International Environmental Law Principles:
A New Solution for the Space Debris Problem?

by

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Abstract

Satellites orbiting the Earth form the exoskeleton of the world's critical infrastructure: global communications, air transport, maritime trade, financial services and weather monitoring all depend on an expansive network of satellites in space. There are however inherent consequences to human activities in outer space. The most critical challenge to the safety, security, and sustainability of outer space is the threat posed by space debris to the spacecraft of all nations. The emerging commercialization, democratization and militarization of space has led to the growth of space debris, heavily concentrated in the orbits where human activities take place. In light of this challenge, this thesis analyzes international space law treaties and soft-law instruments with a view to determine their relevance and effectiveness in addressing the space debris dilemma. It recommends that legal principles from a different legal framework – international environmental law – be applied in outer space to impose stronger obligations on spacefaring countries, and lead to a more successful and equitable strategy to preserve the outer space environment. In practical terms, the precautionary principle, the no-harm rule, and the common but differentiated responsibilities principle should lead to: (1) greater compliance with space debris mitigation measures to stabilize the debris population; (2) improved space situational awareness programs with more detailed and accurate data-sharing between States; and (3) continued research, investment, and the eventual implementation of space debris removal mechanisms.

Résumé

Les satellites en orbite autour de la Terre forment l’exosquelette de l’infrastructure mondiale : les communications globales, le transport aérien, le commerce maritime, et les services financiers et météorologiques dépendent tous d’un vaste réseau de satellites dans l’espace. Néanmoins, les activités humaines dans l’espace entraînent des conséquences inhérentes. Le défi le plus critique pour la sûreté, la sécurité et la durabilité de l’espace est la menace que représentent les débris spatiaux pour les satellites de toutes les nations. La commercialisation, la démocratisation et la militarisation de l'espace ont entraîné une croissance dans la quantité de débris, qui est fortement concentrée dans les orbites où se déroulent les activités humaines. En face de ce défi, cette thèse analyse les traités internationaux du droit spatial et d’autres instruments internationaux en vue de déterminer leur pertinence et leur efficacité pour résoudre le dilemme des débris spatiaux. Cette thèse recommande que des principes juridiques issus d'un cadre juridique différent - le droit international de l'environnement - soient appliqués dans l'espace afin d’imposer des obligations plus strictes aux pays ayant des capacités spatiales. Ceci pourrait mener à une stratégie plus efficace et plus équitable pour préserver l'environnement spatial. En termes pratiques, le *precautionary principle*, le *no-harm rule*, et le *common but differentiated responsibilities principle*, devraient conduire à: (1) un plus grand égard aux mesures de réduction des débris spatiaux afin de stabiliser la population de débris; (2) l’amélioration des programmes de *space situational awareness*, grâce à un partage de données et informations plus détaillé et exact entre les États; et (3) la poursuite des recherches, des investissements, et la mise en œuvre éventuelle de technologies d'élimination des débris spatiaux.

Table of Contents

Introduction

Since the launch of Sputnik in 1957, the use of outer space has undergone significant changes. During the first decades of the space age, outer space was dominated by the two world superpowers at the time – the United States and the Soviet Union. With both sides apprehensive about the possibility of an arms race, outer space use was almost entirely concerned with security issues, and closely interlinked with the nuclear competition and other political considerations of the Cold War.[1] With the collapse of the Soviet Union in 1991, a strong wave of liberalization and globalization began to affect the space industry.[2] A domain that was once practically inaccessible, has today more than 80 different governmental actors.[3] Concomitantly, private and commercial entities have become involved in space activities, drawn by the economic value of space.

Nowadays, space utilization has attained enormous economic significance and brings about many socio-economic benefits, many of which we take for granted. Satellites orbiting the Earth form the exoskeleton of the world's critical infrastructure: global communications, air transport, maritime trade, financial services and weather monitoring all depend on an expansive network of satellites in space.[4] Militarily as well, space technologies for intelligence, reconnaissance, navigation and communication purposes have become ingrained into military operations on Earth, and have enormous strategic and tactical significance.[5] Satellites have become so vital, and our dependence on them so extreme, that if we were suddenly denied access to space-based

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[1] *Space Security 2018 - Space Security Index*, Yearly Report, by Jessica West, Space Security Index Yearly Report 15th Edition (Project Ploughshares & The University of Adelaide, 2018) at 149.

[2] Peter Stubbe, *State accountability for space debris: a legal study of responsibility for polluting the space environment and liability for damage caused by space debris*, Studies in space law 1871–7659 (Leiden; Boston: Brill Nijhoff, 2018) at 35.

[3] Bhavya Lal et al, *Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM)* (IDA Science & Technology Policy Institute, 2018) at 1.

[4] *Job One for Space Force: Space Asset Cybersecurity*, by Gregory Falco, Cyber Security Project (Belfer Center, 2018) at 1.

[5] Ram S Jakhu & Joseph N Pelton, eds, *Global Space Governance: An International Study*, 1st ed. 2017 ed, Space and Society (Cham, Switzerland: Springer International Publishing : Imprint: Springer, 2017) at 267–268.

technology we would suffer almost immediately—economically, militarily, and socially.[6] Our transportation and communication systems would go down along with our weather forecasting capabilities and military targeting systems. The internet would lose its synchronization, credit card validation would no longer work, and all planes would have to be grounded. Space systems have gone from being an exotic new enterprise, to a vital necessity that is central to our daily lives.[7]

Unfortunately, there is an inherent adverse consequence arising from our use of outer space. Since the dawn of the space age over six decades ago, thousands of tons of debris have been left drifting around in orbit.[8] Concerns about space pollution might at first be deemed to be fairly irrelevant given the vast dimensions of the outer space environment [9] And yet, space debris left by past and present missions comprises one of the greatest risks to the sustainability of outer space, and threatens the future viability of human space activities.[10] This thesis will seek to answer two main questions: (1) To what extent does the outer space legal framework address the environmental concern which is space debris; and (2) How applicable are international environmental law principles to space debris, and what practical ramifications could their implementation have on the sustainability of the orbital environment?

This thesis is divided into five chapters. Chapter 1 will introduce the space debris problem in the context of the outer space environment. Chapter 2 will examine the current outer space legal framework from an environmental perspective and determine its relevance and effectiveness in addressing space debris. Chapter 3 will explore some of the emerging threats to the sustainability of outer space, and how they contribute to orbital debris. Chapter 4 will scrutinize principles from international environmental law and evaluate their applicability in the context of space debris. Finally, Chapter 5 will consider some of the practical effects international environmental

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[6] Joseph N Pelton, *New solutions for the space debris problem*, SpringerBriefs in space development, 2191-8171 (Cham: Springer, 2015) at 1.

[7] *Ibid*.

[8] Olavo de O Bittencourt Neto, "Preserving the outer space environment: The 'precautionary principle' approach to space debris" (2013) 14 Proceedings of the International Astronautical Congress, IAC 11213–11223 at 341.

[9] Stubbe, *supra* note 2 at 13.

[10] Bittencourt Neto, *supra* note 8 at 342, footnote 1.

law principles could have on space debris mitigation, space situational awareness programs, and active debris removal activities.

Chapter 1 – Sources and Dangers of Space Debris

Defining the term space debris is not self-evident. The term is neither defined, nor expressly mentioned in UN space treaties. The fact that to this day there is no commonly accepted, legally-binding definition of space debris is concerning.[11] The dangers orbital debris pose to all space operations and the possible confusion over what comprises space debris, both suggest the need for a clearly stated and defined legal term.[12]

Although international law does not define space debris, several definitions have been developed at the international level. Most notably, the Inter-Agency Space Debris Coordination Committee (IADC), composed of a group of thirteen leading space agencies from technologically advanced States, defines space debris as: "all man-made objects, including fragments and elements thereof, in Earth or re-entering the atmosphere, that are non-functional."[13] Similarly, the European Space Agency has defined space debris as: "all non-functional, man-made objects, including fragments and elements thereof, in Earth orbit or re-entering into Earth atmosphere".[14] These definitions, while non-binding, accurately reflect what is commonly understood as comprising space debris.

I. Earth's Orbits

For the purposes of this thesis, space debris will not refer to debris in the whole of outer space. Rather, the subject of interest will be restricted to those orbital regions that are accessible and most used for space activities. Because the debris population reflects the degree of utilization of Earth's orbits, an overview of which orbits are most used for space activities will be useful.

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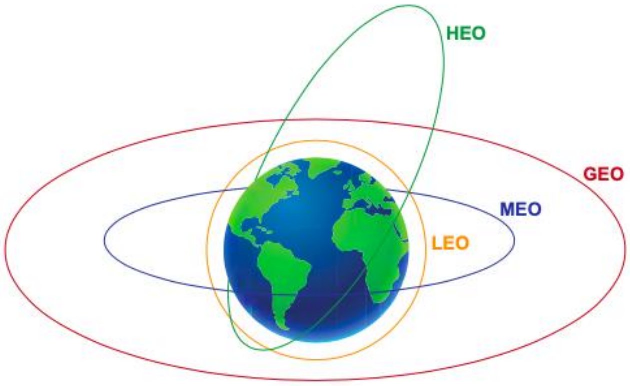
[11] Peter Stubbe, "Common but Differentiated Responsibilities for Space Debris – New Impetus for a Legal Appraisal of Outer Space Pollution" (2010) ESPI Perspectives 31 European Space Policy Institute at 3.
[12] *Orbiting Debris: a Space Environmental Problem.*, by Congress of the US, Office of Technology Assessment (Washington, DC : Congress of the U.S. Office of Technology Assessment, 1990) at 27.
[13] Inter-Agency Space Debris Coordination Committee, *IADC Space Debris Mitigation Guidelines* (2020) at 6.
[14] Pelton, *supra* note 6 at 73–74.

Satellites operate primarily in four different levels of orbit, as seen in Figure 1.1. Those are: Low Earth Orbit (LEO), Medium Earth Orbit (MEO), Geostationary Orbit (GEO), and Highly Elliptical Orbit (HEO).

Figure 1.1 Types of Earth orbits [15]



A. Low-Earth Orbit

Most human activities take place in LEO, a region between 100km and 2,000km above the Earth's surface. Spacecraft in LEO make one complete revolution of the Earth in approximately 90 minutes.[16] These orbits are used primarily used for remote sensing applications, including reconnaissance, weather and science missions. The International Space Station, observation satellites, and some telescopes are all in LEO. The attractiveness of these orbits means that most catalogued space objects, about 70%, are concentrated in LEO.[17]

B. Medium-Earth Orbit

Medium-Earth Orbit is the region of space above LEO (2,000km) and below GEO (35,786km). The orbital period for MEO satellites ranges between two and twelve hours.[18] The most common

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[15] Mark Brady & David Lewis, *Do New Constellations Have to Cost Billions?* (International Telecommunication Union, 2017) at 8.

[16] *SPACE SECURITY 2019 – Space Security Index*, Yearly Report, by Jessica West, SSI Yearly Report 16th Edition (Project Ploughshares & The University of Adelaide, 2019) at 162.

[17] Stubbe, *supra* note 2 at 25.

[18] West, *supra* note 16 at 162.

uses for satellites in this region are navigation and communication. The US Global Positioning System (GPS), for instance, is deployed in MEO.[19]

C. Geostationary Earth Orbit

GEO is a region in which satellites orbit at around 35,786 km above the Earth's equator.[20] The unique feature of this orbit is that it has an orbital period equal to the rotation of the Earth, so that it takes 24 hours for GEO satellites to complete one full orbit. Objects in GEO thus move synchronously with the Earth so that a satellite essentially remains 'fixed' over a region of the Earth.[21] Communication and broadcasting services provided by GEO spacecraft are amongst the most lucrative of space activities: only three GEO satellites can provide global telecommunication service coverage.[22] Moreover, because of their altitude, GEO satellites are frequently used to cover weather events, monitor large storms and cyclones, and provide a big picture of the Earth.[23]

D. Highly Elliptical Orbit

HEO is characterized by a relatively low-altitude perigee and an extremely high-altitude apogee.[24] These elongated orbits can be used to move satellites from an orbit in LEO, out to the GEO region. Because HEO have the advantage of long dwell times at certain points in the sky, they are used for the most part by communication satellites, particularly in the Northern Hemisphere.[25]

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[19] *Ibid*.
[20] Rada Popova & Volker Schaus, "The Legal Framework for Space Debris Remediation as a Tool for Sustainability in Outer Space" (2018) 5:2 Aerospace 55 at 2.
[21] Paul V Anderson, *Characterizing Longitude-Dependent Orbital Debris Congestion in the Geosynchronous Orbit Regime* University of Colorado Boulder, 2015) [unpublished] at 152.
[22] *Ibid*.
[23] West, *supra* note 16 at 162.
[24] *Ibid* at 163.
[25] *Ibid*.

II. Location of Debris

As of January 2021, out of the total 3,372 operating satellites orbiting the Earth, 2,612 were located in LEO, 562 were located in GEO, 139 were located in MEO, and 59 are were located in HEO.[26] However, only a fraction of all space objects are still operational. It is estimated that only between 6-8% of the overall population of catalogued space objects in orbit are functional satellites, with the rest falling into the category of space debris.[27] According to space situational awareness (SSA) sources that track non-functional objects, there are more than 21,000 objects larger than 10cm, and an estimated 150 million objects larger than 1 mm orbiting the Earth.[28] Orbital debris is an inherent consequence of human activities in outer space, so the majority of trackable debris is located in areas of intense space activity, namely LEO and GEO.[29] LEO, as the most highly congested orbit, is the location of roughly half of all debris.[30] Analysts believe that the total orbital population is much greater, because current technology cannot yet detect smaller debris at higher altitudes.[31] For example, objects must be about one meter in diameter to be detected and accurately tracked in GEO.[32]

III. Sources of Debris

Space debris originates from various sources: explosions creating fragments, deterioration of active and inactive payloads, spent rocket thrusters, and by the normal operation of spacecrafts.[33] In outer space, every launch creates some sort of debris. Non-fragmentation debris usually arises from the normal operation of rocket engines. Particles from the rocket combustion process represent an important source of debris, with aluminium oxide being expelled through exhaust

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[26] Union of Concerned Scientists, “Satellite Database”, (1 January 2021), online: *UCSUSA* <https://www.ucsusa.org/resources/satellite-database>.

[27] Congress of the U.S., Office of Technology Assessment, *supra* note 12 at 1; Lal et al, *supra* note 3 at 1.

[28] Popova & Schaus, *supra* note 20 at 2.

[29] David Tan, “Towards a New Regime for the Protection of Outer Space as the Province of All Mankind” (2000) 25:1 Yale J Int’l L 145–194 at 151.

[30] West, *supra* note 16 at 3.

[31] Congress of the U.S., Office of Technology Assessment, *supra* note 12 at 15.

[32] Lal et al, *supra* note 3 at 9, 29.

[33] Bittencourt Neto, *supra* note 8 at 342.

systems into space either as dust particles or slag objects.[34] The size of these objects can range from a micrometer (1 millionth of a meter) for dust particles, to several centimeters for slag objects.[35] From the beginning of spaceflight until 2001, 1,302 space launches are believed to have produced more than 300 tons of dust and slag objects.[36] Another source of non-fragmentation debris is linked to the degradation of spacecraft; harsh conditions, such as extreme ultraviolet radiation, are prevalent in the outer space environment.[37] As a result, the surfaces of space objects degrade over time, creating small debris particles such as paint flakes.[38]

Fragmentation is the most significant source of orbital debris by the numbers and accounts for nearly two-thirds of all catalogued objects in outer space.[39] Since the beginning of human space activities, there have been more than 500 fragmentation events which have created millions of debris objects larger than 1mm.[40] The fragmentation of spacecraft is usually caused by energetic events, such as explosions or collisions. Unfortunately, accidental failures related to the propulsion systems of spacecraft are not that rare.[41] Due to the residual energy and propellant stored onboard decommissioned spacecraft and satellites, explosions sometimes occur and new debris is created.[42] Collisions are responsible for much of the debris in Earth orbit. Collisions can be unintentional, as in the case of two satellites colliding in-orbit, or intentional, such as when anti-satellite weapons are tested in space. It is estimated that about one-third of the debris in Earth orbit stems from just 10 satellite breakups, most of them incidental.[43]

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[34] National Aeronautics and Space Administration, *Orbital Debris Management & Risk Mitigation* (Academy of Program/Project & Engineering Leadership) at 11.
[35] Stubbe, *supra* note 2 at 22–23.
[36] Heiner Klinkrad, *Space Debris: Models and Risk Analysis* (Berlin ; New York : Chichester, UK: Springer-Praxis, 2006) at 23–24.
[37] *Ibid* at 88.
[38] *Ibid* at 27.
[39] Stubbe, *supra* note 2 at 17.
[40] Pelton, *supra* note 6 at 4.
[41] Congress of the U.S., Office of Technology Assessment, *supra* note 12 at 18.
[42] Stubbe, "Common but Differentiated Responsibilities for Space Debris", *supra* note 11 at 2.
[43] National Aeronautics and Space Administration, *supra* note 34 at 7.

A. Intentional Collisions

Deliberate collisions are associated with the development of anti-satellite (ASAT) weapon tests in outer space. In 2007, China intentionally destroyed its own Fengyun-1C weather observation satellite with a ballistic missile, thereby testing and showcasing its ASAT capabilities.[44] This incident created almost 3,400 trackable pieces of debris, half of which are predicted to remain in orbit until 2027.[45] In February 2008, the USA also shot down one of its own spacecraft, perhaps in response to the Chinese ASAT testing. The American reconnaissance satellite - which had malfunctioned immediately after launch - was intercepted by a missile from a US Navy Warship.[46] Luckily, because of the low altitude of the interception at approximately 250 km, the space debris created by this ASAT test re-entered the Earth's atmosphere relatively quickly. More recently in 2019, India also conducted its own ASAT test, creating hundreds of debris objects in the process. While most of them quickly re-entered into the atmosphere and disintegrated, some debris from that incident is still being tracked today.[47]

B. Accidental Collisions

So far, there have been few accidental collisions between catalogued objects in space, and fewer still between operational spacecraft. In 1996, the French military reconnaissance satellite *Cerise* collided with a piece of debris stemming from an Ariane launch vehicle, making it the first verified case of an accidental collision between two man-made objects in space.[48] More recently in 2009, a major collision involving two intact spacecraft took place when the inactive Russian satellite Cosmos 2251 and the US communication satellite Iridium 33 accidentally collided.[49] The real casualty of this collision was the orbital environment. Altogether, the 2009 collision led to the creation of a debris cloud of over 2,200 pieces larger than 10 cm and thousands of smaller

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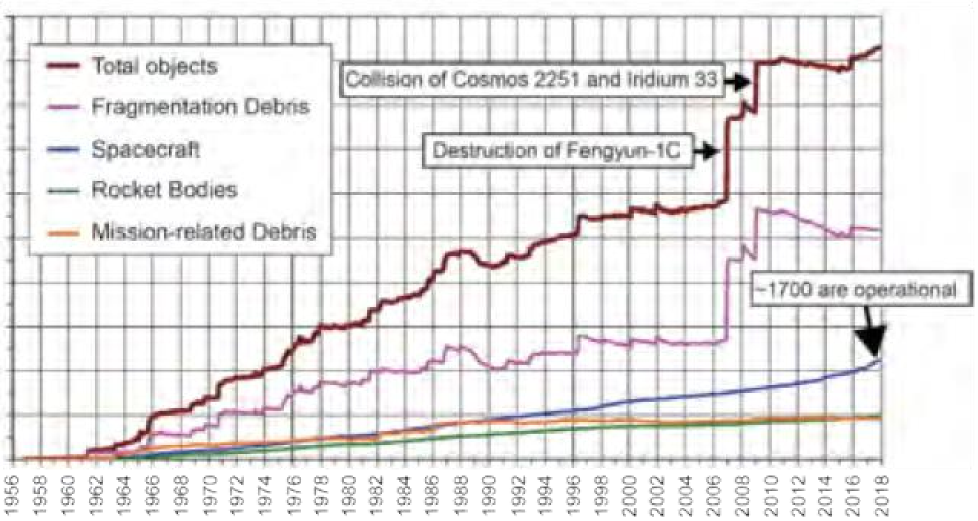
[44] Jakhu & Pelton, *supra* note 5 at 279.
[45] Stubbe, *supra* note 2 at 19.
[46] Jakhu & Pelton, *supra* note 5 at 278.
[47] Caleb Henry, "India ASAT debris spotted above 2,200 kilometers, will remain a year or more in orbit", (9 April 2019), online: *SpaceNews* <https://spacenews.com/india-asat-debris-spotted-above-2200-kilometers-will-last-a-year-or-more/>.
[48] Stubbe, *supra* note 2 at 37.
[49] Dale Stephens & Cassandra Steer, "Conflicts in Space: International Humanitarian Law and Its Application to Space Warfare Section I: Focus Section: Military Use of Outer Space - International Legal Perspectives" (2015) 40 Annals Air & Space L 71–104 at 76–77.

pieces. As of 2012, 90% of the debris from the collision was still in orbit around the Earth, of which nearly 1,400 pieces remained in orbit in 2017.[50] Collisions like the 2007 Chinese ASAT testing and the 2009 Iridium-Cosmos collision have demonstrated the severe effects individual events can have on orbital sustainability.[51] Taken together, these two events led to a dramatic growth in the overall orbital debris population. As the number of new satellites and space objects in orbit continues to increase, catastrophic collisions are expected to become the main driver for future debris population growth.[52]

FIGURE 1.2 Growth in on-orbit population by category [53]



IV. The Harmful Effects of Space Debris

The dangers of space debris are not confined to the numerical augmentation of space objects in orbit.[54] Orbital debris poses very real and dangerous threats to human activities in outer space. The harmful effects of space debris are threefold: 1) severe damage can be caused through in-orbit collisions; 2) re-entering debris can cause damage on Earth; 3) the formation of a self-sustaining debris belt in certain orbits, also known as the "Kessler Syndrome".

