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In October 1957, the launch of *Sputnik I* marked humanity's first step into space.[1] At that same moment, humanity began the process of polluting the outer layers of Earth's atmosphere and beyond.[2] Over the last sixty years, the number of satellites in space has grown exponentially.[3] According to the United Nation's Office for Outer Space Affairs, there are 4,857 satellites orbiting the planet as of August 2018.[4] However, only 1,887 of these satellites are in use, meaning 2,970 satellites orbiting the planet are nothing more than "junk."[5] Satellites are only part of the space debris story. Including these active and inactive satellites, there are over 23,000 total tracked items in space.[6] Plus, there are potentially millions of objects too small to track orbiting the Earth as a result of space travel and human activity.[7] As time goes on, the once empty orbital ring is becoming a dumping ground and, eventually, space debris will limit our ability to utilize space in any way.[8]

When approaching the question of how to address this concern, there are two major issues. The first is international law. Currently, the U.N. has established a list of guidelines for States to follow when they enter space.[9] While these rules apply to many aspects of space use, the international community has not established hardline rules to remove or reduce space debris.[10] The second issue

1. Steve Garber, *Sputnik and the Dawn of the Space Age*, NASA (Nov. 2, 2018), https://perma.cc/8E3V-XB99.

2. MARK WILLIAMSON, SPACE: THE FRAGILE FRONTIER 8 tbl.1 (2006).

3. Alexandra Witze, *The Quest to Conquer Earth's Space Junk Problem* (Oct. 28, 2018), https://perma.cc/68A3-Z8D7 (see table from ESA's Annual Space Environment Report).

4. United Nations Office for Outer Space Affairs, *Online Index of Objects Launched into Outer Space*, (Oct. 24, 2018), https://perma.cc/CMQ5-3BRT.

5. Union of Concerned Scientists, *UCS Satellite Database* (Sept. 20, 2018), https://perma.cc/P6ZC-PX63.

6. European Space Agency, *About Space Debris*, EUROPEAN SPACE AGENCY (Sept. 20, 2018), https://perma.cc/643P-DCLQ (in the United States, the Department of Defense and NASA officially share the responsibility for tracking these items. Objects larger than 4 inches can be tracked from Earth).

7. Mark Garcia, *Space Debris and Human Spacecraft*, NASA (Sept. 20, 2018), https://perma.cc/5HCG-MDPQ.

8. Christopher D. Williams, *Space: The Cluttered Frontier*, 60 J. AIR L. & COM. 1139, 1146 (1995).

9. United Nations: Office for Outer Space Affairs, *Space Law* (Sept. 20, 2018), https://perma.cc/7LNP-SGW3.

10. HOWARD A. BAKER, SPACE DEBRIS: LEGAL AND POLICY IMPLICATIONS 79 (1989).

revolves around the science. While there have been many attempts,[11] no existing technology effectively removes these objects or disposes of the debris.[12] If there is to be any solution, innovations need to be made in the field of space debris removal. Therefore, this paper will explore those two challenges to solving the issue of space debris in three parts. First, the paper will explore the problems and effects of space debris. Second, it will explore the current legal landscape and technical solutions. Finally, it will determine how international law can prevent new space debris and encourage the development of new technologies to remove what is currently there.

I. The Problem with Space Debris

Space debris is not a new problem. The Soviet Union's representative at the 1986 meeting of the U.N.'s Committee on the Peaceful Uses of Outer Space "was of the view that the space debris problem affecting the space environment must be dealt with immediately rather than leaving it until late in the day as had happened with the Earth's environment."[13] Despite these early calls for action, space debris has grown virtually unchecked by any binding international agreement.[14] The result, as we will see, is an ever increasing risk of creating a dust cloud of debris around the planet, which could eliminate space as a viable resource for humanity.[15] To understand the severity, I will first discuss the origins of debris, then examine the effects, and possible effects, on Earth's space environment.

