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NO MAN'S SKY: UTILIZING MARITIME LAW TO ADDRESS THE NEED FOR SPACE DEBRIS REMOVAL TECHNOLOGY

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NO MAN'S SKY: UTILIZING MARITIME LAW TO ADDRESS THE NEED FOR SPACE DEBRIS REMOVAL TECHNOLOGY

*Sandra Drago**

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I. INTRODUCTION

Fifty years from now people will look back and remember the late twentieth and early twenty-first century as a time of technological advancement in the realm of information technology. In the last thirty years, engineers have created computer technology beyond what was ever thought possible. Companies like Google, Apple, Microsoft, and IBM have changed the way people access information in their everyday lives. For instance, an individual can use Google's map application to navigate his or her way around anywhere in the world. While the ability to use navigation technology to travel around the United States may not seem like much of an accomplishment, now, navigation technology has become so advanced that you can use it to find your way around some the world's most exotic, obscure, and remote locations. For example, you can use Google maps to travel the busy streets of Chandni Chowk in Delhi, India or to find a restaurant in Agua Calientes, Peru before making your way to Machu Picchu. As our ability to connect with others around the world has become more and more simplified, globalization has become the norm.

Advancements in technology have led to theories concerning how humans will adjust to change. Author and inventor, Ray Kurzweil, has long toyed around with the idea that society is near the point of singularity.[1] Kurzweil predicts the point of singularity will occur after computer technology has advanced to exceed human intelligence.[2] He wrote a book[3] on the implications of this transformation. He believes "our bodies will evolve as much as our machines," so much so, that a clear separation between the two will no longer exist.[4] According to Kurzweil, humans will be able to slow down aging processes, and neural implants will be able to extend human intelligence.[5] In 2006, he estimated the point of singularity would occur in forty-nine years.[6]

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* B.A. in Literature and Politics from University of California, Santa Cruz; J.D. Santa Clara University School of Law; Senior Research Editor of SCU Law Review Volume 59. This note is dedicated to the memory of Michael Steven Bilecky, who I will always remember for instilling in me a sense of adventure, wonder, and discipline. He was a constant source of knowledge, inspiration, and wisdom. It was truly an honor and privilege to know him. Special thanks to the Santa Clara Law Review Research Team: Andrew Brown, Ruben Peña, and Daniel Pohoretsky. Many thanks to the staff of the Santa Clara Law Review for their input and editing.

1. Robert Levine, *The New Human: Our Singular Future, Interview with Ray Kurzweil*, PLAYBOY, July 2006, at 55. The meaning of singularity depends on context. In the context of historical singularity, the point of singularity refers to the point "at which civilization would fundamentally be transformed." *Id.*
2. *Id.*
3. *See generally* RAY KURZWEIL, THE SINGULARITY IS NEAR (2005).
4. Levine, *supra* note 1, at 55.
5. *Id.* at 56.
6. *Id.* at 55.

While it is too early to conclude whether Kurzweil's theories concerning the point of singularity[7] will materialize, technology is already heading in that direction. Recently Three Square Market, a technology company, teamed up with Biohax, a company specializing in implantable microchips, to implement a voluntary microchip program for employees.[8] Technology is being used to help people with disabilities. Neil Harbisson, a colorblind man, had a sensory antenna implanted into his brain in 2004 to allow him to listen to colors.[9] He is now a wildly successful advocate for cyborg technology.[10]

On the surface it appears that technology, and with it, society, is advancing rather quickly. But in reality, this cannot be further from the truth. Discussions concerning the rapid pace of technological advancement ignore the fact that solutions to real problems have yet to be found. This may be due to the fact that the masterminds capable of solving complex problems lack a sufficient financial incentive to undertake such tasks. As technology continues to advance, we cannot continue to ignore real problems. Doing so will cause us to become a society capable of creating 'cool things' like artificial intelligence and human cyborgs, but also one that is unable to protect citizens from harm. One problem that has yet to be resolved is the problem of "space junk," aka orbital debris. No feasible long term solutions have been found to remove space junk from orbit. Without a solution, space junk will endanger future advancements in space technology by inhibiting future space exploration. Here, the following note is concerned with man-made space debris orbiting the earth that presents a risk to human life and property, including risk of damage to spacecrafts and other space structures.

First, the background section will provide definitions and information necessary to understand the problem presented by orbital debris. Second, the issue section identifies the legal problem as a lack of national and international laws and treatises addressing space debris removal. Third, the analysis section will discuss the current national and international response to space debris. Fourth, the proposal section will discuss

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7. *Id.*

8. Maggie Astor, *Microchip Implants for Employees? One Company Says Yes*, N.Y. TIMES (July 25, 2017), https://www.nytimes.com/2017/07/25/technology/microchips-wisconsin-company-employees.html. Employees have the option of getting a microchip the size of a grain of rice implanted between their thumb and index finger. Once implanted, the microchip allows employees to pay for food and enter the office building by waiving their hand in front of a sensor. *Id.*

9. *See* Neil Harbisson, *I Listen to Color*, TED GLOBAL (June 2012), https://www.ted.com/talks/neil_harbisson_i_listen_to_color?language=en#.

10. *Id.*

maritime law of salvage as a possible solution to the space debris problem. Lastly, the conclusion section will provide a brief summary of the issues discussed.

II. BACKGROUND

After decades of launching satellites and space aircrafts into outer space, we have created a problem that poses a potential danger to human life, property, and future attempts of space exploration. The danger posed by space debris cannot be overstated. Space debris has endangered the International Space Station and human lives.[11] Without an effort to remove space debris from orbit, this problem and the safety risks posed by space debris are likely to continue to grow. Currently, NASA is tracking 500,000 pieces of debris orbiting the earth.[12]

A. What Is Space Junk?

Space junk can be one of two things: it is nonfunctional debris that is either composed of natural particles (meteor) or artificial man-made particles.[13] While natural particles orbit around the sun, man-made debris orbits the earth.[14] Space junk is formally referred to as orbital debris.[15] These man-made particles are often composed of "nonfunctional spacecrafts, abandoned launch vehicle stages, mission-related debris, and fragmentation debris."[16] The primary sources of space debris in Earth's orbit usually fall under one of two categories: (1) "accidental and intentional break-ups which produce long-lived debris," and (2) "debris released intentionally during the operation of launch vehicle orbital stages and spacecraft."[17] Thus, human missions to explore outer space are largely responsible for orbital debris. It is a man- made problem that has yet to be resolved or adequately addressed.[18]

11. *See Space Debris and Human Spacecraft*, NASA (Sept. 26, 2013), https://www.nasa.gov/mission_pages/station/news/orbital_debris.html (last updated Aug. 7, 2017).
12. *Id.*
13. *Id.*
14. *Id.*
15. *Id.*
16. *Id.*
17. Comm. On the Peaceful Uses of Outer Space, *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space*, U.N. DOC. ST/SPACE/49, at 1 (2010), http://www.unoosa.org/pdf/publications/st_space_49E.pdf [hereinafter UNOOSA].
18. *See id.* (orbital debris created by collisions are expected to be remain a source of space debris in the future.).

B. Danger To Space Structures, Human Life, and Property Presented By Orbital Debris

While orbital debris seems of little or no cause for concern, it poses a potential danger to the International Space Station and virtually all space vehicles launched into outer space, including satellites.[19] Even though 500,000 pieces of debris are being tracked, there are millions of pieces of debris that are simply too small to track.[20] The potential risk of damage should not be underestimated—even tiny paint flecks can, and have, damaged spacecrafts.[21] Flying paint flecks are known to have caused damage to space shuttle windows.[22] This is because debris travels at high velocity in outer space. A tiny piece of space debris can travel up to speeds of 17,500 mph.[23] Space debris has caused damage to several space structures.[24] There are several instances in recent history where space debris has caused damage to satellites.[25] It is important to note that every collision between space debris and a functional spacecraft creates more debris and exacerbates the problem.[26]

In 1996, pieces of an old French rocket hit and damaged a French satellite.[27] China destroyed an old weather satellite and added more than 3,000 pieces of space debris in 2007, which is suspected of having caused damage to other spacecrafts.[28] Again in 2009, an United States Iridium commercial satellite was destroyed by a defunct Russian satellite. The satellites collided and created over 2,000 pieces of trackable space debris.[29] Fragments do not need to be large in order to cause significant damage. Orbital debris fragments that are between one and ten cm in size are big enough to "penetrate and damage most spacecraft[s] and could possibly destroy space assets."[30] If a spacecraft is hit by a

19. *Space Debris and Human Spacecraft*, *supra* note 11.
20. *Id.*
21. *Id.*
22. *Id.*
23. *Id.*
24. *Id.*
25. *Space Debris and Human Spacecraft*, *supra* note 11.
26. *Id.* (in 2007 and 2009, in two separate incidents, collisions between satellites created a total of over 5,000 fragments of debris).
27. *Id.*
28. *Id.*
29. *Id.*
30. MISSILE DEFENSE AGENCY, DEP'T OF DEFENSE, BALLISTIC MISSILE DEFENSE SYSTEM (BDMS): PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT, at K318 (2007), https://apps.dtic.mil/dtic/tr/fulltext/u2/a515713.pdf [hereinafter PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT]. *See Space Debris: Hypervelocity Impacts and Protecting Spacecraft*, EUROPEAN SPACE AGENCY, https://www.esa.int/Our_Activities/Operations/Space_Debris/Hypervelocity_impacts_and_protecting_spacecraft. *See also Center for Orbital and Reentry Debris Studies: Space Debris Basics*, THE AEROSPACE CORP., https://aerospace.org/cords [hereinafter *Space Degree Basics*].

piece of orbital debris, it will cause the spacecraft's satellite function to be terminated, and will in turn create a "significant amount of small debris."[31] Collisions can cause dangerous debris clouds, which consist of a concentration of debris particles or fragments.[32] The probability of damage to a functioning spacecraft or satellite is likely to increase by debris clouds.

