SPACE TORTS: APPLYING NUISANCE AND NEGLIGENCE TO ORBITAL DEBRIS

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I. INTRODUCTION

In 2011 and 2012 alone, a defunct NASA satellite,[1] a defunct German satellite,[2] and a defunct Russian space probe all crashed to Earth.[3] While falling space junk gained more media attention, space debris that remains in orbit is even more dangerous. Manmade space junk is polluting the orbits around the Earth,[4] causing damage to satellites and other spacecraft,[5] and threatening future space activities.[6] And the space debris problem is getting worse. For example, in 2007, millions of new pieces of space debris were likely added to the already significant body of debris when China intentionally destroyed a defunct weather satellite.[7]

Allocating liability for damage caused by space debris is also problematic. International treaties regarding space liability are ambiguous and underdeveloped. Only one claim has ever been brought under an international space liability treaty,[8] and it was eventually settled, eliminating the opportunity to test the treaty's effectiveness.[9] And even if a clear set of laws existed, the liable party that created the debris is often unidentifiable due to the limited ability to track space debris.[10]

1. Kenneth Chang, *Satellite Ends Fall, Likely in the Pacific*, N.Y. TIMES, Sept. 25, 2011, at A20, *available at* http://www.nytimes.com/2011/09/25/science/space/25satellite.html?_r=1.

2. Jonathan Amos, *German Rosat Spacecraft Makes Uncontrolled Re-entry*, BBC NEWS: SCI. & ENV'T, Oct. 23, 2011, http://www.bbc.co.uk/news/science-environment-15402157.

3. Alex Knapp, *Failed Russian Probe Phobos-Grunt Will Fall to Earth This Weekend*, FORBES (Jan. 13, 2012, 2:06 AM), http://www.forbes.com/sites/alexknapp/2012/01/13/failed-russian-probe-phobos-grunt-will-fall-to-earth-this-weekend/.

4. John Matson, *On the Trail of Space Trash*, SCI. AM., Nov. 2011, at 18, *available at* http://www.scientificamerican.com/article.cfm?id=on-the-trail-of-space-trash.

5. OFFICE OF SCI. AND TECH. POLICY, INTERAGENCY REPORT ON ORBITAL DEBRIS 8 (Nov. 1995) [hereinafter INTERAGENCY REPORT], *available at* http://www.orbitaldebris.jsc.nasa.gov/library/IAR_95_Document.pdf.

6. William J. Broad, *Orbiting Junk, Once a Nuisance, Is Now a Threat*, N.Y. TIMES, Feb. 6, 2007, *available at* http://www.nytimes.com/2007/02/06/science/space/06orbi.html?ei=5088&en=16b9c6ba615c2e62&ex=1328418000&partner=rssnyt&emc=rss&pagewanted=all.

7. Lieutenant Colonel Joseph S. Imburgia, *Space Debris and Its Threat to National Security: A Proposal for a Binding International Agreement to Clean Up the Junk*, 44 VAND. J. TRANSNAT'L L. 589, 592 (2011).

8. Van C. Ernest, *Third Party Liability of the Private Space Industry: To Pay What No One Has Paid Before*, 41 CASE W. RES. L. REV. 503, 524 (1991). While this case arose in 1978, the author has found no other examples of a similar claim brought under an international treaty.

9. Andrew Brearley, *Reflections upon the Notion of Liability: The Instances of* Kosmos 954 *and Space Debris*, 34 J. SPACE. L. 291, 310 (2008).

10. Mark J. Sundahl, Note, *Unidentified Orbital Debris: The Case for a Market-Share Liability Regime*, 24 HASTINGS INT'L & COMP. L. REV. 125, 133 (2000).

New technology may help solve this identity issue. A new tracking system for space debris, Space Fence, may be able to track smaller debris and help determine who created it.[11] With the possibility of fewer identity issues hindering space debris damage claims from arising, space-liability law should be further developed.

This Note will argue that torts, specifically statutory negligence, negligence by breach of custom, malfunction liability, nuisance, and "live and let live," should be applied to orbital debris. Part II of this Note overviews the orbital debris problem, summarizing sources of debris, the fear of the "cascade effect," the impact of debris on different orbits, the dangers of debris, and the difficulties and new technologies related to tracking debris. Part III discusses the Liability Convention, an international treaty, whether it applies to space debris, and the different standards of liability for damage caused by debris on land and in space. Part IV argues that nuisance and negligence could apply to space debris. This section summarizes previous approaches to cause and identity issues in negligence claims. It then argues that if new tracking technology eliminates some identity issues, statutory negligence, negligence by breach of custom, malfunction liability, and nuisance should apply to space debris, either as "fault" under the Liability Convention or as their own causes of action. Finally, this section suggests that the "live and let live" rule be applied to damage caused by small debris. Lastly, Part V summarizes a few regulatory approaches to space debris and suggests regulations modeled after those relating to marine debris.

II. ORBITAL DEBRIS BACKGROUND

A. SOURCES OF ORBITAL DEBRIS

A number of space activities create debris. Some orbital debris comes from normal operations: a satellite may discard empty tanks, lens caps, rocket bodies, and other objects into space, contributing to debris.[12] Astronauts may also discard or drop objects into space.[13] Paint flaking and plastic and metal erosion on the surfaces of satellites[14] as well as rocket dust and propellant all create small debris.[15]

11. Matson, *supra* note 4, at 18.
12. INTERAGENCY REPORT, *supra* note 5, at 11.
13. *Id*.
14. *Id.* at 13.
15. *Id.*

Historically, most orbital debris originated from defunct satellite and rocket explosions.[16] At the end of a mission, an old satellite may explode because of the failure of its batteries, propellant, or pressurized tanks.[17] Explosion debris varies in size and amount depending on the type of explosion and the amount of small debris vaporized.[18] Between 1961 and 1995, 124 of these explosions were documented.[19] Satellites are sometimes also blown up intentionally. For example, in 2007, China intentionally destroyed a weather satellite, likely creating millions of new pieces of orbital debris.[20]

New NASA models predict that most orbital debris will now come from collisions between existing pieces of debris.[21] Defunct satellites, which are themselves considered debris,[22] may collide with other space objects, creating new pieces of space junk.[23] In 2009, a possibly defunct Russian satellite collided with a privately owned satellite, creating seven hundred new pieces of cataloged debris and likely thousands more pieces of small, uncataloged debris.[24] These small pieces of debris may collide with one another, breaking up into even more pieces.[25]

B. THE CASCADE EFFECT

Debris can stay in orbit for significant periods of time, varying from a few months to millions of years depending on the size of the object and its level of orbit.[26] Orbiting debris gradually falls and eventually either burns in the atmosphere or falls to Earth.[27] The majority of debris, satellites, and other cataloged objects are in lower orbits and will not fall to Earth for anywhere from a few months to a few hundred years.[28] Carbon dioxide that causes global warming on Earth also causes cooling of the thermosphere and a decrease in atmospheric density, which in turn causes debris to stay in orbit even longer.[29]

16. *Id.* at 10–12; Imburgia, *supra* note 7, at 595.
17. INTERAGENCY REPORT, *supra* note 5, at 12.
18. *Id.*
19. *Id.*
20. Imburgia, *supra* note 7, at 592.
21. *Id.* at 595.
22. HOWARD A. BAKER, SPACE DEBRIS: LEGAL AND POLICY IMPLICATIONS 4 (1989).
23. INTERAGENCY REPORT, *supra* note 5, at 12.
24. Imburgia, *supra* note 7, at 596.
25. *Id.*at 597.
26. INTERAGENCY REPORT, *supra* note 5, at 6, 8.
27. *Id.* at 6.
28. *Id.* at 4, 6.
29. Carolyn Fry, *CO2 Prolongs Life of 'Space Junk'*, BBC NEWS (May 5, 2005),

Because debris may remain in orbit for years and collisions between existing pieces of debris create new debris, orbital debris likely will be created more rapidly than it falls out of orbit.[30] New debris collides with other debris, causing an exponential growth of new debris, called the cascade effect.[31] The "critical density" of debris necessary to trigger the cascade effect may have existed as early as 1995.[32] At that time, over eight thousand pieces of debris were being tracked in orbit, and scientists feared that one large collision could trigger a chain reaction of more and more collisions.[33] In 2007, over ten thousand pieces of debris were being tracked, increasing the likelihood of a triggering collision.[34]

The risk of the cascade effect jumped with the destruction of the Chinese weather satellite.[35] In 2007, scientists believed the explosion created thousands of new pieces of traceable debris, increasing the total amount of orbital debris by more than 10 percent.[36] The collision that triggers the cascade effect will likely occur sooner than scientists originally believed.[37]

Proposed methods of removing existing orbital debris and slowing down the cascade effect have so far been too expensive to implement, though developing technology is promising.[38] Ideas include using lasers from Earth to destroy debris,[39] using balloons to intercept smaller pieces of debris,[40] and a "janitor" satellite that would retrieve space debris, reenter Earth, and burn debris in the atmosphere.[41] The janitor satellite is being developed by the Swiss Space Center, and is especially promising, with the Swiss planning on eventually selling an entire fleet.[42] While debris removal technology may not yet be feasible, precautions exist to limit the amount of new debris created by future space activities and prevent increasing the risk

http://news.bbc.co.uk/2/hi/science/nature/4486049.stm.

