Deep Space Thinking: What Elon Musk's Idea to Nuke Mars Teaches Us About Regulating the "Visionaries and Daredevils" of Outer Space

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I. INTRODUCTION

Elon Musk, founder of California-based aerospace company SpaceX,[1] was recently called a "supervillain" on *The Late Show with Stephen Colbert* after revealing his idea to detonate thermonuclear devices over the poles of Mars.[2] Musk does not have sinister intentions; he wants to terraform the Martian atmosphere so that future generations of humans can live there.[3] Musk has long been an advocate of colonizing Mars,[4] arguing that a multi-planetary presence can safeguard the survival of humanity in the future, especially if a catastrophic event ever occurs on Earth.[5]

1. Andrew Smith, *Meet Tech Billionaire and Real Life Iron Man Elon Musk*, TELEGRAPH (Jan. 4, 2014), http://www.telegraph.co.uk/technology/news/10544247/Meet-tech-billionaire-and-real-life-Iron-Man-Elon-Musk.html [http://perma.cc/T9B4-T8CR].

2. James Vincent, *Stephen Colbert Calls Elon Musk Supervillain After Hearing Plan to Nuke Mars*, VERGE (Sept. 10, 2015), http://www.theverge.com/2015/9/10/9300115/elon-musk-stephen-colbert-interviews-super-villain [http://perma.cc/6AE4-2PXC].

3. Keith Wagstaff, *Would Elon Musk's Plan to Nuke Mars Actually Work?*, NBC NEWS (Sept. 10, 2015), http://www.nbcnews.com/science/space/would-elon-musks-idea-nuke-mars-work-n425001 [http://perma.cc/R7Q7-SFY5]. The term "terraform" means to alter or transform the atmosphere of another planet to have the characteristics of landscapes on Earth. *See Terraform*, FREE DICTIONARY, http://www.thefreedictionary.com/terraform [http://perma.cc/HM7Y-APDJ] (last visited Feb. 6, 2016).

4. *See, e.g.*, Elizabeth Howell, *SpaceX's Elon Musk to Reveal Mars Colonization Ideas This Year*, SPACE.COM (Jan. 9, 2015), http://www.space.com/28215-elon-musk-spacex-mars-colony-idea.html [http://perma.cc/4K8U-FTU9].

5. Ross Andersen, *Exodus: Elon Musk Argues that We Must Put a Million People on Mars if We Are to Ensure that Humanity Has a Future*, AEON (Sept. 30, 2014), http://aeon.co/magazine/technology/the-elon-musk-interview-on-mars/ [http://perma.cc/3QK5-4V4C].

Musk believes that Mars has great potential to support human life in the future,[6] and his plan to create a habitable Martian atmosphere is intriguing. Special nuclear devices would be detonated in space over the planet's polar ice caps, "creating two tiny pulsing '[S]uns' over the regions."[7] In theory, generating large amounts of heat over the Martian poles could vaporize and release carbon dioxide contained in Mars' polar ice caps, thickening the atmosphere.[8] A thicker atmosphere could trap heat from the Sun, which normally is absorbed by the planet and then released as infrared radiation.[9] Retaining more heat from the Sun could trigger a cascading greenhouse effect by releasing more carbon dioxide and continuing to heat up Mars until the surface pressure increased enough for liquid water to exist.[10] Formation of liquid water could be very favorable for oxygen-producing plants, and thus, human survival.[11]

Musk's proposal raises fascinating legal questions about non-government activity in outer space.[12] This Note will explore the legal implications of his idea to terraform Mars using fusion nuclear technology. It is not an endorsement of using nuclear devices to alter the Martian atmosphere. Far too many ethical, environmental, technological, and political questions must be addressed before the issue can be decided. Rather, this Note is intended to show that international and national space laws dance around the questions surrounding Musk's proposal without providing a clear-cut legal answer. But incorporating his idea, however farfetched, into any discussion about the future legal rights of non-government entities in outer space will steer

6. *See* Douglas Zimmerman, *Elon Musk Wants to Go to Mars*, SFGATE (Sept. 28, 2015), http://www.sfgate.com/science/article/Elon-Musk-wants-to-go-to-Mars-6535140.php [http://perma.cc/X2VE-Y7JF] (noting that Musk has characterized Mars as "a fixer-upper of a planet").

7. Loren Grush, *Elon Musk Elaborates on His Proposal to Nuke Mars*, VERGE (Oct. 2, 2015), http://www.theverge.com/2015/10/2/9441029/elon-musk-mars-nuclear-bomb-colbert-interview-explained [http://perma.cc/Q3EY-ZA6V].

8. *See* Aaron Mamlit, *Elon Musk Wants to Nuke Mars: Why This Could Be a Good Idea*, TECH TIMES (Sept. 11, 2015), http://www.techtimes.com/articles/83828/20150911/elon-musk-wants-to-nuke-mars-why-this-could-be-a-good-idea.htm [http://perma.cc/MBK8-BNWN].

9. *See* Wagstaff, *supra* note 3.

10. *Id.*

11. *Id.*

12. *See* Gabriele Wohl, Student Work, *Outer Space, Inc.: Transmitting Business, Ethics, and Policy "Across the Universe,"* 111 W. VA. L. REV. 311, 336 (2008) (describing several new private sector ventures in outer space that have given rise to new legal questions).

lawmakers toward preferred, consensus outcomes as the law evolves. Musk's unusual idea is relevant to that discussion because it will help lawmakers demarcate the appropriate legal boundaries of non-government activity in outer space.

Part II prefaces the legal analysis by providing basic information about the Martian atmosphere and the initial public reaction to the use of nuclear devices there. Part III analyzes the legality of Musk's idea under international law. Part IV analyzes the legal implications of Musk's terraforming idea under U.S. law; under existing international law, the U.S. government must regulate private space entities like Musk who are within its jurisdiction. Part V argues that it is unwise for international and U.S. lawmakers to characterize farsighted ideas like Musk's as excessively optimistic,[13] or dismiss them because they lack clear legal answers.[14] Regardless of whether Musk's plan to use nuclear devices over Mars is a bad idea, ignoring its legal implications altogether is bad policy.

II. GENERAL BACKGROUND

Mars is a barren planet without a survivable atmosphere, breathable air, or sources of food.[15] The atmosphere is composed of ninety-six percent carbon dioxide, with only trace amounts of oxygen and water.[16] Mars is much colder than Earth: the average atmospheric temperature is minus 81 degrees Fahrenheit, and temperatures on the surface can dip as low as minus 284 degrees Fahrenheit.[17] The planet also experiences dust storms measuring thousands of kilometers and lasting for months at a time.[18] To have any chance of survival on Mars, humans would have to manufacture all the basic necessities of life on their own.[19]

13. Ed Regis, *Let's Not Move to Mars*, N.Y. TIMES (Sept. 21, 2015), http://www.nytimes.com/2015/09/21/opinion/lets-not-move-to-mars.html [http://perma.cc/65DH-WBFL].

14. *See, e.g.*, Javier Hasse, *No, Elon Musk Can't Legally Nuke Mars – Space Lawyer Explains Why*, BENZINGA (Sept. 11, 2015), http://www.benzinga.com/news/15/09/5830471/no-elon-musk-cant-legally-nuke-mars-space-lawyer-explains-why [http://perma.cc/5KF4-G59C].

15. Regis, *supra* note 13.

16. *See Mars Facts*, NASA, http://mars.nasa.gov/allaboutmars/facts/#detailedFacts [http://perma.cc/7EZF-2JM9] (last visited Nov. 29, 2015).

17. *Id.*

18. *See* Matt Williams, *The Planet Mars*, UNIVERSE TODAY (July 22, 2015), http://www.universetoday.com/14701/mars/ [http://perma.cc/9SKP-F42P].

19. *See* Regis, *supra* note 13.

In spite of Mars' hostile environment, scientific research indicates that life may have existed there at one time, or could be supported in the future. Astronomers have long observed numerous canal-like channels on Mars, convincing many that liquid water used to flow through them.[20] In September 2015, NASA announced its *Mars Reconnaissance Orbiter* had discovered "the strongest evidence yet" that liquid water intermittently flows on the Martian surface.[21] Even though the existence of liquid surface water on Mars is still unproven, significant concentrations of ice water exist within its two polar ice caps.[22] Furthermore, there is a large permafrost mantle surrounding the polar region of Mars, and evidence of subsurface ice water near the center of the planet, suggesting the presence of subsurface ice water across a large geographic area.[23]

Not surprisingly, Musk's idea has elicited a fair amount of criticism.[24] There is doubt that it can even work, and several experts have proposed alternative solutions to avoid the potentially dangerous consequences of using nuclear devices.[25] Further complicating matters is the uncertainty surrounding what Musk means by "pulsing Suns," and if such technology exists, or could

20. Williams, *supra* note 18.

21. Press Release, NASA, NASA Confirms Evidence That Liquid Water Flows on Today's Mars (Sept. 28, 2015), https://www.nasa.gov/press-release/nasa-confirms-evidence-that-liquid-water-flows-on-today-s-mars [http://perma.cc/J29K-W4Q7].

22. *See* Williams, *supra* note 18.

23. *Id.*

24. *See, e.g.*, Adam Epstein, *Elon Musk Proposed Nuking Mars Last Night on Colbert*, QUARTZ (Sept. 10, 2015), http://qz.com/499383/elon-musk-proposed-nuking-mars-last-night-on-colbert/ [http://perma.cc/CZU8-86EP] (highlighting the uncertain risks associated with unleashing large amounts of nuclear radiation on Mars); Alan Neuhauser, *Scientists: Please Don't Nuke Mars*, U.S. NEWS & WORLD REPORT (Sept. 10, 2015), http://www.usnews.com/news/articles/2015/09/10/please-dont-nuke-mars-scientists-ask-elon-musk-after-stephen-colbert-appearance [http://perma.cc/8XMY-CXRZ] (describing the risk of nuclear winter, where so much dust and particles are thrown into the Martian atmosphere from a nuclear explosion that the Sun's energy is blocked and the planet cools down); Regis, *supra* note 13 (arguing that technological, environmental, and cost concerns make the idea of terraforming Mars impractical).

25. *See, e.g.*, Andres Jauregui, *Sorry, Elon Musk: One Does Not Simply Nuke Mars Into Habitability*, HUFFPOST SCIENCE (Sept. 11, 2015), http://www.huffingtonpost.com/entry/elon-musk-nuke-mars_55f1c071e4b093be51bdfffc [http://perma.cc/AJ2W-JZSD] (describing another proposal to introduce freon, a greenhouse gas, into the Martian atmosphere, which might be less harmful to the Martian environment than radiation); Wagstaff, *supra* note 3 (describing one proposal to send genetically-modified microorganisms to Mars to transform its atmosphere).

exist in the near future.[26] Musk recently clarified his original proposal when he suggested sending large fusion pulse bombs over the Martian poles to accomplish his goal,[27] but no additional details have been released. Finally, it is unclear how this kind of complex project could be regulated, or by whom.

III. INTERNATIONAL LEGAL REGIME

International space law is primarily governed by a series of United Nations treaties all negotiated shortly after the global community began creating rules for outer space in the late 1950s.[28] In 1958, the U.N. established the Office for Outer Space Affairs ("UNOOSA"), a small expert unit within the U.N. Secretariat to service the Committee on the Peaceful Uses of Outer Space ("COPUOS").[29] COPUOS is the principal forum for the development of international space law.[30] Legal mechanisms for authorizing and supervising non-government space activities are derived from four widely accepted treaties drafted by COPUOS: (1) the Outer Space Treaty,[31] (2) the Liability Convention,[32] (3) the Rescue and Return Agreement,[33] and (4) the Registration

26. *See* Grush, *supra* note 7. Moreover, some aspects of nuclear technology are often classified and not released for private commercial use. *See* DEP'T OF DEFENSE, INSTRUCTIONS FOR ACCESS TO AND DISSEMINATION OF RESTRICTED DATA AND FORMERLY RESTRICTED DATA 5–7 (2011), http://www.dtic.mil/whs/directives/corres/pdf/521002p.pdf [http://perma.cc/ZD43-MXJL].

27. *See, e.g.*, Maddie Stone, *Elon Musk Clarifies His Plan to "Nuke Mars,"* GIZMODO (Oct. 3, 2015), http://gizmodo.com/elon-musk-clarifies-his-plan-to-nuke-mars-1734457751 [http://perma.cc/WNB2-W63S].

28. *See* Brian Beck, *The Next, Small, Step for Mankind: Fixing the Inadequacies of the International Space Law Treaty Regime to Accommodate the Modern Space Flight Industry*, 19 ALB. L.J. SCI. & TECH. 1, 5 (2009); P.J. Blount, *Renovating Space: The Future of International Space Law*, 40 DENV. J. INT'L L. & POL'Y 515, 516 (2011).

29. *History*, U.N. OFF. OUTER SPACE AFF., http://www.unoosa.org/oosa/en/aboutus/history/index.html [http://perma.cc/L72A-A7EV] (last visited Jan. 6, 2016).

30. *Space Law Treaties and Principles*, U.N. OFF. OUTER SPACE AFF., http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties.html [http://perma.cc/XR6E-2FXF] (last visited Jan, 6, 2016).

31. 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. 2015 [hereinafter Outer Space Treaty].

32. The Convention on International Liability for Damage Caused by Space Objects, Mar. 29, 1972, 24 U.S.T. 2389, 961 U.N.T.S. 187 [hereinafter Liability Convention].

33. The Agreement on the Rescue of Astronauts the Return of Astronauts and the Return of Objects Launched into Outer Space, Apr. 22, 1968, 19 U.S.T. 7570, 672 U.N.T.S. 119 [hereinafter Rescue and Return Agreement].

Convention.[34] All four of these treaties opened for signature between 1967 and 1975.[35] International space law is also affected in varying ways by U.N. soft law guidelines concerning the environment[36] and multilateral agreements like the Partial Test Ban Treaty.[37]

Little has changed in the international space treaty regime for many years, creating some uncertainty with respect to the legality of certain non-government activities.[38] The international space treaties currently in force reflect Cold War fears and ambitions, with little emphasis on modern day concerns about space resources, commercialization, and production.[39] Hegemonic rulemaking premised on Cold War security fears made sense because any treaty regime would have been ineffective without support of the only real spacefaring nations at that time: the United States and the Soviet Union.[40] But the arms control-oriented view that has dominated international space law for the past several decades has opened gaps in outer space governance,[41] particularly with respect to private, commercially oriented activities.

Analyzing the international space law regime to determine the legality of Musk's idea yields two important results. First, the language of the Outer Space Treaty does not provide a clear "yes" or "no" answer about whether Musk can legally pursue a nuclear terraforming mission on Mars. Even if the notion of equipping Musk with nuclear devices and sending him to Mars is inadvisable as a matter of discretion, it is not definitively foreclosed as a matter

34. The Convention on Registration of Objects Launched into Outer Space, Jan. 14, 1975, 28 U.S.T. 695, 1023 U.N.T.S. 15 [hereinafter Registration Convention].

35. *See Space Law Treaties and Principles*, *supra* note 30.

36. *See, e.g.*, U.N. Conference on Environment and Development, *Rio Declaration on Environment and Development*, U.N. Doc. A/CONF.151/5/Rev.1 (June 14, 1992) [hereinafter Rio Declaration], *reprinted in* 31 I.L.M. 874 (1992).

37. Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water, Aug. 5, 1963, 14 U.S.T. 1313, 480 U.N.T.S. 43 [hereinafter Partial Test Ban Treaty].

38. *See, e.g.*, Sarah Coffey, *Establishing a Legal Framework for Property Rights to Natural Resources in Space*, 41 CASE W. RES. J. INT'L L. 119, 124 (2009) (discussing the vague legal framework governing the private use and exploitation of natural resources on the Moon).

39. *Id.* (citing Joanne Irene Gabrynowicz, *Space Law: Its Cold War Origins and Challenges in the Era of Globalization*, 37 SUFFOLK U. L. REV. 1041, 1043 (2004)).

40. *See* Beck, *supra* note 28, at 11.

41. *See, e.g.*, Lori Scheetz, *Infusing Environmental Ethics in the Space Weapons Dialogue*, 19 GEO. INT'L ENVTL. L. REV. 57, 66–70 (2006) (discussing the lack of rules governing harmful dumping of space debris in Earth's orbital atmosphere).

of law. Second, the legality of Musk's proposal also depends in part on how U.S. lawmakers interpret the Outer Space Treaty. Even though all entities using or exploring outer space must conform to international law, the COPUOS treaties transfer significant obligations on states to erect their own legal regulation of private actors under their jurisdictions. Decentralization might be sensible in light of the protean variety of entrepreneurial activity around the world, but it muddles the comparative legal relevance of international law and national law over private actors like Musk.

A. The Outer Space Treaty

The Outer Space Treaty, christened as the "constitution for space,"[42] is the foundation of international space law, incorporating the principles of the U.N. Charter and international legal norms into the exploration and use of outer space.[43] It establishes that outer space is free for exploration and use by all states, for peaceful purposes only, without national appropriation by claim of sovereignty over any celestial body, and for the benefit of all mankind.[44] Adopted in 1967, the Outer Space Treaty focuses heavily on promoting international cooperation and limiting arms expansion to prevent military rivalries from extending into outer space.[45] These principles were well suited to the societal and political realities of the Cold War, when space activities were purely government undertakings by the United States and the Soviet Union.[46] Thus, the Outer Space Treaty is substantively an arms

42. *See* Blount, *supra* note 28, at 517 (citing Stanley B. Rosenfield, *Where Air Space Ends and Outer Space Begins*, 7 J. SPACE L. 137, 144 (1979)).

