Space: A Final Frontier or a Relic of Science Fiction References?

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INTRODUCTION

Imagine you are stargazing. As you look into the sky, you are surprised to realize that, where you could normally see an abundance of stars, the sky appears more barren; the stars are less visible.[1] As you wonder why the stars have seemingly disappeared, an astronaut orbiting space on the International Space Station ("ISS") is scrambling to follow emergency shelter procedures because a piece of scrap metal the size of a chip of paint is traveling 28,000 kilometers per hour towards her spacecraft.[2] In both of these instances, space debris is the culprit. Space debris has the potential to steal the stars away from stargazers and to risk the life of astronauts in space.[3] This "space junk" also has the potential to cause other catastrophic results,[4] making it a problem of epic proportions for all persons on Earth and in space.[5]

The space debris problem has escalated severely in the past decade with the exponential increase of satellite launches.[6] In fact, even if no other satellites or space objects were launched into space, space debris would simply continue to accumulate, further increasing the risk the debris poses to

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1. Ben Turner, *Space Junk Is Blocking Our View of the Stars, Scientists Say*, LIVE SCIENCE (Apr. 29, 2021), https://www.livescience.com/space-junk-blocks-view-of-cosmos.html [https://perma.cc/86NS-USUS] (discussing research finding space debris is increasing the overall brightness of the sky and arguing this increased light "could potentially obscure astronomical sights").

2. *See* EXEC. OFF. OF THE SEC'Y-GEN., UNITED NATIONS, OUR COMMON AGENDA POLICY BRIEF 7: UNITED NATIONS, FOR ALL HUMANITY—THE FUTURE OF OUTER SPACE GOVERNANCE 15 (2023).

3. *See id.*; Turner, *supra* note 1.

4. *See infra* Part II.

5. *Id.*

6. EXEC. OFF. OF THE SEC'Y-GEN., *supra* note 2, at 4, 14.

property and people.[7] At this point, stabilizing the space environment requires active debris removal ("ADR") efforts.[8]

Despite the severity of the space debris problem, current space law—five binding space treaties and international soft law mechanisms—and even legal principles outside of space law are incapable of solving the issue.[9] The current binding space treaties cannot solve the space debris problem because, other than being outdated, it is unclear whether the treaties apply to space debris and, if they do apply, the current terms of the treaties hinder space debris removal.[10] On the other hand, the international soft law mechanisms do define space debris and encourage debris mitigation but are voluntary and unenforceable.[11] These characteristics make soft law ineffective because parties engaging in space exploration reasonably seek to maximize their own benefit from their use of space to the detriment of all other actors.[12] The voluntary mechanisms cannot halt such self-interested actions,[13] especially since mitigation efforts are no longer a sufficient solution.[14] Finally, the legal principles outside of space law—maritime law of finds and the law of abandonment—cannot solve the problem on their own because of unique contours to the space debris problem that frustrate applying these legal constructs.[15]

This Comment proposes a space debris solution that both addresses the shortcomings of the space treaties and incorporates aspects of maritime and property law to encourage ADR.[16] The proposed solution is three-fold:[17] First, the space treaties must be amended to clarify that space debris falls under the definition of a space object;[18] second, the space treaties must be amended to delineate two pathways by which a space object can become abandoned and subsequently "found" and claimed;[19] third, the space treaties must be

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7. Sara Henry, *Cleaning Up Space Junk: Applying the Models of U.S. Domestic Environmental Law to Regulate the Creation of Orbital Debris by Private Actors*, 128 DICK. L. REV. 775, 788 (2024); *see infra* Part II.

8. *See infra* Section II.E.

9. *See infra* Section VI.A.

10. *See id.*

11. *See id.*; *infra* Part IV.

12. Garrett Hardin, *The Tragedy of the Commons*, 162 SCI. 1243, 1244 (1968).

13. *See infra* Section VI.A.

14. *See infra* Section II.E.

15. *See infra* Section VI.A.

16. *See infra* Section VI.B.

17. *See id.*

18. *See id.*

19. *See id.*

amended to mitigate liability for actors participating in good faith ADR efforts.[20]

This Comment proceeds in seven parts. Part I introduces the idea of space debris, providing a definition and background on the source and amount of existing debris.[21] Part II introduces five consequences of the space debris problem: the threat to property and persons; the financial implications of space debris; the Kessler Syndrome; the "tragedy of the space commons"; and that debris mitigation is no longer enough.[22] Part III discusses the three space treaties relevant to space debris.[23] Part IV discusses the international soft law approaches to space debris.[24] Part V delves outside of space law to introduce legal principles from maritime and property law, respectively, each of which may be applied to space debris.[25] Part VI discusses this Comment's proposed solution.[26] First, Part VI addresses the current legal regimes' inability to solve the space debris problem.[27] Second, Part VI introduces this Comment's three-fold solution.[28] Third, Part VI argues the recommended treaty amendments adhere to principles of international acceptance.[29] Part VII then briefly concludes.[30]

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20. *See id.*
21. *See infra* Part I.
22. *See infra* Part II.
23. *See infra* Part III.
24. *See infra* Part IV.
25. *See infra* Part V.
26. *See infra* Part VI.
27. *See infra* Section VI.A.
28. *See infra* Section VI.B.
29. *See infra* Section VI.C.
30. *See infra* Part VII.

I. SPACE DEBRIS

"Space: the final frontier."[31]

When you look into the night sky, what do you see? You are likely to see stars and the light of the moon. You *might* be able to see distant planets or galaxies. But you likely do not see the orbital debris culminating from nearly seventy years of space exploration.[32] In this case, what you can't see can hurt you, as well as the rest of the world. Before addressing the space debris problem in depth, it is worthwhile to contextualize the space debris issue by defining space debris, discussing the sources of space debris, and acknowledging how much space debris orbits the Earth.

A. Defining Space Debris

No universally accepted definition of space debris exists.[33] Notably, none of the binding legal authorities on space law even mention "space debris."[34] In answer to this silence, the Committee on the Peaceful Uses of Outer Space ("COPUOUS") developed a definition "incorporating debris both in Earth orbit but also in the process of 'de-orbiting.'"[35] Under COPUOS's definition, space debris is "[a]ll man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional."[36]

Space debris does not exist forever, but it does stay in orbit for a considerable time depending on its altitude.[37] The greater the altitude, the greater its time in orbit.[38] Debris will typically fall back to Earth within twenty-five years if it is orbiting in an altitude under 600 kilometers.[39] However, debris will orbit Earth for centuries if orbiting at an altitude of at

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31. *Star Trek: The Man Trap* (NBC television broadcast Sept. 8, 1966).

32. *See A Brief History of Space Exploration*, AEROSPACE CORP., https://aerospace.org/article/brief-history-space-exploration [https://perma.cc/4ZCU-ECJA].

33. Annie Handmer & Steven Freeland, *The Use of Law to Address Space Debris Mitigation and Remediation: Looking Through a Science and Technology Lens*, 87 J. AIR L. & COM. 375, 378 (2022).

34. Arpit Gupta, *Regulating Space Debris as Separate from Space Objects*, 41 U. PA. J. INT'L L. 223, 231 (2019).

35. Handmer & Freeland, *supra* note 33, at 378.

36. *Id.*

37. OFF. OF INSPECTOR GEN., NAT'L AERONAUTICS & SPACE ADMIN., IG-21-011, NASA'S EFFORTS TO MITIGATE THE RISKS POSED BY ORBITAL DEBRIS 4 (2021).

38. *Id.*

39. *Id.*

least 800 kilometers.[40] Without outside intervention to deorbit the debris, collisions, explosions, or decay into smaller pieces may occur.[41] Each of these fragmentation events creates more, albeit smaller, debris objects.[42]

B. Source of Space Debris

Various fragmentation events and numerous parties create space debris.[43] Space debris is typically generated either by space launches (as general collateral from the mission), or by larger space objects fragmenting due to time, intentional destruction, accidental collisions, or other fragmentation events.[44] There are various types of fragmentation events, but explosions are currently the primary source of space debris.[45] However, collisions between working satellites and existing space debris are predicted to overtake explosions as the predominant source of space debris.[46]

Many nations contribute to space debris creation.[47] As of 2018, Russia, the United States, and China were the greatest contributors to space debris, followed by France, Japan, India, and the European Space Agency.[48] The

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40. *Id.*

41. *Id.*

42. *Id.*

43. *Space Environment Statistics*, SPACE DEBRIS USER PORTAL, https://sdup.esoc.esa.int/discosweb/statistics/# [https://perma.cc/VP5W-2XFY]; Dave Mosher & Samantha Lee, *More Than 14,000 Hunks of Dangerous Space Junk Are Hurtling Around Earth – Here's Who Put It All Up There*, BUS. INSIDER (Mar. 29, 2018), https://www.businessinsider.com/space-junk-debris-amount-statistics-countries-2018-3.

44. Handmer & Freeland, *supra* note 33, at 378.

45. Fragmentation may result from different fragmentation events: accidental, aerodynamics, anomalous, collision, deliberate, electrical, propulsion, and unknown. *Space Environment Statistics*, *supra* note 43. Accidental fragmentation events include those where design flaws are the ultimate cause of space object break ups. *Id.* Aerodynamic fragmentation events are those where the interaction with Earth's atmosphere is the catalyst for fragmentation. *Id.* Anomalous events are those where an unplanned separation occurs. *Id.* Fragmentation from explosions may occur from electrical fragmentation events, where "[s]tored energy for non-passivated batteries might lead to an explosion," or propulsion fragmentation events where "[s]tored energy for non-passivated propulsion-related subsystems might lead to an explosion." *Id.* Collisions and deliberate space object destruction also result in fragmentation. *Id.*

46. *The Current State of Space Debris*, EUR. SPACE AGENCY (Dec. 10, 2020), https://www.esa.int/Space_Safety/Space_Debris/The_current_state_of_space_debris [https://perma.cc/DQ9D-XUR6]. *See, e.g.*, James E. Dunstan, *Space Trash: Lessons Learned (and Ignored) from Space Law and Government*, 39 J. SPACE L. 23, 24 (2013) ("[T]he collision between the Iridicum 33 (a U.S. Commercial satellite with a mass of 560 [kilograms]) and retired (derelict) Cosmos 2251 (a Russian satellite with a mass of 950 [kilograms]) . . . created another 2,500 trackable objects.").

