ORBITAL DEBRIS: OUT OF SPACE

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I. INTRODUCTION

As of 2010, there are more than 21,000 documented objects in space, exceeding ten centimeters in size.[1] In 1995, estimates suggested that only 5% of the cataloged objects were operational spacecraft, making the remaining 95% orbital debris.[2] In 1983, a .02 millimeter paint fleck collided with the Challenger space shuttle.[3] Fortunately, it only cracked the windshield but still had a replacement cost of $50,000 U.S. dollars.[4] In 1996, a fragment of a Chinese rocket that remained in space ten years after a collision between Chinese and U.S. rockets struck a French microsatellite causing substantial damage and requiring an expensive recovery operation.[5] These examples are just a sampling of instances where orbital debris caused significant and costly damage. Despite attempts to identify debris found in space, a large amount has yet to be catalogued as it continues to be created. For instance, in February 2009, an active U.S. satellite and an inactive Russian satellite collided and generated more than 2,000 pieces of debris, of which only about 1,740 have been identified and catalogued.[6] The orbital debris problem also threatens Earth when orbital debris enters the Earth's atmosphere and crashes into the land or water below. In 1991, fragments from the U.S.S.R.'s Salyut 7 space station unexpectedly reentered the Earth's atmosphere and landed in unpopulated areas of Argentina.[7] Six years later in 1997, parts of a U.S. launch vehicle, including a 450 pound stainless steel propellant tank, ruptured upon impact close to a farmer's house in Georgetown, Texas. Other parts from the launch vehicle landed around Texas and Oklahoma, such as the titanium helium-pressurized sphere that landed 100 miles away in Seguin, Texas.[8]

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[1] SPACESECURITY.ORG, SPACE SECURITY 2011, at 28–29 (Cesar Jaramillo ed., 2011), *available at* http://www.spacesecurity.org/space.security.2011.revised.pdf.

[2] OFFICE OF SCI. & TECH. POL'Y, EXEC. OFFICE OF THE PRESIDENT, INTERAGENCY REPORT ON ORBITAL DEBRIS 11 (1995), *available at* http://orbitaldebris.jsc.nasa.gov/library/IAR_95_Document.pdf [hereinafter INTERAGENCY REPORT].

[3] *Id.* at 13.

[4] Robert C. Bird, *Procedural Challenges to Environmental Regulation of Space Debris*, 40 AM. BUS. L.J. 635, 640 (2003).

[5] MARK WILLIAMSON, SPACE: THE FRAGILE FRONTIER 66 (2006).

[6] *Update on Three Major Debris Clouds*, ORBITAL DEBRIS Q. NEWS, Apr. 2010, at 4, *available at* http://orbitaldebris.jsc.nasa.gov/newsletter/pdfs/ODQNv14i2.pdf (explaining that the U.S. Space Surveillance Network (SSN) tracks and catalogues objects in space, and therefore, provided this data).

[7] WILLIAMSON, *supra* note 5, at 74.

[8] *Id.* (noting that a launch vehicle is a rocket that reaches a desired orbit and then launches a satellite); Russell P. Patera & William H. Ailor, *The Realities of Reentry Disposal*, *in* 99

Orbital debris poses a threat to life and property, both in space and upon its reentry into the Earth's atmosphere.[9] As the presence in space becomes more proliferate among nations, the amount of resulting orbital debris likewise increases. For those reasons, a global solution to the orbital debris problem must be developed and implemented before a catastrophic event causes irreparable harm.[10]

In 1957, in response to the U.S.S.R. successfully launching Sputnik, the world's first man-made satellite, the international community raced to draft laws to regulate space.[11] Four treaties were drafted addressing space law: (1) the Outer Space Treaty, (2) the Liability Convention, (3) the Registration Convention, and (4) the Rescue and Return Agreement.[12] Since the U.S. and the U.S.S.R. were the only states with the technology to reach space at the time these treaties were adopted, space law drafters failed to provide for a world where multiple states would have space capabilities, either through their government or private industry.[13] Despite the four international treaties listed above, and those discussed below, the international legal regime governing space is insufficient to meet modern space demands and remedy current issues, including the urgent orbital debris problem.[14]

In 2008, the United Nations developed and adopted the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space.[15] These Guidelines provide measures to be incorporated into space mission planning and spacecraft design with the aim of reducing mission-related orbital debris.[16] The Guidelines attempt to internationally standardize the safety level of engineering and technology on spacecraft, but are only

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ADVANCES IN ASTRONAUTICAL SCIENCES 1059, 1067 (1998), *available at* http:/www.globalsecurity.org/space/library/report/enviro/reentrypaper.pdf.

[9] WILLIAMSON, *supra* note 5, at 72–75.

[10] LOTTA VIIKARI, THE ENVIRONMENTAL ELEMENT IN SPACE LAW: ASSESSING THE PRESENT AND CHARTING THE FUTURE 18–19 (2008).

[11] Brian Beck, *The Next, Small, Step for Mankind: Fixing the Inadequacies of the International Space Law Treaty Regime to Accommodate the Modern Space Flight Industry*, 19 ALB. L.J. SCI. & TECH. 1, 3 (2009).

[12] *See* sources cited *infra* notes 150–53.

[13] Beck, *supra* note 11, at 3–4.

[14] *See* discussion *infra* Part IV.

[15] G.A. Res. 62/217, para. 26, U.N. Doc. A/RES/62/217 (Feb. 1, 2008). "Mitigation refers to a class of actions designed to lessen the pain or reduce the severity of a problem." DAVE BAIOCCHI & WILLIAM WELSER IV, CONFRONTING SPACE DEBRIS: STRATEGIES AND WARNINGS FROM COMPARABLE EXAMPLES INCLUDING DEEPWATER HORIZON, at xv (2010).

[16] Comm. on the Peaceful Uses of Outer Space, Sci. & Tech. Subcomm., *Inter-Agency Space Debris Coordination Committee Space Debris Mitigation Guidelines*, U.N. Doc. A/AC.105/C.1/L.260 (Nov. 29, 2002) [hereinafter *Mitigation Guidelines*].

voluntary and lack sanctions for noncompliance. As a result, most states fail to wholly comply with them.[17] Furthermore, while the Mitigation Guidelines address the creation of orbital debris, they fail to address the removal of current orbital debris, a process known as "remediation of the space environment."[18]

Many theorists propose that the international community either update and enhance or change space law to specifically address the orbital debris problem.[19] Current proposed theories suggest solutions such as providing (1) a direct financial incentive to states to reduce or eliminate debris, or (2) a requirement that forces state actors to compensate other states in the Space community for spacecraft or satellites damaged by unidentified debris.[20] Accordingly, the legal frameworks proposed to support and enforce these solutions include: (1) a new United Nation's treaty, (2) a code of customary international law, (3) a reformed fault-based liability system, (4) a compensation or liability fund, and (5) a market-share liability system.[21]

While these proposals attempt to assign fault and liability in orbital debris collisions, they fail to provide a practical long-term solution for the entire international space community. Specifically, they rely on the philosophy that "past polluters pay." As such, these proposals assign the bulk of the bill to the U.S. and Russia, the predominant space players and polluters in the past.[22] The U.S. and Russia will likely refuse any such payments and proposed regime changes because of the number of other space actors who now share the responsibility of maintaining and remediating the space environment.[23] Without the support of the U.S. and Russia, any regime modification would be futile.

As of 2011, sixty actors utilize the space environment, predominantly through the use of satellites.[24] Ten actors have independent orbital launch capabilities[25] and five regularly launch spacecraft belonging to other states

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[17] *See* discussion *infra* Part IV.*B*.

[18] BAIOCCHI & WESLER, *supra* note 15. "Remediation refers to the act of applying a remedy in order to reverse events or stop undesired effects." *Id.*

[19] *See* discussion *infra* Part V.

[20] *See* discussion *infra* Part V.

[21] *See* discussion *infra* Part V.

[22] *See* discussion *infra* Part V.

[23] 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, 53 (2007).

[24] SPACESECURITY.ORG, *supra* note 1, at 17. Actor refers collectively to governments, organizations, and corporations.

[25] *Id.*

lacking such capabilities,[26] thus holding significant control and power over the space community. Consequently, this controlling class of actors has the potential to wield effective market power in the space industry, given the substantial and prohibitive cost to non-launch capable states of establishing such capabilities. Market power enables this class of actors to develop and impose a space regime that forces players in the space community to financially contribute to remediating and protecting the space environment and the impact of space activities on Earth.

This Note argues that the class of states with launch capabilities needs to develop a multilateral agreement among themselves, with provisions for entry by new launch-capable states, to self-impose a launch fee system. Proceeds from this fee system will fund the research and development of remediation technology for the space environment, as well as the reduction of prospective orbital debris. This multilateral agreement uses market power as a controlling means to regulate the space environment. Every state that currently utilizes space, either with launch capabilities or by contracting for such capabilities, will contribute to the shared cost of preserving the space environment and benefit from the results of a cleaner and safer environment.