43. Michael Bourbonniere & Ricky J. Lee, *Legality of the Deployment of Conventional Weapons in Earth Orbit: Balancing Space Law and Law of Armed Conflict*, 18 EJIL 873, 878 (2008) (citing Outer Space Treaty, *supra* note 31, at art. III); *see also* Adrian Taghdiri, *Flags of Convenience and the Commercial Space Flight Industry: The Inadequacy of Current International Law to Address the Opportune Registration of Space Vehicles in Flag States*, 19 B.U. J. SCI. & TECH. L. 405, 416 (2013).

44. *See* Outer Space Treaty, *supra* note 31, at arts. I–IV.

45. Joanne Irene Gabrynowicz, *Space Law: Its Cold War Origins and Challenges in the Era of Globalization*, 37 SUFFOLK U. L. REV. 1041, 1043 (2004); *see also* Beck, *supra* note 28, at 12 ("The Outer Space Treaty . . . should be seen as motivated more by the need for an arms control agreement . . . than by a need to set up a system for regulating peaceful spaceflight.").

46. *See* Blount, *supra* note 28, at 517.

control treaty.[47] As a consequence, the legal effect of the Outer Space Treaty on non-government space activities like those envisioned by Musk is less certain.

1. Regulation of Non-Government Activity

In the past, the legal effect of the Outer Space Treaty over the space activities of non-government actors like Musk was open to considerable debate. After all, the Outer Space Treaty was not intended to address private or commercial activity in outer space.[48] With no realistic possibility that a private industry would emerge in the foreseeable future, its drafters had little reason to address issues regarding private activity in space, such as enforceability and dispute resolution.[49] In the 1960s, it was "virtually unimaginable" that any private entity could spearhead its own outer space project.[50]

However, non-government activity in outer space was not completely ignored in the Outer Space Treaty.[51] All signatories, including the United States, agree to supervise and be derivatively liable for the outer space missions of private actors under their governance, pursuant to articles VI and VII.[52] Beyond those provisions, the Outer Space Treaty is relatively silent on the subject of non-government activity in outer space. Nevertheless, the modern consensus among the international space community is that all space activities in the Outer Space Treaty are to be classified as either "international" or "national."[53] And the term "national" includes both government and non-government missions, which means private actors like Musk are subject to the provisions in the

47. *See* COLOGNE COMMENTARY ON SPACE LAW VOLUME I: OUTER SPACE TREATY 72 (Stephen Hobe, Bernhard Schmidt-Tedd & Kai-Uwe Schrogl eds., 2009) [hereinafter COLOGNE COMMENTARY].

48. Michael Tse, *One Giant Leap [Backwards] for Mankind: Limited Liability in Private Commercial Spaceflight*, 79 BROOK. L. REV. 291, 299–301 (2013) (noting that lawmakers in the 1960s could not have known what obligations would be established for unforeseen actors in outer space).

49. *Id.*

50. *Id.*

51. Blount, *supra* note 28, at 530.

52. Outer Space Treaty, *supra* note 31, at arts. VI–VII.

53. *See* COLOGNE COMMENTARY, *supra* note 47, at 51 ("There is no room for classification in terms of 'national' (State or public) or non-governmental (private) beyond the requirements of Article VI of the Outer Space Treaty.").

Outer Space Treaty.[54] Even so, the Outer Space Treaty provides only general legal principles for future international and national lawmakers to build upon.[55]

2. Nuclear Weapons and Weapons of Mass Destruction

The Outer Space Treaty prohibits certain nuclear activities in outer space, but its legal effect on Musk's proposal to use fusion nuclear devices over the poles of Mars is vague. Article IV forbids any party to the Outer Space Treaty from placing nuclear weapons or other weapons of mass destruction in orbit around Earth, on any celestial body, or in outer space.[56] The Outer Space Treaty does not prohibit the actual use of nuclear weapons, but only their placement or installation in outer space or on another celestial body.[57] Neither does it prohibit the general use of all nuclear materials in space for non-weapon purposes.[58] The United States, for example, has used radioisotope thermoelectric generators ("RTGs")[59] and other nuclear power sources in dozens of successful missions, including satellites, deep-space probes, and the Apollo Program.[60] The Soviet Union also had a long history of powering satellites with nuclear reactors.[61]

54. *Id.*

55. Tse, *supra* note 48, at 301 (citing BRUCE A. HURWITZ, STATE LIABILITY FOR OUTER SPACE ACTIVITIES IN ACCORDANCE WITH THE 1972 CONVENTION ON INTERNATIONAL LIABILITY FOR DAMAGE CAUSED BY SPACE OBJECTS 9 (1992)).

56. Outer Space Treaty, *supra* note 31, at art. IV.

57. *See* COLOGNE COMMENTARY, *supra* note 47, at 79. The Partial Test Ban Treaty, discussed *infra* at Section III.B, covers the use of nuclear explosive devices in outer space.

58. Joseph J. MacAvoy, *Nuclear Space and the Earth Environment: The Benefits, Dangers, and Legality of Nuclear Power and Propulsion in Outer Space*, 29 WM. & MARY ENVTL. L. & POL'Y REV. 191, 221 (2004); *see also* Nina Tannenwald, *Law Versus Power on the High Frontier: The Case for a Rule-Based Regime for Outer Space*, 29 YALE J. INT'L L. 363, 371 (2004) (noting that "no prohibition exists on the transit of nuclear weapons through space or the launching of nuclear weapons from Earth into pace for the purpose of destroying incoming missiles").

59. RTGs are not nuclear reactors and they do not produce energy through fission or fusion reactions. MacAvoy, *supra* note 58, at 195. Energy is produced by converting heat from the decay of radioisotopic materials into electricity. *Id.*

60. *Id.* at 205 (noting that between 1958 and 1997 the United States conducted twenty-five separate space missions incorporating an RTG to generate power on many spacecraft, including satellites and deep space vehicles).

61. *Id.* at 212. A nuclear reactor operates by converting heat generated by the controlled fission reaction of heavy atoms into electricity. *Id.* at 197. Space nuclear reactors operate according to the same fission process as nuclear reactors in terrestrial nuclear power plants. *Id.* at 198.

It is unclear whether a pulsing fusion nuclear device that functions like a "small blinking Sun" over the Martian poles in the way Musk has proposed[62] is the kind of nuclear weapon, let alone a weapon of mass destruction, prohibited by the Outer Space Treaty.[63] The plain meaning of weapon is an "instrument used or designed to be used to injure or kill someone,"[64] or alternatively, "an instrument of offensive or defensive combat: used in destroying, defeating, or physically injuring an enemy."[65] According to the International Court of Justice ("ICJ"), nuclear weapons are "explosive devices whose energy results from the fusion or fission of the atom."[66] Nuclear weapons are characterized by their explosive capacity, releasing large amounts of heat, energy, and radiation.[67] They are prohibited by the Outer Space Treaty because of their disproportionate power compared to conventional weapons, not because they might have destructive consequences on Earth if detonated in outer space.[68] Since classification as a weapon depends on a nuclear device's potential destructive force, a nuclear device can still be the kind of weapon the Outer Space Treaty prohibits even if used for non-military purposes.[69] However, not every kind of nuclear device in outer space is properly classified as a nuclear weapon: it is essential that a device have the capacity to cause destructive results by uncontrolled nuclear explosion.[70]

The meaning of the term "weapon of mass destruction" in the Outer Space Treaty is harder to pin down, especially since the term did not originate with outer space activities in mind.[71] Its plain meaning is "a weapon that is intended to kill human beings, without discriminating between combatants and noncombatants,

62. Grush, *supra* note 7.

63. The terms "weapon" and "weapon of mass destruction" are not defined in the Outer Space Treaty. *See generally* Outer Space Treaty, *supra* note 31.

64. *Weapon*, BLACK'S LAW DICTIONARY (10th ed. 2014).

65. *Weapon*, WEBSTER'S THIRD NEW INTERNATIONAL DICTIONARY (1993).

66. *See* COLOGNE COMMENTARY, *supra* note 47, at 76 (citing Legality of the Threat or Use of Nuclear Weapons, Advisory Opinion, 1996 I.C.J. Rep. 243 (July 8)). The ICJ gives advisory opinions on legal questions passed along by U.N. agencies. *Id.* Even though ICJ Advisory Opinions are not binding, they function as the U.N.'s official stance on international legal issues. *Id.*

67. *Id.*

68. *Id.*

69. *Id.* at 77.

70. *Id.* at 76. The difference between nuclear reaction and a nuclear explosion is discussed in Section III.B, *infra*.

71. *Id.* at 77.

on a massive scale."[72] There is no legally binding definition for weapon of mass destruction in outer space, but any device with high destructive potential against humans is likely to be classified as a weapon of mass destruction.[73] The U.N. General Assembly has suggested in the past that weapons of mass destruction include atomic explosive weapons, radioactive material weapons, and any weapons developed in the future possessing characteristics similar to destructive effect of the atomic bomb.[74] Together, these two descriptions suggest that a space-based nuclear weapon of mass destruction must have explosive capacity similar to the atomic bomb, with a high probability of harming people on Earth. Fusion nuclear devices positioned millions of miles away on Mars might not have that kind of destructive potential, putting them outside the scope of a weapon of mass destruction. But that interpretation might conflict with the preventative aims of the Outer Space Treaty, whose language suggests that a nuclear device need not actually cause harm in order to be classified as a weapon or weapon of mass destruction.[75]

Without a mandatory definition of weapon or weapon of mass destruction anywhere in international law, including in the Outer Space Treaty, it is difficult to apply the language of article IV to conclude whether Musk would be legally allowed to use as-yet undeveloped fusion nuclear devices stationed around Mars. The kinds of fusion nuclear devices envisioned by Musk probably are not weapons in the literal sense because there is no indication that Musk would use such devices to kill people.[76] Nor would his proposal to terraform Mars entail combat or warfare against an enemy.[77] Furthermore, the Outer Space Treaty might allow the use of fusion nuclear technology on Mars if it does not involve an uncontrolled explosion, but rather a controlled nuclear reaction.[78] Space technology that has relied on controlled nuclear reactions for power generation, vehicle propulsion, or other scientific

72. *Weapon of Mass Destruction*, BLACK'S LAW DICTIONARY (10th ed. 2014).

73. *See* COLOGNE COMMENTARY, *supra* note 47, at 78.

74. *Id.* (citing G.A. Res. 32/84 B, ¶ 3 (Dec. 12 1977)).

75. *Id.* at 76.

76. *See* note 64, *supra*, and accompanying text.

77. *See* note 65, *supra*, and accompanying text. Because the Outer Space Treaty is one of arms control, its application to atmospheric transformation projects on Mars, which probably cannot be classified as an "enemy" in the ordinary sense of the word, is unclear. *See id.*

78. *See* note 70, *supra*, and accompanying text.

purposes has been used legally for many years.[79] Of course, those uses of nuclear devices in space involve transportation and power generation mechanisms, not planetary transformation, but it is theoretically possible that a controlled fusion reaction to terraform Mars in the future could be done legally under the Outer Space Treaty if it does not involve a nuclear explosion.[80]

It is too early to tell whether the Outer Space Treaty prohibits the use of as-yet unavailable fusion technology envisioned by Musk in space when the precise operation of such devices is unknown. There has been no known attempt to install nuclear weapons or other weapons of mass destruction in outer space, and thus the current scope and breadth of article IV are untested.[81] Installing fusion nuclear devices over the poles of Mars to transform its atmosphere might therefore be permissible under article IV the Outer Space Treaty, unless its language is amended to limit that kind of activity in space.

3. National Appropriation

Article II of the Outer Space Treaty prohibits ownership rights in outer space, and sovereign or territorial claims over any celestial body,[82] which presents an interesting legal problem for Musk. Article II does not directly address "property rights of private individuals and companies, which is understandable because at the time of drafting only government entities were involved in space activities."[83] Some have argued that the omission of a distinct limitation on private property rights in the Outer Space Treaty could arguably leave outer space open to the "manifest destiny" of

79. In 2003, for example, NASA began an initiative called Project Prometheus to develop the safe and reliable operation of a nuclear-reactor-powered spacecraft on long-duration space science missions. *See* Steven A. Mirmina & David J. Den Herder, *Nuclear Power Sources and Future Space Exploration*, 6 CHI. J. INT'L L. 149, 156 (2005). In 2004, U.S. President George W. Bush reaffirmed this effort when he called on NASA to develop "new power generation, propulsion, life support and other systems that can support more distant travels." *Id.* (citations omitted).

80. The full meaning of the Outer Space Treaty with respect to future nuclear technology in space is debatable. *See* Michael Gerrard & Anna Barber, *Asteroids and Comets: U.S. and International Law and the Lowest-Probability, Highest Consequence Risk*, 6 N.Y.U. ENVTL. L.J. 4, 34–35 (1997).

81. *See* COLOGNE COMMENTARY, *supra* note 47, at 71.

82. Outer Space Treaty, *supra* note 31, at art. II.

83. Wohl, *supra* note 12, at 330.

extraterrestrial pioneers.[84] But the negotiating history of the Outer Space Treaty shows that the delegates participating in those discussions were generally of the opinion that article II prohibited both public and private appropriation.[85] The prevailing interpretation of the Outer Space Treaty reaffirms this point of view, and the "national" activities referred to in article II includes those of non-government entities.[86] This reading of the Outer Space Treaty could support an argument that Musk may not carry out a terraforming project on Mars, which would, in effect, put the fate of an entire planet under his control.

However, article II expressly states that national appropriation in outer space by means of use or occupation is not possible.[87] No amount of use or occupation of outer space by non-government actors like Musk will give rise to a legal claim of ownership rights over any part of space, including Mars, under the language of article II.[88] Exploitation of natural resources on other celestial bodies like Mars is a valid use of outer space and is protected by the freedom principle embodied in article I of the Outer Space Treaty, without violating the non-appropriation provision in article II.[89] But using or occupying outer space is not without certain limits: for instance, placing a weapon of mass destruction in orbit around Earth might be a use of outer space under article II, but it is prohibited under article IV of the Outer Space Treaty.[90] Aside from article IV, using fusion nuclear devices to terraform Mars might violate the Outer Space Treaty to the extent that it interferes with the freedom of others to use and explore the planet, or is deemed inconsistent with the principle that space must be explored and used for the benefit and in the interests of all countries.[91]

Whether Musk's idea to terraform Mars with fusion nuclear devices is legal under the non-appropriation provisions in article II of the Outer Space Treaty is a difficult line to draw. On one hand,

84. *Id.*

85. *See* COLOGNE COMMENTARY, *supra* note 47, at 50.

86. Outer Space Treaty, *supra* note 31, at art. VI.

87. *Id.* at art. II ("Outer space . . . is not subject to national appropriation . . . *by means of use or occupation*, or by any other means.") (emphasis added).

88. *See* COLOGNE COMMENTARY, *supra* note 47, at 53–54.

89. *Id.*

90. *Id.*

91. Outer Space Treaty, *supra* note 31, at art. I.

neither outer space nor any celestial body is capable of being appropriated under the language of article II, and thus activities by non-government actors like Musk cannot give rise to "appropriation by use."[92] In addition, the provisions in article I are arguably satisfied because if Musk were to transform the Martian atmosphere and make it more hospitable for humans, that might facilitate access to the planet for others and constitute a major benefit for anyone who goes to Mars thereafter.[93] On the other hand, the level of exploitation that Musk envisions for Mars affects its whole ecosystem and puts a planet under the control of all parties involved in the project, which could run afoul of the letter and spirit of non-appropriation. While it is not clear that terraforming Mars is a *per se* violation of the Outer Space Treaty, to pass muster under article II, Musk would have to show that other provisions of the Outer Space Treaty like article I were satisfied.[94]

4. Harmful Contamination

Article IX of the Outer Space Treaty codifies substantive principles concerning international cooperation, non-harmful interference, and non-contamination of outer space, which addressed fears in the 1960s that certain activities by the United States and the Soviet Union could be harmful to Earth or cause irreparable damage to other celestial bodies like the Moon.[95] First, all spacefaring entities are required to exercise a minimum standard of care to ensure that all activities in outer space are conducted without harming or interfering with other space missions.[96] Second, and more important for Musk's proposed mission to Mars, article IX incorporates customary rules of

92. *See* COLOGNE COMMENTARY, *supra* note 47, at 58–59.

93. Outer Space Treaty, *supra* note 31, at art. I ("The exploration and use of outer space . . . shall be carried out for the benefit and in the interests of all countries . . . [and] shall be free for exploration and use by all States without discrimination . . . .").

94. *See* COLOGNE COMMENTARY, *supra* note 47, at 53–54. The scope of the non-appropriation principle in article II as it relates to non-government entities is an ongoing debate that has gained attention in recent years due to technological advancements, but remains unsettled among international experts. *See id.* at 58–63.

95. *Id.* at 170–72.