30. Matson, *supra* note 4, at 18.

31. *Id.*; Imburgia, *supra* note 7, at 597.

32. Broad, *supra* note 6.

33. *Id.*

34. *Id.*

35. *See id.*; Imburgia, *supra* note 7, at 592.

36. Imburgia, *supra* note 7, at 600.

37. Broad, *supra* note 6.

38. *Id.* (providing comments by Donald J. Kessler, a former head of the orbital debris program at NASA and a leading figure in pioneering analysis of the spacing threat).

39. *Id.*

40. INTERAGENCY REPORT, *supra* note 5, at 36–37.

41. John Heilprin, *Swiss Craft Janitor Satellites to Grab Space Junk*, YAHOO! NEWS (Feb. 15, 2012), http://news.yahoo.com/swiss-craft-janitor-satellites-grab-space-junk-113516830.html.

42. *Id.*

of triggering the cascade effect .[43]

C. ORBITS

Orbital debris exists mostly in two types of orbits, Lower Earth Orbit ("LEO") and Geostationary Earth Orbit ("GEO").[44] As of 1995, LEO contained the most orbital debris, while GEO contained the second most.[45] LEO is generally considered to be between 100 km and 1000 km above sea level.[46] The range is valuable because satellites in LEO can fly over the entire Earth.[47] This orbit is typically used for high-resolution imaging satellites,[48] and increasingly for cellular phone and other telecommunication activities.[49]

GEO is a much narrower orbit, roughly 35,787 km above sea level.[50] Satellites in GEO rotate in sync with the Earth at 3074.7 meters per second,[51] constantly remaining over the same spot on Earth.[52] The orbit is typically used for weather, remote sensing, and telecommunications.[53] Although LEO has the worst debris problem,[54] GEO's narrow range and importance make debris there especially dangerous.[55] To maintain order in the narrow range, orbits within GEO are allotted by the International Telecommunication Union ("ITU").[56] The ITU keeps "an orderly recording of the positions assigned by countries to geostationary satellites."[57]

D. DANGERS OF ORBITAL DEBRIS

Orbital debris can cause damage to satellites and spacecrafts,[58]

43. INTERAGENCY REPORT, *supra* note 5, at 35–37.
44. *Id.* at 4.
45. *Id.*
46. Natalie Pusey, Note, *The Case for Preserving Nothing: The Need for a Global Response to the Space Debris Problem*, 21 COLO. J. INT'L ENVTL. L. & POL'Y 425, 426 (2010).
47. *Id.* at 427.
48. *Id.*
49. Mark Nogueira, Comment, *The Benefits of Low-Earth Orbiting Satellite Technology for the International Community: Can the Potential be Realized?*, 5 IND. J. GLOBAL LEGAL STUD. 739, 739–40 (1998).
50. Pusey, *supra* note 46, at 427.
51. GIJSBERTHA CORNELIA MARIA REIJNEN & WILLEM DE GRAAFF, THE POLLUTION OF OUTER SPACE, IN PARTICULAR OF THE GEOSTATIONARY ORBIT 3 (1989).
52. Pusey, *supra* note 46, at 427.
53. *Id.*
54. INTERAGENCY REPORT, *supra* note 5, at 4.
55. Pusey, *supra* note 46, at 430.
56. CARL Q. CHRISTOL, SPACE LAW: PAST, PRESENT, AND FUTURE 99–100 (1991).
57. REIJNEN & DE GRAAFF, *supra* note 51, at 86.
58. INTERAGENCY REPORT, *supra* note 5, at 3.

endanger astronauts,[59] cause damage on Earth,[60] and prevent future space activities.[61] Debris can travel up to 30,000 kilometers per hour so that even tiny pieces can cause serious damage to functioning satellites.[62] Debris smaller than 0.01 cm in diameter can cause erosion and surface pitting to satellites and other spacecraft.[63] This type of small debris is abundant, and over time, can significantly damage spacecraft surfaces, such as windows.[64] Orbital debris has repeatedly damaged the solar panels on the Hubble telescope,[65] and twenty-seven International Space Station windows over eighteen flights have been replaced as a result of damage caused by small paint flakes.[66] Small debris can also seriously damage sensitive instruments on the outside of satellites and spacecrafts.[67]

Debris larger than 0.01 cm can cause greater damage. Pieces of debris between 0.01 and 1 cm can cause "serious" damage, and pieces of debris larger than 1 cm can cause "catastrophic" damage to satellites and spacecraft.[68] Serious or catastrophic damage caused by collisions with orbital debris have already occurred. The first confirmed collision between a satellite and space debris occurred in 1996 when a French satellite was damaged by debris from a decade-old rocket explosion.[69] A Japanese Midori satellite was likely damaged by another collision,[70] and in 1998, a missile's expended third stage was destroyed by debris.[71] The 2009 collision between a defunct Russian satellite and a privately owned satellite was an unprecedented collision of large debris,[72] and it jeopardized more

59. Matson, *supra* note 4, at 18.

60. *See* Michael Listner, *Revisiting the Liability Convention: Reflections on ROSAT, Orbital Space Debris, and the Future of Space Law*, THE SPACE REV. (Oct. 17, 2011), http://thespacereview.com/article/1948/1 (describing 2011 re-entry of a NASA satellite).

61. Broad, *supra* note 6.

62. Kathy Jones, Krista Fuentes & David Wright, *A Minefield in Earth Orbit: How Space Debris Is Spinning Out of Control [Interactive]*, SCI. AM. (Feb. 1, 2012), http://www.scientificamerican.com/article.cfm?id=how-space-debris-spinning-out-of-control (click on the tab "Debris in Orbit"); INTERAGENCY REPORT, *supra* note 5, at 8 (describing the energy in a 1.3 mm piece of debris traveling at 10 kilometers per second as the same as that of a 22 caliber long rifle bullet).

63. INTERAGENCY REPORT, *supra* note 5, at 8.

64. *Id.* at 8, 13.

65. Sundahl, *supra* note 10, at 130.

66. *Id.*; Jones, Fuentes & Wright, *supra* note 62.

67. *See* Lawrence D. Roberts, *Addressing the Problem of Orbital Space Debris: Combining International Regulatory and Liability Regimes*, 15 B.C. INT'L & COMP. L. REV. 51, 55–56 (1992) (describing the destruction that can be caused by debris).

68. INTERAGENCY REPORT, *supra* note 5, at 8.

69. Jones, Fuentes & Wright, *supra* note 62; Fry, *supra* note 29.

70. Sundahl, *supra* note 10, at 130.

71. *Id.*

72. Traci Watson, *Two Satellites Collide 500 Miles over Siberia*, USA TODAY (Feb 12, 2009, 12:42 AM), http://www.usatoday.com/tech/science/space/2009-02-11-satellites_N.htm.

satellites near the collision, "right there in the heart of the cloud" of debris created by the accident.[73]

Orbital debris is also a danger to astronauts. A 1 cm piece of debris can penetrate the crew compartment of a spacecraft.[74] Because these compartments are pressurized, a puncture could kill astronauts inside and destroy the spacecraft.[75] A 0.5 mm piece of debris can puncture an astronaut's spacesuit,[76] and even a paint chip can kill an astronaut outside a spacecraft.[77] Because of these dangers, the International Space Station maneuvers around debris when a possible collision is identified.[78] Even more dangerous is when debris is not detected in time to maneuver the Space Station.[79] When this occurs, astronauts may have to move to other spaceships attached to the Station so that they can close hatches and maintain pressure if the Space Station is punctured.[80] In 2011, a piece of debris came within a few hundred meters of the Station, and for their safety, six astronauts boarded these outside spaceships.[81]

Debris can also reenter Earth and cause damage on land. In 1978, Cosmos 954, a Soviet spy satellite,[82] became depressurized and started to deorbit to Earth.[83] After a failed attempt to move the satellite to a higher orbit, it crashed into an uninhabited area of Canada, spreading debris over 124,000 square miles.[84] The satellite was powered by a nuclear reactor,[85] and the debris was radioactive.[86] Canada located and cleaned up the crash site wreckage and dangerous nuclear material at a cost of C$13.97 million.[87]