Part II explains the current orbital debris situation, with a discussion of the nature of the space environment, the sources of orbital debris, the limitations on observing and tracking debris, and the estimated amount of orbital debris. Part II provides a scientific analysis of the estimated damage to a spacecraft upon impact with a piece of orbital debris, as well as the likelihood of an orbital debris collision. Additionally, Part II addresses the international community's response to the orbital debris problem; specifically the scientific solutions to avoid the problem, such as shielding, tracking and avoidance maneuvers around debris, controlling re-entry of debris into the Earth's atmosphere, and moving satellites into less congested orbits at the end of their mission life. However, the current international response seeks only to avoid orbital debris collisions rather than actually remedy the fundamental problem.

Part III explains why remediation should take place now rather than waiting for a catastrophic event to occur. Part IV explains the current international laws pertaining to space. Part V analyzes several proposed legal solutions and illustrates their respective flaws. Finally, Part VI posits

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[26] Independent orbital launch capability means a country indigenously has the technology and ability to reach orbital space. The ten actors with independent orbital launch capability are Russia, the United States, China, France, the U.K., India, Japan, Israel, Iran, and the European Space Agency (ESA). The five most active actors in the commercial launch industry are Russia, the ESA, the U.S., China, and India. *Id.* at 99.

that the most effective solution to the orbital debris problem is a multilateral agreement between launch-capable states with market power in the space community to impose a launch fee system and create a global space remediation fund.

II. THE ORBITAL DEBRIS PROBLEM

Understanding the sources and problems of orbital debris requires a general understanding of the technical and scientific background of the space environment, as well as the sources and risks of orbital debris. This Part describes the space environment, orbital debris, the current amount of orbital debris in space, the risks of orbital debris, the future of the space environment, and the current scientific solutions to the orbital debris problem.

A. Popular Orbits

The most functional areas of space are the orbits closest to Earth.[27] These orbits play host to a variety of satellites with differing functions, ranging from military operations, remote sensing, civil communications, meteorology research, and astronomy research.[28] While there are four orbits around the Earth, the two most suitable orbits for satellite operations are the Low Earth Orbit (LEO) and the Geostationary Earth Orbit (GEO).[29] Both orbits are very congested with satellites and contain most of the total mass of orbital debris.[30]

LEO, the closest orbit to Earth, occupies the atmospheric space from an altitude of 100 kilometers above the Earth's sea level to 1,000 kilometers above sea level.[31] Due to the Earth's strong gravitational force in LEO, satellites and spacecraft must travel at high speeds to stay in LEO.[32] Specifically, the average orbital velocity in LEO is approximately 17,000 miles per hour (mph).[33] Therefore, a complete rotation around the Earth only takes a satellite in LEO 100 minutes, and makes LEO particularly useful for

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27 WILLIAMSON, *supra* note 5, at 32.
28 *Id.*
29 Taylor, *supra* note 23, at 5.
30 *Id.*
31 Natalie Pusey, *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).
32 *What is Orbit?*, NASA, http://www.nasa.gov/audience/forstudents/5-8/features/what-is-orbit-58.html (last updated July 7, 2010).
33 *Id.*

satellites that need to quickly view the entire Earth.[34] The combination of LEO's close proximity to the Earth and its quick orbit makes it the most demanded, and thus overcrowded, orbit in space.[35] However, the congestion also makes LEO one of the most dangerous areas of space because there is a greater risk of collision.[36] Depending on an object's mass and surface area, its longevity in LEO ranges from a few years to a few hundred years.[37] As such, orbital debris has the potential to remain trapped in LEO for a long time. With more and more orbital debris being added every year, LEO is likely to become more dangerous unless a solution to orbital debris is found.

The second most demanded earth orbit, GEO, occupies the atmospheric space 35,787 kilometers above sea level, centered over the Earth's equator.[38] GEO is named Geostationary because, in this orbit, satellites rotate at the same speed as the Earth and therefore stay over an exact location on the Earth's surface, such as a state.[39] This allows satellites to maintain a constant visual over a specific location, unlike in LEO where satellites are moving around the Earth at a speed faster than the Earth's rotation, only viewing a location for the time they are over it and then losing visual as they continue to rotate.[40] GEO is slower and more controlled than LEO. GEO has only nominal gravitational pull from the Earth; thus, satellites and orbital debris in GEO have anticipated orbital life spans in excess of one million years.[41] Most communication satellites operate in GEO, because three satellites spanning the earth can provide complete communication coverage.[42] Satellites in GEO do not have to be tracked since they are in a fixed location with minimal motion. This makes the cost of operating satellites once they are in GEO lower than other orbits.[43] However, satellite operators compete for preferential positions over certain densely populated regions, such as North America, which then create satellite clusters at these positions.[44] The International Telecommunications Union (ITU), an organization of the United Nations, manages the placement of geostationary

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34 Pusey, *supra* note 31, at 426–27.
35 WILLIAMSON, *supra* note 5, at 35.
36 *Id.*
37 Pusey, *supra* note 31, at 427.
38 *Id.*
39 *Id.*
40 *Id.* at 426–27.
41 *Id.* at 427.
42 WILLIAMSON, *supra* note 5, at 35.
43 *Id.*
44 Pusey, *supra* note 31, at 427.

objects, such as satellites.[45] Every satellite operator must receive permission from the ITU for use of a specific satellite position.[46]

LEO and GEO have a limited capacity with an increasing demand. With the ever-increasing growth of technology that relies on satellite use, more and more countries are beginning to utilize space. In 1957, only two countries, the U.S. and the U.S.S.R., used space; by 2011, more than fifty countries had satellites in space.[47] Increasing amounts of orbital debris, discussed below, coupled with the increasing amount of state actors using space, have put LEO and GEO in perilous conditions. Both LEO and GEO have a fixed capacity and one day, without remediation of orbital debris, these orbits may reach their limits.

B. Orbital Debris

Orbital debris has several aliases: space junk, space litter, space waste, or space refuse. The United Nations defines orbital debris as "all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional."[48] Natural meteoroids differ from orbital debris in that they pass through the Earth's orbital space, while orbital debris remains trapped in the Earth's orbits.[49]

Orbital debris is a matter of global concern for all nations. As the demand for and use of orbital space increases, due in part to advancing technology that requires satellite operations, the potential for orbital debris likewise increases. The increasing accumulation of orbital debris directly correlates with the increasing risk of a debris collision with spacecraft.[50]

"There are four categories of [orbital] debris: (1) inactive payloads, (2) operational debris, (3) fragmentation debris, and (4) microparticulate debris."[51] In 1995, it was estimated that only 5% of cataloged objects in space were operational spacecraft, making the remaining 95% debris.[52] Inactive payloads are defunct satellites still in space,[53] either because of a

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[45] *Id.* at 428.
[46] *Id.*
[47] *The Space Economy at a Glance in 2011*, OECD (May 23, 2011), http://www.oecd.org/dataoecd/63/5/48301203.pdf.
[48] *Mitigation Guidelines*, *supra* note 16, para. 1.1.
[49] INTERAGENCY REPORT, *supra* note 2, at 3.
[50] G.A. Res. 62/217, *supra* note 15.
[51] Mark J. Sundahl, Note, *Unidentified Orbital Debris: The Case for a Market-Share Liability Regime*, 24 HASTINGS INT'L & COMP. L. REV. 125, 128 (2000).
[52] INTERAGENCY REPORT, *supra* note 2, at 8.
[53] Jennifer M. Seymour, Note, *Containing the Cosmic Crisis: A Proposal for Curbing the*

malfunction or a loss of propellant,[54] and account for 22% of all cataloged objects.[55] Operational debris is any object intentionally or accidently released during a mission,[56] including hardware, propellant tanks, and even frozen sewage.[57] Most operational debris consists of rocket bodies,[58] and accounts for 17% of all cataloged objects.[59] Fragmentation debris is debris from breakups of satellites.[60] Both intentional collisions, as well as accidental collisions and explosions, create fragmentation debris,[61] and such debris creates most of the trackable orbital debris.[62] The U.S. and the Soviet Union, as well as a few other countries, intentionally demolish satellites to avoid impermissible retrieval by third-parties.[63] The U.S. also uses inoperable satellites as targets to test antisatellite missiles and laser technology.[64] This practice generates significant amounts of orbital debris. For example, in 2007, China destroyed an inoperable satellite when it tested an antisatellite missile, which created in excess of 3,000 pieces of debris, accounting for 22% of the currently cataloged objects in LEO.[65] After four years, only a small portion of the debris from this collision has reentered the Earth's atmosphere.[66] Microparticulate debris is the term given to minute particles, such as solid-propellant rocket motors and materials from spacecraft.[67]

Understanding the sources of orbital debris is vital to mitigating the addition of more debris into space. However, the current amount of orbital debris is so high that mitigation is no longer enough and techniques for remediation must be found.

