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Space Junk: An Impending Danger – Who is Responsible for it?

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ABSTRACT

This paper is situated within the domain of environmental law, focusing on studies of how space junk is an impending danger to the environment and who is responsible for it. This paper examines the definition of space debris and its current and potential future impacts, critiques the existing legislative framework and its deficiencies, explores forthcoming technological advancements to address the issue, and advocates for the adaptation of laws to accommodate such advancements. The primary objective of this research is to elucidate the recently identified adverse effects of space debris and underscore the inadequacy of the current legislative regime in addressing the issue on an international scale. This research uses secondary data and identifies additional environmental threats posed by space debris, including climate change, metal vaporization in the ozone layer, mega-constellations, and lunar debris and that existing international law concerning space debris is non-binding and not yet a part of customary law, with only principles existing. This paper emphasizes the necessity of organizing global conventions on space debris, involving prominent space agencies, and declaring space as a global commons. It recommends that these initiatives be undertaken by various entities such as the International Telecommunication Union (ITU), the Committee on the Peaceful Uses of Outer Space (COPUOS), and the United Nations Office for Outer Space Affairs (UNOOSA).

***Keywords**: Outer Space, Satellite, Space Debris, Space Junk, Orbit, Atmosphere, Earth, United Nations, Guidelines.*

I. INTRODUCTION

"It's going to be like an interstate highway, at rush hour in a snowstorm, with everyone driving much too fast,"

- Johnathan McDowell (Harvard)

The Space Industry is considered an integral player in the battle against climate change because space exploration and related scientific research have helped foster a deep understanding of our planet and thus have allowed for more efficient use of the planet's resources. But the so-claimed space custodian is in the shack of an investment spree not foreseen by it. At the current rate of

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unsustainable expansion, with more and more objects being sent into space, the value of space will plummet for future generations. It is common knowledge that the space is devastatingly mind-bogglingly big. But it is also true that the space region closest to Earth is getting crowded. The United Nations Office for Outer Space Affairs (UNOOSA) has stated that with space traffic increasing, the number of in-space collisions is expected to rise. With such a rise in traffic in space, the amount of space debris created by such traffic is also under the threat of rising exponentially, with no proper law to regulate and hold governments and its entities accountable.

In this paper, the author will discuss the definition of space debris and its adverse impacts. The primary focus will be on the emerging effects of space debris on both space and Earth's environment, along with the deficiencies in current legislation and the imperative for a new binding regulatory framework. The paper will subsequently explore potential solutions to address these deficiencies by examining upcoming technological advancements and offering recommendations for bridging the gaps in legislation regarding space debris remediation.

(A) Literature Review

In the previous research on Space Debris, authored by Martha Mejía Kaiser on 'Space Law and Hazardous Space Debris', the main focus of the study has been the different types of hazards caused by space debris such as kinetic, chemical, orbital, etc. She approached the topic with a secondary database methodology and focused on why space debris is a hazard. The section where the author discusses the IDAC guidelines and their impact is the most relevant to our study. The author concluded that urgent measures need to be taken with the technological development in exploration and the increasing use of outer space.

Another journal article, written by Frans von der Dunk on 'Space Debris and the Law', focuses on how to define space debris and how to identify the origin of space debris for compensation purposes. This study maps out interpretations of the Outer Space Treaty which are relevant to our study. The paper on 'Space debris, remarks on current legal issues' by Armel Kerrest emphasizes the need for a legal definition of space debris and responsibility and liability standards for its mitigation. The section where the author discusses the liability convention is relevant to our study.

In the paper written by Abbas Sheer and Shouping Li on 'Space Debris Mounting Global Menace Legal Issues Pertaining to Space Debris Removal: Ought to Revamp Existing Space Law Regime', the focus is on the legal and organizational challenges, suggesting revamping the fuzzy prevailing international space law regime to encounter incoming legal aspects. The section where the author discusses how international space law does not permit interruption

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with space objects without the preceding approval from the launching State is relevant to our study.