Other reentries include a NASA satellite's fall to Earth in 2011. The

73. *Id.*
74. Roberts, *supra* note 67, at 55.
75. *Id.*
76. *Id.*
77. James P. Lampertius, Note, *The Need for an Effective Liability Regime for Damage Caused by Debris in Outer Space*, 13 MICH. J. INT'L L. 447, 450 (1992).
78. Jones, Fuentes & Wright, *supra* note 62.
79. *Id.*
80. *Id.*
81. Matson, *supra* note 4, at 18.
82. Ernest, *supra* note 8, at 524.
83. Joseph A. Burke, Note, *Convention on International Liability for Damage Caused by Space Objects: Definition and Determination of Damages After the Cosmos 954 Incident*, 8 FORDHAM INT'L L.J. 255, 271 (1985).
84. Ernest, *supra* note 8, at 524–25.
85. Burke, *supra* note 83, at 271.
86. Ernest, *supra* note 8, at 524.
87. *Id.* at 525.

twenty-year-old satellite ran out of fuel in 2005[88] and was moved to a lower orbit to reduce the risk of collision with the International Space Station.[89] The satellite weighed six tons.[90] It entered the atmosphere over the Pacific Ocean, where it likely broke up into twenty-six pieces, the largest weighing up to 330 pounds.[91] Although the satellite seemed to fall into the ocean over a 500-mile area and no injuries were reported, NASA initially estimated a one in 3200 chance that someone would be hit by the falling debris.[92] In 1979, a seventy-four ton NASA space station, Skylab, crashed into rural Australia, and a ten-ton NASA satellite fell to Earth the same year.[93] In 1997, an Oklahoma woman was hit by a falling piece of space debris from a rocket booster.[94]

Orbital debris can also add cost to and possibly prevent future space activities. Participants in space activities must design spacecraft to protect themselves against debris.[95] Spacecraft may need "more and more shielding," which is costly and adds weight.[96] The additional weight is even more costly because the heavier spacecraft requires a more expensive launch.[97] Scientists warn that "[s]ooner or later it gets too expensive to do business in space."[98]

E. TRACKING ORBITAL DEBRIS

The limitations of debris tracking can make avoiding collisions and identifying creators of debris difficult, but new technology may alleviate these problems. When orbital debris is tracked, collisions can be avoided by maneuvering spacecraft out of its path.[99] NASA has maneuvered the

88. Dan Harris, Ned Potter & Jessica Hopper, *Space Satellite UARS Falling From Orbit*, ABC NEWS (Sept. 16, 2011), http://abcnews.go.com/Technology/space-satellite-uars-adrift-heading-earth/story?id=14534076#.TydK6ONWqkA.

89. Chang, *supra* note 1.

90. Harris, *supra* note 88.

91. Chang, *supra* note 1.

92. *Id.*

93. Andre G. DeBusschere, *Liability for Damage Caused by Space Objects*, 3 J. INT'L L. & PRAC. 97, 100 (1994); Simone Baribeau, *NASA Satellite Biggest to Make Plunge to Earth Since 1979*, BLOOMBERG BUSINESSWEEK (Sept. 22, 2011), http://www.businessweek.com/news/2011-09-22/nasa-satellite-biggest-to-make-plunge-to-earth-since-1979.html.

94. Chang, *supra* note 1.

95. Broad, *supra* note 6.

96. *Id.*

97. *Mars Odyssey: Aerobraking, Part 2*, CAL. INST. OF TECH., http://mars.jpl.nasa.gov/odyssey/mission/timeline/mtaerobraking/aerobraking2/ (last visited Oct. 28, 2012).

98. Broad, *supra* note 6 (quoting Donald J. Kessler, a former NASA official).

99. Jones, Fuentes & Wright, *supra* note 62.

Space Shuttle several times in the last decade to avoid debris.[100]

Debris can be tracked by either telescopes or radar,[101] though radar is most commonly used.[102] Radar can track smaller debris than telescopes, can track debris during the day as well as night, and can track debris during bad weather.[103] In the United States, NASA and the Department of Defense work together to track debris.[104] The Space Surveillance Network, operated by the Department of Defense, is usually capable of track debris as small as 1 cm,[105] but it cuts off tracking at 5 cm,[106] or roughly the size of a softball.[107] Other radar stations may be able to track some smaller debris.[108]

Unfortunately, debris smaller than 5 cm can still cause "catastrophic" damage.[109] Even if the Space Surveillance Network were to cut off debris tracking at 1 cm, debris that size could be responsible for serious damage.[110] Information about debris smaller than 1 cm is "estimated from minimal data."[111] Much of this information is based on explosion tests performed on Earth rather than observations of debris in space.[112] And collisions with small, untracked debris cannot always be avoided.[113]

Tracking limitations also make identifying who put debris into space difficult. The 1975 Convention on Registration of Objects Launched into Outer Space ("Registration Convention") requires that states must register the objects they launch into space with the United Nations.[114] The treaty has been ratified by fifty-four states, including the United States, Russia, and China.[115] When an object launched into space is registered and

100. *Id.*
101. Sundahl, *supra* note 10, at 133.
102. *See* Matson, *supra* note 4, at 18 (describing the current system of tracking that uses radar).
103. Sundahl, *supra* note 10, at 133.
104. Jones, Fuentes & Wright, *supra* note 62.
105. Roberts, *supra* note 67, at 54.
106. Jones, Fuentes & Wright, *supra* note 62.
107. Matson, *supra* note 4, at 18 (describing the size of debris that is currently tracked.)
108. Comm. on the Peaceful Uses of Outer Space, Scientific and Technical Subcomm., Technical Rep. on Space Debris U.N. Doc. A/AC.105/720, at 6 (1999), *available at* http://www.unoosa.org/pdf/reports/ac105/AC105_720E.pdf.
109. INTERAGENCY REPORT, *supra* note 5, at 8.
110. *Id.*
111. Roberts, *supra* note 67, at 54.
112. *Id.*
113. Jones, Fuentes & Wright, *supra* note 62.
114. Convention on the Registration of Objects Launched into Outer Space, *opened for signature* Jan. 14, 1975, 28 U.S.T. 695 [hereinafter Registration Convention]; Jennifer M. Seymour, Note, *Containing the Cosmic Crisis: A Proposal for Curbing the Perils of Space Debris*, 10 GEO. INT'L ENVTL. L. REV. 891, 901 (1998).
115. Imburgia, *supra* note 7, at 618.

continuously tracked, the source of the object and any debris it creates can be identified.[116] Even if the source of debris that causes damage cannot be easily determined, other parties tracking debris are required to help determine the source.[117] The party responsible for putting the debris into space can then potentially face liability.

But many launches go unregistered, demonstrated by the fact that no launch has ever been registered with a military purpose.[118] And even if a space object that causes debris is registered, the source of debris that is too small to track may still not be identifiable.[119]

New technology may eliminate some tracking problems. The United States Air Force is working on an improved tracking system for orbital debris called Space Fence, which is expected to be functional by 2017.[120] Space Fence would replace a system from the 1960s with newer radar that uses smaller wavelengths to detect smaller debris.[121] Other "smaller-scale projects" are also in development.[122] Instead of debris the size of a softball, debris the size of a marble could potentially be tracked with Space Fence.[123] While this may still be larger than the very small debris that causes window damage on the Space Station, the type of debris that causes catastrophic and serious damage may become easier to track. This improved tracking would make maneuvers to avoid collisions possible more often.[124] The technology could also help in identifying debris' sources because debris from a space object that is registered and continuously tracked can often be identified.[125]

III. THE LIABILITY CONVENTION

A. BACKGROUND

The Convention on International Liability for Damage Caused by Space Objects ("Liability Convention") "represent[s] the most effective

116. Sundahl, *supra* note 10, at 132.
117. Seymour, *supra* note 114, at 901.
118. Imburgia, *supra* note 7, at 618–19.
119. Sundahl, *supra* note 10, at 133.
120. John Matson, *U.S. Taking Initial Steps to Grapple with Space Debris Problem*, SCI. AM. (Aug. 31, 2011), http://www.scientificamerican.com/article.cfm?id=orbital-debris-space-fence.
121. *Id.*
122. *Id.*
123. *Id.*
124. *See* Jones, Fuentes & Wright, *supra* note 62 (describing maneuvers when debris is tracked).
125. *See* Seymour, *supra* note 114, at 901 (describing the Registration Convention's system of tracking debris).