Perils of Space Debris, 10 GEO. INT'L ENVTL. L. REV. 891, 893 (1998).

[54] Taylor, *supra* note 23, at 9.

[55] VIIKARI, *supra* note 10, at 36.

[56] Sundahl, *supra* note 51, at 128.

[57] Bird, *supra* note 4, at 639.

[58] Taylor, *supra* note 23, at 9.

[59] VIIKARI, *supra* note 10, at 35.

[60] Bird, *supra* note 4, at 640–41.

[61] Seymour, *supra* note 53, at 893.

[62] Bird, *supra* note 4, at 640.

[63] Taylor, *supra* note 23, at 10.

[64] Seymour, *supra* note 53, at 893.

[65] *Chinese Debris Reaches New Milestone*, ORBITAL DEBRIS Q. NEWS, Oct. 2010, at 3, 3, *available at* http://orbitaldebris.jsc.nasa.gov/newsletter/pdfs/ODQNv14i4.pdf.

[66] *Update on Three Major Debris Clouds*, *supra* note 6, at 4.

[67] Christopher D. Williams, *Space: The Cluttered Frontier*, 60 J. AIR L. & COM. 1139, 1143 (1995).

C. The Current Space Environment and Orbital Debris

The amount of orbital debris in the space environment directly relates to the amount of risk for collision that spacecraft and satellites encounter when operating in space. The exact amount of orbital debris is unknown due to an inadequacy of tracking and cataloging small objects.[68] While many global agencies have orbital debris detection capabilities, these detection processes merely use ground-based radar to focus on a specific point and track debris that moves through the radar scope.[69] Only the U.S. and Russia have advanced detection systems capable of continuously tracking debris.[70]

Information is limited not only by detection systems, but also by the size of debris.[71] Debris is labeled as either a (1) large object, with a diameter in excess of 10 cm, (2) a risk object, with a diameter between 1 cm and 10 cm, and (3) microdebris, with a diameter of less than 1 cm.[72] The U.S. Space Surveillance Network (SSN), uses ground-based radars to observe and catalog orbital debris.[73] As of 2010, the SSN tracks more than 21,000 large objects.[74] Due to technical and natural limitations, SSN cannot continuously track or catalog risk objects,[75] but it is estimated that more than 300,000 risk objects currently exist in the Earth's orbits.[76] The inherent tracking limitations of risk objects create the most significant threat because risk objects "are capable of causing catastrophic damage if they collide with other space objects," despite their size.[77] Similarly, microdebris also presents a threat of damage upon collision, is untraceable due to size, and estimates suggest that millions of microdebris particles exist in the Earth's space environment.[78]

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[68] 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, 603 (2011).

[69] Pusey, *supra* note 31, at 433.

[70] *Id.*

[71] *Id.*

[72] *NASA Exploring Ways to Clean Up Space Debris*, DNA (Mar. 12, 2011), http://www.dnaindia.com/scitech/report_nasa-exploring-ways-to-clean-up-space-debris_1661364.

[73] WILLIAMSON, *supra* note 5, at 53.

[74] SPACESECURITY.ORG, *supra* note 1, at 28.

[75] Pusey, *supra* note 31, at 433

[76] SPACESECURITY.ORG, *supra* note 1, at 29.

[77] VIIKARI, *supra* note 10, at 36.

[78] INTERAGENCY REPORT, *supra* note 2, at 5–6.

D. The Risks Associated with Orbital Debris

A collision between a spacecraft and even the smallest piece of orbital debris can cause millions of dollars worth of damage.[79] Explaining the likelihood and risks of such a collision shows that orbital debris is an increasing problem that needs the international community's attention immediately.[80] The consequence of orbital debris contacting a spacecraft or satellite is a function of the probability of collision and the magnitude of damage upon impact.[81] The location of the debris also influences the consequences of a collision, since density and velocity varies between orbits.[82]

The probability of collision between orbital debris and a spacecraft depends on the size and orbital altitude of the spacecraft, as well as the anticipated orbital period for the spacecraft.[83] Therefore, a larger spacecraft, traveling at high velocity in LEO for many years, is more likely to collide with another object than a small spacecraft in one fixed location in GEO.[84]

The effect of impact between orbital debris and a spacecraft depends on velocity of both the spacecraft and the debris, the angle of impact with the spacecraft, and the mass of the debris.[85] If a large debris object, moving at a high velocity, directly hits the middle of a spacecraft, moving at high velocity, the impact will cause more damage than if a slow moving microdebris object hits a sidepiece or antenna of a spacecraft. Miniscule debris particles can also cause surface damage over time. When orbital debris is smaller than .01 cm, the typical impact effect on a spacecraft's surface is pitting and erosion; however, over time this may cause significant damage.[86] Objects with a size ranging from .01 cm to 1 cm can cause substantial structural damage upon impact with a spacecraft, if no shields are present.[87] Similarly, a debris fragment of merely .05 mm would be able to "puncture a standard spacesuit and kill an astronaut."[88] Orbital debris larger

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[79] *See* WILLIAMSON, *supra* note 5, at 64 (identifying that in the sixteen months prior to March of 1997, thirteen shuttle windows had to be replaced at a cost of over $40,000 each).

[80] Taylor, *supra* note 23, at 18–19.

[81] *Id.* at 16.

[82] *Id.*

[83] INTERAGENCY REPORT, *supra* note 2, at 19.

[84] *Id.*

[85] *Id.* at 8.

[86] *Id.*

[87] *Id.*

[88] VIIKARI, *supra* note 10, at 38 n.49.

than 1 cm would likely cause catastrophic damage to any spacecraft regardless of shields.[89]

Given the substantial damage that tiny pieces of debris can cause, measures must be taken to avoid debris collisions with operational spacecraft.[90] Avoidance measures, such as tracking orbital debris and then moving spacecraft that are likely to collide with debris, are impossible because SSN can only continuously track objects larger than 5 cm in diameter.[91] While experts cannot ascertain the exact level of risk of collision for a particular object in space, it is estimated that a spacecraft in LEO is 100 times more likely to be struck by debris than a spacecraft in GEO.[92] In LEO, an object will break up into multiple fragments if it is struck by a piece of debris .1% of its own mass.[93] This catastrophic collision would create tens or hundreds of fragments large enough to cause another collision of this scale.[94] These dire consequences show the importance of finding a scientific solution, such as remediation techniques, in order to keep the space environment sustainable for future use.

E. The Future of the Space Environment

Despite current mitigation efforts, natural orbital clearing, and de-orbiting, the amount of orbital debris is increasing.[95] In 2009, orbital debris increased by 13%.[96] Leading NASA physicists concluded that there is a direct correlation between the number of objects in space and the number of collisions between these objects.[97] Some experts posit the application of the cascade effect, which propounds that debris will become self-generating; collisions will produce debris, which will create more collisions, and will result in more debris.[98] Others look to the Kessler Syndrome, under which experts predict that the debris population will increase regardless of future space operations and will eventually cause orbits to become so saturated that

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[89] INTERAGENCY REPORT, *supra* note 2, at 8.

[90] *Id.*

[91] 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, 265 (2010), *available at* http://www.spacelaw.olemiss.edu/jsl/pdfs/articles/jsl-36-welly.pdf.

[92] NAT'L RESEARCH COMM. ON ORBITAL DEBRIS, ORBITAL DEBRIS: A TECHNICAL ASSESSMENT 98 (1995), *available at* http://www.nap.edu/openbook.php?record_id=4765&page=98.

[93] *Id.*

[94] *Id.*

[95] WILLIAMSON, *supra* note 5, at 79.

[96] Welly, *supra* note 91, at 285.

[97] *Id.* at 287.

[98] Bird, *supra* note 4, at 643.

they are unavailable for satellite use.[99] Furthermore, experts anticipate that the exponential increase in debris will create a belt of debris around the Earth.[100] The Kessler Syndrome postulates a bleak outlook for the future of the space environment. Based on these scientific hypothesis, it is essential that the space community begin developing technology to remove debris from space now.