The journal article authored by Chelsea Muñoz-Patchen titled 'Regulating the Space Commons: Treating Space Debris as Abandoned Property in Violation of the Outer Space Treaty' underscores the imperative for spacefaring nations to adhere to the established the space treaty regime, particularly the foundational principles enshrined in the Outer Space Treaty, to uphold the unrestricted access to space for all. It advocates for classifying space debris as abandoned property by amalgamating the existing definition of space debris with the doctrine of abandonment. The segment elucidating the legal principles governing space activities is of particular relevance to our study.

The main areas of debate within environmental law regarding space debris have focused on determining who should be held accountable for space debris collisions and damages and on the need for clear standards facilitated by international cooperation.

A significant gap exists in the relatively limited study of the new emerging dangers of space debris and the potential legal obstacles that may arise in implementing technological advances. This paper aims to address these gaps to the best extent possible.

(B) Objectives of the study

The objectives of the paper are as follows:

1. To examine the nature of space debris and elucidate how it poses an imminent and escalating hazard to Earth.

2. To analyze the emerging issues contributing to space debris formation and its resultant challenges.

3. To assess the existing legislative regime and identify gaps while exploring India's stance.

4. To evaluate the steps taken thus far to mitigate space debris from a technological and legal perspective.

5. To provide suggestions for potential actions to be taken within an international forum, from a legal standpoint, to tackle this issue effectively.

(C) Research Methodology

This paper employs a methodology centred around analysing secondary data sources to examine the imminent dangers of space debris and identify legislative gaps. The analysis draws upon documents accessible through UN websites and official webpages of various space agencies.

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Additionally, secondary sources such as newspaper articles, published journal articles, books on space law, and statutes are considered to fulfil the objectives outlined in this paper.

II. ANALYSIS

(A) What Is Space Debris? How Is It An Impeding Danger?

Currently, more than 2,200 operational satellites orbit Earth. However, such active satellites are not the issue. The inoperative satellites spent rockets and debris, collectively called space debris or space junk, that clutter the region - are concerning. The moment humans entered space with Sputnik I, space junk began to accumulate, and such accumulation is inevitable as long as there is human activity in space. Not only these rocket explosions, rocket launches (which leave behind boosters, fairings, interstages, and other debris), human objects from astronauts (cameras, pliers, gloves, wrenches, spatula, tool bags) also add to the space junk. While spent satellites may eventually re-enter Earth's atmosphere and disintegrate, this process can take years, especially for satellites orbiting at higher altitudes. NASA classifies space junk based on its origin - Natural or Artificial. Artificial space junk is defined as 'any man-made object in orbit around the Earth which no longer serves a useful function'[2]. The Inter-Agency Space Debris Coordination Committee (IADC) defines "space debris" as "all man-made space objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional[3].

As of 2020, there are roughly 34,000 pieces of debris 10 cm in diameter or larger, roughly 900,000 objects from 1 cm to 10 cm, and more than 128,000,000 pieces under 1 cm[4]. The mass of debris in Earth's orbit totals nearly 7 million kilograms[5]. Even minuscule debris poses a significant hazard in space. Dust grains and paint chips can inflict damage on optics and solar panels, diminishing operational lifespans and generating further fragments of debris. This debris travels with a velocity roughly corresponding to an exploding grenade. Colliding with satellites could have devastating effects and bring the entire mission or purpose of the satellite to a complete stop. Stephane Germain, the CEO of GHGSat, has stated that there are already 6,300 tonnes of debris in near-earth orbit, and by 2030, there could be 60,000 satellites flying in this

[2]Charlotte Luke, *Explainer: What Is Space Junk and How Does It Affect the Environment?*, EARTH.ORG, (September 6, 2021), https://earth.org/space-junk-what-is-it-what-can-we-do-about-it/

[3] Muñoz-Patchen, Chelsea, *Regulating the Space Commons: Treating Space Debris As Abandoned Property in Violation of the Outer Space Treaty*, 19 (1) CJlIL 233, 235 (2018)

[4] Dr. Max Polyakov, *We're polluting our future home – before we even live there. Here's why we need to clean up our space junk*, WORLD ECONOMIC FORUM, (May 5, 2021), https://www.weforum.org/agenda/2021/05/why-we-need-to-clean-up-space-junk-debris-low-earth-orbit-pollution-satellite-rocket-noosphere-firefly/

[5] Id

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zone[6]. He also emphasised that the global space-faring community needs to address the debris issue before the orbital environment becomes unusable. Instances of near misses between spacecraft and existing space debris are becoming increasingly frequent.