96. *Id.* at 174–76. The principle of cooperation is applicable to public state activities and private commercial activities that are under the supervision of the state. *Id.* There are no rules of engagement set forth in the Outer Space Treaty, but the requirement to avoid harming or interfering with other space missions is procedural: all that must be shown is that all reasonable steps were exhausted to avoid harm. *Id.*

international environmental law, including the 1972 Stockholm Declaration and the 1992 Rio Declaration on Environmental Law,[97] both of which establish that states must avoid harmful environmental contamination of any area beyond their national jurisdiction, including outer space.[98]

Article IX in the Outer Space Treaty expressly prohibits all entities that use and explore outer space from introducing harmful contamination in the outer space environment or on any celestial body.[99] Even though the term is undefined in the Outer Space Treaty, "harmful contamination" of Mars might encompass a host of things, including radioactivity from a nuclear device, release of synthetic chemicals, or the generation of microorganisms not normally found on the planet.[100] It could also be argued that harmful contamination of Mars describes not just loss of resources or amenities of economic value, but also any destruction of the intrinsic worth of the Martian atmosphere, including biological diversity and natural areas of aesthetic significance.[101] Article IX of the Outer Space Treaty might therefore imply that celestial bodies, including Mars, should be preserved in their pre-existing conditions.[102] Under that interpretation, deliberate transformation of the Martian atmosphere by whatever means appears to be inconsistent with the Outer Space Treaty.

But applying a generic definition of harmful contamination is not necessarily appropriate because its meaning can differ among treaties, depending on what each treaty is intended to regulate and protect.[103] The creation of a more hospitable environment for human inhabitants on Mars, if technologically feasible, might not be considered harmful at all. And the intrinsic worth of the

97. *See* Rio Declaration, *supra* note 36, at princ. 2; U.N. Conference on the Human Environment, *Declaration of the United Nations Conference on the Human Environment (Stockholm Declaration)*, U.N. Doc. A/CONF.48/14/Rev.1 (June 16, 1972).

98. *Id.* The topics of international environmental law and the mechanisms for ensuring global cooperation in this area and consulting with other countries are discussed in more detail in Section III.F, *infra*.

99. Outer Space Treaty, *supra* note 31, at art. IX.

100. *See* COLOGNE COMMENTARY, *supra* note 47, at 171.

101. *See* PATRICIA BIRNIE, ALAN BOYLE & CATHERINE REDGWELL, INTERNATIONAL LAW & THE ENVIRONMENT 184 (3d ed. 2009). Pursuant to the Antarctic Environment Protocol, for example, the entire continent of Antarctica and the surrounding marine environment are legally protected on an ecosystem-wide basis. *Id.* at 186.

102. *Cf.* Gerrard & Barber, *supra* note 80, at 42–43 (discussing possible restrictions on "blowing up or irradiating asteroids or comets" by article IX of the Outer Space Treaty).

103. *See* BIRNIE, BOYLE, & REDGWELL, *supra* note 101, at 185.

Martian ecosystem is arguably minimal, given Mars' apparently low capacity to support any form of known biological species.[104] Moreover, the provisions of article I in the Outer Space Treaty allowing everyone to use and explore all parts of outer space for scientific investigation seem to favor an ambitious terraforming project for the purposes of advancing human development beyond Earth.[105]

The Planetary Protection Policy adopted by the Committee on Space Research ("COSPAR"), a branch of the non-governmental International Council for Science ("ICS"), might give some indication from the international scientific community about what it means to avoid harmful contamination on Mars.[106] The COSPAR guidelines require different reporting procedures and pre-mission scientific assessments for Mars missions, depending on the type of mission and whether any orbital or surface contact is made.[107] The guidelines are aimed at preventing the introduction of non-Martian microorganisms via unsterilized space vehicle surfaces or human carriers.[108] Thresholds are established to limit the maximum allowable number of such microbes from being released on Mars.[109] Even though the COSPAR guidelines do not address atmospheric transformation on Mars, the existing procedures that are carefully designed to minimize introduction of microbes as much as possible suggests that a nuclear terraforming mission, which could alter the whole planet, falls within the ambit of harmful contamination.

Clarification from COPUOS is needed to express what the term "harmful contamination" is intended to regulate and protect before concluding that Musk's proposal would violate article IX of the Outer Space Treaty. Even if the existing corpus of

104. *See* Jauregui, *supra* note 25 (noting that Mars is still believed to harbor no form of biological diversity given its harsh conditions).

105. Outer Space Treaty, *supra* note 31, at art. I.

106. COMM. ON SPACE RESEARCH, INT'L COUNCIL FOR SCI., COSPAR PLANETARY PROTECTION POLICY [hereinafter COSPAR GUIDELINES], https://cosparhq.cnes.fr/sites/default/files/pppolicy.pdf [https://perma.cc/J6AT-H5MT] (last visited Apr. 10, 2016). COSPAR's policies on planetary protection have evolved as new information about the potential for life on Mars has become available. *See* COLOGNE COMMENTARY, *supra* note 47, at 178. In the United States, NASA has responsibility for promulgating planetary protection policies in accordance with COSPAR's guidelines. *Id.*

107. *See* COSPAR GUIDELINES, *supra* note 106, at 2, app. at 3–5.

108. *Id.*

109. *Id.*

international law and outer space policy tends to favor a conservative interpretation that militates against allowing Martian terraforming, there are plausible counter arguments that terraforming Mars to facilitate human access and scientific exploration on the planet is consistent with article IX, and comports with the ambitious framework in article I of the Outer Space Treaty.

B. The Partial Test Ban Treaty

The use of nuclear devices near Mars would implicate the Partial Test Ban Treaty, which prohibits nuclear weapons tests or "any other nuclear explosion" in any environment, including outer space.[110] The Partial Test Ban Treaty was negotiated in the early 1960s among the dominant international powers, notably the United States and the Soviet Union, and became binding law in 1963.[111] Over 100 other nations later became signatory parties to the treaty.[112] In addition to limiting the nuclear arms race,[113] the Partial Test Ban Treaty was specifically concerned with radioactivity, prohibiting nuclear explosions if they cause "radioactive debris to be present outside the territorial limits of the State under whose jurisdiction or control" the explosions were conducted.[114]

The Partial Test Ban Treaty's ban on all types of nuclear explosions in outer space is a serious legal obstacle for fusion nuclear devices that could operate via pulse explosions to heat up the Martian atmosphere.[115] In 1965, Project Orion—a top-secret nuclear research program spearheaded by NASA, the U.S. Air Force, and the U.S. Department of Defense ("DOD")—was shut down largely because it had developed nuclear technology that ran

110. Partial Test Ban Treaty, *supra* note 37.

111. *Id.*

112. Leonardo Caselli, *Space Demilitarization Treaties in a New Era of Manned Nuclear Spaceflights*, 77 J. AIR L. & COM. 641, 647 (2012) (citing C. WILFRED JENKS, SPACE LAW 5 (1965)).

113. *Id.* at 646.

114. *See* Partial Test Ban Treaty, *supra* note 37, at art. I.

115. *See* Mark Prigg, *Elon Musk Details His Plan to BOMB Mars Saying Constant 'Nuclear Pulse Explosions' Would Create Double Suns to Heat the Planet*, DAILY MAIL (Oct. 2, 2015), http://www.dailymail.co.uk/sciencetech/article-3258168/Elon-Musk-details-plan-BOMB-Mars-constant-nuclear-pulse-explosions-create-double-suns-heat-planet.html [https://perma.cc/W6CA-7HP7].

afoul of the Partial Test Ban Treaty.[116] Researchers had developed nuclear pulse rocket technology for space travel.[117] Nuclear pulse rockets eject specially designed atomic bombs that explode at the rear of a spacecraft, pushing it forward.[118] Unlike RTGs, in which energy is produced by converting heat from the non-explosive decay of radioisotopic materials into electricity, pulse rockets are inconsistent with the Partial Test Ban Treaty because they rely on actual nuclear explosions.[119] Just like the Partial Test Ban Treaty barred pulse rockets developed by Project Orion because they operated via nuclear explosions, here, the treaty might also bar the use of fusion pulse devices over Mars if they operate via nuclear explosions.

However, innovative fusion devices for Mars might not be affected by the Partial Test Ban Treaty,[120] depending on whether they operate by the forbidden nuclear explosion or merely a nuclear reaction. A nuclear explosion is a destructive chain reaction, which is different from a controlled chain reaction like fission.[121] Controlled nuclear fission, for example, is not a nuclear explosion because it involves a steady process within a sealed reactor core that produces high levels of energy, but no explosion.[122] The Partial Test Ban Treaty does not prohibit space-based fission reactors, and they are generally legal under current international law.[123] Similarly, the Partial Test Ban Treaty might allow the use of fusion nuclear technology on Mars provided that it does not involve any kind of destructive explosion, but rather a

116. *See* GEORGE DYSON, PROJECT ORION: THE TRUE STORY OF THE ATOMIC SPACESHIP 266 (2002).

117. *Id.*

118. *See* MacAvoy, *supra* note 58, at 202. To date, nuclear pulse rockets have not been tested in outer space. *Id.*

119. A nuclear explosion involves an uncontrolled nuclear chain reaction, not the kind of natural radioactive decay found in RTG power systems. *See* 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 ENVTL. L. REV. 855, 870 (1993). Interestingly, an Orion-type spacecraft does not qualify as a "nuclear weapon" within the meaning of article IV of the Outer Space Treaty, even though it relies on small atomic bombs for propulsion. *See* COLOGNE COMMENTARY, *supra* note 47, at 76.

120. *See* Caselli, *supra* note 112, at 654–55 (discussing the potential legality of future technology such as photon rockets and fusion engines).

121. *Id.* at 657–58.

122. *Id.*

123. *See* Mirmina & Den Herder, *supra* note 79, at 154. Previous space missions involving fission reactors, both foreign and domestic, have been limited to instrumental power systems intended for Earth orbit, not rocket propulsion systems. *Id.* at 158.

controlled reaction similar to fission. That kind of device would also comply with article IV of the Outer Space Treaty.[124] Thus, it is premature to claim that the Partial Test Ban Treaty prohibits the use of as-yet unavailable fusion technology envisioned by Musk because the precise operation of such devices is unknown.

A categorical ban on any nuclear explosion in outer space is also inappropriate given the advancements in nuclear technology for nonviolent uses, especially since the principle aims of the Partial Test Ban Treaty in the context of Cold War security concerns are largely outdated.[125] Not only is a relaxed interpretation of the Partial Test Ban Treaty's treatment of nuclear technology for peaceful purposes—perhaps even controlled explosions—arguably consistent with the Outer Space Treaty,[126] it comports with the Treaty on Non-Proliferation of Nuclear Weapons, ratified by the United States in 1970.[127] Recent guidelines issued by the U.N., which are discussed in the next Section, further support a more liberal construction of the Partial Test Ban Treaty. Moreover, it is unlikely that the international community would object to using advanced nuclear technology on Mars if such activity was carried out for peaceful, scientific reasons.[128] The overall posture of the Partial Test Ban Treaty may present a legal obstacle for Musk in his pursuit of a nuclear terraforming project on Mars, but just like with the Outer Space Treaty, the exact scope and meaning of its language with respect to theoretical nuclear technology is debatable.

C. The Nuclear Principles

Guidance from the U.N. concerning the peaceful use of nuclear technology in outer space could support the use of nuclear fusion

124. *See supra* notes 69–70 and accompanying text.

125. *See* Caselli, *supra* note 112, at 663–67 (arguing that if nuclear pulse rockets, which rely on small nuclear detonations, are banned under the Partial Test Ban Treaty, it would needlessly inhibit deep space exploration).

126. Outer Space Treaty, *supra* note 31, at art. I ("There shall be freedom of scientific investigation in outer space . . . and States shall facilitate and encourage international cooperation in such investigation.").

127. Treaty on the Non-Proliferation of Nuclear Weapons art. 4, July 1, 1968, 21 U.S.T. 483, 729 U.N.T.S. 161 ("All the Parties to the Treaty . . . have a right to participate in . . . the peaceful uses of nuclear energy.").

128. *See* Gerrard & Barber, *supra* note 80, at 39 (arguing that the launch of nuclear weapons to avoid damage to Earth by near-Earth objects might be justified under U.N. principles of self-defense).

technology to terraform Mars. In 1992, COPUOS drafted the Principles Relevant to the Use of Nuclear Power Sources in Outer Space ("Nuclear Principles"), later adopted by the U.N. General Assembly, which specifically addresses the use and operation of nuclear technology in outer space.[129] The Nuclear Principles allow the use of "nuclear power sources in outer space" for peaceful, scientific purposes if a particular space mission cannot rely on an alternate source of energy.[130] This language seems to acknowledge that, for certain space missions, and perhaps the one envisioned by Musk, use of nuclear technology is allowed if it is essential.[131]

While the Nuclear Principles are not legally binding and do not explicitly condone the use of nuclear technology on any particular type of spacecraft,[132] they are the product of extensive negotiations by COPUOS and provide a valuable perspective on the necessity of nuclear technology in space.[133] Principle 1 states that all activities involving the use of nuclear technology in outer space must be carried out in accordance with international law,[134] which clearly incorporates the mandatory restrictions of the Partial Test Ban Treaty. But it can be argued that the Nuclear Principles encourage the use of nuclear technology for long-range interplanetary missions.[135] Musk's proposed use of fusion nuclear technology on Mars may find support in the Nuclear Principles, provided the use of nuclear technology is absolutely necessary and carried out for scientific purposes.

D. The Liability Convention

The risk of harm to humans on Earth or to other human-manufactured objects in outer space from accidents involving a

129. Principles Relevant to the Use of Nuclear Power Sources in Outer Space, G.A. Res. 47/68 (Dec. 14, 1992) [hereinafter Nuclear Principles].

130. *See id.* at princ. 3.

131. *See* Caselli, *supra* note 112, at 667 (citing Steven A. Mirmina & Den Herder, *supra* note 79, at 161).

132. *Id.*

133. *See* Gerrard & Barber, *supra* note 80, at 44 (citing Carl Q. Christol, *Introduction to Nuclear Power Principles*, 32 I.L.M. 917, 917 (1992)).

134. *See* Nuclear Principles, *supra* note 129, at princ. I.

135. *See* Caselli, *supra* note 112, at 667 (citing William Lee Andrews, *Targeted Tax Relief for Space Commerce Part 2: "Astrolaw" – Where Does Space Begin?*, 11 J. INT'L TAX'N 10, 20 (2000). Recently, the Legal Subcommittee of COPUOS suspended work on the effect of international treaties like the Partial Test Ban Treaty pending more consideration of technical issues. *See* Mirmina & Den Herder, *supra* note 79, at 161–62.

spacecraft launched by Musk would implicate the Liability Convention. Ratified in 1972, the Liability Convention sets forth a regime governing liability for damages arising from outer space activities.[136] Damages include "loss of life, personal injury or other impairment of health," and destruction of property of other states.[137] Indirect damages like lost wages and pain and suffering are also covered.[138] Claims are adjudicated via non-binding arbitration before a Claims Commission in the event that disputing governments cannot come to an agreement about compensation through diplomatic means.[139] While the Liability Convention does not address the legality of a nuclear terraforming mission on Mars, it is an important legal instrument because it could influence the magnitude of national government regulation over that kind of mission on Mars and the willingness of Musk to pursue it.

Article II of the Liability Convention provides that "[a] launching [s]tate is absolutely liable to pay compensation for damage caused by its space object on the surface of the Earth or to aircraft in flight."[140] A launching state is not only a state from whose territory or facility a space object is launched, but also any state that "procures the launching" of a space object.[141] A state might qualify as a launching state even when its citizens have merely financed or operated a spaceflight without any government involvement.[142] When read in conjunction with articles VI and VII of the Outer Space Treaty, the Liability Convention renders a national government internationally responsible and strictly liable for any damages to other countries arising from private activities in outer

136. *See generally* Liability Convention, *supra* note 32. The Liability Convention is an expansion and clarification of the liability provisions in articles VI and VII of the Outer Space Treaty. *See* Tse, *supra* note 48, at 301–02. The Liability Convention has been rarely invoked because there have been relatively few spacecraft accidents outside of national borders. *See* Beck, *supra* note 28, at 16.

137. Liability Convention, *supra* note 32, at art. I.

138. *See* Tse, *supra* note 48, at 303.

139. Liability Convention, *supra* note 32, at arts. XIV–XV.

140. *Id.* at art. II. Moreover, article V declares, "[a] State from whose territory or facility a space object is launched shall be regarded as a participant in a joint launching." *Id.* at art. V.

141. *Id.* at art I.

142. *See* Tse, *supra* note 48, at 303–05 (citing Frans G. von der Dunk, *Passing the Buck to Rogers: International Liability Issues in Private Spaceflight*, 86 NEB. L. REV. 400, 410–11 (2007)) (discussing uncertainties surrounding national government liability when a space vehicle is launched from a privately owned spaceport, which is a new phenomenon).

space—even if that government had no direct involvement—as long as it qualifies as a launching state.[143]

Determining liability for the kinds of damages that might result from nuclear activity near Mars is not immediately apparent from the language in the Liability Convention.[144] The treaty only imposes liability on states, not on natural persons or organizations, and covers launches and atmospheric reentries of spacecraft.[145] The Liability Convention might have legal force with respect to a nuclear terraforming project on Mars to the extent that it results in any damages—radioactive or otherwise—to sovereign national territory on Earth, or to objects in space owned by other nations.[146] However, the Liability Convention might not cover activity conducted on or near Mars because the treaty only mentions damage to Earth's environment or to physical objects in space owned by other nations,[147] and the potential of harm to inhabitants of Earth or other human-manufactured spacecraft from a nuclear terraforming project on Mars is unknown.[148]

Even if the Liability Convention were applicable to all aspects of Musk's proposal, legal liability would be determined "in accordance with international law and the principles of justice and equity."[149] Because a terraforming project on Mars would arguably benefit all nations of Earth equally, apportioning liability among many state governments for any damages might be justified.[150] Equal apportionment of liability in the international community

143. *Id.*; *see also* Outer Space Treaty, *supra* note 31, at arts. VI–VII.