F. Current Scientific Solutions

Despite predictions based on the Kessler Syndrome, some scientific solutions may lessen the risk of orbital debris. Current solutions include: (1) shielding attachments to protect spacecraft, (2) tracking systems to avoid collisions with debris, (3) control measures to manage the re-entry of spacecraft, that would become debris, back into Earth's atmosphere, and (4) navigation maneuvers to direct satellites into an outer orbit beyond GEO.[101] Additionally, the space environment does provide one completely natural solution to the orbital debris problem: LEO has some amount of atmospheric drag and is able to cleanse itself of debris on a very small scale.[102] Thus, while these methods are helpful at reducing the amount of future debris, they fail to actually eliminate the problem because they do not remove the current debris already in space. Furthermore, these solutions are very expensive and not all actors utilize them all the time.[103]

All spacecraft and satellites are equipped with outer shields to provide extra protection in case they collide with another object, mainly orbital debris. However, shields are only protective to a limited degree.[104] A shield will enable a spacecraft to withstand impact by pieces of debris that are 1 cm or less in diameter.[105] While these impacts will not totally destroy the spacecraft, in most circumstances they will still require extensive repair.[106] Additionally, a considerable portion of debris in space is larger than 1 cm, which limits the effectiveness of shields against all sizes of orbital debris.[107]

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99 *Id.*
100 Welly, *supra* note 91, at 286.
101 *Id.* at 296.
102 BRUNO PATTAN, SATELLITE SYSTEMS: PRINCIPLES AND TECHNOLOGIES 389 (1993).
103 Welly, *supra* note 91, at 286.
104 *Orbital Debris Shielding*, NASA ORBITAL DEBRIS PROGRAM OFFICE, http://orbitaldebris.jsc.nasa.gov/protect/shielding.html (last updated Feb. 3, 2010).
105 *Id.*
106 WILLIAMSON, *supra* note 5, at 72.
107 *Id.*

Shielding is also expensive and can increase satellite mass and reduce maneuvering capability.[108]

The SSN, as well as other space surveillance networks, tracks orbital debris and predicts the likelihood of collision between two objects.[109] When the probability of collision is too high, the satellite or spacecraft is maneuvered to reduce the chance of collision, known as collision avoidance.[110] For instance, NASA will only use collision avoidance maneuvers when another object is expected to come within 2 km (1.24 miles) of a spacecraft or satellite.[111] The devastating consequences these collisions can have mean that avoidance measures are often taken, even when the chance of collision seems small. For example, in October 2010, the International Space Station (ISS) changed orbit slightly to avoid a piece of debris that had a 1 in 1,000 chance of colliding with the ISS.[112] In March 2009, the ISS crew took last minute refuge in their return vehicle because it was too late to conduct a collision avoidance maneuver due to a piece of debris that changed orbit rapidly.[113] All in all, NASA conducted eight collision avoidance maneuvers in 2009.[114]

There are many drawbacks to the use of collision avoidance. First, SSN is only able to track large debris objects, rendering risk objects (1 cm to 10 cm), which have the capability to destroy a spacecraft, invisible and unavoidable.[115] Second, there is some degree of uncertainty in the position measurements for both the spacecraft and the orbital debris.[116] Lastly, collision avoidance is costly for operators.[117]

LEO has a small amount of atmospheric drag that will naturally pull objects back into the Earth's atmosphere.[118] It takes approximately fifteen

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[108] VIIKARI, *supra* note 10, at 38 n.51.

[109] INTERAGENCY REPORT, *supra* note 2, at 3.

[110] *Orbital Debris Collision Avoidance*, NASA ORBITAL DEBRIS PROGRAM OFFICE, http://orbitaldebris.jsc.nasa.gov/protect/collision_avoidance.html (last updated Aug. 24, 2009).

[111] WILLIAMSON, *supra* note 5, at 69.

[112] Conor Humphries, *Space Station to Shift Orbit to Dodge Space Junk*, REUTERS (Oct. 26, 2010), http://af.reuters.com/article/worldNews/idAFTRE69P16S20101026.

[113] *ISS Crew Seeks Safe Haven During Debris Flyby*, ORBITAL DEBRIS Q. NEWS, Apr. 2009, at 3, 3, *available at* http://orbitaldebris.jsc.nasa.gov/newsletter/pdfs/ODQNv13i2.pdf.

[114] *Avoiding Satellite Collisions in 2009*, ORBITAL DEBRIS Q. NEWS, Jan. 2010, at 2, 2, *available at* http://orbitaldebris.jsc.nasa.gov/newsletter/pdfs/ODQNv14i1.pdf (of these eight avoidance maneuvers, six were needed in order to avoid collisions with debris).

[115] *Orbital Debris Collision Avoidance*, *supra* note 110.

[116] *Id.*

[117] *Id.* (stating "satellites cannot afford to maneuver unnecessarily or for low probability conjunctions").

[118] WILLIAMSON, *supra* note 5, at 73.

years for objects that operate at 600 km (373 miles) above sea level to re-enter the Earth's atmosphere.[119] Unfortunately, most spacecraft operate in altitudes exceeding 850 km (528 miles) above sea level, where decay time is measured in centuries.[120] Objects that are naturally brought back into the Earth's atmosphere will most likely be burned up upon reentry.[121] The main factor in determining whether an object will be completely destroyed upon reentrance into the Earth's atmosphere is the spacecraft's melting temperature.[122] Large objects can remain intact until ground impact if they are comprised of high melting-point materials (titanium or stainless steel).[123]

In LEO, satellites use gravitational pull to reenter the Earth's atmosphere at the end of their mission life, ensuring that they do not become orbital debris when they are no longer operational.[124] This controlled reentry is accomplished by reserving propellant to direct the spacecraft into the Earth's atmosphere at a steeper flight path.[125] Before controlled reentry occurs, a projection of the latitude and longitude for where the object may land is taken into account, as well as any threat to human life or property.[126] U.S. policy dictates that the human casualty probability for a controlled reentry should be less than 1 in 10,000.[127] Therefore, most satellites have projected landings in the ocean or uninhabited regions.[128] While reentry is a great way to dispose of satellites before they become orbital debris, it is only applicable to satellites in LEO. GEO has nominal gravitational pull, with decay times measured in centuries. Therefore, controlled reentry is not a feasible solution to dispose of satellites in GEO. Additionally, there is an uncertain risk to human life during reentry.

Since there is no atmospheric drag in GEO and de-orbiting satellites back down to LEO is extremely expensive, satellites in GEO use a graveyard orbit at the end of their mission life.[129] The graveyard orbit is located directly

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119 *Id.*
120 *Id.*
121 *Space Debris Frequently Asked Questions*, EUR. SPACE AGENCY, http://www.esa.int/esaMI/Space_Debris/SEM2D7WX3RF_0.html (last updated Feb. 20, 2009) [hereinafter *Space Debris FAQ*].
122 WILLIAMSON, *supra* note 5, at 73.
123 *Space Debris FAQ*, *supra* note 121 (noting that even with large objects, only 20% to 40% of the mass will survive to ground impact).
124 *Orbital Debris Reentry*, NASA ORBITAL DEBRIS PROGRAM OFFICE, http://orbitaldebris.jsc.nasa.gov/reentry/reentry.html (last updated Aug. 21, 2009).
125 *Id.*
126 *Id.*
127 WILLIAMSON, *supra* note 5, at 75.
128 *Orbital Debris Reentry*, *supra* note 124.
129 WILLIAMSON, *supra* note 5, at 76.

above and below GEO.[130] Like controlled reentry, satellites use the remainder of their propellant to boost into this orbit before they become inoperable, thus becoming, orbital debris.[131] While the space community as a whole recommends the use of the graveyard orbit, even esteemed space operators, such as NASA, do not uniformly follow this practice.[132] In many instances, the exact amount of remaining propellant is unknown and satellites run out of propellant before reaching the graveyard orbit.[133] Disposing of satellites in the graveyard orbit requires advanced planning, which many of the satellites in GEO were not intended to do.[134] Therefore, their operations must be cut short in order to have enough propellant to reach the graveyard orbit.[135] Additionally, as the graveyard orbit fills up, it could potentially become a source of future orbital debris and effect lower orbits.[136] The use of the graveyard orbit is a simple solution for now; however, it does not come close to fixing the problem of orbital debris.

While shielding, collision maneuvering, reentry of LEO satellites into the Earth's atmosphere, and disposing of GEO satellites into the graveyard orbit are all helpful scientific practices, the amount of orbital debris is still rapidly increasing to a level that is not sustainable for the space environment. The only potential answer to the orbital debris problem is the creation of remediation techniques.

III. THE STAGES OF ENVIRONMENTAL ACTION: THE CASE FOR REMEDIATION

Historically, the sequence of actions in addressing an environmental issue has progressed from identifying the problem, to instituting norms, to mitigation, and then, finally, remediation.[137] The space community has progressed to the stage of mitigation even though the UN Mitigation Guidelines are voluntary.[138] Remediation is the final step to solving the orbital debris problem, although there is no cost-effective, operational

130 *Id.*
131 *Id.*
132 *Id.*
133 *Id.*
134 *Id.*
135 *Id.*
136 *Id.* at 77.
137 BAIOCCHI & WELSER, *supra* note 15, at 15.
138 *See* discussion, *infra* Part IV.*B*. Experts do not consider voluntary guidelines established normative behavior, especially when actors fail to follow said guidelines. *See infra* Part IV.*B*.

method currently available.[139] According to Baiocchi, the next stage of action will arise when the community's tolerance for risk is lower than the amount of risk.[140] The space community will progress to remediation when "the existing level of unwanted [orbital debris] exceeds the community's risk tolerance level."[141]

What changes a community's tolerance of risk? History demonstrates that increasing awareness by educating the community is one means.[142] However, another more probable occurrence is a critical or catastrophic event, which would effectively raise the amount of orbital debris and decrease the community's tolerance threshold.[143]

Examining past environmental events and analogizing them to the current orbital debris problem clearly shows that remediation techniques must be designed and tested now, before a catastrophic event takes place.[144] The 2010 Deepwater Horizon Oil Spill is an excellent example of a community's failure to design and test remediation techniques.[145] The remedies that British Petroleum attempted such as the containment dome and relief well were successful in past oil spills.[146] These approaches did not fail because they constituted new technology, they failed because they were not tested or proven to work at a depth of 5,000 feet.[147] Therefore, it is critical that the space community learns from past environmental disasters and begins to design and test remediation techniques now, prior to a catastrophic event that lowers the community's acceptable level of orbital debris tolerance.