Just 30,000 km above Earth's surface in the equatorial plane is the geostationary orbit in which most communications and weather satellites orbit, which consists of a lot of space junk. But the Low-Earth Orbit (LEO), which extends just above Earth's atmosphere upwards to 2,000 km, has even more junk. This is a massive problem because for any space vehicle to get to the moon and other planets, they have to pass through LEO, and such dense debris with high orbital velocity being there imperils all space activities.

In 2021, the crew of the International Space Station were forced to take shelter onboard to avoid being struck by pieces of a broken satellite orbiting Earth[7]. The International Space Station (ISS), in 2006, encountered a setback when its window, fortified with fused silica and borosilicate glass, sustained a 7mm chip from a collision with space debris. A single collision has the potential to generate thousands of particles of space trash. In 2009, an inactive Russian satellite named Cosmos 2251 collided with an active American communication satellite, Iridium 33, approximately 804 km above Siberia. This collision created approximately 2,000 pieces of debris, each at least 10cm in diameter, with thousands more smaller pieces entering the Earth's atmosphere. Experts estimate that over 50% of the debris from Iridium 33 will persist in orbit for at least a century. A study presented in 2021 at the European Conference on Space Debris says that the problem has been underestimated and that the amount of space junk in orbit could, in a worst-case scenario, increase 50 times by 2100[8].

a. Kessler Syndrome

NASA Scientist Donald J. Kessler came up with the "Kessler syndrome", which states that when space junk creates an impact on an operational spacecraft, it would lead to even more debris, which would lead to further impact. Thus, the operational spacecraft and the orbital debris could reach such a density that every tiny impact creates more debris to the point that usage of LEO might be impossible for decades. Space debris epitomizes the 'tragedy of the commons,' whereby the shared nature of space brings about competing interests, leading to

[6] Nikolai Khlystov, *Space debris is a growing problem. These leaders have a plan to tackle it*, WORLD ECONOMIC FORUM, (13 June 2023), https://www.weforum.org/agenda/2023/06/orbital-debris-space-junk-removal/

[7] Katharine Rooney, *Space junk: what it is and why cleaning it up matters*, WORLD ECONOMIC FORUM, (May 20, 2021), https://www.weforum.org/agenda/2021/05/space-junk-clean-satellite/

[8] Jonathan O'Callaghan, *What if Space Junk and Climate Change Become the Same Problem?*, THE NEW YORK TIMES, (May 12, 2021), https://www.nytimes.com/2021/05/12/science/space-junk-climate-change.html

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overexploitation and rendering the resource unusable for all.

b. Junk in the Lunar region

Humans and their space missions have also left a lot of junk in the lunar region, which includes rocket boosters from over 50 crashed landings and nearly 100 bags of human waste[9]. Since the Moon is no man's land (no one owns it), no one is responsible for keeping it clean. The 1967 United Nations Outer Space Treaty[10] asserts that no nation may lay claim to the moon or its territories, emphasizing the exclusive utilization of celestial bodies for peaceful endeavours. However, it remains silent on the subject of private enterprises and individuals, leaving ambiguities regarding the exploitation of space resources. The United Nations Moon Agreement of 1979[11] states that the Moon and its resources are the common heritage of humanity. However, significant countries like the United States, Russia, and China have never signed it. In 2016, Americans created their own law, leading to the American commercial space industry growing with few restrictions.

c. Mega-constellations of Satellite

Private companies like Elon Musk's Starlink and Amazon are joining China, SpaceX, Amazon's Project Kuiper, One Web Corporation, and Canada's Telesat plan are building mega-constellations in the Low Earth Orbit (LEO). These constellations will hoard tens of thousands of satellites, each with a lifespan of 5-10 years. This will contribute to mass amounts of space debris roaming around in the orbit, which will hinder scientific discovery and endanger anything passing through it. It could even deposit hazardous alumina levels into the earth's upper atmosphere, which might cause solar radiation.