47. Mosher & Lee, *supra* note 43.

48. *Id.*

United States led with its contribution of 3,990 space debris objects in orbit.[49] Russia closely followed with its contribution of 3,959 space debris objects in orbit.[50] China was a third leading contributor with its 3,893 space debris objects in orbit.[51] Current estimates of space debris objects in orbit are far greater than these three countries' space debris contributions combined, however.[52]

C. Amount of Space Debris

As of late February of 2025, more than 13,500 tons of space objects orbit the Earth.[53] Though only 39,340 space objects are regularly tracked by the Space Surveillance Networks, millions of space debris objects are estimated to be in orbit.[54] More specifically, there are currently an estimated 40,500 space debris objects larger than ten centimeters, 1.1 million space objects between the size of one to ten centimeters, and 130 million space debris objects between one millimeter and one centimeter in size.[55]

Space debris numbers have increased since 2022.[56] In 2022, there were 36,500 space debris objects over ten centimeters in size and one million space debris objects between one and ten centimeters in size.[57] In just three years, the number of space debris objects over one centimeter in size increased by 104,000.[58] Given these startling statistics, low Earth orbit ("LEO")—the orbital region at an altitude 2,000 kilometers above Earth[59] and just one of the many orbital regimes polluted by space debris[60]—has even been referred to "as the World's largest garbage dump."[61]

Space debris populations were not always so large; the orbital space debris population has exponentially increased since the advent of space

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49. *Id.*
50. *Id.*
51. *Id.*
52. *Space Environment Statistics*, *supra* note 43.
53. *Id.*
54. *Id.*
55. *Id.*
56. *Compare Space Environment Statistics*, *supra* note 43, *with* Handmer & Freeland, *supra* note 33, at 378.
57. Handmer & Freeland, *supra* note 33, at 378.
58. *Compare Space Environment Statistics*, *supra* note 43, *with* Handmer & Freeland, *supra* note 33, at 378.
59. OFF. OF INSPECTOR GEN., *supra* note 37, at 3 n.5.
60. *Space Environment Statistics*, *supra* note 43.
61. *Space Debris*, NAT'L AERONAUTICS SPACE ADMIN., https://www.nasa.gov/headquarters/library/find/bibliographies/space-debris [https://perma.cc/PKC3-55FV].

exploration.[62] This increase is attributable to two separate, but related reasons.[63] First, the number of space objects launched into space has increased.[64] In 2018 alone, the number of objects launched into space was more than double the number launched in the early 2000s.[65] And in 2023, more satellites were launched than in any prior year.[66] Second, spacecraft collisions and explosions, intentional and unintentional, have contributed to the rise in space debris.[67] The increase of space object launches only increases the risk of spacecraft collisions and, as a result, the creation of additional space debris.[68] To date, the largest of these collision fragmentation events were the 2007 intentional destruction of a Chinese satellite and a 2009 unintentional collision between an American and Russian spacecraft.[69] Together, the 2007 explosion and 2009 collision created more than 5,000 space debris pieces.[70]

Though these numbers are staggering, space debris numbers are only expected to grow.[71] This proliferation is expected because of the anticipated increase space object launches[72]—which heightens the risk of collisions—into a space environment already at "critical mass."[73] For example, by 2030, over 60,000 satellites are expected to be in orbit with over 1.7 million more satellite launches anticipated beginning in the same years.[74] The estimated 1.7

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62. *The Current State of Space Debris*, *supra* note 46; *see also* OFF. OF INSPECTOR GEN., *supra* note 37, at 1.

63. OFF. OF INSPECTOR GEN., *supra* note 37, at 1.

64. *Id.*

65. *Id.* at 1 fig.1.

66. *ESA Space Environment Report 2024*, EUR. SPACE AGENCY (July 19, 2024), https://www.esa.int/Space_Safety/Space_Debris/ESA_Space_Environment_Report_2024 [https://perma.cc/3PRL-HD8L].

67. OFF. OF INSPECTOR GEN., *supra* note 37, at 1.

68. *Id.* at 2.

69. *Id.* at 1.

70. *Id.*

71. *The Current State of Space Debris*, *supra* note 46.

72. *Scientists Call for Global Push to Eliminate Space Debris*, UNIV. OF TEX. AT AUSTIN: COCKRELL SCH. OF ENG'G (Mar. 14, 2023), https://www.ae.utexas.edu/news/scientists-call-for-global-push-to-eliminate-space-debris [https://perma.cc/J6F4-2TVB]; EXEC. OFF. OF THE SEC'Y-GEN., *supra* note 2, at 4, 14.

73. OFF. OF INSPECTOR GEN., *supra* note 37, at 1, 14; Muin F. Bogari, Exploring the Relationship Between the Growing Number of Satellites and Space Debris in Low Earth Orbit, and People's Perception of Space Debris Environmental Impacts 21 (May 2023) (Masters of Engineering Thesis, University of Tennessee at Chattanooga) (on file with author) (noting the presence of numerous satellites and rocket bodies in the LEO region increases the chances of creating more space debris upon collisions or explosions).

74. *Scientists Call for Global Push*, *supra* note 72; EXEC. OFF. OF THE SEC'Y-GEN., *supra* note 2, at 5.

million launches excludes any potential space travel or tourist endeavors, so the true number of future space object launches may be even greater.[75] The estimate merely covers non-geostationary satellites.[76] The increase in past and anticipated space object launches is largely due to space commercialization and technological advancements decreasing spacecraft and launch costs.[77]

The images below illustrate the extent of space debris orbiting Earth in 2019.[78] Overall, the increase in space object launches will generate more space debris, furthering the space debris problem and the need for a solution that actively removes space debris.[79]

75. *See* EXEC. OFF. OF THE SEC'Y-GEN., *supra* note 2, at 5.

76. *Id.*

77. OFF. OF INSPECTOR GEN., *supra* note 37, at 14.

78. *See infra* Figure 1; *infra* Figure 2; *infra* Figure 3. For a video mapping the space debris problem, see Jennifer Green, *Space Junk Map Tracks 200 'Ticking Time Bombs'*, BBC (Apr. 25, 2021), https://www.bbc.com/news/av/science-environment-56845104 [https://perma.cc/UYJ4-5WNX].

79. OFF. OF INSPECTOR GEN., *supra* note 37, at 1, 4; *see infra* Part II.

Figure 1.
This image illustrates the object population in the LEO region.[80]

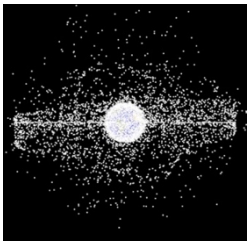

Figure 2.
This image illustrates the object population in the geosynchronous ("GEO") region.[81]

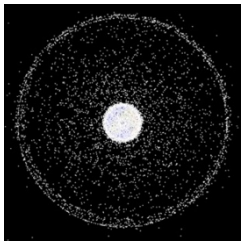

Figure 3.
This image illustrates the concentrations of objects in both the LEO and GEO regions.[82]

II. THE SPACE DEBRIS PROBLEM

"In space, no one can hear you scream."[83]

Space debris is a global problem[84] and, though it may seem either lightyears away from needing meaningful consideration or like a science-fiction novel plot device, the space debris problem has existed for decades.[85] Moreover, space debris concerns everyone; it is not a problem just for SpaceX personnel or National Aeronautics and Space Administration ("NASA") scientists and astronauts.[86]

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80. *Photo Gallery*, NAT'L AERONAUTICS SPACE ADMIN.: ORBITAL DEBRIS PROGRAM OFF., https://orbitaldebris.jsc.nasa.gov/photo-gallery [https://perma.cc/2VK8-TKEE].

81. *Id.* The GEO region is the orbital region at an altitude of approximately 36,000 kilometers. OFF. OF INSPECTOR GEN., *supra* note 37, at 3 n.5.

82. *Photo Gallery*, *supra* note 80.

83. ALIEN (20th Century Studios 1979).

84. *Space Debris FAQ: Frequently Asked Questions*, EUR. SPACE AGENCY (Apr. 2021), https://www.esa.int/Space_Safety/Space_Debris/Space_Debris_FAQ_Frequently_asked_questions [https://perma.cc/J7GZ-37KJ] ("Debris threatens our future in space and everything that relies on it. This is an issue for the entire planet, as all of us rely on services and data delivered via space, and no country can solve this alone.").

85. *See* Donald J. Kessler & Burton G. Cour-Palais, *Collision Frequency of Artificial Satellites: The Creation of a Debris Belt*, 83 J. GEOPHYSICAL RES. 2637, 2645 (1978).

86. *See Space Debris FAQ: Frequently Asked Questions*, *supra* note 84.

As Christa McAuliffe said, "[s]pace is for everybody. It's not just for a few people in science or math or for a select group of astronauts. That's our new frontier out there, and it's everybody's business to know about space."[87] Everyone's stake in space is apparent through the ways space debris impacts facets of the average person's daily life, including losing access to "weather forecasting, climate monitoring, earth sciences, and space-based communications."[88] And at its extreme, the space debris problem may increasingly endanger people on Earth[89] and eventually prevent future access to space.[90] Therefore, everyone should be concerned about space debris and what is being done to address the problem.

The space debris problem is complex, but its implications for, and threat to, humanity may be broken down into five overarching concerns: (1) the endangerment of property and persons both in space and on Earth,[91] as briefly touched on above; (2) space debris' financial implications;[92] (3) the fruition of Kessler Syndrome;[93] (4) the "tragedy of the space commons";[94] and (5) mitigating space debris—the current solution to the problem—is no longer enough. Each are discussed in turn below.

A. Threat to Property and Persons in Space and on Earth

Space debris' increase, especially at exponential rates, corresponds with an "increase in the risks of accident, collision, and debris."[95] This risk endangers property and persons both in space and on Earth.[96] This heightened risk of harm to persons and property exemplifies the necessity of addressing the space debris problem. The threat to property in space, persons in space, and property and persons on Earth are each discussed below.

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87. Rebecca Ramdeholl, *Christa McAuliffe: Space, Our New Frontier for All*, THE AVERAGE SCIENTIST (Aug. 31, 2023), https://theaveragescientist.co.uk/2023/08/31/christa-mcauliffe-space-our-new-frontier-for-all [https://perma.cc/H8YH-SS5Z].

88. *The Cost of Space Debris*, EUR. SPACE AGENCY (May 7, 2020), https://www.esa.int/Space_Safety/Space_Debris/The_cost_of_space_debris [https://perma.cc/JM5Z-2C7A].

89. *See infra* Section II.A.

90. *See infra* Section II.C.

91. *See infra* Section II.A.

92. *See infra* Section II.B.

93. *See infra* Section II.C; Kessler & Cour-Palais, *supra* note 84.

94. *See infra* Section II.D.

95. EXEC. OFF. OF THE SEC'Y-GEN., *supra* note 2, at 14.

96. *See id.*; *e.g.*, *Space Debris Weighing over 1,000 Pounds Reportedly Crashes into Village in Kenya*, CBS NEWS (Jan. 1, 2025), https://www.cbsnews.com/news/space-debris-reportedly-crashes-village-kenya [https://perma.cc/CXG9-2AQH].

1. Threat to Property in Space

Space debris threatens property in space.[97] The risk of property damage rises as the space debris population grows.[98] And both small and large debris increase the risk of damage.[99] For instance, even "[o]bjects as small as a chip of paint, travelling at more than 28,000 [kilometers] per hour, can cause significant damage to spacecraft."[100] Despite their size, smaller space debris objects are especially concerning because generally only objects over five centimeters in size are trackable[101] and able to be maneuvered around by satellites.[102]

According to NASA, "millimeter-sized orbital debris represents the highest mission-ending risk to most robotic spacecraft operating in low Earth orbit."[103] If an operation spacecraft were to collide with space debris larger than even one centimeter, the collision would likely result in the spacecraft being disabled, and, for a decommissioned spacecraft or rocket, could result in explosion.[104] Collisions with debris larger than ten centimeters are assumed to result in "catastrophic break-ups, which completely destroy the spacecraft, thus ending its operation, and generating thousands of debris fragments."[105] To prevent catastrophic collisions with debris, the ISS has "debris shields" to protect itself from debris up to one centimeter in size.[106] The ISS also performs collision avoidance maneuvers when the risk of collision with space debris exceeds a certain predetermined threshold level.[107] By the end of 2020, ISS performed over twenty-six of these maneuvers.[108]

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97. EXEC. OFF. OF THE SEC'Y-GEN., *supra* note 2, at 14.

98. *Id.*

99. *See id.* at 15.

100. *Id.*

101. Space debris can be reliably tracked when at ten centimeters in size. *Space Debris Identification and Tracking*, OFF. OF THE DIR. OF NAT'L INTEL., https://www.iarpa.gov/research-programs/sintra [https://perma.cc/XXC7-X8LH].