IV. CURRENT INTERNATIONAL SPACE LAW

Current international space law is inadequate at addressing the problem of orbital debris. There are four main international treaties enacted through the United Nations which make up the basis of space law.[148] The hazards of orbital debris were unknown at the time these treaties were drafted and they fail to effectively protect the space environment. The U.N.'s Orbital debris

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139 BAIOCCHI & WELSER, *supra* note 15, at 17.
140 *Id.* at 19–21.
141 *Id.* at 20.
142 *Id.* at 22.
143 *Id.*
144 *Id.* at 18.
145 *Id.* at 19.
146 *Id.* at 52 (the containment dome was placed over the wellhead and was designed to capture the oil so that it could be pumped to the surface).
147 *Id.* at 55.
148 *See infra* notes 150–53.

Mitigation Guidelines are the most influential international policy, which aim to reduce the amount of debris generated during missions.[149] While these guidelines show that the space community is aware of the problem and searching for solutions, they only restrict the addition of future debris and fail to address the removal of current debris from the space environment. Therefore, these guidelines, as well as the U.N. treaties, are not an all-encompassing answer to the orbital debris problem.

A. Binding International Treaties

Four international treaties govern outer space activities: (1) the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty),[150] (2) the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (Rescue and Return Agreement),[151] (3) the Convention on International Liability for Damage Caused by Space Objects (Liability Convention),[152] and (4) the Convention on Registration of Objects Launched into Outer Space (Registration Convention).[153] The Outer Space Treaty and the Liability Convention are the most relevant treaties in the discussion on orbital debris and the space environment.

1. The Outer Space Treaty

The Outer Space Treaty was ratified in 1967 and is revered as the constitution of space law.[154] This treaty creates binding legal obligations on the states that ratify it, while some provisions are so widely accepted that they are considered customary international law, which is applicable to both

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[149] *Mitigation Guidelines*, *supra* note 16.

[150] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, *opened for signature* Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter Outer Space Treaty].

[151] Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, *opened for signature* Apr. 22, 1968, 19 U.S.T. 7570, 672 U.N.T.S. 119.

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

[153] Registration of Objects Launched into Outer Space, *opened for signature* Jan. 14, 1975, 28 U.S.T.S. 695, 1023 U.N.T.S. 15.

[154] Ronald L. Spencer, Jr., *State Supervision of Space Activity*, 63 A.F. L. REV. 75, 80 (2009).

parties and non-parties to the convention.[155] An example of customary international law includes Articles I and II, which makes outer space a common pool resource.[156] While there are some broad principles in the treaty that refer to the space environment, there is no clear obligation placed on states to ensure they protect the space environment.[157]

Specifically, there are three general articles relevant to the discussion of a state's responsibility for the space environment. First, under Article VI, states have international responsibility for any national activity, whether by governmental agencies or private actors.[158] This means a private company that launches from a specific state will fall under the control of that state, and in turn that state will be subject to the liabilities and responsibilities under the treaty for that private company's activities. Second, Article VII declares that any party that procures the launch or launches a space object is internationally liable for damage resulting from that object or its parts; this provision is later fleshed out by the Liability Convention.[159] Third, Article IX inadvertently addresses the space environment by stating:

> In the exploration and use of outer space, including the Moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of cooperation and mutual assistance and shall conduct all their activities in outer space… with due regard to the corresponding interests of all other States Parties to the Treaty. States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination . . . .[160]

This treaty as a whole does not sufficiently address the preservation of the space environment or establish clear obligations and sanctions for state parties. On its face, it does not even reference orbital debris. The treaty's major problem is a lack of clearly defined terms, such as harmful contamination, launching state, or space object.[161] Due to these ambiguous

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155 *Id.*

156 Outer Space Treaty, *supra* note 150, arts. I, II (stating space is the "province of all mankind" and is "not subject to national appropriation by claim of sovereignty").

157 Gérardine Meishan Goh, *Softly, Softly Catchee Monkey: Informalism and the Quiet Development of International Space Law*, 87 NEB. L. REV. 725, 737 (2009).

158 Outer Space Treaty, *supra* note 150, art. VI.

159 *Id.* art. VII.

160 *Id.* art. IX.

161 Peter T. Limperis, Note, *Orbital Debris and the Spacefaring Nations: International Law*

terms, the legal obligations under the treaty are uncertain.[162] These terms would have to be specifically defined in order to establish an enforcement regime.[163] This treaty also fails to adequately address the protection of the space environment because it was drafted during the Cold War, when only a few states were concentrating on access to space and the thought of an overcrowded dangerous space environment was not predicted or even considered.[164] Drafters of the treaty failed to realize that space activities would one day become privatized, commonplace, and essential to the functioning of our society.[165]

By initially making space a common pool resource, actors are provoked to take utmost advantage of the resource in the shortest time possible.[166] After a cost-benefit analysis, most actors find it in their best interest to seek the benefits of space activities and ignore the costs of creating orbital debris, thereby spreading the costs of creating debris to all space-faring nations.[167] Most actors choose to ignore the costs of creating debris because it is expensive, time consuming, and there is not an affirmative duty to do so.[168] While some actors have recently made it a priority to start protecting the space environment, there are still many actors that are free-riders. These free-riders have either not taken the initiative to reduce the amount of debris they produce or have relied on the research and construction of mitigation guidelines that other actors and organizations produce. This inconsistency within the space community can and potentially will cause friction among states. While recognizing that some actors, especially ones that are new to the space community, are not responsible for the current space environment, a solution requiring equal contribution between actors is more realistic considering that the power players in the space community are undoubtedly the actors most responsible for the current orbital debris problem. These power players most likely feel responsible for the current situation, though it is perhaps unfeasible for them to provide all the resources to finding a solution, especially when, at the time they were directly harming the space

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Methods for Prevention and Reduction of Debris, and Liability Regimes for Damage Caused by Debris, 15 ARIZ. J. INT'L & COMP. L. 319 (1998); Lawrence D. Roberts, *Addressing the Problem of Orbital Debris: Combining International Regulatory and Liability Regimes*, 15 B.C. INT'L & COMP. L. REV. 51 (1992).

162 Welly, *supra* note 91, at 293.

163 *Id.*

164 Roberts, *supra* note 161, at 52.

165 *Id.*

166 *Id.* at 59.

167 Welly, *supra* note 91, at 287.

168 Pusey, *supra* note 31, at 447.

environment by producing a large amount of debris, they did not know the effects of their actions. Additionally, many actors, specifically the U.S., are cutting funding to their space programs.[169] According to Professor Garrett Hardin, this will eventually lead to a *tragedy of the commons,* where the space environment is ruined.[170]

2. Liability Convention

The Liability Convention was enacted in 1972 to expand on article VII of the Outer Space Treaty.[171] It was drafted in response to the international community's fear of space objects reentering the Earth's atmosphere and the corresponding threat to life.[172] Drafters were not concerned about damage to objects in space.[173] The Liability Convention assigns strict liability for any damage that occurs on the Earth's surface and fault-based liability for damage that arises in space.[174]

Fault-based liability for collisions transpiring in space is not feasible.[175] First, evidentiary problems exist because it is complicated, and in many instances impossible, to identify the owner of orbital debris.[176] In most cases, the identity of the offending state is unknown and a claim is never filed, leaving the cost of repair or replacement on the owner of the spacecraft or satellite.[177] The Convention also does not define the terms "standard of care" or fault.[178] This makes it difficult to hold a state liable because it is unclear when a state's action would be considered the cause of damage.[179] The Liability Convention does not incentivize actors to reduce the amount of debris they create or to remove debris because they do not fear they will be held liable.[180]

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169 Brian Berger, *House Appropriators Propose $103M NASA Budget Cut*, SPACE NEWS (Feb. 11, 2011), http://www.spacenews.com/policy/110210-house-propose-nasa-cut.html.

170 Welly, *supra* note 91, at 283–85. Hardin's "tragedy of commons" theory as applied to outer space suggests that because the costs of space exploration (such as the creation of space debris) are distributed by self-interested actors across all humankind, the cost of space exploration remains artificially low, thus encouraging further debris-causing activity. *Id.* at 287.