144. Tse, *supra* note 48, at 312 (noting that the claims resolution procedures under the Liability Convention have questionable relevance in the non-government space sector).

145. Beck, *supra* note 28, at 14.

146. *See* Tse, *supra* note 48, at 302–03.

147. *See* Liability Convention, *supra* note 32, at arts. III–IV.

148. *See* Andrew Griffin, *Elon Musk Plans to Drop Nuclear Bombs Above Mars to Give It Two New Suns so It Can Keep Warm*, INDEPENDENT (Oct. 5, 2015), http://www.independent.co.uk/life-style/gadgets-and-tech/elon-musk-plans-to-drop-nuclear-bombs-above-mars-to-give-it-two-new-suns-so-it-can-keep-warm-a6679736.html [http://perma.cc/3ED3-G7PD] (noting that Musk's plan involves technology that has not been invented or tested yet). The fact that environmental impacts on Mars are unknown also makes it nearly impossible to calculate the right amount of damages. *Id.*

149. Liability Convention, *supra* note 32, at art. XII.

150. *See* Gerrard & Barber, *supra* note 80, at 37–38 (applying the same analysis to their discussion of a planetary defense system that only a few nations might be able to build in order to detect near-Earth objects).

might also be justified if Musk is viewed as coming to the aid of an entire planet.[151]

The Liability Convention might influence the level of national government regulation over a nuclear terraforming mission on Mars and Musk's willingness to pursue the mission in the first place.[152] For example, the United States adjusted its regulation of non-government space launches and reentries in the late 1980s to protect itself against liability for damages under the Liability Convention and to make private U.S. space entities more competitive with respect to their European counterparts.[153] While the degree to which a private actor like Musk could be liable for damages arising from detonating nuclear devices over Mars is unclear, it is unlikely that he would be absolutely liable.[154] That kind of reassurance does not necessarily make things easier for Musk. Non-government space activities with potentially huge consequences like planetary transformation would probably spur the United States or any other participating government with regulatory jurisdiction over those activities to monitor and control all aspects of their execution with great care, especially since damages under the Liability Convention are not capped.[155] But even if the Liability Convention creates incentives to exercise high levels of regulatory control over a non-government terraforming project on Mars, the treaty does not create a legal bar that prevents that kind of mission altogether.

151. *Id.*; *see also* Andersen, *supra* note 5 (discussing Musk's theory that interplanetary colonization is essential for human survival).

152. A discussion of how the United States regulates private space activity and apportions liability to private spaceflight operators under the Liability Convention and the Outer Space Treaty is found in Section IV.B, *infra*.

153. *See* Timothy Robert Hughes & Esta Rosenberg, *Space Travel Law (and Politics): The Evolution of the Commercial Space Launch Amendments Act of 2004*, 31 J. SPACE L. 1, 16–17 (2005) (highlighting the enactment of legislation in 1988 partially indemnifying private U.S. space companies in the event of a catastrophic accident to assuage industry fears of unlimited financial liability, which had stifled private space development in the United States relative to European competitors that already enjoyed government indemnification).

154. Tse, *supra* note 48, at 303–05.

155. The Outer Space Treaty requires state signatories to continually supervise all non-governmental space entities within their jurisdiction, which suggests tight regulation over all aspects of Musk's proposal from Earth to Mars. *See* Outer Space Treaty, *supra* note 31, at art. II. Spacefaring nations like United States are keenly aware that they bear international responsibility for national activities in outer space and are internationally liable for any damages without limit. *See* Hughes & Rosenberg, *supra* note 153, at 15.

E. The Registration Convention

The Registration Convention was ratified in 1975 and requires each launching state sending spacecraft into Earth's orbit or farther into outer space to maintain a registry of those objects.[156] The Registration Convention defines a launching state in much the same way as the Liability Convention.[157] Registration of a space object with a launching state grants that state jurisdiction and control over both the spacecraft and any personnel.[158] Jurisdiction and control over a space object is the principal determinant of liability for any damages.[159] When there are two or more launching states, the Registration Convention requires all participants to determine among themselves how space objects are to be registered.[160] In those situations, the state of registry is not automatically liable for damages caused by the spacecraft, because all participating states are free to negotiate who maintains jurisdiction and control over any space object, regardless of on whose registry it is listed.[161] However, the state of registry is most likely to be held liable for any damage caused by a spacecraft.[162]

Even though nothing in the Registration Convention prohibits Musk from pursuing a nuclear terraforming mission on Mars, the treaty could influence how participating state actors negotiate oversight duties and apportion liability for that kind of mission. As noted above, the liability regime set forth in the Liability Convention would likely induce participating national governments like the United States to regulate tightly all aspects of a nuclear terraforming mission on Mars.[163] However, the prospect of heavy government regulation and control merely affects the cost-benefit analysis for entrepreneurs like Musk. The Registration Convention

156. *See generally* Registration Convention, *supra* note 34.

157. *Compare* Registration Convention, *supra* note 34, at art. I, *with* Liability Convention, *supra* note 32, at art. I.

158. Beck, *supra* note 28, at 16 (citing Outer Space Treaty, *supra* note 31, at art. VIII).

159. *See* Outer Space Treaty, *supra* note 31, at art. VII; Liability Convention, *supra* note 32, at arts. I–II.

160. Registration Convention, *supra* note 34, at art. II.

161. *Id.* Because recoverable compensation is unlimited under the Liability Convention, negotiations among governments participating in a nuclear terraforming project would probably focus on the amount of financial risk a particular government might be willing to accept given its pro rata contribution of resources to the project. *See* Liability Convention, *supra* note 32, at art. IV.

162. *See* Beck, *supra* note 28, at 16.

163. *See* note 155, *supra*, and accompanying text.

does not impose an outright legal restriction on Musk's proposal to conduct a nuclear terraforming project on Mars.

F. International Environmental Law

Pursuant to articles III and IX of the Outer Space Treaty, all activities related to the exploration and use of outer space must be carried out in accordance with international environmental law, which includes protection of the outer space environment.[164] Article IX of the Outer Space Treaty specifically provides that all public or private space missions must avoid harmful environmental damage not only on Earth, but also on any celestial body.[165] That requirement makes sense because the control and prevention of transboundary environmental harm is well settled in customary international law.[166] The Rio Declaration, adopted by consensus at the U.N. Conference on Environment and Development in 1992, is perhaps the most widely endorsed expression of the law in this area.[167] The Articles on Transboundary Harm from Hazardous Activities written by the International Law Commission ("ILC") also provide important guidance on nationally sponsored activities with transboundary environmental risks.[168]

International law governing transboundary environmental impacts can be summarized by two primary rules.[169] First, states have a duty to prevent, reduce, and control transboundary environmental harm from activities within their jurisdiction and control.[170] Second, states have a duty to cooperate with each other in mitigating transboundary environmental risks through notification, consultation, and negotiation with other countries.[171]

164. Outer Space Treaty, *supra* note 31, at arts. III, IX; *accord* COLOGNE COMMENTARY, *supra* note 47, at 176–77.

165. Outer Space Treaty, *supra* note 31, at art. IX.

166. *See* Günther Handl, *Transboundary Impacts*, *in* THE OXFORD HANDBOOK OF INTERNATIONAL ENVIRONMENTAL LAW 531, 532 (Daniel Bodansky, Jutta Brunnee & Ellen Hey eds., 2007). The ICJ has also endorsed the prohibition of transboundary injurious use of natural resources. *Id.* at 533–34.

167. *See* BIRNIE, BOYLE, & REDGWELL, *supra* note 101, at 112.

168. *See generally* Draft Articles on Prevention of Transboundary Harm from Hazardous Activities, Report of the International Law Commission on the Work of Its Fifty-third Session, U.N. GAOR, 56th Sess., Supp. No. 10, at 370, U.N. Doc. A/56/10 (2001) [hereinafter 2001 Transboundary Harm Principles].

169. *See* BIRNIE, BOYLE, & REDGWELL, *supra* note 101, at 137.

170. *Id.*

171. *Id.* This principle is expressed in article IX in the Outer Space Treaty, which addresses the mechanism of international consultation with regard to the avoidance of

Neither of these rules categorically prohibits nationally sponsored activities that may cause transboundary environmental harm: even where an activity might be harmful, it does not automatically mean that activity is legally prohibited.[172] Thus, if the use of fusion nuclear devices over the Martian poles does carry a risk of transboundary environmental harm to other countries, that fact alone does not automatically render such activity illegal.

1. Preventing, Controlling, and Reducing Transboundary Environmental Impacts

The Rio Declaration contains three provisions that directly address transboundary environmental impacts, shedding some clarification on the obligations to prevent, reduce, and control any environmental risks associated with Musk's proposal. Principle 2 provides that "[s]tates have . . . the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other [s]tates or of areas beyond the limits of national jurisdiction."[173] Principle 18 requires states to provide notification of certain activities or events likely to produce harmful effects on the environments of other states.[174] Principle 19 requires states to give prior notification and consult in good faith with the international community before undertaking activities that may have significant transboundary environmental effects.[175]

Two additional provisions in the Rio Declaration are also relevant in evaluating the obligation to prevent, reduce, and control environmental damage resulting from a terraforming mission on Mars, even though they do not explicitly refer to transboundary impacts. Principle 17 provides that "[e]nvironmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a

potentially harmful interference in outer space. *See* COLOGNE COMMENTARY, *supra* note 47, at 179. Any spacefaring entity that plans an activity or experiment in outer space must, prior to the planned mission, engage in appropriate consultation with other countries if it has reason to believe that the activities might have harmful transboundary effects. *Id.*

172. *See* Handl, *supra* note 166, at 535.

173. Rio Declaration, *supra* note 36, at princ. 2.

174. *Id.* at princ. 18.

175. *Id.*

competent national authority."[176] Principle 15 states "[w]here there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."[177] The precautionary approach embodied in principle 15 means that action should be taken to control or abate the possible environmental harm arising from that activity even if there is scientific uncertainty about its likelihood.[178] Principle 15 can also be applied to situations where potentially dangerous effects of an activity have been identified, but the exact magnitude of the environmental harm has not been proven.[179] In all cases, there still has to be at least some scientific basis for predicting the risk of harmful environmental impacts.[180]

The Rio Declaration embodies the prevailing view—elaborated further by the ILC and the ICJ—that state-based environmental impact assessments ("EIAs"), and international notification and consultation are the main legal tools to prevent or minimize the risk of adverse transboundary environmental harm in outer space. A threshold of foreseeability must be met before a formal EIA is obligatory.[181] The requirement to notify other states following an EIA arises only when transboundary harm is foreseeable.[182] For activities with foreseeable transboundary impacts, the necessity of an EIA and subsequent notification is all but presumed under international law, even if the risk is small.[183] Regardless, states are actually enjoined from engaging in certain activities only when those activities will likely have transboundary impacts that are significant.[184] This qualification is important: a state is only

176. *Id.* at princ. 17. Moreover, the 2001 Transboundary Harm Principles provide that "[a]ny decision in respect of the authorization of an activity . . . shall, in particular, be based on an assessment of the possible transboundary harm caused by that activity." *See* 2001 Transboundary Harm Principles, *supra* note 168, at art. 7.

177. Rio Declaration, *supra* note 36, at princ. 15.

178. *See* BIRNIE, BOYLE, & REDGWELL, *supra* note 101, at 154–58.

179. *Id.* at 156.

180. *Id.*

181. *Id.* at 171.

182. Handl, *supra* note 166, at 539, 542.

183. *See* BIRNIE, BOYLE, & REDGWELL, *supra* note 101, at 171.

184. "Significant harm" has no bright line definition. *See* Handl, *supra* note 166, at 535–40. Whether transboundary impacts cross the legal threshold of "significant harm" depends on multiple factors, including the likelihood of occurrence and the magnitude of damage. *Id.* at 539. Harm must be more than "*de minimis*, trivial, or simply detectable." *Id.* at 535 (internal quotation marks omitted).

obliged to restrict activities with *significantly* harmful transboundary effects that are reasonably foreseeable.

The extent to which the foregoing principles would require limiting the use of fusion nuclear devices over Mars is an open question. The precautionary approach enshrined in principle 15 of the Rio Declaration provides some guidance. Many environmental problems "involve harm which is subtle, cumulative, and manifest only after a long period of time; in these circumstances" only preventative reviews may be capable of mitigating long-term transboundary harm.[185] The environmental consequences of a nuclear terraforming project on Mars are still theoretical,[186] leaving open the possibility of harmful transboundary impacts on Earth—or even the entire solar system—over a long period of time.[187] If the precautionary protocols in principle 15 apply to all activities in outer space, categorical prohibition of a nuclear terraforming mission on Mars might be the sensible course of action given the uncertainty and conceivable irreversibility of the endeavor.

On the other hand, because the full panoply of environmental outcomes of transforming a planetary atmosphere is unknown, the legal obligation to restrain or prohibit such activity is blurry. Not only might Earth's environment be unaffected or unharmed by activity that occurs millions of miles away on Mars, but destructive consequences in outer space are not guaranteed.[188] It is therefore unclear that the instruments of international environmental law require the prohibition of a nuclear terraforming project on Mars, unless and until the environmental ramifications of that kind of activity are more fully understood. Even if an EIA identified foreseeable harm arising from a nuclear terraforming project on Mars, the sponsoring state is not restricted from allowing such activity unless the harm is determined to be significant. Some

185. *See* BIRNIE, BOYLE, & REDGWELL, *supra* note 101, at 212.

186. *See* Jauregui, *supra* note 25 ("[T]he physics behind Musk's plan haven't been worked out fully, [but] modern science may hold the key to making it work . . . ."); Wagstaff, *supra* note 3 ("Even the most advanced computer simulations would have trouble predicting the aftermath of starting a runaway greenhouse effect.").

187. For example, nuclear reactions in outer space could release electromagnetic pulses that impact the nearby area. *See* COLOGNE COMMENTARY, *supra* note 47, at 76 (discussing the destructive impact of nuclear explosions on manmade satellites by means of electromagnetic shock).

188. *See* Wagstaff, *supra* note 3 (noting that modern thermonuclear devices "can be designed to leave very little fallout").

experts hypothesize that the effects of a nuclear explosion on Mars would be fleeting,[189] suggesting the environmental effects of a nuclear device on Mars might not be significant.

2. Notifying, Consulting, and Negotiating With the International Community

International cooperation is the second essential component of managing transboundary environmental risks, and is therefore an important aspect of reviewing and approving a terraforming mission on Mars. As implied above, nobody—including Musk—is free to put common areas like outer space at risk without taking into account the interests of the international community.[190] The negotiation and consultation processes to manage possible transboundary environmental risks in outer space have not been formally established.[191] But customary international practice grants potentially affected states the right to participate in a national EIA, to the extent of being provided scientific data, contributing to the review, and trying to influence its ultimate conclusion.[192]

The power of multilateral participation in the environmental review process is limited. The EIA is, after all, a national procedure for evaluating the likely impact of a proposed activity on the environment.[193] States are not legally barred from creating environmental risk to others, "even where, as in the case of nuclear installations [on Earth], these involve the possibility of serious harm."[194] An adverse assessment by a participating foreign government places no affirmative duty on the proposing state to refrain from proceeding with the project because affected states that participate in the review process have no veto power.[195] An obligation to cooperate with other states will not necessarily "impose substantive limitations on the activities that states propose

189. *See* Jauregui, *supra* note 25 (quoting Dr. Seth Shostak, senior astronomer at the SETI Institute: "Nuclear explosions, as photogenic as they are, are transient. A few weeks after the megaton mushrooms, Mars might just revert to its former, inhospitable self.").

190. *See* BIRNIE, BOYLE, & REDGWELL, *supra* note 101, at 178; *accord* Outer Space Treaty, *supra* note 31, at art. IX.

191. BIRNIE, BOYLE, & REDGWELL, *supra* note 101, at 177–80 (discussing the still evolving international system of environmental negotiation and consultation processes in general).

192. *Id.*

193. A detailed discussion of the EIA process under U.S. law, which arguably would apply to a terraforming mission on Mars spearheaded by Musk, is found in Section IV.C.1, *infra*.

194. *See* BIRNIE, BOYLE, & REDGWELL, *supra* note 101, at 179.

195. *Id.*

to undertake," nor must they "refrain from acting if negotiations prove unsuccessful," because the EIA process does not require prior joint approval of a proposed activity.[196]

Ironically, non-environmental considerations might give the international community more leverage to override a terraforming mission on Mars via the environmental review process. States are free to take into account whatever they deem relevant when negotiating the transboundary environmental parameters of any particular activity, subject only to the underlying duty to negotiate in good faith.[197] Relevant factors could extend beyond just environmental concerns.[198] The use of nuclear technology on Mars would likely be a major point of international contention, not least because any harm resulting from a nuclear-induced atmospheric transformation on Mars could be irreversible. Global supervision in the environmental review process might be one way to avoid costly economic or foreign policy repercussions of moving forward with a terraforming project on Mars if it received strong opposition from the international community. A national government body sponsoring the review and regulation of Musk's nuclear proposal for Mars is best served by negotiating consensus outcomes with its international partners. Global collaboration adds an element of uncertainty to the legal effect of international environmental law principles on Musk's proposal for Mars, but there does not appear to be a clear prohibition against his idea if people are on board with it.

G. Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques

Entered into force in October 1978, the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques ("ENMOD")[199] prohibits the use of environmental modification techniques "having widespread, long-lasting or severe effects as the means of destruction, damage or

196. *Id.*

197. *Id.* at 180.