d. Climate Change Exacerbates Space Debris

Climate change in the surface level of the earth causes global warming, but in the upper atmosphere, the increased concentration of greenhouse gasses causes a global cooling effect, which causes the atmosphere to shrink and reduces air density. This reduces the atmospheric drag, so the orbital lifetimes of satellites increase because the reduction in atmospheric drag makes it easier for satellites to travel around the Earth[12]. This allows the satellites to live longer

[9] Chris Impey, *Analysis: Why trash in space is a major problem with no clear fix*, PBS NEWS HOUR, (September 3, 2023, 9:00 AM), https://www.pbs.org/newshour/science/analysis-why-trash-in-space-is-a-major-problem-with-no-clear-fix

[10] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty), Jan. 27 1967, 18 U.S.T. 2410; 610 U.N.T.S. 205.

[11] The Moon Agreement, December 18 1979, 1363 U.N.T.S. 22, 18 I.L.M. 1434 (1979)

[12] Olivia Cooper, *Climate change and space debris, a vicious cycle*, ASTROBITES, (January 20, 2023), https://astrobites.org/2023/01/20/climate-change-exacerbates-space-debris/

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in their orbits and leads to the accumulation of space debris. This leads to the vicious cycle of satellite population growth and worsening climate change, which negatively impacts the environment of satellite debris.

e. Vaporized Metals From Burned-Up Space Junk

The new pollutants scientists have found to be concerning are the vaporized metals from burned-up space junk that are floating around in Earth's stratosphere, which is the same region where the ozone layer lies. Researchers sampled stratospheric air over Alaska and the U.S. Midwest using specialized mass spectrometers and discovered surprising amounts of many metals commonly used in rockets and satellites[13]. Data from the National Oceanic and Atmospheric Administration (NOAA) flights suggest that most of the aluminium, copper and lithium now found in the stratosphere is from space junk.

Earlier researchers did not think far ahead about where the burnt and vaporized metal might go upon re-entry into Earth's atmosphere. Now, with the research discovered, it is found that these particles go into the stratosphere. An indisputable link has been established between metals in the stratosphere and spacecraft re-entry. This metallic pollution will accelerate in years as the number of rocket launches and atmospheric re-entries continues to grow.

(B) Existing Legislative Regime of Space Debris and Its Lacunae

The concept of space debris has been the centre of scientific and technical analysis for many years. However, despite its significance, this issue is yet to attain the requisite legal acknowledgement necessary to speed up the development of a comprehensive international framework capable of addressing the legal intricacies it presents.

In the 1990s, NASA gave out specific guidelines to mitigate the orbital debris hazard, and in 2002, the Inter-Agency Space Debris Coordination Committee adopted a set of guidelines on "Coordination of activities related to the issues of man-made and natural debris in space." The guidelines are:

- Limit debris
- Reduce break-ups
- Dispose of after missions
- Prevent on-orbit collisions

[13] Leonard David and Lee Billings, *Space Junk Is Polluting Earth's Stratosphere with Vaporized Metal*, SCIENTIFIC AMERICAN, (October 26, 2023), https://www.scientificamerican.com/article/space-junk-is-polluting-earths-stratosphere-with-vaporized-metal/

- Avoid intentional releases of debris
- Improve on-ground casualty risk assessment
- Ensure dark and quiet skies

The International Organization for Standardization (ISO) offers comprehensive technical guidance for implementing the Space Debris Mitigation Guidelines, including the ISO 24113:2011 standard, updated in 2019. These detailed recommendations mark a significant advancement in applying the IADC Mitigation Guidelines across states with varying economic and technical capacities. Certain scholars suggest that opinio juris and state practice are evolving to solidify some IADC guidelines as norms of customary international law. Adherence to these mitigation guidelines in state practice is also anticipated to establish a baseline standard of care, potentially attributing fault for damages resulting from non-compliance. Consequently, failure to adhere to mitigation guidelines could be construed as "fault," potentially leading to liability for orbital collisions under the Liability Convention.

