impacts that attend such operations. Environmental impacts of terrestrial mining include air and water pollution and soil contamination. The primary environmental issues of concern arising from space mining are a bit different. They include: (1) debris; (2) pollution of earth's atmosphere; (3) contamination; and (4) nuclear contamination. This section provides a high-level introduction to each of these topics. Importantly, the issues discussed in this Article do not relate only to mining space resources. Rather, they are relevant to many different kinds of space activities, including scientific research missions, activities related to commercial satellite communications, and military activities.

9. George F. Sowers & Christopher B. Dreyer, *Ice Mining in Lunar Permanently Shadowed Regions*, 7 New Space 235-44 (2019).
10. Harrison Schmitt, Return to the Moon: Exploration, Enterprise, and Energy in the Human Settlement of Space, ch. 8 (2006) (calculating the economic return on investment in the development of helium-3 resources on the moon).
11. Robert Zubrin, Mars Direct: Space Exploration, The Red Planet, and the Human Future (2013) (arguing for the efficiency of direct flight to Mars from the earth).
12. Nadia Drake, *Elon Musk: A Million Humans Could Live on Mars by the 2060s*, Nat'l Geographic, Sept. 27, 2016, https://www.nationalgeographic.com/science/article/elon-musk-spacex-exploring-mars-planets-space-science.
13. Roberto Orosei et al., *Radar Evidence of Subglacial Liquid Water on Mars*, 361 Science 490 (2018).
14. Igor Levchenko et al., *Mars Colonization: Beyond Getting There*, 3 Global Challenges 1800062 (2018).
15. Mars Colonies: Plans for Settling the Red Planet (Frank Crossman ed., 2019).
16. NASA, *Asteroids: In Depth*, https://solarsystem.nasa.gov/small-bodies/asteroids/in-depth/ (last visited Dec. 15, 2020).
17. Center for Near Earth Object Studies, *NEO Basics*, https://cneos.jpl.nasa.gov/about/neo_groups.html (last visited Dec. 15, 2020).
18. *Id*.
19. George Pendle, *'Roid Rage*, Esquire, Apr. 1, 2017, https://classic.esquire.com/article/2017/4/1/roid-rage.
20. *Id*.

B. Debris

The United Nations Committee on the Peaceful Uses of Outer Space (U.N. COPUOS) was established in 1959. It is charged with promoting "international cooperation in peaceful uses of outer space, studying space-related activities that could be undertaken by the United Nations, encouraging space research programmes, and studying legal problems arising from the exploration of outer space."[21] U.N. COPUOS includes the management and mitigation of the effects of space debris within its scope of oversight.

Consistent with this responsibility, the Scientific and Technical Subcommittee of the U.N. COPUOS developed, over the course of more than a decade, Space Debris Mitigation Guidelines, which the U.N. General Assembly endorsed in 2007.[22] The COPUOS Guidelines define space debris as "all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional."[23] In other words, space debris are objects that have been sent into space and that no longer serve a purpose.

Space debris is concerning to both governments and nongovernmental entities. At present, there are more nonfunctional than functional satellites orbiting earth—specifically, 3,000 nonfunctional and 2,000 active satellites.[24] Additionally, there are about 34,000 pieces of space debris bigger than 10 centimeters and 128 million pieces of space debris larger than one millimeter.[25]

Space debris poses significant risks for space activities of all kinds, including space mining ventures. While relatively rare at present, the consequences of collisions with space debris can be dire, even incapacitating active spacecraft.[26] Particles as small as one centimeter in size can cause significant property damage, and collisions with astronauts undertaking extra-vehicular missions can be fatal.[27] Collisions can also release harmful substances such as radioactive material (discussed below in Section I.E).[28] Space debris also pose a threat to earth if any debris reenter the atmosphere and crash to earth's surface.[29]

There is further risk that the amount of debris will be self-propagating, as bits of debris collide with each other and form more, smaller bits of debris. This phenomenon, called the Kessler Syndrome, could render certain areas of space unusable for earth orbit.[30] Most of the space debris orbiting earth will do so for decades, if not centuries, unless steps are taken to remove debris from orbit.[31]

Space debris mitigation is a hot topic among leading space facing nations. During the June 2021 G7 Leaders' Summit, delegates from the Member Nations "pledged to take action to tackle the growing hazard of space debris."[32]

The effects of space debris can be mitigated by: (1) curtailing or preventing the creation of new debris; (2) designing satellites to withstand impacts by small debris; and (3) conducting operations in areas of orbit with less debris.[33] There are also technologies that could collect and eliminate existing space debris, but the legal framework for active debris removal is unsettled.[34]

C. Pollution

Another environmental consideration that may arise in the context of space mining—and, indeed, in all space activities—is pollution. Of greatest concern is the depletion of the ozone layer caused by spacecraft launches. Launches deposit emissions directly into the stratosphere layer of earth's atmosphere, which is the atmospheric layer that lies between the troposphere (the layer closest to earth's surface) and the mesosphere.[35] The stratosphere contains the ozone layer, making it subject to regulation under the Montreal Protocol on Substances That Deplete the Ozone Layer.[36] Depletion of the ozone allows harmful ultraviolet radiation from the sun to reach earth's surface.[37]

Researchers Martin Ross and James Vedda explain that rocket emissions of concern are: (1) chlorine and alumina particles from solid rocket motors; and (2) soot particles, which are commonly referred to as "black carbon."[38]

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21. United Nations Office for Outer Space Affairs, *Committee on the Peaceful Uses of Outer Space*, https://www.unoosa.org/oosa/en/ourwork/copuos/index.html (last visited Dec. 15, 2020).
22. United Nations Office for Outer Space Affairs, Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space (2010) [hereinafter COPUOS Guidelines].
23. *Id*. at 1.
24. *See* Jonathan O'Callaghan, *What Is Space Junk and Why Is It a Problem?*, Natural History Museum, https://www.nhm.ac.uk/discover/what-is-space-junk-and-why-is-it-a-problem.html (last visited Dec. 15, 2020).
25. *See id*. In 1978, NASA scientist Donald Kessler hypothesized that the density of space debris in low earth orbit could one day become great enough to lead to a chain reaction in which space debris continually collide with each other, rendering earth's orbit unusable. *See id*., *accord* Paul B. Larsen, *Solving the Space Debris Crisis*, 83 J. Air L. & Com. 475, 475 n.1 (2018).
26. *See* O'Callaghan, *supra* note 24 (stating that the risk of collision requiring avoidance maneuvers is 1/10,000).
27. Lotta Viikari, *Environmental Aspects of Space Activities*, *in* Handbook of Space Law 717, 722 (Frans von der Dunk & Fabio Tronchetti eds., 2015).
28. *See id*. at 723.
29. *See id*.
30. Louis de Gouyon Matignon, *The Kessler Syndrome*, Space Legal Issues, Mar. 27, 2020, https://www.spacelegalissues.com/space-law-the-kessler-syndrome/:

    > The Kessler syndrome, also called the Kessler effect, collisional cascading or ablation cascade, is a scenario in which the density of objects in Low Earth Orbit (LEO) is high enough that collisions between objects could cause a cascade where each collision generates space debris that increases the likelihood of further collisions.

31. Molly K. Macauley, *The Economics of Space Debris: Estimating the Costs and Benefits of Debris Mitigation*, 115 Acta Astronautica 160 (2015).
32. Press Release, UK Space Agency, *G7 Nations Commit to the Safe and Sustainable Use of Space* (June 13, 2021).
33. Astromaterials Research & Exploration Science Orbital Debris Program Office, NASA, *Debris Mitigation*, https://orbitaldebris.jsc.nasa.gov/mitigation/ (last visited Dec. 17, 2020).
34. *See* Committee on the Peaceful Uses of Outer Space, Report of the International Interdisciplinary Congress on Space Debris Remediation and On-Orbit Satellite Servicing, U.N. Doc. A/AC.105/C.1/2012/CRP.16 (2012).
35. Martin Ross & James A. Vedda, Center for Space Policy and Strategy, The Policy and Science of Rocket Emissions 3-4 (2018).
36. *Id*. at 3; Montreal Protocol on Substances That Deplete the Ozone Layer, 1522 U.N.T.S. 3 (1987) [hereinafter Montreal Protocol].
37. *See* Lynn Shapiro, *The Need for International Agreements Concerning the Ozone Depleting Effects of Chemical Rocket Propulsion*, 4 S. Cal. Interdisc. L.J. 739, 741 (1995).
38. Ross & Vedda, *supra* note 35, at 5.

Black carbon particles accumulate in the stratosphere and form a "black umbrella" that intercepts sunlight, which results in the warming of the surrounding stratosphere and cooling of the earth's surface.[39] Alumina particles do the inverse—they form a "white umbrella" that reflects sunlight back into space.[40] This compounds the cooling of the earth's surface.[41]

Cooling may at first appear to have the beneficial impact of offsetting the rise in global temperatures due to climate change. But, as Ross and Vedda explain, the black umbrella and white umbrella phenomena deplete the ozone layer of the atmosphere in two ways: "First, a slightly warmer stratosphere accelerates existing chemical reactions that reduce ozone levels. Second, chemical reactions on the collective surface area of the alumina particles also reduce ozone."[42] They note that the effect of rocket emissions on the ozone layer is "left . . . in a policy void"[43]—likening the current moment of rocket launch regulation to the early days of space debris regulation, when the problems likely to be caused by debris were underestimated[44]—and urge that more research is needed to fully understand the impacts of rocket emissions on earth's atmosphere.[45]

D. Contamination

Concerns about contamination, also known as *planetary protection*, fall into two categories: forward contamination and backward contamination.

The National Aeronautics and Space Administration's (NASA's) Planetary Protection Independent Review Board (PPIRB) explains these categories as follows:

> In its essence, Planetary Protection . . . refers to (i) managing contact between terrestrial life forms and organic material from celestial bodies as it relates to adversely affecting the scientific study of these bodies, called forward contamination; and (ii) mitigating harmful contact between pathogens or biology from other celestial bodies and terrestrial biology, called backward contamination.[46]

As noted, preventing forward contamination is principally concerned with safeguarding the integrity of outer space environments for science research purposes.[47] The non-interference principle is well established in international law, and in science fiction related to the exploration of outer space.[48] One scholar illustrates the concern as follows:

> [I]n mid-November 2014, scientists at the [European Space Agency] announced that Philae had discovered organic molecules on the surface of Comet 67P. [European Space Agency] researchers . . . concluded that some of the molecules are of types never previously observed on a comet. Had a mining craft without proper sterilization protocols touched down on the comet, thereby contaminating the comet's environment with organic material from Earth, the possibility of deriving scientific knowledge from the asteroid would have been forever lost.[49]

By contrast, preventing backward contamination is principally concerned with protecting earth from foreign contaminants as a matter of global safety.[50]

As with all of the environmental impacts discussed in this section, contamination is not unique to space mining. The example of forward contamination described above could be caused by any space activity that involves contact with celestial bodies. That said, the probability of such contamination necessarily increases with greater human presence in space, and the level of contact with celestial bodies necessary for space mining poses perhaps a greater risk of contamination than other space activities.

E. Nuclear Contamination

For all space activities, nuclear contamination is a significant safety and environmental hazard. The risk arises from the possibility that a spacecraft carrying a nuclear power source (NPS) may collide with another space object or with a piece of debris in space, or crash to earth due to mechanical or operational malfunctions. NPSs are used in outer space missions where other power sources are not viable or not practicable. For example, NPSs have been used in place of solar panels for lengthy missions to the far reaches of the solar system, because solar panels are unsuitable for such missions.[51]

The risk to earth posed by the use of NPSs in space was highlighted by the Cosmos-954 satellite crash. The Soviet Union launched Cosmos-954 in 1977.[52] After the satellite's reactor core failed to boost it into safe orbit, the satellite fell

39. *See id*. at 4.
40. *See id*.
41. *See id*.
42. *See id*.
43. *Id*. at 5.
44. *See id*. at 2.
45. *See id*. at 9.
46. PPIRB, Report to NASA/SMD, Final Report 4 (2019) [hereinafter PPIRB Report].
47. It is also worth pointing out, however, that some in the scientific community advocate for broadening the scope of forward contamination to include ethical, not only scientific, considerations. *See, e.g.*, Aaron Gronstal, *Putting the Ethics Into Planetary Protection*, Astrobiology at NASA, Aug. 13, 2018, https://astrobiology.nasa.gov/news/putting-the-ethics-into-planetary-protection/; John D. Rummel et al., *Ethical Considerations for Planetary Protection in Space Exploration: A Workshop*, 12 Astrobiology 1017 (2012).
48. Richard J. Peltz, *On a Wagon Train to Afghanistan: Limitations on Star Trek's Prime Directive*, 25 U. Ark. L. Rev. 635 (2003).
49. Samuel Roth, *Developing a Law of Asteroids: Constants, Variables, and Alternatives*, 54 Colum. J. Transnat'l L. 827, 865-66 (internal citations omitted).
50. Ker Than, *Stanford's Scott Hubbard Contributed to New "Planetary Quarantine" Report Reviewing Risks of Alien Contamination*, Stanford News, May 7, 2020, https://news.stanford.edu/2020/05/07/new-planetary-quarantine-report-reviews-risks-alien-contamination-earth/.
51. U.N. COPUOS Scientific and Technical Subcommittee & International Atomic Energy Agency, Safety Framework for Nuclear Power Source Applications in Outer Space 1 (Doc. A/AC.105/934) (2009).
52. *See* Mike Wall, *The Biggest Spacecraft Ever to Fall Uncontrolled From Space*, SPACE.com, Oct. 13, 2019, https://www.space.com/13049-6-biggest-spacecraft-falls-space.html.