198. *See id.*

199. *See generally* Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, *opened for signature* May 18, 1977, 31 U.S.T. 333, 1108 U.N.T.S. 152 [hereinafter ENMOD].

injury to any other State Party."[200] The term "environmental modification technique" refers to any technique that deliberately changes the "dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space."[201]

The deployment of a nuclear device capable of modifying a planetary atmosphere on Mars may be considered an act of bad faith that undermines the purpose of ENMOD.[202] But that conclusion rests on the assumption that such a device sent into outer space is intended for use as a weapon.[203] ENMOD prohibits environmental alterations as means of warfare, but it does not address damage to the environment generally or provide for protection of the environment itself from collateral damage from a peaceful, non-military mission.[204] Moreover, the treaty only contemplates environmental damage to Earthly environments.[205] As suggested earlier, detonation of fusion nuclear devices over the polar regions of Mars might not have a harmful effect on Earth at all.[206] ENMOD does not appear to prohibit Musk's proposed use of nuclear devices on Mars because he does not have a hostile purpose to injure others.[207]

IV. THE UNITED STATES LEGAL REGIME

In addition to international instruments of outer space law, national governments have developed their own legal frameworks to regulate non-government activities in outer space. National space law is critically important due to the increasing

200. *Id.* at art. I.

201. *Id.* at art. II.

202. *See* Michael C. Mineiro, *The United States and the Legality of Outer Space Weaponization: A Proposal for Greater Transparency and a Dispute Resolution Mechanism*, 303 ANNALS AIR & SPACE L. 441, 459 (2008) ("The deployment of a space weapon capable of . . . [widespread, long-lasting, or severe] environmental modification may be considered a violation of the principle *pacta sunt servanda*, an act in bad faith undermining the purpose and objective of [ENMOD].")

203. *See id.*

204. *See* John Alan Cohen, *Modes of Warfare and Evolving Standards of Environmental Protection Under the International Law of War*, 15 FLA. J. INT'L L. 481, 511 (2003).

205. ENMOD, *supra* note 199, at arts. I–II (defining prohibited environmental modification in outer space as it relates to damage of other State parties on Earth).

206. *See* Wagstaff, *supra* note 3 ("[M]odern thermonuclear weapons can be designed to leave very little fallout . . . and wouldn't pose much danger centuries after they hit.").

207. *Id.*

participation of non-government entities in space activities, and the need to make sure those activities are properly supervised.[208] Some nations have already adopted unique regulations to address the specific needs and practical considerations of the growing number of non-government missions.[209] National legal systems complement the international rules governing outer space.[210]

U.S. law is relevant to Musk's nuclear idea for Mars for three reasons. First, all state parties to the Outer Space Treaty bear responsibility for non-government activities in outer space because such activities require "authorization and continuing supervision" by the appropriate government.[211] Musk conducts rocket launches and other outer space activities via SpaceX, a U.S. company,[212] and is therefore in the legal orbit of the U.S. government. Licensing by federal agencies is how the United States satisfies its treaty obligations to authorize and continually supervise the space activities of non-government entities.[213] Second, domestic legislation in the United States pertaining to non-government space activity is persuasive authority for the development of international space law because the United States is a major spacefaring nation.[214] And because the United States arguably possesses the most complete and comprehensive set of outer space regulations in the world,[215] its legal mechanisms for handling complex proposals from a prolific entrepreneur like Musk could be the most useful international model. Third, the architecture of outer space legal regulation has evolved from an international treaty regime overseeing the exploration and use of outer space by

208. *National Space Law*, U.N. OFF. OUTER SPACE AFF., http://www.unoosa.org/oosa/en/ourwork/spacelaw/nationalspacelaw.html [http://perma.cc/55RR-492M] (last visited Jan. 8, 2016).

209. *Id.*

210. *Id.*

211. *See* Outer Space Treaty, *supra* note 31, at art. VI. The Constitution "mandates that a properly ratified treaty is the 'supreme law of the land,' creating an interface between United States domestic law and international space treaties." Gabrynowicz, *supra* note 45, at 1047.

212. *See* SPACEX, http://www.spacex.com/about [http://perma.cc/EM7N-DNYP] (last visited Jan. 5, 2016).

213. 161 CONG. REC. H3513 (daily ed. May 21, 2015) (letter from Joanne Irene Gabrynowicz submitted for the record by Rep. Edwards).

214. *See* Gabrynowicz, *supra* note 45, at 1047 (pointing out that the practices of strong maritime nations in the past influenced the development of international maritime law).

215. 161 CONG. REC. H3518–19 (daily ed. May 21, 2015) (letter from Henry R. Hertzfeld, Matthew Schaefer & James C. Bennett submitted for the record by Rep. Posey).

national governments to one dependent on nation-by-nation regulation of privately managed outer space activities.[216]

A. Regulation of Non-Government Space Activity Before 2015

Regulation of the private space industry in the United States lifted off in the mid-1980s. In 1984, Congress passed the Commercial Space Launch Act ("CSLA"),[217] laying the foundation for regulation over non-government space activities.[218] CSLA's purpose was to encourage and promote unmanned commercial launches into space by the private sector, subject to licensing requirements promulgated by the federal government.[219] CSLA gave the Department of Transportation ("DOT") statutory power to administer licensing protocols, a responsibility delegated to the DOT's newly created Office of Commercial Space Transportation ("OCST").[220] Issuance of private launch licenses was allowed only if private spacecraft and their payloads satisfied public safety criteria and the proposed launch did not contradict U.S. national security or foreign policy objectives.[221] CSLA also allowed use of U.S. government property and services by private licensees and required each licensee to purchase liability insurance.[222]

The adoption of new legislation concerning private space activities continued in the late 1980s and 1990s. In 1988, Congress amended CSLA to replace its previous liability insurance system,

216. Gabrynowicz, *supra* note 45, at 1051. The U.N. has also noted that effective laws and policies on space activities are not just created on an international level, but on a national level too. *See, e.g.*, U.N. Office for Space Affairs on United Nations/Republic of Korea Workshop on Space Law, U.N. Doc. ST/SPACE/22 (2004), http://www.unoosa.org/res/oosadoc/data/documents/2004/stspace/stspace22_0_html/st_space_22E.pdf [http://perma.cc/7H2S-RG6H].

217. Commercial Space Launch Act of 1984, Pub. L. No. 98-575, 98 Stat. 3055 (codified as amended in scattered sections of the U.S.C.).

218. *See* Hughes & Rosenberg, *supra* note 153, at 11–12.

219. Commercial Space Launch Act of 1984, § 3(1)–(3).

220. *See* Hughes & Rosenberg, *supra* note 153, at 13 n.41. The OCST was established in 1984 as part of the Office of the Secretary of Transportation within the DOT. *See About the Office*, FED. AVIATION ADMIN., https://www.faa.gov/about/office_org/headquarters_offices/ast/about/ [http://perma.cc/N86X-LXCL] (last visited Jan. 10, 2015). In November 1995, the office was transferred to the Federal Aviation Administration as the agency's only space-related line of business. *Id.*

221. Commercial Space Launch Act of 1984, § 6(b)(1)–(2). The DOT issued additional licensing regulations in 1988, asserting jurisdiction over manned and unmanned launches. *See* 40 C.F.R. §§ 400–15 (2016).

222. Commercial Space Launch Act of 1984, § 16.

allowing the U.S. government to partially indemnify private licensees in the event of a catastrophic accident.[223] All launch participants were allowed to waive potential legal claims against each other but were financially responsible for any losses up to a certain point determined by the Federal Aviation Administration ("FAA"), after which the U.S. government would cover them.[224] This liability and indemnification regime, which protected private space entities against unlimited liability exposure, remains in effect today.[225] In 1998, Congress granted the FAA explicit statutory authority to license the reentry of privately operated space vehicles into Earth's atmosphere and to indemnify the operators of those reentering vehicles, just in the same way the FAA had regulated launch licenses.[226] Incremental licensing jurisdiction allowed the FAA to keep pace with advancing space technology, which had progressed to the point where private companies had the capability not only to launch spacecraft, but to bring them back to Earth.[227]

Domestic space policy was refined in 2004 to address a "belief in the commercial market" for private space activities and the regulation of those activities by the government.[228] That year, Congress passed the Commercial Space Launch Amendments Act ("CSLAA"), formally authorizing private and commercial passengers to engage in suborbital space travel, and establishing a licensing regime for these kinds of endeavors under the auspices of the FAA.[229] Importantly, CSLAA included an eight-year moratorium, dubbed a "regulatory learning period," which prohibited the FAA from issuing safety regulations concerning the design and operation of privately licensed spaceflight systems for

223. Commercial Space Launch Amendments Act of 1988, Pub. L. No. 100-657, 102 Stat. 3900 (codified as amended scattered sections of the U.S.C.).

224. Hughes & Rosenberg, *supra* note 153, at 16–18.

225. *Id.* (noting that U.S. government indemnification makes sense not only to assuage investor fears of unlimited liability, but to satisfy treaty obligations under the Liability Convention).

226. Commercial Space Act of 1998, Pub. L. No. 105-303, 112 Stat. 2843. As described in note 220, *supra*, the FAA had taken over the licensing responsibilities of the OCST three years earlier in 1995.

227. *See* Joanne Irene Gabrynowicz, *One Half Century and Counting: The Evolution of U.S. National Space Law and Three Long-Term Emerging Issues*, 4 HARV. L. & POL'Y REV. 405, 421 (2010).

228. *Id.* at 412–13 (discussing the growth of the space tourism industry).

229. *See generally* Commercial Space Launch Amendments Act of 2004, Pub. L. No. 108-492, 118 Stat. 3974 (codified as amended in scattered sections of the U.S.C.).

the sole purpose of protecting human passengers.[230] This provision reflected the general attitude underlying CSLAA that the DOT should not overregulate the private spaceflight industry before it has the opportunity to grow.[231] Even though NASA had regulated outer space activity for a long time, U.S. lawmakers believed that the DOT was ill equipped to exercise complete regulatory authority over for-profit space companies developing their own spaceflight systems.[232] CSLAA attempted to balance the needs of the private space industry to evolve in a regulatory environment that neither stifled innovation nor exposed the public to excessive risk.[233]

Under current U.S. law, the FAA is the lead federal agency within the DOT for regulatory guidance pertaining to private space activity.[234] Because the first regulations over non-government space entities were issued in the 1980s—when no appreciable private missions were taking place—the DOT developed a flexible process intended to be responsive to an emerging industry.[235] Currently, all vehicles traveling into space or reentering Earth's atmosphere have to be approved by the FAA's Office of Commercial Space Transportation ("FAA/AST"). To obtain a license, private applicants must obtain policy[236] and general public safety[237] approvals from FAA/AST. Applicants must also provide sufficient information concerning the environmental impacts associated with

230. *See* Hughes & Rosenberg, *supra* note 153, at 45. This limitation only applies to spaceflights carrying human beings, and the DOT still retained the authority to regulate design and operation of a private launch vehicle to protect the general public. *See id.* In 2012, Congress extended the moratorium because there was still a great deal of testing and data to gather on human launch systems. *See* FAA Modernization and Reform Act of 2012, Pub. L. No. 112-95, § 827, 126 Stat. 11, 133.

231. H.R. REP. NO. 114-119, at 22 (2015).

232. *Id. See also* Hughes & Rosenberg, *supra* note 153, at 46–48 (citing commentary from House lawmakers during floor debates over the provisions of CSLAA).

233. *See* Michael C. Mineiro, *An Intersection of Air and Space Law: Licensing and Regulating Suborbital Commercial Human Space Flight Operations*, AIR & SPACE LAW., Vol. 22, No. 4, 2010, at 9, 9–10.

234. *See* Maria-Vittoria Giugi Carminati, *Breaking Boundaries by Coming Home: The FAA's Issuance of a "Reentry License" to SpaceX*, AIR & SPACE LAW., Vol. 24, No. 2, 2011, at 8, 9.

235. 65 Fed. Reg. 62,812, 62,813 (Oct. 19, 2000).

236. During a policy review, the FAA consults with the DOD, Department of State, NASA, and other federal agencies to determine the impact of a launch or reentry on the United States' national security, foreign policy interests, and international obligations. *See* 14 C.F.R. § 431.23 (2016).

237. During a public safety review, the FAA determines whether a launch or reentry of a private space vehicle can be accomplished without jeopardizing public safety and the safety of property, which is measured by a pre-determined mathematical risk threshold defined by the FAA. *See* 14 C.F.R. §§ 431.31–.35 (2016).

a launch or reentry to enable the FAA to comply with the National Environmental Policy Act ("NEPA"), the Council on Environmental Quality Regulations for Implementing the Procedural Provisions of NEPA, and its own procedures for considering environmental impacts.[238] All space missions involving nuclear technology must also undergo a specialized, multi-agency review process.[239]

In spite of meaningful legal developments between 1984 and 2004, no unified regime to regulate all non-government space activity has been established in the United States. The FAA/AST regulates private spacecraft and payload launches, reentries, and operations of launch sites, but its current licensing power does not apply to orbital or in-space operations: anything done in outer space following completion of a launch and before reentry into Earth's atmosphere is not covered.[240] The Federal Communications Commission ("FCC") regulates satellites in orbit and negotiates international space policy.[241] The Department of State handles registration of satellite and satellite part exports under the International Traffic in Arms Regulation.[242] Decentralized regulation in the United States has created uncertainty about the exact rights and responsibilities of private space entrepreneurs like Musk.[243]

238. *See* 14 C.F.R. §§ 431.91–.93 (2016). NEPA requires all branches of the U.S. government to give proper consideration to the environment prior to undertaking any major federal action that significantly affects the environment. *See* National Environmental Policy Act, 42 U.S.C. §§ 4321–70h (2012). CEQ was created by NEPA to review the federal government's various programs and activities in light of the Act's policies and issues mandatory regulations binding upon federal agencies in the implementation of NEPA's procedural provisions. *See* Exec. Order No. 11991, 3 C.F.R. § 123 (1978).

239. *See infra* Section IV.C.2.

240. *See* Hughes & Rosenberg, *supra* note 153, at 21, 48–50 (noting that CSLAA allowed FAA to license launches, reentries, and use of U.S. government space facilities, but not on-orbit operations).

241. *See* Commercial Space Transportation Regulations, 14 C.F.R. §§ 404, 413, 420 (2016).

242. *See* International Traffic in Arms Regulations, 22 C.F.R. §§ 120–30 (2016).

243. *See, e.g.*, Leonard David, *Moon Space Law: Legal Debate Swirls Around Private Lunar Ventures*, SPACE.COM (Feb. 24, 2015), http://www.space.com/28645-moon-space-law-lunar-legal-debate.html [http://perma.cc/Q9RR-ENSY] (noting that, despite the FAA's recent approval of a payload review request by the privately-held Bigelow Aerospace, investors still hesitate to develop financial and technical capacity to build industry on the moon without a clearer legal framework).

B. The SPACE Act of 2015

1. Legislative History

On November 25, 2015, President Obama signed into law the U.S. Commercial Space Launch Competitiveness Act ("SPACE Act"),[244] which contains favorable space regulations for private entrepreneurs looking to expand into outer space.[245] The final version of the SPACE Act established a number of legal provisions applicable to private industry actors, including—most notably—ownership rights over resources obtained from celestial bodies. Title IV states that a U.S. citizen "engaged in commercial recovery of an asteroid resource or a space resource . . . shall be entitled to any . . . space resource obtained, including to possess, own, transport, use, and sell the asteroid resource . . . ."[246] Some have characterized this provision as "the single greatest recognition of property rights in history."[247] The SPACE Act extended the same liability and indemnification regime established in the CSLA until 2025.[248] The SPACE Act also provided an extension until 2023 of the CSLAA's "regulatory learning period" in which the FAA is prohibited from issuing human passenger safety regulations on private space vehicles.[249] Finally, the SPACE Act requires the White House Office of Science and Technology Policy ("OSTP"), in consultation with the Secretary of State, NASA, and other relevant federal agencies, to identify current and future non-government

244. SPACE Act of 2015, Pub. L. No. 114-90, 129 Stat. 704. The SPACE Act originated in the House of Representatives as H.R. 2262 (the "Spurring Private Aerospace Competitiveness and Entrepreneurship Act"), a bill introduced by Representative Kevin McCarthy (R-CA) and eleven Republican co-sponsors on May 12, 2015. S. REP. NO. 114-88, at 5 (2015). Meanwhile, Senator Ted Cruz (R-TX), the chairman of the Space, Science, and Competitiveness Subcommittee of the Senate Committee on Commerce, Science, and Transportation, had introduced S. 1297—a companion bill identical to Rep. McCarthy's original version of H.R. 2262—on May 12, 2015. *Id.* at 4. Differences between the House and Senate bills were resolved on November 10, 2015, when S.A. 2805—an amendment merging the language of H.R. 2262 and S. 1297—was submitted to the Senate floor. *See* 161 CONG. REC. S7933 (daily ed. Nov. 10, 2015).

245. *See, e.g.*, *President Obama Signs Bill Recognizing Asteroid Resource Property Rights into Law*, PLANETARY RESOURCES (Nov. 25, 2015) [hereinafter PLANETARY RESOURCES], http://www.planetaryresources.com/2015/11/president-obama-signs-bill-recognizing-asteroid-resource-property-rights-into-law/ [http://perma.cc/8VWL-9Z7U].

246. SPACE Act § 402.

247. PLANETARY RESOURCES, *supra* note 245 (quoting Eric Anderson, co-founder and co-chairman of Planetary Resources, Inc.).