171 Liability Convention, *supra* note 152.

172 Pusey, *supra* note 31, at 438–39.

173 *Id.*

174 Liability Convention, *supra* note 152, arts. II, III.

175 Williams, *supra* note 67, at 158.

176 *Id.*

177 Sundahl, supra note 51, at 143.

178 Limperis, *supra* note 161, at 331.

179 *Id.*

180 Williams, *supra* note 67, at 161.

Claims under the Liability Convention do not provide much guidance either, as evidenced by the fact that it has only been used once,[181] when a nuclear propelled Soviet satellite, Cosmos 954, crashed into Canada.[182] The cost of cleanup was more than $14 million Canadian dollars, C$3 million of which was paid by the Soviet Union after Canada invoked the Liability Convention.[183] There was uncertainty as to whether the Soviets were even required to pay under the Liability Convention, since Canada only suffered the expense of cleanup and no persons or property were harmed.[184] The Liability Convention has never been tested in regards to in-orbit collisions, although there have been many.

B. Non-Binding International Policies

The United Nations Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space adopted by the General Assembly in December of 2007 is the main international agreement aimed at combating the orbital debris crisis.[185] The Inter-Agency Space Debris Coordination Committee (IADC), which is an international organization consisting of members from all of the major space-faring states, first developed the Mitigation Guidelines.[186] They are based on common principles found in several handbooks and standards promulgated by national and international organizations within the space community.[187] With cost-effectiveness in mind, the IADC developed these guidelines to "be considered during the planning and design of spacecraft and launch vehicles in order to minimize or eliminate the generation of debris during operations."[188] There are two general categories of mitigation measures: ones that restrain the production of debris in the short term and ones that restrain the production of debris in the long term.[189] The first category focuses on the reduction of debris during missions, while the second focuses on post-mission disposal of spacecraft in crowded orbits, such as LEO and GEO.[190]

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181 Beck, *supra* note 11, at 15.
182 Welly, *supra* note 91, at 281.
183 Beck, *supra* note 11, at 15.
184 *Id.*
185 G.A. Res. 62/217, *supra* note 15, para. 26, at 6.
186 Pusey, *supra* note 31, at 442.
187 *Mitigation Guidelines*, *supra* note 16, para. 6.
188 *Id.* para. 3.
189 *Id.* para. 6
190 *Id.*

The first measure calls for the proper design of a spacecraft so as to limit the release of debris during normal operations.[191] For example, sensor covers and other items on a spacecraft should not be intentionally released.[192] Minimalizing the potential for on-orbit break-ups is the second measure.[193] Depleting or safely storing any on-board sources of stored energy, thereby reducing the potential for post mission break-ups, can achieve this.[194] This second measure also seeks to minimize the potential for break-ups during the operational phase by properly designing the spacecraft and then periodically monitoring it to detect malfunctions.[195] Additionally, this measure aims to avoid the intentional destruction of a spacecraft.[196] The third guideline addresses post mission disposal.[197] Spacecraft in GEO should be removed to the graveyard orbit as discussed earlier, at an altitude of about 235 km (146 miles) higher than GEO, so as not to affect the geostationary orbit.[198] Spacecraft in LEO region that have completed their operational phases should be de-orbited or maneuvered into an orbit with a reduced lifetime.[199] The guidelines state that after the completion of a mission, spacecraft should be de-orbited into the Earth's atmosphere within twenty-five years.[200] Lastly, the Mitigation Guidelines wish to prevent on-orbit collisions.[201]

While the Mitigation Guidelines are certainly a step in the right direction, they are not a comprehensive solution for the debris overload in space. These Guidelines brought the problem of orbital debris into the international spotlight and provided guidance to countries for spacecraft design and mission control.[202] However, they are essentially a codification of frequent practices of various space-faring nations and do not institute any new development in the field of debris mitigation.[203] Additionally, these guidelines "are not legally binding under international law."[204] Therefore,

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[191] *Id.* at 5.1.
[192] *Id.*
[193] *Id.* at 5.2.
[194] *Id.* at 5.2.1.
[195] *Id.* at 5.2.2.
[196] *Id.* at 5.2.3
[197] *Id.* at 5.3.
[198] *Id.* at 5.3.1.
[199] *Id.* at 5.3.2.
[200] *Id.* at 5.3.2–.3.
[201] *Id.* at 5.4.
[202] Taylor, *supra* note 23, at 40.
[203] VIIKARI, *supra* note 10, at 96.
[204] Ram Jakhu, *Towards Long-Term Sustainability of Space Activities: Overcoming the Challenges of Space Debris* 15, IAASS (Feb. 15, 2011), *available at* http://www.oosa.unvienna.org/pdf/pres/stsc2011/tech-35.pdf.

even countries that endorse the guidelines do not always comply with them; in 2008 and 2009, both the U.S. and Russia failed to perform disposal maneuvers on five spacecrafts.[205] Even with these guidelines in place, only one in three spacecraft in GEO is disposed of in the graveyard orbit.[206]

Lastly, these measures are aimed solely at mitigation, which, at best, only slows down the growth of orbital debris.[207] As the Kessler Syndrome states, even without adding to the amount of debris in orbit, the current amount of orbital debris is capable of becoming self generating and will one day produce a belt of debris around the Earth that will limit the use of outer space.[208] According to Nicholas L. Johnson, NASA Chief Scientist of Orbital Debris, "[o]nly remediation of the near-Earth environment—the removal of existing large objects from orbit—can prevent future problems for research in and commercialization of space."[209] Although the Mitigation Guidelines were a great first step, efforts should now be focused on remediation techniques.

V. PROPOSALS FOR A NEW LEGAL REGIME

Numerous proposals suggest altering the legal regime to adequately address the problem of orbital debris. The main suggestions are: (1) the adoption of a new international treaty, (2) the development of customary international law, (3) reformation of the Liability Convention, (4) the creation of a compensation fund, and (5) the implementation of a market share liability system. Each proposal has serious defects that would inhibit their ability to fully correct the degradation of the space environment.

A. A New International Treaty

Using the traditional form of international cooperation by creating a new U.N. treaty will not provide an effective solution to the current problem. A treaty promulgated through the U.N. would prove to be ineffective because a consensus between all of the space-faring nations would be very time consuming and would most likely result in a watered-down resolution.[210]

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[205] *Drifting in GEO*, ORBITAL DEBRIS Q. NEWS, July 2010, at 3, 3, *available at* http://orbitaldebris.jsc.nasa.gov/newsletter/pdfs/ODQNv14i3.pdf.

[206] VIIKARI, *supra* note 10, at 115.

[207] *Id.* at 116.

[208] Welly, *supra* note 91, at 286.

[209] Taylor, *supra* note 23, at 43 (quoting J.C. Liou & N.L. Johnson, *Risks in Space from Orbiting Debris*, SCIENCE, Jan. 20, 2006, at 340).

[210] *See* VIIKARI, *supra* note 10, at 100 (referring to consensus negotiations within U.N.

The differing interests of developed nations versus undeveloped nations would create conflict and frustration, and, thus, delay the process.[211]

> Unlike other subjects . . . the topic of space debris does not involve a balancing of interests; what is important is that the common safety interest of the space nations be satisfied. As the problem of space debris is of great urgency to all space nations, the forum to be chosen for concluding international agreements should promise an objective and fruitful discussion speedily leading to an acceptable solution . . . . [T]he Outer Space Committee of the United Nations does not seem to be the right forum for such a discussion.[212]

B. Customary International Law

Customary law is not a feasible solution to the orbital debris problem. Customary law "consist[s] of customs that are accepted as legal requirements or obligatory rules of conduct."[213] In order for a norm to become customary law nations must actually feel obliged to practice the custom.[214] Most of the Mitigation Guidelines, as well as other actions done to protect the space environment, are not considered norms, because all actors in the space community do not routinely follow them.[215] Examples include spacecraft that are not disposed of in the graveyard orbit or spacecraft that are not de-orbited in LEO.[216] In addition, the Mitigation Guidelines are only voluntary; therefore, the second element of customary law, *opinio juris*, is not satisfied.[217] Customary international law is also not a proper instrument because it is confined to general rules and would, therefore, not be suitable

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committees).

211 *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, 467 (1992) (commenting on the appropriate approach to change the liability scheme).

212 *Id.* (quoting Jürgen Reifarth, *An Appropriate Legal Format for the Discussion of the Problem of Space Debris*, *in* ENVIRONMENTAL ASPECTS OF ACTIVITIES IN OUTER SPACE 147, 301, 309 (Karl-Heinz Böckstiegel ed., 1990)).

213 BLACK'S LAW DICTIONARY 391 (7th ed. 1999).

214 *See* Taylor, *supra* note 23, at 28–29 (stating that "for a norm-creating provision to become customary international law . . . the rule must be 'settled practice . . . carried out in such a way, as to be evidence of a belief that this practice is rendered obligatory by the existence of a rule of law requiring it' ").