Cosmos-954

The Soviet Union placed the Cosmos-954 satellite in orbit in 1977.[a] Cosmos-954 carried a nuclear reactor. The satellite fell from orbit, and left radioactive debris in western Canada, including portions of the Northwest Territories, Alberta, and Saskatchewan.[b]

The satellite was a spy satellite.[c] That may explain why the Soviet Union did not inform Canada that the satellite might fall in Canada, and refused to provide information about the nature of the nuclear reaction on the satellite.[d]

Canada brought a claim against the Soviet Union under the Convention on International Liability for Damage Caused by Space Objects, discussed below in Section II.A.2, seeking reimbursement of costs incurred in remediating the contamination caused by the crash of Cosmos-954.[e] Even though the total cost of remediation was CDN $13,970,143.66, Canada only sought reimbursement of CDN $6,041,174.70.[f] Canada and the Soviet Union settled their dispute with a payment from the Soviet Union to Canada of CDN $3,000,000.[g]

a. Settlement of Claim Between Canada and the Union of Soviet Socialist Republics for Damage Caused by "Cosmos 954" (Released on April 2, 1981), *available at* https://www.jaxa.jp/library/space_law/chapter_3/3-2-2-1_e.html (last visited Jan. 7, 2021) [hereinafter Cosmos 954 Settlement].
b. *Id.*
c. David Goren, *Nuclear Accidents in Space and on Earth: An Analysis of International Law Governing the Cosmos-954 and Chernobyl Accidents*, 5 Geo. Int'l Env't L. Rev. 855, 856 (1993).
d. Cosmos 954 Settlement, *supra* note a, ¶¶ 4, 5.
e. *Id.*
f. *Id.* ¶ 8.
g. *Id.*

to earth, spreading radioactive debris over a large area of northwestern Canada.[53]

Again, concerns involving NPSs are not unique to space mining. And it does not appear that space mining would disproportionately increase the threat of nuclear contamination relative to other space activities. In any event, however, space miners will need to be aware of the regulatory requirements associated with NPSs before employing them in mining missions.

II. Legal Framework

A. *Regulation of Space Mining Generally*

1. International Law

There are areas where humans are active, but which are not subject to the jurisdiction of any Nation State: the deep sea, Antarctica (and perhaps the Arctic), and outer space. In these circumstances, nations tend to enter into international treaties to govern national and private actions. For example, activities in the deep sea—the area outside the territorial waters of any nation—are subject to the United Nations Convention on the Law of the Sea (UNCLOS).[54] Similarly, there is a 1959 treaty setting aside Antarctica as "a natural reserve, devoted to peace and science."[55] The status of the Arctic is less settled. It remains subject to UNCLOS, and to a number of competing and overlapping jurisdictional claims.[56]

But having a treaty in place does not provide clear and unequivocal resolution of every dispute or issue that might arise in these areas beyond national jurisdiction. First, not every country active in one of these areas may sign or ratify a treaty. The United States, for example, is not a signatory to UNCLOS. The Antarctic Treaty was originally signed by only 12 countries, but now has 52 signatories.[57] Second, treaties tend to state fairly broad principles, and leave room for interpretation.

Thus, even where a treaty exists, there may be a need to call on canons of construction and general principles of international law, especially customary international law. Customary international law is the general practice of States, which is in turn generally accepted as law by States.[58] For example, the United States has accepted most of the key principles of UNCLOS as customary international law, and acts consistent with those principles.[59] The United States does not, however, accept the provisions of UNCLOS related to seabed mining, and would likely argue that those provisions do not form part of customary international law.[60] The body of international law "governing" space activities is not strictly binding.[61] The preservation and regulation of space will rely predominately on nations' willingness and resources to enforce domestic policy as it relates to space and to conform behavior to customary international law.[62]

a. Outer Space Treaty

Outer space, like the deep sea and the South Pole, does not fall under the sovereignty of any earthly nation. Rather, space law "is usually defined as a branch of general (public) international law, a subset of rules, rights and obligations of states within [international law] specifically related to outer space and activities in or with respect to that

53. *See id.*

54. United Nations Convention on the Law of the Sea, Nov. 16, 1994, 1833 U.N.T.S. 3 [hereinafter UNCLOS].
55. The Antarctic Treaty, Dec. 1, 1959, 12 U.S.T. 794, 402 U.N.T.S. 71.
56. Reg Fowler, *The USS Manhattan Revisited: Russian Policy on Arctic Sea Passage, and Implications for Freedom of Navigation*, Special Institute: International Mining and Oil & Gas Law, Development, and Investment (2013); Reg Fowler, *Cracks in the Ice: The Need for Review of the Legal Status of the Arctic Continental Shelf*, Special Institute on International Mining and Oil & Gas Law, Development and Investment (2011).
57. British Antarctic Survey, *The Antarctic Treaty Explained*, https://www.bas.ac.uk/about/antarctica/the-antarctic-treaty/the-antarctic-treaty-explained/ (last visited Dec. 15, 2020).
58. Michelle M. Kundmueller, *The Application of Customary International Law in U.S. Courts: Custom, Convention, or Pseudo-Legislation?*, 28 J. Legis. 359, 361 (2002).
59. Thomas Schoenbaum, *UNCLOS and the United States*, 1 Admiralty & Mar. L. §2:2 (6th ed. 2019).
60. *Id.*
61. Minna Palmroth et al., *Toward Sustainable Use of Space: Economic, Technological, and Legal Perspectives*, 57 Space Policy 1, 5 (2021).
62. *Id.*

realm."[63] And, as with the deep sea and Antarctica, there is an international treaty that provides the fundamental framework for activities in outer space, including mineral resource development.

The Outer Space Treaty, or the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, is the fundamental treaty framing international space law.[64] It entered into force in 1967, just prior to the Apollo 11 moon landing, and fewer than 10 years after the launch of Sputnik.[65] The Outer Space Treaty has been signed and ratified by over 100 nations, including all space-faring nations—like the United States.

The Outer Space Treaty provides that

> [t]he exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries . . . and shall be the province of all mankind. Outer space, including the moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies.[66]

The Treaty also prohibits any nation from appropriating celestial bodies: "Outer 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."[67]

As we think about resource development in outer space, and responsibility for the environmental consequences of space mining, it is important to note that the Outer Space Treaty imposes supervisory obligations on Nation States. As stated in the Treaty:

> State Parties to the Outer Space Treaty shall bear international responsibility for national activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Outer Space Treaty. The activities of non-governmental entities in outer space . . . shall require authorization and continuing supervision by the appropriate State Party to the Treaty.[68]

When Nation States were the only organizations acting in space, this principle was not hard to apply, and was generally uncontroversial. As noted above, however, private parties are now present in outer space, and are leading the way on the utilization of natural resources in outer space. As a result, the supervisory role of States is more meaningful and more nuanced. In the words of two prominent legal scholars, it has become necessary "to find means to transform the international obligations imposed on States to obligations incumbent on private actors in order to ensure that private entities comply with international space law and its principles."[69]

The Outer Space Treaty contains some ambiguities that might be read to limit natural resource development in outer space.[70] On balance, however, the Outer Space Treaty states general principles and provides a framework that would allow nations and private parties to develop and use natural resources in outer space.

The Outer Space Treaty assures a right of free access to celestial bodies for all nations, even though it prohibits appropriation or national ownership of the bodies themselves. This principle of free access is consistent with the Treaty's statement that the exploration and use of space "shall be carried out for the benefit and in the interests of all countries."[71] The prohibition on *national* appropriation does not, on its face, prohibit the exercise of *private* rights over extracted resources, or the ownership of extracted resources by governmental or private parties.

Indeed, granting private property rights to asteroid *resources* does not conflict with the international prohibition on national appropriation of asteroid *bodies*. In fact, the Outer Space Treaty anticipates the development—and hence, ownership—of extracted resources. The Treaty includes the phrase "exploration and use" twice in its terms. The word "use" seems to indicate that the drafters of the Outer Space Treaty expressly considered and authorized the development and deployment of space resources.[72] The diplomatic history of the Treaty indicates that perhaps the tension between the Treaty's prohibition on the national appropriation of celestial bodies and its authorization of the use of space resources was left ambiguous to gain broader support for the Treaty.[73]

63. Frans von der Dunk, *International Space Law*, *in* Handbook of Space Law 29 (Frans von der Dunk ed., 2015).
64. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter Outer Space Treaty].
65. Peter Jankowitsch, *The Background and History of Space Law*, *in* Handbook of Space Law 5 (Frans von der Dunk ed., 2015).
66. Outer Space Treaty, *supra* note 64, art. I (emphasis added).
67. *Id.* art. II (emphasis added). In 2001, a NASA spacecraft landed on the asteroid 433, known as Eros. Gregory Nemitz claimed he owned Eros, and brought an action in federal district court seeking parking and storage fees from the United States. Nemitz v. United States, 2004 WL 3167042 (D. Nev. 2004), *aff'd*, 126 Fed. Appx. 343 (9th Cir. 2005). Nemitz claimed ownership because he had registered the asteroid with the website of the Archimedes Institute, and filed a security interest under the Uniform Commercial Code. The court rejected his ownership claim, including his argument that the ratification of the Outer Space Treaty created a right for Nemitz to own Eros. *Id.* at *2.
68. Outer Space Treaty, *supra* note 64, art. VI.
69. Irmgard Marboe & Karen Traunmüller, *The Legal Framework of the Use of Outer Space Technologies* 73 (Facultas Verlag 2013).
70. For an in-depth discussion of these ambiguities, see Scot W. Anderson et al., *The Development of Natural Resources in Outer Space*, 37 J. Energy & Nat. Resources L. 227.
71. Outer Space Treaty, *supra* note 64, art. I.
72. *See* Joanne Gabrynowicz, Written Testimony of Joanne Irene Gabrynowicz Before the Subcommittee on Space of the Committee on Science, Space, and Technology United States House of Representatives, at 7 (Sept. 10, 2014), *available at* https://docs.house.gov/meetings/SY/SY16/20140910/102649/HHRG-113-SY16-Wstate-GabrynowiczJ-20140910-U2.pdf.
73. *See* Roth, *supra* note 49, at 841-42 (2016) (internal citations omitted).

Notwithstanding these uncertainties, the U.S. State Department has consistently maintained that the Outer Space Treaty allows for commercial extraction and ownership of resources.[74] It has been the State Department's position for several decades that the Treaty's non-appropriation principle applies to space resources only when such resources are "in place." This prohibition does not extend to governmental or private ownership of resources once they are removed from the celestial body.[75]

This position of the United States is consistent with the majority view. The International Institute of Space Law, for example, takes the position that while the Outer Space Treaty does not create an express right to take and consume space resources, it also does not prohibit such action.[76]

b. The Moon Agreement

A decade later saw an attempt to expand and recast the law of space, including principles relevant to the extraction of natural resources in outer space. In 1979, the U.N. promulgated the Moon Agreement, officially the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies. The Moon Agreement affects more than the moon; it also applies to asteroids.[77]

As noted above, the Outer Space Treaty declares that the moon and other celestial bodies in the solar system, as well as their natural resources, are the "province of all mankind."[78] The Moon Agreement goes further, characterizing the bodies and their resources as being the "common heritage of all mankind,"[79] a phrase that some interpret to create a common interest in moon resources. UNCLOS also describes the deep sea as the common heritage of mankind, and this concept gave rise to an international regulatory body for the deep sea: The International Seabed Authority.[80]

If the "common heritage" concept in the Moon Agreement were widely adopted, the development of natural resources in outer space might look more like the framework for mining in the deep sea. The Moon Agreement, however, has been signed by fewer than 20 countries and was not signed by any space-faring nation.[81] Moreover, the Donald Trump Administration in 2020 issued an Executive Order stating explicitly that "the United States does not consider the Moon Agreement to be an effective or necessary instrument to guide nation states regarding the promotion of commercial participation in the long-term exploration, scientific discovery, and use of the Moon, Mars, or other celestial bodies," and instructing the Secretary of State to "object to any attempt by any other state or international organization to treat the Moon Agreement as reflecting or otherwise expressing customary international law."[82] This view reflects the majority view about the lack of efficacy of the Moon Agreement.