regulation of the space environment to date."[126] The treaty was endorsed by the United Nations General Assembly in 1971 and took effect in 1972,[127] with the United States, Russia, and China among its parties.[128] It imposes liability on states whose space objects cause damage or are involved in accidents.[129] Although the Liability Convention is an international treaty, this Note argues, as others have, that some type of tort law similar to that of the United States, whether through the Liability Convention or otherwise, would be appropriate for claims arising from damage caused by space debris.[130]

The Liability Convention allows states to bring claims against other states, but private companies that are damaged by a space object may petition their government to bring a claim on their behalf.[131] And if a private company causes damage, a victim may also recover because states are held liable for damage caused by all objects launched within their borders, whether the space object was launched or owned by the state or a private actor.[132]

States party to the Liability Convention have waived their sovereign immunity to the extent the Liability Convention applies to a case.[133] The treaty encourages a diplomatic approach to settling claims, but if diplomacy is unsuccessful, a claims commission recommends an award.[134]

126. Roberts, *supra* note 67, at 63.

127. Burke, *supra* note 83, at 255.

128. Imburgia, *supra* note 7, at 616.

129. Burke, *supra* note 83, at 257.

130. *See* BAKER, *supra* note 22, at 71 (evaluating the applicability of res ipsa claims brought for damage caused by orbital debris); CHRISTOL, *supra* note 56, at 232 (arguing that following the Liability Convention, "the general criteria for a fair international tort law for the space environment are now in place"); Lauren Bressack, Note, *Addressing the Problem of Orbital Pollution: Defining a Standard of Care to Hold Polluters Accountable*, 43 GEO. WASH. INT'L L. REV. 741, 768–69 (2011) (arguing that negligence is "fault" within the meaning of the Liability Convention); Marc S. Firestone, Comment, *Problems in the Resolution of Disputes Concerning Damage Caused in Outer Space*, 59 TUL. L. REV. 747, 755–58 (1985) (discussing choice-of-law issues relating to damage caused in space and questioning whether any one nation's law should apply, though still acknowledging that some type of tort law is appropriate). This Note argues that the bases of recovery discussed below would be appropriate for space debris. But, even if not all the bases of liability under American tort law could be brought under the Liability Convention, some claims based on American tort law could still be brought outside of the treaty. *See* Joseph A. Bosco, *Manufacturer Liability to Third Parties for Outer Space Activities*, 7 NORTHROP U. L.J. 1, 1–30 (1986) (describing that American courts could exercise jurisdiction over space tort claims, and that American tort law could apply).

131. Firestone, *supra* note 130, at 758–59.

132. Ernest, *supra* note 8, at 520.

133. R. BENDER, LAUNCHING AND OPERATING SATELLITES: LEGAL ISSUES 308–09 (1998).

134. Joel Stroud, *Space Law Provides Insights on How the Existing Liability Framework Responds to Damages Caused by Artificial Outer Space Objects*, 37 REAL PROP. PROB. & TR. J. 363, 374–75 (2002).

B. APPLICATION TO SPACE DEBRIS

Whether the treaty applies to all space debris is unclear, but the Liability Convention likely covers at least some types of debris.[135] The Liability Convention concerns "liability for damage caused by space objects."[136] Article I of the treaty states that "The term 'space object' includes component parts of a space object as well as its launch vehicle and parts thereof."[137]

The treaty's definition of "space object" extends to large debris such as an entire defunct satellite,[138] but there is debate whether "component parts of a space object" include other types of space debris. Some academics believe that the lack of a definition of "component parts" makes the Liability Convention's application to smaller space debris uncertain.[139] Others argue that "component parts of a space object" include all space debris.[140] Commentators who believe the Liability Convention has a broader application to space debris argue that it is reasonable to believe that "component parts" include objects not connected to a satellite or space object.[141] They argue that small, unconnected pieces of debris such as explosion fragments or loose screws fall within the meaning of "component parts."[142] The Liability Convention may not extend to debris as small as a paint flake, but commentators largely agree that the treaty extends to at least some pieces of debris smaller than an entire defunct satellite.

C. DAMAGE ON EARTH

The Liability Convention treats damage caused by space objects on Earth differently from damage caused by space objects in space. The treaty states in Article II that "[a] launching State shall be absolutely liable to pay compensation for damage caused by its space object on the surface of the

135. Roberts, *supra* note 67, at 64 (summarizing commentators' opinions of the Liability Convention's applicability to space debris).

136. Convention on International Liability for Damage Caused by Space Objects, Mar. 29, 1972, 24 U.S.T. 2389, 2391 [hereinafter Liability Convention].

137. *Id.* at 2392.

138. *See* Burke, *supra* note 83, at 271–80 (describing the reentry of the Cosmos into Canada. The incident is the only invocation of the Liability Convention to date. There was argument over what damages were covered by the treaty, and the incident was resolved diplomatically. There was never, however, an argument that the entire satellite was not covered by the Liability Convention).

139. Imburgia, *supra* note 7, at 616.

140. Roberts, *supra* note 67, at 64.

141. Seymour, *supra* note 114, at 900.

142. Listner, *supra* note 60; BAKER, *supra* note 22, at 64.

earth or to aircraft in flight."[143] States whose space objects cause damage on Earth are strictly liable.[144] Commentators note that "absolute" liability is reasonable because states that launch space objects know that they will cause damage when they crash back to Earth, and a person's chance of being harmed on Earth is too small to encourage individuals to take precautions.[145] No reciprocity of risk exists between those causing damage and those being damaged on Earth. The treaty states in Article VI that

> exoneration from absolute liability shall be granted to the extent that a launching State establishes that 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 of natural or juridical persons it represents.[146]

A State whose space object causes damage on Earth can escape strict liability by showing negligence by the damaged party. But in cases where space objects cause damage on Earth during reentry, like the Cosmos 954 satellite that crashed into Canada, gross negligence by the damaged party may be impossible to show given that it was a "fixed target."[147] It seems similarly unlikely that contributory negligence would apply to a fixed target such as a plot of land.

Canada's claim resulting from the 1978 Soviet Cosmos 954 satellite crash is the only claim ever brought under the Liability Convention.[148] Although the satellite crashed into an uninhabited area, Canada brought a claim for C$6 million as a result of the need to clean up the nuclear debris spread by the crash.[149] Some commentators have argued that the Liability Convention's definition of damage would not cover the crash.[150] The Liability Convention defines damage in Article I as "loss of life, personal injury or other impairment of health; or loss of or damage to property of States or of persons, natural or juridical, or property of international intergovernmental organizations."[151] Some argue that because the Cosmos 954 satellite made only uninhabited land "unsafe to an unknown degree"

143. Liability Convention, *supra* note 136, 24 U.S.T. at 2392.

144. Listner, *supra* note 60.

145. Robert P. Merges & Glenn H. Reynolds, Comment, *Rules of the Road for Space?: Satellite Collisions and the Inadequacy of Current Space Law*, 40 ENVTL. L. REP. NEWS & ANALYSIS 10009, 10009 (2010).

146. Liability Convention, *supra* note 136, 24 U.S.T. at 2394.

147. Brearley, *supra* note 9, at 309.

148. Dan St. John, *The Trouble with Westphalia in Space: The State-Centric Liability Regime*, 40 DENV. J. INT'L L. & POL'Y 686, 710 (2012).

149. Brearley, *supra* note 9, at 309–10.

150. Burke, *supra* note 83, at 276–77.

151. Liability Convention, *supra* note 136, 24 U.S.T. at 2392.

and did not cause any other injury or property damage, the Liability Convention would not apply.[152] But others argue that Canada's claim included "only reasonable costs and those which it could accurately calculate."[153] They argue that the cost of cleaning up the nuclear debris was covered by the treaty because the Liability Convention's purpose is to restore the damaged party "to the condition which would have existed if the damage had not occurred."[154] Either way, the Soviet Union settled the claim in 1981 for C$3 million without admitting liability.[155] The incident demonstrates that states are willing to invoke the Liability Convention and will argue strict liability for damage caused on Earth.

The Liability Convention is relatively clear regarding damage caused by space debris on Earth: strict liability applies, and there is an opportunity to show contributory negligence.

D. DAMAGE IN SPACE

The Liability Convention treats damage that occurs in space differently than damage on Earth. It states in Article III that

> [i]n the event of damage being caused elsewhere than on the surface of the earth to a space object of one launching State or to persons or property on board such a space object by a space object of another launching State, the latter shall be liable only if the damage is due to its fault or the fault of persons for whom it is responsible.[156]

The treaty therefore applies to both damage to a space object as well as damage to the people or property on board the space object. Furthermore, Article III has a "fault" standard of liability rather than one that is "absolute,"[157] although the Liability Convention does not define what constitutes "fault." This ambiguity in what constitutes "fault" has many possible answers, which this Note explores.