C. Orbital Debris Re-entry Into Earth's Atmosphere

In addition to potential damage to satellites and other space vehicles, there is also the possibility of re-entry into Earth's atmosphere.[33] According to the Aerospace Corporation's re-entry statistics, over 5,400 metric tons of materials have survived re-entry over the last fifty years.[34]

Most satellites vaporize or melt as they get closer to Earth's atmosphere.[35] As a satellite enters Earth's atmosphere, compression and friction generates heat.[36] Upon re-entry, orbital debris can travel at high velocity upwards of 29,000km/hr.[37] The heat generated by travelling at such high speeds can melt or sometimes vaporize an entire satellite—similar to the way meteors burn during a meteor shower.[38] While most satellites burn completely, this is not always the case; some may survive reentry.[39]

During reentry, the object decelerates rapidly and is subjected to atmospheric pressure which causes it to break apart.[40] As an object goes through "denser regions of the atmosphere," the velocity and temperature decreases, causing it to impact the ground at a lower speed.[41] Because "drag on the object is directly proportional to atmospheric density, and atmospheric density varies greatly at high altitudes," it is difficult to determine exactly where debris will land.[42] Fortunately, there have been

31. PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT, *supra* note 30 at L4-L5. *See also Space Degree Basics*, *supra* note 30.

32. *Danger: Orbital Debris*, THE AEROSPACE CORPORATION (May 4, 2018), https://aerospace.org/story/danger-orbital-debris.

33. *Center for Orbital and Reentry Debris Studies: Spacecraft Reentry*, THE AEROSPACE CORP., formerly available at http://www.aerospace.org/cords/research/ (last visited Jan. 18, 2018) (on file in Law Review Office) [hereinafter *Spacecraft Reentry*].

34. *Id.*

35. *Id.*

36. *Id. See also* John Leslie, Does Space Junk Fall From The Sky?, NAT'L OCEANIC & ATMOSPHERIC ADMIN. (Jan. 19, 2018), https://www.nesdis.noaa.gov/content/does-space-junk-fall-sky.

37. *Spacecraft Reentry*, *supra* note 33.

38. *Id.*

39. *Id.*

40. *Id.*

41. *Id.*

42. *Id.*

some advancements to prevent injury to people on Earth.[43] Some satellites are now equipped with rocket motors that allow the satellite to reenter a desired area.[44] Surprisingly, there is only one reported incident of a person being struck by debris from a reentering satellite.[45] However, it is likely that several incidents have not been reported.[46]

However, not all objects that reenter are capable of being tracked and propelled to a desired location. According to reentry data, over the last fifty years, 5,400 metric tons of materials have survived reentry.[47] The Russian Mir Space Station is the largest object to reenter, weighing at 120,000 kg.[48] Over fifty debris objects have been recovered and documented.[49] On January 22, 1997, a "250-kg stainless steel tank, a 30-kg pressure sphere, and a 45-kg thrust chamber" were recovered after reentry.[50] Pieces of debris that survive reentry tend to be large and heavy, and pose a threat to people and property.[51]

Additionally, pieces of debris that survive reentry create a "debris footprint."[52] A debris footprint is an area on the ground containing all debris pieces, including small untracked pieces.[53] The width of a debris footprint typically range from twenty to forty km.[54] While serious injuries resulting from re-entry have not been reported and the risk of being injured is relatively low in comparison to the hazards humans face daily, a likelihood of harm to persons and property on Earth still exists given the growing quantity of debris currently in orbit and the width of a debris footprint.[55]

D. Mitigation As The Current National and International Response To Orbital Debris

While orbital debris is recognized as a serious threat by the national and international community, enacting policies that carry the force of law has proven to be difficult in a neutral zone like outer space. The international community's response to rising levels of orbital debris has

43. *Spacecraft Reentry*, *supra* note 33.
44. *Id.*
45. *Id.*
46. *Id.*
47. *Id.*
48. *Id.*
49. *Spacecraft Reentry*, *supra* note 33.
50. *Id.*
51. *Id.*
52. *Id.*
53. *Id.*
54. *Id.*
55. *Spacecraft Reentry*, *supra* note 33.

been to adopt mitigation measures to minimize the creation of future orbital debris.[56] The implementation of mitigation measures are recommended but are rarely legally required.[57] The failure to enact policies that require members to act is surprising given that orbital debris can damage spacecrafts, lead to the loss of a mission, or the loss of life in cases where a spacecraft is manned.[58]

In the context of manned spacecrafts, the dangers posed by orbital debris invoke a sense of urgency and demand a response from policymakers. Finding a solution to issues presented by orbital debris becomes "highly relevant due to crew safety implications."[59] Perhaps this is why the international community responded by adopting mitigation guidelines. While mitigation guidelines are insufficient to solve the problem, they provide guidance for reducing orbital debris moving forward. In the early history of space exploration, nations were free to launch objects into Earth's orbit without guidance or deference to mitigation procedures.[60] It was not until the mid 1990's that the UN Office for Outer Space Affairs, considered the issue of space debris.[61] Previously, spacecraft designers were not encouraged to consider mitigation procedures.[62] Now, design efforts have been prompted by "the recognition of the threat posed" by orbital debris.[63] These measures can be divided into two approaches: (1) "those that curtail the generation of potentially harmful space debris in the near term," and (2) "those that limit their generation over the long term."[64] The first approach involves the "curtailment of the production of mission-related space debris and the avoidance of break-ups."[65] The second approach concerns "end-of-life procedures that remove decommissioned spacecraft and launch vehicle orbital stages from regions populated by operational spacecraft."[66]

Mitigation guidelines apply only to mission planning and the operation of newly designed spacecrafts.[67] In formulating the basis for mitigation guidelines, prior incidents are often evaluated and used to prevent

56. UNOOSA, *supra* note 17.
57. *See id.* at 2 (stating "[t]hese guidelines are applicable to mission planning and the operation of newly designed spacecraft and orbital stages and, if possible, to existing ones. They are not legally binding under international law.").
58. *Id.* at 1.
59. *Id.*
60. *See id.*
61. *Id.* at iii.
62. *See* UNOOSA, *supra* note 17 at 2.
63. *Id.*
64. *Id.* at 1.
65. *Id.*
66. *Id.*
67. *Id.* at 2.

reoccurrence.[68] For example, in the past, malfunctions have led to fragmentation.[69] Mitigation methods may involve planning for potential scenarios where malfunction occurs in order to prepare for a particular event and reduce the probability of a "catastrophic" event.[70] Some mitigation methods address past accidental collisions by limiting the probability of an accident by estimating the likelihood of a collision with known objects during the "system's launch phase and orbital lifetime."[71] This is important because studies have shown that the primary source of new space debris is likely to come from accidental collisions.[72]

Some international organizations have responded by adopting collision avoidance procedures that require an analysis of existing data.[73] Another mitigation method calls for the depletion of a spacecraft's stored energy at the end of a mission.[74] This method addresses the unintentional fragmentation of spacecrafts that arise from collisions involving abandoned spacecrafts that were decommissioned while still containing a significant amount of stored energy.[75] Passivation, a method of energy depletion, has been very effective.[76] Passivation requires "the removal of all forms of stored energy, including residual propellants and compressed fluids and the discharge of electrical storage devices."[77] Mitigation procedures prevent the creation of future orbital debris but do not address removal of existing debris. The enactment of mitigation guidelines by the international community, while not sufficient to solve the problem of orbital debris, offers hope and encouragement that a multilateral solution is possible.

III. ISSUE

While mitigation efforts are encouraging and important in addressing the problem of orbital debris, they fail to address the removal of existing debris from orbit. All national and international treaties and guidelines addressing the problem of orbital debris have only set forth preventative measures that reduce the amount of debris, but they do not entirely eliminate it. A spacecraft following every mitigation guideline set forth above, will still create a substantial amount of debris. Given

68. *See* UNOOSA, *supra* note 17 at 2.
69. *Id.* at 3.
70. *Id.*
71. *Id.*
72. *Id.*
73. *Id.*
74. UNOOSA, *supra* note 17 at 3.
75. *Id.*
76. *Id.*
77. *Id.*

that it is impossible to entirely eliminate orbital debris through mitigation and given that levels of orbital debris will continue to rise, a solution that addresses the removal of debris from orbit is necessary. Attempts to address this problem have failed largely because current efforts are geared towards mitigation. Current space law fails to address removal of debris and does not provide a mechanism to encourage innovation and technology. The proceeding section takes a close look at current national and international approaches to addressing orbital debris.