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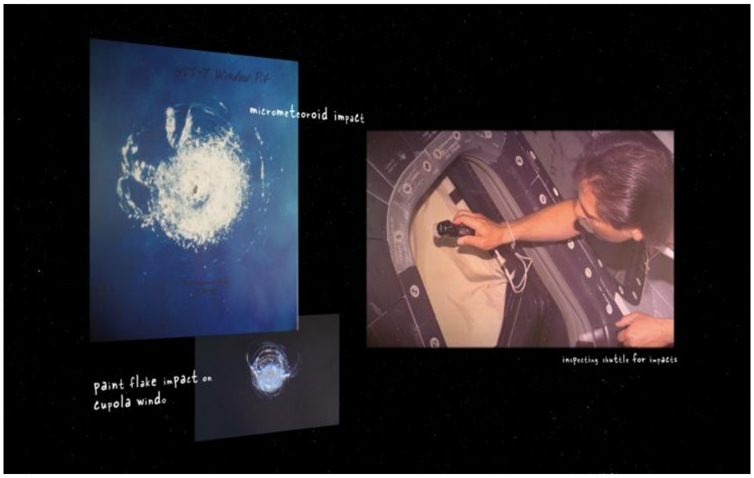
[50] Stubbe, *supra* note 2 at 18; National Aeronautics and Space Administration, *supra* note 34 at 7.
[51] Popova & Schaus, *supra* note 20 at 3.
[52] Benjamin Bastida Virgili & Holger Krag, *Small Satellites and the Future Space Debris Environment* (Darmstadt, Germany, 2015) at 2–5.
[53] National Aeronautics and Space Administration, *supra* note 34.
[54] Stubbe, *supra* note 2 at 38.

A. Collision of Debris with a Functional Space Object

A significant risk of space debris is that of in-orbit collisions with functional space objects. The orbital velocity in LEO is approximately 7km/sec, while in GEO it's 3.1 km/sec.[55] As such, impacts with objects a few centimeters in diameter are likely to be catastrophic, and can completely cripple functional satellites. [56] An object the size of a small ball may not sound like much, but a chunk of metal this size and traveling at a speed of 29,000 km an hour has the kinetic energy of a large-sized bomb.[57] Even small pieces of debris as small as 1mm can cause degradation to a functional spacecraft and endanger astronauts.[58] Human crews currently operate in LEO, where the debris flux and the relative velocities between debris and spacecraft are extremely high.[59] A chip of paint travelling at hypersonic speeds could pierce a space suit or crack the windshield of spacecraft.[60] In 1983, a tiny titanium oxide paint chip, estimated to be about 0.2 mm in diameter, collided with the shuttle orbiter *Challenger*, damaging a window.[61]

FIGURE 1.3 Damage caused by a 0.2 mm speck of paint [62]



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[55] Secure World Foundation, "The Persistent Problem of Orbital Debris", (2018), online: *swfound.org* <https://swfound.org/space-sustainability-101/the-persistent-problem-of-orbital-debris/>.
[56] Theodore J Muelhaupt et al, "Space traffic management in the new space era" (2019) 6:2 Journal of Space Safety Engineering (Space Traffic Management and Space Situational Awareness) 80–87 at 81.
[57] Pelton, *supra* note 6 at 4.
[58] Popova & Schaus, *supra* note 20 at 2.
[59] Congress of the U.S., Office of Technology Assessment, *supra* note 12 at 40.
[60] *Ibid* at 7.
[61] *Ibid* at 2; National Aeronautics and Space Administration, *supra* note 34 at 11.
[62] National Aeronautics and Space Administration, *supra* note 34 at 11.

The growing threat of orbital debris has direct practical consequences for operational spacecraft. According to a 2018 report, data on 308,984 close calls with space debris and 655 emergency alerts were issued to satellite operators in 2017.[63] The average number of collision avoidance maneuvers needed to be performed by the International Space Station (ISS) has greatly increased in recent years because of the growth in orbital debris.[64] In 2020 alone, the ISS conducted three debris avoidance maneuvers.[65] Constant tracking and monitoring of the ISS does not provide total protection from collision. In March 2009, a collision threat was recognized when it was already too late to plan and execute an avoidance maneuver; the only option left was to evacuate the ISS' crew into the Russian *Soyuz* spacecraft.[66] While the debris fortunately did not impact the ISS, this incident illustrates the high-risk potential of space debris.[67]

B. Risk of Debris Re-entry in Earth's Atmosphere

While space debris usually disintegrates during atmospheric re-entry, larger objects or objects constructed from more resistant material can survive and crash on Earth.[68] Between the first space launch in 1957 and January 2002, approximately 27,000 tons – or nearly 25 million kilograms – of space debris has re-entered the atmosphere.[69] This can pose a danger to aircraft in flight, and persons and property on the ground.[70] Statistically speaking , the risks of a person being killed by re-entering debris are very low – equivalent to the probability of being killed while travelling 1 meter in a car, or working 1 second as a fire fighter.[71] Nevertheless, re-entering space objects can still cause severe damage and attract significant public attention. Concerns have been raised about the potential environmental contamination caused by deorbiting

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[63] Dave Mosher, "The US government logged 308,984 potential space-junk collisions in 2017 — and the problem could get much worse", (April 2018), online: *Business Insider* <https://www.businessinsider.com/space-junk-collision-statistics-government-tracking-2017-2018-4>.

[64] Muelhaupt et al, *supra* note 56 at 84.

[65] National Aeronautics and Space Administration, "Orbital Debris Quarterly News" (2020) 24:4 NASA Orbital Debris Program Office 12 at 2.

[66] Stubbe, "Common but Differentiated Responsibilities for Space Debris", *supra* note 11 at 1.

[67] *Ibid*.

[68] Stubbe, *supra* note 2 at 29.

[69] Klinkrad, *supra* note 36 at 241.

[70] Bittencourt Neto, *supra* note 8 at 341.

[71] Klinkrad, *supra* note 36 at 271.

satellites carrying residual fuel, particularly those that carry considerable amounts of toxic and highly explosive rocket propellant.[72]

A notorious example is that of the Soviet satellite *Cosmos 954* in 1978, whose fragments - which were radioactively contaminated due to a nuclear power source on board - dispersed over Canadian territory.[73] Another example is that of the US Space Shuttle *Columbia*, which broke apart during re-entry in 2003. Roughly 84,000 recovered fragments representing 38% of the spacecraft's initial mass of 82 tons struck the ground, posing a danger to an estimated 216,000 people.[74] More recently in 2018, a nearly intact *Zenit* rocket weighing 8,300 kg deorbited over Peru.[75]

C. The Kessler Syndrome

Perhaps the most serious long-term danger of space debris is the "Kessler Syndrome", a nightmarish scenario conceived by the American scientist Donald Kessler in 1978.[76] The Kessler Syndrome assumes that a significant in-orbit collision probability exists in densely populated orbital regions – such as LEO and GEO. It predicts that if orbital debris growth continues unchecked, the probability of collisions will increase.[77] Once a collision does occur and creates additional orbital debris, that debris augments the risk of further collisions. As a consequence, the number of collisions and space debris will increase exponentially. The fear with this cascading effect is the eventual formation of a self-sustaining debris-belt orbiting the Earth: self-sustaining because even if no additional space launches take place, the orbital debris population will continue to grow through in-orbit collisions.[78] Some experts claim that the current debris population has already reached that congested level in which the collision-cascading process can

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[72] Stubbe, *supra* note 2 at 38.
[73] Bittencourt Neto, *supra* note 8 at 344, footnote 11.
[74] Klinkrad, *supra* note 36 at 243–244.
[75] Spaceflight101, "Zenit Rocket Parts Crash Land in Peru", (28 January 2018), online: *Spaceflight101* <https://spaceflight101.com/zenit-rocket-parts-crash-land-in-peru/>.
[76] Bittencourt Neto, *supra* note 8 at 343.
[77] Tan, *supra* note 29 at 152–153.
[78] Stubbe, "Common but Differentiated Responsibilities for Space Debris", *supra* note 11 at 2.

only be stopped through the removal of high-risk space debris.[79] In any case, what is clear is that a self-sustaining debris belt would jeopardize the feasibility of future space missions, and make certain orbits in LEO and GEO unusable for the long run.

V. Atmospheric Drag

Unlike the environment on Earth which can usually be cleaned up and restored to a previous state, outer space is governed by celestial mechanics which make it difficult to clean up debris.[80] The only natural process through which orbital debris is eliminated is called "atmospheric drag". Earth's residual atmosphere extends into outer space and creates an energy-dissipating effect on space objects. Dependent on the mass, cross-sectional area and orbital position of the debris,[81] atmospheric drag will slow down space objects in orbit, reduce their altitude, and eventually cause them to re-enter the atmosphere.[82] As such, larger objects tend to slow down faster than more compact objects with comparable mass, while the higher the object is in outer space, the less it will be affected by atmospheric drag.[83]

The upper reaches of Earth's atmosphere stretch well into LEO, and orbital debris in this region can re-enter the Earth's atmosphere and disintegrate.[84] How long this process takes depends on the initial altitude of the debris. Above 600km, debris in LEO can remain a threat to space activities for several decades if not centuries[85], while space debris at more than 1,500 km will essentially remain in outer space forever.[86] While there is at least a chance for natural self-clean-up in LEO, no such opportunity exists for debris in GEO, the second most populated satellite orbit. The GEO region is at a much higher altitude than LEO: at almost 36,000km, it would take millions of years for atmospheric drag to cause objects in GEO to re-enter the atmosphere.[87]

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[79] J -C Liou, "An active debris removal parametric study for LEO environment remediation" (2011) 47:11 Advances in Space Research 1865–1876 at 1865.
[80] Popova & Schaus, *supra* note 20 at 3.
[81] *Ibid*.
[82] Stubbe, *supra* note 2 at 31.
[83] *Ibid* at 32.
[84] Congress of the U.S., Office of Technology Assessment, *supra* note 12 at 12.
[85] West, *supra* note 16 at 3.
[86] Popova & Schaus, *supra* note 20 at 3.
[87] Congress of the U.S., Office of Technology Assessment, *supra* note 12 at 26.

Therefore, while a natural way to get rid of space debris exist, atmospheric drag is not the solution to the orbital debris dilemma. As Chapter 3 will demonstrate, more governmental and private actors than ever before are gaining access to outer space, posing new and dangerous threats to the already congested LEO and GEO orbits. In view of the prospectively increasing rate of collisions and concomitant proliferation of debris, natural air drag effects will not be sufficient to stabilize the outer space environment.[88] A growth in the quantity of space debris will compromise the safety and success of both manned and unmanned space missions.[89] The question then must be asked: does the current international space law regime adequately address the problems associated with the rapid proliferation of space debris? The simple answer is: no. As the following chapter will demonstrate, space law treaties neither expressly prohibit the creation of space debris, nor do they impose an obligation on States or their space actors to remove space objects from orbit.[90]

Chapter 2 – Outer Space Law and Orbital Debris

The field of international law most obviously applicable to space activities is the international law of outer space. Space law consists of five (5) United Nations treaties. Those are:

1) The 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies (hereinafter 'the Outer Space Treaty', or OST);
2) The 1968 Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (hereinafter 'the Rescue Agreement');
3) The 1972 Convention on International Liability for Damage Caused by Space Objects (hereinafter 'the Liability Convention');
4) The 1975 Convention on Registration of Objects Launched into Outer Space (hereinafter 'the Registration Convention');

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[88] Stubbe, *supra* note 2 at 33.
[89] Bittencourt Neto, *supra* note 8 at 345, footnote 16.
[90] Popova & Schaus, *supra* note 20 at 6.

5) The 1979 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (hereinafter 'the Moon Agreement').

I. Space Law Treaties

Unfortunately, the UN space treaties say virtually nothing on the topic of space debris. At the time of their negotiation and ratification in the 1960s and 70s, environmental considerations were not the most urgent items on the agendas of spacefaring nations.[91] Space law developed during the Cold War, in a political climate dominated by an arms race and great ideological divide between the United States and the USSR. Spacefaring and non-spacefaring nations alike were accordingly more concerned with not allowing any one State to colonize space for strategic weapons deployment.[92]

The five UN space treaties were not formulated to address and did not foresee the complex problems of orbital pollution we face in the 21st century.[93] As such, space law reflects neither the scientific and technical innovations of the last several decades, nor the 'reality on the ground' so to speak. The outer space legal framework raises environmental concerns only in the context of the efficient use of space resources and research opportunities and does not provide broader protection to the space environment.[94] There is widespread agreement amongst the legal community that space law is ill-suited to adequately address the problems associated with the rapid proliferation of space debris. Nevertheless, the space legal regime does contain a number of environmental provisions which have been interpreted by legal scholars as being pertinent to space debris. A discussion of key relevant provisions of the UN treaties on outer space to determine their potential applicability to the hazard of space debris is therefore useful and will be conducted below.

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[91] Lotta Viikari, *The Environmental Element in Space Law: Assessing the Present and Charting the Future*, Studies in Space Law (Leiden, The Netherlands: Brill | Nijhoff, 2008) at 55.
[92] Jakhu & Pelton, *supra* note 5 at 283–284.
[93] Tan, *supra* note 29 at 157.
[94] Lawrence D Roberts, "Addressing the Problem of Orbital Space Debris: Combining International Regulatory and Liability Regimes" (1992) 15:1 Boston College International & Comparative Law Review, online: <https://lawdigitalcommons.bc.edu/cgi/viewcontent.cgi?article=1531&context=iclr> at 52.

A. Outer Space Treaty

The 1967 Outer Space Treaty (OST) introduced many of the fundamental principles pertaining to the exploration and use of outer space. It is therefore regarded by many scholars as the *Magna Carta* of space law and provides the basis for the next four treaties.[95] The starting point of space law is the freedom of use and exploration of outer space. Article I (2) of the OST provides that:

> "Outer space, including the moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies".[96]

Yet, this freedom of action is neither unlimited nor absolute. Rather, it is also determined by the rights and interests of other States and of all *mankind*. Article I (1) of the OST stipulates that:

> "The exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind."[97]

There is a healthy amount of debate on what the term "*province of all mankind* means", and the concrete obligations it entails. At a minimum, Article I of the OST is believed to impose a duty upon States to use space in a manner that does not jeopardize the interests of other States, regardless of whether they are engaged in space activities or not.[98] Because space debris compromises the future access and use of space - as protected under article I of the OST - it could be argued that the OST requires responsible environmental behavior on the part of all

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[95] Tan, *supra* note 29 at 156.

[96] United Nations Office for Outer Space Affairs, *International Space Law: United Nations Instruments* (UN, 2018) at Article I (2) OST.

[97] *Ibid* at Article I (1) OST.

[98] Tan, *supra* note 29 at 175.

space users.[99] After all, the freedom of use and exploration of outer space is conditional on the preservation of the orbital environment.

The environmental regulation of space activities is dealt with more directly in article IX of the OST, which is the basic provision for all environmental protection in outer space.[100] This provision requires parties to conduct their space activities, including on the Moon and other celestial bodies, so as to:

> "[…] avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose."[101]

Whether Article IX addresses Earth's orbits – the outer space environment at risk by space debris - is questionable. From the wording of the text, it appears that the environmental concern addressed by this provision is the possible contamination of Earth through the introduction of some biological elements, bacteria, or other extraterrestrial matter from outer space. Nonetheless, article IX does impose an obligation on States to conduct their space activities with "due regard to the corresponding interests of all other States Parties to the Treaty."[102] Any activities or experiments that might cause potentially harmful interference with the activities of other States require appropriate international consultations beforehand.[103] The consultation clause in Article IX does not seem concerned with the protection of the space environment per se, but rather with safeguarding other States' space activities.[104] However, it could be argued that an obligation to avoid the creation of space debris – which would endanger and harmfully interfere with the space activities of other States – flows from Article IX.[105] Given the wording of Article IX and States' practice, this argument is somewhat unconvincing. Firstly, the term "appropriate

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[99] Viikari, *supra* note 91 at 59.

[100] Popova & Schaus, *supra* note 20 at 6.

[101] United Nations Office for Outer Space Affairs, *supra* note 96 at Article IX OST.

[102] *Ibid*.

[103] *Ibid*.

[104] George T Hacket, *Space Debris and the Corpus Iuris Spatialis*, Forum for Air and Space Law (Gif-sur-Yvette, France: Editions Frontières, 1994) at 104–120.

[105] Stubbe, "Common but Differentiated Responsibilities for Space Debris", *supra* note 11 at 7.

international consultations" is quite ambiguous, leading to more questions than answers. Moreover, the consultations do not have to lead to a particular result. Nothing in Article IX suggests that the results of the consultations must be taken into account, or that the potentially affected State can bar the harmful space activity from taking place.[106]

While it is true that international consultations and cooperation could provide a positive force for environmental protection, history has shown that the impact of Article IX is limited at best, trivial at worst.[107] As will be discussed in more detail later in this thesis, recent anti-satellite tests have been undertaken by China, the United States, Russia and India. Even though those ASAT tests clearly had the potential to – and in most cases did - create a large quantity of space debris which could endanger the space activities of other spacefaring nations, international consultations were never conducted.[108] Practically speaking, Article IX of the OST does not restrict potentially hazardous space activities, and has had negligible success in addressing the orbital debris problem.[109]

B. Moon Agreement

Despite its name, the Moon Agreement also applies to all other celestial bodies within the solar system, except the Earth.[110] This UN treaty only has one general environmental protection clause which resembles its OST equivalent analysed above.[111] The first sentence of Article 7.1 states that:

> "In exploring and using the Moon, States Parties shall take measures to prevent the disruption of the existing balance of its environment, whether by introducing adverse changes in that environment, by its harmful contamination through the introduction of extra-environmental matter or otherwise."[112]

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[106] Viikari, *supra* note 91 at 61.
[107] *Ibid*.
[108] *Ibid*.
[109] Roberts, "Addressing the Problem of Orbital Space Debris", *supra* note 94 at 60.
[110] United Nations Office for Outer Space Affairs, *supra* note 96 at Article 1.1 Moon Agreement.
[111] *Ibid* at Article IX OST.
[112] *Ibid* at Article 7.1 Moon Agreement.

Once again, it is debatable whether Article 7.1 even applies to Earth's orbits and space debris; the wording of the provision seems to be concerned exclusively with the Moon environment. This provision could theoretically be regarded as a step forward from the OST and offer more elaborate environmental protection, since the term "disruption of the environment" is a more extensive and embracing concept than "harmful contamination".[113] Nevertheless, Article 7 suffers from many of the same ills that plague Article IX of the OST.[114] Terminology such as *harmful contamination* and *adverse changes* are ambiguous and not defined. Just like the Outer Space Treaty, the Moon Agreement also fails to establish a system of sanctions, and it is not clear what consequences stem from a breach of Article 7.1. Article 15.2 of the Moon Agreement mirrors the obligation to enter into international consultations articulated in article IX of the OST. Again though, the lack of enforcement or requirement to respect the results of the consultations make this provision rather trivial.

C. Liability Convention

Responsibility and liability are of focal significance to any discussion on space debris. A strong liability regime for damage induced by orbital debris – whether to the environment or to other States – could indirectly solve the problem by incentivizing States to take more precaution while conducting their space activities. On the other hand, as long as there is uncertainty over who the debris belongs to or originated with, it will be difficult to assign responsibility.

The general rule, articulated in Article VI of the OST, is that States bear international responsibility for their activities in outer space. Article VII of the OST further establishes that launching States are liable for any damage caused to another State Party, whether that damage takes place on Earth, in air space, or in outer space. The 1972 Liability Convention built upon these provisions by establishing two separate regimes for liability, depending on where the damage takes place. The first is one of absolute liability, to be applied in the case of damage

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[113] Viikari, *supra* note 91 at 62.

[114] Roberts, "Addressing the Problem of Orbital Space Debris", *supra* note 94 at 62.

caused by a space object on the surface of the Earth, or to aircraft in flight.[115] The second type of liability is based on fault, and applies when the damage occurs in outer space.[116] Article V of the Liability Convention further specifies that in the case of joint launches, all launching States are jointly and severally liable for any damage caused.[117]

One of the shortcomings of the Liability Convention is that damage is only compensable if it results in the: "loss of life, personal injury or other impairment of health; or loss of or damage to property of States or of persons, natural or juridical, or property of international intergovernmental organizations."[118] Damage to the environment itself is thus excluded. A potential orbital polluter does not need to fear being found liable for causing significant damage to the environment, as long as no damage is caused to property and persons.[119] The Liability Convention does not mention environmental problems such as orbital debris: it is entirely concerned with damages suffered by States, legal, and juridical persons arising from the space activities of other States. This emphasis limits its ability to promote broader environmental protection.[120]

Furthermore, the ambiguous terminology of the Liability Convention sheds doubts on whether it even covers damage caused by space debris. The Liability Convention only applies to damage caused by a space object, which is defined to include the: "component parts of a space object as well as its launch vehicle and parts thereof."[121] This definition is vague, and it is questionable whether it encompasses space debris – which encompass nearly 94% of all officially cataloged objects in orbit.[122] While designing inactive satellite as "space objects" is fairly straightforward, the answer becomes more uncertain with smaller pieces of debris, such as fragmentation debris and microparticulate matter.[123] As was seen Chapter 1, even a 1mm paint flake can cause

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[115] United Nations Office for Outer Space Affairs, *supra* note 96 at Article II Liability Convention.
[116] *Ibid* at Article III Liability Convention.
[117] *Ibid* at Article V Liability Convention.
[118] *Ibid* at Article I (a) Liability Convention.
[119] Viikari, *supra* note 91 at 69.
[120] Roberts, "Addressing the Problem of Orbital Space Debris", *supra* note 94 at 64.
[121] United Nations Office for Outer Space Affairs, *supra* note 96 at Article I (d) Liability Convention.
[122] National Aeronautics and Space Administration, *supra* note 34 at 13.
[123] Viikari, *supra* note 91 at 70.

significant damage to spacecraft in orbit. The implications of whether the term “space object” includes debris, are enormous. If space debris does not qualify as a space object for the purposes of the Liability Convention, the instrument becomes rather meaningless in establishing liability for space activities.[124] Space debris, as the most common and dangerous form of potential damage to space activities, would thus fall outside the scope of international legal regulation.[125]

There is ample debate amongst the legal community on whether space debris falls within the definition of a “space object” or is something distinct altogether. Professor Bin Cheng has written extensively on the matter, arguing that abandonment cannot exist in outer space.[126] Accordingly, non-functional space objects – such as fragmentation debris –retain the status of space objects as per the Liability Convention and remain under the launching State’s jurisdiction.[127] Professor Cheng’s arguments are persuasive at first. Article I.(d) of the Liability Convention does refer to the component parts of a space object, and its launch vehicle and parts thereof. The definition does not differentiate based on the space object’s usefulness or functionality, so there is no reason to assume that fragmentation debris somehow differs from the component parts of a space object.[128]

Nonetheless, given the number of initiatives by the international community to clarify and integrate the terms “space object” and “space debris” together, Professor Cheng’s confidence is perhaps somewhat misplaced. For instance, the 2004 European Code of Conduct for Space Debris Mitigation defines a space object as: “any man-made space system and any of its components or fragments”, and space debris as “any man-made space object including fragments and elements thereof, in Earth orbit or re-entering the Earth's atmosphere, that is non-functional.”[129] This definition clarifies that space objects retain their status even after their breakup, abandonment, or deterioration.