E. OTHER MEANS OF RECOVERY

The Liability Convention does not preclude recovery based on other laws. The treaty states in Article XXIII that "The provisions of this Convention shall not affect other international agreements in force in so far

152. Burke, *supra* note 83, at 277.
153. Brearley, *supra* note 9, at 310.
154. *Id.* at 309; Liability Convention, *supra* note 136, 24 U.S.T. at 2397.
155. Brearley, *supra* note 9, at 310.
156. Liability Convention, *supra* note 136, 24 U.S.T. at 2392.
157. *Id.* at 2392. This is in contrast to Article II, which imposes absolute liability.

as relations between the States Parties to such agreements are concerned."[158] The Canadian claim resulting from the Cosmos 954 incident illustrated this, since the claim was not based exclusively on the Liability Convention: it also cited "general principles of international law" including "mitigation of or prevention of damage."[159] Assuming jurisdictional and choice-of-law requirements are met, American tort claims may also be brought for damage caused by space objects.[160]

IV. APPLYING TORTS

Law regarding damage caused by space debris on Earth is relatively clear. Usually the identity of the debris is known, and strict liability applies under the Liability Convention. Law regarding damage caused by debris in space is less clear. The identity of the debris is often unknown and ambiguity exists regarding the Liability Convention's "fault" standard. This part will discuss previous solutions to identity issues. It will then argue that if new tracking technology makes space debris easier to identify, then nuisance, statutory negligence, negligence by breach of custom, and malfunction liability should be applied to damage caused by space debris, either as "fault" under the Liability Convention or as their own causes of action. Finally, this part argues that the "live and let live" rule should be applied to damage caused by small debris.

A. PREVIOUS SOLUTIONS TO IDENTITY ISSUES

Two major solutions to unknown debris have been proposed: a liability pool and market share liability.[161] Under a liability-pool system, a party would put money into a fund after every launch of a space object, and parties injured by unknown debris would be compensated by the fund.[162] A launching party would contribute a particular amount to the fund relative to the quantity of debris the space object will likely create.[163]

Some criticize this approach. They argue that a liability pool would internalize cost, but would do so "imperfectly" because knowing how much

158. *Id.* at 2402.

159. Burke, *supra* note 83, at 274–76.

160. Bosco, *supra* note 130, at 1, 7, 16, 30–31 (reviewing these jurisdictional and choice-of-law issues, and concluding that there are many advantages to using a claim under the theory of "abnormally dangerous activities").

161. Sundahl, *supra* note 10, at 137–143.

162. *Id.* at 137–38.

163. *Id.* at 137.

debris a space object will create beforehand is impossible.[164] They argue that parties with good mission designs that end up creating debris as a result of human error may pay too little into a liability pool.[165]

Critics argue for a market share approach to liability, similar to that proposed in *Sindell v. Abbott Laboratories*.[166] In *Sindell*, women brought suit against drug companies that manufactured diethylstilbesterol ("DES"), a drug that prevented miscarriages, because it was later found to cause cancer.[167] The drugs produced by different manufacturers were identical, and it was impossible to identify which manufacturer produced the DES taken by any individual plaintiff.[168] The court "approach[ed] the issue of causation from a different perspective" and applied market-share liability, where each manufacturer was liable for their percentage of the total amount of DES produced.[169]

Some commentators maintain that market-share liability should also be applied to space debris. They argue that market-share liability has not been expanded beyond DES cases because "truly fungible products are rare," but that orbital debris fits the DES model.[170] A space actor's percentage of debris could be determined by looking at the number of operational objects it has in orbit, the number of objects it has ever launched, or the number of identified debris fragments attributable to it.[171]

Others criticize this proposal. They argue that states likely will not support the approach because it places too much emphasis on "past transgressions."[172] States prefer systems like the liability pool that base liability on future activities.[173] This is probably especially true of China, which became responsible for the largest recorded creation of space debris when it destroyed a weather satellite in 2007.[174] Both solutions have flaws, and hopefully new tracking technology will eliminate identity issues related to the cause of debris. The biggest issue regarding liability for space debris will be what constitutes fault.

164. *Id.* at 138.
165. *Id.*
166. Sindell v. Abbott Labs., 607 P.2d 924, 973 (Cal. 1980).
167. *Id.* at 925–26.
168. *Id.* at 936.
169. *Id.* at 937.
170. Sundahl, *supra* note 10, at 143.
171. *Id.* at 145.
172. Roberts, *supra* note 67, at 70.
173. *Id.*
174. Imburgia, *supra* note 7, at 600.

B. STATUTORY NEGLIGENCE

An increasing number of space-debris commentators are analyzing what constitutes fault, and statutory negligence has been proposed as one possibility. Some have advocated for treaty amendments that would make a statutory negligence claim more likely to succeed.[175] Others have suggested that violation of proposed best practices could constitute "fault."[176] This section argues that violation of either space-debris mitigation guidelines or the Registration Convention is statutory negligence, a basis for liability as "fault" either within the meaning of the existing Liability Convention or outside the treaty.

Statutory negligence occurs when the violation of a safety statute causes an accident that the statute both contemplated and intended to prevent.[177] In *Martin v. Herzog*, Justice Cardozo explained that when a driver on a highway at night did not turn on the headlights, when there was a statute stating that drivers must turn on their headlights at night, when the statute was meant to protect the safety of people on highways, and when somebody was injured because the driver did not turn on the headlights, a court will find negligence per se.[178]

Statutory negligence has been extended to other types of torts, including aviation.[179] In *Wojciechowicz v. United States*, a claim arose from an airplane crash, and the court recognized statutory negligence, stating, "The FAA has promulgated regulations titled Federal Aviation Regulations (FARs), that govern, *inter alios*, the operation of airplanes by pilots. . . . [The] regulations constitute the 'rules of the road' for pilots and have the force and effect of law. Their violation entails negligence *per se*."[180] Statutory negligence and violation of safety regulations have been applied to aviation torts and should be extended to space torts.

Statutory negligence as fault would eliminate the difficulty in proving that failure to take a precaution is negligence.[181] Because violation of a

175. Bressack, *supra* note 130, at 777–79.

176. BAKER, *supra* note 22, at 84. *See* Seymour, *supra* note 114, at 902–06 (describing United States' and other parties' space debris guidelines).

177. Martin v. Herzog, 126 N.E. 814, 815 (N.Y. 1920). "Justice Cardozo's approach to the violation of safety statutes in the *Martin* case is clearly the majority position in [the United States]." JAMES A. HENDERSON, JR. ET AL., THE TORTS PROCESS 185 (7th ed. 2007).

178. *Id.* at 814–15.

179. Wojciechowicz v United States, 576 F. Supp. 2d 241, 273 (D.P.R. 2008).

180. *Id.* at 273 (citations omitted).

181. Merges & Reynolds, *supra* note 145, at 10009 (illustrating one such difficulty by explaining that failure to move a defunct satellite out of the path of other active satellites may not actually be

safety statute is negligence per se, statutory negligence would eliminate difficulties of determining what acts or omissions are negligent.

Several existing "statutes" relating to space debris are relevant. The issues in bringing a statutory negligence claim under them will likely be whether the regulation or guideline is a "statute," and if so, whether the regulation or guideline is a statute intended to prevent accidents. The Registration Convention, discussed earlier in this Note, is one relevant international treaty. The Registration Convention requires states to register space objects that they launch into orbit.[182] The Registration Convention is an international treaty that has been ratified by the United States, Russia, and China,[183] and could be argued to be a statute within the meaning of statutory negligence. It could also be argued to be a statute that protects against accidents because Article VI acknowledges that third parties will track and monitor space objects that have been registered,[184] which prevents collisions,[185] and acknowledges that space objects could cause damage to "natural or juridical persons."[186] Arguably, one of the treaty's aims was to prevent collisions involving an untracked and unregistered space object, and a statutory negligence claim may succeed for a collision involving unregistered debris.

Individual states have also issued safety guidelines relating to space debris that could be considered statutes for the purpose of allowing a statutory negligence claim. Among the many regulations relating to space debris in the United States[187] are NASA's Procedural Requirements[188] and Process for Limiting Orbital Debris.[189] The regulations aim to limit the creation of space debris,[190] are intended to be safety statutes that prevent "risk to human life due to generated orbital debris,"[191] and are "mandatory"

negligence).

182. Registration Convention, *supra* note 114, at 700.

183. Imburgia, *supra* note 7, at 618.

184. Registration Convention, *supra* note 114, at 700.

185. Merges & Reynolds, *supra* note 145, at 10010.

186. Registration Convention, *supra* note 114, at 700.

187. Michael W. Taylor, *Trashing the Solar System One Planet at a Time: Earth's Orbital Debris Problem*, 20 GEO. INT'L ENVTL. L. REV. 1, 32–36 (2007) (summarizing various U.S. agencies' requirements regarding space debris).