248. SPACE Act §§ 102–103.

249. *Id.* § 111(9).

outer space activities and recommend how, and by whom, those activities should be regulated.[250]

A closer look at the evolution of the SPACE Act as it progressed through the House and Senate uncovers some controversial legal issues regarding the appropriate level of U.S. government regulation over non-government activities in space, which are relevant to any outer space project spearheaded by Musk. Chief among the concerns is the continuation of the moratorium on the FAA's ability to fix explicit safety protocols concerning human passengers on private spacecraft—an intentionally limited form of regulation.[251] During the House floor debate, Rep. Donna Edwards (D-MD) argued that a "regulation-free" period for safety requirements puts no pressure on private space operators to establish industry-wide standards that could be used as an important tool for self-regulation.[252] Dissatisfaction about restraining the FAA's regulatory oversight of private space activity in this way is not new.[253] Moreover, Rep. Eddie Bernice Johnson (D-TX) argued that the SPACE Act is incongruous because it simultaneously deems the private space industry as developed enough to carry out complicated outer space missions, but not developed enough to allow complete regulation by the FAA.[254]

House opponents of the SPACE Act also attacked its legal compliance with the Outer Space Treaty due to the grant of private property rights to celestial resources. Whether the exploration and use of outer space includes the right to remove, take possession,

250. *Id.* § 108.

251. 161 CONG. REC. H3512–14 (daily ed. May 21, 2015) (statement of Rep. Edwards).

252. *Id.* Moreover, said Rep. Edwards, the fact that all participants in a privately run outer space mission waive legal claims against each other while enjoying partial indemnification from the U.S. government decreases an incentive to ensure space missions are carried out as safely as possible. *Id.*

253. For example, in 2004 during the House floor debate over CSLAA, former Rep. James Oberstar (D-MN) argued that postponing FAA regulation of the passenger safety standards of launch and operation of private spaceflight vehicles constituted a dangerous "tombstone mentality." *See* Hughes & Rosenberg, *supra* note 153, at 47–48 (citing 150 CONG. REC. H100150 (daily ed. Nov. 19, 2004)).

254. 161 CONG. REC. H3515 (daily ed. May 21, 2015) (statement of Rep. Johnson). In 2014, about six months before a fatal crash involving Virgin Galactic's *SpaceShipTwo* suborbital tourism vehicle, George Nield, head of the FAA/AST, testified before Congress that the government has enough data to begin crafting safety regulations for the budding commercial spaceflight industry and that it would be "irresponsible" not to. Dan Leone, *Senate Bill Would Again Delay Full Commercial Space Regulation*, SPACE NEWS (May 7, 2015), http://spacenews.com/senate-bill-would-again-delay-commercial-space-regulation/#sthash.Caw2GiyC.dpuf [http://perma.cc/HLT6-XEYP].

and use in-situ natural resources from celestial bodies is a long-standing debate among U.S lawmakers.[255] During the House floor debate, Rep. Edwards asserted that the grant of private property rights over tangible resources obtained from celestial bodies violates the non-appropriation principle in article II of the Outer Space Treaty.[256] Under this theory, allowing space resources to become the property of private entrepreneurs subject to U.S. federal law constitutes national appropriation by the U.S. government.[257] And it was argued that Congress was "not at all close" to resolving the issue.[258] Rep. Johnson suggested that more Congressional hearings and committee meetings were needed to determine whether property rights over space resources were legally permitted under the Outer Space Treaty.[259]

Despite claims that the House version of the SPACE Act would be dead on arrival in the Senate,[260] the Senate's amended version kept most of its provisions intact. Apprehension about anemic regulation over private space activity was ameliorated to some extent by interim reporting requirements built in to the final version of the SPACE Act. The DOT, in consultation with the commercial space sector (including the FAA) is required to submit biennial reports to both the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House, identifying "industry metrics that might indicate readiness of the commercial space sector and the [DOT] to transition to a safety framework that may include

255. In 1980, for example, at the second session of hearings on the Moon Agreement, the legal adviser to the Department of State, Robert Owens, during testimony before the Senate Subcommittee on Science, Technology and Space, stated,

> The United States has long taken the position that Article I of [the Outer Space Treaty] . . . recognizes the right of exploitation. We were and are aware, however, that this view is not shared by all States or commentators, some of whom take the position that the nonappropriation provisions in Article [II] of [the Outer Space Treaty] preclude exploitation of celestial natural resources and the reduction to private property.

H.R. REP. NO. 114-153, at 7–8 (2015).

256. *See* Outer Space Treaty, *supra* note 31, at art. II.

257. 161 CONG. REC. H3513 (daily ed. May 21, 2015) (letter from Joanne Irene Gabrynowicz submitted for the record by Rep. Edwards).

258. *Id.* at H3515 (statement of Rep. Johnson).

259. *Id.* (noting that only one Congressional hearing about space resource property rights was held during the 113th Congress).

260. *Id.* at H3530–31.

[more government] regulations."[261] DOT must also commission an independent report on the same subject for submission to the House and Senate by 2022.[262] The purpose of these provisions is to inform Congress in the future as to whether it should extend regulatory moratoriums over the private space industry, or impose more government regulation.[263] The amended Senate bill also required the White House's OSTP, in cooperation with relevant federal agencies, to identify current and future non-government outer space activities and recommend how, and by whom, those activities should be regulated.[264]

2. Legal Implications of Limited Regulatory Authority

Limited regulation over non-government space missions, like those in Title I of the SPACE Act discussed above, are not only legal in the United States but also satisfy the supervisory obligations under article VI of the Outer Space Treaty. The enactment of the CSLA's licensing provisions in 1984 established legal precedent in the United States for internationally compliant space regulation over private space activity, even in the absence of specific statutory law or regulation describing the particulars of the activity in question.[265] In fact, the FAA/AST has issued licenses to private space entities based on speculative technology,[266] which arguably sets a legal precedent allowing Musk to obtain a license to use fusion technology on Mars even before such technology exists. But the SPACE Act does not attempt to define if or to what extent the FAA/AST should be in charge of regulating non-government activities in space conducted by actors like Musk before more investigation is completed by the OSTP.[267]

Flexible licensing regulation not only enjoys considerable support from the private space industry,[268] but also is a pragmatic strategy to create a legal system in the United States that satisfies

261. *See* 161 CONG. REC. S7935 (daily ed. Nov. 10, 2015) (text of S.A. 2805).

262. *Id.*

263. H.R. REP. NO. 114-119, at 11–12 (2015).

264. *See* 161 CONG. REC. S7934 (daily ed. Nov. 10, 2015) (text of S.A. 2805).

265. 161 CONG. REC. H3518–19 (daily ed. May 21, 2015) (letter from Henry R. Hertzfeld, Matthew Schaefer & James C. Bennett submitted for the record by Rep. Posey).

266. *See* Hughes & Rosenberg, *supra* note 153, at 38 (discussing the FAA's license to XCOR Aerospace, Inc., allowing the company to conduct thirty-five suborbital space missions based on blueprints of a launch vehicle that had not yet been constructed).

267. *See* SPACE Act of 2015, Pub. L. No. 114-90, § 108, 129 Stat. 704, 707–08.

268. *See* 161 CONG. REC. H3519 (daily ed. May 21, 2015).

existing treaty obligations while giving private entrepreneurs the "framework they need to continue to innovate, and to keep the United States at the head of [the private commercial space industry]."[269] Enacting a comprehensive regulatory framework that addresses all possible contingencies in the private space industry is therefore unnecessary.[270] This means that not only is it legally possible for Musk to obtain a license even if his space vehicle payload contains speculative technology like fusion nuclear devices, but also the FAA/AST might not have the final say in the matter.[271]

3. Legal Implications of Private Ownership Over Celestial Resources

The majority of U.S. lawmakers also endorse the legality of Title IV, which grants ownership rights to private entities that obtain tangible resources from celestial bodies.[272] The Outer Space Treaty provides that outer space is free for exploration by all states without discrimination.[273] State governments are also encouraged to promote and facilitate scientific missions in outer space.[274] No celestial body is subject to national appropriation by claim of sovereignty.[275] But the establishment of a regime to equitably manage exploitation of space resources is a concept the Outer Space Treaty completely avoids.[276] In any event, the removal, possession, and use of in-situ natural resources from celestial bodies by spacefaring entities have been allowed many times in the past without legal objection.[277]

269. PLANETARY RESOURCES, *supra* note 245 (quoting U.S. Congressman Derek Kilmer (R-WA)).

270. 161 CONG. REC. H3518–19 (daily ed. May 21, 2015) (letter from Henry R. Hertzfeld, Matthew Schaefer & James C. Bennett submitted for the record by Rep. Posey).

271. This appears to defeat an argument that Musk would never be able to launch nuclear technology because the FAA/AST would not allow it. *See* Hasse, *supra* note 14.

272. *See* 161 CONG. REC. S7938 (daily ed. Nov. 10, 2015) (text of S.A. 2805).

273. Outer Space Treaty, *supra* note 31, at art. I.

274. *Id.*

275. *Id.* at art. II.

276. *See* Wohl, *supra* note 12, at 331.

277. *See* H.R. REP. NO. 114-153, at 8–9 (2015) (noting that the United States, Russia, and Japan have all removed, taken possession, and used lunar resources without any protest by another nation, and that there has never been an express finding by a court of law that such activities violate the non-appropriation provisions in article II of the Outer Space Treaty). Moreover, according to a 2011 report of the NASA Office of the Inspector General titled *NASA's Management of Moon Rocks and Other Astromaterials Loaned for Research, Education and*

National governments are also allowed to control and retain jurisdiction over objects and personnel sent to outer space, including objects landed or constructed on a celestial body.[278] U.S. lawmakers have construed the Outer Space Treaty as granting non-government entities the same rights to use and explore outer space that are given to national governments, as long as the non-government entities are regulated and continually supervised.[279] Thus, non-government entities that use and explore outer space arguably have a legal right to remove and use in-situ celestial resources, whether or not the end use of such resources is for private purposes.[280] The U.S. government's legal jurisdiction to regulate private U.S. entities would extend to in-situ outer space resources obtained by those entities without improperly "appropriating" the celestial bodies from which the resources were taken.[281]

Of course, Musk's proposal presents a different legal problem with respect to the non-appropriation restrictions of the Outer Space Treaty than does the extraction of in-situ natural resources from celestial bodies. The Outer Space Treaty does not clarify the exact scope of the U.S. government's legal authority to regulate private in-space activities because it does not attempt to categorize or define all types of non-government entities and activities.[282] And as discussed above, the FAA/AST's regulatory power is restricted because it does not apply to orbital or in-space operations, nor can it be concluded that the FAA/AST will have such power in the future.[283] The SPACE Act attempts to fill this void in part by requiring the OSTP to identify all current and future non-government space activities, with recommendations on the right way to regulate those activities.[284] Those recommendations are pending at the time of this writing.

Public Display, lunar material retrieved from the Moon during the Apollo Program in the 1960s and 1970s is U.S. government property. *See id.*

278. *See* Lawrence L. Risley, *An Examination of the Need to Amend Space Law to Protect the Private Explorer in Outer Space*, 26 W. ST. U. L. REV. 47, 52, 69 (1998).

279. *Id.*

280. *Id.*

281. 161 CONG. REC. H3518–19 (daily ed. May 21, 2015) (letter from Henry R. Hertzfeld, Matthew Schaefer & James C. Bennett submitted for the record by Rep. Posey); *see also* Risley, *supra* note 278, at 53.

282. *See* Blount, *supra* note 28, at 518.

283. *See supra* note 267 and accompanying text.

284. SPACE Act of 2015, Pub. L. No. 114-90, § 108, 129 Stat. 704, 707–08.

Supposing that the OSTP is able to devise a regulatory mechanism or delegate responsibility to an existing agency office like FAA/AST to oversee a terraforming project on Mars, that kind of mission might be construed as a violation of the Outer Space Treaty. It is clear from the SPACE Act that the U.S. government believes it possesses regulatory jurisdiction over in-situ celestial resources obtained by private U.S. entities, without violating the non-appropriation provisions found in article II of the Outer Space Treaty. The same reasoning is harder to apply to Musk's nuclear terraforming project, which would affect the planet's entire atmosphere.[285] The United States would ostensibly have jurisdiction to supervise those activities pursuant to article VI of the Outer Space Treaty, as long as it does not interfere with other nations' access to, or equal enjoyment of, that area.[286] But for the U.S. government to assert plenary authority over a terraforming mission on Mars could amount to de facto appropriation because the entire planet—not just fractional in-situ resources obtained for private use—would arguably be subject to its regulatory control. Proclaiming that kind of legal power might violate the letter and spirit of non-appropriation in article II of the Outer Space Treaty, even if continuous use does not technically amount to or justify appropriation.[287] Terraforming Mars might also violate article I of the Outer Space Treaty to the extent that it blocks any other spacefaring entity from free access to use and explore the planet.[288]

Conversely, there is a plausible argument that a non-government terraforming mission on Mars is compliant with the Outer Space Treaty. First, changing the Martian atmosphere to facilitate a human presence on the planet could be construed as an undertaking "carried out for the benefit and in the interests of all countries," in keeping with article I.[289] If the Martian atmosphere became more hospitable, it might facilitate, not restrict, access to Mars by other spacefaring entities, although this conclusion is by no means guaranteed in light of scientific uncertainty.[290] Second, detonating fusion nuclear devices over the Martian poles might entail legal jurisdiction *over those activities alone*, without claiming

285. *See, e.g.*, Wagstaff, *supra* note 3.
286. Risley, *supra* note 278, at 59–60.
287. *See supra* notes 87 and 88 and accompanying text.
288. *Id.* at art I.
289. *Id.*
290. *See, e.g.*, Neuhauser, *supra* note 24.

sovereignty over Mars.[291] This argument finds support in Title IV of the SPACE Act, which establishes a legal distinction between asserting jurisdiction over in-situ celestial resources obtained by non-government entities and asserting national sovereignty over the celestial bodies from which the resources were taken.[292] The correct legal conclusion depends on the correct interpretation of the language in the Outer Space Treaty, which is far from unambiguous.[293]

C. NEPA and NLSA Reviews

Outer space activities involving the use of nuclear technology are subject to two additional prongs of regulation in the United States.[294] First, all proposed space missions regulated by a U.S. government agency must comply with NEPA.[295] NEPA permits interim, non-in-depth assessments for complex or long-term projects, which means that approving a nuclear terraforming mission on Mars does not require precise calculation of all possible environmental impacts from the beginning.[296] Second, nuclear space missions must undergo a detailed safety review procedure by federal agencies and external experts, known as the Nuclear Launch Safety Approval ("NLSA") process.[297] Whether Musk's nuclear terraforming proposal would survive the NLSA review is uncertain, but as long as the mission undergoes a thorough assessment and minimizes Earth-based threats during the launch phase, it would likely be able to withstand legal challenges in court.[298]

291. *See* Outer Space Treaty, *supra* note 31, at arts. I–II.

292. SPACE Act of 2015, Pub. L. No. 114-90, § 403, 129 Stat. 704, 722 ("It 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.").

293. *See* 161 CONG. REC. H3515 (daily ed. May 21, 2015) (statement of Rep. Johnson) ("We are not at all close to resolving the many unanswered questions and issues concerning space resource utilization and property rights.").

294. Mirmina & Den Herder, *supra* note 79, at 165.

295. *See* National Environmental Policy Act of 1969, Pub. L. No. 91-190, 83 Stat. 852 (1970) (codified as amended in 42 U.S.C. §§ 4321–47). As discussed earlier, the nationally administered EIA is an important tenet of international environment law too. *See supra* Section III.F.

296. *See infra* Section IV.C.1.

297. Mirmina & Den Herder, *supra* note 79, at 165.

298. *See infra* notes 356–357 and accompanying text.

1. National Environmental Policy Act

The NEPA process begins when a federal agency has a proposal.[299] A federal agency must prepare an environmental impact statement ("EIS") for "every recommendation or report on proposals for . . . major [f]ederal actions significantly affecting the quality of the human environment."[300] Major federal action includes "actions with . . . effects that may be major, and which are potentially subject to federal control and responsibility."[301] "Actions include new and continuing activities, including projects and programs entirely or partly financed, . . . regulated, or approved by a federal agency."[302] To determine if a full EIS is needed, a federal agency must usually prepare an environmental assessment ("EA").[303] An EIS need not be completed if the federal agency finds, on the basis of an EA, that a proposed action will not have a significant impact on the environment.[304] NEPA does not require that an EA or EIS meet any specific, substantive environmental requirements in order to comply with the statute.[305] Instead, NEPA merely imposes procedural requirements on the regulatory decision-making process; the relevant agency need only show that all reasonably foreseeable environmental impacts—direct, indirect, and cumulative—of a proposed action were sufficiently considered before a decision concerning that proposal was made.[306]

299. According to Council on Environmental Quality regulations, a "[p]roposal exists at that stage in the development of an action when an agency subject to [NEPA] has a goal and is actively preparing to make a decision on one or more alternative means of accomplishing that goal and the effects can be meaningfully evaluated." 40 C.F.R. § 1508.23 (2016). Additionally, "[a] proposal may exist in fact as well as by agency declaration that one exists." *Id.*

300. 42 U.S.C. § 4332 (2012). As the Supreme Court has clarified, "[t]he statute . . . speaks solely in terms of proposed actions; it does not require an agency to consider the possible environmental impacts of less imminent actions when preparing the impact statement on proposed actions." Kleppe v. Sierra Club, 427 U.S. 390, 410 n.20 (1976).