2. Other International Space Law

The balance of space law comprises just three treaties: (1) the Convention on International Liability for Damage Caused by Space Objects (Liability Convention)[83]; (2) the Convention on Registration of Objects Launched Into Outer Space (Registration Agreement)[84]; and (3) the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched Into Outer Space (Rescue Agreement).[85]

The Liability Convention—opened for signature in 1972—creates a liability framework for damage caused by spacecraft. Under the Liability Convention, liability attaches to "launching States," defined as the State that launches or procures the launch of a space object, or the State from whose territory or facility a space object is launched.[86] It sets a strict liability standard for accidents on the earth's surface, providing that a launching State is "absolutely liable" for damage caused to the surface of the earth or an aircraft in flight.[87] The launching State may be relieved of this absolute liability if the claiming State (or those claiming under its jurisdiction) acted with gross negligence, or with the intent to cause damage, and if the launching State was acting in compliance with international law.[88]

Where the damage occurs somewhere other than earth's surface, a negligence standard applies: the launching State is liable only if the damage arises from the fault of either the launching State itself or the persons for whom it is responsible.[89] The Liability Convention also addresses joint liability. If one State causes damage to another, and that damage creates collateral damage to a third State, the first two States are jointly and severally liable to the third.[90] If the damage occurs on earth's surface, their liability is

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74. Matthew Schaefer, Statement of Matthew P. Schaefer Before the United States Senate, Committee on Commerce, Science and Transportation, Subcommittee on Space, Science, and Competitiveness, at 4 (May 23, 2017), *available at* https://www.commerce.senate.gov/services/files/BE9DF6DC-3CDA-4B6A-A49A-686D8B412010.
75. Brian J. Egan, Remarks at the Galloway Symposium on Critical Issues in Space Law: The Next Fifty Years of the Outer Space Treaty (Dec. 7, 2016), *available at* https://2009-2017.state.gov/s/l/releases/remarks/264963.htm.
76. International Institute of Space Law, Position Paper on Space Resource Mining (2015), *available at* http://www.iislweb.org/docs/SpaceResourceMining.pdf.
77. Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, Dec. 18, 1979, 1363 U.N.T.S. 3 [hereinafter Moon Agreement]; *see also* Roth, *supra* note 49, at 842.
78. Outer Space Treaty, *supra* note 64, art. I.
79. Moon Agreement, *supra* note 77, art. 11, §1.
80. Dr. Betsy Baker & Catherine Danley, *Resource Rights in the Continental Shelf and Beyond: Why the Law of the Sea Convention Matters to Mineral Law*, 64 Rocky Mountain Min. L. Inst. 2 (2018).
81. *See* Roth, *supra* note 49, at 844.
82. Exec. Order No. 13914, 85 Fed. Reg. 20381, §2 (Apr. 10, 2020).
83. United Nations Convention on International Liability for Damage Caused by Space Objects, Sept. 1, 1972, 961 U.N.T.S. 187 [hereinafter Liability Convention].
84. Convention on Registration of Objects Launched Into Outer Space, Sept. 15, 1976, 1023 U.N.T.S. 15 [hereinafter Registration Agreement].
85. Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched Into Outer Space, Dec. 3, 1968, 672 U.N.T.S. 119 [hereinafter Rescue Agreement].
86. Liability Convention, *supra* note 83, art. I.
87. *Id*. art. II.
88. *Id*. art. VI.
89. *Id*. art. III.
90. *Id*. art. IV.

absolute; if it occurs somewhere else, their liability is based on fault.[91]

The Registration Agreement requires signatories to register vehicles launched into space and provide that information to the Secretary-General of the United Nations.[92] These requirements can enable the identification of the State or States that launched a certain space object. This would be relevant to determining the liable party under the Outer Space Treaty and the Liability Convention in the event of an accident or other damage, and to ensure that obligations under the Rescue Agreement are met.

The Rescue Agreement, in turn, sets out requirements related to and a process for the return of objects and people who land outside their national territory upon reentry to earth.[93]

3. Domestic Law

There has been significant interest by nations to enact national space laws in the face of an increasing number of binding international guidelines and standards.[94] These guidelines and standards could, over time, become customary international law. The United States and Luxembourg have led the way in creating national laws designed to interpret the Outer Space Treaty consistent with the general view that the Treaty allows the extraction and utilization of resources in outer space.[95]

The United States enacted the Commercial Space Launch Competitiveness Act.[96] Title IV of that Act provides a legal framework for mineral development and ownership in outer space.[97]

Title IV, the Space Resource Exploration and Utilization Act, creates private-property rights over resources extracted from space.[98] It directs the president to (1) facilitate the commercial exploration for and commercial recovery of space resources by U.S. citizens; (2) discourage government barriers to the development of such industries, in a manner consistent with U.S. international obligations; and (3) promote the right of U.S. citizens to engage in such industries free from harmful interference.[99] The president must also identify the authorities that will be responsible for overseeing space resource extraction missions.[100]

As noted above, anyone acting in outer space does so under the supervision and responsibility of a government. Under the Act,

> [a] United States citizen engaged in commercial recovery of an asteroid resource or a space resource under this chapter shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States.[101]

The Act defines "asteroid resource" as "a space resource found on or within a single asteroid,"[102] and defines "space resource" as "an abiotic resource in situ in outer space," which includes water and minerals.[103]

To allay any concerns that the statute is inconsistent with the prohibition of appropriation in the Outer Space Treaty, the Act states that "[i]t is the sense of Congress that by the enactment of this Act, the United States does not thereby assert sovereignty or sovereign or exclusive rights or jurisdiction over, or the ownership of, any celestial body."[104] The table on the next page summarizes the roles of various federal agencies over U.S. space activities.

Building on the framework established by the Space Resource Exploration and Utilization Act, the United States developed in 2020 an international agreement designed to provide greater certainty for companies acting in space. The administrative action embodies the interpretation of the Outer Space Treaty favored by the United States, and represents movement toward solidifying that interpretation as customary international law. This agreement, called the Artemis Accords, relates to NASA's Artemis program, which has targeted a return to the moon by 2024 and, from there, further exploration on to Mars.[105]

Significantly, the Artemis Accords do not represent a unilateral action by the United States. NASA has executed the Artemis Accords with the national space agencies of Australia, Brazil, Canada, Italy, Japan, Luxembourg, New Zealand, the Republic of Korea, Ukraine, the United Arab Emirates, and the United Kingdom.[106] Notably, "[t]he principles set out in the [Artemis] Accords are intended to

91. *Id.*
92. *See* Registration Agreement, *supra* note 84, arts. II, IV.
93. Rescue Agreement, *supra* note 85.
94. Palmroth et al., *supra* note 61, at 3.
95. *See* Anderson et al., *supra* note 70.
96. U.S. Commercial Space Launch Competitiveness Act, Pub. L. No. 114-90, 129 Stat. 704 (2015) [hereinafter Space Launch Act]. For a complete analysis of the Act, see Michael Dodge, *The U.S. Commercial Space Launch Competitiveness Act of 2015: Moving U.S. Space Activities Forward*, 29 Air & Space Law. 4 (2016).
97. The other parts of the Act include the following: Title I, the Spurring Private Aerospace Competitiveness and Entrepreneurship Act, updates requirements for the commercial launch industry. Space Launch Act, *supra* note 96, §§102-117 (codified at 51 U.S.C. §§50901-50923); Title II, Commercial Remote Sensing, affirms congressional oversight of the commercial space industry and requires additional executive branch reports regarding the licensing process for private space-based remote sensing systems. *Id.* §§201-202 (codified at 51 U.S.C. §§60121-60126); Title III, Office of Space Commerce, renames the Office of Space Commercialization to the Office of Space Commerce and clarifies its functions. *Id.* §§301-302 (codified at 51 U.S.C. §§50701-50703).
98. *Id.* §§402-403 (codified at 51 U.S.C. §§51301-51303).
99. 51 U.S.C. §51302(a).
100. 51 U.S.C. §51302(b).
101. 51 U.S.C. §51303.
102. 51 U.S.C. §51301(1).
103. 51 U.S.C. §51301(2).
104. 51 U.S.C. §51301(1).
105. *See* NASA, The Artemis Accords: Principles for a Safe, Peaceful, and Prosperous Future, *available at* https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords_v7_print.pdf (2020).
106. The Artemis Accords: Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids for Peaceful Purposes, Oct. 13, 2020, *available at* https://www.nasa.gov/specials/artemis-accords/img/Artemis-Accords-signed-13Oct2020.pdf [hereinafter The Artemis Accords].

Federal Agencies' Roles in U.S. Space Activities[a]

National Aeronautics and Space Administration (NASA) is an independent federal agency with primary oversight for U.S. space flight and space operations, and related scientific research.

The U.S. Department of Commerce, through the National Oceanic and Atmospheric Administration (NOAA), includes the Office of Space Commerce, the National Environmental Satellite, Data, and Information Service, Commercial Remote Sensing Regulatory Affairs, and the National Telecommunications and Information Administration.

Federal Communications Commission (FCC), an independent agency like NASA, regulates telecommunications satellites operated by the federal government and by private industry.

U.S. Department of Defense (DOD) includes oversight of the national security policy for outer space through the assistant secretary of defense (ASD) for Homeland Defense and Global Security. The ASD is responsible for formulating national security strategy for outer space, among other matters. DOD also includes the recently created U.S. Space Force.

U.S. Department of State includes the Office of Space and Advanced Technology, and also addresses security issues related to outer space.

U.S. Department of Transportation Federal Aviation Administration (FAA) includes the Office of Commercial Space Transportation.

Note: Because space activities are under federal jurisdiction, even when conducted by private parties, those activities are subject to review under the National Environmental Policy Act (NEPA),[b] which can require the engagement of other federal agencies. In the recent environmental analysis prepared for a SpaceX launch site in Texas, the FAA was the lead agency on the Environmental Impact Statement (EIS), and the cooperating agencies in the EIS were NASA, the National Park Service, the U.S. Army White Sands Missile Range, and the U.S. Army Corps of Engineers. The FAA also consulted with the U.S. Fish and Wildlife Service.[c]

a. Georgetown Law Library, *Space Law: The Law of Outer Space, Other U.S. Government Agencies Involved in Space Policy & Regulation,* https://guides.ll.georgetown.edu/c.php?g=1037047&p=7762102 (last updated Dec. 8, 2020).
b. 42 U.S.C. §§4321-4370h, ELR Stat. NEPA §§2-209.
c. FAA, Office of Commercial Space Transportation: Final Environmental Impact Statement for the SpaceX Texas Launch Site, Cameron County, Texas (May 2014).

apply to civil space activities conducted by the civil space agencies of each Signatory."[107]

The key points addressed include the following:

- The Artemis Accords create a system in which the Parties agree that space resources can be extracted and used without violating the Outer Space Treaty, thereby further reinforcing the United States' interpretation of the Treaty's non-appropriation principal.[108] Parties will also implement a system to create "safety zones" around each country's operations to avoid interference with one another's space activities.[109]

- Parties to the Artemis Accords commit to the Outer Space Treaty's principle of using space for only peaceful purposes, as well as to the principles of the Rescue Agreement and Registration Agreement.[110]

- Parties commit "to us[ing] reasonable efforts to utilize current interoperability standards for space-based infrastructure, to establish such standards when current standards do not exist or are inadequate, and to follow such standards."[111]

- The Accords recognize the need to manage space debris, and require signatories to "commit to plan for the mitigation of orbital debris, including the safe, timely, and efficient passivation and disposal of spacecraft at the end of their missions, when appropriate, as part of their mission planning process."[112]