IV. Analysis

Currently, governmental agencies and organizations address the problem of orbital debris through mitigation procedures and data-sharing agreements. However, none are focused towards encouraging innovation in removal technology, and the majority are voluntary.[78] For instance, NASA has procedural requirements for limiting orbital debris[79] and orbital debris mitigation standard practices.[80] The Department of Defense has made substantial steps by enacting a data-sharing agreement to address threats to spacecrafts.[81] Furthermore, the Inter-Agency Space Debris Committee has devised a data sharing agreement with other countries in order to advance research concerning orbital debris.[82] An analysis of the current national and international approaches to addressing orbital debris is necessary to understanding the need for a different approach.

A. National Response to Space Junk

President Obama addressed the issue of orbital debris in the National Space Policy of 2010.[83] The Policy directed NASA and the Department of Defense to "pursue research and development of technologies and techniques…to mitigate and remove on-orbit debris…,"[84]

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78. *See infra* Section IV.B.2.

79. NPR 8715.6A, NASA Procedural Requirements for Limiting Orbital Debris and Evaluating the Meteoroid and Orbital Debris Environments, NASA (Feb. 16, 2017), https://www.orbitaldebris.jsc.nasa.gov/library/npr_8715_006b_.pdf [hereinafter NASA Procedural Requirements: NPR 8715.6B].

80. U.S. Government Orbital Debris Mitigation Standard Practices, Orbital Debris Program Office, NASA (2001), https://www.orbitaldebris.jsc.nasa.gov/library/usg_od_standard_practices.pdf [hereinafter U.S. Mitigation Standard Practices].

81. *See infra* Section IV.A.3.

82. *See infra* Section IV.B.1.

83. National Space Policy of the United States of America, Exec. Office of the President (June 28, 2010), https://history.nasa.gov/national_space_policy_6-28-10.pdf [hereinafter National Space Policy].

84. *Debris Remediation*, Orbital Debris Program Office, NASA, https://www.orbitaldebris.jsc.nasa.gov/remediation/.

however, this portion of the Policy was never implemented and the directive has been removed from the White House website.[85] There is currently no government entity in the United States that has been assigned the task of removing orbital debris.[86] The current national response to the orbital debris issue involves mitigation procedures and data sharing agreements.

The failure to assign a government entity the task of removing orbital debris is not surprising. The task is complex and the financial costs are high. However, finding a solution to the issue of orbital debris has become more important than ever. On December 11, 2017, President Donald Trump renewed the United States' interest in space exploration by issuing a Presidential Policy Directive, amending the National Space Policy, calling for human expansion into outer space.[87] Notably, the Directive declares that the United States is to:

> [l]ead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations.[88]

When taken seriously, the Directive indicates future space missions will involve placing humans in outer space for long periods of time. If the problem of space debris is not adequately addressed, it will not only be satellites and expensive machinery at peril, but human lives.

1. United States Orbital Debris Mitigation Standard Practices

In 2001, the United States government formalized efforts to address the issue of orbital debris in a set of guidelines developed by NASA and the Department of Justice entitled "Orbital Debris Mitigation Standard Practices" (ODMSP).[89] The ODMSP lists four main objectives, and for each objective the ODMSP outlines specific mitigation guidelines aimed

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85. *See* NATIONAL SPACE POLICY, *supra* note 83.

86. *Debris Remediation*, *supra* note 84.

87. Memorandum on Reinvigorating America's Human Space Exploration Program, DAILY COMP. PRES. DOCS., 2017 DCPD NO. 00902 (Dec. 11, 2017), https://www.whitehouse.gov/presidential-actions/presidential-memorandum-reinvigorating-americas-human-space-exploration-program/.

88. *Id.*

89. U.S. MITIGATION STANDARD PRACTICES, *supra* note 80. *See* Letter from Office of Science and Technology Policy, Exec. Office of the President, to the Senate Committee on Commerce, Science, and Transportation (Aug. 14, 2017), https://www.whitehouse.gov/wp-content/uploads/2017/12/08-14-17-OSTP-Orbital-Debris-Report.pdf.

at accomplishing the particular objective. The ODMSP objectives and guidelines are as follows:

> (1) Objective One: "control of debris released during normal operations" by requiring "programs and projects" to "assess and limit the amount of debris released in planned manner during normal operations,"[90] The objective is fulfilled by designing crafts that "eliminate or minimize debris released during normal operations."[91]
>
> (2) Objective Two: "minimizing debris generated by accidental explosions" by requiring "programs and projects" to "assess and limit the probability of accidental explosion during and after completion of mission operations,"[92] To fulfill the objective, the guidelines require a demonstration that the craft design is unlikely to cause an accidental explosion during a mission, and by depleting stored energy after the completion of a mission.[93]
>
> (3) Objective Three: "selection of safe flight profile and operational configuration[s]" by requiring "programs and projects" to "assess and limit the probability of operating space systems becoming a source of debris by collisions with man-made objects or meteoroids,"[94] To avoid collisions during the orbital lifetime of the craft, the guidelines require an estimation and probability assessment to be conducted during the development stages.[95] In order to avoid collisions with small pieces of orbital debris, spacecraft designs must consider and "limit the probability that collisions with debris… will cause loss of control."[96]
>
> (4) Objective Four: "postmission disposal of space structures" by implementing the use of "[p]rograms and projects" to plan for "cost effective disposal procedures for launch vehicle[s]" at the end of mission life in order to "minimize impact on future space operations."[97] The objective requires one of three post-mission disposal methods: atmospheric reentry, maneuvering to a storage orbit, or direct retrieval.[98]

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90. U.S. MITIGATION STANDARD PRACTICES, *supra* note 80.

91. *Id.*

92. *Id.*

93. *See id.* ("[i]n developing the design of a spacecraft or upper stage, each program, via failure mode and effects analyses or equivalent analyses, should demonstrate either that there is no credible failure mode for accidental explosion, or, if such credible failure modes exist, design or operational procedures will limit the probability of the occurrence of such failure modes"). For more on failure modes, see FAILURE MODES AND EFFECTS ANALYSIS (FMEA), NASA (July 2000), https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20000070720.pdf.

94. U.S. MITIGATION STANDARD PRACTICES, *supra* note 80, at 2.

95. *See id.* ("[i]n developing the design and mission profile for a spacecraft or upper stage, a program will estimate and limit the probability of collision with known objects during orbital lifetime").

96. *Id.*

97. *Id.* at 3.

98. *Id.*

The fourth objective of the mitigation standards outlines three methods of disposal. The ODMSP seems to allow atmospheric re-entry into the atmosphere so long as "the risk of human casualty" is less than 1 in 10,000.[99] The atmospheric reentry option allows a spacecraft to stay in orbit until it travels to another orbit or until it reenters the Earth's atmosphere.[100] In cases where the structure is fitted with a drag enhancement, the drag device must not cause the structure to fragment in the event that a collision occurs while the object remains in orbit.[101] A drag enhancement is used to reduce the time the object will remain in orbit.[102] This guideline is intended to reduce the possibility of creating orbital debris by prohibiting the use of drag enhancement devices that may fragment or cause another spacecraft to fragment as it is decaying.[103] While this measure is justifiable and progressive in terms of its goals, the permissible risk to human life (1 in 10,000) that it allows is baffling and indicative of excessive risk taking.[104]

The option to maneuver a structure to a storage orbit allows a space structure to be relocated to a "storage regime."[105] The ODMSP characterizes storage regimes by their altitude and emphasizes the need to use maneuvers that will not leave the structure near an operational orbit.[106] The goal here is to remove the structure from an operational orbit regime and into a designated area where it will no longer pose a threat.[107] However, this option is problematic. Using a storage orbit as a dumping site for orbital debris will preclude any future plans to make use of these orbits in a "more productive manner."[108] The direct retrieval option requires the retrieval and removal of a structure from orbit at some time after the completion of a mission.[109] The ODMSP requires the removal

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99. *Id.*
100. *See* U.S. MITIGATION STANDARD PRACTICES, *supra* note 80 at 3.
101. *Id.*
102. *Id.*
103. *Id.*
104. *Id.*
105. U.S. MITIGATION STANDARD PRACTICES, *supra* note 80, at 3. For more information on storage regimes, see Wikipedia, *Supersynchronous Orbit* ("The geo graveyard belt orbital regime is valuable as a storage and disposal location for derelict satellite space debris after their useful economic life is completed as geosynchronous communication satellites"), https://en.wikipedia.org/wiki/Supersynchronous_orbit (last visited Mar. 10, 2019).
106. U.S. MITIGATION STANDARD PRACTICES, *supra* note 80, at 3.
107. *Id.*
108. KIM LUU, ET. AL., AIR FORCE RES. LABORATORY, EFFECTS OF PERTURBATIONS ON SPACE DEBRIS IN SUPERSYNCHRONOUS STORAGE ORBITS 11 (Oct. 1998), https://apps.dtic.mil/dtic/tr/fulltext/u2/a361503.pdf.
109. U.S. MITIGATION STANDARD PRACTICES, *supra* note 80, at 3.

of a structure when it becomes practical to do so,[110] but it does not provide a recommended time frame. These measures for retrieval are important and noteworthy, as they provide guidelines for safe removal.