301. 40 C.F.R. § 1508.18 (2016).

302. *Id.*

303. 40 C.F.R. § 1501.4(b) (2016). An EA is a "concise public document" that provides "sufficient evidence and analysis for determining whether to prepare an [EIS]." 40 C.F.R. § 1508.9 (2016).

304. 40 C.F.R. § 1508.13 (2016). Issuance of a Finding of No Significant Impact ("FONSI") in an EA enables the reviewing agency to proceed with the action, but the FONSI is subject to challenge in court. Gerrard & Barber, *supra* note 80, at 23.

305. Dep't of Transp. v. Pub. Citizen, 541 U.S. 752, 756 (2004) (quoting Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 350 (1989)).

306. *Id.*

Each federal agency has its own NEPA implementing procedures to address specific missions and decision-making authority. For example, a NEPA review process is built into the FAA/AST's process for licensing launches and reentries of private space vehicles to Earth's atmosphere.[307] There are two kinds of review under NEPA: programmatic and project-specific.[308] Programmatic reviews are high-level assessments that analyze the broad, reasonably foreseeable environmental consequences of wide-ranging federal programs involving a series of activities or projects to be implemented over a long time period or over a large geographic area.[309] Project-specific reviews analyze more particularized considerations, such as the precise environmental footprint of an activity at a particular location.[310] A series of proposed actions that are related to each other closely enough to qualify, in effect, as a single course of action should be evaluated in a single EIS or EA.[311]

The Council on Environmental Quality ("CEQ") has developed guidelines for determining whether federal agency activities require a programmatic or project-specific review.[312] CEQ interprets its regulations as allowing for the use of a programmatic approach to developing either an EIS or an EA.[313] Programmatic reviews are appropriate when there are limitations in available information and uncertainty regarding timing, location, and environmental impacts of a large-scale, complex proposal with interrelated phases.[314] Even in the absence of environmental data,

307. As discussed earlier, pursuant to the SPACE Act, the particular federal agency that would have plenary authority over a terraforming project on Mars is not necessarily the FAA. *See supra* notes 267, 283 and accompanying text.

308. Memorandum from the Council on Envtl. Quality, Exec. Office of the President to the Heads of Federal Departments and Agencies 6 (Dec. 18, 2014) [hereinafter CEQ Memo], https://www.whitehouse.gov/sites/default/files/docs/effective_use_of_programmatic_nepa_reviews_18dec2014.pdf [http://perma.cc/X9XV-58AZ].

309. *See id.* at 10. For example, a proposal for federal action comprising multiple interrelated phases that are temporally or spatially connected might require a programmatic review. *See* 40 C.F.R. § 1508.18(b) (2016).

310. *See* 40 C.F.R. § 1508.18(b).

311. 40 C.F.R. § 1502.4(a) (2016).

312. CEQ's interpretation of NEPA enjoys substantial deference in the courts. Andrus v. Sierra Club, 442 U.S. 347, 357–58 (1979) (citing Warm Springs Dam Task Force v. Gribble, 417 U.S. 1301, 1309–10 (1974)).

313. CEQ Memo, *supra* note 308, at 12.

314. *See* CEQ Memo, *supra* note 308, at 33–35 (recognizing that a programmatic EIS is still appropriate even when the lack of a project-specific proposal hinders the ability to

agencies may establish parameters for subsequent analyses based on programmatic review that adequately examines reasonably foreseeable consequences of a program, policy, plan, or series of projects.[315] The level of scrutiny in a programmatic review is not the same in all circumstances, but—as with all environmental reviews—it must be detailed enough to allow for informed decision-making by a reviewing agency.[316] When a programmatic review is appropriate, there may be a need for future "tiered" analyses targeting specific phases or aspects of the project and analyzing more particularized considerations.[317] Using a programmatic and tiered review structure can be efficient because it facilitates agency decisions that precede more in-depth decisions appropriate at later phases of a long-term project, without having to assess all possible environmental impacts from the beginning.[318] Programmatic analysis and subsequent tiered analysis support a decision-making process that is fully compliant with NEPA.[319]

Musk's plan would likely require a programmatic EIS prepared by the appropriate federal agency if NEPA is legally applicable. Because the environmental data of detonating an as-yet unavailable fusion nuclear device over the poles of Mars is lacking, a programmatic EIS encompassing the launch, positioning, detonation, and possible Earth reentry phases is appropriate due to the uncertainty regarding timing, location, and cumulative environmental impacts.[320] In addition, a programmatic EIS is justified when a group of activities that share the same goal may have a significant environmental impact, even if some of the individual component activities do not require detailed assessment.[321] Here, for example, the risk of an uncontrolled

analyze environmental impacts in depth). Moreover, project-level environmental impacts need not be evaluated at the programmatic level when the decision to act on a particular phase is yet to be made. *See, e.g.*, Citizens for Better Forestry v. U.S. Dep't of Agric., 481 F. Supp. 2d 1059, 1086 (N.D. Cal. 2007) (quoting Friends of Yosemite Valley v. Norton, 348 F.3d 789, 800 (9th Cir. 2003)).

315. CEQ Memo, *supra* note 308, at 10. For example, programmatic NEPA reviews are used when agencies revise forest or land and resource management plans, establish programs to control invasive species, or develop recovery projects following a major natural disaster, in multiple jurisdictions. *Id.* at 7 n.9.

316. *Id.* at 31.

317. *Id.* at 12–15.

318. *Id.*

319. *Id.* at 27.

320. *Id.* at 11.

321. *See* Gerrard & Barber, *supra* note 80, at 27.

reentry into Earth's atmosphere of any Mars-bound space vehicle carrying nuclear materials (perhaps due to a failed launch) certainly has the potential for significant and measurable environmental damage, whereas the impacts of atmospheric transformation on Mars are unknown. Nevertheless, the fact that both activities are constituent elements of the same general mission would likely justify an initial programmatic review of the entire mission.[322]

The SPACE Act did not designate a lead federal agency or agencies responsible for reviewing the environmental impacts of a celestial terraforming mission, but the legal framework among existing outer space regulators suggests the same review process would be applied. The environmental review procedures of the FAA/AST—the principal federal body currently authorized to regulate the private space industry—require compliance with the CEQ's regulations for implementing NEPA, including programmatic reviews with subsequent tiered review when necessary.[323] Moreover, an EIS assessing the environmental effects on Earth is required for NASA-sponsored actions that require development and operation of new spacecraft or development and operation of nuclear systems such as reactors and thermal devices used for propulsion or power generation.[324] These criteria that separately trigger the preparation of an EIS for NASA-sponsored programs might also apply to Musk's proposed mission. When viewed together, the FAA/AST and NASA protocols suggest that an EIS would be a requirement before Musk is granted permission to start heating up Mars, albeit at the less detailed programmatic level.

Interestingly, NEPA establishes decision-making procedures rather than required outcomes in environmental performance.[325] A programmatic review of a planetary terraforming proposal with no available data on the environmental impacts of changing the Martian atmosphere could theoretically comply with NEPA, as long as all reasonably foreseeable impacts and alternative measures were

322. Even certain events that have a low probability of occurrence must be addressed. *Id.* at 30.

323. 14 C.F.R. § 431.91 (2016); *see also* FED. AVIATION ADMIN., ORDER NO. 1050.1D, POLICIES AND PROCEDURES FOR CONSIDERING ENVIRONMENTAL IMPACTS (1986), http://www.faa.gov/documentLibrary/media/Order/1050.1D.pdf [http://perma.cc/N26T-278K].

324. 14 C.F.R. § 1216.306 (2016).

325. *See* Gerrard & Barber, *supra* note 80, at 31.

fully considered and a detailed system of thorough project-level reviews for subsequent phases of the proposal were set up. NEPA's allowance of programmatic and tiered structure for complex or long-term projects could thus allow for the approval of a terraforming mission to Mars without having to calculate from the outset the full panoply of possible environmental impacts that could result from transforming the Martian atmosphere. That a terraforming project could pass muster under NEPA is by no means guaranteed, because a significant hole in environmental data would render a reviewing agency unable to make an informed decision.

However, NEPA's review protocols might have a reduced legal effect with respect to a terraforming project on Mars because extraterritorial application of U.S. statutes to outer space activities is unclear, and because foreign policy considerations may override NEPA. Most of the potential environmental impacts of Musk's nuclear terraforming devices would occur millions of miles away from Earth, and thus NEPA's extraterritorial reach must be considered. There is a longstanding presumption that congressional legislation is meant to apply only within the territorial jurisdiction of the United States and will not have extraterritorial application.[326]

Whether a statute applies extraterritorially depends on if the statutory language contains a "plain statement of extraterritorial statutory effect"[327] indicating a congressional purpose to extend coverage beyond places over which the United States has sovereignty or some measure of legislative control.[328] The presumption against extraterritoriality does not apply when the conduct regulated by the government occurs within the United States.[329] Enforcement of a federal statute like NEPA is not improper if the regulated conduct occurs within the United States, regardless of whether significant effects of the regulated conduct are felt abroad.[330] Even if extraterritorial application of NEPA is

326. Foley Bros., Inc. v. Filardo, 336 U.S. 281, 285 (1949). *But see* United States v. Bowman, 260 U.S. 94, 98 (1922) (holding that the territorial presumption does not necessarily govern the interpretation of criminal statutes that, by their nature, implicate the legitimate interests of the United States abroad).

327. Astoria Fed. Sav. & Loan Ass'n v. Solimino, 501 U.S. 104, 109 (1991).

328. Equal Opportunity Comm'n v. Arabian Am. Oil Co., 499 U.S. 244, 248 (1991).

329. Envtl. Def. Fund v. Massey, 986 F.2d 528, 531 (D.C. Cir. 1993).

330. *Compare, e.g.*, Aalmuhammed v. Lee, 202 F.3d 1227, 1238 (9th Cir. 2000) (reversing dismissal based on extraterritorial application of federal statute because conduct at issue occurred in the United States), *with* Grunenthal GmbH v. Hotz, 712 F.2d 421, 425–26 (9th

legally permissible, however, applying NEPA to activities outside the United States might be inappropriate if there are overriding foreign policy or national security concerns.[331] It is unknown whether the drafters of NEPA thought that an environmental review should analyze potential changes in the outer space environment, and courts have yet to resolve the issue.[332]

While U.S. law does not necessarily compel any particular answer, federal agency sponsorship and regulation of a terraforming project on Mars might justify extraterritorial application of NEPA. In *Environmental Defense Fund v. Massey*, arguably the most frequently cited case concerning extraterritorial application of NEPA, the D.C. Circuit held that NEPA requirements applied to a federally sponsored food incineration project in Antarctica.[333] That conclusion rested on two important assumptions. First, because NEPA only regulates the federal decision-making process, and that activity occurs within the United States, the presumption against extraterritorial application of NEPA did not apply even if the effects of that decision were felt in Antarctica.[334] Second, due to low probability of foreign conflict in a global commons territory like Antarctica plus the modest degree of legislative control the United States possessed there, NEPA was applicable.[335] The court reasoned that because Antarctica was not a sovereign nation but "a continent most frequently analogized to outer space," the presumption against extraterritoriality should not apply.[336]

Just like in *Massey*, where NEPA applied to a federally sponsored program in Antarctica because the review process took place in the United States, here, NEPA could apply to a federally sponsored terraforming project on Mars because any EA pursuant to NEPA

Cir. 1983) (finding that there was subject matter jurisdiction over securities fraud action involving sale of foreign securities between foreign corporations because alleged fraudulent conduct occurred in United States).

331. *Massey*, 986 F.2d at 534–35. Where there is no potential for conflict between U.S. laws and those of other nations, the purpose behind the presumption against extraterritoriality is eviscerated, and the presumption applies with significantly less force. *Id.*

332. *See* Gerrard & Barber, *supra* note 80, at 26. Note that the NASA EIS procedures focus on Earth-based effects, and do not explicitly require assessment of the outer space environment. *See* 14 C.F.R. § 1216.306 (2016).

333. *Massey*, 986 F.2d at 532–33.

334. *Id.* (noting that NEPA imposes "no substantive requirements which could be interpreted to govern abroad").

335. *Id.* at 533–34.

336. *Id.* (citing Beattie v. United States, 756 F.2d 91, 99 (D.C. Cir. 1984)).

would occur in the United States, even if the substance of that decision occurs in outer space. And just as the presumption against applying NEPA extraterritorially to activities in Antarctica did not apply in *Massey* because Antarctica is not subject to any one nation's laws, here, the presumption against applying NEPA to a terraforming project on Mars might not apply because Mars is not subject to any one nation's laws.[337] The line of jurisprudence[338] suggests that NEPA could apply extraterritorially to federally sponsored activities in outer space,[339] including any activities on Mars that are regulated and overseen by a U.S. federal agency.

However, foreign policy implications of a nuclear terraforming project on Mars could override application of NEPA. In *Natural Resources Defense Council v. U.S. Department of the Navy*, for example, the D.C. Circuit held that any NEPA requirements pertaining to U.S. nuclear export decisions did not apply where they conflicted with U.S. foreign policy because international cooperation in the area of nuclear exportation was unique and delicate.[340] In *Committee for Nuclear Responsibility v. Seaborg*, the D.C. Circuit refused to issue an injunction under NEPA to stop an underground nuclear explosion sponsored by the Atomic Energy Commission, despite the potential for negative impacts to the environment, because the U.S. government asserted harm to national security and foreign policy.[341] *NRDC* and *Seaborg* illustrate that the statutory requirements under NEPA might not apply where U.S. foreign policy interests outweigh the benefits derived from complying with NEPA. In *Massey*, which cites favorably to both *NRDC* and *Seaborg*, U.S. foreign policy was not threatened by forced compliance with NEPA, because an environmental review of a food incineration project in Antarctica did not hamper international cooperation

337. Outer Space Treaty, *supra* note 31, at art. II.

338. *See, e.g.*, Nat. Res. Def. Council v. U.S. Dep't of the Navy, No. CV-01-07781, 2002 U.S. Dist. LEXIS 26360, at 30 (C.D. Cal. Sept. 17, 2002) (holding that planning for U.S. Navy's sea tests of experimental anti-submarine warfare technologies took place entirely in the United States and therefore NEPA review of ocean environment impacts was not subject to the presumption against extraterritoriality); Hird v. Richardson, 127 F. Supp. 2d 833, 843–44 (W.D. Mich. 1999) (holding that NEPA applied extraterritorially to a Russian ship transporting a nuclear reactor to Canada as part of U.S.-sponsored program, because an EA did not substantially interfere with U.S. foreign policy interests).

339. *See* Gerrard & Barber, *supra* note 80, at 26.

340. Nat. Res. Def. Council v. Nuclear Regulatory Comm'n, 647 F.2d 1345, 1366 (D.C. Cir. 1981).

341. Comm. for Nuclear Responsibility v. Seaborg, 463 F.2d 796, 798 (D.C. Cir. 1972).

and did not involve foreign policy interests that were particularly unique and delicate.[342] But unlike in *Massey*, where deploying food incineration machinery on Antarctica did not concern foreign policy interests that were unique and delicate,[343] here, Musk's idea to implement fusion devices over Mars is highly sensitive because it requires the use and deployment of nuclear technology.[344]

A federally sponsored program regulating the use of nuclear technology on Mars must place a high priority on avoiding conflict with other nations.[345] Putting responsibility for the environmental analysis of a massive geoengineering project on Mars solely in the hands of a U.S. government agency might be a major point of contention because outer space is "the province of all mankind," and "freedom of scientific investigation" includes "international cooperation in such investigation."[346] Without a cooperative, internationally-supervised assessment of the environmental impacts of a nuclear terraforming mission on Mars, it would be harder for the U.S. government to prove that its actions were being conducted for the "benefit and in the interests of all countries."[347] NEPA processes might therefore have weaker effect on Musk's proposal because the need for meaningful international participation and a global perspective in the decision-making process is very important.

2. Nuclear Launch Safety Approval ("NLSA")

Multiple federal agencies are involved in the review of space missions involving legally permissible nuclear power sources like RTGs or fission reactors.[348] The Department of Energy ("DOE") conducts a Safety Analysis Report ("SAR") and provides the required nuclear materials.[349] The Interagency Nuclear Safety

342. Envtl. Def. Fund v. Massey, 986 F.2d 528, 535 (D.C. Cir. 1993).

343. *Id.*

344. *See Nat. Res. Def. Council*, 647 F.2d at 1358 ("[T]he Commission simply by deliberating on nuclear export questions will influence the denouement of United States foreign relations in a particularly sensitive arena: that of controlling proliferation of nuclear materials among nations.").

345. *See supra* Section III.G.

346. Outer Space Treaty, *supra* note 31, at art I.

347. *Id.*

348. Mirmina & Den Herder, *supra* note 79, at 167. However, this review process has only been applied to NASA missions using legally acceptable nuclear devices like RTGs, which have been the only types of U.S.-sponsored missions relying on nuclear technology. *Id.* But a private actor like Musk would almost certainly have to follow similar steps.