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[124] *Ibid*.
[125] *Ibid*.
[126] Bin Cheng, *Studies in International Space Law* (New York, United States: Clarendon Press ; Oxford University Press, 1997) at 505.
[127] *Ibid* at 505–506.
[128] *Ibid* at 506.
[129] European Space Agency, *European Code of Conduct for Space Debris Mitigation* (2004) at 13–14.

Even in cases where space debris causes indisputable material damage and does fall under the Liability Convention, proving fault and identifying the debris in question is an almost insurmountable obstacle to any successful compensation claim.[130] Not only would the affected party need to identify the launching State associated with the debris that caused the damage; it would also have to prove that there exists such fault (when the incident takes place in outer space) on the part of the launching State so that it can be held liable for damages.[131]

Granted, this situation is typically less complex when damage is caused by space debris re-entering the atmosphere and falling down to Earth.[132] Firstly, there is no need to establish fault because the absolute liability regime applies for any damage caused on Earth or to aircraft in flight.[133] Moreover, objects that are capable of re-entering the Earth’s atmosphere tend to be larger and therefore more likely to be identifiable. Only one claim has ever been brought forward under the Liability Convention: the 1978 Cosmos 954 case, in which a USSR nuclear-powered defunct satellite disintegrated over Northern Canada.[134] The dispute was eventually settled by a protocol between the Canada and the Union of Soviet Socialist Republics in 1981.[135] The specificity of damage, the requirement of fault, and the difficulty in identifying small debris fragments, all contribute to the overall impotence of the Liability Convention.[136]

While some legal scholars have suggested that Article XXI of the Liability Convention could be pertinent in addressing the environmental degradation caused by space activities, the problem is that it fails to cover issues of liability or responsibility, and is at best aspirational.[137] Article XXI covers damage caused by space objects presenting a: “large-scale danger to human life or

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[130] Bittencourt Neto, *supra* note 8 at 169.

[131] Roberts, “Addressing the Problem of Orbital Space Debris”, *supra* note 94 at 65; Viikari, *supra* note 91 at 71.

[132] Viikari, *supra* note 91 at 71, note 63.

[133] United Nations Office for Outer Space Affairs, *supra* note 96 at Article II Liability Convention.

[134] Klinkrad, *supra* note 36 at 3; “Canada: Claim Against the Union of Soviet Socialist Republics for Damage Caused by Soviet Cosmos 954” (1979) 18:4 Cambridge University Press: International Legal Materials 899–930.

[135] *Protocol Between the Government of Canada and the Government of the Union of Soviet Socialist Republics* (United Nations Office for Outer Space Affairs, 1981); Karl-Heinz Böckstiegel & Marietta Benkö, *Space Law: Basic Legal Documents* (Eleven International Publishing, 2005) at A.IX.2.2 1-7.

[136] Tan, *supra* note 29 at 168.

[137] Viikari, *supra* note 91 at 61.

seriously interfering with the living conditions of the population or the functioning of vital centres". This provision could be applicable in the case of large, possibly nuclear, space debris re-entering the atmosphere and posing a danger to the population on Earth. But it might equally be applicable to in-orbit damage to spacecraft caused by debris. The disruption of GPS navigation satellites, for example, would seriously interfere with the functioning of our society. Modern aviation, maritime and land transportation systems, global financial systems, health services, information and communication systems all rely upon Global Positioning Systems.[138] Regardless, the problem with Article XXI is that it only aspires to provide "appropriate and rapid assistance to the State which has suffered the damage, when it so requests".[139] The article therefore does not regulate issues of responsibility or liability, nor does it offer any real environmental protection.[140]

D. Registration Convention

The 1975 Registration Convention requires launching States to register their space objects into a national register.[141] The Secretary-General of the UN must also maintain a register, which is administered by the UN Office for Outer Space Affairs (UNOOSA).[142] Pursuant to article IV of the Registration Convention, States must provide the UN with information on:

a) Name of launching State or States;

b) An appropriate designator of the space object or its registration number;

c) Date and territory or location of launch;

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[138] Stephens & Steer, "Conflicts in Space", *supra* note 49 at 95–96.
[139] United Nations Office for Outer Space Affairs, *supra* note 96 at Article XXI Liability Convention.
[140] Viikari, *supra* note 91 at 69.
[141] Legal Subcommittee, *Convention on Registration of Objects Launched into Outer Space* (United Nations Office for Outer Space Affairs, 1976) at Article II (1).
[142] United Nations Office for Outer Space Affairs, "United Nations Register of Objects Launched into Outer Space", online: *UNOOSA* <https://www.unoosa.org/oosa/en/spaceobjectregister/index.html>; Legal Subcommittee, *supra* note 141 at Article III.

d) Basic orbital parameters;

e) General function of the space object.[143]

One of the principal flaws of the Registration Convention is the requisite level of accuracy for the information provided. In fact, a substantial number of objects launched into space are not registered with the UN at all, even though the Registration Convention would require it. Only 90% of all satellites, probes, and other space objects launched into orbit have been registered with the UN.[144] The non-registration of functional space objects is expected to worsen.[145] While only 8% of space objects were not registered in 2010, that number rose to almost 27% in 2014.[146] Naturally, this is highly concerning. The Liability Convention and Registration Convention work hand in hand, and the information registered with the UN pursuant to the Registration Convention could be crucial in identifying the State(s) involved in a collision between a space object and orbital debris.

An additional complication lies in the fact that the information that States must provide pursuant to the Registration Convention is very basic, and not always useful for the purposes of identification. This is particularly the case with GEO satellites: the orbital parameters information as required by the Convention[147] is practically the same for all GEO satellites, which reside in the same orbital region at around 36,000km from Earth.[148] The registration of the most distinctive orbital parameter for GEO satellites – their location relative to the surface of the Earth – is not required by the Convention, leading to concerns regarding its effectiveness in identifying satellites.[149]

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[143] Legal Subcommittee, *supra* note 141 at Article IV.
[144] *Transparency and Confidence-Building Measures in Outer Space Activities*, Report of the Secretary-General, by United Nations General Assembly, Report of the Secretary-General A/72/65 (United Nations, 2017) at 7.
[145] Simonetta Di Pippo, *IISL-ECSL Symposium "40 Years of Entry into Force of the Registration Convention - Today's Practical Issues"* (United Nations Office for Outer Space Affairs, 2016) at 23.
[146] *Ibid* at 13.
[147] Legal Subcommittee, *supra* note 141 at Article IV (d).
[148] Viikari, *supra* note 91 at 77.
[149] *Ibid*.

Moreover, under the Registration Convention, States can choose to remain silent in the case of explosions, changes in orbital positions, or the fragmentation of their registered space objects.[150] Paragraph 2 and 3 of Article IV only require that States notify the UN of space objects which are no longer in Earth's orbit, or any other additional information according to their own discretion. This is unfortunate, since more detailed registration practices could facilitate the identification of hazardous space debris and provide valuable information on the dangers of certain orbital parameters.[151]

Luckily, these problems are partly remedied by the practice of States in registering their space objects, which often goes beyond the obligations enumerated in the Registration Convention. Many States, such as France and the United States, share information with the UN on both their functional as well as their non-functional space objects.[152] However, this behavior is not uniform and remains at the discretion of each State. The variation in registration practices by States undermines the Registration Convention and compromises the reliability of the UN register.

E. The Rescue Agreement

The 1968 Rescue Agreement provides guidance for situations in which space objects or astronauts have suffered an accident or are in distress. Article 2 requires States to render assistance to spacecraft personnel in distressing situations, while Article 5 instructs States to return space objects found in their territory to the launching State. Nothing in the agreement is truly useful for the purposes of space debris or the environmental deterioration of Earth's orbits.

II. International Actors

Treaties on space law neither expressly prohibit the creation of space debris, nor do they impose an obligation on States or their space actors to remove orbital debris from orbit.[153] Because of the

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[150] Popova & Schaus, *supra* note 20 at 8.
[151] Viikari, *supra* note 91 n 113.
[152] Di Pippo, *supra* note 145 at 20.
[153] Popova & Schaus, *supra* note 20 at 6.

political circumstances around which the Outer Space Treaty was concluded, this first UN space treaty is largely preoccupied with the freedom of exploration and use of outer space, and comparatively little with the need to preserve it from an environmental standpoint. Any protection of the environment from orbital debris appears to be almost incidental.[154] The subsequent UN space law treaties have not rectified the shortcomings of the OST. Quite the opposite: the terms and phraseology used in the treaties – such as "space object", "harmful contamination" and "interference" – are ambiguous, confusing, and leave too much room for interpretation.[155]

Where the UN space treaties have fallen short, other organizations have stepped up. More advanced norms for environmental purposes in the space sector have been proposed by other organs at the international level, such as the International Telecommunication Union (ITU), the Inter-Agency Space Debris Coordination Committee (IADC), and the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS).

A. International Telecommunication Union

UN space treaties and principles play a fundamental role in the regulation of the outer space environment. But given the vagueness of their terminology, one of the most important actors in the regulation of the international space sector – in practice – has been the International Telecommunication Union (ITU).[156] Established in 1865, the ITU is a specialized UN organization which initially regulated radiocommunications, and later expanded to the telecommunication sector. The ITU strives to guarantee undisturbed telecommunication services in outer space, and the instruments it has at its disposal have relevance from an environmental point of view. The ITU has three major functions regarding satellite communications: it regulates the use of the radio spectrum, sets international equipment and other technical and operational standards for telecommunications, and has an important role in the utilization of GEO.[157]

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[154] Tan, *supra* note 29 at 157.
[155] Cheng, *supra* note 126 at 492.
[156] Viikari, *supra* note 91 at 85.
[157] Francis Lyall, *Law and Space Telecommunications* (Aldershot Hants England: Dartmouth, 1989) at 311.

Through the allocation of radio frequencies, the ITU maximizes the effective use of the radio spectrum. The spectrum allocation information is then constantly monitored and made public, which helps minimize any harmful frequency interference.[158] Because virtually all States use telecommunications and share a common interest in guaranteeing undisturbed telecommunication activities, the ITU has virtually global adherence with 193 member States.[159]

Although radio frequency interference could be considered an environmental problem of sorts, more interesting for the purposes of this thesis is the ITU's regulation regarding the use of GEO. The ITU has long been concerned with the physical overcrowding of GEO, from both functional satellites, and non-functional debris.[160] It voiced its concern already in the 1970s, maintaining that GEO was a limited natural resource, to which all States were entitled equitable access.[161] This concern was enshrined in Article 44.2 of the ITU Constitution, which reads:

> "Member States shall bear in mind that radio frequencies and any associated orbits, including the geostationary-satellite orbit, are limited natural resources and that they must be used rationally, efficiently and economically".[162]

Space debris threatens the safe operation of GEO satellites, and because of the orbit's dynamics, debris in GEO will remain there essentially forever. In 2010, the ITU adopted the IADC's recommendation on the environmental protection of GEO, which called upon member States to transfer their GEO satellites at the end of their lifetime to a "graveyard orbit" high above GEO.[163] It further required that every reasonable effort be made to release as little debris as possible during the placement of a satellite in GEO.[164] However, these recommendations are non-binding and questions remain whether the ITU is best placed and equipped to deal with the

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[158] Jakhu & Pelton, *supra* note 5 at 282.
[159] International Telecommunication Union, "ITU Membership", (2021), online: *ITU* <https://www.itu.int/en/myitu/Membership>.
[160] Viikari, *supra* note 91 at 87.
[161] *Ibid*.
[162] International Telecommunication Union, *Constitution of the International Telecommunication Union* (ITU, 2019) at Article 44 (2).
[163] Radiocommunication Sector of ITU, *RECOMMENDATION ITU-R S.1003-2* - Environmental protection of the geostationary-satellite orbit* (2010) at 3.
[164] *Ibid*.

space debris challenge. The ITU's role is more that of a coordinator rather than a regulator.[165] The space environment and the safety of satellite operations face increasingly severe challenges; it is unlikely that they can be overcome by an organization whose primary goal is to guarantee telecommunication services free from interference, and which has no enforcement mechanism to ensure compliance.[166]

Competition for GEO orbital slots – and the radio spectrum that comes with it - has intensified in the last decades. Some actors have begun to file requests for satellite frequency bands and orbital positions prematurely and in excessive quantity. This begun with the small nation of Tonga in 1988 which, after applying for several orbital slots and satellite frequency assignments, proceeded to rent and auction those out to other operators.[167] Since then, the over-filing for the registration of desirable orbital positions and frequency bands has become a common occurrence. The phenomenon has been nicknamed the "paper satellite problem", since States have taken to registering non-existent (at least yet) satellites to secure orbital positions.[168] The consequences of the paper satellite problem include a considerable increase in the workload of the ITU, and an erosion of its effectiveness. Over-filing has lengthened the timeframes for the ITU coordination process, which today takes several years.[169]

This problem is likely to be exacerbated with the coming into play of small satellite constellations in LEO, which are covered by ITU regulations to the extent that they use radio frequencies. These large constellations will test existing regulations, and the 'first come first served' approach to assigning frequencies and orbital slots.[170] For instance, the ITU will have to define more clearly what is means for a constellation to be 'brought into use', and thus eligible to benefit from ITU's legal protection against harmful interference.[171] Are all frequencies associated with a satellite constellation brought into use with the launch of the first satellite, or

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[165] Viikari, *supra* note 91 at 88.
[166] *Ibid* at 88–89.
[167] Iulia-Diana Galeriu, "'Paper Satellites' and the Free Use of Outer Space", (April 2018), online: *NYU Law Global* <https://www.nyulawglobal.org/globalex/Paper_satellites_free_use_outer_space1.html>.
[168] *Ibid*.
[169] Viikari, *supra* note 91 at 90; Galeriu, *supra* note 167.
[170] Galeriu, *supra* note 167.
[171] West, *supra* note 16 at 17.

when the entire constellation is deployed? Coordination questions such as these must be answered to avoid confusion, and the dangerous overcrowding of orbits that are already seeing increasingly intensive utilization.

B. Inter-Agency Debris Coordination Committee

Founded in 1993, IADC is an international technical body composed of national space agencies, whose purpose is to address space debris issues, encourage cooperation on space-debris related research, and identify options for debris mitigation.[172] As covered in Chapter 1, the IADC filled a huge gap in UN space law by defining the term space debris as: “all man-made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional”.[173] Another important contribution of the IADC is its work in debris mitigation. In 2001, UNCOPUOS requested that the IADC issue a set of voluntary space debris mitigation guidelines, which were formulated in 2002 and developed into a refined version in 2007.[174] The guidelines identify the best practices, core recommendations, and commonly accepted standards in relation to the mitigation of space debris, and apply to multiple orbits, including LEO[175] and GEO.[176] The IADC debris mitigation guidelines’ objectives are threefold: 1) to limit the creation of debris released during normal space operations; 2) to minimize the potential for on-orbit break-ups and collisions, and; 3) to facilitate the removal of non-operational space objects from densely populated orbits.[177] In GEO, the removal of satellites is achieved by transferring them to an orbit at least 235km above GEO[178], while in LEO the IADC guidelines suggest a 25-year post-mission orbital lifetime limit, after which satellites must de-orbit back into the atmosphere.[179]

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[172] Muelhaupt et al, *supra* note 56 at 85.
[173] Inter-Agency Space Debris Coordination Committee, *supra* note 13 at 6.
[174] Pelton, *supra* note 6 at 4–5.
[175] Inter-Agency Space Debris Coordination Committee, *supra* note 13, s 3.3.2(1).
[176] *Ibid*, s 3.3.2(2).
[177] *Ibid*, s Introduction.
[178] *Ibid*, s 5.3.1.
[179] *Ibid*, s 5.3.2.

There are several concerns with the IADC Space Debris Mitigation Guidelines. The first one is that the guidelines do not impose very restrictive mitigation strategies, even though the constant growth of space debris would require it. As a collection of the least demanding recommendations and common practices of the various space agencies and private actors that comprise the IADC, the guidelines do not introduce any major innovations in the area of debris mitigation.[180] It should for example be considered whether the 25-year post-mission disposal rule is up to date with the expected mega satellite constellations that will soon be released in LEO.[181] The historical failure rate of space objects is approximately 15%.[182] For a constellation of two thousand (2000) satellites with a 5-year lifetime, that means approximately 60 failed satellites a year, or 300 satellites in total. This is clearly unacceptable. Even in an optimistic scenario where the compliance rate with the IADC guidelines is practically perfect, simulation campaigns have shown that the proliferation of debris in LEO will continue.[183]

Moreover, and equally as important, the IADC Guidelines are not legally binding and do not create rules of international law. It is true that the guidelines have been adopted by several States, which have incorporated them into their own national space programs.[184] Countries which directly use the IADC guidelines - or which have their own debris mitigation guidelines that are consistent with the IADC's guidelines - include the US, Japan, France, Italy, and the UK.[185] Nonetheless, States are in principle free to decide how, if at all, to conform to their requirements.[186] Compliance with the guidelines is achieved on a voluntary basis and cannot be legally enforced: having the status of recommendations, their violation or non-observation does not give rise to international responsibility or sanctions.[187]

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[180] Viikari, *supra* note 91 at 96, 247.

[181] Popova & Schaus, *supra* note 20 at 11; Timothy Maclay, Walt Everetts & Doug Engelhardt, "Op-ed | Responsible satellite operations in the era of large constellations", (23 January 2019), online: *SpaceNews* <https://spacenews.com/op-ed-responsible-satellite-operations-in-the-era-of-large-constellations/>.

[182] Muelhaupt et al, *supra* note 56 at 83.

[183] Popova & Schaus, *supra* note 20 at 3.

[184] Jakhu & Pelton, *supra* note 5 at 281.

[185] *Ibid* at 288.

[186] Patricia W Birnie & Alan E Boyle, *International law and the environment*, xxvii, 563 p. (Oxford : New York: Clarendon Press ; Oxford University Press, 1992) at 26.

[187] Jakhu & Pelton, *supra* note 5 at 288.

C. United Nations Committee on the Peaceful Uses of Outer Space

The United Nations serves as a useful forum for States to come together and address the growing challenges in outer space. The UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) is the principal international body responsible for the development of international law in outer space: the five UN space treaties were developed under its supervision.[188] Established in 1959, the UNCOPUOS has two subcommittees: the Legal Subcommittee and the Scientific and Technical Subcommittee, both of which operate on the basis of consensus. Long concerned about the sustainability of outer space and orbital debris management, the UNCOPUOS has included the issue of space debris as a separate annual agenda item since 1994.[189] In 2007, the Scientific and Technical Subcommittee adopted its own space debris mitigation guidelines based on the IADC guidelines. The guidelines – which are also not legally binding under international law - are intended to be considered for the mission planning, design, manufacture and operational (launch, mission, disposal) phases of spacecraft.[190] The guidelines are as follows:

> "Guideline 1: Limit debris released during normal operations";
>
> "Guideline 2: Minimize the potential for break-ups during operational phases";
>
> "Guideline 3: Limit the probability of accidental collision in orbit";
>
> "Guideline 4: Avoid intentional destruction and other harmful activities";
>
> "Guideline 5: Minimize potential for post-mission break-ups resulting from stored energy";

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[188] Muelhaupt et al, *supra* note 56 at 85.

[189] *Report of the Scientific and Technical Subcommittee on the Work of its Thirty-First Session*, by UN Committee on the Peaceful Uses of Outer Space (Vienna: United Nations, 1994) at paras 63–74.

[190] United Nations Office for Outer Space Affairs, *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space* (United Nations, 2010) at 2.

> "Guideline 6: Limit the long-term presence of spacecraft and launch vehicle orbital stages in the ... [LEO] region after the end of their mission"; and
>
> "Guideline 7: Limit the long-term interference of spacecraft and launch vehicle orbital stages with … [GEO] region after the end of their mission".[191]

UNCOPUOS has 93 member States as well as a number of non-governmental organizations that have been granted observer status.[192] The fact that all major spacefaring countries take part in the work of the Scientific and Technical Subcommittee is encouraging, and has in practice facilitated the approval and implementation of the guidelines on the international level. Nevertheless, there is consternation that the UNCOPUOS mitigation strategies are even less stringent that the IADC guidelines. With regards to post-mission disposal, the UNCOPUOS guidelines do not specify at what altitude GEO satellites must be de-orbited, nor do they reference the 25-year rule for LEO satellites. Part of the problem lies the fact that negotiations at UNCOPUOS take place on the basis of consensus.[193] Just like with the IADC guidelines, this has resulted in watered-down outcomes.[194] As one legal scholar put it: "To achieve the compromise required for consensus, lengthy negotiations and national policy rivalries often overshadow the critical issues."[195] With space becoming increasingly accessible and the number of space actors growing, the UNCOPUOS will find it increasingly difficult to reach consensus decisions.