Notably, the objectives in the ODMSP do not mention the creation of new technology to remove existing orbital debris. The ODMSP's objectives merely focus on preventing and reducing the creation of additional orbital debris by encouraging clever spacecraft designs. Additionally, they do not sufficiently address the threat of already existing orbital debris and fail to provide a solution that would entirely eliminate the creation of more debris.

Most importantly, the ODMSP contains a significant flaw. The ODMSP states "[e]ach instance of planned release of debris larger than 5mm…should be evaluated and justified on the basis of cost effectiveness and mission requirements."[111] This loophole permits circumvention of the ODMSP. Given the high cost of space technology, companies or government agencies hoping to launch satellites and/or spacecrafts into outer space can use this loophole to launch poorly designed spacecrafts and satellites by justifying their design on the basis of cost effectiveness and mission requirements.

The ODMSP, as a whole, provides a solid framework for regulating the design of future space technology. However, the ODMSP fails to address the removal of existing orbit debris and contains loopholes that support the creation of structures that may cause more orbital debris so long as it can be justified on the basis of costs. Because space technology is costly, there will be several cases that will fall under the exception.

2. NASA Procedural Requirements for Limiting Orbital Debris

NASA, has enacted procedural requirements for limiting orbital debris in a document appropriately titled NASA Procedural Requirements for Limiting Orbital Debris and Evaluating the Meteoroid and Orbital Debris Environments.[112] The NASA Procedural Requirements (NPR) are in accordance with the National Space Policy and the U.S. Government Orbital Debris Mitigation Standard Practices mentioned above.[113] The scope of the NPR is limited and applies only to "programs and projects responsible for NASA or NASA-sponsored objects launched into space" so long as "federal authority to oversee the mitigation of orbital debris … does not reside with another Federal department or agency."[114] The NPR does not apply to launch vehicles under the jurisdiction of the

110. *Id.*
111. *Id.*
112. NASA PROCEDURAL REQUIREMENTS: NPR 8715.6B, *supra* note 79.
113. *Id.* at 3.
114. *Id.*

Department of Defense—this includes the data sharing agreement mentioned below,[115] or contributions to the International Space Station.[116]

The NPR is intended to implement the guiding policies present in the U.S. National Space Policy.[117] The NPR articulates the United States' interest in safety and the preservation of the space environment by reiterating two guiding policies.[118] The first states "[to] [p]reserve the space environment… for the purposes of minimizing debris and preserving the space environment for the responsible, peaceful, and safe use of all users…."[119] The second states "[to] [f]oster the development of space collision warning measures."[120] The NPR affirms its commitment to the United Nations Space Debris Mitigation Guidelines and the ODMSP; similarly, the NPR applies only when it is "consistent with mission requirements and cost effectiveness."[121] More importantly, the NPR reflects the Unites States' commitment to data sharing. The NPR states its intent to "[d]evelop, maintain, and use space situational awareness information from commercial, civil, and national security sources to detect, identify and attribute actions in space that are contrary to responsible use and the long-term sustainability of the space environment."[122]

As the amount of orbital debris has continued to grow, data sharing agreements between different countries and agencies have become monumentally important. The NPR tackles this issue by focusing much of its efforts on developing space collision warning measures.[123] The NPR allows several different agencies to collaborate and communicate with each other. The NPR states:

> The Secretary of Defense, in consultation with the Director of National Intelligence, the Administrator of NASA, and other departments and agencies, may collaborate with industry and foreign nations to: maintain and improve space object databases; pursue common international data standards and data integrity measures; and provide services and disseminate orbital tracking information to commercial and international entities, including predictions of space object conjunction.[124]

115. *Id.*
116. *See id.* at 4.
117. *Id.* at 6.
118. NASA PROCEDURAL REQUIREMENTS: NPR 8715.6B, *supra* note 79, at 6-7 (previously set forth in the 2010 National Space Policy).
119. *Id.* at 6.
120. *Id.* at 7.
121. *Id. See infra* Section IV.A.1. (cost effectiveness exception leads to loopholes for noncompliance).
122. NASA PROCEDURAL REQUIREMENTS: NPR 8715.6B, *supra* note 79, at 7.
123. *Id.*
124. *Id.*

It makes sense to pursue collaborations with foreign entities because outer space concerns a large expansive zone no country has or can claim jurisdiction over. Moreover, all countries with satellites in outer space benefit from these collaborations since orbital debris affects all nations engaged in space exploration.

The NPR also assigns NASA the responsibility of approving exceptions to the U.S. Government Orbital Debris Mitigation Standard Practices.[125] The majority of the NPR deals with exceptions and relief from requirements.[126] Section 1.3 sets forth the process for requesting and granting relief.[127] An evaluation for request for relief considers four points:

> (1) whether the object at issue poses any additional risks to the public and space environment,
>
> (2) whether the additional risk is acceptable given the importance of the mission,
>
> (3) if the design and operation measures have been applied to a reasonably practicable extent, and
>
> (4) whether a violation of the Unites States Governmental Orbital Debris Mitigation Standard Practices would occur if the relief requested were granted.[128]

In determining whether a request for relief will be granted, the NPR seems to apply a sort of balance test by weighing the need to approve an exception and the possible risks posed by allowing an exception.[129] When a violation of the ODMSP is likely to occur, the Chief may obtain the Administrator's consent to adjudicate the request or may elevate the request to the Administrator.[130] When a request for relief is elevated, the Administrator, along with the Chief and Safety and Mission Assurance, make a determination considering applicable National Space Policy with regard to human safety and property risk.[131] This process may be appealed by the Mission Directorate Associate Administrator.[132]

The remainder of the NPR focuses on the responsible parties charged with the task of implementing the NPR in accordance with the U.S. mitigation standards.[133] For example, the Chief is responsible for collecting, developing, promulgating and advising "on procedures, tools,

125. *Id.*
126. *Id.*
127. *Id.*
128. NASA PROCEDURAL REQUIREMENTS: NPR 8715.6B, *supra* note 79, at 7.
129. *Id.*
130. *Id.* at 7-8.
131. *Id.* at 8.
132. *Id.*
133. *See id.* at 9.

models, methods, and data bases, including characterizations and forecasts of the orbital debris and meteoroid environments, to assess and mitigate the risk of orbital debris generation, disposal operations, and orbital debris and meteoroid impacts."[134] In short, the Chief is given the task of collecting the proper data in order to assess the risk of a collision. The Orbital Debris Program Office has five principal tasks:

> (1) updating orbital debris environment models to support the Chief,[135]
>
> (2) conduct measurements of the orbital debris environment and conducts research needed to support the development of the orbital debris environment models,[136]
>
> (3) assist NASA project managers in orbital debris assessments by providing information and completing evaluations and end of mission plans,[137]
>
> (4) assist the Department of Defense and other U.S. Government Departments and organizations in the characterization of the orbital debris environment and the application of mitigation procedures and policies,[138] and
>
> (5) to contribute in the determination of whether to adopt international orbital debris mitigation guidelines though international forums.[139]

The majority of tasks given to the program are related to data sharing and adoption of mitigation measures. One of the stated goals of the NPR is to "pursue research and development of technologies and techniques" through NASA and the Secretary of Defense, "to mitigate and remove on-orbit debris, reduce hazards, and increase understanding of the current and future debris environment."[140] Yet, the NPR does not assign any entity, provide any guidelines, requirements, or call for research pertaining to the removal of orbital debris. The focus is on prevention of future orbital debris and emergency procedures. Thus, similar to the ODMSP, the NPR fails to address the creation of technology geared towards the removal of existing orbital debris. It does nothing to encourage innovation and fails to create a department in charge of leading technology.

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134. NASA PROCEDURAL REQUIREMENTS: NPR 8715.6B, *supra* note 79, at 9.
135. *Id.*
136. *Id.*
137. *Id.* at 10.
138. *Id.*
139. *Id.*
140. NASA PROCEDURAL REQUIREMENTS: NPR 8715.6B, *supra* note 79, at 7.