- The Parties have agreed that they "intend to preserve" historically significant sites, such as the Apollo 11 lunar landing location, pursuant to standards to be agreed upon among the Parties.[113]

a. Hague International Space Resources Governance Working Group Building Blocks

The Hague International Space Resources Governance Working Group[114] undertook an effort to "assess, on a global scale, the need for a regulatory framework for space resource activities and to prepare the basis for such regulatory framework."[115] The Working Group prepared a draft set of "Building Blocks" for a regulatory framework for the development of resources in space, and circulated the draft for comment on September 17, 2017.[116] The Work-

107. *See id.* §1.
108. *See id.* §10, ¶ 2.
109. *See id.* §11.
110. *See id.* §§3, 6-7.
111. *See id.* §5.
112. *See id.* §12.
113. *See id.* §9.
114. The Working Group platform is a consortium serviced by a secretariat. The founding consortium partner is the International Institute of Air and Space Law, Leiden Law School, Leiden University (the Netherlands). Members are major stakeholders from government, industry, universities, and research centers. The number of members to the Working Group is limited to 25, at which the number currently stands. Tanja Masson-Zwaam et al., *The Hague Space Resources Governance Working Group—A Progress Report*, *in* Proceedings of the International Institute of Space Law 165 (P.J. Blount et al. eds., 2016).
115. *Id.* at 164.
116. Working Group, Draft Building Blocks for the Development of an International Framework on Space Resource Activities (2017), *available at* https://www.universiteitleiden.nl/binaries/content/assets/rechtsgeleerdheid/instituut-voor-publiekrecht/lucht--en-ruimterecht/space-resources/revised-building-blocks-following-the-meeting-of-april-2019.pdf.

ing Group then formally adopted the Building Blocks on November 12, 2019.[117]

The objective of the Building Blocks is to "create an enabling environment for space resource activities that takes into account all interests and benefits all countries and humankind."[118] Toward this end, the Working Group rests the Building Blocks on international law and the Outer Space Treaty, including the notion that the development of space resources should be exclusively for peaceful purposes, and for the benefit and in the interests of all countries and humankind irrespective of their degree of economic and scientific development.[119]

The Building Blocks provide a comprehensive, albeit high-level, outline for a legal and regulatory framework for the development of natural resources in outer space. As such, the Building Blocks could form the basis for a future comprehensive treaty related to the mining of celestial bodies, or provide a thoughtful and well-reasoned resource for governments and private parties considering how best to operate in this industry. There are several provisions of the Building Blocks that illuminate how to work on resource development in outer space, and how to manage the environmental impacts of those activities.

The Building Blocks accept the requirement in the Outer Space Treaty that States supervise activities in outer space. The Working Group builds on that concept by recommending that States and intergovernmental organizations implement this responsibility by creating laws to authorize and regulate these activities, as well as the products generated by these activities, consistent with international legal principles.[120]

More specifically, the Building Blocks recommend developing a process to allow space miners to register their mining rights.[121] The Working Group also recommends an international framework assuring that raw minerals, volatile materials, and the products from these items, can be lawfully acquired with mutual recognition of these property rights.[122]

The Building Blocks provide not only a foundation for resource development, but also a conceptual framework for responsible space mining. The document lays out the following principles:

- *Due regard for interests of all countries and humankind*

  The Working Group proposes that governments should give due regard to the interests of all countries and humankind.[123] The concept of "due regard" has its origins in UNCLOS. Article 87 of UNCLOS recognizes the freedom of the high seas, but the exercise of this freedom is to be exercised "with due regard for the interest of other States."[124] According to the leading commentary on UNCLOS,

  > [t]he standard of "due regard" requires all States, in exercising their high seas freedoms, to be aware of and consider the interests of other States in using the high seas, and to refrain from activities that interfere with the exercise by other States of the freedom of the high seas. . . . "States are bound to refrain from any acts that might adversely affect the use of the high seas by nationals of other States."[125]

  Thus, this Building Block advocates for the free use of outer space, but with some recognition of the interest of other Parties using outer space.

- *Avoidance of harmful impacts resulting from space resource activities*

  This Building Block suggests that Parties should act in a manner to guard against unknown or unquantified risks, including potential damage to the safety of persons, the environment, or property, and to prevent adverse changes in the environment of the earth, harmful contamination of celestial bodies or outer space, and interference with space activities or scientific resources.[126]

- *Monitoring and redressing harmful impacts resulting from space resource activities*

  States and organizations should monitor whether any harmful impacts result from space resource activities authorized by them.[127] This Building Block also recommends developing a process to require redressing such impacts.

- *Liability in case of damage resulting from space resource activities*

  This Building Block references existing treaties concerning damage in space,[128] and suggests that an international framework should encourage operators to provide, individually or collectively, compensation for damage resulting from their space resource activities.

117. Working Group, Final Building Blocks for the Development of an International Framework in Space Resource Activities (2019), https://www.universiteitleiden.nl/binaries/content/assets/rechtsgeleerdheid/instituut-voor-publiekrecht/lucht--en-ruimterecht/space-resources/bb-thissrwg--cover.pdf [hereinafter Building Blocks].
118. *Id.* ¶ 1.1.
119. *Id.* ¶¶ 4.1-4.3.
120. *Id.* ¶ 5.
121. *Id.* ¶ 7.
122. *Id.* ¶ 8.
123. *Id.* ¶ 9.
124. UNCLOS, *supra* note 54, art. 87(2).
125. United Nations Convention on the Law of the Sea 1982: A Commentary 87.9(1) (Satya N. Nandan et al. eds., 1995).
126. Building Blocks, *supra* note 117, ¶ 10.
127. *Id.* ¶ 12.
128. Specifically, it references Articles VI and VII of the Outer Space Treaty and the 1972 Convention on International Liability for Damage Caused by Space Objects.

B. *Regulation of Environmental Issues That May Attend Space Mining*

1. Debris

a. International Law and Policy

i. Outer Space Treaty

The issue of space debris is not addressed directly in the Outer Space Treaty or the other treaties comprising international space law. However, as the Outer Space Treaty provides a broad framework for space activities, its provisions—especially Article IX—can be interpreted to impose some obligation to mitigate space debris.

Article IX requires that activities be conducted with "due regard to the corresponding interests of all other States parties to the Treaty."[129] As discussed above, a "due regard" standard requires that States "be aware of and consider the interests of other States . . . and . . . refrain from activities that interfere" with the interests of other States.[130]

Article IX also requires that "States . . . conduct exploration of [the moon and other 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."[131] Because space debris collisions can release harmful contaminates that may damage the moon and other celestial bodies, Article IX arguably requires mitigation of space debris to prevent that injury. And, as noted above, the accumulation of debris orbiting the earth could escalate and compound to the point that satellites can no longer orbit the earth.[132] But these general principles and duties do not provide clear direction as to when and how Parties are to actively undertake the mitigation or remediation of space debris.[133]

Finally, Article IX imposes a duty on Parties to the Treaty to undertake international consultations if there is "reason to believe that [a proposed] activity . . . would cause potentially harmful interference with activities of other States parties in the peaceful exploration and use of outer space, including the moon and other celestial bodies . . . ."[134] In other words, a Party that reasonably suspects that a planned activity of another Party would cause potentially harmful interference may request consultation.[135] Thus, Article IX could be read to require international consultations if a proposed mission may result in the creation of space debris that compromises the ability of other Parties to the Outer Space Treaty to peacefully explore and use outer space. Of course, the consultation requirement simply promotes a conversation and does not empower one Party to prevent another from pursuing a potentially hazardous activity.[136]

Despite the general nature of the provisions of the Outer Space Treaty, a Party creating a hazard might face a claim for liability. Parties "bear international responsibility for national activities in outer space" and, as discussed above, governments must authorize and continually supervise the nongovernmental entities in outer space subject to their jurisdiction.[137] A Party that launches an object or procures the launching of an object is "liable for damage to another State party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth . . . ."[138] The Registration Convention might provide information that would help identify the responsible owner of a piece of debris in the event of a collision.[139]

ii. U.N. COPUOS Guidelines

As noted above, the Scientific and Technical Sub-Committee of the U.N. COPUOS has developed the COPUOS Guidelines to address the problem of space debris accumulation. These guidelines are "the leading international arrangement to mitigate space debris."[140] They consist of seven guidelines, which "should be considered for the mission planning, design, manufacture and operational (launch, mission and disposal) phases of spacecraft and launch vehicle orbital stages."

U.N. COPUOS Guidelines[a]
1. Limit debris released during normal operations
2. Minimize the potential for breakups during operational phases
3. Limit the probability of accidental collision in orbit
4. Avoid intentional destruction and other harmful activities
5. Minimize potential for post-mission breakups resulting from stored energy
6. Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-earth orbit region after the end of their mission
7. Limit the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous earth orbit region after the end of their mission
a. United Nations Office for Outer Space Affairs, Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space §4 (2010).

129. Outer Space Treaty, *supra* note 64, art. IX.
130. *See* United Nations Convention on the Law of the Sea 1982: A Commentary, *supra* note 125.
131. Outer Space Treaty, *supra* note 64, art. IX.
132. Larsen, *supra* note 25 (discussing the Kessler Effect).
133. *See* Viikari, *supra* note 27, at 729 (internal quotation marks omitted).
134. Outer Space Treaty, *supra* note 64, art. IX.
135. *See id.*
136. *See* Viikari, *supra* note 27, at 730-31.
137. Outer Space Treaty, *supra* note 64, art. VI; *see also* Liability Convention, *supra* note 83, arts. II, III.
138. Outer Space Treaty, *supra* note 64, art. VII.
139. *See* Registration Agreement, *supra* note 84, art. II.1. *But see* Viikari, *supra* note 27, at 737-39 (discussing the limitations of the Registration Convention in the context of space debris).
140. Viikari, *supra* note 27, at 743 (internal quotation marks omitted). The COPUOS Guidelines were based on a set of guidelines developed by the Inter-Agency Space Debris Coordination Committee. *See* COPUOS Guidelines, *supra* note 22, §2.

Though nonbinding, the COPUOS Guidelines direct Member States and international organizations to voluntarily implement the Guidelines through domestic law mechanisms.[141] One scholar remarks that "the fact that all major spacefaring states take part in the work of the [Scientific and Technical Sub-Committee] . . . should facilitate the approval and implementation of the Guidelines on the national level."[142]

There is also an Inter-Agency Space Debris Coordination Committee (IADC) that includes NASA, the European Space Agency, and other national space agencies. The IADC issued a set of space debris mitigation standards that are similar to the U.S. Orbital Debris Mitigation Standard Practices discussed below.[143]

iii. Hague International Space Resources Governance Working Group Building Blocks

The Working Group's Building Blocks, discussed above, envision a binding international framework that addresses the environmental consequences of space mining with far more specificity than is set out under existing international law. Under the Building Blocks, the international framework should provide for the "[a]voidance and mitigation of potentially harmful impacts resulting from space resource activities."[144]

The Building Blocks expressly recognize space debris, and would require managing the risks that accompany the accumulation of space debris (e.g., damage to persons, outer space and earth environments, and property). Under the Building Blocks, the international framework envisioned would require nations and international organizations to implement an oversight process to ensure the avoidance of harmful impacts from space debris.[145] It would require nations and international organizations to monitor and respond to such harmful impacts, including considering whether a specific resource activity—such as mining platinum from an asteroid or ice from the moon—should be adjusted or terminated.[146]

b. Domestic Law and Policy

Recognizing the risk of space debris, in 1995, NASA developed orbital debris mitigation guidelines. The U.S. government adopted these guidelines two years later, titled the Orbital Debris Mitigation Standard Practices, which NASA subsequently updated in 2019.[147] These standards helped form the basis for related international standards.[148]

Hague International Space Resources Governance Working Group Build ing Blocks

The Building Blocks state that responsible nations and international organizations should be required to adopt measures to avoid and mitigate a number of risks, including[a]:

a) Risks to the safety of persons, the environment or property;

b) Damage to persons, the environment or property;

c) Adverse changes in the environment of the Earth, taking into account internationally agreed planetary protection policies;

d) Harmful contamination of celestial bodies, taking into account internationally agreed planetary protection policies;

e) Harmful contamination of outer space;

f) Harmful effects of the creation of space debris;

g) Harmful interference with other on-going space activities, including other space resource activities;

h) Changes to designated and internationally endorsed outer space natural or cultural heritage sites;

i) Adverse changes to designated and internationally endorsed outer space sites of scientific interest.

a. Working Group, Final Building Blocks for the Development of an International Framework in Space Resource Activities ¶ 10 (2019), https://www.universiteitleiden.nl/binaries/content/assets/rechtsgeleerdheid/instituut-voor-publiekrecht/lucht--en-ruimterecht/space-resources/bb-thissrwg--cover.pdf.