188. NASA, NPR 8715.6A, PROCEDURAL REQUIREMENTS FOR LIMITING ORBITAL DEBRIS (2009) [hereinafter PROCEDURAL REQUIREMENTS], *available at* http://nodis3.gsfc.nasa.gov/npg_img/N_PR_8715_006A_/N_PR_8715_006A_.pdf.

189. NASA, STD 8719.14A, PROCESS FOR LIMITING ORBITAL DEBRIS (2011) [hereinafter PROCESS FOR LIMITING ORBITAL DEBRIS], *available at* http://www.iadc-online.org/References/Docu/NASA-STD%208719-14%20Rev%20A%20Change%201%20-%20Approved.pdf .

190. *Id.* at 5; PROCEDURAL REQUIREMENTS, *supra* note 188, at 4.

191. PROCESS FOR LIMITING ORBITAL DEBRIS, *supra* note 189, at 15.

requirements.[192] Like Federal Aviation Authority regulations that have been recognized as having the "force and effect of law" so that "their violation in [sic] negligence *per se*,"[193] NASA regulations should be considered statutes whose violation is also negligence per se. If a piece of orbital debris was created by the United States in a way that violated these regulations and caused injury in space, statutory negligence should apply.

C. NEGLIGENCE BY BREACH OF CUSTOM

Liability could also be based on negligence by breach of custom.[194] Negligence by breach of custom requires a defendant to fail to comply with a reasonable industry or local custom.[195]

Like statutory negligence, the doctrine has also been expanded to areas of law similar to space. In *Cappello v. Duncan Aircraft Sales of Florida, Inc.*, a claim arose from an airplane crash.[196] The court recognized that there were "detailed sets of assumptions, customs and patterns of conduct shared by pilots and FAA flight assistants . . . . These assumptions and expectations arise from hundreds of FAA rules and guidelines . . . and the customary way they have come to be applied in the flying community."[197] The court looked at industry customs and whether the defendant had breached them.[198]

Commentators argue that space debris guidelines represent a consensus among most countries.[199] If so, the breach of the guidelines should be considered evidence of negligence. The United Nations Committee on the Peaceful Uses of Outer Space ("COPUOS") has issued nonbinding guidelines relating to space debris that recommend limiting the creation of debris during space missions, limiting explosions and breakups that contribute to debris, and moving defunct satellites to disposal orbits.[200]

192. *Id.* at 9–10; PROCEDURAL REQUIREMENTS, *supra* note 188, at 1.

193. *In re* N-500L Cases, 691 F.2d 15, 28 (1st Cir. 1982).

194. *See* Taylor, *supra* note 187, at 28–30 (discussing how customary norms are recognized as a binding form of international law, how the Outer Space Treaty has made all international law applicable to outer space, and the possible role of custom in space law).

195. Trimarco v. Klein, 436 N.E.2d 502, 505–06 (N.Y. 1982); 1 RESTATEMENT (THIRD) OF TORTS: LIABILITY FOR PHYSICAL AND EMOTIONAL HARM § 13 (2010) (noting that the Restatement's position on custom is "widely accepted by American jurisdictions").

196. Cappello v. Duncan Aircraft Sales of Fla., Inc., 79 F.3d 1465, 1467 (6th Cir. 1996).

197. *Id.* at 1468.

198. *Id.* at 1472–74.

199. Elise Epperson Crow, Comment, *Waste Management in Space: Addressing the Challenge of Orbital Debris*, 18 SW. J. INT'L LAW 707, 719 (2012).

200. U.N. OFFICE FOR OUTER SPACE AFFAIRS, SPACE DEBRIS MITIGATION GUIDELINES OF THE COMMITTEE ON THE PEACEFUL USES OF OUTER SPACE 2–4 (2010) [hereinafter GUIDELINES], *available*

Although nonbinding, these guidelines can be considered to be industry customs because they are meant to reflect "the existing practices as developed by a number of national and international organizations."[201] Some observers argue that debris-creating actions, like China's destruction of a weather satellite in 2007, show that there is not yet an accepted custom regarding space debris.[202] But, as others have argued, actions like China's could be considered a breach of custom rather than evidence that no custom exists.[203] And unlike a statutory negligence claim, a claimant alleging negligence by breach of custom need show only that the guidelines were an industry norm, rather than a statute with the force of law.

Two weaknesses of basing liability on negligence by breach of custom are that breach of a custom is not negligence per se, and that while the Registration Convention may be considered a "statute," it may not yet be a custom. Unlike statutory negligence, breach of a custom is not negligence per se.[204] Although customs like guidelines help show negligence, ambiguity regarding fault in damage caused by space debris may still exist until guidelines are made binding, as some have advocated.[205] Breach of custom also may not apply to the Registration Convention because, although it is a treaty, it is not always followed and at least 225 launches went unregistered between 1980 and June 2006.[206] Registering space objects may not yet be common enough to be considered a custom. Still, this form of liability is useful as many states have guidelines similar to COPUOS's, and the guidelines likely reflect industry customs.

D. MALFUNCTION LIABILITY

Another basis for liability is malfunction liability, or strict product liability. One view of malfunction liability is that

> a prima facie case of defectiveness can be made by proof of the fact of a malfunction, failure, or occurrence of an accident in conjunction with other circumstantial evidence such as a lack of an abnormal use of the

at http://orbitaldebris.jsc.nasa.gov/library/Space%20Debris%20Mitigation%20Guidelines_COPUOS.pdf.

201. *Id*. at iv.

202. Taylor, *supra* note 187, at 28–29.

203. Henry T. Scott, *Improving the Shield: Mitigating the Danger of Space Debris by Enforcing and Developing Already Existing Space Law*, 34 ANNALS AIR & SPACE L. 713, 754–56 (2009).

204. Trimarco v. Klein, 436 N.E.2d 502, 506 (N.Y. 1982).

205. Bressack, *supra* note 130, at 776–77.

206. Imburgia, *supra* note 7, at 618.

> product and the lack of a reasonable secondary cause not attributable to defectiveness.[207]

If a product fails, and there is no evidence of another cause of the failure, then a prima facie case for malfunction liability exists under this view.[208]

Others have looked at malfunction liability in aviation law and argued that the doctrine should be extended to space.[209] In *Lindsay v. McDonnell Douglas Aircraft Corp.*, a plaintiff sued a manufacturer of an airplane after the plane crashed.[210] The plaintiff alleged that a plane malfunction caused the crash.[211] The court explained that "[w]e do not think it incumbent upon the plaintiff to show that the defendant installed a defective part, knowing it to be faulty. This places an undue burden over and beyond the principles of strict liability in tort."[212] The court stated that in this type of product malfunction case, circumstantial evidence including the failure of the airplane was sufficient evidence of a defect.[213]

Commentators have argued that this theory of liability without proof of a specific defect should be extended to space law generally,[214] and the doctrine would also suit space debris. If a satellite explodes, causes debris, and that debris causes damage, the manufacturer of the satellite could be held liable.

Malfunction liability as a form of recovery has two benefits: First, like violation of a safety statute, proof of a defect is sufficient to establish liability and avoids the ambiguity involved in determining if some act or omission rises to the level of negligence. Second, malfunction liability does not require evidence of a specific defect. If a satellite explodes, there is no evidence of a cause of the explosion other than a malfunction, the explosion causes debris, and the debris causes damage, then a prima facie case of malfunction liability would exist. This is especially useful in the context of space debris because it is often difficult to determine exactly what type of malfunction caused a space object to explode.[215] While explosions are generally caused by engine or propulsion system failures,

207. Christopher H. Hall, Annotation, *Strict Products Liability: Product Malfunction or Occurrence of Accident as Evidence of Defect*, 65 A.L.R. 4th 346, 354 (1988).

208. *Id.*

209. *See* Bosco, *supra* note 130, at 30–36, 48–51.

210. Lindsay v. McDonnell Douglas Aircraft Corp., 460 F.2d 631, 633 (8th Cir. 1972).

211. *Id.* at 633–34.

212. *Id.* at 637–38.

213. *Id.* at 640.

214. Bosco, *supra* note 130, at 47, 51.

215. BAKER, *supra* note 22, at 7.

"[t]he cause of several recorded explosions has yet to be determined."[216] Malfunction liability would not require a plaintiff to show a specific defect, but rather only that the space product was being used in the intended way and that no evidence existed of a secondary cause of the accident.