Moreover, just like the IADC guidelines, the UNCOPUOS guidelines remain voluntary at the international level. The effectiveness of those mitigation strategies thus depends on the responsible actions of the spacefaring community as a whole, which is difficult to achieve without enforcement mechanisms. Another concern that has been raised is that the UN is very government-centric, and that the private industry and academia are not always well-

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[191] *Ibid* at 2–4.
[192] United Nations Office for Outer Space Affairs, "Members of the Committee on the Peaceful Uses of Outer Space", (2021), online: *UNOOSA* <https://www.unoosa.org/oosa/en/members/index.html>.
[193] Pelton, *supra* note 6 at 84.
[194] Viikari, *supra* note 91 at 100.
[195] Howard A Baker, "Protection of the Outer Space Environment: History and Analysis of Article IX of the Outer Space Treaty Space Law" (1987) 12 Annals Air & Space L 143–174 at 165.

represented.[196] With the private sector increasingly involved in space activities, there is a risk of dissonance between the mitigation strategies UNCOPUOS puts in place and the measures that are actually needed to adequately address the space debris problem. Given their knowledge and expertise, academia and private entities should be more thoroughly included in the UNCOPUOS negotiation processes since they could offer valuable insights on space debris regulation and mitigation.[197]

III. Concluding Remarks

Concerningly, space debris is neither mentioned nor defined in international law. While more advanced norms for debris mitigation have been proposed by organizations at the international level, these soft-law instruments and recommendations are non-binding and do not place an enforceable duty on States. The diversity of the stakeholders involved, the growth of space activities and of human reliance on space applications, and the need for long-term management of the orbital environment, all indicate the need for clear, persistent and extensive environmental regulations for highly used orbits in LEO and GEO.[198]

Chapter 3 – New Threats to the Sustainability of Outer Space

The last decade has seen an explosion in commercial and private space activities. Terms like "NewSpace" and "Space 2.0" are often used to describe this global trend towards developing faster and cheaper access to space, which is distinct from more traditional government-driven activities focused on politics, security, and science.[199] As this Chapter will demonstrate, there are sweeping changes transpiring in the space environment. NewSpace represents a significant break with past experience: growth in the number of objects in space, growth in the number and diversity of operators, diversity in the types of activities in space, and changing satellite

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[196] Lal et al, *supra* note 3 at 76–77.
[197] *Ibid* at 75.
[198] Viikari, *supra* note 91 at 117.
[199] Muelhaupt et al, *supra* note 56 at 80.

technology.[200] While satellites bring with them important benefits to humanity, it is imperative to proceed responsibly so as not to exacerbate the space debris problem.

I. Commercialization of Outer Space

Although the United States, Russia, and European governments are still dominant players in the space arena, where government programs experience capability gaps, commercial services have stepped in. In the United States, increased investment and participation by the private sector is changing the commercial space industry: more than 200 start-up space ventures received roughly 21.8 billion in investment since 2000.[201] European States, Japan, and China are also supporting greater investment in commercial space activities. Full State ownership of space programs has now given way to a mixed system in which commercial space actors receive significant government and military contracts, and a variety of subsidies. Governments across the world are increasingly supporting technological research and development, subsidizing space industries, adopting enabling policies and regulations, and purchasing commercial services.[202] Future market growth will become increasingly driven by commercial operators.

Modern-day national space policies place great emphasis on maintaining a robust and competitive space industry, whilst simultaneously encouraging partnerships with the private sector.[203] For instance, the 2015 U.S. Commercial Space Launch Competitiveness Act was intended to facilitate a pro-growth environment for the development of the commercial space sector.[204] Under Title IV—Space Resource Exploration and Utilization – federal agencies are tasked with facilitating the right of American citizens to engage in commercial space activities and the commercial recovery of space resources, in accordance with the United States' international obligations.[205] This objective was reiterated in the 2020 National Space Policy, which emphasizes the importance of a commercial space sector that supports U.S. needs, is

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[200] Lal et al, *supra* note 3 at 81.
[201] West, *supra* note 16 at 79.
[202] West, *supra* note 1 at 94.
[203] West, *supra* note 16 at xiii.
[204] Jakhu & Pelton, *supra* note 5 at 283.
[205] 114th US Congress, *U.S. Commercial Space Launch Competitiveness Act* (GPO, 2015) at 18–20.

globally competitive, and advances U.S. leadership in the next generation of new markets, innovation, and entrepreneurship.[206]

Outside of the United States as well, public-private collaboration in outer space is flourishing. In the 2016 Space Strategy for Europe, the European Union (EU) and the European Space Agency (ESA) came together to protect and develop their mutual interests in space, and emphasized the need to keep the EU's private and public space industries competitive.[207] Fittingly, the ESA supports over 140 start-ups each year.[208] In China as well, the government-led space industry was opened to private investment in 2014, although private-sector space activities remain tied to China's national goals.[209] India recently produced a bill on space activities which promotes the country as a hub for commercial space activities, positions India as a satellite-manufacturing nation, and encourages the use of Indian rockets for satellite launches.[210]

II. Democratization of Outer Space

The commercialization of space has led to the democratization of the outer space environment. Unlike the 1950s and 60s, space is no longer the playground for wealthy States and well-resourced academia.[211] The costs of producing and launching satellites has dropped dramatically: during the Shuttle era in the 1980s a payload cost an average of 30,000 USD per kg; today, that

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[206] "U.S. Secretary of Commerce Wilbur Ross Applauds New National Space Policy That Drives American Leadership in Space Commerce", (December 2020), online: *US Department of Commerce* <https://www.commerce.gov/news/press-releases/2020/12/us-secretary-commerce-wilbur-ross-applauds-new-national-space-policy>.

[207] European Commission, *Space Strategy for Europe* (2016).

[208] The European Space Agency, "ESA - The ESA 500: fostering start-up companies to use space technology on Earth", (18 September 2017), online: *ESA.int* <https://www.esa.int/Newsroom/Press_Releases/The_ESA_500_fostering_start-up_companies_to_use_space_technology_on_Earth>.

[209] West, *supra* note 16 at 92.

[210] Vidhi Bubna, "The upcoming Space Activities Bill in India and what it needs to address", (11 September 2020), online: *Modern Diplomacy* <https://moderndiplomacy.eu/2020/09/11/the-upcoming-space-activities-bill-in-india-and-what-it-needs-to-address/>.

[211] David Livingstone & Patricia Lewis, "Space, the Final Frontier for Cybersecurity?", (September 2016), online: *Chatham House – International Affairs Think Tank* <https://www.chathamhouse.org/2016/09/space-final-frontier-cybersecurity> at 9.

number is down to 5,000 USD per kg.[212] This has made space accessible to more countries and private companies than ever before.[213] Over eleven new space agencies were approved or proposed in 2018 alone by countries which include Egypt, Greece, Turkey, and the Philippines, while New Zealand, Costa Rica and Kenya, amongst others, all launched their first satellite into orbit.[214] For some, space capabilities represent a technological achievement and a source of national prestige. For others, dependence on space-based technology simply requires additional space infrastructure. The democratisation of space has led to a blooming market, which is predicted to increase in value exponentially in the next few years. The global space economy, estimated to be worth nearly $350 billion in 2018, is expected to grow to well over $1 trillion by 2040.[215]

The human use of the space domain seems to be approaching a turning point. As the First United Nations Conference on Space Law and Policy noted in 2018, the growing number of private and public space actors is creating new opportunities, but also challenges to the safety, security, and sustainability of outer space activities.[216]

III. Satellite Constellations

One of the greatest challenges to the long-term sustainability of future space activities lies with the proposals and ongoing deployment of satellite constellations in LEO. Even if only a fraction of the constellations currently being proposed are deployed, the coming decade may see the launch of thousands – possibly tens of thousands – of small satellites in LEO.[217] The total

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[212] Bhavya Lal et al, "Strategic Role of Government in Space Commercialisation" *Room: The Space Journal* (2019) 20.

[213] Lal et al, *supra* note 3 at 9.

[214] West, *supra* note 16 at 69–70.

[215] Jeff Foust, "A Trillion-Dollar Space Industry Will Require New Markets", (6 July 2018), online: *SpaceNews* <https://spacenews.com/a-trillion-dollar-space-industry-will-require-new-markets/>.

[216] *Report on the United Nations/Russian Federation Conference on Space Law and Policy*, by UN Committee on the Peaceful Uses of Outer Space, A/AC.105/1195 (Moscow, Russia: United Nations, 2018).

[217] Lal et al, *supra* note 3 at 1.

number of satellites in orbit is expected to increase at a much higher rate than seen historically, heightening the risks of collision. [218]

Constellations in LEO can range from just a handful to several thousand satellites. Satellites are often categorized based on their weight as well as function. Under the broadest definition, satellites that have a mass of less than 500kg are considered to be “smallsats”.[219] The technical terms for lighter satellites include: “microsatellites” (10-100kg), “nanosatellites” (1-10kg) and “picosatellites” (0.1 – 1kg).[220] “Cubesats” have the same weight as “nanosatellites” but have a standardized cube-like structure based on 10-cm wide units, hence their name.[221] For the purposes of this thesis, the broader term of “smallsats” will be used to refer to satellites in LEO constellations.

A. Uses for *Smallsat* Constellations

The smallsat constellation business model is thriving because of their low-production costs, and the unique services that they can provide. The low-cost of smallsats minimizes the financial risks for companies and start-ups, significantly facilitating new entries into the market. Because they can be developed for a fraction of the cost of conventional satellites, smallsats have revolutionized access to space for universities, civil-society, and start-ups around the world.[222]

In the 1990s, smallsats were used predominantly for educational purposes.[223] Nowadays too, smallsats are used to conduct educational, scientific, and observation missions. High-resolution Earth-imaging is a lucrative commercial application for smallsat constellations, which can be used to track forest fires, find water sources, and monitor agricultural crops.[224] The constellation

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[218] Muelhaupt et al, *supra* note 56 at 80.

[219] Bastida Virgili & Krag, *supra* note 52 at 1.

[220] West, *supra* note 16 at 161.

[221] *Will Maturing Cubesat Propulsion Call for More Regulation?*, by European Space Policy Institute, ESPI Briefs 25 (2018) at 1.

[222] *Ibid*.

[223] Bastida Virgili & Krag, *supra* note 52 at 1.

[224] West, *supra* note 16 at 44.

of over 150 5-kg smallsats produced by *Planet*, for example, provides daily Earth-imaging services to a variety of governmental and private actors based on a subscription model.[225]

Commercial plans to use large constellations of satellites to provide global broadcast services have accelerated in recent years. Companies such as *OneWeb* and *SpaceX* plan to use smallsat constellations to provide broadband internet services, and meet the growing demand for data caused by technological advances such as artificial intelligence, virtual reality, and the Internet of Things.[226] Unlike satellites at higher orbits, smallsats in LEO can provide near real-time broadband internet services across the globe.[227] Whereas GEO satellites benefit from remaining at the same point over the Earth, they do incur a longer transmission delay due to the latency associated with a higher orbital altitude.[228] Satellites in LEO, which orbit the Earth less than 2,000km away, can overcome this problem and thus provide a unique service that is transforming the communications sector.

B. Satellite Constellations – Past and Present

In the past ten years, the number of smallsats launched as part of a larger constellation has grown by a factor of ten, from as few as 20 satellites in 2011 to nearly 200 in 2019.[229] The trend towards smaller satellites and larger constellations is glaring; satellite constellations are expected to become the space-market growth-driver within the next few years. By 2022, the smallsats market is forecast to exceed 7 billion USD, with an annual growth rate of just over 20%.[230]

Two dozen companies, when taken together, have proposed placing well over 20,000 satellites in LEO over the next 10 years, as seen in Figure 1.4.[231] Although many of these constellations may

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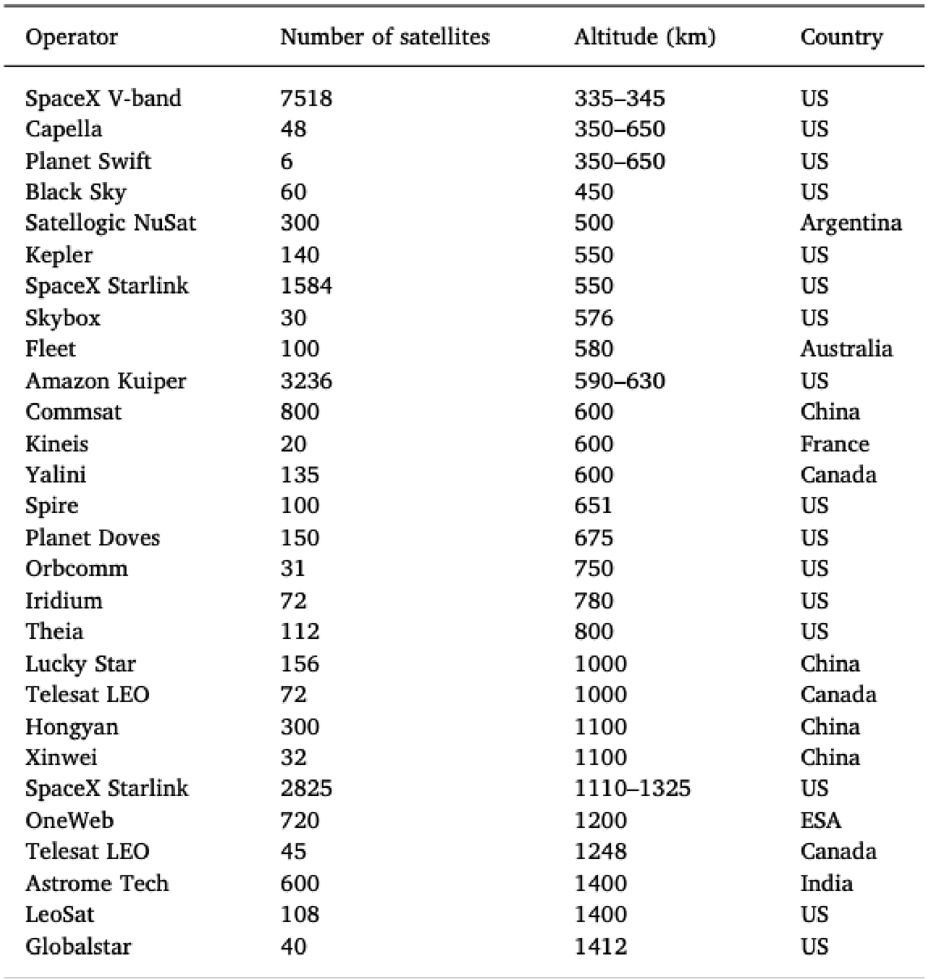
[225] Planet, "Our Approach: Aerospace Know-How Meets Silicon Valley Ingenuity", (2021), online: *planet.com* <https://planet.com/company/approach/>.
[226] West, *supra* note 16 at 80.
[227] Trevor Lafleur, Ane Aanesland & Dmytro Rafalskyi, "Miniaturising Propulsion Systems for Small Satellites" *Room: The Space Journal* (2019).
[228] *Ibid*.
[229] *Nano/Microsatellite Forecast, 10th Edition (2020)*, Forecast Report, by Caleb Williams, Forecast Report 10th Edition (SpaceWorks, 2020) at 7.
[230] Lafleur, Aanesland & Rafalskyi, *supra* note 227.
[231] Muelhaupt et al, *supra* note 56 at 80; Maclay, Everetts & Engelhardt, *supra* note 181.

never be launched as listed, according to the latest data, approximately 6,200 small satellites are expected to be launched between 2017 and 2026: two-thirds of them for various commercial organizations, and the remaining for civilian and military agencies in over 60 countries.[232] According to the aerospace engineering company *SpaceWorks Enterprise*s, more than 2,400 small satellites could be launched by 2025.[233] For perspective, only around 8,100 payloads have been placed in Earth's orbits over the entire history of the space age.[234]

Figure 1.4 Some of the announced NewSpace constellations [235]



Operator	Number of satellites	Altitude (km)	Country
SpaceX V-band	7518	335–345	US
Capella	48	350–650	US
Planet Swift	6	350–650	US
Black Sky	60	450	US
Satellogic NuSat	300	500	Argentina
Kepler	140	550	US
SpaceX Starlink	1584	550	US
Skybox	30	576	US
Fleet	100	580	Australia
Amazon Kuiper	3236	590–630	US
Commsat	800	600	China
Kineis	20	600	France
Yalini	135	600	Canada
Spire	100	651	US
Planet Doves	150	675	US
Orbcomm	31	750	US
Iridium	72	780	US
Theia	112	800	US
Lucky Star	156	1000	China
Telesat LEO	72	1000	Canada
Hongyan	300	1100	China
Xinwei	32	1100	China
SpaceX Starlink	2825	1110–1325	US
OneWeb	720	1200	ESA
Telesat LEO	45	1248	Canada
Astrome Tech	600	1400	India
LeoSat	108	1400	US
Globalstar	40	1412	US

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[232] Lal et al, *supra* note 3 at 9, iii.
[233] Williams, *supra* note 229.
[234] Muelhaupt et al, *supra* note 56 at 80.
[235] *Ibid* at 81.

In the United States alone, the Federal Communications Commission (FCC) approved requests for over 8,000 satellites in 2018. Notably, *SpaceX* was licensed to launch a second *Starlink* constellation of over 7,000 satellites in LEO at an altitude of 350km.[236] Several other companies also won approval for expanded services using satellite constellations in LEO. The Canadian firm *Telesat* gained approval for a constellation of 117 satellites, while *Keppler Communications* was permitted to deploy a constellation of 140 satellites.[237] New, non-traditional space companies such as Facebook, Amazon and Google are also seeking to join the market: Amazon recently hinted at an upcoming constellation of 3,236 satellites in LEO to provide broadband internet service, while Google also secured a license for a constellation comprising of approximately 1,000 satellites.[238] According to the Union of Concerned Scientists, there were 3,372 operational satellites in all orbits in January 2021.[239] This figure puts LEO satellite constellations into perspective: the SpaceX constellation alone is planned to contain an excess of 7,000 satellites.[240]

C. Dangers of Smallsat Constellations

Satellite constellations in LEO pose different dangers depending on their altitude. Large constellations operating at low altitudes can have a substantial effect on spaceflight safety when the constellation is active. Constellations at higher altitudes could have a long-term effect on the orbital environment, since any malfunction would leave space debris in orbit for decades because of the lack of atmospheric drag.

Various studies have been conducted on the dangers large satellite constellations pose to the sustainability of outer space. A constellation of around 3,000 satellites operating in LEO at 600km, could potentially create 600-900 pieces of debris larger than 10cm for the time during

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[236] West, *supra* note 16 at 20.

[237] *Ibid*.

[238] Business Insider, "Satellite Space Race Between Amazon, SpaceX, Google, OneWeb and Telesat", (9 May 2019), online: *Business Insider India* <https://www.businessinsider.in/indiainsider/amazon-spacex-google-oneweb-and-telesat-battle-in-outer-space/slidelist/69244932.cms>.

[239] Union of Concerned Scientists, *supra* note 26.

[240] West, *supra* note 16 at 20.

which the constellation is active.[241] Simulation exercises have also been conducted on the expected number of collisions resulting from large satellite constellations operating in LEO. These simulations have found that for the SpaceX projected constellation of 7,000 smallsats, one annual collision can be expected to materialize during the first 20 years in orbit, gradually increasing and reaching a peak of 8 annual collisions.[242] The dangers of smallsat constellations stem from a number of causes, which will be further analyzed below.

1. Self-conjunctions

Satellite constellations pose a collision risk not only to other operational space objects in LEO; a large constellation must also consider dangerous, close approaches with itself. The potential for collisions within a constellation is troubling. Depending on the configuration of the constellation, an operator could see thousands of self-conjunctions warnings each day.[243] A recent study conducted by the European Space Agency estimates that just one large smallsat constellation could increase the number of conjunctions by a factor of 70 compared to today.[244] Once SpaceX launches its proposed constellation of 7,000 satellites, it will receive an estimated 7.2 million conjunction warnings per year.[245] Granted, conjunction warning messages have a significant error ellipse of 100km or more; the actual number of projected collisions if the warnings are not heeded are only 2-3 collisions a year. [246] While low, this number is still unacceptable – the Iridium-Cosmos collision in 2009 demonstrated the impact a singular event can have on the stability of the orbital environment. Clearly, it will be extremely difficult for satellite operators to sort through the enormous haystack of conjunction warnings and find the 'needles'.[247]

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[241] Muelhaupt et al, *supra* note 56.
[242] Lal et al, *supra* note 3 at 18–19.
[243] Muelhaupt et al, *supra* note 56 at 83.
[244] B Bastida Virgili et al, "Risk to Space Sustainability from Large Constellations of Satellites" (2016) 126 Acta Astronautica (Space Flight Safety) 154–162.
[245] Lal et al, *supra* note 3 at 19.
[246] Muelhaupt et al, *supra* note 56 at 83; Lal et al, *supra* note 3 at 19.
[247] Muelhaupt et al, *supra* note 56 at 83.

2. Difficulties in Identification

The increased risk of self-conjunctions within a constellation is accompanied by another dangerous trend, which is the miniaturisation of satellites.[248] Nanosatellites and picosatellites – whose weight ranges from 10kg to 0.1kg - might be too small to be accurately identified and tracked by surveillance systems, making them invisible for collision avoidance.[249] Despite their relatively light mass, nanosatellites and picosatellites travelling at nearly 30,000km an hour can reach sufficient impact energies to cause catastrophic break-ups if collisions do occur. Cubesats too, which thanks to improved technology have small cross-sections, antennas and solar panels, are more difficult to observe.[250] Even the U.S. Space Command – which has at its disposal the most innovative tracking technology yet- reports that it is struggling with the identification of new, small satellites.[251]

3. Manoeuvrability

Much like a busy motorway during rush-hour, more satellites in orbit means a higher probability of collision. But unlike cars, smallsats in constellations have restricted manoeuvring capability, and are unable to perform collision avoidance or deorbit manoeuvres.[252] Because they lack onboard propulsion capabilities, once smallsats are placed in a specific orbit they are essentially stuck there.[253] While atmospheric drag will eventually cause the satellites to deorbit, that process could take years and in the meanwhile pose a significant risk to all other satellites.