102. *Copernicus Sentinel-1A Satellite Hit by Space Particle*, EUR. SPACE AGENCY (Aug. 31, 2016), https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-1/Copernicus_Sentinel-1A_satellite_hit_by_space_particle [https://perma.cc/ED9A-TCNS].

103. Sophie Lewis, *Space Junk Slams into International Space Station, Leaving Hole in Robotic Arm*, CBS NEWS (June 2, 2021), https://www.cbsnews.com/news/space-junk-damage-international-space-station [https://perma.cc/X958-EPDQ].

104. *Space Debris FAQ: Frequently Asked Questions*, *supra* note 84.

105. *Id.*

106. *Id.*

107. *Id.*

108. *Id.*

Not only can small space debris objects cause significant damage to spacecrafts, small objects *have* caused damage to space objects.[109] In 2016, space debris hit the Copernicus Sentinel-1A satellite's solar panel.[110] The space debris was only a millimeter in size,[111] the same size as a sharp pencil point.[112] Despite the debris' small size, the satellite solar panel's affected area was approximately forty centimeters.[113] Other than the physical damage, the collision impacted the satellite's power, orientation, and orbit.[114] In 2021, space debris damaged the ISS's Canadarm2, causing a "gaping hole in a section of the arm boom and thermal blanket."[115] NASA has also reported that damage from paint fleck debris from another collision event damaged multiple space shuttle windows, which were then replaced.[116] Though this threat of property damage is a notable concern, it is not the only nor most considerable threat space debris poses.

2. Threat to Persons in Space

In addition to endangering property in space, space debris and the threat of collision threatens persons in space.[117] For example, in 2009, the ISS initiated a nine-minute evacuation because a thirteen-centimeter piece of space debris was passing nearby.[118] Space personnel were again put at risk in 2021 when seven ISS astronauts had to take shelter in response to orbital debris passing too close to their spacecraft.[119] These collisions and close calls illustrate the active danger to persons and spacecrafts currently in space, as

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109. Leonard David, *European Satellite Hit by Space Particle*, SPACE.COM (Aug. 31, 2016), https://www.space.com/33920-european-satellite-space-particle-strike.html [https://perma.cc/2T48-TYPS].

110. *Id.*; *Copernicus Sentinel-1A Satellite Hit by Space Particle*, *supra* note 102.

111. David, *supra* note 109; *Copernicus Sentinel-1A Satellite Hit by Space Particle*, *supra* note 102.

112. Terese Winslow, *Tumor Size in Millimeters*, NAT'L INSTS. OF HEALTH: NAT'L CANCER INST. (Mar. 13, 2019), https://visualsonline.cancer.gov/details.cfm?imageid=12163 [https://perma.cc/Y226-6VQL].

113. *Copernicus Sentinel-1A Satellite Hit by Space Particle*, *supra* note 102.

114. *Id.*

115. Lewis, *supra* note 103.

116. *Id.*

117. Handmer & Freeland, *supra* note 33, at 379.

118. *Id.*

119. Meghan Bartels, *Space Debris Forces Astronauts on Space Station to Take Shelter in Return Ships*, SPACE (Nov. 15, 2021), https://www.space.com/space-debris-astronauts-shelter-november-2021 [https://perma.cc/XPA8-FJWL].

well as those that will be entering space in the future.[120] However, space is not the only place where property and persons are threatened by space debris.

3. Threat to Property and Persons on Earth

Even property and persons on Earth are at risk of injury from space debris.[121] This risk is evident from numerous documented close calls with falling debris.[122] In December of 2024, 1,100 pounds of space debris fell into a Kenyan village.[123] The debris was likely a separation ring from a launch vehicle.[124] Earlier in 2024, a Florida home was struck by space debris, luckily, while the family was on vacation.[125] In 2022, a SpaceX Dragon capsule crashed into an Australian sheep farm.[126] Even aircrafts are put at risk by space debris.[127] Recent research expressed concern regarding the increasing possibility of collisions between larger space debris objects (such as rocket bodies) and in-flight aircrafts.[128] Increased air traffic density in addition to increased spacecraft launches heightens this risk.[129] Clearly, Earth is not a safe zone from the space debris threat.[130] In addition to the significant implications for persons and property on Earth and in space, space debris carries serious financial consequences.

B. Financial Implications of Space Debris

The space debris problem also carries serious financial implications.[131] Some estimates calculate the annual financial losses from space debris as

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120. *Id.*; *Copernicus Sentinel-1A Satellite Hit by Space Particle*, *supra* note 102; Lewis, *supra* note 103.

121. *See Space Debris FAQ: Frequently Asked Questions*, *supra* note 84.

122. *Space Debris Weighing over 1,000 Pounds Reportedly Crashes into Village in Kenya*, *supra* note 96.

123. *Id.*

124. *Id.*

125. *Id.*

126. *Id.*

127. Ewan Wright et al., *Airspace Closures Due to Reentering Space Objects*, 15 SCI. REPS. 2966 (2025).

128. *Id.* at 2966–67. The results of such collisions would be "catastrophic," despite "the probability of a strike [being] low." *Id.* at 2966.

129. *Id.* at 2971.

130. *See Space Debris FAQ: Frequently Asked Questions*, *supra* note 84.

131. R. BUCHS, LAUSANNE: EPFL INT'L RISK GOVERNANCE CTR., COLLISION RISK FROM SPACE DEBRIS: CURRENT STATUS, CHALLENGES, AND RESPONSE STRATEGIES 13 (2021), https://spacewatch.global/wp-content/uploads/2021/07/IRGC-2021.-Collision-risk-from-space-debris-Current-status-challenges-and-response-strategies.pdf [https://perma.cc/TR8R-Y8YK].

falling anywhere between a little over a thousand dollars (for a commercial GEO operator) to thirty-one million dollars (for a military LEO operator) because of small debris (one to ten centimeters in size).[132] However, the full extent of space debris' financial impact is unclear because of untracked debris damage, the lack of transparency regarding costs to prevent debris damage, and the defensive purpose behind space debris monitoring.[133] Available data and estimates reveal space debris' financial implications include (1) the cost of avoiding space debris collisions;[134] (2) the cost of losing and replacing damaged spacecrafts;[135] and (3) the cost of leaving valuable metals and space craft components/parts in space.[136]

1. Cost of Avoiding Space Debris Collisions

Space debris imposes a financial burden on parties launching space objects because avoiding space debris collisions is a costly endeavor.[137] For example, the estimated cost for a human spaceflight operator to avoid space debris is $1 million per propellant maneuver with the labor behind each maneuver costing an additional $8,000.[138] Even issuing a warning is costly; each warning is estimated to cost $200.[139] Other estimates suggest the cost per satellite maneuver to avoid space debris may climb upwards of $10 million due to fuel loss.[140] Without considering the loss of the space object itself, simply avoiding debris collision is financially burdensome.

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132. THOMAS J. COLVIN ET AL., OFF. OF TECH., POL'Y, & STRATEGY, NAT'L AERONAUTICS SPACE ADMIN., COST AND BENEFIT ANALYSIS OF ORBITAL DEBRIS REMEDIATION 54 tbl.6 (2023), https://www.nasa.gov/wp-content/uploads/2023/03/otps_-_cost_and_benefit_analysis_of_orbital_debris_remediation_-_final.pdf [https://perma.cc/5SP4-GNEP]. These calculations assume space debris levels remain constant every year.

133. BUCHS, *supra* note 131, at 13.

134. *See* COLVIN ET AL., *supra* note 132, at 53 tbl.5; *The Cost of Space Debris*, *supra* note 88.

135. COLVIN ET AL., *supra* note 132, at 53 tbl.5; BUCHS, *supra* note 131, at 13.

136. D. Perry Rihl II, *Cleaning Up the Mess: Incentivizing the Salvage of Orbital Debris*, 10 GEO. MASON J. INT'L COM. L. 68, 82 (2019).

137. *See* COLVIN ET AL., *supra* note 132, at 53 tbl.5; *The Cost of Space Debris*, *supra* note 88.

138. *See* COLVIN ET AL., *supra* note 132, at 53 tbl.5.

139. *Id.*

140. Dylan Houle, *Preventing the Next Global Crisis: Addressing the Urgent Need for Space Debris Removal*, 111 CAL. L. REV. 1955, 1959 (2023).

2. Cost of Losing and Replacing Damaged Spacecrafts

Spacecraft maneuvers to avoid debris may be costly, but the damage or loss of an operational spacecraft is the more substantial financial loss.[141] In fact, the removal of 100,000 small space debris objects (ranging in size from one to ten centimeters) is estimated to save $23 million in damages.[142] Damage that escalates to a lost space vehicle is especially costly, though the estimated loss varies by the type of spacecraft and the space program.[143] The estimated cost of losing a human spaceflight operator vehicle is $200 million.[144] But the greatest financial loss is associated with lost civil operational and military operator vehicles, which are both estimated to cost $820 million to lose.[145] At the other end of the spectrum, the least costly operator vehicle to lose is a CubeSat/SmallSat, which is estimated to cost $300,000.[146]

These estimates are based on the cost of replacing the inoperable satellite,[147] but the total cost of losing a spacecraft may be greater because of the initial financial investments into each spacecraft or mission.[148] For example, the Hubble Space Telescope program was a $4.7 billion investment at its launch.[149] Therefore, damage to the satellite creates a greater financial loss because of the greater initial financial investment.[150] An additional cost to losing satellites and other space crafts to space debris is that additional space debris inhibits the replacement of destroyed spacecrafts.[151] Debilitated and inoperable spacecrafts become space debris themselves, decreasing the "optimal number of satellites," hindering their full replacement.[152] The loss of a spacecraft is a substantial financial blow, but an additional financial implication from space debris is the loss of the scrap metal itself.

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141. COLVIN ET AL., *supra* note 132, at 53 tbl.5; BUCHS, *supra* note 131, at 13.

142. Michael B. Runnels, *On Who Should Pay When Orbital Debris "Trickles-Down" in A Tragedy of the Low Earth Orbit Commons*, 88 J. AIR L. & COM. 775, 792 (2023).

143. COLVIN ET AL., *supra* note 132, at 53 tbl.5; BUCHS, *supra* note 131, at 13–14.

144. COLVIN ET AL., supra note 132, at 53 tbl.5.

145. *Id.* at 53 tbl.5.

146. *Id.*

147. *See, e.g.*, *id.* at 85 tbl.20.

148. *See* BUCHS, *supra* note 131, at 13.

149. *Id.*

150. The prior estimates were based off an assumption that a 1,000 kilogram satellite would cost approximately $500 million for design, manufacture, launch, and operation costs. COLVIN ET AL., *supra* note 132, at 8. Therefore, the satellite loss may be greater because the initial financial investment may significantly surpass the worth of the satellite. *Compare id.*, *with* BUCHS, *supra* note 131, at 13.

151. Anelí Bongers & José L. Torres, *Orbital Debris and the Market for Satellites*, 209 ECOLOGICAL ECON. 1, 8–9 (2023).

152. *Id.* at 8.

3. Cost of Leaving Valuable Metals and Spacecraft Parts in Space

An additional financial implication is the loss of valuable scrap metal.[153] Space debris isn't an accumulation of random trash materials, but is made up of lucrative metals like aluminum, titanium, copper, and precious metals, in some scenarios.[154] Aluminum, the most commonly used material in spacecrafts, is likely the most common space debris material.[155] Importantly, both aluminum and titanium are considered critical materials,[156] which are materials essential for modern-day economy.[157]

Some estimates show the scrap metals making up space debris are worth millions—if not billions—of dollars.[158] This is an important financial loss to consider because space materials, such as those orbiting as space debris, are recyclable.[159] Given this recycling opportunity, potentially millions of dollars' worth of useable materials are orbiting unclaimed in space.[160] The financial implications from space debris are substantial, but space debris has graver consequences effecting the whole of humanity, like the Kessler Syndrome.