A. The Sources of Space Debris

Space debris is "a blanket term for any man-made artifact discarded, or accidentally produced, in space, either in orbit around a planetary body (where it is also known as orbital debris) or on a trajectory between planetary bodies."[16] Since humans entered the realm of space, the two major sources of space debris have been launching systems and satellites.[17]

Especially in early space programs, rocket design necessarily creates space debris.[18] To escape Earth's gravitational field, rockets are made up of several

11. European Space Agency, *supra* note 6.

12. J. C. Liou & N. L. Johnson, *Risks in Space from Orbiting Debris*, 311 SCIENCE 340, 340 (2006).

13. David Tan, *Towards a New Regime for the Protection of Outer Space as the Province of All Mankind*, 25 YALE J. INT'L L. 145, 153 (2000) (internal quotation marks omitted).

14. Joseph S. Imburgia, *Space Debris and Its Threat to National Security: A Proposal for a Binding International Agreement to Clean Up the Junk*, 44 VAND. J. TRANSNATION'L. L. 586, 591 (2011).

15. Williams, *supra* note 8, at 1146.

16. WILLIAMSON, *supra* note 2, at 46.

17. *Id.* at 47.

18. *Id.*

layers of material.[19] These layers detonate at a given interval to provide enough power to propel the rocket further.[20] After passing the orbital level, the rocket runs out of fuel and separates from the shuttle, leaving the launching apparatus in orbit.[21] Overall, this process leaves a significant amount of debris behind in the upper atmosphere and beyond.[22]

Space debris from satellites include materials from the launching process, explosions, collisions, and retired satellites which remain in orbit.[23] Objects part of the normal function of launching vehicles or satellites range from spent rocket stages to lost bolts and even flecks of paint.[24] Satellite explosions and collisions produce the most space debris from a single event and continue to proliferate the problem.[25] Satellite explosions may be caused by the presence of unspent fuel aboard the vessel.[26] After an explosion, satellites can transform into over 3,000 trackable pieces of debris, and similar breakups will continue to occur at an increasing rate as more satellites enter orbit.[27] Also, anti-satellite weapon tests are another source of avoidable debris.[28] The most recent and most catastrophic anti-satellite test occurred in 2007, when a Chinese anti-satellite test destroyed a weather satellite.[29] The result was a cloud of debris that extended 2,292 miles and contained over 900 fragments.[30]

Collisions between objects in space also exacerbates the problem of debris.[31] During the first decade of space exploration, many did not think that collisions would be likely.[32] In fact, major collisions were rare in the first decades of orbital use.[33] Now, starting from around 1990, there is about one collision every five years between cataloged objects.[34] Also, every day brings the threat of new collisions.[35]

19. *Id.*
20. *Id.*
21. WILLIAMSON, *supra* note 2, at 47–48.
22. *E.g., id.* at 8 tbl.1 (noting the "firsts" of space accompanied by dates).
23. Imburgia, *supra* note 14, at 593.
24. Garcia, *supra* note 7.
25. Emily Kwong, *Space Junk: How Cluttered is the Final Frontier?* (Jan. 13, 2020), https://perma.cc/M59P-FQW5.
26. *Id.*
27. *Id.*
28. *Id.*
29. Leonard David, *China's Anti-Satellite Test: Worrisome Debris Cloud Circles Earth*, SPACE.COM (Nov. 1, 2018), https://perma.cc/4F7T-6UN3.
30. *Id.*
31. Kwong, *supra* note 25.
32. Melissa Davey, *"We've Left Junk Everywhere:" Why Space Pollution Could Be Humanity's Next Big Problem*, THE GUARDIAN (Mar. 25, 2017), https://perma.cc/3G6U-XE4L.
33. Meghan Bartels, *Satellite Collisions Could Become More Common and Scientists Want to Understand Why*, NEWSWEEK (Apr. 25, 2018), https://perma.cc/Q4HC-2QZT.
34. NASA, *The Collision of Iridium 33 and Cosmos 2251: The Shape of Things to Come*, 60TH INT'L ASTRONAUTICAL CONGRESS 11 (2009), https://perma.cc/4CUD-X3AD (hereafter "Collision").
35. Witze, *supra* note 3.