4. Disposal and Transit

Smallsat constellations will require frequent replacement given the satellites' short lifespans.[254] The development of manoeuvring capabilities for smallsats, both through thrusters and other passive means, is currently underway and will be explored more thoroughly in Chapter 5. Some

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[248] European Space Policy Institute, *supra* note 221.
[249] Bastida Virgili & Krag, *supra* note 52 at 1.
[250] Lal et al, *supra* note 3 at 17.
[251] David Todd, "Space Launch Industry Analysis" *Room: The Space Journal* (2019) at 40.
[252] Muelhaupt et al, *supra* note 56 at 85.
[253] Bastida Virgili & Krag, *supra* note 52 at 1.
[254] Muelhaupt et al, *supra* note 56 at 83.

private companies have proposed the use of low-thrust electric propulsion systems, which would spiral satellites down to Earth's atmosphere over a period of several months.[255] While this technology could accelerate atmospheric re-entries and thus be beneficial, it does pose dangers of its own.

Disposal and replacement maneuvers for smallsat constellations will see potentially thousands of satellites transitioning each year through different orbits and posing a risk to functional satellites in those regions. Satellites will have to transit through lower orbits where the Hubble Telescope, the ISS, and other critical LEO satellites operate.[256] Failures are expected to occur not only within the operational constellation, but also among deorbiting satellites. The traffic up and down LEO will be substantial, and failures could leave hundreds of satellites stranded along the transit paths, permanently increasing the collision risk. [257]

5. Low reliability

The smallsat market rewards cost minimisation and fast production processes. Gone are the lengthy, formal, high-cost and rigorous satellite inspections; gone are the testing, analysis, and documentation phases that have characterized satellite production in the past.[258] In terms of risk and reliability, failures in large constellations can be tolerated since there is safety in numbers. Failed satellites can be actively replaced thanks to a flexible network approach to their interconnection.[259] Consequently, smallsats part of a constellation do not go through stringent quality control processes, are not very reliable, and typically have planned operational lifetimes of 5-10 years so as to achieve lower-cost and higher production rates, while also enabling rapid technology refresh.[260] According to cubesat data released in 2015 by the Orbital Debris Program

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[255] ThrustMe, "Our Missions: Successful Tests of the First Iodine Electric Propulsion System in Space", (2021), online: *thrustme.fr* <https://www.thrustme.fr/why-space-propulsion>.
[256] Muelhaupt et al, *supra* note 56 at 81.
[257] *Ibid*.
[258] Roger Dewell, "The Changing Economics of Space" *Room: The Space Journal* (2019) at 30.
[259] *Ibid*.
[260] Muelhaupt et al, *supra* note 56 at 81,86.

Office at NASA, up to 18% of cubesats are unresponsive upon arrival or within their first week in space.[261]

IV. Militarization of Outer Space

The commercialization and democratization of outer space are not the only growth-factors for the proliferation of space debris. The growing interdependence between satellites and questions of national security makes space assets potential targets of military attacks.[262] The more States are dependent on military satellites, the more they have to lose if their space infrastructure is attacked.[263] Space systems for intelligence gathering, communications, and navigation are thus a critical point of military vulnerability.

A. Space Law and the Peaceful Use of Outer Space

The use of outer space for peaceful purposes is a fundamental principle of space law articulated in all five UN space treaties. Yet, what comprises a non-peaceful use of outer space is a complicated question. Article IV of the *1967* Outer Space Treaty prohibits the placement of weapons of mass destruction, the establishment of military bases, the testing of weapons, and the conduct of military manoeuvres in outer space.[264] Nevertheless, some military uses and activities are consistent with the peaceful use of outer space. There is general agreement amongst legal commentators that peaceful in the context of outer space law means "non-aggressive".[265] This position is overwhelmingly supported by State practice. Satellites can therefore be used for military applications such as communications, reconnaissance, imaging, and remote sensing.

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[261] West, *supra* note 16 at 7.
[262] Jakhu & Pelton, *supra* note 5 at 273.
[263] *Ibid* at 296.
[264] United Nations Office for Outer Space Affairs, *supra* note 96 at Article IV.
[265] Jakhu & Pelton, *supra* note 5 at 285.

B. Military Importance of Outer Space Emphasized on the National Level

As the world's militaries become increasingly reliant on space systems, the prospect that conflict on Earth will spill into outer space becomes more likely.[266] Current geopolitical competition is fueling the militarization of outer space, and heightening the incentives to devise cyber espionage, interference, and attack strategies against rivals' space operations.[267]

Space is both literally and figurately the ultimate high ground,[268] and its military importance is being emphasized on the national level. The United States has recently reoriented its military organization and capabilities to maintain core military functions in the event of warfare in outer space. In March 2018, the U.S. White House released the America First National Space Strategy, aimed to ensure U.S. leadership and success in outer space through strategic competition.[269] Based on four pillars—resilient and defensive space architecture, deterrence and warfighting options, foundational capabilities, and shaping domestic and international environments— the 'America First' space strategy emphasizes the importance of American supremacy in outer space.[270] Unimpeded access and use of outer space is a core element of US national security. In 2019, the U.S. Department of Defence (DoD) increased funding for space programs by over 18% for a total 25.4-billion USD as part of the National Defense Strategy to "compete, deter, and win in this environment."[271] Also in 2019, the United States Space Force was established as the sixth branch of the U.S. armed forces.

China's space program also supports its military with a growing array of advanced capabilities specifically devised for security and defensive purposes. The Union of Concerned Scientists database lists 59 of China's satellites as being primarily military, with many more serving a dual

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[266] *Ibid* at 268, 292.
[267] David P Fidler, "Cybersecurity and the New Era of Space Activities", (April 2018), online: *Council on Foreign Relations* <https://www.cfr.org/report/cybersecurity-and-new-era-space-activities> at 145.
[268] Jakhu & Pelton, *supra* note 5 at 269.
[269] Marcia Smith, "White House Releases Fact Sheet on New National Space Strategy – Updated", (24 March 2018), online: *Space Policy Online* <https://spacepolicyonline.com/news/white-house-releases-fact-sheet-on-new-national-space-strategy/>.
[270] *Ibid*.
[271] *The Space Report: The Authoritative Guide to Global Space Activity*, Quarterly Report, by John Holst & Becki Yukman, Quarterly Report 1 (Space Foundation, 2019).

function.[272] Outer space is central to China's military: China's 2015 White Paper on Military Strategy emphasizes the strategic concept of "active defense" and "peace through strength" in space.[273] All indications suggest that China has increased spending on military and defense-related space programs: in 2018, China announced a defense budget of $11.1-trillion yuan, representing a 8.1% increase from 2017.[274]

Japan in recent years has shifted its policy towards a more proactive defense of its space assets. In 2008, Japan made a radical change to its 1969 legislation which limited the country's space activities to civilian purposes only, and allowed for the development of space weapons as long as they were defensive in nature.[275] Japan's 2015 Basic Plan on Space Policy is notable for its renewed emphasis on the use of outer space for national security.[276] The country first dedicated military satellite was launched in 2017, and Japan has invested in its ability to jam hostile satellite communications, while also upgrading its military cyber-defence unit.[277] In 2018, Japan's defense budget increased for the fifth straight year, with a considerable percentage being dedicated to reconnaissance satellites.[278]

Elsewhere in the world, there is also the growing perception that the active protection of one's space assets has become necessary.[279] In Europe, the 2016 Space Strategy for Europe articulated the importance of enhancing the use of European space capabilities for military and security purposes, specifically by "reinforcing synergies between civil and security space activities."[280]

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[272] West, *supra* note 16 at 98.
[273] China Daily, "China's Military Strategy: Full Text", (26 May 2015), online: *ChinaDaily* <https://www.chinadaily.com.cn/china/2015-05/26/content_20820628.htm>.
[274] West, *supra* note 16 at 103.
[275] Jakhu & Pelton, *supra* note 5 at 276.
[276] Lal et al, *supra* note 3 n 80.
[277] Japan News-Yomiuri, "Japan government to OK jamming hostile satellites", (14 December 2018), online: *The Guam Daily Post* <https://www.postguam.com/the_globe/philippines_asia/japan-government-to-ok-jamming-hostile-satellites/article_f9b4acde-fe82-11e8-8dac-8f7c91291838.html>.
[278] Shingo Ito, "With Eye on China, Japan Unveils Record Defence Budget", (21 December 2018), online: *Japan Today* <https://japantoday.com/category/politics/with-eye-on-china-japan-unveils-record-defence-budget>.
[279] Jakhu & Pelton, *supra* note 5 at 276.
[280] Martin Banks, "Mixed Reviews on EU Plan to Use Commercial Space Assets for Military", (Agusut 2016), online: *Defense News* <https://www.defensenews.com/air/2016/08/03/mixed-reviews-on-eu-plan-to-use-commercial-space-assets-for-military/>.

Russia too, in its 2015 National Security Strategy, emphasized the need to use space for military and defensive purposes.[281] This strategy was preceded by an organizational shift in which Russia merged its air force and space command to form the Aerospace Forces.

C. Rhetoric and ASAT Testing

This bolstering of space-based military capabilities has been accompanied by harsh and inflammatory rhetoric by the main spacefaring nations, all suggesting that a growing number of States now see outer space as a warfighting domain.[282] Increasingly, the U.S. defense community considers outer space to be a hostile environment, in which armed conflict is likely to spill over. The United States has described the space domain as being "congested, contested and competitive"[283], with American military commanders recently predicting that "we are going to fight in space…from space…and into space".[284] US Air Force Chief of Staff General David L Goldfein was even more direct, warning that it is not a question of if, but of when airmen would be fighting in space.[285] The view that space is no longer a sanctuary, as articulated in the 2016 USAF White Paper, is indicative of the current political mood.[286]

The situation is troubling and could potentially escalate. Reckless and dangerous military flexing has taken place in recent years, exemplified by the anti-satellite (ASAT) testing by China, the United States, India and Russia. In 2007, China launched an ASAT missile to destroy a non-functional Chinese weather satellite at an altitude of about 850km.[287] This singular event created

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[281] Olga Oliker, "Unpacking Russia's New National Security Strategy", (7 January 2016), online: *Center for Strategic & International Studies* <https://www.csis.org/analysis/unpacking-russias-new-national-security-strategy>.

[282] Nathan Strout, "Space Command calls out another Russian anti-satellite weapon test", (16 December 2020), online: *C4ISRNET* <https://www.c4isrnet.com/battlefield-tech/space/2020/12/16/space-command-calls-out-another-russian-anti-satellite-weapon-test/>; China Daily, *supra* note 273; Lal et al, *supra* note 3 n 80; John E Hyten, *Space Mission Force: Developing Space Warfighters for Tomorrow* (2016) at 2.

[283] Jakhu & Pelton, *supra* note 5 at 271.

[284] Fidler, *supra* note 267.

[285] Sandra Erwin, "Air Force Chief Goldfein: 'We'll be fighting from space in a matter of years'", (24 February 2018), online: *SpaceNews* <https://spacenews.com/air-force-chief-goldfein-well-be-fighting-from-space-in-a-matter-of-years/>.

[286] Hyten, *supra* note 282 at 2.

[287] Jakhu & Pelton, *supra* note 5 at 274.

about 3,000 trackable space debris objects, some of which remain in orbit to this day.[288] In April 2020, the ISS conducted a collision avoidance maneuver which was triggered by a high-risk fragment generated from the Chinese 2007 ASAT test.[289] In 2008, the United States conducted an ASAT test of its own, intercepting a re-entering military satellite with a ballistic missile. Luckily, because of the low altitude of the satellite and its downward trajectory, little debris remained in orbit following the collision.

India has been developing its military space capabilities for years. Back in 2017, Indian Defence Secretary Sanjay Mitra announced the creation of a dedicated space defense unit, tasked with developing space as an operational theater for the military.[290] India conducted an ASAT test in 2019 to verify – and demonstrate – that it had the capacity to safeguard its space assets, creating hundreds of debris pieces in the process.[291] Although most debris re-entered the Earth's atmosphere within a few days, some fragments stayed in orbit for several months, causing the impact risk to the ISS to rise by 44%.[292]

Russia has conducted three ASAT tests in the past year alone. In April and December 2020, Russia tested its ground-based ASAT capabilities using direct-ascent missile, which have the capacity to reach targets in LEO anywhere from 100 miles to 1,200 miles.[293] In July 2020, Russia tested technology that could potentially be used as a co-orbital ASAT, during which its Cosmos 2543 satellite injected a new object into orbit and conducted a non-destructive test.[294]

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[288] Pelton, *supra* note 6 at 3.
[289] National Aeronautics and Space Administration, "Orbital Debris Quarterly News" (2020) 24:3 NASA Orbital Debris Program Office 14 at 1.
[290] Space Daily, "Cyber and Space Defense Units to Enter Operation in India", (18 July 2017), online: *Space Daily* <http://www.spacedaily.com/reports/Cyber_and_Space_Defense_Units_to_Enter_Operation_in_India_999.html>.
[291] Brian Weeden & Victoria Samson, "Op-ed | India's ASAT test is wake-up call for norms of behavior in space - SpaceNews", (April 2019), online: *SpaceNews* <https://spacenews.com/op-ed-indias-asat-test-is-wake-up-call-for-norms-of-behavior-in-space/> at 147.
[292] Weeden & Samson, *supra* note 291.
[293] Sandra Erwin, "Space Force official: Russian missile tests expose vulnerability of low-orbiting satellites", (16 December 2020), online: *SpaceNews* <https://spacenews.com/space-force-official-russian-missile-tests-expose-vulnerability-of-low-orbiting-satellites/>.
[294] Hanneke Weitering, "Russia has launched an anti-satellite missile test, US Space Command says", (16 December 2020), online: *Space.com* <https://www.space.com/russia-launches-anti-satellite-missile-test-2020>.

While Russia's tests have fortunately not created any space debris, they have heightened tensions and risk escalating the situation. Just a few months ago, US Secretary of Defence Christopher C. Miller responded to the Russian ASAT tests by saying:

> "Our adversaries have made space a war-fighting domain, and we have to adapt our national security organizations, policies, strategies, doctrine, security classification frameworks and capabilities for this new strategic environment. Over the last year we have established the necessary organizations to ensure we can deter hostilities, demonstrate responsible behaviors, defeat aggression and protect the interests of the United States and our allies."[295]

V. Concluding Remarks

By almost any metric used to measure activity in outer space - whether it be payloads in orbit, the size of smallsat constellations, the rate of launches, the number of conjunctions or the potential for debris creation - NewSpace represents a fundamental break with past experience.[296] The rapid expansion of space traffic enabled by the smallsat revolution is enabling unparalleled opportunities for commercial, education and national interests.[297] However, it is also creating more threats to functioning spacecraft than ever before.[298] In the last three years, more than 20,000 satellites were licensed to operate in LEO, reflecting an almost tenfold increase in the total number of satellites currently operating in all orbits. The potential impacts of large satellite constellations on the creation of orbital debris is painfully clear. Such an extensive rise in the number of smallsats in LEO will lead to the congestion of that orbital environment and a proportional increase in debris and the risk of catastrophic collisions.[299] The militarization of outer space also poses a serious threat to the long-term sustainability of the outer space environment. Reckless ASAT tests conducted in recent years have created thousands of debris fragments, increasing the risk of in-orbit collisions.

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[295] Strout, *supra* note 282.
[296] Muelhaupt et al, *supra* note 56 at 80.
[297] National Aeronautics and Space Administration, *supra* note 65 at 8.
[298] *Ibid*.
[299] National Aeronautics and Space Administration, "Orbital Debris Quarterly News" (2018) 22:3 NASA Orbital Debris Program Office 12 at 4–9.

Chapter 4 – International Environmental Law Principles, and their Applicability to Outer Space

With the commercialization and democratization of outer space, a "business as usual" approach will not work.[300] An examination of the existing legal framework has revealed that existing space law has proven incapable of resolving the space debris problem.[301] The existing space safety and debris mitigation processes were designed for the current population profile, launch rates and orbital density… not for the thousands of satellites anticipated to be launched in the coming years.[302] The statistics concerning the accumulation of space debris in LEO and GEO demonstrate that the preservation of outer space requires more than the existing UN space treaties and recommendations adopted by various international organs can offer.

A new outer space treaty seems unlikely given today's political climate, as will be discussed below. This chapter will suggest that the answer to the issue may be found in a different *corpus* of international law - international environmental law. Because of the urgency of the space debris crisis, and the unlikeliness that space-specific norms will be enacted in the near future, there is a need to rely on existing rules of environmental protection to regulate space pollution. It will first be argued that environmental law is applicable to outer space activities and can bridge the gaps between the UN space treaties and the protection of the space environment.[303] Thereafter, three fundamental principles of international environmental law will be introduced, and their applicability to outer space discussed.

I. Problems with Conventional Treaty-Making

International agreement is often difficult to achieve. This is particularly the case with respect to the global commons, which require a delicate balance between an ideology of fairness and equity, and the utilitarian needs of competing States.[304] In the outer space context, Article I of the Outer Space Treaty maintains that all States, regardless of their economic or scientific

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[300] Muelhaupt et al, *supra* note 56 at 80.
[301] Roberts, "Addressing the Problem of Orbital Space Debris", *supra* note 94 at 67.
[302] Muelhaupt et al, *supra* note 56 at 1.
[303] Roberts, "Addressing the Problem of Orbital Space Debris", *supra* note 94 at 65.
[304] Viikari, *supra* note 91 at 207.

development, have an interest in the exploration and use of outer space. And yet, as was demonstrated in Chapters 2 and 3, there is intense competition for the valuable, highly profitable LEO and GEO orbital slots.

Traditionally, international rules are established though the adoption of legally binding agreements. In the early stages of outer space law, the UNCOPUOS was able to negotiate four space treaties by consensus, all of which entered into force within a mere decade.[305] The first and most fundamental of the treaties – the 1967 Outer Space Treaty – received wide acceptance, came into force within a year, and was signed and ratified by all States active in space utilization.[306] Unlike the 1960s and 70s where only a handful of States had access to space, the 1980s saw a lot more interests and voices at the negotiating table. With the number of spacefaring States mounting, it became increasingly difficult to find agreement by consensus. This is perfectly exemplified by the last UN space treaty: negotiations for the 1979 Moon Agreement lasted for nearly a decade, and only gained the five ratifications required for its entry into force in 1984. As of January 1st 2020, the Moon Agreement has attracted no more than eighteen ratifications, all by States that do not have independent launch capabilities.[307] The United States, Russia and China have yet to sign and ratify the Moon Agreement, making it a failure from an international law standpoint.

Ideally, the inadequacies of the existing multilateral treaty regime concerning orbital pollution would be ameliorated through the adoption of a new treaty that deals specifically with space debris. In practice however, it will be very difficult for actors to negotiate and agree on new, legally binding space debris rules. The negotiation phase alone could take years. Future treaty negotiations will likely suffer the same fate as the 1984 Moon Agreement, especially since the number of countries with spacefaring capabilities has skyrocketed in the last 40 years.[308]

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[305] Jakhu & Pelton, *supra* note 5 at 288.
[306] United Nations Office for Outer Space Affairs, *Status of International Agreements Relating to Activities in Outer Space as at 1 January 2020* (UNOOSA) at 1–10.
[307] *Ibid* at 10.
[308] West, *supra* note 16 at 69–70.

New international norms cannot be forced unto States, keeping with the doctrine of State sovereignty. However, orbital debris will affect the space activities of all States indiscriminately; it is an inherently international problem. Because rules in outer space must be widely accepted to be considered effective, space treaty negotiations are largely based on consensus or unanimity. In practice, this had led to the 'lowest-common-denominator approach', where the measures adopted become watered-down so as to become acceptable to the least enthusiastic party.[309] Even a widely ratified treaty may therefore be quite useless if it does not impose sufficient obligations on its signatories.

Another potential hurdle is that once an international agreement is adopted, it must still be ratified by a minimum number of States to enter into force. This could take time - there are some agreements that never gain enough ratifications to enter into force for a variety of reasons.[310] Over time, the provisions of an instrument may become obsolete due to changes in circumstances or because of scientific and technological developments. This is particularly true with the current space debris situation, which may reach new, serious, potentially irreversible proportions if not dealt with quickly by the international community.

Since 1984, space law negotiations have become more complicated, and the formulation of international space law has come to a standstill. The UNCOPUOS, unable to produce new space treaties, concentrated on developing non-binding recommendations and guidelines to promote safer practices in outer space, particularly concerning the mitigation of space debris.[311] Non-binding norms, while useful, have still relatively low rates of compliance and are not enough to stop the proliferation of debris in LEO and GEO.[312] Clearly, a different solution is needed.

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[309] Ved P Nanda & George Pring, *International environmental law and policy for the 21st century*, 2nd rev. ed. ed, International environmental law ; v 9 (Leiden ; Martinus Nijhoff Publishers, 2013) at 10.
[310] Viikari, *supra* note 91 at 212.
[311] *Ibid* at 57.
[312] Muelhaupt et al, *supra* note 56 at 85.

II. International Environmental Law Principles

International environmental law has developed in its relatively short history a number of fundamental, guiding legal principles.[313] While some of those principles are still new and *emergent*, others are well-established principles of customary international law. This is noteworthy because unlike treaty law, which only binds States that have explicitly accepted its obligations, customary international law is binding without States having to formally consent to its rules.[314] International customary law does require two elements: 1) the objective element of State practice, which must be relatively consistent, uniform, widespread, and representative ; and 2) the subjective element of *opinio juris*, or States' conviction that the conduct is required by law.[315] Environmental law principles, as an important source of international law, could be used to fill the legal *lacuna* of existing space treaties with respect to the protection of outer space from orbital debris.

A. Is International Environmental Law Applicable to Outer Space?

At the onset, it is important to consider whether activities in outer space even fall within the material scope of environmental law.[316] Environmental law is, after all, concerned for the most part with Earth's environmental problems, such as greenhouse gas emissions and the preservation of wildlife… issues that do not arise in the context of outer space. This raises the question as to whether outer space can be regarded as part of the environment, and thus subjected to international environmental law. There are three reasons to believe that it can.