3. Department of Defense Space Situational Awareness Agreement

Governmental agencies responsible for space exploration have formed data sharing agreements with other governments in order to evaluate close approaches of a given satellite with debris.[141] The United States Department of Defense initiated the Space Situational Awareness Agreement (SSAA) to create a surveillance network to track debris.[142] The SSAA's stated goal is to "promote the responsible, peaceful, and safe use of space by fostering cooperative SSA and supporting safe space operations through the provision of advanced services and emergency notifications."[143] Membership provides access to Space-Track.org, which contains historical and current satellite data, decay and re-entry data, as well as orbital date request forms all of which are available at no cost or obligation.[144] Members must participate in a two-way information exchange, which involves conjunction assessment, launch support, deorbit and reentry support, disposal/end-of-life support, collision avoidance support, anomaly resolution, and electromagnetic interference investigation.[145]

The purpose is to provide advanced services to mitigate collision risks.[146] More importantly, the SSA provides emergency notifications and allows countries to collaborate and share information that allows space agencies to predict whether orbital debris posing a risk to a spacecraft is threatening enough to warrant an avoidance maneuver.[147] The importance of the SSA cannot be overstated since the current solution to an immediate threat posed by orbital debris is to order a spacecraft to perform an avoidance maneuver.[148] Avoidance maneuvers are becoming more and more frequent. In October of 2015, Orbital Debris Quarterly News, a NASA publication, reported the 24th and 25th collision avoidance maneuver in the history of the International Space Station.[149] Notably, it was also the 3rd and 4th maneuver performed in 2015.[150] While moving out of the way seems like a sensible short-term solution, without

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141. *Reentry and Collision Avoidance*, EUROPEAN SPACE AGENCY, http://www.esa.int/Our_Activities/Operations/Space_Debris/Reentry_and_collision_avoidance.

142. *United States Strategic Command Space Policy: Space Situational Awareness Sharing*, DEP'T OF DEFENSE, http://www.unoosa.org/pdf/pres/stsc2012/tech-40E.pdf.

143. *Id.*

144. *Id.*

145. *Id.*

146. *Id.*

147. *Id.*

148. *Two More Collision Avoidance Maneuvers for the International Space Station*, NASA 19 ORBITAL DEBRIS Q. NEWS (Oct. 2015), https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/odqnv19i4.pdf.

149. *Id.*

150. *Id.*

a long-term plan of attack to address the removal of debris, avoidance maneuvers will become more frequent.

B. International Response to Space Junk

Currently, the international response to the issue of orbital debris has focused on research, data sharing, mitigation procedures, liability, and registration of space structures.[151] The United Nations (UN) has been the guiding force in matters concerning outer space policy and law-making.[152] The UN has set forth space debris mitigation guidelines, liability procedures for collisions, and registration requirements for all structures launched into outer space.[153]

1. Inter-Agency Space Debris Coordination Committee

In contrast to the Situational Awareness Agreement, the Inter-Agency Space Debris Coordination Committee (IADC) is more research-oriented and focuses on data sharing with an eye towards mitigation.[154] The IADC was established in October 25, 1993 by four governmental agencies NASA (USA), RKA (Russia), Japan, and the European Space Agency.[155] Since IADC's inception, membership has grown to thirteen countries.[156] The primary purpose of the IADC is to "exchange information on space debris research activities between member space agencies, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities and to identify debris mitigation options."[157] With its emphasis on cooperation, the potential for progress sounds promising. In order to facilitate data sharing, the IADC has divided tasks into separate working groups, with each group responsible for certain data collection.[158] This organized structure of data sharing indicates an international desire to use a cohesive committee to address the problem of space debris. Additionally, multilateral cooperation indicates it is possible to come to a solution that will not only receive worldwide acceptance and participation, but also financial backing necessary to achieve a desired outcome. The IADC is a step in the right direction, but it's focus is limited and lacks measures

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151. *See infra* Section IV.B.1-5.
152. *Id.*
153. *Id.*
154. *Terms of Reference*, INTER-AGENCY SPACE DEBRIS COORDINATION COMMITTEE, https://www.iadc-online.org/index.cgi?item=torp_pdf.
155. *Id.* at 3.
156. *Id.* at 8.
157. *Id.* at 7.
158. *Id.* at 11. For example, Group 1 is in charge of measurements. *Id.* Group 2 is in charge of environment and database. *Id.* at 12. Group 3 is in charge of protection. *Id.* at 13. Group 4 is in charge of mitigation. *Id.* at 15.

that will encourage the innovation of new technology that address the removal of existing orbital debris.

2. Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space

The United Nations Office for Outer Space Affairs has set forth guidelines for orbital debris mitigation in the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space (SDMG).[159] While outer space law has been around for several decades, the United Nations did not address the problem of space debris as a priority matter until 1994.[160] In 1995, a subcommittee was appointed and instructed to focus on understanding orbital debris.[161] This was an important moment in the history of international space policy. Previously, the issue of orbital debris was often pushed aside. By appointing a subcommittee, the UN authorized and opened the door for research into orbital debris. The subcommittee was instructed to focus on "debris measurement techniques; mathematical modelling of the debris environment; characterizing of the space debris environment; and measures to mitigate the risks of space debris, including spacecraft design measures to protect against space debris."[162] The UN set forth a workplan to cover several topics concerning orbital debris each year from 1996-1998.[163] Each session was to be used to review current "operational debris mitigation practices and consider future mitigation methods with regard to cost efficiency."[164]

In the following years, these measures led to the preparation, creation, and adoption of the technical report on space debris.[165] The purpose of the report was to create an "accumulation of advice and guidance, in order to establish a common understanding that could serve as the basis for further deliberations" on matters concerning space debris.[166] By 1999, the technical report on space debris was adopted, distributed, and made available to the Third United Nations Conference on the Peaceful Uses of Outer Space, and the Legal Subcommittee, as well as other international organizations and scientific meetings.[167] In 2001, the Subcommittee agreed to establish a work plan that would take place between 2002 and 2005, with the goal of "expediting international adoption of

159. UNOOSA *supra* note 17.
160. *Id.* at iii.
161. *Id.*
162. *Id.*
163. *Id.*
164. *Id.*
165. UNOOSA, *supra* note 17, at iii.
166. *Id.*
167. *Id.*

voluntary debris mitigation measures" and to continue to receive support and collaboration from other international organizations to report on research and share data concerning other relevant aspects of space debris.[168]

By December of 2007, the General Assembly endorsed the Space Debris Mitigation Guidelines.[169] These guidelines reflect the existing practices developed by other national and international organizations.[170] The hope was to invite other member states to adopt the guidelines through their own national mechanisms.[171]

There are seven mitigation guidelines set forth by the UN Office for Outer Space Affairs. They are important to understanding the international approach to orbital debris and the failure to address removal. The first guideline seeks to "[l]imit debris released during normal operations" by designing space structures that do not release debris under normal conditions.[172] Member states are instructed to minimize the release of debris.[173] The second guideline seeks to "[m]inimize the potential for break-ups during operational phases" by designing spacecrafts that do not fragment when in "failure mode" and planning disposal measures when failure is detected in order to avoid fragmentation.[174] The guideline involves planning for potential scenarios in order to reduce the probability of a "catastrophic" event.[175] The third guideline addresses the need to limit the possibility of an accidental collision in orbit.[176] In developing the design of a spacecraft, "the probability of an accidental collision . . . should be estimated and limited."[177] When considering the design of a space structure, the guidelines recommend that the design consider the risks and dangers present throughout all stages of a space structure's life.[178] In cases where available data indicates a high probability of a potential collision, the guideline states, an adjustment of launch time or avoidance maneuvers should be considered in order to reduce the likelihood of a potential collision.[179] Collision avoidance is becoming more and more relevant. Studies show that as "the number and mass of space debris increase, the primary source of new

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168. *Id.*
169. *Id.* at iv.
170. *Id.*
171. UNOOSA, *supra* note 17, at iv.
172. *Id.* at 2.
173. *Id.*
174. UNOOSA, *supra* note 17, at 2.
175. *Id.* at 3.
176. *Id.*
177. *Id.*
178. *See id.* at 2-3.
179. *Id.* at 3.

space debris is likely to be from collisions."[180] This guideline is significant and telling, as it reveals how the international community is choosing to respond to the problem of space debris. The guideline is limited to addressing an emergency situation and only proposes a quick fix to address the symptoms of a growing problem. It does not provide a solution or an approach that is intended to solve the problem itself.

The fourth guideline seeks to "avoid intentional destruction and other harmful activities" by recommending the avoidance of the intentional destruction of "on-orbit spacecrafts and launch vehicle orbital stages or other harmful activities that generate long-lived debris."[181] If an intentional break-up is necessary, the guideline states it should be conducted at "low altitudes" in order to limit the orbital lifetime of the resulting debris.[182] The fifth guideline addresses the need to "minimize potential for post-mission break-up resulting from stored energy" by recommending the depletion of stored energy.[183] Depletion is recommended when there is no longer a purpose for stored energy.[184] This usually takes place at the end of mission operations and/or after post-mission disposal.[185] This guideline is a preventative measure intended to prevent the creation of more orbital debris in outer space, however, it does not address removal.