215 *Id.*

216 *Id.* at 28.

217 *Id.* at 28–29.

for the specific technical problems of orbital debris.[218] Moreover, it is generally based on existing state practice and, as a result, is not suitable for the anticipatory, forward-looking legal framework needed to address the orbital debris.[219]

C. Reforming the Liability Convention

Several proposals call for various changes to the existing fault-based liability regime for damage sustained in orbit under the Liability Convention. Proponents claim that the Liability Convention can become more effective and properly incentivize actors to reduce, and one day remove, orbital debris.[220] Some proposals suggest specific definitions for orbital debris and fault.[221] Others suggest modifying the regime so that actors who fail to implement mitigation measures are presumed liable for damage.[222] Those who believe a fault-based system is unfeasible or unfair often suggest a strict liability regime, thereby eliminating fault.[223] However, as discussed above, none of these proposals are sufficient because determining the culpable state through identification of debris is nearly impossible.

D. Compensation or Liability Fund

Some commentators suggest further reforming the liability convention by also proposing a damage compensation fund.[224] Under this proposed regime, all space users would be required to pay into a fund; the fee would be based on the estimated amount of debris the proposed mission would create.[225] Proceeds would be used to compensate actors whose spacecraft sustained damage caused by unidentified debris and who therefore cannot pursue a claim because they cannot identify the culpable party.[226] Presumably, actors would then take affirmative steps, such as safer spacecraft design or the eventual removal of debris, to reduce their liability or payment into the fund.

This regime, however, is flawed in many ways. First, not all damage to spacecraft can be attributed to artificial man-made orbital debris. Some of it

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218 Lampertius, *supra* note 211, at 466–67.
219 *Id.* at 467.
220 Taylor, *supra* note 23, at 53.
221 Williams, *supra* note 67, at 1189.
222 Lampertius, *supra* note 211, at 464.
223 Taylor, *supra* note 23, at 53.
224 Roberts, *supra* note 161, at 69–70.
225 Sundahl, *supra* note 51, at 137.
226 *Id.* at 137–38.

occurs from natural satellites, such as meteors.[227] Second, determining how much debris a mission will create is not an accurate formula, therefore, some states may not fully feel the effects of their contribution to the debris problem.[228] Third, if a major or multiple collisions occurred that were caused by unidentified debris, the fund may be depleted.[229]

Another variation on this concept is the idea that "past polluters pay" in proportion to the amount of debris they are responsible for in the space environment.[230] The two biggest past polluters are the U.S. and U.S.S.R.[231] It is likely that the U.S. and Russia will be unwilling to adopt this regime because it is not in their best interest.[232] If the U.S. and Russia, who have notable influence among the space-faring nations, do not support this change, it is highly unlikely that the international community would be able to adopt this regime.

E. Market-Share Liability

Another faction of commentators believe that market-share liability would be a successful regime change because it would make actors fully internalize the costs of producing debris.[233] Internalizing the cost means that actors would be held responsible for their debris and would either continue to pay that price or would find ways to reduce their liability. This regime focuses on protecting an injured party who has no recourse when unidentifiable debris causes damage.[234] Under this theory, every country is held liable for its proportion of total debris in space, thus the injured party's damages would be collected from every actor who has debris in space at that time.[235]

Under a market-share scheme, Russia and the U.S. would be paying the bulk of the bill.[236] "These states are the great pioneers in space use but they are also the primary contributors to the debris problem."[237] In 2005, it was

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227 WILLIAMSON, *supra* note 5, at 45–47.
228 Sundahl, *supra* note 51, at 138.
229 *See id.* (noting that it would take several years for such a pool to collect enough funds to meet the demands for compensation).
230 Roberts, *supra* note 161, at 70.
231 WILLIAMSON, *supra* note 5, at 57.
232 Taylor, *supra* note 23, at 52.
233 Sundahl, *supra* note 51, at 137–38.
234 *Id.* at 147.
235 *Id.*
236 *Id.* at 144.
237 *Id.*

estimated that the U.S. and Russia were responsible for 90% of the debris in space.[238] However, these numbers have presumably changed due to China's recent anti-satellite missile test, which increased the amount of debris.[239]

Proponents of this system believe it will create an instant compensation system, so that states will no longer have to absorb the costs of collisions.[240] They believe it would create an incentive for states to reduce their production of large debris.[241] They also claim it will encourage states to improve remediation or removal techniques, which would lower the amount of debris they are responsible for and, consequently, lower their proportion of liability and payment.[242] Additionally, advocates allege that states would improve their registering, tracking, and cataloguing systems, because actors could potentially exculpate themselves if they had more accurate tracking systems.[243]

However, many drawbacks exist in a market-share liability system that would inhibit its acceptance by the international community. Some states may choose not to adopt or improve mitigation measures because their portion of liability would remain small regardless of their actions.[244] The main reason why market-share liability could fail to be adopted is that, once again, the U.S. and Russia will probably reject this proposal.[245] Under this regime, both countries will never recover more than two-thirds of the value of their damaged or destroyed spacecraft.[246] Furthermore, increased mitigation techniques will not reduce their amount of liability because of past pollution; only debris removal will reduce their contribution.[247] Lastly, and most importantly, if a significant amount of collisions by unidentified debris occurred, the U.S. and Russia would easily owe millions of dollars.[248] Since the U.S. and Russia are the major actors in the space community, their support is vital for the adoption of this regime.[249] It is highly unforeseeable that they would support a regime that imposes such a high burden of liability on them.

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[238] *Id.*
[239] *Chinese Debris Reaches New Milestone*, *supra* note 65, at 3.
[240] Sundahl, *supra* note 51, at 147.
[241] *Id.*
[242] *Id.* at 147–48.
[243] *Id.* at 148.
[244] *Id.* at 150–51.
[245] *Id.* at 152.
[246] Taylor, *supra* note 23, at 51.
[247] Sundahl, *supra* note 51, at 151.
[248] *Id.* at 152.
[249] Taylor, *supra* note 23, at 52.

VI. MARKET POWER AND A MULTILATERAL AGREEMENT

Effective remediation techniques for the space environment need to be developed and tested now, before a catastrophic event takes place. Current international space law does not effectively address the situation. The demographics of the space community provide a select group of actors with market power. This market power can be leveraged to enable a regime change to address the problem of orbital debris. This Note posits that the five actors with market power should sign a multilateral agreement that requires a fee to be levied for every launch that occurs. These fees will go into an account that will fund the design and testing of technology to remediate the space environment. Imposing a launch fee on every actor is the only feasible solution because (1) individual actors in the space community either cannot or will not develop remediation techniques on their own in the immediate future, (2) the space community as a whole will not be able to reach a voluntary consensus on paying into a fund to design remediation techniques, and (3) market power, in regards to the space community, is the sole means of control.

This proposal is aimed at finding a legal avenue to facilitate a scientific solution in the shortest amount of time. Financing the research and development of remediation techniques has been a large hindrance to finding a solution so far; this proposal directly addresses these financing issues. This proposal also gets to the heart of the problem by directly developing remediation techniques, rather than imposing a regime that would incentivize actors to develop the needed technology for remediation. Additionally, many of the changes or additions to the current legal regime discussed above would be less crucial after a technique is found and remediation begins.

The demographics of the space community are unique and inherently lend certain actors market power, which is the most effective way to implement a regime change. Most actors rely on other actors for access to space. Out of the sixty actors who utilize space, only ten have independent orbital launch capability: Russia, the United States, China, France, the U.K., India, Japan, Israel, Iran, and the ESA.[250] Furthermore, only a few of these states are active in the commercial launch sector.[251] "For a launch to be considered commercial, at least one of the payload's launch contracts must be subject to international competition; thus, in principle, a launch opportunity is available

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[250] SPACESECURITY.ORG, *supra* note 1, at 78.
[251] *Id.* at 102.

to any capable launch services provider."[252] Russia, Europe, and the U.S. dominate in the commercial launch industry; Russia launches the most satellites annually, commercial or otherwise.[253] Recently, India and China have launched satellites for other countries with more frequency.[254] A few private commercial companies also have independent launch capabilities.[255] For instance, Arianespace, a European corporation, and the first commercial satellite launch company, is responsible for placing half of the commercial satellites in orbit that are currently in service.[256] For purposes of this Note, private companies will be grouped under the respective state from which they launch, and any reference to a specific state will refer to those private companies as well. The effects of the multilateral agreement, i.e., the launch fee, will pertain to private companies because under the Outer Space Treaty, states have responsibility for any object launched from their jurisdiction; private commercial launch companies are governed and regulated by their respective states.[257] For example, the Department of Transportation regulates commercial space launch activities in the U.S.[258] Therefore, a company will be bound by their country's national legislation, such as a multilateral agreement.