One weakness of malfunction liability is that it applies only to damage caused by debris that was created by malfunctions. Although damage caused by debris created by satellite explosions or even a satellite that became defunct due to a malfunction would be covered, damage caused by debris created by intentional explosions or collisions would not. For example, damage caused by debris from China's weather satellite would not be covered because the debris was created intentionally and not by malfunction. Likewise, damage caused by debris from the 2009 collision between satellites would also likely not be covered because the collision involved a defunct satellite that probably did not malfunction. Nevertheless, due to the amount of debris created by explosions and other malfunctions, malfunction liability remains a useful basis of liability for damage caused by space debris.

E. NUISANCE

Nuisance could be another form of fault within the meaning of the Liability Convention, or its own cause of action in the context of space law. Several Space Law academics have examined applying nuisance to space in order to solve problems other than debris, like microbiological testing in space.[217] And nuisance has long been applied to harm caused by airports and flying aircraft, including harm caused by airport debris and dust.[218] As one Space Law expert noted ten years before the ratification of the Liability Convention, nuisance law is also appropriate for space debris.[219]

216. *Id.*

217. MORRIS D. FORKOSCH, OUTER SPACE AND LEGAL LIABILITY 138–39 (1982); Jay H. Ginsburg, *The High Frontier: Tort Claims and Liability for Damages Caused by Man-Made Space Objects*, 12 SUFFOLK TRANSNAT'L L.J. 515, 551–52 (1989); Philip McGarrigle, *Hazardous Biological Activities in Outer Space*, 18 AKRON L. REV. 103, 129–31 (1984).

218. Meloy v. City of Santa Monica, 12 P.2d 1072, 1074 (Cal. Ct. App. 1932) (denying a nuisance claim brought against a city by the owner of airport-adjacent property because the city was not liable for the actions of its airport-operating tenant); Jack L. Litwin, *Airport Operations or Flight of Aircraft as Nuisance*, 79 A.L.R. 3d 253, 274–76 (1977).

219. *See* J.F. McMahon, *Legal Aspects of Outer Space*, 38 BRIT. Y.B. INT'L L. 339, 391–92 (1962) (arguing that some form of international nuisance could be applied to dangerous activities in space, including leaving inactive satellites in orbit); J.F. McMahon, *Legal Aspects of Outer Space: Recent Developments*, 41 BRIT. Y.B. INT'L L. 417, 424 (1965–1966) (updating the argument and noting that some form of international nuisance is already codified in treaties that regulate potentially dangerous space activities, but not mentioning nuisance as a basis of liability).

A nuisance requires a defendant to substantially and unreasonably interfere with the enjoyment or use of a plaintiff's land or property.[220] Nuisance by abnormally dangerous activities may be particularly appropriate for damage caused by space debris. Others have suggested the doctrine for space dangers like microbiological testing.[221] A party commits a nuisance by abnormally dangerous activity when "his conduct is a legal cause of an invasion of another's interest in the private use and enjoyment of land, and the invasion is . . . unintentional and otherwise actionable under the rules controlling liability for . . . abnormally dangerous conditions or activities."[222] Strict liability applies to nuisance caused by abnormally dangerous activities,[223] and if creating space debris is considered abnormally dangerous, then the ambiguity as to whether something rises to the level of a nuisance will be eliminated.

Space Law academics have argued that debris-creating activities are abnormally dangerous.[224] As discussed in Part II, orbital debris presents significant dangers to other space objects as well as humans. And even if paint flaking and creation of other small debris does not rise to the level of abnormally dangerous, actions like China's intentional destruction of a weather satellite or the failure of parties to remove satellites from orbit at the end of the satellites' lives may certainly be considered abnormally dangerous.

In order for nuisance to apply to damage caused by orbital debris in space, plaintiffs would first have to establish that they had property rights.[225] One Space Law expert who applied international nuisance to dangerous space activities largely did not address the private-property issue.[226] Other commentators applying nuisance to microbiological testing in space have questioned the doctrine's effectiveness because international treaties "ban appropriation of space by states or individuals," meaning that private property rights arguably do not exist.[227]

220. Litwin, *supra* note 218, at 259.

221. McGarrigle, *supra* note 217, 132–35.

222. RESTATEMENT (SECOND) OF TORTS § 822 (1979). *See* United States v. Hooker Chems. & Plastics Corp., 722 F. Supp. 960, 965 (W.D.N.Y. 1989) (explaining a nuisance claim under New York law).

223. RESTATEMENT (SECOND) OF TORTS § 822, cmts. b & j.

224. BAKER, *supra* note 22, at 85–86; OFFICE OF TECH. ASSESSMENT, OTA-BP-ISC-72, ORBITING DEBRIS: A SPACE ENVIRONMENTAL PROBLEM 32 (1990).

225. Crane-McNab v. County of Merced, 773 F. Supp. 2d 861, 867 (E.D. Cal. 2011) (stating that, in California, nuisance encompasses almost all types of interference with property).

226. McMahon, *Legal Aspects of Outer Space*, *supra* note 219, at 389–93.

227. Ginsburg, *supra* note 217, at 551–52 & n.158; McGarrigle, *supra* note 217, at 129–30.

But those commentators have not applied nuisance to objects orbiting in GEO specifically. Property rights could arguably exist in GEO because the ITU allocates and assigns those orbits.[228] In order to maintain "effective and economical use of the geostationary satellite orbit," the ITU keeps an "orderly recording of the positions assigned by countries to geostationary satellites, with a view to ensuring formal international recognition thereof."[229] Because GEO is narrow, these a priori property allocations are important.[230] The allocations have force, and efforts to circumvent ITU orbital allocation have failed. In 1976, eight countries along the equator tried to assert sovereignty over geosynchronous orbits "directly over their territories."[231] The UN rejected the countries' claims, although the ITU agreed to set aside orbital "'parking spaces' for future use by non-space-faring countries."[232] Both the UN's rejection of the claims and the ITU's concession to set aside orbital slots show the organization's power to reserve orbital property for some actors while excluding others, granting successful applicants a limited private property right similar to a property easement.[233]

And even if enforcing property rights in GEO is contrary to existing treaties that recognize space as a commons, proposals for formalized property rights in GEO could one day be adopted, eliminating the private-property issue and making nuisance claims more likely to succeed.[234] The space-debris problem has been described as a tragedy of the commons, a situation where self-interested actors will pollute ownerless property instead of preserving the property's value over time.[235] Assigning private-property rights is one solution to a tragedy of the commons,[236] and some have argued that formal orbital private property would alleviate the debris problem.[237] Others have argued that courts should adopt the view that the space commons is owned by everyone, rather than no one, so that individual actors can assert their interests in space through actions such as

228. CHRISTOL, *supra* note 56, at 99–100; Nima Nayebi, Note, *The Geosynchronous Orbit and the Outer Limits of Westphalian Sovereignty*, 3 HASTINGS SCI. & TECH. L.J. 471, 485–86 (2011) (describing orbit allocation in the GSO, which is another way of referring to the GEO).

229. REIJNEN & DE GRAAFF, *supra* note 51, at 86.

230. CHRISTOL, *supra* note 56, at 99–100.

231. Nayebi, *supra* note 228, at 486–90.

232. *Id.*

233. Stroud, *supra* note 134, at 370.

234. Ezra J. Reinstein, *Owning Outer Space*, 20 NW. J. INT'L L. & BUS. 59, 95–97 (1999).

235. Nicholas D. Welly, *Enlightened State-Interest—A Legal Framework for Protecting the "Common Interest of All Mankind" from Hardinian Tragedy*, 36 J. SPACE L. 273, 283–86 (2010).

236. *Id.* at 288, 312–13 (acknowledging property rights as a solution, though ultimately rejecting private property in favor of international cooperation).

237. Reinstein, *supra* note 234, at 97.

nuisance claims even if they cannot assert their individual ownership over space.[238]

For now, plaintiffs whose space objects were damaged by orbital debris may be able to argue that the ITU assigned them the orbit where damage occurred, and that a defendant's orbital debris interfered with their use of their orbital "property." Even with limited property rights in space, a nuisance claim may succeed because of the "legal preferences accorded to successful [ITU orbital allocation] applicants."[239]

A limitation on nuisance as a form of "fault" is that it may apply only to GEO and not LEO, where most orbital debris is located.[240] This is because while property rights may arguably exist in GEO (as discussed above), the ITU does not allocate orbits in LEO. Without property rights, nuisance will not apply to LEO, where most debris is located. But nuisance would still be useful in GEO for the same reasons the ITU allocates orbits there. GEO is narrow, overcrowding is an issue, and space debris poses unique dangers in these conditions.

One benefit of a nuisance standard of fault is that injunctions could prevent the creation of future space debris. The typical remedy for a nuisance is an injunction.[241] If a party intentionally destroyed a satellite, the debris damaged another space object in an allocated orbit, and the debris was found to be a nuisance, then an injunction could possibly be issued ordering the party not to create debris in the same way again, and future space debris could be prevented. This makes nuisance and its injunctive relief a more appealing basis of fault than negligence or malfunction liability.