Guideline six was enacted to "[l]imit the long-term presence of spacecraft and launch vehicle stages in the low-Earth orbit (LEO) region after the end of their mission" by recommending the removal of non-operational spacecrafts that pass through the LEO in a "controlled fashion."[186] When removing the spacecraft from orbit in a controlled fashion would be impossible, the guideline recommends disposal in "orbits that avoid their long-term presence" in the LEO region.[187]

Additionally, when removing an object from LEO the guideline recommends giving "due consideration" to the possibility of atmospheric re-entry and the potential risks to human life or property that may arise during re-entry.[188] This includes the risk of releasing hazardous substances into the environment.[189] Unlike the ODMSP,[190] the SDMG, only requires that due consideration be given, but does not define what

180. UNOOSA, *supra* note 17, at 3.
181. *Id.*
182. *Id.*
183. *Id.*
184. *Id.*
185. *Id.*
186. UNOOSA, *supra* note 17, at 3.
187. *Id.*
188. *Id.* at 4.
189. *Id.*
190. *See infra* Section IV.A.1.

constitutes an undue risk of harm. This omission could be problematic. Lastly, the seventh guideline seeks to "limit the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous Earth orbit (GEO) region after the end of their mission" by recommending that a non-operational spacecraft that passes through the GEO region be left in an orbit that avoids long-term interference with the GEO region.[191] This guideline recommends spacecraft disposal take place in an orbit above the GEO region because it reduces the potential for future collision, the likelihood of interference, and return to the GEO region.[192] As previously mentioned, the problem with using storage orbits as dumping sites for orbital debris is that it may preclude any future plans to use these orbits in a "more productive manner."[193]

These guidelines set forth above are intended to minimize the quantity of space debris released into orbit. However, they do not set forth any guidelines for removal of existing debris and they fail to incentivize the creation of new technology to address removal. Moreover, the SDMG contains several flaws. First, the application of the guidelines proposed in the SDMG is entirely voluntary.[194] They are not legally binding on member states or other countries.[195] Thus, the SDMG does not carry the weight necessary to encourage countries to abide by the guidelines or provide an effective way of enforcing the guidelines. Second, like the ODMSP in the U.S.,[196] the SDMG contains loopholes. Exceptions may be granted so long as they can be justified.[197]

3. The United Nations Outer Space Treaty

One of the most important developments concerning international space law is the UN Treaty[198] on "Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies" (hereinafter "Outer Space Treaty").[199] This treaty was entered into force on October 10, 1967 with the intention of

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191. UNOOSA, *supra* note 17, at 4.
192. *Id.*
193. LUU, ET AL., *supra* note 108.
194. UNOOSA, *supra* note 17, at 2.
195. *Id.*
196. *See infra* Section IV.A.1.
197. UNOOSA, *supra* note 17, at 2.
198. *See generally*, Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, Jan. 27, 1967, 610 U.N.T.S. 205.
199. *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, *in* UNITED NATIONS TREATIES AND PRINCIPLES ON OUTER SPACE, http://www.unoosa.org/pdf/publications/STSPACE11E.pdf [hereinafter *Outer Space Treaty*].

providing a legal basis for the peaceful use of outer space and a framework for developing law governing outer space.[200] The Outer Space Treaty sets forth several governing principles that reflect the desire for multilateral cooperation. Three are relevant to addressing orbital debris. First, Article I states "exploration and use of outer space . . . shall be carried out for the benefit and . . . interest of all countries . . . and shall be the province of all mankind."[201] In other words, outer space constitutes an area without jurisdiction that is open and free to all countries, so long as their conduct is in accordance with international law.

Second, Article IV of the treaty prohibits member states from placing "nuclear weapons or any other kind of weapons of mass destruction" in orbit around Earth.[202] Space exploration is intended to be a neutral zone where only "peaceful exploration" is to take place.[203] For example, the treaty prohibits the establishment of military bases, as well as installations and fortifications, and testing of any weapons on the moon or other celestial bodies, but permits the use of military personnel for scientific research.[204]

Third, the treaty addresses liability and authorizes compensation for damages to spacecrafts.[205] A launching State is "internationally liable" for damage caused by all objects launched into outer space.[206] Article VII, states that "each State Party … is internationally liable for damage to another State Party . . . by such object or its component parts. . . ."[207] Thus, member states are responsible for damage caused by their spacecrafts even when they fragment and break off a main structure.[208] The issue of liability may seem impossible to enforce, given that it may be difficult to identify a random piece of space debris, but launching a spacecraft into outer space requires a member state to go through a registration process.[209] The Outer Space Treaty sets the groundwork for other laws and guidelines. The concepts in the treaty have been expanded and now govern several activities in outer space.

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200. *Id.* at v.
201. *Id.* at 4.
202. *Id.*
203. *Id.*
204. *Id.*
205. *Outer Space Treaty*, *supra* note 199, at 5.
206. *Id.*
207. *Id.*
208. The issue of liability is expanded on in the Liability Convention section discussed below.
209. Registration was expanded in the Registration Convention discussed below.

4. United Nations Convention on International Liability for Damage Caused by Space Objects

The UN Convention on International Liability for Damage Caused by Space Objects (hereinafter, The Liability Convention) came into force on September 1, 1972.[210] The United States was one of the original parties to the treaty.[211] The treaty is important for two main reasons: first, it formally recognized and addressed damages resulting from a spacecraft or man-made debris and the need to ratify uniform rules to establish liability and payment of damages.[212] At the time of its conception, member states hoped it would result in "the strengthening of international co-operation in the field of space exploration . . . ."[213] Second, under the Liability Convention, because member states are held liable for damages caused by one of their spacecrafts or from a pieces of spacecraft debris, member states have an interest in solving the problem of orbital debris.[214]

The Liability Convention sets forth rules that establish liability. For example, Article III states that if a space object is damaged by another space object, the latter is liable only if the damage was "due to its fault or the fault of persons for whom it is responsible."[215] If an event causing destruction causes further damage to a third space object, the first two launching states shall be jointly and severally liable to the third state space object. Liability is based on the fault of either of the first two states.[216] Moreover, the burden of compensation for damage to the third object will be apportioned between the first two states "in accordance with the extent to which they are at fault, but if fault cannot be determined the burden of compensation shall be apportioned equally between them."[217] When two states jointly launch a space object, they are both jointly and severally liable.[218] Even when a state allows another state to launch a space object from their territory of facility, the state allowing the launch is regarded as a participant in a joint launching.[219]

The Liability Convention also sets forth rules for indemnification and exoneration. Article V states, a "launching State which has paid

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210. Convention on International Liability for Damage Caused by Space Objects, *opened* Mar. 29, 1972, 961 U.N.T.S. 187, 188, https://treaties.un.org/doc/Publication/UNTS/Volume%20961/volume-961-I-13810-English.pdf [hereinafter Liability Convention].

211. *Id.*

212. *Id.* at 189.

213. *Id.*

214. *Id.*

215. *Id.* at 190.

216. Liability Convention, *supra* note 210, at 190.

217. *Id.*

218. *Id.*

219. *Id.*

compensation for damage shall have the right to present a claim for indemnification to other participants in the joint launching."[220] Article VI, allows a launching state to be exonerated from absolute liability so long as it has not violated any other international laws and the launching state can establish that the damage resulted from the claimant State's (or juridical persons it represents) gross negligence, or an act or omission done with intent to cause damage.[221] Moreover, the Conventions sets forth the procedural guidelines for presenting a claim for compensation.[222] The claimant has either "one year following the date of the occurrence of the damage or [one year following] the identification of the launching State [that] is liable" for the damage.[223] This period may be extended to one year following the date "the State could reasonably be expected to have learned of the facts through the exercise of due diligence."[224] The laws in place are flexible and allow the Claimant sufficient time to address damages. For example, the Claimant is permitted to revise the claim and submit documentation after the expiration of time-limits until one year after the full extent of damage is known.[225] Additionally, a Claimant does not need to exhaust any local remedies prior to presenting a claim.[226] Thus, there is a high likelihood that the damage will be discovered and a launching State will be held liable for damages.

Under the Liability Convention, an aggrieved State may hold the launching State liable for all damages incurred.[227] The amount of damages awarded to a Claimant are proportional to the damages caused.[228] The treaty states that a launching State liable for damages must pay compensation sufficient to "restore the person, natural or juridical, State or international organization on whose behalf the claim is present to the condition which would have existed if the damage had not occurred."[229] Since damages can potentially be very high,[230] the Liability Convention

220. *Id.*
221. *Id.*
222. Liability Convention, *supra* note 210, at 191.
223. *Id.*
224. *Id.*
225. *Id.*
226. *Id.*
227. *Id.*
228. Liability Convention, *supra* note 210, at 191.
229. *Id.* Amount of damages awarded reflects tort law in the United States.
230. *See generally* Gary Brown & William Harris, *How Satellites Work,* HowStuffWorks.com, https://science.howstuffworks.com/satellite.htm (last visited Apr. 21, 2019) (launching a satellite "can cost anywhere between $10 million and $400 million"). *See also* Edward F. Hennessey, *Liability for Damage Caused by Accidental Operation of a Strategic Defense Initiative System*, 21 CORNELL INT'L L. J. 318, 322 n.38 (1988) (Canada filed a claim under the Liability Convention against Russia for $6,026,083.56 even though no harm to persons and property occurred).

provides an incentive for member states to comply with the mitigation guidelines and an interest in creating space debris removal technology.