C. Kessler Syndrome

Another concerning implication of space debris is that, as the problem escalates, it becomes increasingly likely the dreaded Kessler Syndrome will come to fruition.[161] The Kessler Syndrome was a scenario first articulated by Donald J. Kessler and Burton G. Cour-Palais in 1978.[162] Kessler Syndrome predicts a "cascading phenomena."[163] Kessler and Cour-Palais predicted that

153. Rihl II, *supra* note 136, at 82.

154. Fumihiro Hayashi et al., *Unveiling the Resource Potential of Space Debris: A Forecast of Valuable Metals to 2050*, 193 WASTE MGMT. 376, 377 (2025).

155. *Id.*

156. *Id.*

157. *Critical Raw Materials*, U.N. ECON. COMM'N FOR EUR., https://unece.org/unece-and-sdgs/critical-raw-materials (last visited Oct. 26, 2025).

158. Rihl II, *supra* note 136, at 82.

159. *See* Frank Koch, *The Value of Space Debris*, 8 EUR. CONF. ON SPACE DEBRIS PROC. 1, 1 (2021), https://conference.sdo.esoc.esa.int/proceedings/sdc8/paper/3/SDC8-paper3.pdf [https://perma.cc/9NBJ-ALTN].

160. *See id.*; Rihl II, *supra* note 136, at 82.

161. *The Cost of Space Debris*, *supra* note 88.

162. Kessler & Cour-Palais, *supra* note 85.

163. Sraavya Poonuganti, *It's Raining Rockets: Heightening State Liability for Space Pollution*, 23 CHI. J. INT'L L. 490, 492 n.5 (2023) (citing Jordan Liew, *The Kessler Syndrome: A World Without Satellites*, GEO. INT'L ENV'T L. REV. ONLINE (2015), https://gielr.wordpress.com/2015/02/11/the-kessler-syndrome-a-world-without-satellites-georgetown-international-environmental-law-review-2 [https://perma.cc/RU3D-5LJ3].

if the orbital space debris trends of 1978 persisted, a "cascading phenomena" would inevitably occur where space debris collisions with itself and other space objects would continuously create new space debris, exponentially increasing the space debris population and eventually forming the space debris equivalent to an asteroid belt.[164]

Already, the beginning stages of the Kessler Syndrome have manifested, as demonstrated by the 2009 American and Russian spacecraft collision[165] and other documented debris collisions.[166] And it is too late to simply stop sending additional space objects, such as satellites, to space.[167] Since 2005, NASA has estimated that the levels of space debris in Earth's orbit has accumulated to a point that collisions would continue to occur without more space objects being launched into space.[168] Further inaction towards solving the space debris problem risks the ultimate catastrophic result from Kessler Syndrome: Earth's orbital zones becoming effectively unusable due to an orbital belt of space debris,[169] preventing further space operations and a future of space travel or exploration. This worst-case scenario, and lesser stages of space debris pollution, also leads to another significant negative implication of space debris: the "tragedy of the space commons."[170]

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164. *Id.*; Kessler & Cour-Palais, *supra* note 85, at 2645. At the time, Kessler and Cour-Palais indicated that "[e]ffective methods exist to alter the current trend without significantly altering the number of operational satellites in orbit," including cutting back on the number of large non-operational satellites and improving the design of satellites to prevent fragmentation of the space objects by accidental fragmentation events. *Id.*

165. OFF. OF INSPECTOR GEN., *supra* note 37, at 1.

166. *Space Debris 101*, AEROSPACE CORP., https://aerospace.org/article/space-debris-101 [https://perma.cc/JDS7-2JWX] (last visited Oct. 26, 2025) ("There have been four documented collisions between objects big enough to track, and several other suspected collisions.").

167. EXEC. OFF. OF THE SEC'Y-GEN., *supra* note 2, at 15; *see also* Major Marc G. Carns, *Consent Not Required: Making the Case That Consent Is Not Required Under Customary International Law for Removal of Outer Space Debris Smaller Than 10cm2*, 77 A.F. L. Rev. 173, 184 (2017) ("There is also evidence that even if no new debris is added to space, the potential for an increase in debris, to the point of possibly one day making space unusable, could already exist.").

168. EXEC. OFF. OF THE SEC'Y-GEN., *supra* note 2, at 15.

169. Joseph Kurt, *Triumph of the Space Commons: Addressing the Impending Space Debris Crisis Without an International Treaty*, 40 WM. & MARY ENV'T L. & POL'Y REV. 305, 309 (2015).

170. Peng Wang, Tragedy of Commons in Outer Space: The Case of Space Debris 2 (May 4, 2013) (unpublished paper) (on file with SSRN), https://ssrn.com/abstract=2260856.

D. Tragedy of the Space Commons

An additional consequence of the space debris problem is the impending "tragedy of the space commons."[171] The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including Moons and Other Celestial Bodies ("Outer Space Treaty") describes outer space as "the province of all mankind" and "free for the exploration and use by all States."[172] By declaring outer space "the province of all mankind," the Outer Space Treaty effectively declared outer space a common resource—a resource accessible by all without the ability to be restricted by others.[173] As a global commons, outer space is vulnerable to the "tragedy of the commons."[174]

The "tragedy of the commons" is a phenomenon popularized by Garrett Hardin in 1968.[175] Hardin explained the "tragedy of the commons" as the result of rational, self-interested actors acting for their positive gains to the detriment of their common property:

> Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons . . . As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility *to me* of adding one more animal to my herd?" . . . the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another. . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy.[176]

In Hardin's explanation, the herdsmen consider the positives and negatives of adding cattle to their herd.[177] The positive considerations are the herdsmen's receipt of what benefits each may derive from the additional animal (i.e., the proceeds that come from having an additional animal).[178] The

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171. *Id.*

172. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies art. I, paras. 1–2, *opened for signature* Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 (entered into force Oct. 10, 1967) [hereinafter Outer Space Treaty].

173. Chelsea Muñoz-Patchen, *Regulating the Space Commons: Treating Space Debris as Abandoned Property in Violation of the Outer Space Treaty*, 19 CHI. J. INT'L L. 233, 236 (2018); Wang, *supra* note 170, at 3.

174. Wang, *supra* note 170, at 3.

175. Hardin, *supra* note 12, at 1244.

176. *Id.*

177. *Id.*

178. *Id.*

negative considerations arise from the additional animals' overgrazing of the common resource.[179] The resulting "tragedy" is the depletion of the common resource.[180]

As Hardin argues, "[e]ach man is locked into a system that compels him to increase his herd without limit—in a world that is limited."[181] A common (and limited) resource is accessible to and used by multiple owners, none of whom has the right to exclude another owner.[182] "Tragedy" occurs when the multiple, non-exclusory owners overuse the resource, depleting it.[183] Despite multiple owners recognizing their overuse will deplete the common resource, "no one [has] the capacity individually to stop such result and just to the contrary, rational individuals are prone to reap some additional profit before the final exhaustion."[184]

Space debris is instigating a "tragedy of the commons" in outer space.[185] Outer space is a common resource,[186] and the space debris, created and added to by multiple, non-exclusory owners, are polluting outer space like the open pasture is overgrazed by the herders' cattle.[187] With each State continuing to contribute to the space debris problem yet failing to actively remove any space objects or debris, outer space becomes increasingly crowded, frustrating States' ability to freely explore and use outer space in the future.[188] The "tragedy" here is the loss of outer space as the "province of all mankind."[189] The space debris problem and its consequences, like those previously described, are exacerbated by the fact the problem is no longer salvageable through mitigation efforts.

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179. *Id.*
180. *Id.*
181. Hardin, *supra* note 12, at 1244.
182. Wang, *supra* note 170, at 3.
183. *Id.* at 4.
184. *Id.* at 5.
185. Muñoz-Patchen, *supra* note 173, at 236, 250.
186. *See* Outer Space Treaty, *supra* note 172, art. I, paras. 1–2.
187. Muñoz-Patchen, *supra* note 173, at 250.
188. *Id.*
189. Outer Space Treaty, *supra* note 172, art. I, para. 1; *see* Muñoz-Patchen, *supra* note 173, at 250.

E. Mitigation Is No Longer Enough

Space debris has historically, and largely continues to be, addressed through mitigation,[190] which is defined as "attempts to prevent future debris generation through the design, operation, and post-mission disposal of spacecraft to ensure they do not explode or collide with other objects."[191] However, space debris mitigation is no longer a sufficient approach if resolving, rather than slowing, the threat of space debris is the end goal. Rather, ADR is necessary to solve the space debris problem,[192] as the space debris population has reached a tipping point where mitigation of space debris is no longer enough.[193]

A 2005 NASA study indicated that "even if no future objects were launched into orbit, the debris already in space would continue to collide with each other."[194] More recent NASA reports indicate that ninety percent of all spacecraft must be removed from orbit post-mission—in addition to actively removing five defunct spacecraft a year—in order to stabilize the future orbital debris environment.[195] The inability of space debris to resolve itself in a timely manner further contributes to the necessity for ADR.[196] Estimates suggest current "debris will remain in orbit for at least one hundred years, posing a threat to satellites for decades to come while also continuing to collide with other debris."[197] Therefore, for there to be any meaningful difference accomplished, ADR must become a key part of any space debris solution.

The space debris problem endangers people and property, has significant financial implications, may lead to the Kessler Syndrome and the "tragedy of the space commons," and is too great a problem for mitigation to fix.[198] Despite these disastrous consequences, the space debris problem is ineffectively governed by the current binding space law regime.[199] The existing legal framework governing space law is discussed below.

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190. *See, e.g.*, OFF. OF INSPECTOR GEN., *supra* note 37, at 11 ("Currently, no U.S. government entity has been assigned, received funding, or actively undertaken the task of removing existing orbital debris.").

191. *Id.* at 4.

192. *See* Henry, *supra* note 7, at 787–88.

193. *Id.*

194. *Id.* at 788.

195. OFF. OF INSPECTOR GEN., *supra* note 37, at 17.

196. *See Space Debris 101*, *supra* note 166.

197. Houle, *supra* note 140, at 1960.

198. *See supra* Part II.

199. *See infra* Section VI.A.

III. CURRENT BINDING SPACE LAW

"Do or do not, there is no try."[200]

Five binding legal authorities primarily govern outer space activities:[201] (1) the Outer Space Treaty;[202] (2) the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space ("Rescue Agreement");[203] (3) the Convention on International Liability for Damage Caused by Space Objects ("Liability Convention");[204] (4) the Convention on Registration of Objects Launched into Outer Space ("Registration Convention");[205] and (5) the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies ("Moon Agreement").[206]

Each of the space treaties were signed prior to 1980 and entered into force prior to 1985.[207] The primary catalyst for forming each treaty was geopolitical concerns.[208] For example, the stage was set for the first space treaty by World War II's conclusion and the subsequent rising competition between the United States and the Soviet Union, especially after the Iron Curtain's

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200. STAR WARS: THE EMPIRE STRIKES BACK (LucasFilm Ltd. 1980).

201. *See* Comm. on the Peaceful Uses of Outer Space, *Status of International Agreements Relating to Activities in Outer Space as at 1 January 2024*, U.N. Doc. A/AC.105/C.2/2024/CRP.3 1–4 (Apr. 24, 2024) (noting there are five United Nations treaties governing outer space activities, though other international agreements exist and address space communications, the peaceful use of outer space, and the banning of nuclear weapon testing in space).