In fact, NASA receives an average of twenty-one warnings about potential collisions daily.[36] These collisions can make a huge impact.[37] In 2009, a nonfunctional Russian satellite and a communications satellite from the United States collided in the "most severe accidental fragmentation on record."[38] Ultimately, this incident left over 1,800 pieces of trackable debris in an area of heavy satellite traffic.[39]

When satellites are retired, they too become a member of the space debris community. Because the environment of space is so harsh, satellites have a limited functional lifespan.[40] The estimated lifespan of commercial satellites is fifteen years.[41] This has two major effects on space debris: first, the high turnover means that there are more retired satellites in orbit and, second, more launches create more breakoff debris.

There are more satellites in orbit today than ever before, and that number only continues to increase.[42] In 2017, more satellites were launched than in any other year of space exploration, which represents a general trend of exponential growth in satellite launches.[43] According to the 20th edition of Euroconsult's "Satellites to be Built & Launched," the space industry is only going to expand.[44] There could be as much as a threefold increase in satellite launches in the next decade.[45] With the growth of the space industry, there will be a growth in over 20,000 pieces of space debris currently surrounding our planet.[46]

In addition, without intervention, objects in space will remain there for a very long time.[47] One factor affecting how long objects remain in orbit is how far away from Earth the objects are.[48] Satellites and other debris congregate in particular orbital areas.[49] The two most populous orbital zones are the low Earth orbital ("LEO") and geosynchronous Earth orbit ("GEO").[50] The lifespan of debris in

36. *Id.*
37. Collision, *supra* note 34, at 11–12.
38. Collision, *supra* note 34, at 14.
39. *Id.*
40. Michael W. Taylor, *Trashing the Solar System One Planet at a Time: Earth's Orbital Debris Problem*, 20 GEO. INT'L ENVTL. L. REV. 1, 3 (2007).
41. *Hearings on Commercial Space Transportation Before the Subcomm. on Aviation of the House Comm. on Transportation and Infrastructure*, 109th Cong. 1 (2005) (statement of Mr. John W. Douglass, President and Chief Executive Officer, Aerospace Industries Association of America).
42. Kendall Russell, *Satellite Launches to Increase Threefold Over the Next Decade*, SATELLITE TODAY (Oct. 15, 2018), https://perma.cc/M6MT-N8EW.
43. Witze, *supra* note 3 (see table from ESA's Annual Space Environment Report).
44. Russell, *supra* note 42.
45. *Id.*
46. European Space Agency, *supra* note 6.
47. Taylor, *supra* note 40, at 6–7 (describing the life space of objects in low Earth orbit and objects in geosynchronous orbit).
48. *Id.*
49. *Id.* at 5.
50. NAT'L RESEARCH COUNCIL, COMM. ON SPACE DEBRIS, ORBITAL DEBRIS: A TECHNICAL ASSESSMENT 18 (1995) (LEO encompasses orbits up to 5,500 km from earth,

LEO ranges from a few months to 20,000 years depending on how close the object starts to Earth.[51] For objects in GEO, experts estimate that objects could remain there for anywhere from one million to ten million years.[52] These lifespans indicate that the problem will not take care of itself anytime soon.

B. The Negative Consequences of Unchecked Space Debris

Now that we have a better picture of what creates the problem of space junk, we can examine the consequences. For one, collisions are more likely as more objects accumulate in space.[53] These collisions create more debris, meaning operational satellites are in a more dangerous environment, putting valuable property at greater risk of destruction.[54] Space debris may also interfere with signals coming from satellites.[55] These collisions create more debris, which further increases the likelihood of more collisions.[56] As the cycle continues, it becomes "self-generating and thus uncontrollable."[57] Ultimately, if the debris around Earth continues to grow, humans may limit our ability to use outer space for satellites or space travel in the future.[58] This situation is known as the Cascade Effect or the Kessler Effect.[59]

The Cascade Effect is one of the most dangerous threats posed by orbital debris because it represents an existential threat to space travel and utilization of satellites and space in general.[60] The fear of the cascade effect results from its conclusion: "collisions will eventually produce an impenetrable debris that will encase Earth."[61] Even small fragments in space can cause substantial damage due to the high speeds of orbit.[62] Hugh Lewis, a space debris researcher at the University of Southampton's School of Engineering Science, noted "you only need something the size of a marble to completely destroy a spacecraft."[63] Because of the long lifespan of space fragments, the Cascade Effect would result in centuries of uninhabitable space.[64] Today, space is a rich platform for a plethora of

while GEO is higher. GEO occupies the plane 35,787 km above the Earth's equator. Objects in GEO move as fast as the Earth revolves around its axis).