The Liability Convention sets forth procedural guidelines in cases where settlement negotiations are stalled. The Convention provides provisions that encourage parties to come to a settlement agreement.[231] When a settlement agreement does not occur within one year from the date the launching State is notified of the submitted claim, a Claims Commission is formed to address the claim.[232] The Commission is composed of three members, one appointed by the Claimant State, one appointed by the launching State, and a chairman who is chosen by both parties.[233] The Claims Commission is charged with the task of deciding the merits of the claim and determining the amount of compensation awarded to the Claimant.[234] All decisions and awards of the commission are decided by a majority vote.[235] Prior to rendering a decision, the parties can agree to a final and binding decision, or the Commission will render a final and recommendatory award, which the parties are expected to comply with in good faith.[236] These procedures ensure that claims will be addressed and prevents matters from being left unresolved.

Notably, the Liability Convention addresses two important scenarios. First, it considers rapid assistance during an emergency. It sets forth emergency measures in cases where the damage presents a "large scale danger to human life or seriously interferes with the living conditions of the population . . . ."[237] In these cases, rapid assistance to the State that has suffered damage is considered by the UN.[238] Second, it has safeguards in place to prevent a member state from fleeing liability after causing damages.[239] A member state cannot withdraw without notice.[240] After giving notice of withdrawal, the withdrawal does not take effect until one year after giving notice of withdrawal.[241] By holding member states financially responsible for damage to other crafts, the Liability Convention has the likely effect of encouraging member states to adopt mitigation procedures in order to decrease their liability risk and increases the probability that member states will be open to participating in agreements addressing space debris removal. While the Liability

231. Liability Convention, *supra* note 210, at 192.
232. *Id.*
233. *Id.*
234. *Id.* at 193.
235. Liability Convention, *supra* note 210, at 193.
236. *Id.*
237. *Id.*
238. *Id.*
239. *Id.* at 195.
240. *Id.*
241. Liability Convention, *supra* note 210, at 195.

Convention has the likely effect of encouraging compliance with mitigation guidelines and procedures, it does not contain any provisions requiring removal of existing orbital debris or creation of new technologies addressing orbital debris removal. It falls short of providing a complete solution.

5. United Nations Convention on Registration of Objects Launched into Outer Space

The Convention on Registration of Objects Launched into Outer Space (hereinafter, the Registration Convention) was carried into force with the same philosophy and desire for multilateral cooperation championed by the Outer Space Treaty.[242] The purpose of the Registration Convention was to establish and maintain a "central register of objects launched into outer space."[243] According to Article IV, which sets forth the registry requirements, the launching State must register a space object by forwarding the following information to the Secretary-General of the United Nations: (1) name of launching State(s), (2) the space objects registration number or a comparable designator, (3) the location, territory, and date of launch, (4) orbital parameters, and (5) the general function of the space object.[244]

Registration is useful for several reasons. Notably, it simplifies the identification of a spacecraft for liability purposes. The articles in the Registration Convention reveal a strong commitment to enforcing the Liability Convention. In cases where identification of a space object is not possible, member states "possessing space monitoring and tracking facilities" must respond to "the greatest extent feasible" to a request from a member state who has suffered damages and assist in the identification of the space object that caused damages.[245] While the Registration Convention does not address the removal of orbital debris, it does create an incentive for member states to comply with mitigation procedures in order to minimize their risk of liability. By requiring countries to register their spacecrafts and satellites, the Registration Convention helps identify the liable party. By raising the likelihood that a liable party will be caught, the Registration Convention provides an incentive for member states to invest or create orbital debris removal technology.

242. Convention on Registration of Objects Launched into Outer Space, *approved* Nov. 12, 1974, 1023 U.N.T.S. 15, https://treaties.un.org/doc/Publication/UNTS/Volume%201023/volume-1023-I-15020-English.pdf.

243. *Id.* at 16.

244. *Id.* at art. IV.

245. *Id.*

V. PROPOSAL

Unfortunately, neither national nor international space law contains solutions to the space debris problem. Current measures have focused on mitigation and do not address removal of existing debris. Since national and international efforts have not been fruitful in inventing space debris removal technology, the task of creating such technology should be left to the world's brightest individuals. Thus, a solution will involve policies that encourage and incentivize innovation in space technology in a manner that expands participation beyond national and international organizations.

Lack of funding is one of the major road blocks for companies trying to solve the space junk problem. Recently, D-Orbit, the Italian space company responsible for creating D-Sat, resorted to crowdfunding on Kickstarter[246] to raise €25,000 in order to test D-Sat.[247] Their efforts on Kickstarter failed; they only raised €12,328 and had 166 backers.[248] While D-Orbit eventually funded the project and launched D-Sat on June 23, 2017,[249] their attempt at crowdfunding reflects the financial challenges faced by companies attempting to solve the space debris problem. Because of exorbitant costs, when it comes creating solutions for space debris, the lack of funding stifles innovation and prevents innovators from venturing into the realm of space technology. Conceptually, D-Sat sounds very promising. The satellite is attached with a decommissioning device, referred to as D3, that takes the device out of orbit at the end of the satellite's life.[250] However, it is not surprising that crowdfunding would fail. Space debris is not a concern for most people. It does not have the same appeal and draw of a humanitarian cause, but it is nevertheless important.

In order to solve the space debris problem, the solution must consider the costs of creating technology and create an incentive to encourage innovation. Current treaties and international laws do not address the need to encourage and incentivize the creation of technology capable of addressing the space debris problem.[251] A solution that financially

246. *See About Kickstarter*, KICKSTARTER, https://www.kickstarter.com/about ("Kickstarter helps artists, musicians, filmakers, designers, and other creators find the resources and support they need to make their ideas a reality. To date, tens of thousands of creative projects—big and small—have come to life with support of the Kickstarter community").

247. D-SAT, https://www.kickstarter.com/projects/433487168/d-sat (last visited Apr. 19, 2019).

248. *Id.*

249. *Id.*

250. *Products*, D-ORBIT, http://www.deorbitaldevices.com/products/ (last visited Jan. 12, 2018).

251. *See* infra Section IV.B.

supports innovation and technological advancements in space exploration technologies by rewarding innovators would be the best path towards solving the space junk problem. A solution can be found in maritime law of salvage.[252] The application of maritime salvage law to outer space can provide a solution that addresses both the cost of creating space technology and the need to incentivize innovators to create space technology aimed specifically at removing orbital debris.

A. Maritime Law of Salvage

Maritime law and space law have often been compared to one another because of the inherent similarities between space and oceans.[253] Since the Law of the Sea Convention in 1982, laws governing the high seas have been ratified with the goal of establishing "the notion of the common heritage of mankind as a guiding principle for regulating the use of global commons."[254] The same ideals are reflected in data-sharing agreements and UN treaties pertaining to outer space.[255] Since no single country has jurisdiction over outer space or the sea, they are mainly governed by international treaties.[256] Historically, the law of salvage "governs the voluntary and successful rescue of property that is lost at sea or is in some sort of marine peril."[257] Under maritime law of salvage, the salvor,[258] who retrieves the lost property, is entitled to a reward for performance.[259]

The 1986 International Convention on Salvage was entered into force on July 1, 1996.[260] Case law in the United States indicates the treaty set forth in the Salvage Convention determines the outcome of salvage claims.[261] Traditionally, the law of salvage required a salvor to

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252. The idea of using maritime law of salvage to encourage innovation in space junk technology was conceived in September 2017. I am indebted to Michael Steven Bilecky for several discussions that helped me to focus this section. Further research revealed the application of maritime law to address orbital debris has been previously considered by others. *See generally*, 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, 457 n.74 (1992) (commenting on a need for laws of space navigation analogous to maritime law).

253. *See* Gabrielle Hollingsworth, *Space Junk: Why the United Nations Must Step in to Save Access to Space*, 53 SANTA CLARA L. REV. 239, 249-50 (2013).

254. *Id.* quoting Nina Tannenwald, *Law Versus Power on the High Frontier: The Case for a Rule-Based Regime for Outer Space*, 29 YALE J. INT'L L. 363, 373 (2004).

255. *See infra* Section IV.B.

256. *See* William C. Pannell, *Pirate Battles in Outer Space: Preventing Patent Infringement on the 8th Sea*, 46 U. MEM. L. REV. 733, 740 (2016).