202. Outer Space Treaty, *supra* note 172.

203. Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, Dec. 19, 1967, 9 U.S.T. 7570, 672 U.N.T.S. 119, 7 I.L.M. 149 (1968) [hereinafter Rescue Agreement].

204. Convention on International Liability for Damage Caused by Space Objects, *opened for signature* Mar. 29, 1972, 24 U.S.T. 2389, 861 U.N.T.S. 187, 10 I.L.M. 965 (entered into force Sept. 1, 1972) [hereinafter Liability Convention].

205. Convention on Registration of Objects Launched into Outer Space, *opened for signature* Jan. 14, 1975, 28 U.S.T. 695, 1023 U.N.T.S. 15, 14 I.L.M. 43 (entered into force Sept. 15, 1976) [hereinafter Registration Convention].

206. Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, *opened for signature* Dec. 18, 1979, 1363 U.N.T.S. 22, 18 I.L.M. 1434 [hereinafter Moon Agreement].

207. *Beyond Mitigation: Process and Challenges of Orbital Debris Remediation*, SPACE GENERATION ADVISORY COUNCIL (June 21, 2024), https://spacegeneration.org/beyond-mitigation-progress-and-challenges-of-orbital-debris-remediation [https://perma.cc/B3VS-JQLG]; *Treaties: Agreement Governing the Activities of States on the Moon and Other Celestial Bodies*, U.N. OFF. FOR DISARMAMENT AFFS., https://treaties.unoda.org/t/moon/participants?status=parties [https://perma.cc/ZU89-SNQL].

208. Peter Jankowitsch, *The Background and History of Space Law*, *in* HANDBOOK OF SPACE LAW 2 (Frans von der Dunk ed., 2015).

creation.[209] At the time, space technology was in its infancy and tensions were high, though agreements were being reached to ban nuclear weapons from outer space.[210] A few years after such an agreement, eighty-nine parties signed the first of the space treaties, the Outer Space Treaty, with the four other treaties signed within the following decade.[211]

As an initial matter, this Comment will not discuss the Rescue Agreement[212] and Moon Agreement[213] because these treaties are less relevant to the space debris solution posited by this Comment. This Part continues by discussing the other three space treaties: the Outer Space Treaty, the Liability Convention, and the Registration Convention.

A. The Outer Space Treaty

Eighty-nine parties signed the Outer Space Treaty in 1967.[214] The Outer Space Treaty's depositories were the United Kingdom, Russian Federation, and United States governments.[215] As of 2024, 114 parties have ratified, accepted, or approved accession/succession of the Outer Space Treaty.[216] Some scholars remark "the treaty was drawn up not only in some haste within the space of less than [twelve] months but also less than ten years after the launch of the earth's first satellite."[217] The Outer Space Treaty was, and remains, unique to international law, especially to the law of the high seas, in

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209. *Id.* at 2–3.

210. *Id.* at 3.

211. Outer Space Treaty, *supra* note 172; Rescue Agreement, *supra* note 203; Liability Convention, *supra* note 204; Registration Convention, *supra* note 205; Moon Agreement, *supra* note 206.

212. The Rescue Agreement governs how parties to it should act when there are distressed persons and property in space or a launching party's space object has fallen to Earth outside its jurisdiction. *See* Rescue Agreement, *supra* note 203.

213. The Moon Agreement—the last of the binding space treaties—governs how parties to the treaty should act regarding the use and exploration of the moon and other celestial bodies. *See* Moon Agreement, *supra* note 206. Specifically, the Moon Agreement secures peaceful and shared use of the moon and other celestial bodies. *See id.*

214. Outer Space Treaty, *supra* note 172.

215. *Treaties: Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, U.N. OFF. FOR DISARMAMENT AFFS., https://treaties.unoda.org/t/outer_space/participants?status=signatories [https://perma.cc/E9EW-7WUK].

216. Comm. on the Peaceful Uses of Outer Space, *supra* note 201, at 10.

217. Jankowitsch, *supra* note 208, at 5.

that it prioritized peace[218] and opportunities for future scientific and economic endeavors.[219]

The Outer Space Treaty establishes outer space as a common resource to all "State Parties"[220] by declaring it "the province of all mankind."[221] State Parties may freely and without discrimination explore—physically and scientifically—and use outer space and its celestial bodies "for the benefit and in the interest of all countries."[222] The Outer Space Treaty further protects outer space's status as a common resource by prohibiting outer space's national appropriation by any State Party.[223] This prohibition serves as one of the limits to State Parties' use of outer space, as well.[224]

There are several other limitations on State Parties' free use and exploration of outer space.[225] Other than preventing non-peaceful uses of outer space, such as its weaponization, the Outer Space Treaty requires State Parties to act "with due regard to the corresponding interests of all other State Parties to the treaty."[226] Additionally, the use of outer space may not "harmful[ly] interfer[e]" with other State Parties' use of outer space, nor "harmful[ly] contaminate" outer space.[227] The Outer Space Treaty also seeks to protect Earth, barring outer space activities adverse to Earth's environment.[228] Some scholars argue space debris violates the due regard requirements under the Outer Space Treaty because space debris hinders other nations' space exploration and pollutes the outer space environment.[229]

The Outer Space Treaty does not define space debris, nor is "space debris" ever mentioned in its text.[230] The closest the Outer Space Treaty comes to discussing space debris is its discussion of space objects, though there is no definition provided for space objects either.[231] Some scholars contend that space objects and their component parts include space debris, though other

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218. Articles III and IV of the Outer Space Treaty specifically call for State Parties to act in the interest of international peace and to use outer space and its celestial bodies solely for peaceful purposes. Outer Space Treaty, *supra* note 172, art. III–IV.

219. Jankowitsch, *supra* note 208, at 5.

220. State Parties, as referred to in this Comment, are the sovereign nations who signed the respective treaty being discussed.

221. Outer Space Treaty, *supra* note 172, art. I, para. 1.

222. *Id.* art. I.

223. *Id.* art. II.

224. *Id.*

225. *See id.*

226. *Id.* art. IV, IX.

227. Outer Space Treaty, *supra* note 172, art. IX.

228. *Id.*

229. Muñoz-Patchen, *supra* note 173, at 250, 252.

230. *See* Outer Space Treaty, *supra* note 172.

231. *Id.*

scholars argue space debris, given its non-functional and fragmented nature, should fall outside the scope of the Outer Space Treaty.[232]

Space objects and their component parts are discussed in two important contexts, the first being State Parties' ownership and jurisdiction over objects launched into space.[233] Under Article VIII of the Outer Space Treaty, State Parties retain perpetual jurisdiction and ownership over objects they launch into space.[234] This ownership persists whether or not the object remains in space or has returned to Earth.[235] The Outer Space Treaty offers no mechanism by which to sever this ownership or jurisdiction.[236] This indefinite ownership and jurisdiction is cited by many scholars as a hindrance to solving the space debris problem.[237] As one scholar frames it, if space debris is a space object, then "when a state removes the space debris of another state from orbit due to the danger posed by it to active space objects or even astronauts, the action may be considered against international law, and may even be considered an act of piracy."[238]

Space objects and their component parts are also discussed in the context of State Party liability.[239] Under Article VII of the Outer Space Treaty, State Parties are internationally liable for damage their launched space objects cause to another State Party, on Earth or in space.[240] Liability is incurred whether the State Party "launches[,] . . . procures the launching of an object into outer space," or permits the offending space object to be launched from its territory.[241] The Outer Space Treaty does not specify how causation is determined to establish liability.[242] The Outer Space Treaty's lackluster liability provisions were expanded on by the Liability Convention.[243]

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232. Gupta, *supra* note 34, at 234.
233. Outer Space Treaty, *supra* note 172, art. VII–VIII.
234. *Id.* art. VIII.
235. *Id.*
236. *See id.*
237. Carns, *supra* note 167, at 226; Gupta, *supra* note 34, at 238, 241–42.
238. Gupta, *supra* note 34, at 241.
239. Outer Space Treaty, *supra* note 172, art. VII.
240. *Id.*
241. *Id.*
242. *See id.*
243. Liability Convention, *supra* note 204.

B. The Liability Convention

In 1972, sixty-four parties signed the Liability Convention, including the United States.[244] Unlike its predecessor, the Liability Convention defines "space object."[245] Under the Liability Convention, "[t]he term 'space object' includes component parts of a space object as well as its launch vehicle and parts thereof."[246] Space debris is not defined or discussed, however.[247]

The Liability Convention establishes when State Parties are liable for damage caused by their space object and the type of liability to be applied.[248] Under Article II of the Liability Convention, launching State Parties are "absolutely" liable for damage its space objects cause to Earth's surface or in-flight aircrafts.[249] Under Article III, State Parties are liable under a fault-based standard for damage caused by their space objects in space.[250] This fault-based standard requires a showing of fault and damages, but "fault" is not defined.[251] Joint and several liability is applied where fault can be attributed to multiple State Parties.[252] In such cases, damages are apportioned according to fault.[253]

There are exceptions to liability imposed under the Liability Convention.[254] A launching State Party may be exonerated from absolute liability if it can show "the damage has resulted either wholly or partially from gross negligence or from an act or omission done with intent to cause damage on the part of a claimant State or . . . persons it represents."[255] On the other hand, no exoneration is permitted if the damages resulted from space activities that were not conforming to international law.[256]

The Liability Convention is less "widely utilized" than the Outer Space Treaty despite its expansion of the Outer Space Treaty's "extremely limited"

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244. *Id.*; *Convention on International Liability for Damage Caused by Space Objects*, U.S. DEP'T OF STATE, https://www.state.gov/wp-content/uploads/2019/03/238-Space-Object-Damage.pdf (June 30, 2017).

245. Liability Convention, *supra* note 204, art. I(d).

246. *Id.*

247. *See id.*

248. *Id.*

249. *Id.* art. II.

250. *Id.* art. III.

251. James P. Lampertius, *The Need for an Effective Liability Regime for Damage Caused by Debris in Outer Space*, 13 MICH. J. INT'L L. 447, 453–54 (1992).

252. Liability Convention, *supra* note 204, art. IV–V.

253. *Id.*

254. *Id.* art. VI.

255. *Id.*

256. *Id.*

liability provisions.[257] In fact, no State Party has used the Liability Convention to seek damages from other State Parties that have caused damage from debris they intentionally created.[258] The Liability Convention has been "scrutinized for its lack of clarity."[259] Not only is "fault" undefined, but there is also no standard of care defined to determine fault.[260] Accordingly, fault may be interpreted to mean either "subjective blameworthiness or objective breach of a preexisting legal duty."[261] This oversight was intentional.[262] The drafters of the Liability Convention believed it was unlikely for damage in space to occur and they were concerned that more definitive standards of care would prevent the Liability Convention's ratification.[263] Like the Liability Convention, the Registration Convention also expanded on the Outer Space Treaty.[264]

C. The Registration Convention

In 1976, twenty-five parties signed the Registration Convention, including the United States of America and China.[265] The Registration Convention does not define "space debris," but it does define "space object," using the same definition from the Liability Convention: "The term 'space object' includes component parts of a space object as well as its launch vehicle and parts thereof."[266] The lack of reference to "space debris" is concerning because there is no mechanism under the Registration Convention by which to identify space debris.[267]

The Registration Convention creates the proper identification method for space objects, requiring launching State Parties to register their space objects

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257. Andrew Hoffmann, *A New Era in the Weaponization of Space: The U.S. Space Force & an Update to the Outer Space Treaty*, 29 TRANSNAT'L L. & CONTEMP. PROBS. 327, 331–32 (2020).