The U.S. Congress also passed a statute requiring NASA to engage in international efforts to address space debris, and to coordinate with other U.S. agencies.[149]

There was a fifth objective added in the 2019 revision of the Standard Practices, which adds several new items, discussed below.

To accomplish these objectives, NASA and other federal agencies are to design spacecraft to eliminate or minimize debris.[150] If there is a planned release of debris, where the debris will be larger than five millimeters and in orbit for more than 25 years, then the federal agency approving the mission (including missions conducted by private parties) must evaluate and justify that outcome, and the debris must remain in orbit for under 100 years.[151]

To reduce the risk of explosion, U.S. agencies are to determine whether an explosion might result from spacecraft design, and adopt operational procedures.[152] The risk of an explosion must be less than one in 1,000.[153] The Standard Practices require an analysis of the possibility of collisions, and spacecraft should be designed to reduce the

141. *Id.* §3.
142. Viikari, *supra* note 27, at 743.
143. IADC, IADC Space Debris Mitigation Guidelines (2007), *available at* https://www.unoosa.org/documents/pdf/spacelaw/sd/IADC-2002-01-IADC-Space_Debris-Guidelines-Revision1.pdf.
144. Building Blocks, *supra* note 117, ¶ 10.
145. *Id.* ¶ 11.
146. *Id.* ¶ 12.
147. Astromaterials Research & Exploration Science Orbital Debris Program Office, *supra* note 33.
148. *Id.*
149. National and International Orbital Debris Mitigation, 42 U.S.C. §18441.
150. U.S. Government Orbital Debris Mitigation Standard Practices, November 2019 Update 1-1(2019), *available at* https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf.
151. *Id.*
152. *Id.* at 2-1, 2-2.
153. *Id.* at 2-1.

Orbital Debris Mitigation Standard Practices: Four Key Objectives

The Orbital Debris Mitigation Standard Practices state four key objectives and provide related standard practices to accomplish those objectives.[a] The objectives are:

1. **Control of Debris Released During Normal Operations:** Programs and projects will assess and limit the amount of debris released in a planned manner during normal operations.
2. **Minimizing Debris Generated by Accidental Explosions:** Programs and projects will assess and limit the probability of accidental explosion during and after completion of mission operations.
3. **Selection of Safe Flight Profile and Operational Configuration:** Programs and projects will assess and limit the probability of operating space systems becoming a source of debris by collisions with man-made objects or meteoroids.
4. **Post-Mission Disposal of Space Structures:** Programs and projects will plan for, consistent with mission requirements, cost-effective disposal procedures for launch vehicle components, upper stages, spacecraft, and other payloads at the end of mission life to minimize impact on future space operations.

a. U.S. Government Orbital Debris Mitigation Standard Practices, November 2019 Update (2019), *available at* https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf.

chance of a collision with objects larger than 10 centimeters to less than one in 1,000 to mitigate the risk of a loss of control of the vehicle.[154]

The Standard Practices provide more detailed guidance on how to dispose of a vehicle after its mission. The agency might design the vehicle to re-enter the atmosphere or perhaps enter orbit around the sun.[155] If the object will re-enter the atmosphere, the risk of human casualty must be less than one in 10,000.[156] The vehicle could also place the object in a "storage orbit," away from standard operational orbits.[157] Finally, the space object (i.e., the satellite, vehicle, or other object placed in orbit) might be placed in an eccentric orbit that would result in the eventual reentry of the object into the atmosphere, or the vehicle might be retrieved within five years of the end of its mission.[158] Tether systems—two space objects, such as satellites, connected by a wire—are subject to specialized rule due to their unusual properties.[159]

Additional Standard Practices

Under these additional Standard Practices:

1. Large constellations of satellites (greater than 100 objects) should be disposed of by re-entry or heliocentric orbit, with a chance of success of at least 90%.[a]
2. Small satellites should have a total orbit of less than 100 years, and less than 25 years after end of mission.[b]
3. Satellite servicing and related operations should also be designed to minimize the risk of generating space debris.[c]
4. Operations to remove debris should be designed to minimize the risk of generating additional debris.[d]
5. Tethering systems require unique analysis.[e]

a. U.S. Government Orbital Debris Mitigation Standard Practices, November 2019 Update 5-1(2019), *available at* https://orbitaldebris.jsc.nasa.gov/library/usg_orbital_debris_mitigation_standard_practices_november_2019.pdf.
b. *Id.* at 5-2.
c. *Id.* at 5-3.
d. *Id.* at 5-4.
e. *Id.* at 5-5

The fifth objective, added in 2019, provides "Clarification and Additional Standard Practices for Certain Classes of Space Operations."[160]

In addition to the broad application of the Standard Practices to federal agencies, several agencies with regulatory supervision over activities in outer space have developed specific regulations relating to space debris.

The Federal Communications Commission (FCC) has promulgated regulations applicable to placing communication satellites in orbit since 2004.[161] For example, a Party seeking to place a communications satellite in orbit is required to submit a debris mitigation plan to the FCC as part of its permit application.[162] The FCC also established debris mitigation rules and broadened them in 2020. The 2020 FCC order requires "satellite operators to quantify their collision risk, probability of successfully disposing spacecraft, [and] the casualty risk associated with spacecraft that re-enter Earth's atmosphere."[163]

The FCC order followed a public hearing on a Notice of Proposed Rulemaking first published in 2018.[164] The 2018 notice included more rigorous debris mitigation standards for consideration by the FCC, including a requirement

154. *Id.* at 3-1, 3-2.
155. *Id.* at 4-1(a).
156. *Id.*
157. *Id.* at 4-1(c)-(d).
158. *Id.* at 4-1(e)-(f).
159. The tethering process can be used to launch an object into a high orbit from a lower-orbiting object, as well as other uses: "Tethered systems provide propellantless propulsion that can be used in attitude control, orbit transfers, momentum dumping, station-keeping, and a variety of other applications. A mechanical connection is established through the tether that enables the transfer of energy and momentum from one object to the other." Brandon Copp, Applications of Tethered Space Systems in Spacecraft Propulsion (2012). A conductive tether moving through the ionosphere could generate enough electrical current to provide propulsion for a satellite. Jeremy Hsu, *Kilometer-Long Space Tether Tests Fuel-Free Propulsion*, Sci. Am., Nov. 4, 2019.
160. *Id.* at 5.
161. Mitigation of Orbital Debris, Second Report and Order, 19 FCC Rcd. 11567 (2004).
162. *Id.*
163. Caleb Henry, *FCC Punts Controversial Space Debris Rules for Extra Study*, SPACENEWS, Apr. 23, 2020, https://spacenews.com/fcc-punts-controversial-space-debris-rules-for-extra-study/.
164. Mitigation of Orbital Debris in the New Space Age, Notice of Proposed Rulemaking, 33 FCC Rcd. 11352 (2018).

that a satellite be maneuverable, and a requirement that satellite operators indemnify the U.S. government from collisions with their debris, and post a bond to back up that indemnity.[165] Those proposals in the notice, and others relating to risk quantification, were remanded by the FCC commissioners for further study.[166]

The Federal Aviation Administration (FAA) maintains regulatory jurisdiction over the launch of vehicles and objects into outer space. The FAA recently updated its space debris regulations.[167] The FAA currently requires a debris analysis as part of a space launch plan. The debris analysis will address (1) each reasonably foreseeable cause of vehicle breakup and intact impact; (2) vehicle structural characteristics and materials; and (3) energetic effects during breakup or at impact.[168] The analysis must also include a debris risk analysis.[169] The debris risk calculates the predicted consequences of each reasonably foreseeable failure during the flight in terms of conditional expected casualties.[170]

Finally, National Oceanic and Atmospheric Administration (NOAA) licenses the operation of private remote sensing space systems under the Land Remote Sensing Policy Act of 1992.[171] NOAA's licensing regime previously required a plan for disposal of remote sensing satellites. Given that these satellites will also require a license from the FCC, NOAA recently determined that it would remove its separate requirement and defer to the FCC regime.[172]

2. Pollution

a. International Law and Policy

The Outer Space Treaty does not directly address harm to earth's atmosphere caused by space activities, including rocket emissions. And it does not include language that lends itself to providing even an indirect hook to regulate rocket emissions. Article IX sets out certain requirements designed to mitigate harmful interference with the activities of other State Parties, and could be interpreted to extend to harmful interference with a State's launch activities, which may, theoretically, be caused by ozone depletion or other earth-based environmental harms.[173] But Article IX restricts activities that take place *in outer space*.[174] Because the commonly accepted definition of "outer space" is that it begins at the edge of earth's atmosphere, activities that take place elsewhere (e.g., within earth's atmosphere itself) appear to be outside of Article IX's scope.[175]

However, regulation of substances that damage the ozone layer are regulated at the international level by the Montreal Protocol.[176] The Montreal Protocol identifies substances that deplete the ozone layer, and limits the global permissible levels of production and consumption of those identified substances.[177]

But the Montreal Protocol does not limit the production and consumption of the substances used to propel rockets during launch,[178] leaving rocket launches in the "policy void" described by Ross and Vedda.[179] Scholars in the field point out two factors that inhibit the application of the Montreal Protocol, in its present form, to rocket emissions. First, the metric used to identify compounds for phase-out—ozone-depleting potential—does not capture rocket emissions because that metric is assessed at earth's surface; thus, compounds emitted directly into the stratosphere are not assessed.[180]

Second, the definition of "production" would not apply to production of the substances that harm the ozone layer during rocket launches because those substances are the result of combusting rocket fuel, rather than the components of the fuel itself.[181] Thus, the Montreal Protocol would fail to curtail release of these compounds because

165. Henry, *supra* note 163.
166. Report and Order and Further Notice of Proposed Rulemaking, In re Matter of Mitigation of Orbital Debris in the New Space Age, 35 FCC Rcd. 4156 (5) (2020).
167. Streamlined Launch and Reentry License Requirements, 85 Fed. Reg. 79566 (Dec. 10, 2020).
168. 14 C.F.R. §450.121 (2020).
169. 14 C.F.R. §450.135 (2020).
170. *Id.*
171. Licensing of Private Remote Sensing Space Systems, 84 Fed. Reg. 21282 (proposed May 14, 2019).
172. Department of Commerce, NOAA, Licensing of Private Remote Sensing Space Systems, 85 Fed. Reg. 30790, 30799 (May 20, 2020) ("Commerce has opted to defer to FCC license requirements regarding orbital debris and spacecraft disposal, and therefore there is no longer any license condition requiring specific orbital debris or spacecraft disposal practices in this final rule, and Commerce licenses will not include any such condition.").
173. Outer Space Treaty, *supra* note 64, art. IX; Ross & Vedda, *supra* note 35, at 7.
174. Outer Space Treaty, *supra* note 64, art. IX ("States Parties to the Treaty . . . shall conduct all their activities *in outer space* . . . with due regard to the corresponding interests of all other States Parties to the Treaty.") (emphasis added); art. IX:

> If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals *in outer space*, including the Moon and other celestial bodies, would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space, including the Moon and other celestial bodies, it shall undertake appropriate international consultations before proceedings with any such activity or experiment.