257. David J. Bederman, *Bederman on The Abandoned Shipwreck Act* (Dec. 27, 2007), 2008 Emerging Issues 1694.

258. Salvor refers to a person or entity who salvages a ship.

259. Bederman, *supra* note 257.

260. International Convention on Salvage, 1989, July 14, 1996, 1953 U.N.T.S. 165 [hereinafter Int'l Convention on Salvage].

261. Sunglory Maritime LTD. v. PHI Inc., 212 F. Supp. 3d 618, 637 (2016).

successfully retrieve a ship or cargo in order to receive compensation, but more recently, in the 1989 Salvage Convention (hereinafter, Salvage Convention) there was an exception in cases where the salvor performs a service that saves the environment.[262] Because of the current threat space debris poses to outer space, the retrieval or removal of space debris from orbit would fall under this exception.[263] Prior to the 1989 Convention, the amount rewarded was limited to the value of the vessel that is recovered.[264] The Convention added provisions to provide special compensation to include out of pocket expenses accrued by the salvor.[265] Similarly, these provisions can be applied to encourage space technology by providing special compensation to inventors. This solution will take into consideration the out of pocket costs accrued throughout the process of creating space technology.

Under the Salvage Convention, the amount of financial compensation awarded to a salvor depends on certain factors.[266] The amount rewarded to a salvor is determined with the intent to encourage salvage operations.[267] As applied to the creation of space technology and the recovery of space junk, the amount awarded must be such that would encourage innovation and make it worthwhile to expend the time and resources necessary. Traditionally, the amount rewarded considers the value of the vessel or property salvaged.[268] A reward also takes into consideration the skill and effort in preventing or minimizing damage to the environment.[269] As applied to the context of space law, the amount rewarded must consider the value of the debris retrieved and the skill and effort taken to create space technology. The reward-for-recovery mechanism present in salvage law should be applied as long as the new technology makes a genuine attempt to remove space debris from orbit and does not itself create more debris; an example being the innovation of decommissioning devices such as D-Orbit's D3.[270] Notably, the Salvage Convention considers promptness of the services rendered.[271] Given the current high levels of space debris and plans to launch more satellites into outer space, an appropriate solution may reward those who are the

262. Nicholas J. Gaskell, *The 1989 Salvage Convention and the Lloyd's Open Form (LOF) Salvage Agreement 1990*, 16 TUL. MAR. L. J. 1, 10 (1991).

263. Int'l Convention on Salvage, *supra* note 260, art. 14.

264. Convention for the Unification of Certain Rules of Law Relating to Assistance and Salvage at Sea, 37 Stat. 1658, 1670, Sept. 23, 1910 ("In no case shall the sum to be paid exceed the value of the property salved.").

265. *Id.*

266. *See id.* at art. 13.

267. *Id.*

268. *Id.*

269. *Id.*

270. D-ORBIT, *supra* note 250.

271. Int'l Convention on Salvage, *supra* note 260.

first to pioneer space technologies addressing space junk more generously than those that follow. This would motivate powerhouse tech companies like Space X to use their current skills and technologies to address this problem. By providing rewards, the greatest and brightest individuals will have an incentive to come up with innovative solutions for modern day problems.

Innovators, like Elon Musk, have shown interest in space technology. In 2002 Elon Musk founded SpaceX.[272] Recent advancements indicate SpaceX may be capable of providing cost-effective solutions to solve the issue of orbital debris. The space company is currently the "only private company ever to return a spacecraft from low-Earth orbit."[273] SpaceX's dedication to creating cost effective reusable space technology and their demonstrated ability to create spacecrafts capable of returning from orbit, including rockets capable of re-flight, indicates that a solution may be on the horizon.[274] The problem lies in the fact that space companies currently have no financial incentive to spend money creating space debris removal technology. In the overall vastness of outer space, the problem of orbital debris is easily ignored.

The application of maritime law of salvage in this context would need to involve international cooperation and responsibility over the space debris problem. The best approach would involve the ratification of a UN treaty that adopts a modified version of the principles set forth in the Salvage Convention and creates a budget to address space debris removal technology. This approach does not advocate for the use of government contracts between government agencies and private space

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272. *Quick Facts About SpaceX*, SPACEX, http://www.spacex.com/about (last visited Apr. 26, 2018). *See* Tom Junod, *Elon Musk: Triumph of His Will*, ESQUIRE (Nov. 14, 2012), https://www.esquire.com/news-politics/a16681/elon-musk-interview-1212/. Musk had to overcome several financial hurdles. In order to make SpaceX a reality, Musk and Jim Cantrell negotiated and met with the Russian Space Program to purchase three repurposed ICBM's (inter-continental ballistic missiles) for seven million apiece. After negotiations, they were told each ICMB would cost them $21 million. After his experience with the Russian Space Program, Musk decided SpaceX would have to build their own rockets.

273. *Quick Facts About SpaceX*, *supra* note 272.

274. *See Booster Staging*, NASA, https://www.grc.nasa.gov/www/k-12/rocket/rktstage.html (all rockets use a propulsion system, "[i]n order to lighten the weight of the vehicle to achieve orbital velocity, most launchers discard a portion of the vehicle in a process called staging). In October of 2018 SpaceX launched an Argentine earth-observing satellite using its Falcon 9 two stage rocket. *See* Stephen Clark, *SpaceX Aces First Rocket Landing in California After Launching Argentine Satellite*, SPACEFLIGHT NOW (Oct. 8, 2018) (After the Falcon 9 was launched, the rocket shed its second stage at altitude of 250,000 feet, and was able to return to the Vandenburg Air Force Base), https://spaceflightnow.com/2018/10/08/spacex-aces-first-rocket-landing-in-california-after-launching-argentine-satellite/. *See Falcon 9*, SPACEX, https://www.spacex.com/falcon9 (last visited Oct. 9, 2018) (The Falcon 9 is "the first orbital class rocket capable of reflight."). SpaceX designed the Falcon 9 for reusability and to reduce the cost of access to space. *Id.*

companies for the purpose of removing or destroying orbital debris,[275] such an approach would stifle innovation by limiting funding and the creation of technology to a single company. Additionally, if the past is any indication of the future, governments are simply not interested in providing funding for the sole purpose of developing orbital debris removal technology. The objective is to encourage the world's best engineers to invent space technology and innovative solutions to real modern problems. By awarding funding to a single company, government contracts tend to limit the number of inventors working on a particular problem, thus, lessening the chance of creating the best solution. While this solution involves a certain level of privatization and subjects what has been a government function to the free market, it is a solution worth exploring.

VI. CONCLUSION

National and international policies addressing the problem of orbital debris all suffer the same defect. Current responses focus on debris mitigation and emergency responses to immediate threats, but they fail to address the removal of existing orbital debris. Since mitigation procedures only minimize debris and do not entirely eliminate it, space exploration will continue to create more debris. In absence of national and international policies addressing the removal of debris, the amount of debris in orbit will continue to grow. In the best-case scenario, without an approach to remove debris, space exploration will one day be hindered by the amount of man-made space junk in orbit. It is possible that in the future, space travel will be entirely off the table because of space debris. Astrophysicist Neil deGrasse Tyson said it best, "[w]e may be putting so much debris in space, that we will close ourselves off from space travel because of the dangers it would take to get through our own garbage heap."[276] In the worst-case scenario, space debris will threaten human lives and property.

One solution is to adopt an approach that encourages innovation. This is where maritime law of salvage comes in. In practice, the law of salvage encourages the retrieval and return of property lost at sea by rewarding performance.[277] In the context of space debris, the same reward

275. *See* Alexander William Salter, *Space Debris: A Law and Economics Analysis of The Orbital Commons*, 19 STAN. TECH L. REV. 221 (2016).

276. *#919 – Neil deGrasse Tyson, The Joe Rogan Experience*, at 1:47:30-41 (Feb. 21, 2017), https://www.stitcher.com/podcast/the-joe-rogan-experience/e/49211145?autoplay=true.

277. *See* 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 (1992).

system can be applied in order to create a financial incentive for the brilliant minds of this world to participate in finding a solution to orbital debris.

By creating a reward system that compensates innovators for their contributions, the law of salvage will encourage and incentivize innovation in a way current policies do not. Space companies like SpaceX have been developing new space technologies fairly rapidly.[278] A financial incentive will go a long way in directing their focus to solving the problem of orbital debris. The urgency of finding viable solutions to the space debris problem cannot be overstated. As of August 2018, a total of approximately 8,126 objects have been launched into outer space, twenty-two percent of these objects have been launched into space within the last eight years.[279] In 2017 alone, 453 objects were launched into outer space.[280] As the number of satellites launched into space continues to increase, the space debris problem will continue to exacerbate. The increased interest in the development of space technology is likely to attract inventors capable of developing space debris removal technology. The only thing missing is a financial incentive to help fund this altruistic endeavor. The application of maritime law of salvage to outer space law is an option worth exploring.

278. *See How Many Satellites Are Orbiting The Earth in 2018?*, PIXALYTICS (Aug. 22, 2018), https://www.pixalytics.com/sats-orbiting-the-earth-2018/.

279. *Id.*

280. *Id.*