258. *Id.* at 334.

259. *Id.* at 333; Lampertius, *supra* note 251, at 452–53.

260. Lampertius, *supra* note 251, at 453–54.

261. *Id.* at 456.

262. *Id.* at 453–54.

263. *Id.* at 454.

264. *Convention on Registration of Objects Launched into Outer Space*, U.N. OFF. FOR OUTER SPACE AFFS., https://www.unoosa.org/oosa/sk/ourwork/spacelaw/treaties/introregistration-convention.html [https://perma.cc/F5CT-6ME6].

265. *Status of Treaties: Convention on Registration of Objects Launched into Outer Space*, U.N., https://treaties.un.org/pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XXIV-1&chapter=24&Temp=mtdsg3&clang=_en [https://perma.cc/VQE6-RME3].

266. Registration Convention, *supra* note 205, art. I(b).

267. Lampertius, *supra* note 251, at 455.

and report their space objects to the United Nations Secretary-General.[268] Launching State Parties must report the space object's registration number/designator, the date and location of its launch, the object's orbital parameters, and the general function of the space object.[269] State Parties are expected to help identify space objects that have caused damage.[270] State Parties must also notify the United Nations if their space object is no longer in Earth's orbit.[271] Overall, the Registration Convention requires State Parties to keep track of their property in space.[272]

The Outer Space Treaty and its progeny are not the only forms of space law; international organizations have also implemented soft law mechanisms to address space debris.

IV. CURRENT SOFT LAW MECHANISMS

> *"We are going to pull off the true crime of the century. We are going to steal the moon!"*[273]

Though the space treaties explored above are the primary international binding authorities governing space activities, they offer neither a plan nor a solution to the space problem.[274] In the absence of such direction, soft law mechanisms have developed to address space debris.[275] In general, soft law instruments are a form of non-binding authorities where compliance is voluntary.[276] Scholars have looked favorably toward soft law approaches to the space debris problem because of this voluntariness and malleability, which may encourage more countries to accept the guidelines.[277] Another reason soft law has been favored by some is because soft law approaches are likely to be—and, in some cases, already are—generally accepted by the

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268. Registration Convention, *supra* note 205, art. II–III.
269. *Id.* art. IV.
270. *Id.* art. VI.
271. *Id.* art. IV.
272. *See* Registration Convention, *supra* note 205.
273. DESPICABLE ME (Universal Pictures 2010).
274. *See supra* Section VI.A.
275. Handmer & Freeland, *supra* note 33, at 385.
276. Gary Marchant et al., *Governing Emerging Technologies Through Soft Law: Lessons for Artificial Intelligence—an Introduction*, 61 JURIMETRICS J. 1, 5 (2020).
277. Steven Freeland & Yun Zhao, *Rules of the "Space Road:" How Soft Law Principles Interact with Customary International Law for the Regulation of Space Activities*, 44 J. SPACE L. 405, 428 (2020).

international community.[278] This general acceptance has the potential to facilitate the soft law's evolution towards customary international law.[279]

There are four noteworthy international soft law instruments addressing space debris: (1) the Artemis Accords;[280] (2) the Inter-Agency Space Debris Coordination Committee ("IADC") Space Debris Mitigation Guidelines ("IADC Guidelines");[281] (3) the COPOUS Space Debris Mitigation Guidelines ("COPOUS Mitigation Guidelines");[282] and (4) the COPOUS Guidelines for the Long-Term Sustainability of Outer Space Activities ("COPOUS Sustainability Guidelines").[283]

Each of these soft law instruments attempt to remedy the space debris problem by encouraging debris mitigation efforts.[284] The Artemis Accords do so through its signatories agreeing "to plan for the mitigation of orbital debris" and to limit "new, long-lived harmful debris" generation, especially from "normal operations, break-up in the operational or post-mission phases, and accidents and conjunctions."[285] The IADC Guidelines encourage debris mitigation by instructing participating parties to: limit debris during normal operations, limit the chance for on-orbit explosive break-ups, prevent debris creation through proper post-mission disposal procedures, prevent on-orbit collisions, and appropriately design and operate spacecraft constellations.[286] Similarly, the COPOUS Mitigation Guidelines—which were developed

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278. *See* Handmer & Freeland, *supra* note 33, at 388; Marchant et al., *supra* note 276, at 7–8.

279. Freeland & Zhao, *supra* note 277, at 428.

280. NAT'L AERONAUTICS & SPACE ADMIN., *The Artemis Accords: Principles For Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids* (2020), https://www.nasa.gov/wp-content/uploads/2022/11/Artemis-Accords-signed-13Oct2020.pdf?emrc=67e0834d03d3f [https://perma.cc/U3DQ-BGWF].

281. Comm. on the Peaceful Uses of Outer Space, *IADC Space Debris Mitigation Guidelines*, U.N. Doc. A/AC.105/C.1/2025/CRP.9 (Feb. 3, 2025).

282. U.N. OFF. FOR OUTER SPACE AFFS., *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space* (2010), https://www.unoosa.org/pdf/publications/st_space_49E.pdf [https://perma.cc/JN9K-R6RT].

283. U.N. OFF. FOR OUTER SPACE AFFS., *Guidelines for the Long-Term Sustainability of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space* (2021), https://www.unoosa.org/documents/pdf/PromotingSpaceSustainability/Publication_Final_English_June2021.pdf [https://perma.cc/9UBE-UFCT].

284. *See* NAT'L AERONAUTICS & SPACE ADMIN., *supra* note 280, at 6–7; Comm. on the Peaceful Uses of Outer Space, *supra* note 281, at 7, 11–16; U.N. OFF. FOR OUTER SPACE AFFS., *supra* note 282, at 2–4; U.N. OFF. FOR OUTER SPACE AFFS., *supra* note 283, at 14, 27, 38.

285. NAT'L AERONAUTICS & SPACE ADMIN., *supra* note 280, at 6–7. In furtherance of this goal, the signatories agree to consider post-mission passivation and disposal of spacecrafts in an efficient and safe manner, when appropriate. *Id.* at 6.

286. Comm. on the Peaceful Uses of Outer Space, *supra* note 281, at 11–16.

based on the IADC Guidelines[287]—instruct participating parties to: limit debris generation during normal operations, minimize the chance for break-ups from operational phases and post-mission phases, limit the opportunity for accidental collisions, avoid intentional destruction or other harmful activities in orbit, and limit long-term post-mission orbits in the LEO and GEO regions.[288] Finally, the COPOUS Sustainability Guidelines instruct that space objects should be designed and operated to increase space object trackability, to mitigate debris creation, and to avoid any long-term orbits in the protected LEO and GEO regions.[289]

Notably, two of these four soft law instruments have also accomplished what the space treaties have not: define space debris.[290] The IADC Guidelines and the COPOUS Mitigation Guidelines both define space debris as "all human made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional."[291] Neither the Artemis Accords nor the COPOUS Sustainability Guidelines define space debris, however.[292] Overall, the soft law approaches discussed in this Part may be non-binding, but they have offered a definition for space debris and have directly addressed the problem through a space law lens. Some scholars, however, argue that the space debris problem needs solutions outside space law.[293]

V. APPLYING LEGAL PRINCIPLES OUTSIDE INTERNATIONAL SPACE LAW TO SPACE DEBRIS

"We're deep in space, corner of No and Where."[294]

In response to the inadequacies of the binding space treaties and soft law mechanisms, some scholars suggest implementing legal principles outside of

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287. *See* Comm. on the Peaceful Uses of Outer Space, *supra* note 281.

288. U.N. OFF. FOR OUTER SPACE AFFS., *supra* note 282, at 2–4.

289. U.N. OFF. FOR OUTER SPACE AFFS., *supra* note 283, at 14, 27, 38. The IADC Guidelines and COPOUS Mitigation Guidelines are cited as acceptable standards for debris mitigation efforts. *Id.* at 10.

290. *See* NAT'L AERONAUTICS & SPACE ADMIN., *supra* note 280, at 6–7; Comm. on the Peaceful Uses of Outer Space, *supra* note 281, at 8; U.N. OFF. FOR OUTER SPACE AFFS., *supra* note 282, at 2–4; U.N. OFF. FOR OUTER SPACE AFFS., *supra* note 283, at 14, 27, 38; *supra* Part III.

291. Comm. on the Peaceful Uses of Outer Space, *supra* note 281, at 8; U.N. OFF. FOR OUTER SPACE AFFS., *supra* note 282, at 1.

292. *See* NAT'L AERONAUTICS & SPACE ADMIN., *supra* note 280; U.N. OFF. FOR OUTER SPACE AFFS., *supra* note 283.

293. *See infra* Part V.

294. *Firefly: Objects in Space* (Fox television broadcast Dec. 13, 2002).

space law to address the space debris problem.[295] This Part will focus on two such proposed legal principles outside of space law.[296] The first set of principles arise out of maritime law.[297] The other principle addressed in this Part arises from property law: the law of abandonment.[298] Both the maritime law principles and the law of abandonment are discussed in further detail below.

A. Maritime Law, Derelict Property, and the Law of Finds

Some scholars suggest that maritime law principles may apply to the space debris problem.[299] First, property rights in sunken objects are perpetual, just as a State's ownership of a space object is perpetual.[300] Second, like international waters, outer space cannot be claimed by any State.[301] These similarities support the notion that it is reasonable to apply maritime law principles to space debris, in particular, the dereliction and law of finds principles.[302]

Under maritime law, once an object has become derelict or abandoned, the object becomes "up for grabs," so to speak, and free for collection by any interested parties under the law of finds.[303] The necessary consideration in such operations and challenged collections is whether the object had, in fact, been abandoned.[304] In making this determination, three elements must be met.[305] First, the object must be abandoned *sine spe recuperandi*, or "without hope of recovery," thereby severing any claim to ownership.[306] Second, the object must be considered abandoned property or *res derelictae*.[307] Finally, the object's abandonment must have occurred in international waters.[308] Per

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295. *See* Rihl II, *supra* note 136, at 76.
296. *See id.* at 75–76, 78–79.
297. *Id.* at 75–76, 79.
298. Emily M. Nevala, *Waste in Space: Remediating Space Debris Through the Doctrine of Abandonment and the Law of Capture*, 66 AM. U. L. REV. 1495, 1515 (2017).
299. Rihl II, *supra* note 136, at 75–76.
300. *Id.* at 78–79.
301. *Id.* at 75–76.
302. *Id.* at 79–80.
303. *Id.*
304. *Id.* at 80.
305. Rihl II, *supra* note 136, at 80.
306. *Id.*
307. *Id.*
308. *Id.*

the law of finds,[309] "the subsequent finder establishes an ownership right superior to all but the original owner."[310]

B. Law of Abandonment

Other scholars have proposed applying the law of abandonment to the space debris problem.[311] The law of abandonment governs the unilateral transfer of property.[312] Under the law of abandonment, voluntarily abandoned property becomes common property claimable by the first finder.[313] Three elements must be met to satisfy the law of abandonment and permit this unilateral transfer of ownership: (1) the owner must perform a manifest act; (2) the manifest act must show the owner's voluntary "intent to forsake the property;"[314] and (3) the first two elements must occur concurrently.[315]

Furthermore, the owner must be aware of the consequences of their actions; it is not enough to intentionally abandon the property without realizing the abandonment results in the owner relinquishing their rights.[316] It is equally insufficient for the owner to stop using or maintaining their property.[317] Furthermore, since intent to abandon is imperative to the law of abandonment, property can only be abandoned if the owner knows the property exists.[318]

These maritime and property law principles offer unique approaches to the space debris problem that should be incorporated into a larger space debris solution centered around amending the existing space treaties.[319]

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309. Other scholars have recommended an approach similar to the maritime law of salvage to address the space debris problem. *Id.* at 84–87; *see also* Sandra Drago, *No Man's Sky: Utilizing Maritime Law to Address the Need for Space Debris Removal Technology*, 59 SANTA CLARA L. REV. 389 (2019).