1. Outer Space as *Global Commons*

The global commons are those areas of the environment outside the boundaries and beyond the jurisdiction of any one State.[317] In 2020 the United States made headlines by expressly rejecting outer space as a global commons in the context of the commercial exploration, recovery and use

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[313] Nanda & Pring, *supra* note 309 at 19.
[314] Popova & Schaus, *supra* note 20 at 4.
[315] Nanda & Pring, *supra* note 309 at 11.
[316] Stubbe, "Common but Differentiated Responsibilities for Space Debris", *supra* note 11 at 6.
[317] *Ibid* at 7.

of space resources.[318] Nonetheless, outer space and celestial bodies, like the high seas, Antarctica, and Earth's climate, are considered by many scholars to hold the status of global commons under international law.[319] The common interest of all mankind in the exploration and use of outer space is articulated throughout the UN space treaties, including in the preamble and Article I (1) of the OST, the preambles of the Liability Convention and the Registration Convention, and Articles 4 and 11 of the Moon Agreement.[320]

Environmental protection is a fundamental tenet in the *global commons*: environmental problems such as climate change and the depletion of the stratospheric ozone layer belong to and affect all States, and therefore require global solutions.[321] The international law of the high seas – also part of the global commons – can serve as a useful source for comparison.[322] The use of analogies from different legal frameworks necessitates caution since different environments have their own unique characteristics.[323] Nevertheless, given that space law has been developed in view of the law of the sea and that both share similar challenges, legal scholars have argued that outer space be accorded a similar level of environmental protection.[324] The 1982 UN Convention on the Law of the Sea (UNCLOS) provides a comprehensive framework for the regulation and preservation of Earth's oceans.[325] Two-hundred miles from coastal shores, the high seas and ocean sea floor lie outside of national jurisdiction[326] and just like outer space, are designated as the "common heritage of mankind".[327] Because of the transboundary character of the high seas, UNCLOS imposes a general obligation on States to protect and preserve the marine environment.[328] This duty of care towards the marine environment must be respected by States during the use and exploration of the high seas and the ocean sea floor.[329] Many scholars believe that UNCLOS's

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[318] Executive Office of the President, *Executive Order 13914: Encouraging International Support for the Recovery and Use of Space Resources* (Federal Register: The Daily Journal of the United States Government, 2020).
[319] Nanda & Pring, *supra* note 309 at 37; Pelton, *supra* note 6 at 33; Viikari, *supra* note 91 at 5,129.
[320] United Nations Office for Outer Space Affairs, *supra* note 96.
[321] Birnie & Boyle, *supra* note 186 at 6.
[322] Viikari, *supra* note 91 at 20–21, 174.
[323] *Ibid* at 20.
[324] *Ibid* at 20–21 note 65; Stubbe, *supra* note 2 at 90, 182 note 177, 192–193.
[325] Nanda & Pring, *supra* note 309 at 264.
[326] *Ibid*.
[327] United Nations, *United Nations Convention on the Law of the Sea* (UN, 1982) at Article 136.
[328] *Ibid* at Article 192.
[329] *Ibid* at Article 193.

provisions on the protection and preservation of the marine environment constitute applicable rules of customary law.[330]

2. Article III of the 1967 Outer Space Treaty

A second argument supporting the application of international environmental law to outer space can be found in Article III of the Outer Space Treaty:

> "States Parties to the Treaty shall carry on activities in the exploration and use of outer space, including the Moon and other celestial bodies, in accordance with international law, including the Charter of the United Nations, in the interest of maintaining international peace and security and promoting international cooperation and understanding."

As part of the larger corpus of international law, international environmental law would therefore seem to extend into the outer space environment.[331] International environmental law principles can thus be applied to outer space activities which risk creating debris.

3. Anthropocentric Approach to Environmental Law

Several legal scholars have argued that the preservation of the natural livelihood of mankind is one of the underlying motivations for the development of international environmental law.[332] Perhaps ironically, justifications for international environmental protection are to a large extent anthropocentric.[333] Environmental protection stems for the desire – at least in part – to preserve the natural resources and natural conditions for humankind - not just for the current generation, but for future generations as well.[334] Ecosystems, natural resources and wildlife are protected by international law because for their value to humanity, whether that be economic, aesthetic, or

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[330] Nanda & Pring, *supra* note 309 at 266.
[331] Jakhu & Pelton, *supra* note 5 at 284.
[332] Birnie & Boyle, *supra* note 186 at 5.
[333] *Ibid*.
[334] Edith Brown Weiss, ed, *Environmental change and international law: new challenges and dimensions* (Tokyo, Japan: United Nations University Press, 1992) c 12.

even religious and moral.[335] Outer space has gained incredible significance for humankind: space technology and applications provide a myriad of economic, scientific, military, and social benefits. Because of our ever-increasing reliance and dependence on space applications for all aspects of our lives, outer space could be considered as belonging to the natural livelihood of mankind, and therefore be protected by international environmental law.[336]

International environmental law is thus applicable to the outer space environment. The remainder of this chapter will scrutinize three principles of international environmental law, and their applicability to space debris. The precautionary principle, the no-harm rule, and the common but differentiated responsibilities principle were selected not only because of their status as established principles of international environmental law, but also because of their pertinence to outer space, and the practical effects they could have towards the mitigation of present and future orbital debris.

III. Precautionary Principle

In the environmental law context, legislators will often hesitate to adopt costly regulations when there is no definite evidence to suggest that a proposed activity will cause environmental degradation.[337] The lack of scientific certainty has historically represented one of the biggest obstacles to environmental regulation.[338] Nonetheless, precaution is justified in environmental law because there is often too much at stake as far as natural resources are concerned. Environmental damage can often be irreparable, as is the case with nuclear leaks and the extinction of species. Abstract dangers, even though not yet fully realized, must therefore be carefully dealt with. In the context of outer space, it is often hard to predict with certainty what impacts space activities will have on the proliferation of new space debris. But because of the practically irreversible consequences of space debris at higher altitudes, it is obvious that the greatest precaution must be exercised to preserve the future usability of the orbital environment.

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[335] Birnie & Boyle, *supra* note 186 at 5.
[336] Stubbe, "Common but Differentiated Responsibilities for Space Debris", *supra* note 11 at 6.
[337] Nanda & Pring, *supra* note 309 at 63.
[338] *Ibid*.

The precautionary principle is a fundamental tenet of international environmental law which protects against environmental harm even when full scientific certainty about the threat does not exist.[339] The precautionary approach first appeared in the 1982 World Charter for Nature. Article 11. (a) of the Charter declared:

> (a) Activities which are likely to cause irreversible damage to nature shall be avoided.

Article 11. (b) said:

> (b) Activities which are likely to pose a significant risk to the environment must be preceded by an exhaustive examination; their proponents shall demonstrate that expected benefits outweigh potential damage to nature, and where potential adverse effects are not fully understood, the activities should not proceed.[340]

The precautionary principle thus requires States to conduct a proactive investigation and diligent planning before deciding to undertake an activity that risks causing environmental harm. Indifference or procrastination based on the lack of definite scientific evidence is to be rejected whenever the risks to the environment are deemed to be unjustified or irreversible.[341] The 1990 Bergen Ministerial Declaration on Sustainable Development also makes several references to the precautionary approach, although the principle is not defined.[342] This was done two years later in the 1992 Rio Declaration on Environment and Development (Rio Declaration). Article 15 of the Rio Declaration states:

> "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

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[339] Viikari, *supra* note 91 at 159.

[340] UN General Assembly, *World Charter for Nature* (UN General Assembly (37th Session: 1982-1983), 1982) publisher: UN,.

[341] Bittencourt Neto, *supra* note 8 at 348.

[342] Weiss, *supra* note 334 at 5.

The precautionary principle as formulated above reflects a significant shift of the burden of proof in environmental law.[343] No longer would potential victims of an environmentally risky activity need to prove future harm. Rather, the burden would lie on the proponents of the activity in question to prove that it was safe. The precautionary principle thus triggered a reversal in the evidentiary presumption of environmental law towards a presumption of harm.[344] As such, potentially dangerous and irreversibly damaging activities must not be undertaken unless sufficient evidence of their safety vis-a-vis the environment is provided.

Yet, difficult questions concerning the point at which the precautionary principle becomes applicable to any given activity have somewhat undermined its normative character and practical utility.[345] Even for highly qualified scientific specialists – let alone politicians - it is difficult to evaluate the concept of risk. Numerous variables must be considered, as well as judgements about probability, scale, and the long-term effects of harm.[346] Some international treaties have attempted to provide at least some guidance as to what scientific proof is needed to prompt precaution. The 1992 Convention for the Protection of the Marine Environment of the North-East Atlantic for instance, states in Article 2(a) that the precautionary principle should be applied "when there are reasonable grounds for concern" that the activities may bring about environmental degradation.[347] In the context of outer space, the risks associated with orbital debris have been recognised within academia and the space industry for some time.[348] A collision in LEO or GEO has the potential to precipitate the Kessler Syndrome, and thus threaten the spacecraft of all States and render the entire orbit unusable for the indeterminate future.[349]

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[343] Nanda & Pring, *supra* note 309 at 64.
[344] *Ibid*.
[345] Birnie & Boyle, *supra* note 186 at 98.
[346] Viikari, *supra* note 91 at 164.
[347] OSPAR Commission, *Convention for the Protection of the Marine Environment of the North-East Atlantic* (1992) at Article 2 (a).
[348] Viikari, *supra* note 91 at 114.
[349] Jakhu & Pelton, *supra* note 5 at 281–282.

A. Status of the Precautionary Principle

Whether the precautionary principle is part of customary international law is disputable: it is after all a recently formulated environmental principle dating back less than four decades. However, the increasing frequency with which the principle is being mentioned and its widespread use both internationally and domestically, all suggest that it has a legal core on which there is sufficient international consensus to attain the status of custom.[350] Some legal scholars, like Professor Philippe Sands, have argued that the precautionary principle is a customary principle of international law:

> " There is certainly sufficient State practice to support the conclusion that the principle, as elaborated in Article 15 of the Rio Declaration and various international conventions, has now received sufficient broad support to allow a strong argument to be made that it reflects a principle of customary law[…]".[351]

Other scholars such as Ved Nanda and George Pring argue that there is insufficient international consensus or State practice to establish the principle as customary international law.[352] The United States, for instance, opposes the precautionary principle. The U.S. argues that environmental regulation should be based on evidence of significant risk of harm, rather than on mere conjecture about uncertain risks.[353] Whether a principle can become customary international law when it is opposed by an important and powerful persistent objector such as the United States, is a subject of debate. According to Professor Patrick Dumberry, the concept of persistent objector is not widely supported by State practice and has seldom been endorsed by international courts and tribunals.[354] Moreover, Dumberry argues that the status of persistent objector does not prevent the application of a norm of customary law to the objecting State.[355] At

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[350] Birnie & Boyle, *supra* note 186 at 119–121.

[351] Philippe Sands, *Principles of International Environmental Law*, 2d ed (Cambridge University Press, 2003) at 279.

[352] Nanda & Pring, *supra* note 309 at 64.

[353] Jonathan B Wiener & Michael D Rogers, "Comparing Precaution in the United States and Europe" (2002) 5:4 Journal of Risk Research 317–349 at 318.

[354] Patrick Dumberry, "Incoherent and Ineffective: The Concept of Persistent Objector Revisited" (2010) 59:3 The International and Comparative Law Quarterly 779–802 at 801–802.

[355] *Ibid*.

the very minimum, a strong argument can be made that the precautionary principle is gaining international recognition.[356] The principle has been widely endorsed both at the domestic level (such as in Germany since the 1970s) and in international treaties, appearing in virtually all of the key international environmental treaties and declarations adopted since 1992.[357]

B. Application to Outer Space

It is commonly understood that there are no limitations to the geographical application of the precautionary principle: it extends to environmental threats no matter their location, including transboundary risks and risks to the global commons.[358] The space sector is full of uncertainties and risks of various kinds, which would seem to speak in favour of the application of the precautionary principle. Because space debris could result in long-lasting, potentially irreversible damage to the orbital environment, the precautionary principle could require that States exercise extra caution during their space activities.

A precedent from a different global commons can be found in the regulation of deep seabed mining – an environment also beyond the limits of national jurisdiction which just like outer space, has also been proclaimed the common heritage of mankind.[359] The precautionary principle has been explicitly incorporated in deep seabed regulation. Regulation 31.2 of the 2013 Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area, states:

> "In order to ensure effective protection for the marine environment from harmful effects which may arise from activities in the Area, the Authority and sponsoring States shall apply a precautionary approach, as reflected in principle 15 of the Rio Declaration to such activities."[360]

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[356] Birnie & Boyle, *supra* note 186 at 98.
[357] Bittencourt Neto, *supra* note 8 at 347,349.
[358] Viikari, *supra* note 91 at 160.
[359] *Ibid* at 174.
[360] International Seabed Authority Council, *Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area* ([New York] : [ISBA], 2013) , s 31.2.

By analogy, the precautionary principle could be applied to outer space.[361] The concern has been raised that a strict interpretation of the precautionary principle in outer space would have the practical effect of hindering innovation and growth.[362] Because of the uncertainty associated with the outer space environment, the precautionary principle might severely encumber the functioning and development of space activities, particularly in the commercial sector.[363] In other words, the precautionary principle would make it unreasonably difficult for spacefaring nations to prove that their activity is harmless under a reversed burden of proof. This argument is not very convincing. The precautionary principle does not require nations to halt all of their space activities unless they can prove 'beyond a reasonable doubt' that their proposed activities are safe. Rather, the principle calls for States to act with care and foresight when making decisions that may have an adverse impact on the environment, and take cost-effective measures to prevent environmental degradation. The potential risks associated with outer space are relatively well understood, and space debris is one of the problems for which there exists a plethora of scientific evidence. Unfortunately, the Kessler Syndrome is not an abstract danger anymore: it is a tangible threat believe to be well underway in certain LEO and GEO orbits. Especially in light of the smallsat mega constellations about to be put into orbit, the precautionary principle should be applied to require that all space operators comply with the IADC debris mitigation guidelines, and safely dispose of their satellites at the end of their lifetime. Chapter 5 will address in detail some of the practical implications the precautionary principle could have in the conduct of space activities.

IV. The No-Harm Rule

There are no borders in outer space. Because it is shared environment, it is crucial that all States act responsibly to ensure that outer space is maintained for long-term use and access.[364] Space debris generated from the irresponsible actions of just one spacefaring nation have the potential to endanger the viability of future space activities of all. The no-harm rule asserts that States

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[361] Viikari, *supra* note 91 at 174.
[362] Arie Trouwborst, *Precautionary Rights and Duties of States*, Nova et Vetera Iuris Gentium (Leiden; Boston: Martinus Nijhoff Publishers, 2006) at 200–201.
[363] Viikari, *supra* note 91 at 176.
[364] Muelhaupt et al, *supra* note 56 at 86.

must not cause or spread environmental harm outside of their borders. A manifestation of the "Golden Rule" - which is present in so many of the world's cultures and religions - the no-harm rule is one of the most deeply rooted and prescriptive rules of international law.[365] It is however a relatively recent environmental law principle. The first articulation of the no-harm rule occurred in the 1941 Trail Smelter Arbitration case, in which the tribunal concluded that:

> "[N]o state has the right to use or permit the use of its territory in such a manner as to cause injury […] in or to the territory of another or the properties or persons therein, when the case is of serious consequence and the injury established by clear and convincing evidence."[366]

The significance of this rule in environmental law is twofold. Firstly, the no-harm rule denies the right of a State to exercise its sovereignty in such a way so as to cause transboundary harm. Secondly, the rule applies not only to government action, but also to government inaction.[367] Private sector activities must thus be adequately controlled by the government so as to prevent transboundary harm from occurring.[368] As articulated in the Trail Smelter Arbitration case, the no-harm rule is limited in that it requires the transboundary environmental injury to be serious, and elevates the burden of proof to the demanding level of clear and convincing evidence.

Multiple international environmental declarations and treaties have adopted the no-harm rule, but with some important distinctions. Notably, Principle 21 of the 1972 Stockholm Declaration of the UN Conference on the Human Environment (Stockholm Declaration), and Principle 2 of the 1992 Rio Declaration affirmed that:

> "States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their

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[365] Nanda & Pring, *supra* note 309 at 23.
[366] *Reports of International Arbitral Awards: Trail Smelter Case (United States, Canada)*, by United Nations, Volume III (1941) at 1965.
[367] Nanda & Pring, *supra* note 309 at 23–24.
[368] *Ibid*.

> jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction."[369]

Compared to its formulation in the Trail Smelter Arbitration case, the no-harm rule expressed here can be distinguished in two ways. Firstly, it expands the scope of protection of the rule to areas beyond the limits of national jurisdiction.[370] This has been interpreted to include not only the territory of other States, but also the global commons such as Antarctica, the stratosphere, and outer space.[371] Moreover, the no-harm rule, as expressed in the Stockholm Declaration and the Rio Declarations, does not specify that the environmental harm to other States must be serious, and the injury established by clear and convincing evidence. This leaves some unanswered questions about what degree, amount, or level of harm is required – is there a minimum harm threshold that is acceptable?[372] Clearly, it would be unreasonable to qualify every piece of debris as "serious environmental harm". After all, every space activity involves the creation of at least some sort of debris, whether it be slag objects from the normal combustion of rocket propellant or mission-related debris.[373]

A. Status of the No-Harm Rule

Nevertheless, based on widespread State practice and important judicature, most legal commentators believe that the no-harm rule has crystallized into a principle of customary international law.[374] They point in particular to the 1996 Nuclear Weapons Advisory Opinion, in which the International Court of Justice directly referenced the no-harm rule as formulated in the Stockholm and Rio Declarations, and confirmed its status as customary international law:

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[369] United Nations, *Declaration of the United Nations Conference on the Human Environment* (UN, 1972) at Principle 21; UN General Assembly, *Rio Declaration on Environment and Development* (United Nations, 1992) at Principle 2.

[370] UN General Assembly, *supra* note 370 at Principle 2; United Nations, *supra* note 370 at Principle 21.

[371] Nanda & Pring, *supra* note 309 at 24.

[372] *Ibid* at 25.

[373] Stubbe, "Common but Differentiated Responsibilities for Space Debris", *supra* note 11 at 7.

[374] *Ibid* at 6.

> “The existence of the general obligation of States to ensure that activities within their jurisdiction and control respect the environment of other States or of areas beyond national control is now a part of the corpus of international law relating to the environment.”[375]

B. Application to Outer Space

The irresponsible activities of just one State have the potential to generate virtually irreparable damage to the entire orbital environment. Because of celestial mechanics, space debris will stay in orbit for a long period of time unless intentionally removed, and eventually cause the most used orbits in the LEO and GEO regions to become unusable. As articulated in Principle 21 of the Stockholm Declaration and Principle 2 of the Rio Declaration, the no-harm rule places a responsibility on States to ensure that their space activities do not cause harm to Earth’s orbits or to the space activities of other States. It is in the common interest of all States, whether spacefaring or otherwise, to subscribe to an environmental framework that allows for the development of space activities in a manner that leaves the orbital environment in a substantially unimpaired condition for future generations.

V. Common but Differentiated Responsibilities Principle

Responsibility for the creation of orbital debris is not equally shared among States. Non-spacefaring countries, who have not yet been able to benefit from space activities, presently encounter a degree of environmental degradation for which they are not responsible but whose negative consequences they have to face.[376] Environmental protection programs can be very expensive undertakings. The US Environmental Protection Agency for instance, had in 2011 a yearly budget of over $9 billion USD, and more than 14,000 employees.[377] Many developing nations not only feel that their economies cannot afford environmental protection programs, but also that they should not have to bear such expenses for environmental problems that they did

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[375] *Legality of the Threat or Use of Nuclear Weapons*, by International Court of Justice, Advisory Opinion (I.C.J., 1996) at 241–241.

[376] Stubbe, “Common but Differentiated Responsibilities for Space Debris”, *supra* note 11 at 10.

[377] United States Environmental Protection Agency, “EPA’s Budget and Spending”, (2020), online: *US EPA* <https://www.epa.gov/planandbudget/budget>.

not create.[378] Part of the argument is that developed States became wealthy because of their exploitation of the environment, and are now hypocritically preventing developing countries from doing the same.[379]

Contemporary international environmental law instruments often differentiate between the responsibilities imposed on developed and developing countries: these can include different standards, delayed compliance timelines, and less stringent commitments.[380] Due to the historical responsibility of certain States with respect to environmental degradation, as well as differences in their technological and economic capability to respond to it, a double standard in international environmental law is considered to be the 'equitable' thing to do.[381]

The concept of common but differentiated responsibilities (CBDR) was first articulated in Principle 7 of the 1992 Rio Declaration:

> "States shall cooperate in a spirit of global partnership to conserve, protect and restore the health and integrity of the Earth's ecosystem. In view of the different contributions to global environmental degradation, States have common but differentiated responsibilities. The developed countries acknowledge the responsibility that they bear in the international pursuit of sustainable development in view of the pressure their societies place on the global environment and of the technologies and financial resources they command."

The CBDR principle contains two main elements. The first one is that all States have a common responsibility towards protecting the environment. Many environmental problems – in outer space included - cannot be solved by just one or a handful of nations. The Earth's climate, for instance, is a shared environment that requires a global effort to protect. Only by securing the support and participation of all States can greenhouse gas emissions be reduced, and irreversible environmental damage avoided. In the context of global warming, developing countries like

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[378] Nanda & Pring, *supra* note 309 at 41.
[379] Stubbe, "Common but Differentiated Responsibilities for Space Debris", *supra* note 11 at 9.
[380] Viikari, *supra* note 91 at 178.
[381] *Ibid* at 179.

China and India have become some of the world's biggest polluters, so getting them on board is crucial.[382]

Yet, States are not all equal in their contributions to global environmental degradation, or in their capacity to respond to it.[383] The second component of the CBDR principle claims that as a matter of fairness, developed States that have greater responsibility for causing environmental damage should assist those less responsible. Besides, developed States often have more technological and financial resources to respond to environmental degradation. They should therefore bear the grunt of the responsibility, and assist nations who may not have access to those same resources fulfil their obligations.[384] As a matter of equity, developed nations should take the first decisive steps in the fight towards environmental protection and preservation, with the participation of developing countries being conditional on developed countries' performance of their commitments.[385]

A. Status of the CBDR Principle

Debate persists on whether the CBDR principle has achieved the status of customary international law. It has been argued, for example, that the technology transfer and funding obligations contained within the CBDR principle have only sparsely and trivially been applied in practice.[386] Developed States have been reluctant to agree to anything other than ambiguous or relatively irrelevant financial and technological commitments.[387] Nonetheless, the principle has been generally accepted on the international level, and appears to have become an established principle of international environmental law.[388]

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[382] Union of Concerned Scientists, "Each Country's Share of CO2 Emissions", (August 2020), online: *UCSUSA* <https://www.ucsusa.org/resources/each-countrys-share-co2-emissions>.