Based on the makeup of the space community and the reliance on a few actors for access to space, the five actors that dominate the space launch industry have market power. "The capability to launch is a rare commodity and provides those who possess it with interesting leverage."[259] Russia, the ESA, and the U.S. have significant control and power over the space community since they provide most of the community's access to space. Market power enables them to impose a system that forces players in the space community to abide by a regime or system they impose in order to gain access to space. It is imperative that Russia, the U.S., and the ESA be involved in the multilateral agreement, because they are the most prominent states in the space launch sector. However, it would also be prudent to include India and China due to their most recent launches of foreign state

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[252] *Id.*
[253] *Id.*
[254] *Id.* at 86, 104.
[255] *Id.* at 108.
[256] *Service and Solutions*, ARIANESPACE, http://www.arianespace.com/about-us/service-solutions.asp (last visited Feb. 28, 2012).
[257] Outer Space Treaty, *supra* note 150, art. VII.
[258] Taylor, *supra* note 23, at 36.
[259] Ben Baseley-Walker, *Responsible Launching: Space Security, Technology, and Emerging Space States*, SPACE REV. (Mar. 29, 2010), *available at* http://www.thespacereview.com/article/1596/1.

satellites and their recent announcements to take a more vital role in the space launch sector.[260]

While these fees will be collected based on the number of launches that occur in each the jurisdiction, each actor can individually decide how they will structure their collection of money from other actors to pay for this fee. In essence, the actual government will not have to bear the entirety of every fee because it can pass the cost down to the private company who actually conducted the launch or to another state if they are contracting out their launch capabilities. However, some actors will pay more due to the fact that they launch more objects into space. Furthermore, the fees will have to be balanced so that it is a reasonable amount, but also enough to find a solution. The agreement should not set a fixed fee; it should be flexible so it can change with time if need be. After a technique is developed the fees can be adjusted to cover the cost of using that technique to clean up the space environment and then regular missions thereafter to remove future debris.

The five actors with market power can decide on how best to use these funds. One option is to create a committee that evaluates and funds various scientific teams working on remediation techniques. Another more ideal option is to create a new entity or organization that not only manages the fund, but also conducts the scientific research. This Note will not address all of the nuances and problems that would arise with the creation of a new entity resulting from this multilateral agreement, however some general thoughts and ideas are suggested. It would be optimal if scientists currently working on remediation teams in their home states went to one central location and worked together, thus further promoting international cooperation, a main goal in space exploration and also within the U.N. The agreement can either require each party to provide a given number of scientists, allow it to be voluntary, or allow for scientists from other states not in the agreement to join the team. Having scientists on site would undoubtedly put the brightest minds together, leading to faster results. Having one entity conduct research would also eliminate the possibility that some research is being duplicated, is a likely scenario today since most states are individually pursuing a solution. Additionally, if this one entity solely focused on finding a solution, individual states would no longer need to pursue their own research, which would allow states to divert funding from those research teams to pay the launch fees without any added cost.

The use of these funds will also have to be carefully drafted in the multilateral agreement so as to incentivize these five actors to agree. For

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260 SPACESECURITY.ORG, *supra* note 1, at 102.

example, each actor will probably want a share of control over the entity to ensure that progress is being made. While in the past states used advances in space exploration to tout their power and were inclined to find a solution on their own for recognitions sake, this approach must be curbed because the dangers of orbital debris are too pressing and international cooperation is needed to find a solution in the near future. International cooperation is possible however, as evidenced by the creation and launch of the International Space Station. Working together to build and maintain the ISS created good will among nations, a potential outcome for the creation of an international remediation agreement as well.[261]

This proposal is necessary because the space community will not be able to reach a consensus on implementing an effective solution within a short time period. Today's space community has many actors with diverse interests, which makes it difficult to reach a consensus decision within the legal community. Advanced actors, such as the U.S., Russia, and the ESA, with developed space programs are starting to shift from state run programs to privatized commercialization.[262] They are focused on making the utilization of space economically feasible for private actors; with this in mind, remediation of the space environment is vital to keep costs low enough to promote the use of space by private actors. On the other hand, emerging actors in the space community, which tend to have less developed programs, may not view damage to the space environment with the same level of concern as developed space-faring nations.[263] Access to space, and having an equal claim to geostationary slots, are the main concerns of these countries.[264] These polarized interests make it difficult for the international community to move forward in addressing the problem of orbital debris. Having five actors implement a regime with their market power is more logistically feasible than a general consensus among all actors in the space community.

This proposal is superior to the suggested regime changes mentioned above for many reasons. First, a multilateral approach could be implemented in less time than the suggested proposals, especially a new international treaty or the development of customary international law. It would also be unlike a new international treaty or the development of customary

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[261] *Id.* at 76 ("International cooperation can also help nations undertake vast collaborative projects in space, such as the International Space Station, whose complex technical challenges and prohibitive costs are difficult for any one actor to take on.").

[262] BAIOCCHI & WELSER, *supra* note 15, at xxi.

[263] Baseley-Walker, *supra* note 259.

[264] VIIKARI, *supra* note 10, at 23.

international law because it would not be watered down and would allow for an effective and specific solution. It is unlike proposals to reform the liability convention, to create a compensation fund, and the adoption of a market share plan, in that this proposal specifically addresses remediation rather than attempting to incentivize actors to remediate the space environment. Incentives do not ensure hard and fast results. Some actors might be disincentivized to spend money on remediation techniques if they have to spend billions of dollars on damages under a market-share liability plan. Furthermore, a fee per launch regime is forward looking, instead of based on past transgressions, which is important considering states did not know the harm in producing orbital debris.

The remediation of space will benefit all space-faring states by making the space environment less dangerous, and will subsequently lower the risk of collisions. A multilateral agreement to impose a fee on all launches spreads the cost of remediation to all actors in the community currently seeking access to space. Russia, the U.S., and China are responsible for a majority of the debris located in space.[265] Since many states believe that past polluters should pay,[266] it is in the best interest of Russia, the U.S., and China to choose a regime that benefits them by spreading the cost of remediation to all actors in the community. Furthermore, these countries, especially the U.S. and Russia, have led the way in regards to space exploration and should once again take such an important and prominent role and lead the way with remediation.

A multilateral agreement between the five states that have market power is the sole means of control in the space community. This fee system will provide the fastest and most efficient way to clean up the space environment. States that do not have independent launch capability will be forced to either pay the tax or acquire launch capability; since, the cost of developing launch technology is extremely expensive and launch programs take many years to become successful,[267] most states will probably chose to pay the necessary fee. Thus, if actors with launch capabilities, which are not included in the multilateral agreement begin to commercially launch other actors' spacecraft, then the five actors in the agreement can use various forms of political

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[265] *See* discussion *supra* Part V.

[266] *See* discussion *supra* Part V.

[267] *See Canada Says It Could Build Launch Rockets*, SPACE TRAVEL (Jan. 3, 2011), http://www.space-travel.com/reports/Canada_says_it_could_build_launch_rockets_999.html (stating that though Canada has the technological ability to build rockets, it could take between ten and twelve years to build a launcher); *see also* Michael K. Robel, *The Cost of Medium Lift*, SPACE REV. (June 1, 2004), http://www.thespacereview.com/article/150/1.

pressure to convince them to sign onto the agreement. A safe space environment is important because "[t]he world has become increasingly reliant on the benefits derived from space-based technologies."[268] Remediation of the space environment is the only way to fix the orbital debris problem and in the long run, all states will benefit from a multilateral agreement among the leaders in the commercial launch industry to collect a fee for every launch that occurs in their jurisdiction.

VII. CONCLUSION

At the beginning of the space age, little thought was given to the risks of orbital debris. Space has become more crowded and an increasingly dangerous environment, due to the growing number of new actors with access to space and the ability of debris to become self-generating. "Millions of individuals rely on space applications on a daily basis for functions as diverse as weather forecasting, navigation, communications, and search-and-rescue operations."[269] The space community needs to adopt a legal regime that enables the development of technology to remediate the space environment now before a catastrophic event occurs.

Currently sixty actors utilize space, predominately by using satellites.[270] However, only ten have independent orbital launch capability, of which only five regularly launch spacecraft belonging to other states.[271] This limited group of actors with independent launch capabilities holds significant power and control over the space community. Specifically, this class has the potential to wield effective market power in the space industry. Such power enables these actors to develop and impose a system that forces players in the space community to financially contribute to remediating the space environment. The states that dominate the launch market, Russia, the U.S., the ESA, China, and India, need to implement a multilateral agreement that provides for the imposition of a fee for every launch. Proceeds will fund development of technology to remediate the space environment. This is the only feasible solution because (1) individual states and consortia either cannot, or will not, develop remediation techniques on their own, (2) the space community as a whole will not be able to reach a voluntary consensus on paying into a fund to design remediation techniques, and (3) market power is the sole means of control within the space community.

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[268] SPACESECURITY.ORG, *supra* note 1, at 8.
[269] *Id.* at 77.
[270] *Id.* at 19.
[271] *Id.* at 84.