51. Taylor, *supra* note 40, at 6.
52. Taylor, *supra* note 40, at 7.
53. Williams, *supra* note 8, at 1146.
54. *Id.*
55. *Id.*
56. *Id.*
57. BAKER, *supra* note 10, at 13.
58. Williams, *supra* note 8, at 1146.
59. *Id.* at 1145.
60. Imburgia, *supra* note 14, at 598.
61. Jennifer M. Seymour, *Containing a Cosmic Crisis: A Proposal for Curbing the Perils of Space Debris*, 10 GEO. INT'L ENVTL. L. REV. 891, 914 (1998).
62. Kate Kelland, *Preventing Collisions with Space Junk Could Be Costly*, WASH. POST (Oct. 30, 2018), https://perma.cc/JC6A-XNZQ.
63. *Id.* (quoting Hughe Lewis; internal quotation marks omitted).
64. Imburgia, *supra* note 14, at 598.

technologies from cell phones, GPS, and weather monitoring, including tracking greenhouse gases, to military strategy and scientific studies, like the ISS.[65] If collisions result in an impenetrable debris cloud, these activities and space exploration of any form would be shut down.[66]

In addition to collisions and the Cascade Effect, space debris may also reenter Earth's atmosphere and cause damage.[67] Debris will eventually return to Earth, usually breaking up into harmlessly miniscule pieces during reentry.[68] As larger pieces of debris return to Earth however, there's a greater danger factor.[69] In November 2018, two large objects dropped onto a Myanmar mining facility and destroyed a home.[70] One object was barrel-like and about fifteen feet long.[71] This incident is a reminder that what goes into space does not just disappear.

However, some debris is inherently dangerous regardless of size because it contains radioactive material.[72] During the Cold War era, many satellites were built with radioactive components.[73] Today, there is an estimated 1,500 kilograms of radioactive material in orbit, which mostly rests in LEO.[74] As these materials make their way back onto Earth, the impact sites are at risk for radioactive contamination.[75] In fact, this scenario occurred in 1978, when a Soviet satellite reentering Earth's atmosphere dispersed radioactive debris across Canada's Northwest Territory.[76] Luckily, specialists detected no radioactivity in the surrounding area.[77] However, the risk increases as the Cold War era satellites continue to age and reentry to Earth becomes more likely.[78]

II. Current Space Management Practices

Starting at the dawn of the space age, the international community has attempted to regulate how States use the area around the Earth.[79] However, these attempts have not bound the States to hard and fast rules and, therefore, the actions

65. NASA, *What is a Satellite*, NASA (Nov. 18, 2018), https://perma.cc/UP5P-9XT6.
66. Imburgia, *supra* note 14, at 598.
67. Taylor, *supra* note 40, at 22.
68. *Id.* at 22–23.
69. Dom Galeon, *The Space Debris Problem: Dual Impact in Myanmar Shows What's to Come*, FUTURISM (Nov. 14, 2016), https://perma.cc/GW5F-FQGQ.
70. *Id.*
71. *Id.*
72. Taylor, *supra* note 40, at 23.
73. *Id.*
74. *Id.*
75. *Id.*
76. 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, 213 (2004).
77. *Id.*
78. Taylor, *supra* note 40, at 22.
79. Imburgia, *supra* note 14, at 611.

of individual States have largely overridden the international guidelines.[80] In addition, "there is no legal concept of space debris under international space law and thus no mechanisms to regulate it."[81] State scientists have also made some attempts to reduce the risks associated with space debris.[82] However, there has been little success in actually removing retired satellites or smaller debris from space.[83] In this section, I will lay out some key regulations on space activity in international law and from State agencies, and why those regulations are ineffective to handle the expansive problem.