[383] Lavanya Rajamani, "The changing fortunes of differential treatment in the evolution of international environmental law" (2012) 88:3 International Affairs 605–623 at 605.

[384] Stubbe, "Common but Differentiated Responsibilities for Space Debris", *supra* note 11 at 4–5.

[385] Rajamani, *supra* note 384 at 612.

[386] Stubbe, "Common but Differentiated Responsibilities for Space Debris", *supra* note 11 at 11.

[387] Viikari, *supra* note 91 at 181; Nanda & Pring, *supra* note 309 at 43.

[388] Birnie & Boyle, *supra* note 186 at 103; Nanda & Pring, *supra* note 309 at 43.

The importance of the CBDR principle was reiterated in Article 10 of the Kyoto Protocol to the United Stations Framework Convention on Climate Change, which was adopted in 1997 and came into force in 2005. The Kyoto Protocol implemented the CBDR principle by providing for specific greenhouse-gas-reduction requirements for developed countries, establishing different reporting obligations, and instructing developed States to assist developing countries meet their environmental commitments.[389] The CBDR principle was also retroactively incorporated into the 1985 Vienna Convention and the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer. For example, Article 5 of the Montreal Protocol to the Vienna Convention gave developing States a longer time frame within which to phase out production and consumption of ozone-depleting substances, while Articles 10 and 10(a) addressed financial assistance and technology transfer to developing States.[390]

B. Application to Outer Space Law

By putting space debris pollution in the context of the CBDR principle, the discussion of the issue is broadened by equity considerations. Because of their historical responsibility for orbital debris, developed countries engaged in space activities should be at the forefront of debris mitigation and removal efforts.[391] Ideally, spacefaring States' level of support would be proportionally allocated on the basis of their estimated contribution to the total debris population.[392]

This does not mean that the CBDR principle excludes developing countries from enacting particular commitments towards debris mitigation. At the end of the day, a collective effort by all will be needed to deal with the current debris situation. With more and more developing countries gaining access to the 'final frontier', it will become increasingly crucial that all nations take a minimum number of measures to conserve, protect, and eventually restore the outer space environment. Rather, the CBDR principle should have the effect of assisting developing countries meet their space debris mitigation commitments in a way that recognizes their

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[389] Nanda & Pring, *supra* note 309 at 43.
[390] United Nations, *Montreal Protocol on Substances that Deplete the Ozone Layer* (UN, 1989).
[391] Stubbe, "Common but Differentiated Responsibilities for Space Debris", *supra* note 11 at 2.
[392] Roberts, "Addressing the Problem of Orbital Space Debris", *supra* note 94 at 70.

capabilities and interests.[393] The policies that each State adopts should vary according to their individual space competences, responsibility towards the current orbital debris situation, and the technological and financial resources available at their disposal. Some of the ways in which the CBDR principle can be applied in practice, will be explored in the next chapter.

Chapter 5 – Practical Effects of International Environmental Law Principles on Space Debris

The existing legal framework does not adequately address the orbital debris problem. Moreover, voluntary mitigation strategies are neither stringent enough nor sufficiently complied with to preserve the long-term sustainability of outer space. This chapter will contend that the three international environmental law principles discussed in Chapter 4 – the precautionary principle, the no-harm rule, and the CBDR principle – could be utilized to: a) require more stringent compliance with orbital debris mitigation guidelines; b) improve space situational awareness (SSA) programs and data sharing; c) encourage the continued research and eventual implementation of active debris removal mechanisms.

I. Improved Adherence to Debris Mitigation Guidelines

The precautionary and no-harm principles should be employed to require universal international compliance with existing debris mitigation rules and guidelines. This is particularly the case in LEO, where smallsat constellations will cause a sharp increase in orbital density. In GEO as well, precaution is warranted and satellites must be removed from orbit as per the graveyard orbit strategy.

Studies have repeatedly found that the most crucial factor in controlling the on-orbit population is compliance with debris mitigation standards.[394] In particular, analyses of global space operations indicate that the biggest issue in low-Earth orbits is associated with the low

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[393] Rajamani, *supra* note 384 at 608.
[394] Muelhaupt et al, *supra* note 56 at 83.

compliance rate of the 25-year post-mission disposal rule.[395] Articulated in the 2007 IADC Space Debris Mitigation Guidelines, the rule states that a space object in LEO must lower its altitude so as to re-enter the Earth's atmosphere within 25 years of its launch.[396] The rule has been thoroughly studied and its effectiveness in curtailing the growth of future debris in LEO has been confirmed. In 2015, the European Space Agency (ESA) conducted analyses using its Debris Environment Long-Term Analysis (DELTA) instrument to predict the future evolution of space debris, and the associated collision risks in LEO, MEO, and GEO regions.[397] In particular, the studies looked at the long-term effects that mitigation measures would have on the space environment. The study found that non-compliant satellites would have a strong impact on Earth's orbits, and eventually lead to an exponential increase in the number of collisions and debris proliferation.[398] That said, fully compliant satellites were found to have virtually no long-term effect on the orbital environment.[399] All in all, the ESA study demonstrated the importance of passivation and post-mission disposal of satellites.

The problem is that compliance with debris mitigation guidelines remains relatively low. In 2016, only 66% of successful clearance attempts were undertaken in LEO.[400] According to 2015 data released by the NASA Orbital Debris Program Office, up to 18% of cubesats are non-functional upon arrival or within their first week in space, with a further 20% of cubesats being non-compliant with debris mitigation guidelines.[401] The current rate of compliance with post-mission disposal mitigation guidelines is simply not good enough, especially at the dawn of the NewSpace era which will see a staggering growth in the number of commercial and private space activities. Large smallsat constellations in particular present a new and dangerous challenge to orbital stability and sustainability.[402] Based on past launches in LEO, only 75% of smallsats were compliant with the 25-year rule.[403] Practically speaking, this means that for a

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[395] Bastida Virgili & Krag, *supra* note 52 at 1–8.
[396] Inter-Agency Space Debris Coordination Committee, *supra* note 13 at Article 5.3.2.
[397] Bastida Virgili & Krag, *supra* note 52 at 2.
[398] *Ibid* at 3.
[399] *Ibid* at 8.
[400] Popova & Schaus, *supra* note 20 at 3.
[401] West, *supra* note 16 at 7.
[402] Jakhu & Pelton, *supra* note 5 at 281.
[403] Bastida Virgili & Krag, *supra* note 52 at 8.

constellation of 2,000 satellites, 500 satellites will become debris and pose a dangerous threat to other functional satellites at that altitude. In March 2020, the IADC updated its debris mitigation guidelines so as to reflect the importance of the 25-year deorbit rule in LEO: Article 5.3.2 asserts that the success probability for post-mission disposal should be of at least 90%. The updated IADC guidelines further recognized that for large constellations, a shorter residual orbital lifetime and higher success probability for post-mission disposal may be necessary.[404] Indeed, studies show that even with 90% global compliance with the 25-year rule, the LEO debris population will continue to grow by over 110% over the next 200 years.[405] Large smallsat constellations will need to meet the highest standards of reliability to ensure they do not cause irreparable harm to the orbital environment. In accordance with the precautionary principle and the no-harm rule, satellite operators must aim for a 99% post-mission-disposal reliability.[406] This is necessary for the safety of the constellation itself, for the spacecraft belonging to other States, and for the preservation of the LEO environment.

In GEO, part of the mitigation strategy has been the graveyard orbit. As formulated in the IADC debris mitigation guidelines, satellites at the end of their active lifetime must be transferred to an orbit at least 235km above GEO.[407] This strategy has seen mixed results: of the 80% of GEO operators between 2001 and 2010 that attempted to comply with the graveyard orbit strategy, merely 50% were fully compliant and able to transfer their satellites at least 235km above GEO.[408] The remaining satellites were either abandoned in GEO, or in a higher orbit that intersects it.[409] Low compliance can primarily be attributed to the significant fuel cost for executing the post-mission removal maneuver.[410] Profit is GEO is directly proportional to the satellite's operational lifetime; operators are therefore reticent to end a satellite's operations prematurely.[411]

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[404] Inter-Agency Space Debris Coordination Committee, *supra* note 13, s 5.3.2.
[405] Popova & Schaus, *supra* note 20 at 3.
[406] National Aeronautics and Space Administration, "Orbital Debris Quarterly News" (2020) 24:1 NASA Orbital Debris Program Office 16 at 6–7.
[407] Inter-Agency Space Debris Coordination Committee, *supra* note 13, s 5.3.1.
[408] Anderson, *supra* note 21 at 5.
[409] Mark Hempsell, "Wake-Up Call for Debris Creation in Geostationary Orbit" *Room: The Space Journal* (2019) at 21.
[410] Anderson, *supra* note 21 at 77.
[411] *Ibid* at 142.

The rate of compliance has been improving. In 2016, more than 80% of clearance attempts were successfully undertaken in GEO.[412] Yet, it is clear that the safety and long-term sustainability of the geostationary orbit requires near perfect compliance. It is estimated that even under the optimistic, present-day 80% mitigation rate, near-miss events in GEO will increase by a factor of two within 50 years.[413] These calculations do not even take into account the fact that objects in GEO smaller than a meter cannot yet be accurately tracked.[414] As mentioned in Chapter 1, because of the high orbital speeds in GEO, an object just a few centimeters in diameter could cause catastrophic damage if a collision were to take place.[415] A stringent application of the precautionary principle and the no-harm rule should therefore be applied in GEO because of the practically irreversible nature of space debris in this orbit. In accordance with these environmental law principles, States must safely dispose of their GEO satellites so as to avoid long-lasting environmental damage to the geostationary orbit.

A. Enforcement Through National Licensing

The question remains of how to encourage and enforce stronger adherence to debris mitigation guidelines. As more non-governmental entities become involved in space, there will be a need for increased oversight of space activities.[416] On the international level, a standardization system to coordinate behavior across operators does not exist.[417] Given the lack of an appropriate international body tasked with the governance of space activities, enforcement must be achieved on the national level.[418] Accordingly, the precautionary principle and the no-harm rule could be incorporated into the space launch application process, and enforced by national licensing authorities.

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[412] Popova & Schaus, *supra* note 20 at 3.
[413] Anderson, *supra* note 21 at 78.
[414] Lal et al, *supra* note 3 at 9, 29.
[415] Anderson, *supra* note 21 at 122.
[416] Lal et al, *supra* note 3 at 79.
[417] *Ibid* at 13.
[418] Muelhaupt et al, *supra* note 56 at 85.

The IADC and UNCOPUOS debris mitigation guidelines, despite their non-binding nature, have been useful in serving as a model for the development of national space laws.[419] Ultimately, spacefaring States have a vested interest – worth millions if not billions of dollars – in preserving Earth's orbits and minimizing the generation of debris.[420] Some States, such as Argentina, the Netherlands, Poland and Switzerland have confirmed their adherence to the IADC Guidelines.[421] Other countries, like Australia, France, Russia and Japan, have developed their own debris mitigation guidelines for their national space agencies which are inspired by the IADC guidelines.[422] Naturally, national space laws do impose concrete obligations on private actors to implement debris mitigation measures while conducting their space activities.

The legal basis behind States' ability to prescribe debris mitigation measures on commercial and private entities can be found in Article VI of the Outer Space Treaty. This article asserts that States bear international responsibility for national space activities - whether those activities are carried out by governmental agencies, or private and other non-governmental entities.[423] Moreover, the State is given responsibility for the authorization and continuing supervision of space activities carried out by non-governmental actors.[424]

National administrative bodies thus have powerful instruments at their disposal to improve and enforce compliance with space debris mitigation guidelines. Launch permits and license issuance, for example, could be made conditional on compliance with commonly accepted debris mitigation measures - such as the IADC Guidelines.[425] Some scholars have expressed concern that this could give rise to a varied set of behaviors in space.[426] Nevertheless, it would at least ensure that a pre-established threshold of technical and safety requirements relating to orbital debris is respected by all space actors. Many national licensing authorities around the world have included space debris mitigation rules as a precondition to the issuance of launch permits; space

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[419] Popova & Schaus, *supra* note 20 at 11.
[420] National Aeronautics and Space Administration, *supra* note 34 at 23, 25.
[421] Popova & Schaus, *supra* note 20 at 12.
[422] Viikari, *supra* note 91 at 110.
[423] United Nations Office for Outer Space Affairs, *supra* note 96 at Article VI OST.
[424] *Ibid*.
[425] Popova & Schaus, *supra* note 20 at 12.
[426] Lal et al, *supra* note 3 at 13.

operators seeking national authorization for their space activities must first demonstrate compliance with debris mitigation standards.

An in-depth example of a country that has incorporated space debris mitigation measures in its national licensing procedure, is the United States. In the U.S., the Federal Communications Commission (FCC) has been at the forefront of orbital debris regulation, which is applicable to all commercial companies that operate in the US market.[427] FCC space debris regulations are based on and essentially incorporate the recommendations of the IADC.[428] Since 2004, the FCC has required that end-of-lifetime disposal strategies be in accordance with IADC mitigation guidelines.[429] Any satellite operator seeking to provide services in the United States, must thus include a plan for orbital debris mitigation to gain FCC approval.[430] This applies to both U.S. commercial satellites as well as non-American satellites which want to access the U.S. market.[431] The National Aeronautics and Space Administration (NASA), and the Department of Defence (DoD) have also adopted policies for orbital debris mitigation based on the IADC and UNCOPUOS guidelines in all of their space activities.[432]

The FCC's oversight has had practical results in controlling the behavior of private actors. For example, the FCC's approval in 2019 of the SpaceX *Starlink* constellation was contingent on receiving more detailed debris-mitigation plans.[433] This led SpaceX to request an orbital altitude change for a portion of its constellation – from 1,150km to 550km – which would facilitate compliance with the IADC 25-year post-mission disposal rule.[434] Given the atmospheric drag at this lower altitude, *Starlink* satellites would take less than five years to re-enter the atmosphere.[435] The OneWeb company, which sought permission to launch 900 satellites in LEO

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[427] *Ibid* at A-9.
[428] Viikari, *supra* note 91 at 109.
[429] *Ibid* at 253.
[430] Muelhaupt et al, *supra* note 56 at 84.
[431] Viikari, *supra* note 91 at 109.
[432] *Ibid* at 106.
[433] Jon Brodkin, "SpaceX cuts broadband-satellite altitude in half to prevent space debris", (29 April 2019), online: *Ars Technica* <https://arstechnica.com/tech-policy/2019/04/spacex-changes-broadband-satellite-plan-to-limit-debris-and-lower-latency/>.
[434] *Ibid*.
[435] *Ibid*.

for internet broadband service, also elected to lower the orbital altitude of its spacecraft to 200km so as to bring about rapid re-entry and minimize the creation of debris.[436]

Despite this apparent success, there are still some pressing concerns. First of all, not all spacefaring States are imposing policies and rules on space debris mitigation.[437] Long term self-interest does not appear to be a sufficiently compelling force for the national implementation of debris mitigation measures.[438] Moreover, commercial space activities are developing and innovating quickly, making it difficult for national regulatory regimes to keep up. Even the United States, which has the most comprehensive and robust licensing regime in the world, is struggling to reform its existing policies and regulations so as to respond to the growing number and diversity of commercial space activities.[439] Partly because of the United States' desire to remain competitive in the commercial space sector, the FCC has been approving satellite licensing requests at a staggering pace. This has had a direct influence on smallsat constellation plans. *OneWeb* cited a change in FCC rules –which grants companies six years to deploy 50% of their constellation – as a key reason for choosing to deploy more satellites.[440]

Furthermore, an incident in 2019 exposed some of the cracks in the existing system of national oversight for commercial satellites. In January 2019, four satellites built by Swarm Technologies were launched in LEO without FCC authorization, amounting to the first unauthorized launch of commercial satellites in the United States.[441] The FCC had not granted the lauch license because of concerns over the satellites' small size. Four times smaller than a cubesat, the Swarm satellites were believed to be difficult to track by radar and therefore constitute a risk to other satellites.[442] Even so, Swarm Technologies proceeded to launch the satellites on an Indian rocket, believing it

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[436] West, *supra* note 16 at 12.
[437] Jakhu & Pelton, *supra* note 5 at 289.
[438] *Ibid*.
[439] West, *supra* note 16 at 157.
[440] Caleb Henry, "OneWeb asks FCC to authorize 1,200 more satellites", (20 March 2018), online: *SpaceNews* <https://spacenews.com/oneweb-asks-fcc-to-authorize-1200-more-satellites/>.
[441] West, *supra* note 16 at 20.
[442] Mark Harris, "FCC Accuses Stealthy Startup of Launching Rogue Satellites - IEEE Spectrum", (March 2018), online: *IEEE Spectrum: Technology, Engineering, and Science News* <https://spectrum.ieee.org/tech-talk/aerospace/satellites/fcc-accuses-stealthy-startup-of-launching-rogue-satellites>; Federal Communications Commission, *Dismissed Without Prejudice: Swarm Technologies, Inc.* (Experimental Licensing Branch, 2017).

might be able to get FCC authorization after the fact.[443] The FCC responded by revoking Swarm's application for another launch, and fined the company for launching satellites without authorization. The FCC also issued a warning to all other commercial operators that they would be penalized if they launched spacecraft without approval.[444]

Once in orbit, the Swarm satellites were accurately tracked almost immediately by both U.S. military as well as commercial radars, suggesting that the FCC's denial may not have been technically sound in the first place.[445] This incident led to questions about whether the FCC is the right organization to make determinations on space safety, and demonstrated that there are still problems with the regulatory approval process for space activities; better coordination between States is needed to ensure that launch permits are issued before any launches take place.[446]

Through national licensing schemes, spacefaring nations can enforce compliance with debris mitigation guidelines. The incorporation of the precautionary principle and the no-harm rule in the launch permit procedure can have the practical effect of ensuring that States and their private actors comply with space debris mitigation guidelines while conducting their space activities. Precaution is warranted in an environment where any incident affects the interests of all States for the long-term. For this reason, the regulation of private entities must be applied in a consistent manner by all space users to preserve a safe orbital environment.

II. Information Sharing and Space Situational Awareness

Outer space is a remote environment which is difficult to monitor. The less information States and private operators have at their disposal, the more complex, challenging, and hazardous space activities become.[447] Space Situational Awareness (SSA) refer to the ability to detect, track, identify, and catalog objects in outer space. The precautionary principle and no-harm rule could

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[443] Harris, *supra* note 443.
[444] Federal Communications Commission, *FCC Fact Sheet: Streamlining Licensing Procedures for Small Satellites* (Notice of Proposed Rulemaking, IB Docket No. 18-86, 2018) at 17–18.
[445] West, *supra* note 16 at 156.
[446] Harris, *supra* note 443; West, *supra* note 16 at 156.
[447] Jakhu & Pelton, *supra* note 5 at 273.

compel States to use SSA technologies to produce catalogs on space objects, predict collisions in orbit, diagnose spacecraft failures and malfunctions, and detect new orbital debris.

In an increasingly congested orbital environment with new commercial and civil actors gaining access every year, SSA constitutes a vital tool for supporting the safety and preservation of space assets.[448] SSA programs are a cost-efficient way in which the proliferation of new debris and the dangerous effects of existing debris can be mitigated. Greater knowledge of what is in space can help decrease the need for expensive collision avoidance maneuvers.[449] Moreover, SSA can be a useful tool to check if States are complying with their debris mitigation commitments, while also holding them accountable for any incidents that occur in space.

Maintaining accurate and precise awareness of the location of satellites and debris is increasingly critical for sustainable and safe operations in outer space.[450] Granted, not all spacefaring nations have access to accurate and reliable SSA technology. A rigorous application of the CBDR principle could require developed spacefaring nations to share SSA technology with developing countries conducting activities in outer space. Heightened awareness of the orbital environment will encourage developing States to observe the best practices and standards in outer space, and avoid activities and practices that could harm the orbital environment.[451]

From a technological point of view, the three environmental law principles discussed in Chapter 4 could encourage increased research and investment in SSA capabilities. The brand-new *Space Fence* project – a ground-based radar system operated by the US Space Force which became operational in March 2020 – increased the detection and monitoring capacity of the American Space Surveillance Network from approximately 25,000 objects, to an estimated 200,000 objects.[452] It remains to be seen whether improvements in SSA technology and networks will

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[448] West, *supra* note 16 at 31.
[449] Muelhaupt et al, *supra* note 56 at 86.
[450] Lal et al, *supra* note 3 at iii.
[451] West, *supra* note 16 at 31.
[452] Roger Mola, “How Things Work: Space Fence”, online: *Air & Space Magazine* <https://www.airspacemag.com/space/how-things-work-space-fence-180957776/>; Lockheed Martin, “Space Fence: The World’s Most Advanced Radar”, (2021), online: *Lockheed Martin* <https://www.lockheedmartin.com/en-us/products/space-fence.html>.

immediately translate to greater safety and security. Improved debris tracking capabilities means that satellites operators can expect a sharp increase in the number of conjunction warnings and alerts.[453] In 2017, the U.S. Space Surveillance Network provided data on nearly 310,000 close calls with space debris and issued 655 emergency alerts to satellite operators.[454] As SSA capabilities improve, those numbers are likely to worsen. The emergence of satellite constellations in LEO exacerbates the need for more precise and accurate data to mitigate the risk of collisions with space debris. Inaccurate data will lead to an excessive false-alarm rate, and the higher workload associated with it.[455] As such, even with improved space situational awareness capabilities, it is imperative that operators communicate effectively so as to avoid collisions.