310. Rihl II, *supra* note 136, at 80.

311. Nevala, *supra* note 298, at 1515.

312. *Id.*

313. *Id.* at 1516.

314. *Id.* This "owner must intend a total desertion," of their property. *Id.* at 1518.

315. *Id.* at 1516–17, 1519.

316. *Id.* at 1518.

317. Nevala, *supra* note 298, at 1518.

318. *Id.* at 1519.

319. *See infra* Part VI.

VI. SOLVING THE SPACE DEBRIS PROBLEM: ENCOURAGING ADR THROUGH TREATY AMENDMENTS

> *"This mission is too important for me to allow you to jeopardize it."*[320]

Space debris is a problem.[321] As explored in previous Parts, the existing volume of space debris in orbit is astronomical, and it continues to grow, further exacerbating space debris' threat to property and persons in space and on Earth; its potentially devastating financial implications; the swiftly-approaching realization of Kessler Syndrome; the tragedy of the space commons; and the unviability of mitigation-based solutions.[322] And the current legal regime—consisting of both the binding space treaties and the non-binding soft law guidelines—is insufficient to effectively address this problem alone or together.[323] The legal principles outside of space law also cannot resolve the space debris problem themselves, even if applied directly to space.[324] This Comment proposes a solution to the space debris problem predicated on encouraging ADR through amending the existing space treaties.

This Comment does not dispute that amending a treaty is a difficult process; amending the space treaties may be especially difficult since they have been in force for fifty years without amendment.[325] The difficulty associated with amending existing treaties does not, however, make treaty amendments any less necessary. It is the position of this Comment that amending the treaties, whether it is the proposed approach or not, is the only feasible way to truly solve the space debris problem.

Treaty amendments are necessary because binding international law is necessary to influence international actors' space use. As rational and selfish actors, nations and their private industries will continue acting for their sole benefit, depleting outer space, the "province of all mankind," and a common resource.[326] Binding law is necessary to enforce and incentivize a space debris solution that may be initially burdensome and contrary—in the short-term—to self-interested space exploration and use.[327] Additionally, current binding

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320. 2001: A SPACE ODYSSEY (Warner Bros. 1968).
321. *See supra* Part II.
322. *See supra* Part I; *supra* Part II.
323. *See infra* Section VI.A.
324. *See infra* Section VI.A.
325. Hoffmann, *supra* note 257, at 332.
326. *See* Hardin, *supra* note 12, at 1244.
327. *See id.*; *infra* Section VI.A.

space law actively hinders space debris solutions,[328] further necessitating treaty amendments.

This Part proceeds in three parts: (1) a discussion of why the existing legal regime is not sufficient to solve the space debris problem; (2) this Comment's proposed solution to the space debris problem; and (3) a discussion of how this Comment's solution meets the requirements for an effective space law regime.[329]

A. Existing Legal Regimes Are Insufficient to Solve the Space Debris Problem

The existing space law regime capable of addressing space debris consists of the space treaties[330] and international soft law.[331] Some scholars suggest supplementing these space-specific legal approaches with principles from maritime law and property law.[332] Each of these approaches are insufficient solutions to the space debris problem, as illustrated below.

1. Current Binding Space Law Is Insufficient

The existing binding space law (i.e., the space treaties) is insufficient to solve the space debris problem. The reason for this is three-fold: (1) space debris is not defined nor explicitly referenced in any space treaty; (2) the space treaties are outdated; and (3) the space treaties actively hinder space debris solutions.

a. The Space Treaties Fail to Define or Address Space Debris

None of the space treaties define or address space debris explicitly; in fact, "space debris" does not appear in any of the treaty texts.[333] The closest the treaties get to addressing space debris is in their discussion of space objects.[334]

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328. *See infra* Section VI.A.

329. Hoffmann, *supra* note 257, at 350.

330. *See supra* Part III.

331. *See supra* Part IV.

332. *See supra* Part V.

333. Outer Space Treaty, *supra* note 172; Moon Agreement, *supra* note 206; Rescue Agreement, *supra* note 203; Liability Convention, *supra* note 204; Registration Convention, *supra* note 205.

334. *See* Outer Space Treaty, *supra* note 172; Moon Agreement, *supra* note 206; Rescue Agreement, *supra* note 203; Liability Convention, *supra* note 204; Registration Convention, *supra* note 205.

Yet, it is unclear whether "space objects" include space debris, leading to uncertainty as to whether the treaties directly govern space debris.[335]

b. The Space Treaties Are Outdated

The space treaties are outdated. All the space treaties were signed and entered into force prior to 1985.[336] At the time, the Cold War was ongoing, and space exploration was in its infancy; mankind had yet to even set foot on the moon.[337] In those early days, space was primarily concerned with preventing "a new form of colonial competition,"[338] and encouraging peace.[339] Drafters of the Liability Convention hadn't even considered that damage in space could become a likely occurrence.[340] Simply put, today's age of space exploration is substantially different from when the space treaties were created.

The difference between today's space age and the space age of the treaties' creation is evident from the increase in satellite launches.[341] The number of satellite launches was "remarkably consistent" from 1957 to 2012.[342] This trend changed in the last decade, however, and satellite launches have increased exponentially,[343] with no end to this surge in sight.[344] The inability of space law to adequately address the modern era of space exploration is unsurprising. As Brian Israel states, "up to a point, the older the treaty—the more that has changed since its negotiation and conclusion—the less likely it is to be updated through international lawmaking on the same level."[345]

c. The Space Treaties Actively Hinder Space Debris Solutions

The existing space treaties actively hinder efforts to solve the space debris problem. First, under the Outer Space Treaty, State Parties have perpetual

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335. Gupta, *supra* note 34, at 233–34.

336. *Beyond Mitigation: Process and Challenges of Orbital Debris Remediation*, *supra* note 207; U.N. OFF. FOR DISARMAMENT AFFS., *supra* note 207.

337. Gupta, *supra* note 34, at 227.

338. BUREAU OF ARMS CONTROL, VERIFICATION, & COMPLIANCE, *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies*, U.S. DEP'T OF STATE, https://2009-2017.state.gov/t/isn/5181.htm [https://perma.cc/AY7Y-3SYG].

339. Jankowitsch, *supra* note 208, at 4.

340. Lampertius, *supra* note 251, at 452.

341. EXEC. OFF. OF THE SEC'Y-GEN., *supra* note 2, at 4.

342. *Id.*

343. *Id.*

344. *Id.* at 5; Napper et al., *supra* note 72.

345. Brian Israel, *The End of Treaties? Treaty Stasis*, 108 AJIL UNBOUND 63, 63 (2015).

ownership over space objects they launch into space.[346] The resulting concern is that acts to remove or destroy space debris will intrude on another State Party's ownership rights, thereby risking an international incident.[347] Since space debris is non-functional,[348] it may be difficult to know whether a party has relinquished its ownership rights; this is especially true when the space debris is smaller, and the nation may or may not be aware of its existence.[349]

The Registration Convention, which governs identification procedures for space objects, does not provide any additional clarity nor requirements on identifying when perpetual ownership over space debris has ceased. Without a sure-fire way to know what is and is not "owned" by a nation, debris removal may incite international discord if a party decides to enforce its rights over space debris.[350] Even if ownership is known, perpetual ownership hinders space debris removal because a State Party may not be willing to have its non-functional property removed.

The Liability Convention further complicates efforts to solve space debris through its imposition of fault-based liability on launching nations that damage another nation's space object while in outer space.[351] Attempts to remove debris may very well cause damage to another space craft, especially given the clutter of existing space debris. This damage implicates liability under the Liability Convention.[352] This risk of liability may discourage unilateral removal of debris. Additionally, if debris being removed is damaged, the party removing the debris may be held liable to the nation able to claim ownership over the debris because of the Outer Space Treaty's perpetual ownership provisions.[353]

2. Current Soft Law Is Insufficient

The soft law addressing space debris is insufficient to solve the space debris problem for two reasons. First, the guidelines are voluntary and unenforceable.[354] The voluntariness of soft law is problematic here because rational actors tend to overuse common resources;[355] space—free for all to

346. Outer Space Treaty, *supra* note 172, art. VIII.
347. Muñoz-Patchen, *supra* note 173, at 244.
348. *Id.* at 238.
349. *See Copernicus Sentinel-1A Satellite Hit by Space Particle*, *supra* note 102.
350. Muñoz-Patchen, *supra* note 173, at 244.
351. Liability Convention, *supra* note 204, art. III.
352. *See id.*
353. *See id.*; Outer Space Treaty, *supra* note 172, art. VIII.
354. Marchant et al., *supra* note 276, at 5.
355. Hardin, *supra* note 12, at 1244.

use without limitation—is a common resource vulnerable to such misuse.[356] Without legally enforceable mechanisms to prevent such abuse, space's continued depletion and inaccessibility are likely to continue as actors continue to reap individualized benefits.[357]

Second, the guidelines are mitigation-focused.[358] However, mitigation is no longer capable of solving the space debris problem.[359] It is merely a band-aid on a wound that continues to bleed; it can slow the deterioration of the space environment and accessibility, but without further interventions, space debris will continue to increase even if no other space objects are launched into space.[360] As such, ADR is necessary.[361] Yet, none of the guidelines provide standards for ADR.[362]

3. Current Legal Principles Outside Space Law are Insufficient

The direct application of maritime law principles and property law's law of abandonment are ill-suited to solving space debris on their own. The deficiencies of both maritime law and the law of abandonment, as they currently exist, are discussed below.

a. Maritime Law Deficiencies

Maritime law alone cannot effectively address space debris. Under maritime law, abandonment is predicated on the object being abandoned without hope for its recovery.[363] However, the solution to space debris requires remediation, not mitigation;[364] as such, some level of recovery—or at least accessibility—of space debris is necessary. Furthermore, the relinquishment of ownership by abandonment is in direct conflict with the Outer Space Treaty, which provides for perpetual ownership of a space object.[365] If maritime law principles are followed, a party may very well be in violation of the Outer Space Treaty by interfering with space debris that maritime law, not space law, determines is abandoned. For these reasons, the

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356. Muñoz-Patchen, *supra* note 173, at 236.
357. *See* Hardin, *supra* note 12, at 1244.
358. *See supra* Part IV.
359. *See supra* Section II.E.
360. Henry, *supra* note 7, at 788.
361. *See supra* Section II.E.
362. *See supra* Part IV.
363. Rihl II, *supra* note 136, at 80.
364. *See supra* Section II.E.
365. Outer Space Treaty, *supra* note 172, art. VIII.

direct application of maritime law is not enough to solve the space debris problem.

b. Law of Abandonment Deficiencies

The law of abandonment alone is also incapable of effectively addressing space debris. The law of abandonment requires a manifest act and intention to forsake the property.[366] This would not cover space debris that is non-functional, no longer used, or not maintained. As such, it may be difficult to find a substantial number of space debris objects that have been abandoned, and ownership relinquished, under general property law. Furthermore, under the law of abandonment, a party must know an object exists to forsake it.[367] With the overwhelming number of small space debris objects,[368] it is unlikely a nation can know each and every object it retains ownership of under the Outer Space Treaty. In fact, space debris under ten centimeters cannot currently be reliably tracked.[369] Therefore, like maritime law, the direct application of the law of abandonment is not enough to solve the space debris problem.