A. International Space Law

Before the first man walked on the moon, the international community began to establish a legal scheme for space.[84] The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies ("Outer Space Treaty") has since been ratified by 109 countries, including the United States.[85] The Outer Space Treaty established space as a "Common Heritage of Mankind," meaning it is a common resource pool for everyone on Earth.[86] The treaty states that space "shall be free for exploration and use by all States," and no one State can lay a legal claim on anything found in space.[87] While the Outer Space Treaty didn't contemplate space debris, it does assert that any object in space would remain the responsibility of the State that launched it.[88] Because nations are responsible for their citizens under the treaty, States should also regulate the commercial activity of their private actors.[89] However, the treaty does not say what this responsibility entails.[90] The treaty does suggest that States must restrict "contamination of space" and should "adopt appropriate measures for this purpose" when necessary.[91] However, it is unclear what counts as contamination and when intervention is necessary.[92] In fact, the

80. *Id.* at 611–612.

81. Steven Freeland, *Up, Up and . . . Back: The Emergence of Space Tourism and Its Impact on the International Law of Outer Space*, 6 CHI. J. INT'L L. 1, 20 (2005).

82. Taylor, *supra* note 40, at 19–23.

83. *Id.*

84. 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, 610 U.N.T.S. 205 (hereinafter "Outer Space Treaty").

85. U.N. Office for Outer Space Affairs, Status of International Agreements to Activities in Outer Space (Apr. 1, 2019), https://perma.cc/5JLG-8KZ7.

86. Outer Space Treaty, supra note 84, at art. II.

87. *Id.*

88. *Id.* at art. VII.

89. *Id.* at art. VI.

90. *Id.*

91. Outer Space Treaty, *supra* note 84, at art. IX.

92. *Id.*

Outer Space Treaty contains no clear restriction on the behavior of States except that activities in space be "peaceful."[93]

The Outer Space Treaty introduces the idea of a State's liability for its action in space, and the 1972 Liability Convention ("Liability Convention") establishes a structure for a tort policy between international actors in space.[94] However, at the time of the Convention, space debris in orbit was less pervasive, and therefore the main focus was damage caused by debris hitting Earth.[95] For damage incurred in space, the document is silent.[96] Also, because the Convention defines "damage" as only extending to people and property, there is no liability for damaging the environment of space itself.[97] Ultimately, a State cannot be liable for polluting orbitals in space under this convention.[98]

As an attempt to clarify the terms in the Outer Space Treaty, the Liability Convention did provide a definition of space object, which included the component parts and the launching apparatus, meaning States would be liable for smaller debris.[99] However, the challenge here is in assigning blame. According to the Convention, before States can be liable blame must be assigned to one actor.[100] Because the origin of smaller objects is not typically known, assigning blame can be very difficult.[101] Even in large collisions, like the one in 2009 between a Russian satellite and American satellite, there was no blame assigned and therefore, no liability placed on either State for the creation of over 1,800 pieces of debris.[102] Because there are no clear consequences for State actors who generate debris, there is little incentive for them to change their behavior.

In 1975, the international community made another attempt to regulate objects in space: The Convention on Registration of Objects Launched into Outer Space ("Registration Convention").[103] Under this convention, nations who launch objects into space must register them with the international community and ensure that these objects comply with international standards.[104] However, once again the international community was silent about space debris.[105] In fact, nations are not required to provide information about orbital position or whether objects have

93. *Id.*

94. Convention on International Liability for Damage Caused by Space Objects, Mar. 29, 1972, 24 U.S.T. 2389 (hereinafter "Liability Convention").

95. BAKER, *supra* note 10, at 79.

96. *Id.*

96. Liability Convention, *supra* note 94, at art. I.

98. N. Jasentuliyana, *Space Debris and International Law*, 26 J. SPACE. L. 139, 143 (1998).

99. Liability Convention, *supra* note 94, at art. I & art. III (assigning liability to a State "if the damage is due to its fault or the fault of persons for whom it is responsible").

100. Imburgia, *supra* note 14, at 617.

101. *Id.*

102. Collision, *supra* note 35, at 14.

103. Convention on Registration of Objects Launched into Outer Space, Jan. 14, 1975, 28 U.S.T. 695 (hereinafter "Registration Convention").

104. *Id.* at art. II.