But nuisance could still be applied even if an injunction would be difficult or impossible to enforce. In *Boomer v. Atlantic Cement Co.*, a cement plant that emitted dirt and smoke was found to be a nuisance,[242] but because the plant was valuable[243] and completely eliminating the pollution

238. McGarrigle, *supra* note 217, at 130–31.

239. Lawrence D. Roberts, *A Lost Connection: Geostationary Satellite Networks and the International Telecommunication Union*, 15 BERKELEY TECH. L.J. 1095, 1111 (2000) ("[T]he ITU process does not, strictly speaking, allocate the . . . orbital positions that it registers. . . . The ITU acts as an efficiency-enhancing resource through which sovereign states attempt to avoid potential usage conflicts and as a convenient forum for resolving disputes that arise. Nevertheless . . . the legal preferences accorded to successful applicants have a significant impact on the development and operation of geostationary systems.").

240. INTERAGENCY REPORT, *supra* note 5, at 4.

241. Boomer v. Atlantic Cement Co., 257 N.E.2d 870, 872 (N.Y. 1970).

242. *Id.* at 871.

243. *Id.* at 872.

would be difficult if not impossible,[244] the court issued permanent damages rather than an injunction.[245] Satellites and other spacecraft, like the cement plant, are valuable and important to communication and other global needs, and some debris, such as debris created by paint flaking and metal erosion, may be difficult to prevent even if an injunction was issued. Space treaties may also prevent injunctive relief. The Liability Convention contemplates monetary damages but is silent on "injunctive relief . . . appropriate under common law claims of nuisance."[246] And treaties that recognize space as a commons may prevent injunctions that order defendants to refrain from using space in a certain way. Nevertheless, like in *Boomer*, harm caused by debris could still be remedied as a nuisance using damages if injunctive relief was impossible or extremely difficult.

Because of its remedies and the importance of GEO, nuisance could be particularly beneficial as a basis of liability for damage caused by space debris.

F. LIVE AND LET LIVE

Although new tracking technology will allow smaller debris to be identified, the source of very small debris such as paint flakes or rocket dust may remain anonymous. This type of debris usually causes small damage such as erosion, surface pitting, damage to a satellite's solar panels, or damage to a spacecraft's windows.[247] This remaining unidentified debris would not be a problem in a common law tort regime because it is likely that no liability would exist for damage caused by this debris even if it could be identified. A "live and let live" rule could be applied. The "live and let live" rule is appropriate in situations in which all parties create "modest" harm that is "fairly" and evenly distributed.[248]

In a real-property context, a "live and let live" approach is appropriate when

> [i]t is as much for the advantage of one owner as of another; for the very nuisance the one complains of, as the result of the ordinary use of his

244. *Id.* at 873–74.

245. *Id.* at 873–75.

246. Liability Convention, *supra* note 136, 24 U.S.T. at 2397–98; Ginsburg, *supra* note 217, at 543–44.

247. INTERAGENCY REPORT, *supra* note 5, at 8, 13.

248. Gregory C. Keating, *Distributive and Corrective Justice in the Tort Law of Accidents*, 74 S. CAL. L. REV. 193, 208–09 (2000) (comparing situations in which harm is evenly distributed, such as common usage of land and houses, to situations in which harm is not evenly distributed even if the risk of harm is, such as the ordinary use of roads.)

> neighbour's land, he himself will create in the ordinary use of his own, and the reciprocal nuisances are of a comparatively trifling character.[249]

Parties that reciprocally cause each other small damage should "live and let live."

Damage caused by small debris, such as paint flakes, fits these criteria and is modest and evenly distributed among space actors. Damage to the surface of a solar panel due to exposure to paint flakes or pieces of eroded metal is relatively small compared to damage caused by larger debris.[250] Window or thermal panel damage is equally distributed among space actors, and most space actors contribute to the very-small-debris population because most satellites produce paint flakes and eroded metal.[251]

A "live and let live" approach is useful for small damage caused by space debris because this type of debris may remain unidentified even with new tracking technology. The lack of identification would not be an issue if no liability existed for this type of damage.

V. REGULATION

If space is already so congested with debris that the cascade effect is inevitable, tort law may be unable to solve problems associated with orbital debris on its own. With tort law, parties may be held liable for damage they cause and may even try to limit the amount of new debris they create in the future. But if or when the cascade effect occurs, new debris would be created at an exponential rate even without human activity. A regulatory approach, rather than (or in addition to) tort law may be necessary if the cascade effect becomes a reality.

Others have suggested regulatory approaches to debris, including a space-access tax that would create an orbital maintenance fund that could be used to better track and remove debris.[252] Another proposal would charge states based on the amount of debris they have created, with funds going to efforts to remove debris.[253] This proposal is especially appealing with promising technology like the "janitor" satellite. Others suggest applying NASA's orbital debris mitigation guidelines to all American

249. Bamford v. Turnley, (1862) 122 Eng. Rep. 27 (Ex.) 33; 3 B & S 62.

250. INTERAGENCY REPORT, *supra* note 5, at 13 (describing paint flakes and other deterioration debris causing damage to solar panels and windows).

251. *See id.* (hypothesizing that paint flaking and erosion are caused by exposure to atomic oxygen and erosion of organic binders, something that all space objects are subject to).

252. Pusey, *supra* note 46, at 448–49.

253. Imburgia, *supra* note 7, at 629–32.

space activities, and eventually to space activities globally.[254]

Regulation of space debris could be modeled after regulatory regimes that involve similar problems. Space is a global commons,[255] and regulations could be modeled on regimes related to issues affecting other global commons, such as marine litter in the oceans. In response to the problem of marine debris, the United Nations Environment Programme ("UNEP") has helped different regions organize and implement regional activities, including reviewing the extent of the debris problem, preparing a regional action plan, and organizing a regional meeting of authorities and experts.[256] UNEP has suggested port and tourist fees, similar to the proposed space-access tax, that could be used to monitor, assess, and cleanup marine debris.[257] Following this model, regulation of space debris could include reviewing the amount of debris different states create, preparing plans for each state to limit new debris creation, and organizing meetings within states that include authorities and experts.

Likewise, UNEP has engaged in global activities to curb the problem of marine debris. For example, it issued guidelines relating to surveying and monitoring debris and arranged for intergovernmental organizations to assess the economic and environmental impact of abandoned fishing gear.[258] A regulatory regime for space debris could similarly help intergovernmental organizations assess the economic and environmental impact of leaving satellites in orbit at the end of their lives.

International conventions have also been created to curb marine debris. These conventions regulate waste dumping and activities that add to the marine-debris population.[259] Similar conventions relating to space debris could be created, or existing space treaties could be amended to include provisions aimed at preventing the creation of new debris, rather than focusing only on holding parties liable for damage.

254. Seymour, *supra* note 114, at 912–14.

255. BAKER, *supra* note 22, at 79.

256. LJUBOMIR JEFTIC, SEBA SHEAVLY & ELLIK ADLER, U.N. ENV'T PROGRAMME, MARINE LITTER: A GLOBAL CHALLENGE 7 (2009), *available at* http://www.unep.org/regionalseas/marinelitter/publications/docs/Marine_Litter_A_Global_Challenge.pdf.

257. INST. FOR EUROPEAN ENVTL. POLICY, U.N. ENV'T PROGRAMME, GUIDELINES ON THE USE OF MARKET-BASED INSTRUMENTS TO ADDRESS THE PROBLEM OF MARINE LITTER 35 (2009), *available at* http://www.unep.org/regionalseas/marinelitter/publications/docs/Economic_Instruments_and_Marine_Litter.pdf.

258. JEFTIC, SHEAVLY & ADLER, *supra* note 256, at 18–20.

259. *Id.* at 21–23.

VI. CONCLUSION

Action must be taken to reduce the space debris problem, and holding parties liable for damage their debris causes will internalize costs and discourage the creation of future debris. Events like Secretary of State Hillary Clinton's statements in January 2012 that the United States will hold talks with the European Union to develop rules to limit debris are encouraging.[260] The development of new tracking technology that could help eliminate issues regarding the origin and identity of space debris, combined with the increased probability of debris-related collisions and damage in the future, means that more claims could be brought under the Liability Convention or other laws. With fewer identification problems, less attention will be devoted to causation issues and more will be given to what constitutes "fault." Statutory negligence, negligence by breach of custom, malfunction liability, and nuisance are possibilities. In order to preserve space for future generations to use and explore, space torts are a necessity.

260. Heilprin, *supra* note 41.