(emphasis added).
175. NOAA National Environmental Satellite Data and Information Service, *Where Is Space?*, https://www.nesdis.noaa.gov/content/where-space (last updated Feb. 22, 2016) (explaining that a commonly accepted definition of the edge of the atmosphere and the beginning of space is at the Kármán Line, which is located 100 kilometers or 62 miles above sea level). Notably, NASA and the U.S. military define space as beginning 12 miles below the Kármán Line. *See id.*
176. Montreal Protocol, *supra* note 36.
177. Shapiro, *supra* note 37, at 757.
178. World Meteorological Organization, Global Ozone Research and Monitoring Project—Report No. 58, Scientific Assessment of Ozone Depletion: 2018, at ES.50 (2019), *available at* https://ozone.unep.org/sites/default/files/2019-05/SAP-2018-Assessment-report.pdf [hereinafter 2018 Scientific Assessment].
179. *See* Ross & Vedda, *supra* note 35, at 5.
180. *Id.* at 6.
181. *See* Shapiro, *supra* note 37, at 759-60; Montreal Protocol, *supra* note 36, art. 1 ("'Production' means the amount of controlled substances produced, minus the amount destroyed by technologies to be approved by the Parties and minus the amount entirely used as feedstock in the manufacture of other chemicals. 'Consumption' means production plus imports minus exports of controlled substances.").

the compounds are not "produced" within the Protocol's definition; they are byproducts generated during launch.[182]

Accordingly, in the mandatory quadrennial Scientific Assessment of Ozone Depletion,[183] "the assessment [of rocket emissions] therefore regresses to subjective descriptions."[184] For example, the 2018 Scientific Assessment of Ozone Depletion notes that "[r]ocket launches presently have a small effect on total stratospheric ozone (much less than 0.1%)."[185] It recognizes, however, that "[s] pace industry developments indicate that rocket emissions may increase more significantly than reported in the previous Assessment."[186]

In the context of ozone depletion caused by increasing numbers of rocket launches, it is worth mentioning the potential benefits that could be realized through space mining. If the moon is used as a space base and refueling station—which would only be achievable by mining its resources—this would presumably result in fewer rocket launches from earth's surface, thereby reducing emissions into the stratosphere. Notwithstanding the potential benefits that space mining could present related to mitigating harms from rocket launch emissions, Ross' and Vedda's cautionary point is well-taken: "[T]he launch community, in the U.S. and globally, should tackle the question of launch emissions while it is still manageable, and be prepared to respond to regulatory attention and inquiry."[187]

b. Domestic Law and Policy

At the domestic level, the environmental impacts of spacecraft launches are assessed under the National Environmental Policy Act (NEPA).[188] The FAA is the agency charged with licensing U.S. commercial space launch activities, which is considered a major federal action under NEPA, and therefore conducts NEPA reviews for proposed launches.[189] The assessments that federal agencies produce under NEPA take one of three forms:(1) a categorical exclusion; (2) an environmental assessment (EA); and (3) an environmental impact statement (EIS).[190] The level of review required for a proposed action will depend on the likelihood of environmental effects, and the significance of those effects.[191] In its NEPA guidelines for launches and launch sites, the FAA states that EISs should consider atmospheric impacts, including impacts to stratospheric ozone.[192]

EA and SpaceX

One such example of an EA is that prepared in connection with SpaceX's launch licenses at the Kennedy Space Center and Cape Canaveral Air Force Station, which includes discussion of ozone impacts.[a]

In the EA, the FAA notes that the Clean Air Act[b]—like the Montreal Protocol—does not regulate rocket engine emissions as ozone depleting substances.[c] The FAA recognizes, however, that rocket emissions "produce gases and particles" that deplete the ozone layer.[d] It concludes that "[t]hese emissions are a small fraction of the total emissions" and "are not expected to result in significant climate-related impacts."[e]

a. FAA, Final Environmental Assessment and Finding of No Significant Impact for SpaceX Falcon Launches at Kennedy Space Center and Cape Canaveral Air Force Station (2020), https://www.faa.gov/space/environmental/nepa_docs/media/SpaceX_Falcon_Program_Final_EA_and_FONSI.pdf.
b. 42 U.S.C. §§7401-7671q, ELR Stat. CAA §§101-618.
c. FAA, *supra* note a, at 71.
d. *Id.*
e. *Id.*

3. Contamination

a. International Law and Policy

Article IX of the Outer Space Treaty requires that States avoid both forward and backward contamination. It provides:

> States Parties to the Treaty shall . . . conduct exploration of [the moon and other 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.[193]

To guide compliance with the general mandates of the Outer Space Treaty, the Committee on Space Research

182. *See* Shapiro, *supra* note 37, at 759-60.
183. *See* Montreal Protocol, *supra* note 36, art. 6.
184. *See* Ross & Vedda, *supra* note 35, at 6.
185. 2018 Scientific Assessment, *supra* note 178, at ES.50.
186. *Id.*
187. *See* Ross & Vedda, *supra* note 35, at 9. An interesting question exists about the interplay between "Space Law"—which is the body of law discussed in this article—and "Air Law," comprising a number of conventions applicable to air space and aircraft that address, among other things, environmental impacts of aircraft. *See* Paul Dempsey & Maria Manoli, *Suborbital Fights and the Delineation of Air Space Vis-à-Vis Outer Space: Functionalism, Spatialism and State Sovereignty* 10 (2018) (prepared for the 57th session of the Committee on the Peaceful Use of Outer Space, Legal Subcommittee). A thorough and insightful discussion of this topic is contained in Paul Dempsey's and Maria Manoli's submission to the U.N. COPUOS. *See generally id.*
188. *See* 42 U.S.C. §§4321 et seq. NEPA requires that federal agencies evaluate the environmental impacts of major federal actions, specifically:

> (i) the environmental impact of the proposed action, (ii) any adverse environmental effects which cannot be avoided should the proposal be implemented, (iii) alternatives to the proposed action, (iv) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and (v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

42 U.S.C. §4332(C).

189. Office of the Associate Administrator for Commercial Space Transportation, FAA, Guidelines for Compliance With the National Environmental Policy Act and Related Environmental Review Statutes for the Licensing of Commercial Launches and Launch Sites 5 (2001) [hereinafter FAA NEPA Guidelines].
190. 40 C.F.R. §1501.3(a) (2020).
191. *See id.*
192. FAA NEPA Guidelines, *supra* note 189, at 62.
193. Outer Space Treaty, *supra* note 64, art. IX.

(COSPAR) has developed a Planetary Protection Policy, based on the following policy statement:

> The conduct of scientific investigations of possible extraterrestrial life forms, precursors, and remnants must not be jeopardized. In addition, the Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from an interplanetary mission. Therefore, for certain space mission/target planet combinations, controls on contamination shall be imposed in accordance with issuances implementing this policy.[194]

The COSPAR Planetary Protection Policy sets out a sliding scale of recommended protective measures based on (1) the degree to which the target body is of interest to understanding chemical evolution or the origin of life; and (2) the likelihood of contamination.[195] It also recommends highly protective standards for earth-return missions, noting that the moon "must [also] be protected from back contamination to retain freedom from planetary protection requirements on Earth-Moon travel."[196]

The international framework envisioned under the Building Blocks would also require the implementation of measures to prevent both forward and backward contamination. Section 10 provides that the international framework should require nations and international organizations to adopt measures to avoid and mitigate "[a]dverse changes in the environment of the Earth, taking into account internationally agreed planetary protection policies [i.e., backward contamination]; [and] (d) Harmful contamination of celestial bodies, taking into account internationally agreed planetary protection policies [i.e., forward contamination]."[197]

b. Domestic Law and Policy

Consistent with the vision of the Building Blocks, NASA has developed policies designed to comply with the Outer Space Treaty's requirements related to planetary protection. NASA Policy Directive 8020.7G establishes that "[i]t is NASA's policy to comply with planetary protection provisions in support of U.S. obligations under the 1967 Outer Space Treaty,"[198] and charges the associate administrator for the Science Mission Directorate, or its designee, with the administration of NASA's planetary protection policy.[199] That policy includes, among other considerations, "[m]onitoring space flight missions as necessary to meet the requirements for planetary protection certification" by NASA.[200]

The policy further enumerates specific responsibilities of the planetary protection officer, which include "[c]ertifying" prior to launch and prior to reentry, if applicable, that:

> a) All measures have been taken to assure meeting NASA policy objectives as established in this directive and all implementing procedures and guidelines.
>
> b) The recommendations of relevant regulatory agencies with respect to planetary protection have been considered, and pertinent statutory requirements have been fulfilled.
>
> c) The international obligations assessed by the Office of the General Counsel and the Office of External Relations have been met, and international implications have been considered.[201]

The specific requirements under Policy Directive 8020.7G are set out in (1) NPR 8020.12D (Planetary Protection Provisions for Robotic Extraterrestrial Missions); and (2) NPD 8900.5B (NASA Health and Medical Policy for Human Space Exploration).

A key complication related to NASA's planetary protection policies, however, is that they do not apply to private space missions that are unaffiliated with NASA. Policy Directive 8020.7G states that it applies to "all space flight missions, robotic and human, which may intentionally or unintentionally carry Earth organisms and organic constituents to the planets or other solar system bodies, and any mission employing spacecraft which are intended to return to Earth and/or its biosphere from extraterrestrial targets of exploration."[202] But NASA is not a regulatory agency, and therefore appears to lack authority to require that private space missions that are wholly unaffiliated with it comply with its planetary protection policies.[203] This gap has led to the authorization of private space missions without planetary protection evaluation prior to launch.[204]

This issue was taken up in a recent report by the NASA Planetary Protection Independent Review Board (PPIRB), which sets out how NASA's existing planetary protection policies can be improved "in light of current plans for Mars sample return, emerging capabilities for private sector robotic missions, eventual human missions to Mars, and the exploration of the icy moons of the outer planets."[205] While the PPIRB did not assess contamination issues specific to resource recovery,[206] it made several recommendations related to updating NASA's planetary

194. COSPAR Panel on Planetary Protection, COSPAR Policy on Planetary Protection 1 (2020).
195. *See id.* at 1-2 (Categories I-IV).
196. *See id.* at 2-3 (Category V).
197. Building Blocks, *supra* note 117, ¶ 10.
198. NASA, Policy Directive 8020.7G: Biological Contamination Control for Outbound and Inbound Planetary Spacecraft §1.a (effective Feb. 19, 1999).
199. *See id.* §5.a.
200. *Id.* §5.a.(3).
201. *Id.* §5.b.
202. *Id.* §2.a.
203. *See* 51 U.S.C. §20112; *see also* PPIRB Report, *supra* note 46, at 10.
204. *See* Paul Voosen, *NASA Must Rework Planetary Protection Plans, Panel Advises*, Science Mag., Oct. 18, 2019, https://www.sciencemag.org/news/2019/10/nasa-must-rework-planetary-protection-plans-panel-advises (explaining that SpaceX launched the Tesla Roadster into space on board the Falcon Heavy in 2018 without planetary protection evaluation).
205. PPIRB Report, *supra* note 46, at 5.
206. *Id.* at 9.

protection policies in light of increased private-sector space activities.[207]

For example, the report recommended that "[planetary protection] policy should also recognize that it is both a NASA and a national objective to encourage private sector space initiatives and commercial robotic and human planetary missions."[208] Accordingly, it recommended that planetary protection governmental oversight should be "implemented in a transparent, timely, and predictable manner, minimizing costs and burdens on private sector activities where possible."[209] And regarding implementation of these requirements, it notes that "[a]lthough NASA is not a regulatory agency, the [a]gency can likely affect control over non-NASA U.S. missions by linking [planetary protection] compliance to eligibility for current or future NASA business or NASA support."[210] The PPIRB also recommends that the federal government work to identify the appropriate agency to implement planetary protection requirements for missions not involving NASA.[211]

In December 2020, the White House National Space Council issued a "National Strategy for Planetary Protection."[212] A group of U.S. government representatives involved with the Planetary Protection Interagency Working Group, which convened earlier in the year to set the national agenda on planetary protection, developed the strategy.[213] Like the PPIRB report, development of the strategy was motivated by the changing landscape of space exploration, including the increasing role of the private sector.[214] The strategy sets out a number of objectives and action items summarized in the table below. Whether and how the Joseph Biden Administration will proceed with these objectives remains to be seen.

4. Nuclear Contamination

a. International Law and Policy

Though the Outer Space Treaty prohibits placing nuclear weapons into orbit, it does not address the use of NPSs.[215] To fill this gap, the U.N. has adopted nonbinding Principles Relevant to the Use of Nuclear Power Sources in Outer Space. These set out, among other things, safety guidelines for the use of NPSs in space, notice requirements in the event of malfunctioning space objects containing NPSs, and a liability and compensation framework for damage caused by NPS-bearing space objects.[216] Nota-

National Strategy for Planetary Protection	
Objective 1—Forward Contamination ***Avoid harmful forward contamination by developing and implementing risk assessment and science-based guidelines and updating the interagency payload review.***	
Objective 1.1 Develop a forward contamination risk assessment framework.	**Near-term deliverable:** Develop a forward contamination risk assessment framework within one year.
Objective 1.2 Develop flexible science-based forward contamination guidelines.	**Near-term deliverables:** Develop guidelines for forward contamination mitigation within nine months. Develop risk-informed decisionmaking implementation strategies for human missions within one year.
Objective 1.3 Assess the interagency aspects of the U.S. government payload review process.	**Near-term deliverable:** Develop a report reviewing the U.S. government payload review process within nine months.
Objective 2—Backward Contamination ***Avoid backward contamination by developing a Restricted Return Program to protect against adverse effects on the earth environment due to the potential return of extraterrestrial life.***	
Objective 2.1 Develop a risk assessment framework.	**Near-term deliverable:** Develop a backward contamination risk assessment framework within nine months.
Objective 2.2 Develop an approval framework.	**Near-term deliverable:** Develop an approval framework within nine months.
Objective 2.3 Develop a return procedures framework.	**Near-term deliverable:** Develop a return procedures framework within one year.
Objective 3—Private Sector Engagement ***Incorporate the perspective and needs of the private sector by soliciting feedback and developing guidelines regarding private sector activities with potential planetary protection implications.***	
Objective 3.1 Engage with industry.	**Near-term deliverable:** Engage with private sector to develop industry feedback on governmental initiatives that would benefit from private sector involvement.
Objective 3.2 Develop guidelines for private sector activities.	**Near-term deliverable:** Develop guidelines on authorization and continuing supervision within six months.