105. BAKER, *supra* note 10, at 77.

broken up in space, factors that would help the international community combat debris.[106] States are also not under any mandatory obligation to report or update reports.[107]

In 2007, the Committee for the Peaceful Uses of Outer Space ("COPUOS") created seven, nonbinding guidelines for mitigating space debris.[108] These guidelines were then endorsed and adopted by the U.N. General Assembly.[109] These guidelines are an acknowledgement of the problem and a general call for more research and monitoring.[110] However, the biggest problem is that they are nonbinding on nations.[111] As demonstrated above, since 2007, the problem has become worse. Yet, the international community has failed to establish guidelines strong enough to curb behavior likely to lead to more space pollution.

B. Available Technologies to Combat Space Debris

Domestic agencies, like NASA and the European Space Agency ("ESA"), have developed methods to reduce the risk of space debris.[112] However, technology currently in practice only manages retired satellites and not the smaller pieces of orbital debris.[113] How satellites are removed depends on whether they reside in LEO or GEO. Satellites in LEO can be brought down to Earth.[114] One way is to retrieve them with a robotic arm attached to a manned spacecraft.[115] While this method allows for a lot of control, it is very expensive and puts astronaut lives at risk, and therefore, is rarely employed.[116] A more common method is to retire the satellite with residual fuel and use the fuel to maneuver the satellite to a controlled landing into the Pacific Ocean.[117] This solution, however, may create another pollution problem, this time on Earth as more satellites build up in our oceans. It should be noted that international law requires neither of these options, and nations may simply leave objects in orbit indefinitely.[118]

106. *Id.*
107. *Id.*
108. Comm. on the Peaceful Uses of Outer Space, Report of the Scientific and Technical Subcommittee on its forty-fourth session, held in Vienna from 12 to 23 February 2007, Annex IV P. 1, U.N. Doc. A/AC.105/890 (Mar. 6, 2007).
109. Comm. on the Peaceful Uses of Outer Space, Report of the Scientific and Technical Subcommittee on its forty-fourth session, held in Vienna from 12 to 23 February 2007, *supra* note 108.
110. *Id.*
111. *Id.*
112. WILLIAMSON, *supra* note 2, at 260.
113. *Id.*
114. *Id.* at 76.
115. *Id.* at 260.
116. *Id.*
117. WILLIAMSON, *supra* note 2, at 76.
118. Liou & Johnson, *supra* note 12, at 340.

When satellites are in GEO, they cannot safely return to Earth.[119] Instead, the main method to remove GEO satellites from high traffic areas is the use of "graveyard orbitals."[120] Like LEO satellites, GEO satellites retain some fuel, which is used to navigate them to a less populated orbit where they are retired to remain indefinitely.[121] In theory, these satellites will be removed when the technology capable of bringing them back to Earth develops.[122] In reality, this is not so much a solution as a delay tactic which provides humanity with more years of GEO use.[123]

Without a viable process to remove smaller space debris and satellites from GEO, mitigation measures may not be enough.[124] Some scientists believe that there is currently enough debris to set off the Cascade Effect's promised chain reaction, resulting in a cloud of debris.[125] Therefore, human intervention must go beyond these mitigation measures and seek technologies to actively remove the debris present in space.

III. Moving Forward, International Environmental Law Should More Strictly Protect Space as the Common Heritage of Mankind.

Although the Outer Space Treaty lacks the necessary enforcement tools to make it effective, its ideological vision for space as the Common Heritage of Mankind is the necessary mindset to solve the problem of space debris.[126] To protect the space environment, nations must consider the impacts they are making on other States, even those that are not currently capable of launching objects into space. In addition, as mentioned above, technology must be developed to not only mitigate the effects of space debris, but to also remove small debris and GEO satellites. Plus, there needs to be a better method to recycle satellite materials if, and when, they are brought back to Earth.

A. Shifting the Law to Encourage Equal Use of and Responsibility for the Space Environment

To send a satellite into space, the International Telecommunication Union ("ITU") must confirm that there is an available orbital slot.[127] ITU manages the finite number of orbital slots in both the LEO and GEO.[128] To avoid signal

119. WILLIAMSON, *supra* note 2, at 75.
120. *Id.*
121. *Id.*
122. *Id.*
123. Imburgia, *supra* note 14, at 628.
124. Imburgia, *supra* note 14, at 599.
125. *Id.* at 597.
126. Outer Space Treaty, *supra* note 84, at art. II.
127. R. BENDER, LAUNCHING AND OPERATING SATELLITES: LEGAL ISSUES 40 (1998).
128. *Id.*

interference, the availability of a unique radio frequency is the first limit on the number of satellites which can effectively operate in space.[129] The limited nature of operations in space therefore has the secondary function of preventing even more overpopulation. In addition, this provides ITU a lot of discretion to fulfill the promise of a space as a resource for all.[130]