Despite maritime law and the law of abandonment's inability to solve the space debris problem on their own, the legal principles should be incorporated into treaty amendments as part of the space debris solution.

B. Proposed Solution to the Space Debris Problem

To solve the space debris problem, ADR must be encouraged through amending the relevant space treaties to: (1) create a legally binding definition of space debris; (2) incorporate abandonment principles and the law of finds; and (3) provide for a mitigated liability standard for finders or other parties seeking to recover space debris. This proposed solution will be most effective if the recommended treaty amendments are all introduced contemporaneously with one another. This approach is ideal because each amendment addresses different yet related aspects of the space debris problem.

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366. Nevala, *supra* note 298, at 1518.
367. *Id.* at 1519.
368. *Space Environment Statistics*, *supra* note 43.
369. *Space Debris Identification and Tracking*, *supra* note 101 and accompanying text.

1. Legally Binding Definition of Space Debris

Since there is currently no international binding definition of space debris,[370] the space treaties should be amended to clarify that "space objects" include space debris.[371] Doing so does officially subject space debris to the perpetual jurisdiction, liability, and registration rules of the space treaties.[372] But, along with the other proposed amendments, it clarifies State Parties' ownership rights in such space objects. This definition also prevents confusion regarding what objects may or may not be considered "debris" and does not conflict with international soft law mechanisms.[373] This Comment does not propose the amendment's exact language, but, for illustrative purposes, the definition may look something like this: Space objects include the component parts of a space object; its launch vehicle and parts thereof; and space debris, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional.

Other scholars argue that space debris should be declared outside the scope of a space object under the space treaties.[374] Doing so, however, risks pushback from State Parties who would want to retain jurisdiction over space objects that might be considered space debris. Amending the space treaties to clarify that the definition of "space object" includes space debris is a concession to encourage adoption of the abandonment and law of finds principles outlined in the following Section.

2. Incorporating Abandonment Principles and the Law of Finds

This Comment proposes incorporating a version of maritime and property law principles. These legal principles should be incorporated as two different treaty amendments. The first amendment incorporates abandonment principles, determining when space objects become abandoned. The second amendment incorporates the law of finds, encouraging ADR.

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370. Major Adam G. Mudge, *Incentivizing "Active Debris Removal" Following the Failure of Mitigation Measures to Solve the Space Debris Problem: Current Challenges and Future Strategies*, 82 A.F. L. REV. 88, 119 (2022).

371. Other scholars have similarly proffered amending the "space object" definition to include "space debris." *See, e.g.*, Lauren Bressack, *Addressing the Problem of Orbital Pollution: Defining a Standard of Care to Hold Polluters Accountable*, 43 GEO. WASH. INT'L L. REV. 741, 778 (2011).

372. Outer Space Treaty, *supra* note 172, art. VIII; Liability Convention, *supra* note 204; Registration Convention, *supra* note 205.

373. *See supra* Part IV.

374. Mudge, *supra* note 370, at 141.

a. Amendment 1: Space Object Abandonment

The Outer Space Treaty should be amended to define when space objects (now including space debris) become abandoned.[375] Abandonment should be a rebuttable presumption; this accounts for possible pushback from State Parties. Abandonment should be possible through one of two pathways. The first pathway to abandonment relies on the space object's size. If a space object becomes too small, it is presumed abandoned. The threshold size that would trigger a presumption of abandonment would be ten centimeters, as recommended by Major Marc G. Carns.[376] This size threshold is recommended because it is already unlikely that ownership can properly be determined over space debris smaller than ten centimeters.[377] Therefore, it is reasonable to deem space debris abandoned if it is ten centimeters or smaller.

The mechanism for determining when a space object has reached the requisite size threshold is outside the scope of this article but, once determined, the Registration Convention should be amended to include such mechanisms as a part of the registration requirements. Since small space objects are difficult to track, State Parties wishing to exert ownership over small space objects will bear the burden of proving the object is not abandoned and will be required to register those small space objects.

The second pathway to abandonment is predicated on State Party inaction. A space object becomes abandoned if a State Party ceases to exert control over an object or to assert its ownership for a certain time period. Under this approach, two elements must be met before an object becomes abandoned. First, a State Party with ownership rights in a space object must no longer be exercising its control or ownership over the space object. The following non-exhaustive list of control and ownership activities could be considered:[378] updating other nations on the status and activity of the space object; maintenance of the space object; continuous tracking of the space object.

Second, this lack of ownership or control must continue for a certain period of time. Space missions take a considerable amount of planning and time,[379] so the time frame requirement must reflect realistic expectations of

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375. For a discussion of space object abandonment in the context of a new space treaty, see Mudge, *supra* note 370, at 144.

376. Carns, *supra* note 167, at 177.

377. *Id.* at 191; *Space Debris Identification and Tracking*, *supra* note 101 and accompanying text.

378. It is less likely these considerations are to be objected to because they are similar to the requirements under the Registration Convention. Registration Convention, *supra* note 205, art. IV.

379. *See* Kelly McSweeney, *DAWN Spacecraft: Uncovering the Relics of the Early Solar System,* NORTHROP GRUMMAN, https://www.northropgrumman.com/what-we-do/space/

space mission timelines to be reasonable. A time frame of twenty years[380] may be sufficient.[381] Once a space object is determined abandoned under at least one of the abandonment pathways described above, the space object's registration can be updated to reflect its newly abandoned status.

b. Amendment 2: "Finding" Space Objects

A second treaty amendment should incorporate the law of finds. Under an abandoned space objects doctrine, finders may truly become keepers. If a space object fits one of the two definitions of abandoned space objects, discussed above, perpetual ownership ceases, and a finder who successfully captures the abandoned object[382] will be awarded free title to the object. Perpetual ownership only serves to hinder unilateral ADR because, as space law currently stands, it is unclear whether a State has the right to remove the debris or if their attempt or success at doing so would interfere with another State's ownership rights in the object.[383] Additionally, this abandoned space objects doctrine will incentivize the capture of space objects and, thus, ADR. This incentive is necessary because without it there will be no reason for States to unilaterally take timely steps toward ADR.[384]

The ability for States to "find" and assert ownership over abandoned space objects is likely to spur State action because space debris includes valuable resources. Space objects and debris are made up of valuable scrap metal; such scrap metal in space is estimated to be worth millions—potentially billions—of dollars.[385] Furthermore, space and space exploration is increasingly privatized.[386]

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spacecraft/dawn/uncovering-the-relics-of-the-early-solar-system [https://perma.cc/N3D5-5JZ4] (describing the over twenty year process the Dawn mission underwent, from development to completion).

380. Other scholars also recommend a twenty year or longer time frame. Rihl II, *supra* note 136, at 89.

381. Given the many ways that control and ownership could be asserted without a full-blown space mission—for maintenance or other purposes—the suggested time frame could reasonably be lessened to ten to fifteen years. A committee of experts would be best to consult to establish the best time frame by which to determine abandonment of space objects.

382. For the capture of the space object to effectively result in ADR, the capture would likely require successfully removing the space object from outer space orbit. The exact contours of this removal process are outside the scope of this Comment, however.

383. Muñoz-Patchen, *supra* note 173, at 244.

384. *Id.*

385. Rihl II, *supra* note 136, at 82.

386. Gupta, *supra* note 34, at 246.

It would be natural for a market in valuable space object metals to grow as privatization and commercialization increase.[387] In 2021, the global commercial space economy was approximately $370 billion in total.[388] The global space economy is only anticipated to grow; by the 2040s, it is estimated to grow between $1 trillion–$3 trillion.[389] For these reasons, this abandonment and quasi-law of finds approach should encourage ADR, even if movements towards ADR initially only take the form of developing more technology that can be used for ADR missions. Essentially, the opportunity to claim abandoned, but valuable, space objects will hopefully create an economic incentive to spur a sort of peaceful "space race."

3. Mitigating Liability

The final recommendation in this Comment's proposed solution is amending the Liability Convention. Under Article III of the Liability Convention, if a launching State's space object damages either another launching State's space object or persons or property on board, fault-based liability is imposed.[390] Therefore, a party attempting to remove space debris would be liable for any damage they cause to other launching party's space objects.[391]

The threat of liability can cause a chilling effect on any ADR operations because the risk of liability would outweigh the potential benefits of a successful ADR operation. Given this, the Liability Convention should be amended to allow for a mitigated liability standard. Liability would be mitigated for any damage caused to space objects during a good-faith effort to capture abandoned space debris. The amendment can include a term of years after which the mitigated liability standard can be reevaluated for amendment. This Liability Convention amendment would remove another existing barrier to ADR efforts.

C. Proposed Solution Meets the Requirements for an Effective Space Law Regime

The proposed amendments are an adequate space debris solution on an international level because they meet the three requirements for an effective

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387. *See id.*
388. Handmer & Freeland, *supra* note 33, at 405.
389. *Id.*
390. Liability Convention, *supra* note 204, art. III.
391. *See id.*

space law regime.[392] These requirements are: (1) "wide international acceptance," (2) "incentives for state and private actors to use outer space," and (3) "flexibility to adapt to changes in the international community."[393]

First, the treaty amendments proposed will likely inspire "wide international acceptance." Additionally, the treaty amendments simply clarify that space debris are space objects, and they incorporate existing legal principles instead of creating an entirely novel legal basis for abandoning and finding property. Compared with solutions to implement an entirely new treaty, amending the current treaties is anticipated to face less resistance since it is not overhauling the existing space regime. Second, the suggested space debris solution would likely incentivize State and private actors to not only use outer space but to undertake ADR missions. This solution benefits State and private actors because, under the proposed treaty amendments, such actors would be clearly told how to protect their rights in space objects while also being given the opportunity to obtain valuable space objects without causing an international incident. Third, drafted correctly, the proposed amendments can include a means to more readily adjust the agreement as needed to meet international needs or changes.

For these reasons, the proposed treaty amendments may provide the impetus for international efforts to solve the space debris problem.

VII. CONCLUSION

> *"The universe is big. It's vast and complicated and ridiculous. And sometimes, very rarely, impossible things just happen and we call them miracles."*[394]

Space debris is a problem that threatens the province of all mankind—outer space—and has the potential to prevent all future space exploration and use, trapping humanity on Earth.[395] Space debris also currently threatens persons and objects in outer space.[396] Despite its increasingly dangerous nature, current space law does not—and cannot—adequately address the

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392. Hoffman, *supra* note 257, at 348. *But cf.* Michael W. Taylor, *Trashing the Solar System One Planet at a Time: Earth's Orbital Debris Problem*, 20 GEO. INT'L ENV'T L. REV. 1, 56 (2007) (describing five criteria for international acceptance of a new legal orbital debris mitigation regime).

393. *Id.*

394. DOCTOR WHO*: The Pandorica Opens* (BBC Studios television broadcast, aired June 19, 2010).

395. *See supra* Part II.

396. *Id.*

space debris problem.[397] This is because the existing binding space law was not created to address modern outer space issues and actively hinders ADR efforts, and soft law alternatives are voluntary and unenforceable.[398] However, amending the current space treaties to clarify that space debris is a space object, to incorporate the law of abandonment and the law of finds to space law, and to alleviate the liability associated with ADR efforts offers a potential solution to the space debris problem.[399] By applying this Article's proposed doctrine of abandoned space objects, space, the final frontier, may be rescued from becoming an unreachable province of science fiction and time's past.

397. *See supra* Section VI.A.
398. *Id.*
399. *See supra* Section VI.B.