349. *Id.*

Review Panel ("INSRP"), an ad hoc body formed for each mission, conducts an independent evaluation of the SAR.[350] The INSRP is comprised of four experts from NASA, DOE, DOD, and the Environmental Protection Agency ("EPA"), as well as consultants from government, industry, and academia.[351] With technical assistance from the Nuclear Regulatory Commission ("NRC"), the INSRP evaluates the SAR and prepares its own Safety Evaluation Report ("SER").[352] Finally, the SAR and SER are attached to a formal request for launch approval, which is submitted to the Director of the OSTP in the White House, who may grant approval or refer the request to the President.[353]

The U.S. government's intricate procedure for reviewing nuclear-powered space missions prioritizes public safety, with the primary focus being to prevent damage to Earth's atmosphere.[354] Opposition to nuclear space technology is primarily based on fears of terrestrial nuclear accidents, such as a failed launch, and not activities carried out far beyond Earth's atmosphere.[355] Thus, nuclear space technologies deployed in previous NASA missions have been carefully designed to minimize damage to the terrestrial environment as much as possible,[356] and their use has withstood judicial challenges.[357]

That Musk's idea would pass muster under NLSA review is not guaranteed, but as long as the mission undergoes thorough review and minimizes Earth-based threats, it might be able to withstand

350. *Id.*

351. *Id.*

352. *Id.*

353. *Id.*

354. *Id.* at 168.

355. *See* Caselli, *supra* note 112, at 662 (citing Richard Berkley, *Space Law Versus Space Utilization: The Inhibition of Private Industry in Outer Space*, 15 WIS. INT'L L.J. 421, 434 (1997) (describing how it is the nuclear pollution on Earth that typically "creates hysteria" among the media and the public)).

356. *See* MacAvoy, *supra* note 58, at 218 (describing how NASA limits its use of nuclear technology to nuclear-safe orbits, which "practically eliminates the possibility of a catastrophic re-entry of radioactive materials"); Mirmina & Den Herder, *supra* note 79, at 155–56 ("Because fission reactors can be designed to remain [dormant] during launch and ascent, the risks of 'meltdown' associated with terrestrial reactor plants can be avoided while the device is in, or capable of re-entering, the Earth's atmosphere.").

357. *See, e.g.*, Haw. County Green Party v. Clinton, 980 F. Supp. 1160, 1169 (D. Haw. 1997) ("NASA studies show there is a low probability of injury to Plaintiffs. . . . This, weighed against the potential danger of delay in launching as well as the specific monetary harm alleged by Defendants, fails to meet Plaintiffs' burden of showing that the balance of harm tips in their favor.").

legal challenges in court. In *Hawaii County Green Party v. Clinton*, for example, the U.S District Court in Hawaii found that the net benefit to the public of NASA's *Cassini* spacecraft bound for Saturn far outweighed the low probability of radioactive fallout on Earth, deferring to NASA's expertise and thorough planning.[358] In two earlier lawsuits, the D.C. District Court reached similar conclusions, backing NASA's implementation of nuclear space technology due to adequate oversight and minimization of Earth-based risks.[359] It can be argued that regardless of whether Musk could actually obtain U.S. government approval for his nuclear terraforming proposal, there is no clear legal restriction against such activity as long as the NLSA review standards are followed and his spacecraft puts no one on Earth in immediate danger.

V. THE RELEVANCE OF MUSK'S PROPOSAL TO THE DEVELOPMENT OF OUTER SPACE LAW

The success of several cutting-edge space projects accomplished through the imagination of private entrepreneurs demonstrate that non-government activity in outer space is here for the long haul.[360] No longer are national governments the only entities carrying out space missions. State-based regulation of outer space, particularly in the United States, has adapted accordingly to allow for the growth and development of non-government space activities. Private companies in the United States already exercise considerable influence over some of the largest outer space projects in cooperation with NASA.[361] Countries around the world are also marching down the same path, crafting new legal regimes designed to promote non-government commercial activity in outer

358. *Id.* at 1167–69.

359. *See* Fla. Coal. for Peace & Justice v. Bush, No. 89-2682-OG, 1990 U.S. Dist. LEXIS 13345 at *2, *4 (D.D.C. Oct. 5, 1990) (ruling in favor of NASA's RTG-powered *Ulysses* spacecraft); Fla. Coal. for Peace & Justice v. Bush, No. 89-2682-OG, 1990 U.S. Dist. LEXIS 13345 at *1 (D.D.C. Oct. 10, 1989) (ruling in favor of NASA's RTG-powered *Galileo* mission).

360. *See, e.g.*, Tse, *supra* note 48, at 318–19 (discussing the space tourism activities of Virgin Galactic CEO Richard Branson); Hughes & Rosenberg, *supra* note 153, at 2–3, 8–9 (discussing the successful operation of an FAA-licensed spaceship funded largely by Microsoft's co-founder Paul Allen, as well as several other successful ventures by well-known businessmen such as Jeff Bezos and Elon Musk).

361. *See Commercialization of Space: Commercial Space Launch Amendments Act of 2004*, 17 HARV. J.L. & TECH. 619, 623 (2004) (noting that NASA's industrial partners like Boeing and Lockheed Martin wield tremendous influence over the agency because of their multi-billion dollar contracts).

space.[362] It is not too optimistic to claim that non-government space activity will take over a significant portion—if not the majority—of the outer space market in the near future.[363]

The current pace of technology is such that entrepreneurial innovation is moving swiftly ahead of the law.[364] It is unrealistic to expect private entities will continue to use and explore space absent the ability to take advantage of all the rewards that exist in outer space.[365] Without a stable legal framework in which all non-government actors are assured that they will have a legal claim over the fruits of their labor, development of the private space industry could stall.[366] That result is toxic to the entire outer space industry, whose future is dependent on a competitive marketplace with savvy entrepreneurs.[367] And yet, legal uncertainty persists.

A. Musk's Proposal Matters When Thinking About How to Clarify Undefined Legal Rights

Robust expansion of private industry actors in outer space depends in part on more clearly defined limits on celestial property rights. The Outer Space Treaty's omission of language addressing private appropriation in outer space has created ambiguity about how someone like Musk can use or exploit the resources of any celestial body—Mars, asteroids, or otherwise—setting a tone in the law that discourages the non-government industry from establishing a significant presence in those kinds of locations.[368]

362. *See* Gabrynowicz, *supra* note 227, at 416–17.

363. Charles Krauthammer, *Space: The Visionaries Take Over*, WASH. POST (Dec. 31, 2015), https://www.washingtonpost.com/opinions/space-the-visionaries-take-over/2015/12/31/d0f9d956-affa-11e5-b820-eea4d64be2a1_story.html [http://perma.cc/XE42-J42D] ("Space travel has now slipped the surly bonds of government—presidents, Congress, NASA bureaucracies . . . Our trajectory in space will now be the work of a functioning market of both ideas and commerce. It no longer will hinge on the whims of only tangentially interested politicians.").

364. *See* Wohl, *supra* note 12, at 339.

365. *See* Risley, *supra* note 278, at 66.

366. *See* Coffey, *supra* note 38, at 120 (discussing the reluctance of many private and public actors to conduct potentially lucrative mining activities on the Moon when there is no reliable regulatory or legal regime); Hughes & Rosenberg, *supra* note 153, at 2–3 (noting that the "tantalizing commercial possibilities" in outer space depend on application of good laws and regulations); Tannenwald, *supra* note 58, at 363–64 (highlighting an increased risk of conflict in outer space without international agreements on permitted activity and arrangements for distributing benefits).

367. Krauthammer, *supra* note 363.

368. Risley, *supra* note 278, at 66.

This is unfavorable because private rights to celestial resources constitute one of the primary incentives that will stimulate more investment in the non-government space industry.[369] Title IV of the SPACE Act clarifies the uncertainty for U.S. spacefaring entities to some extent by granting private ownership rights to in-situ celestial resources that are obtained for private use. As discussed above, there is still unsettled debate in the United States about whether Title IV is compliant with the non-appropriation provisions in the Outer Space Treaty.[370] Even if the Outer Space Treaty does allow limited claims over in-situ space resources, it does not provide a right to exclude.[371] Theoretically, a non-government mineral mining expedition on another celestial body could not lawfully prevent others from entering its area of operation and extracting resources,[372] a risk that could make private investors fearful of contributing money to such projects in a competitive region.[373] Better legal standards are needed, considering there is vast potential for the abundant resources harvestable in outer space to improve the lives of people on Earth.[374]

Incorporating Musk's idea seriously into any discussion about the legal contours of celestial property rights steers us toward the preferred result. Regardless of whether civilian use of a nuclear device to transform a planet's atmosphere is unconscionable, thinking about that kind of extreme scenario helps distinguish between what kinds of celestial property use rights should be allowed and what kinds should not. Putting Musk's idea on the

369. *See* 161 CONG. REC. H8192 (daily ed. Nov. 16, 2015) (letter from Robert Richards, Founder and CEO of Moon Express, a privately-held company based in California).

370. *Id.* H8194 (statement of Rep. Bridenstine).

371. Outer Space Treaty, *supra* note 31, at arts. I–II.

372. *See* Coffey, *supra* note 38, at 139.

373. *See, e.g.*, Leonard David, *China's 1st Round-Trip Moon Shot Sets Stage for Bigger Lunar Feats*, SPACE NEWS (Nov. 5, 2014), http://www.space.com/27661-china-moon-mission-sample-return.html [http://perma.cc/7578-2RLN] (discussing China's increased presence on the Moon and its plans to continue lunar expansion).

374. *See* Coffey, *supra* note 38, at 120 (discussing the benefits of obtaining helium-3, a valuable clean energy resource that is very rare on Earth, but abundant on the Moon); James Conca, *Beyond Earth's Atmosphere: Energy Needs For Space Colonization*, FORBES (May 5, 2013), http://www.forbes.com/sites/jamesconca/2013/05/05/beyond-earths-atmosphere-energy-needs-for-space-colonization/#2715e4857a0b17be700c2528 [http://perma.cc/GT8K-WS7L] (highlighting growing shortages of key inorganic elements, such as rare earth elements for electronic gadgets and renewable energy systems, platinum and other related metals, and helium for medical equipment, suggesting that humans may need more nonrenewable resources than Earth can provide).

spectrum of deliberation can establish the proper legal boundaries under which all the "visionaries and daredevils"[375] who wish to use and explore outer space can operate, while filtering out the private space missions unworthy of sponsorship. The international treaty regime governing the general use of nuclear technology in outer space, while somewhat unclear, might render Musk's specific proposal for Mars illegal in the first place. If it is allowable, however, an entirely different set of legal questions arise concerning the extent of non-government property rights on celestial bodies and the limits of state-based regulatory control over these activities that are no less relevant, but largely unanswered. Thus, Musk's idea to use nuclear devices to terraform Mars is an important scenario to contemplate as international and national policymakers draft new legal rules and regulations defining the property rights of non-government actors in outer space that conform to the principles of non-appropriation in the Outer Space Treaty.

The development of international maritime law also provides useful historical precedent showing why Musk's proposal can be a relevant consideration influencing how outer space regulation should develop.[376] The existing outer space law regime loosely resembles maritime law prior to 1958, before nations discovered that a lack of agreed-upon rules created a chaotic environment fostering misuse of the ocean.[377] The traditional law of the high seas and older treaties allowed chaotic claims to national jurisdiction, extermination of fisheries, and pollution of the marine environment.[378] The ad hoc approach did not work because the

375. Hughes & Rosenberg, *supra* note 153, at 46 (quoting former U.S. Congressman Sherwood Boehlert).

376. *See generally* John J. Klein, *Space Warfare: A Maritime-Inspired Space Strategy*, 2 ASTROPOLITICS 33 (2004). The development of international transboundary environmental law, which is relevant to the discussion of outer space activity, first evolved from developments concerning non-navigational uses of international waterways. *See* Handl, *supra* note 166, at 533. The way in which legal rules derived from a global commons area like the high seas might therefore serve as a good analogy for the outer space commons. *See id.*

377. *See* Tannenwald, *supra* note 58, at 387–93.

378. *Id.* (citing Elizabeth Mann Borgese, *The Process of Creating the International Ocean Regime to Protect the World's Resources*, *in* FREEDOM FOR THE SEAS IN THE 21ST CENTURY: OCEAN GOVERNANCE AND ENVIRONMENTAL HARMONY 23, 23–24 (Jon M. Van Dyke, Durwood Zaelke & Grant Hewison eds., 1993)).

lack of cooperation ignored long-term consequences of not conserving the marine environment.[379]

Noninterventionist regulation over the "unlimited and undefined freedoms" in traditional ocean law had therefore ceased to serve the interests of international justice.[380] Laissez faire regulation over the outer space environment could have the same result. Granted, analogizing oceanic law to outer space is perhaps overly simplistic because different motivations and interests inform the future of outer space activity.[381]

While solutions to legal questions in outer space might be different, the maritime law analogy shows how a lack of well-defined regulation could result in the abuse or destruction of valuable environmental resources, whether on Earth or not. Underdeveloped legal rules that conceivably tolerate Musk's terraforming mission on Mars could result in irreparable destruction to Mars. His idea can stimulate critical thinking about how to avoid environmental harm that might result from the vaguely defined legal freedoms in outer space. If steps are taken at the international level to prepare for future legal questions and enforcement mechanisms, alliances and partnerships between countries can ensure that the resources in outer space may be used in a safe, profitable, fair, and efficient manner.[382] Damage to the outer space environment, like what happened to the marine environment before the advent of meaningful legal rules, can be avoided.

B. Musk's Proposal Matters as We Look to the Future

Sound legal policy-making for all outer space activity must include creative thinking beyond just what is expected in the short term, which is another reason that Musk's idea is relevant to current debates about regulation of non-government spacefaring entities. It is perhaps axiomatic to say that the evolution of technology and material prospects of increased human presence in

379. *Id.*

380. *Id.* at 29 (quoting R. P. Anand, *Changing Concepts of Freedom of the Seas: A Historical Perspective*, *in* FREEDOM FOR THE SEAS IN THE 21ST CENTURY: OCEAN GOVERNANCE AND ENVIRONMENTAL HARMONY 72, 82 (Jon M. Van Dyke, Durwood Zaelke & Grant Hewison eds., 1993)).

381. *See id.* at 32–38.

382. *See* Wohl, *supra* note 12, at 348.

outer space are unknown. The inherent uncertainty of human development in outer space is precisely why creative thinking about all possible future capabilities of non-government space actors like Musk, even if not necessarily likely, is appropriate to accomplish long-term, legally sustainable policy objectives.[383] Without such reflection, present-day political forces and short-term knowledge drive legal policy-making for outer space, which is unworkable over the long term as technology capabilities evolve.[384] As demonstrated by the evolution of maritime law analogy, ad-hoc policymaking concerning a valuable international resource like outer space pleases nobody.

Some scholars have argued that the best way to structure a sustainable legal framework for outer space is to incorporate "scenario building" in the decision-making process.[385] Building decision-focused, imaginative, and logical scenarios helps prepare most effectively for an uncertain future by steering us to "preferred outcomes" in space.[386] A scenario-building process has worked effectively in the past for NASA space missions, which incorporated into their astronaut training programs lessons on plausible, important scenarios (not just the most likely scenarios), and avoided disaster in the process.[387]

A similar strategy can help international and national lawmakers design a legal system that addresses the myriad possible outcomes in the private space industry, including the potential capability of someone like Musk to carry out a terraforming mission on Mars. He has already announced his intention to put human beings on Mars in the 2020s, and NASA wants to send a manned mission to Mars by 2035.[388] Musk's history-making success in returning a

383. *See* Wade L. Huntley, Joseph G. Bock & Miranda Weingartner, *Planning the Unplannable: Scenarios on the Future of Space*, 26 SPACE POL'Y 25, 31 (2010).

384. *Id.* at 28–29 (discussing the legal inadequacy of a static treaty regime to address the evolving nature of space weaponization as new technology comes to market).

385. *Id.* at 31.

386. *Id.* (citing KEES VAN DER HEIJDEN, SCENARIOS: THE ART OF STRATEGIC CONVERSATION (2d ed. 2005)).

387. *Id.* (discussing how Neil Armstrong saved the Gemini VIII in 1966 during an accident because of some obscure training session that his crewmembers did not have to complete).

388. *See* Sebastian Anthony, *SpaceX Says It Will Put Humans on Mars by 2026, Almost 10 Years Ahead of NASA*, EXTREME TECH (June 18, 2014), http://www.extremetech.com/extreme/184640-spacex-says-it-will-put-humans-on-mars-by-2026-almost-10-years-ahead-of-nasa [http://perma.cc/RR5Y-RCAH].

SpaceX rocket back to the Earth in December 2015 shows that not only his but others' capabilities might soon exceed what the outer space legal system is capable of handling.[389] Even though Musk's idea to use nuclear devices on Mars is no doubt a long way off, with uncertain environmental impacts, the time is now to start thinking about that kind of scenario to create a sustainable legal framework for non-government space activity as technology continues to evolve.

VI. CONCLUSION

A legal system that is capable of defining the rights and responsibilities of all non-government entities in outer space must be able to address a proposal of any magnitude because it must be adaptable to the creative ingenuity of the visionaries and daredevils like Musk. His unusual idea for Mars is relevant to the discussion of how the law should regulate private spacefarers in the future because it can help lawmakers demarcate the right legal boundaries of non-government activity in outer space. Technology should not precede sound legal policy, and "it is to be hoped that jurists will not let themselves be outdistanced by technicians."[390]

389. *See* Christian Davenport, *Elon Musk's SpaceX Returns to Flight and Pulls off Dramatic, Historic Landing*, WASH. POST (Dec. 21, 2015), https://www.washingtonpost.com/news/the-switch/wp/2015/12/21/elon-musks-spacex-pulls-off-dramatic-historic-landing/ [http://perma.cc/ZG4T-7P5P].

390. Caselli, *supra* note 112, at 664 (citations omitted).