Currently, ITU assigns slots on a "first come, first served" basis, meaning developed countries with space programs are currently occupying all available slots.[131] However, ITU has the discretion to maintain as they choose, meaning they could assign an equal number of satellites for every nation.[132] Guaranteed slot assignments for all countries would accomplish two goals. First, it would allow States without a space program to rent out their slots and reap some of the benefits of space exploration.[133] If developing countries charge for the use of their a priori orbitals, it creates an additional roadblock before nations can launch a satellite because it necessitates negotiation prior to launch. The extra discussion may preclude unnecessary satellites from entering space by encouraging nations to share satellite technologies instead of launching their own. Second, it would mean that every nation has an equal stake in preventing the continued proliferation of space debris. This means that nations previously unaffected by space debris have incentive to push for stricter regulations.

To that point, international law must develop a new legal regime designed to promote the removal and mitigation of space debris. One of the first places to start is to strengthen the Registration Convention. States should be required to report information like orbital position and instances of fragmentation that can affect the space debris problem. Keeping a record of these developments will allow the international community to monitor which States are producing debris and respond accordingly. Additionally, registration should occur before satellites are launched into space so that satellites can be denied. This way, the registration board holds leverage over bad actors in the celestial environment.

Furthermore, liability in space needs to adjust with the growing problem of space debris. For example, under the Liability Convention, objects in space are never abandoned but are eternally the property of the launching nation.[134] Therefore, the Liability Convention could actually make it more difficult to clean up space. Because of this rule, any attempt to remove small pieces of debris in bulk would require the consent of the owner of each fragment. To simplify the space cleanup project, the definition of ownership needs to be adjusted to allow for abandoned property in space, which would allow cleanups without unnecessary liability. Also, the Liability Convention should include activity within the region of space, including any pollution of the space environment.

129. *Id.*
130. Outer Space Treaty, *supra* note 84, at art. II.
131. BENDER, *supra* note 127, at 42.
132. *Id.* at 44.
133. BENDER, *supra* note 127, at 43.
134. Liability Convention, *supra* note 94, at art. IX.

B. Encouraging Scientific Innovation

Ultimately, to prevent future disaster, space debris must be removed. Therefore, innovative technology must be developed. Currently, scientists are proposing new theories to solve the problem.[135] These ideas range from in-space trash collectors, including a giant "NERF ball" covered in goo to collect small objects, to ground-based lasers capable of pulling satellites back to Earth.[136] However, none of these theories have passed NASA's viability standards.[137] To develop a technology capable of handling all aspects the space debris issue, there needs to be extensive research, which means extensive funds.

Because space is the responsibility of the international community, there should be an international fund responsible for paying for the research and development of debris-removal technology. The system should be based on the polluter pays principle or on the principle that "States should take those actions necessary to ensure that polluters and users of natural resources bear the full environmental and social costs of their activities."[138] Because space is a resource for the benefit of the entire planet, the nations that reduce its value should pay the highest cleanup fee. The United States, Russia, and China are the three greatest producers of space debris and should provide a commensurate amount to the fund.[139] Going forward, as nations produce and report debris, the international community could charge them a fee that will also go towards the fund.

Conclusion

The space debris problem is complicated. A solution requires the cooperation of each nation in space, despite the business opportunity a new satellite presents. In order to meet the challenge, international law needs to shift the balance of power and return space to its position as the Common Heritage of Mankind.

135. Jeanna Bryner, *Cosmic Clean-Up: Wild Ideas to Sweep Space*, SPACE.COM (Mar. 19, 2008), https://perma.cc/ZT6L-STZB.

136. *Id.*

137. *Id.*

138. DAVID HUNTER, JAMES SALZMAN & DURWOOD ZAELKE, INTERNATIONAL ENVIRONMENTAL LAW AND POLICY 485 (5th ed. 2015).

139. Union of Concerned Scientists, *supra* note 5.