207. *See id.* at 17-18.
208. *Id.* at 17.
209. *Id.*
210. *Id.* at 10.
211. *Id.* at 18.
212. The White House National Space Council, National Strategy for Planetary Protection (2020), *available at* https://fas.org/spp/eprint/protection.pdf.
213. *Id.* at i.
214. *Id.* at 2.
215. Outer Space Treaty, *supra* note 64, art. IV.
216. *See* G.A. Res. 47/68, Principles Relevant to the Use of Nuclear Power Sources in Outer Space (Dec. 14, 1992), princ. 3, 5, 9.

bly, the Nuclear Power Source Principles apply only to NPSs used for electric power generation, and not to NPSs used for propulsion.[217]

Jointly with the International Atomic Energy Agency, the Scientific and Technical Subcommittee of the U.N. COPUOS has developed guidelines, called the NPS Safety Framework, for the safe use of NPSs in space.[218] The purpose of the NPS Safety Framework is to provide guidance to governments in developing their own safety frameworks, and for the development of international intergovernmental frameworks.[219] It sets out guidance for governments, including recommending that governments justify the use of NPSs in space at the authorization stage[220]; guidance for management of organizations that conduct space missions involving NPSs, including that the operating organization should have primary responsibility for the safe use of such NPSs[221]; and technical guidance.[222] The NPS Safety Framework is limited in scope to safety considerations for earth's environment, including earth's human population.[223] It does not consider the protection of humans in space or space environments, due to a dearth of scientific data available to inform such applications.[224]

The Hague Building Blocks do not expressly address the use of NPS systems. However, Section 10 contains broad language regarding avoiding and mitigating the potential for harmful impacts, presumably including those associated with the use of NPSs.[225]

b. Domestic Law and Policy

On August 20, 2019, President Trump issued a presidential memorandum that "update[d] the process for launches of spacecraft containing space nuclear systems."[226] The Space Nuclear Systems Memorandum applies to radioisotope power systems, radioisotope thermoelectric generators and heater units, and fission reactors used for power and propulsion, and to both governmental and commercial launches.[227] It provides safety guidelines for launches involving nuclear systems, setting out probability thresholds of harm to the public that should not be exceeded for different levels of exposure.[228] It also directs NASA, in coordination with the Secretaries of Defense and Energy, to evaluate further safety guidelines that may be appropriate for the use of nuclear fission reactors in space.[229]

The Space Nuclear Systems Memorandum sets out a three-tiered authorization process for launches containing nuclear systems, based on (1) the system used; (2) "the level of potential hazard"; and (3) "national security considerations."[230] It establishes a process for conducting safety analyses, requiring the preparation of a "mission Safety Analysis Report" for all tiers of federal government launches,[231] and directs the Secretary of the U.S. Department of Transportation (DOT) to, "if necessary," require safety analysis reports for commercial launches following a rulemaking process.[232]

The memorandum also directs the NASA Administrator to establish an Interagency Nuclear Safety Review Board, consisting of representatives of "the Departments of State, Defense, Energy, and Transportation, the Environmental Protection Agency, NASA, and, as appropriate, the Nuclear Regulatory Commission," and spells out the Review Board's oversight role for Tier II and Tier III missions.[233] It requires that the Secretary of DOT issue guidance on the process to obtain a license for the launch or reentry of spacecraft using a nuclear system.[234] It also requires annual reports of launches involving radioactive sources in quantities above a certain threshold ("1,000 times to 100,000 times the A2 value listed in Table 2 of the International Atomic Energy Agency's Specific Safety Requirements No. SSR-6 (Rev.1)").[235]

Relatedly, under regulations that took effect on March 10, 2021, the FAA will evaluate launches and reentries of radionuclides "on a case-by-case basis, and issue an approval if the FAA finds that the launch or reentry is consistent with public health and safety, safety of property, and national security and foreign policy interests of the United States."[236] The regulations set out the following

217. *See id.*:

> *Affirming* that this set of Principles applies to nuclear power sources in outer space devoted to the generation of electric power on board space objects for non-propulsive purposes, which have characteristics generally comparable to those of systems used and missions performed at the time of the adoption of the Principles[.]

218. *See* U.N. COPUOS Scientific and Technical Subcommittee & International Atomic Energy Agency, *supra* note 51.
219. *See id.* at 1.
220. *See id.* at 3-4.
221. *See id.* at 4-5.
222. *See id.* at 5-7.
223. *See id.* at 2.
224. *See id.*
225. *See* Building Blocks, *supra* note 117, ¶ 10 ("[T]he international framework should provide that States and international organizations responsible for space resource activities shall adopt appropriate measures with the aim of avoiding and mitigating potentially harmful impacts, including . . . a) Risks to the safety of persons, the environment or property; b) Damage to persons, the environment or property . . . .").
226. Presidential Memorandum on Launch of Spacecraft Containing Space Nuclear Systems §1 (Aug. 20, 2019).
227. *See id.*
228. *See id.* §3.
229. *See id.*
230. *See id.* §4. Tier 1 applies to "launches of spacecraft containing radioactive sources of total quantities up to and including 100,000 times the A2 value listed in Table 2 of the International Atomic Energy Agency's Specific Safety Requirements No. SSR-6 (Rev. 1), Regulations for the Safe Transport of Radioactive Material, 2018 Edition ('Table 2')." *Id.* Tier II applies to (i) launches "containing radioactive sources in excess of 100,000 times the A2 value" listed in Table 2, (ii) Tier I launches for which "the probability of an accident . . . resulting in an exposure in the range of 5 rem to 25 rem TED to any member of the public is equal to or greater than 1 in 1,000,000," and (iii) launches containing systems utilizing low-enriched uranium "with a potential for criticality," which the memorandum defines as "the condition in which a nuclear fission chain reaction becomes self-sustaining." *Id.* Finally, Tier III applies to "launches . . . containing a space nuclear system for which . . . the probability of an accident . . . resulting in an exposure in excess of 25 rem TED to any member of the public is equal to or greater than 1 in 1,000,000." *Id.*
231. *See id.* §5(b).
232. *See id.*
233. *See id.* §5(c).
234. *See id.* §5(d). As of the writing of this Article, the FAA is still in the process of developing this guidance.
235. *See id.* §6.
236. 14 C.F.R. §450.45(e)(6) (2020).

requirements related to the radionuclide that the launch applicant must satisfy: "(i) [i]dentify the type and quantity [of the radionuclide]; (ii) [i]nclude a reference list of all documentation addressing the safety of its intended use; and (iii) [d]escribe all approvals by the Nuclear Regulatory Commission for pre-flight ground operations."[237]

C. Related Issues

1. Conservation

In addition to navigating regulatory efforts to mitigate the environmental issues that may attend space mining, the space mining industry may be affected by calls to withdraw portions of the solar system for the purposes of conservation.

One such call is to limit areas open to exploitation of space resources by a "one-eighth principle."[238] Authors Martin Elvis and Tony Milligan describe this principle as follows:

> While economic growth remains exponential, we should regard as ours[, humanity's,] to use no more than one-eighth of the exploitable materials of the Solar System . . . The remaining seven-eighths of the exploitable Solar System should be left as space wilderness.[239]

Rather than invoking concepts of protection of nature, the one-eighth principle seeks to withdraw areas from exploitation in order to avoid depletion of the solar system's resources.[240] Thus, the wilderness designation would prevent human use of the withdrawn areas, but would not necessarily prohibit all forms of human impact.[241]

Though they do not go so far as to specify a percentage of the solar system to be withdrawn from resource utilization, the Building Blocks do contemplate the designation of internationally protected areas in space. Section 18 provides for "[t]he establishment and maintenance of an international database for making publicly available iii. [t]he list of designated and internationally endorsed outer space natural and cultural heritage sites; and iv. [t]he list of designated and internationally endorsed sites of scientific interest . . . ."[242] An international body would be charged with listing such sites.[243] The international framework envisioned under the Building Blocks would also require responsible States and international organizations to implement measures designed to avoid and mitigate harm to such sites.[244]

At the international level, legal efforts to protect portions of earth's oceans that are not subject to any national jurisdiction may foreshadow similar efforts in outer space. For example, over the past few years, U.N. delegates have been negotiating a new legally binding instrument—likely an extension of UNCLOS—to protect marine life in international waters.[245] Further negotiations have been postponed, as of the time of this writing, due to COVID-19,[246] but the success of the negotiations and the terms of any resulting instrument will likely inform outer space conservation efforts going forward.

2. Historic Site Preservation

Significant interest similarly exists in protecting sites of historic or cultural value in space. Existing protections for historical and cultural sites located in international waters could serve as an analogous legal framework to this end. UNCLOS and the 2001 Convention for the Protection of Underwater Cultural Heritage protects valuable archaeological and historical sites located in the "Area," defined as "the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction."[247]

Specifically, UNCLOS states that "[a]ll objects of an archaeological and historical nature found in the Area shall be preserved or disposed of for the benefit of mankind as a whole, particular regard being paid to the preferential rights of the State or country of origin, or the State of cultural origin, or the State of historical and archaeological origin."[248] The Underwater Cultural Heritage Convention specifically protects "traces of human existence having a cultural, historical or archaeological character which have been partially or totally under water, periodically or continuously, for at least 100 years," including such traces located in the Area.[249]

At the domestic level, NASA has set out recommendations to protect certain U.S. government assets located on the moon based on their historical and scientific value.[250]

The Artemis Accords also address protection of certain historically significant sites in outer space. They provide that "[t]he Signatories intend to preserve outer space heritage, which they consider to comprise historically significant human or robotic landing sites, artifacts, spacecraft, and other evidence of activity on celestial bod-

237. *Id.*
238. *See* Martin Elvis & Tony Milligan, *How Much of the Solar System Should We Leave as Wilderness?*, 162 Acta Astronautica 574-80 (2019).
239. *Id.* at 575.
240. *See id.*
241. *See id.*
242. Building Blocks, *supra* note 117, ¶ 18.b.
243. *See id.* ¶ 18.c.ii.
244. *See id.* ¶ 10.
245. Olive Heffernan, *U.N. Makes a Bold Move to Protect Marine Life on the High Seas*, Sci. Am., Sept. 7, 2018, https://www.scientificamerican.com/article/u-n-makes-a-bold-move-to-protect-marine-life-on-the-high-seas/.
246. G.A. Res. 72/249, Intergovernmental Conference on an International Legally Binding Instrument Under the United Nations on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas Beyond National Jurisdiction (Dec. 24, 2017), https://www.un.org/bbnj/; UNCLOS, *supra* note 65, art. 1.(1) (defining "Area").
247. *Id.* art. 149.
248. Convention for the Protection of Underwater Cultural Heritage, Nov. 2, 2001, 2562 U.N.T.S. 3, art. 1(a) (defining "[u]nderwater cultural heritage"); arts. 11, 12 (describing protections for underwater cultural heritage in the Area).
249. NASA, NASA's Recommendations to Space-Faring Entities: How to Protect and Preserve the Historic and Scientific Value of U.S. Government Lunar Artifacts (2011), https://www.nasa.gov/pdf/617743main_NASA-USG_LUNAR_HISTORIC_SITES_RevA-508.pdf.
250. *Id.*

SA Recommendations to Protect Moon-Based U.S. Government Assets

NASA's recommendations apply to the following assets[a]:

A. Apollo lunar surface landing and roving hardware;

B. Unmanned lunar surface landing sites (e.g., Surveyor sites);

C. Impact sites (e.g., Ranger, S-IVB, LCROSS, lunar module . . . ascent stage);

D. [U.S. Government] experiments left on the lunar surface, tools, equipment, miscellaneous [extravehicular activity] hardware; and

E. Specific indicators of U.S. human, human-robotic lunar presence, including footprints, rover tracks, etc., although not all anthropogenic indicators are protected as identified in the recommendations.

a. NASA, NASA's Recommendations to Space-Faring Entities: How to Protect and Preserve the Historic and Scientific Value of U.S. Government Lunar Artifacts 5 (2011), https://www.nasa.gov/pdf/617743main_NASA-USG_LUNAR_HISTORIC_SITES_RevA-508.pdf.

ies in accordance with mutually developed standards and practices."[251] The signatories further express an intention to contribute to efforts to establish practices and rules at the international level related to the goal of preserving outer space heritage.[252]

Civic society also plays a role regarding historic site preservation. An organization called For All Moonkind has worked with federal officials and appealed to the U.N. to declare that the Apollo 11 landing site and the Soviet Luna 2 spacecraft, which remains on the moon's surface 60 years after landing, deserve special recognition.[253] These efforts, NASA's recommendations, and the Artemis Accords may form the basis of U.S. law if Sen. Gary Peters' (D-Mich.) and Sen. Ted Cruz's (R-Tex.) bill—the One Small Step to Protect Human Heritage in Space Act—were to be enacted into law.[254] The Act would require a commitment to abide by NASA's requirements related to protecting U.S. government lunar artifacts as a condition on a license to conduct lunar activities.[255] It passed the U.S. Senate in July 2019.[256]

The Outer Space Treaty presents a significant limitation on the ability of an individual nation to protect areas of concern to it. A nation would run afoul of the Outer Space Treaty's prohibition on the national appropriation of outer space and its mandate of free access if it attempted to unilaterally protect a portion or all of outer space by excluding other States.[257] Thus, while efforts like the United States' to protect sites of interest located on celestial bodies through national legislation and other means are effective as applied to the missions of the enacting nation, some sort of international consensus would be necessary to enforce the protective requirements on an international basis.