A. Importance of Cooperation and Data Sharing for SSA

All spacefaring nations have some SSA capabilities and knowledge of orbiting objects.[456] The U.S. Space Force, for example, operates an extensive Space Surveillance Network of satellite, radar, and optical sensors that track over 25,000 space objects, their orbits, as well as their function and capabilities.[457] Several other spacefaring nations - such as Canada, the UK, France and Japan – also have their own space surveillance systems which contribute to the larger American network.[458] In GEO as well, the United States has a number of space-based programs – namely satellites in orbit –used to identify, track, and monitor space objects and debris.[459] Canada also has a dedicated space-based SSA asset: its *Sapphire* satellite, launched in 2013, contributes to the U.S. Space Surveillance Network.[460] Elsewhere in the world, the International

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[453] Daniel L Oltrogge & Salvatore Alfano, "The technical challenges of better Space Situational Awareness and Space Traffic Management" (2019) 6:2, online: <https://www-sciencedirect-com.proxy3.library.mcgill.ca/science/article/pii/S2468896719300333> at 72–79.

[454] Mosher, *supra* note 63.

[455] Muelhaupt et al, *supra* note 56 at 86.

[456] Lal et al, *supra* note 3 at 7.

[457] *Space Situational Awareness: Status of Efforts and Planned Budgets*, by U S Government Accountability Office, www.gao.gov (2015) at 22.

[458] West, *supra* note 1 at 45.

[459] Michael Peck, "Air Force Activates Two Space Tracking Satellites", (25 September 2017), online: *C4ISRNET* <https://www.c4isrnet.com/c2-comms/satellites/2017/09/25/air-force-activates-two-space-tracking-satellites/>.

[460] Royal Canadian Air Force, "Space Capabilities", (October 2020), online: *Government of Canada* <http://www.rcaf-arc.forces.gc.ca/en/space/capabilities.page>.

Scientific Optical Network (ISON) detects and catalogs manmade debris in high-altitude orbits using some 90 telescopes in 16 countries.[461] Coordinated by Russia's Keldysh Institute of Applied Mathematics, ISON produces orbital predictions, solutions and analyses.[462]

Painting a comprehensive picture of space is beyond the capability of any single State, and cooperation should be encouraged. To have a comprehensive representation of the outer space environment requires not only a global network of sensors and telescopes, but also data sharing between the SSA networks and satellite operators.[463] The common but differentiated responsibilities principle could be particularly relevant here, and spur greater SSA data-sharing between developed and developing spacefaring countries.

The importance of SSA data-sharing recently featured in the new 2019 UNCOPUOS guidelines on the sustainability of outer space. According to those non-binding guidelines, the long-term sustainability of outer space is enhanced by the collection, sharing, and dissemination of space debris monitoring information.[464] SSA information is shared through bilateral and multilateral agreements. In the United States, data from the Space Surveillance Network flows into the SSA Sharing Program – a service which provides basic satellite catalog information, and various levels of support to space operators during the launch, on-orbit, and re-entry operations of satellites.[465] Data sharing can be therefore instrumental in ensuring safe space operations.[466] The SSA Sharing Program also issues emergency notifications, alerting satellite operators to potential collisions in orbit, or high risks of human casualty or property damage on Earth.[467] Such services provide a minimum level of space flight safety support for entities which have an SSA agreement with the United States. According to recent statistics, such data is provided to more

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[461] I Molotov et al, *International Scientific Optical Network (ISON) for the near-Earth Space Monitoring: the Latest Achievements and Prospects* (COPUOS STSC, 54th session, 2017) at 2–3.
[462] *Ibid* at 7.
[463] Lal et al, *supra* note 3 at vii.
[464] UN Committee on the Peaceful Uses of Outer Space, *Guidelines for the Long-term Sustainability of Outer Space Activities* (United Nations Office for Outer Space Affairs, 2018) at Guideline B.3.
[465] Lal et al, *supra* note 3 at A-7, A-8; West, *supra* note 16 at 34.
[466] Muelhaupt et al, *supra* note 56 at 86.
[467] Lal et al, *supra* note 3 at A-8.

than 285 satellite operators, of which 32% are commercial and only 14% are part of the U.S. government.[468]

The CBDR principle could be a driving force towards increasing the number of bilateral and multilateral SSA collaboration agreements between developed spacefaring nations and emerging spacefaring nations. Globally, there seems to be a desire for SSA partnerships, since they are often mutually beneficial.[469] For example, Chile and the European Union have recently brokered an agreement in which the European Southern Observatory was granted permission to operate three SSA astronomical observation sites in Chile.[470] In return, Chilean university students were granted training and access to these sites and technology.

Greater cooperation and transparency between developing and developed spacefaring countries could flow from the application of the CBDR principle. However, this is easier said than done since increased transparency may be at odds with questions of national security.[471] Most governments see SSA first and foremost as having a national security function, which hinders the wider sharing and trust in SSA data.[472] In Germany, for instance, the *Ministry of Defence* operates the German Space Surveillance Center; in France, the French Space Command coordinates SSA services under the supervision of the Ministry of Defence.[473] States have been reticent in the past to share potentially sensitive SSA data. Some space operators have questioned the accuracy and completeness of the SSA data provided to them through the SSA Sharing Program, and believe that more high-quality information is required to make well-informed decisions about possible collision maneuvering. South Korean government officials, for example, estimate that they receive data on only 40% of objects tracked by the American SSN.[474] There are however hopeful signs that we are moving towards greater SSA cooperation and transparency. In 2018, the Department of Commerce was made responsible in the United Stated

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[468] *United States Strategic Command Space Situational Awareness*, by Clinton Crosier, Zotero, 54th Session (Vienna, Austria: UNCOPUOS Scientific and Technical Subcommittee, 2017) at 6; Lal et al, *supra* note 3 at 81, A-8.
[469] Lal et al, *supra* note 3 at 72.
[470] *Ibid* at 69.
[471] Jakhu & Pelton, *supra* note 5 at 293.
[472] Lal et al, *supra* note 3 at 79.
[473] *Ibid* at 60.
[474] *Ibid* at 21–22.

for both SSA and space traffic management, taking over that role from the Department of Defence which will retain management for military-to military SSA data-sharing.[475] The Department of Commerce has vowed to collaborate with commercial, non-profit and international partners, which is very encouraging.[476] Increased transparency could perhaps also be achieved through the use of commercial SSA programs. Commercial operators are increasingly involved and contributing to global space situational awareness capabilities. The market for commercial SSA services is growing, and its ability to track debris in orbit is comparable to the U.S. military's capabilities.[477] For example, the American private company *ExoAnalytics* has dozens of observatories and hundreds of telescopes worldwide, allowing it to track nearly all objects in GEO larger than 10cm.[478] The company has indicated that their optical sensors can achieve an accuracy of 0.1-0.25 arcseconds in GEO, with one arcsecond translating to a 170 meters accuracy.[479] While *ExoAnalytics* services are expensive - from $90,000/month for the use of 28 dedicated sensors to $1.36-million/month for services using 400 sensors – the use of SSA from commercial operators could translate into more accurate and transparent SSA data.[480]

III. Active Debris Removal

The current guidelines for debris mitigation are non-binding, modest and some would argue, incomplete.[481] Studies modelling the orbital evolution of space debris indicate that mitigation measures alone will not suffice to ensure the future access and usability of outer space.[482] While mitigation is definitely part of the solution, further measures are necessary to stabilize the orbital

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[475] Michael Sheetz, "VP Pence: Commerce Department will oversee new space debris policy", (16 April 2018), online: *CNBC* <https://www.cnbc.com/2018/04/16/vp-pence-commerce-department-will-oversee-new-space-debris-policy.html>.

[476] *Implementation of U.S. Space Traffic Management Policy*, by Kevin O'Connell, Zotero, 56th Session (Vienna: UNCOPUOS Scientific and Technical Subcommittee, 2019) at 6.

[477] Lal et al, *supra* note 3 at 55.

[478] ExoAnalytic Solutions, "Space Domain Awareness – ExoAnalytic Solutions", (2021), online: <https://exoanalytic.com/space-domain-awareness/>.

[479] Lal et al, *supra* note 3 at 36.

[480] ExoAnalytic Solutions, "Commercial Price List – ExoAnalytic Solutions", (2021), online: <https://exoanalytic.com/space-domain-awareness/commercial-price-list/>.

[481] Pelton, *supra* note 6 at 37.

[482] Popova & Schaus, *supra* note 20 at 1.

environment. Dr. Donald Kessler, father of the Kessler Syndrome scenario, has recently written that even without any new launches the orbital population will continue to increase through collisions, which will become the dominant debris-generating mechanism in the future.[483] The danger is particularly prevalent in the LEO region between 700km - 1,000 km from Earth. Mitigation measures in LEO can slow down the growth of space debris but are not enough to stop it. These findings were studied in detail by the IADC in debris simulation campaigns, which concluded that certain orbits in LEO would become totally useless in 100 years, unless debris was actively removed.[484] In GEO as well, mitigation measures – under the current re-orbit success rates – are not enough to stabilize that increasingly congested orbital environment.[485] As illustrated earlier in this thesis, debris generated in GEO remains there permanently due to the lack of any atmospheric drag at that altitude. The graveyard orbit strategy does help slow down the rate of future debris growth in GEO, but does not affect existing debris in that orbit.[486]

The international environmental law principles analyzed in Chapter 4 must be utilized to encourage States to undertake debris removal activities. The debris population in certain LEO and GEO regions has already reached the threshold where the collision-cascading Kessler Syndrome is well under way.[487] Accordingly, the further proliferation of space debris can only be stopped through a combination of aggressive mitigation standards and compliance, and the timely removal of high-risk space debris.[488] Proactive debris removal is thus necessary to stabilize the growth of space debris arising from in-orbit collisions.[489] Active debris removal – the removal of non-functional and uncontrolled objects from orbit – is expected to play a crucial role in preserving the sustainability of outer space.[490] This is particularly the case in GEO, where existing debris will basically remain in orbit forever.

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[483] Pelton, *supra* note 6; J-C Liou & N L Johnson, "Risks in Space from Orbiting Debris" (2006) 311:5759 Science 340–341 at 39.
[484] Jakhu & Pelton, *supra* note 5 at 289.
[485] Anderson, *supra* note 21 at 77.
[486] Popova & Schaus, *supra* note 20 at 7.
[487] Pelton, *supra* note 6; Anderson, *supra* note 21 at 77.
[488] Anderson, *supra* note 21 at 145.
[489] Popova & Schaus, *supra* note 20 at 4.
[490] *Ibid* at 7.

Studies have suggested that the removal of just a handful of the most hazardous debris elements could help stabilize the orbital environment. GEO debris modelling work by Paul Anderson and Hanspeter Schaub at the University of Colorado Boulder, demonstrate that the removal of the top 10 highest cumulative risk objects in specific regions of GEO could lead to a 50% reduction in the mean number of near-miss events, and nearly eliminate events that could potentially warrant evasive action by operators.[491] In accordance with the precautionary principle, States should undertake debris removal for high-risk debris for which they are responsible. Despite the lack of full scientific certainty that debris will be involved in a collision, the precautionary principle requires that States take cost effective measures to prevent serious environmental degradation to Earth's orbits. Debris can remain in orbit for decades if not hundreds of years, posing a danger to other space objects and to the environment as a whole. As per the no-harm rule, States must also ascertain that their space debris does not cause damage to areas beyond the limits of their national jurisdiction. Just one collision between two large space objects – as the Iridium-Cosmos 2009 collision demonstrated – have the potential to generate thousands of new debris elements.[492] Therefore, an effective environmental protection of outer space cannot entail the mere mitigation of future orbital debris; a proactive approach to the removal of existing high-risk debris is warranted in accordance with the precautionary principle and the no-harm rule.

The distinction between existing debris and the creation of future debris is important. With respect to cleaning up existing debris, the common but differentiated responsibilities principle should be applied. Because of their historical responsibility for space debris creation, developed spacefaring countries should take the lead in the continued research and eventual implementation of active debris removal mechanisms. The financial burden for the removal of existing debris should also be assumed – at least initially - by developed spacefaring States who have more means and resources to undertake debris removal missions.[493] The CBDR principle should not however be construed in a way that suggests that developing States refrain from implementing mitigation measures when conducting their space activities.[494] That would undermine all current efforts to protect and preserve outer space. The responsibility to halt the proliferation of future

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[491] Anderson, *supra* note 21 at 48.
[492] Pelton, *supra* note 6 at 37.
[493] Stubbe, "Common but Differentiated Responsibilities for Space Debris", *supra* note 11 at 10.
[494] *Ibid* at 11.

space debris belongs to all spacefaring nations, whether developed or not. Because of the global nature of space debris, only collective and universal action can stabilize the ongoing degradation of outer space.[495] The IADC and UNCOPUOS debris mitigation guidelines should therefore be observed by all nations conducting activities in outer space.

A. Issues with Active Debris Removal

Naturally, removing debris from orbit is not an easy task. While the development and testing of active debris removal technology is ongoing, there are still legal, political, financial, and technical challenges that exist. Issues relating to active debris removal warrant a separate and more extensive discussion. Nevertheless, some of those issues will be briefly discussed below, as well as the ways in which international environmental law principles might assist in the undertaking of debris removal.

1. Legal Issues

From a legal point of view, debris removal activities involve a number of complications. First of all, orbital debris must be defined and distinguished from a *space object* as articulated in the Liability Convention and Registration Convention. This distinction, which does not currently exist in international law, must be clear and unambiguous to all entities who might be involved in debris removal activities.[496] According to Article VIII of the OST, the launching State retains jurisdiction and control over a space object while it is in outer space or on a celestial body. Therefore, under UN treaty law, removal of space debris is only permissible if conducted or authorized by the launching State.[497] If the launching State does not consent to undertake the removal or provides authorization to a third party to remove the object, any space debris removal would be considered unlawful.[498] This unnecessarily impedes the conduct of debris removal

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[495] *Ibid*.
[496] Pelton, *supra* note 6 at 69.
[497] Popova & Schaus, *supra* note 20 at 10.
[498] *Ibid* at 9.

activities.[499] Differentiating between space debris and space object would facilitate the transfer of jurisdiction and control of orbital debris to another entity for the purpose of removal. [500]

An additional legal challenge is that under the OST[501] and Liability Convention[502], responsibility for any accident that occurs as a result of a space collision does not lie with the offending operator or owner of the spacecraft.[503] Rather, the responsibility for paying liability claims rests solely on the launching State, even in the absence of any wrongful conduct from its part.[504] A launching State might therefore be reluctant to conduct active debris removal activities, since it risks incurring large liability claims.[505] In the case of a collision or accident during the debris removal process, the launching State may be held liable for the crash. Under the current space law, launching States not only lack an incentive to remove their space debris from orbit; they actually risk substantial financial penalties if the removal process somehow adversely affects another space object and creates liabilities.[506]

Owners and operators of space objects other than the launching State currently have no obligation under international law to exercise due diligence and engage in active debris removal so as to minimize collisions and orbital debris buildup.[507] Granted, space operators have significant vested interests in preserving the orbital environment and protecting investments that run into the millions, if not billions of dollars.[508] But the only way they can be held responsible for their actions is under national space law and licensing processes. Environmental law principles could place a legal duty on States and their private actors to remove their debris from orbit, and thus ensure that no damage occurs to other space objects and the orbital environment as a whole. Notwithstanding the lack of scientific certainty that a collision involving dangerous

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[499] Pelton, *supra* note 6 at 74.
[500] *Ibid*.
[501] United Nations Office for Outer Space Affairs, *supra* note 96 at Article VII OST.
[502] *Ibid* at Article III Liability Convention.
[503] Pelton, *supra* note 6 at 31.
[504] Popova & Schaus, *supra* note 20 at 10.
[505] Pelton, *supra* note 6 at 32.
[506] *Ibid* at 48.
[507] *Ibid* at 75.
[508] Muelhaupt et al, *supra* note 56 at 84.

debris will take place, States and their private actors must act with foresight and proactively undertake to remove debris.

2. Political Issues

One of the main concerns with active debris removal activities, is security. Satellites are oftentimes strategic assets, and it is doubtful whether States which do not possess the financial or technological capabilities to conduct active debris removal would allow third parties to remove their satellites from orbit.[509] An inactive space object may, for instance, still carry valuable classified information.[510] Because of the dual character – both civil and military – of many satellites, debris removal remains a sensitive topic and presents a hurdle to its future implementation. Moreover, there is a fear that future debris removal technologies could be used as *space weapons* against active and functional satellites.[511] Because of their ability to intercept and potentially dock with another satellite, debris removal spacecraft might, in the wrong hands, be used as a co-orbital ASAT weapon.[512] Nonetheless, the urgency and danger of space debris demand action. Political inaction will precipitate the Kessler Syndrome, which will affect the space activities of all States indiscriminately. In accordance with the precautionary principle and no-harm rule, spacefaring nations could begin by removing their own high-risk debris from orbit through a transparent, confidence-inducing process.

3. Financial Issues

There is also a financial hurdle that must be overcome. Debris removal activities are likely to be very expensive, and it is not clear under the current legal framework who should incur the costs. Legal author Joseph Pelton has suggested that all space operators should be required, under national or regional regulation, to put a small percentage into a debris removal fund.[513] Applicable to governmental and non-governmental entities alike, this debris removal tax would

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[509] Popova & Schaus, *supra* note 20 at 10.
[510] Viikari, *supra* note 91 at 33.
[511] Pelton, *supra* note 6 at 6; Popova & Schaus, *supra* note 20 at 10.
[512] Jakhu & Pelton, *supra* note 5 at 275–276.
[513] Pelton, *supra* note 6 at 36.

be used towards compensating private companies or public organizations for developing and operating the new debris removal technology in LEO and GEO.[514] While satellite owners and operators might object to this initiative, payments into the fund would be relatively modest compared to the costs of postponing the debris removal process.[515] If debris continues to cascade out of control, the cost of active debris removal might truly soar into levels involving trillions of U.S. dollars.[516] In accordance with the CBDR principle, developed spacefaring nations must display leadership and include the debris removal tax into the national launch permit and license issuance process. Comparably to how companies purchase insurance before launching an object in outer space, regulatory approval for a space activity should be conditional on a pre-determined contribution towards the debris removal fund.[517]

4. Technological Issues

Designing and building a satellite to identify, track, rendezvous, dock, and deorbit a piece of debris is an extraordinarily difficult task on its own. There are still many challenges to be overcome in terms of finding cost-effective, safe, and technically efficient ways to remove space debris from orbit.[518] Given their technological and economic capabilities, developed spacefaring nations should continue to research and develop active debris removal technology as per the CBDR principle. Eventually, these debris removal technologies could be transferred to developing spacefaring nations. So far, a number of projects and models have been conceived and tested.[519]

Passive debris removal measures, for example, involve the pre-launch instalment of drag-augmentation devices, which can be deployed to accelerate the decay of satellites, and make de-orbit maneuvers two to three times more rapid.[520] These technologies include inflatable balloons,

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[514] *Ibid*.
[515] *Ibid* at 48.
[516] *Ibid*.
[517] *Ibid* at 36.
[518] *Ibid* at 72.
[519] Jakhu & Pelton, *supra* note 5 at 290.
[520] Pelton, *supra* note 6 at 55.

inflatable tube membranes, and solar sails.[521] Passive debris removal technology is an appropriate, effective and economical way to accelerate the de-orbit of smallsat constellations in LEO operating at relatively low orbits. It could help space operators ensure that smallsats meet the post-mission removal standard of 25 years.[522] This technology is not as effective in higher LEO orbits and does not work in MEO or GEO where the atmospheric drag is minimal.[523]

A number of concepts for debris removal at higher orbits have been proposed, including various forms of harpooning, net capturing, tethering, and magnetic capture methods.[524] In GEO, propulsion thrusters are already being used not only to transfer satellites approaching their end-of-life to graveyard orbits, but also to conduct collision avoidance maneuvers. A very exciting technology that is currently being developed is that of thrust propulsion systems for small satellites in LEO. *ThrustMe* is a French company working on iodine electric propulsion technology for small satellites.[525] The use of iodine as propellant, and the feasibility of miniaturizing the size of the thruster system to fit on smallsats, were both successfully tested earlier this year.[526] Having an on-board propulsion system would permit smallsats to change orbit as needed, compensate for atmospheric drag, avoid collisions, and accelerate post-mission disposal.[527]

Conclusion

The most critical challenge to the safety, security, and sustainability of outer space is the threat posed by space debris to the spacecraft of all nations. The total amount of space debris is increasing each year, heavily concentrated in the orbits where human activities take place. Our growing dependency and appetite for space has revealed the urgent need to develop legal and regulatory mechanisms to properly address the threat space debris poses to the long-term

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[521] *Ibid*.

[522] Benjamin Rasse, Patrice Damilano & Christian Dupuy, “Satellite Inflatable Deorbiting Equipment for LEO Spacecrafts” (2014) 1:2 Journal of Space Safety Engineering 75–83.

[523] Pelton, *supra* note 6 at 56.

[524] Pelton, *supra* note 6.

[525] Lafleur, Aanesland & Rafalskyi, *supra* note 227 at 34–39.

[526] ThrustMe, “RF Acceleration”, (2021), online: *thrustme.fr* <https://www.thrustme.fr/rf-acceleration>; ThrustMe, *supra* note 255.

[527] Lafleur, Aanesland & Rafalskyi, *supra* note 227 at 39.

sustainability of the outer space environment. Unfortunately, the current legal framework does not adequately address the problems associated with the rapid proliferation of space debris. Largely because of the circumstances and historical context within which the UN space treaties were formulated, the legal response hitherto fails to offer satisfactory protection to the orbital environment. Soft-law instruments and recommendations, while useful, cannot be legally enforced and fail to impose restrictive debris mitigation strategies, even though the increasing congestion of Earth's orbits would require it.

This thesis suggests that principles from a different legal regime - international environmental law - are applicable to the outer space environment. The precautionary principle, the no-harm rule, and the common but differentiated responsibilities principle, could be applied to impose stronger commitments and new obligations on space faring countries, and lead to a more equitable and successful outcome against space debris. Practically speaking, these international environmental law principles could firstly lead to global compliance with space debris mitigation measures, which would help slow down the creation of new debris, and contribute to stabilizing the outer space environment. Secondly, these principles should advance greater collaboration and data-sharing around SSA programs, which will provide a more complete picture of outer space and help prevent in-orbit collisions. Finally, these principles should promote greater research, and the eventual implementation of debris removal strategies. Measures such as these will help ensure that the hugely beneficial use and exploration of outer space can continue for years to come.

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