III. Looking Ahead

A. *China and Russia in Space*

Chinese activities in space are growing rapidly. China is preparing to launch its first section of a new space station.[258] China is not a signatory to the Artemis Accords.[259] The Chinese response to the Accords was "decisively negative." Chinese media reported the Accords as "a disingenuous attempt to stymie Chinese space ambitions."[260]

As discussed above, international law addresses areas where sovereign states cannot claim land or resources—the deep sea, Antarctica (maybe the Arctic), and space. China has on occasion disregarded international norms when conducting itself in the South China Sea,[261] where it has made territorial claims, despite international law prohibiting Chinese claim over the islands and routes in the Sea.[262] There is some concern among international organizations and signatories to the Artemis Accords that China will ignore international norms and treaties and treat space (and its resources) "as a source of resources, technological advancements, and global prestige."[263]

Russia's response to NASA's announcement of the Artemis Accords was similar to that of China. The leader of Russia's space organization, Roscosmos, does not approve of the "US-centric approach" contemplated in the Artemis Accords and NASA goals.[264]

The real concern with Russia and China's expression of distaste regarding the Artemis Accords is that it introduces an additional layer of uncertainty in space activities. If Russia and China agree on a system that competes with the system established by the Artemis Accords and complementary international law, space activities will be potentially more costly because industry will need to work

251. Artemis Accords, *supra* note 106, §9.1.
252. *Id.* §9.2.
253. *See* Nell Greenfieldboyce, *How Do You Preserve History on the Moon?*, NPR, Feb. 21, 2019, https://www.npr.org/2019/02/21/696129505/how-do-you-preserve-history-on-the-moon%3B; *see also* Leonard David, *Space Act Calls for Protection of Apollo 11 Landing Site*, SPACE.com, June 4, 2019, https://www.space.com/congress-protect-apollo-11-landing-site.html.
254. David, *supra* note 253.
255. *See* One Small Step to Protect Human Heritage in Space Act, S. 1694, 116th Cong. (2019).
256. *See id.*
257. Outer Space Treaty, *supra* note 64, arts. I, II.
258. Leah Crane, *China Is About to Start Building a Space Station in Orbit*, New-Scientist, Apr. 27, 2021, https://www.newscientist.com/article/2275818-china-is-about-to-start-building-a-space-station-in-orbit/.
259. Elliot Ji et al., *What Does China Think About NASA's Artemis Accords?*, Diplomat, Sept. 17, 2020, https://thediplomat.com/2020/09/what-does-china-think-about-nasas-artemis-accords/.
260. *Id.*
261. *South China Sea Dispute: China's Pursuit of Resources "Unlawful," Says US*, BBC News, July 14, 2020, https://www.bbc.com/news/world-us-canada-53397673.
262. *Id.*
263. Capt. Bryant A. Mishima-Baker, *Moon Wars: Legal Trouble in Space and Moon Law*, JAG Reporter 1 (2021).
264. Loren Grush, *Head of Russian Space Program Calls for More International Cooperation in NASA's Moon Plans*, Verge, Oct. 12, 2020, https://www.theverge.com/2020/10/12/21512712/nasa-roscosmos-russia-dmitry-rogozin-artemis-moon-interntational-cooperation.

within two competing systems and there will be less guidance on a singular approach.

Moreover, Russia and China have indicated they intend to cooperate on the moon.[265] If China and Russia remain opposed to the Artemis Accords and collaborate on a moon base, competing systems are created. It is easy to imagine that China and Russia would claim sovereign powers over a territory on the moon that they "(1) landed on first; (2) cultivated into a useful location; and (3) spent billions of dollars on."[266] A claim of sovereignty was outlawed in the Outer Space Treaty, but an analogy can be drawn between the Outer Space Treaty and international laws and customs prohibiting sovereign claim over the seas.[267] International maritime law recognizes that open seas may be used freely by all nations.[268] China has claimed sovereign control over parts of the South China Sea, and these claims have largely been respected by international merchants.[269] It is reasonable to think a similar claim may be made on the moon.

The uncertainty around respect for sovereign moon bases is made more difficult by the United States' rejection of the sentiment that the moon and its natural resources are "the common heritage of mankind."[270] This uncertainty created by potentially competing systems is seen as some of the cause for hesitancy on beginning a lunar resource renaissance.[271]

B. *Private Parties in Space*

The space race captivating the world is not just occurring between sovereign powers. Billionaires have taken to space—some of them are creating a new experience for wealthy tourists while other seek human settlements on Mars.[272] Elon Musk, chief executive officer of SpaceX, believes the company will lead the way in making humanity a multiplanetary species.[273] One SpaceX vehicle is looking like it could make asteroid mining a reality. Martin Elvis, an astronomer from the Harvard-Smithsonian Center for Astrophysics, has said he believes the Falcon Heavy can potentially increase the number of asteroids that could be landed on by a factor of 15.[274]

The Falcon Heavy costs $90 million per launch, but the value of minerals on NEAs dwarfs that cost.[275] Musk has shown his commitment to humanity being a multiplanetary species by specifically addressing services provided on Mars in SpaceX's Starlink user agreement.[276] The user agreement reads "[f]or services provided on Mars, or in transit to Mars via Starship or other colonization spacecraft, the parties recognize Mars as a free planet and that no Earth-based government has authority or sovereignty over Martian activities."[277]

Musk is not the only billionaire working to make humanity a space-dwelling species. Jeff Bezos' Blue Origin sites its long-term goal as "build[ing] the tools so humans can create giant floating colonies around the Earth, [to] support[ ] all manner of ecosystems."[278]

No matter which billionaire's vision is accurate, both Musk's Martian city and Bezos' earth-orbiting colonies require significant resources that will need to be mined from space.

C. *Environmental Concerns*

The two main environmental areas of concern moving forward are avoiding contamination and debris removal and mitigation. As the number of missions to and from space increases, concern around forward and backward contamination grows.[279] One concern associated with contamination of space by earth-grown organisms is that it will be difficult to tell what celestial bodies are capable of growing and sustaining.[280]

Fortunately, scientists believe that any organisms introduced to other celestial bodies will have made certain adaptations that prove distinguishable from earth-grown organisms.[281] One of the key adaptations to watch for in DNA tests run on organisms from space is a greater resistance against radiation.[282] Knowing this and other adaptations as identifiers distinguishing earth-grown and transplanted organisms protects the integrity of the study of life on celestial bodies.[283]

Tracking, mitigation, and removal of space debris is an ongoing issue. As discussed earlier, the Kessler Effect posits that "once past a certain critical mass, the total amount of space debris will keep increasing."[284] Technology is advancing to assist in collecting and mitigating further space debris buildup. There is some concern, however, that private industry may add significantly to the buildup of space debris. SpaceX, for example, has around 400 Starlink satellites in low earth orbit, and plans to send up to 12,000 sat-

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265. Megan A. MacKay, *Property Rights in Celestial Bodies*, 104 Marq. L. Rev. 575, 602 (2020).
266. Mishima-Baker, *supra* note 263.
267. *Id.*
268. *Id.*
269. *Id.*
270. Moon Agreement, *supra* note 77, art. 11.
271. Mishima-Baker, *supra* note 263.
272. Jackie Salo, *Richard Branson, on His Virgin Galactic Rocket Plane, Becomes First Billionaire to Get to Space*, N.Y. Post, July 11, 2021, https://nypost.com/2021/07/11/richard-branson-to-fly-to-space-on-virgin-galactic-rocket/.
273. SpaceX, *Mission*, www.spacex.com/mission (last visited Aug. 30, 2021).
274. Kristin Houser, *Falcon Heavy Could Make Asteroid Mining a Reality*, Futurism, Feb. 20, 2018, https://futurism.com/falcon-heavy-asteroid-mining.
275. *Id.*
276. *Id.*
277. *Elon Musk Laying Foundation for Martian Constitution? Here's What Experts Think*, Tech Times, Jan. 11, 2021, https://www.techtimes.com/articles/255802/20210111/elon-musk-laying-foundation-martian-constitution-heres-what-experts-think.htm.
278. *Id.*
279. Mike Brown, *Blue Origin's Jeff Bezos Details His Radical Vision for Colonies in Space*, Inverse, May 10, 2019, https://www.inverse.com/article/55709-blue-origin-s-jeff-bezos-details-his-radical-vision-for-colonies-in-space.
280. Christopher Mason, *Could Humans Have Contaminated Mars With Life?*, BBC, May 10, 2021, https://www.bbc.com/future/article/20210510-could-the-perseverance-rover-have-carried-life-to-mars.
281. *Id.*
282. *Id.*
283. *Id.*
284. *Id.*

ellites into orbit.[285] Amazon is planning a similarly scaled satellite constellation to inhabit low earth orbit.[286] Space agencies have established orbital debris research programs that observe debris and developed strategies to control the effects of space debris.[287] It is clear that private industry will play a significant role in space debris mitigation efforts.[288]

IV. Conclusion

We are in the first phase of a second space age, building on the development of outer space exploration that led to the Outer Space Treaty in 1967. In 1967, there were 139 orbital launches, the high point in orbital space launches. The number dropped to a low of 51 in 2001 as space exploration lost its luster.

2020, however, witnessed 110 orbital launches, tied for the highest annual number since the low numbers in the early 2000s.[289] Humankind has again focused on outer space. But refocusing on outer space has brought new participants—private industry. In 2009, private capital invested less than $500 million in the space industry. In 2019, that investment was just under $6 billion, a record level of private investment.[290]

Renewed activity in outer space, and new sources of investment and technology, will magnify and accelerate the potential environmental effects of space activities. When the Outer Space Treaty was being negotiated, there were about 2,000 objects in orbit around the earth. Today, there are more than 25,000.[291] And outer space, especially near earth orbit, will become more active, more crowded, and more regulated.

Those venturing into space, or investing in those ventures, will need to keep abreast of the current applicable legal framework, and also look for ways to improve the law to address concerns related to pollution, contamination, and debris while allowing exploration and development to move forward. In that regard, the environmental law of outer space is no different than environmental law here on earth.

285. European Space Agency, *The Kessler Effect and How to Stop It*, https://www.esa.int/Enabling_Support/Space_Engineering_Technology/The_Kessler_Effect_and_how_to_stop_it (last visited July 12, 2021).

286. Martin McCoustra, *Space Junk: Astronomers Worry as Private Companies Push Ahead With Satellite Launches*, Conversation, May 13, 2020, https://theconversation.com/space-junk-astronomers-worry-as-private-companies-push-ahead-with-satellite-launches-137572.

287. *Id.*

288. *Id.*

289. Space Launch Report, *2020 Space Launch Report*, http://spacelaunchreport.com/log2020.html (last visited Aug. 19, 2021).

290. Alex Knapp, *Space Industry Investments Hit Record High as Venture Capital Seeks the Next SpaceX*, Forbes, Jan. 16, 2020.

291. European Space Agency, ESA's Annual Space Environment Report 18, Fig. 2.1(a) (2021).