The Magna Carta of space law, the Outer Space Treaty of 1967, is very general regarding space debris and does not offer a particular solution. The treaty also offers no proper guidance regarding mitigating space debris at the State level. The only option at hand is for lawyers to interpret the articles.

Article IX states that parties to the treaty shall conduct all their activities in outer space with due regard to the corresponding interests of all other State Parties. This clause can be interpreted to mean that state parties have an obligation to avoid the creation of, reduce, and even remove space debris to allow all States to participate in the exploration and use of outer space with minimal risk from debris. The article also talks about how the study and exploration of outer space shall be conducted so as to avoid their harmful contamination. Still, the treaty does not define 'harmful contamination'. Generally, the phrase is construed as biological or radioactive contamination, not space debris. Article IX also obliges the state parties to avoid adverse changes in the Earth's environment from introducing extraterrestrial matter. However, being man-made, space debris cannot be considered such a matter. Thus, it absolves the state party's obligation to prevent such adverse changes caused by space debris. Additionally, this article delineates the 'due regard[14]' obligation, mandating that States Parties conduct all their activities in outer space while duly considering the corresponding interests of other States Parties. The level of consideration necessary corresponds to the importance of the rights at stake. Regarding

[14] Yannick Radi, *Clearing up the Space Junk: On the Flaws and Potential of International Space Law to Tackle the Space Debris Problem*, 12 ESIL 1, 4-7 (2023)

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the latter, it is crucial to reiterate that space debris obstructs the exercise of the fundamental right in international space law: the freedom to utilize and explore outer space. This underscores the need for a significant level of consideration by States Parties. Furthermore, this provision establishes the 'no harm principle,' which can be interpreted within the context of the customary international law's prohibition against causing transboundary environmental harm.

As per Article VI of the Treaty, the state bears international responsibility for the activities conducted by its nationals in outer space, whether the nationals are governmental agencies or private entities. Therefore, if such operators create space debris, then the state party is responsible for the actions of its private operators and the consequences and resulting damage.

Article VIII provides that launching states retain ownership of the objects and their components launched into space. Article VII holds the party internationally responsible for any damage caused by such object or its component, and it, read along with the Liability Convention of 1972[15], provides that launching States are liable for damage caused by debris generated by private entities for which such States are responsible.

Only parties to the convention can file a claim. The parties who claim would have to prove that damage was caused to its citizens or space objects that are registered, identify the space object that caused the damage and establish that the other party is its “launching State” and also prove that the damage was caused by the fault of the other party or the fault of a private entity for whom the other party is responsible. The challenge lies in the identification of particulate debris and its attribution to the originator of the launched object. Currently, Earth-based tracking stations possess the capability to monitor space debris exceeding approximately 10cm in size[16]. However, smaller debris pieces remain untracked and uncatalogued, making it challenging to definitively identify them for the purpose of attributing responsibility to the launching State. Further complexity arises when assigning fault to the launching state. Fault liability typically assumes the existence of a standard of care by which the reasonableness of the defendant's actions can be evaluated. Establishing fault necessitates the claimant State to demonstrate that the debris owner responsible for the damage failed to adhere to national or international standards or guidelines governing space activities and debris mitigation. Yet, the absence of mandatory international standards for debris mitigation complicates the establishment of a benchmark against which fault can be measured.

The United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) was

[15] The Liability Convention, March 29, 1972, 24 U.S.T. 2389, 861 U.N.T.S. 187.
[16]Tim Robinson, *Space debris: The legal issues*, AERO SOCIETY (January 3, 2014), https://www.aerosociety.com/news/space-debris-the-legal-issues/

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formed in 2010 with the primary objective of addressing the proliferation of space debris. Annually, member States and organizations share insights and research on space debris at the Committee's Scientific and Technical Subcommittee. A pivotal outcome of these deliberations was the endorsement by the General Assembly in 2007 of Space Debris Mitigation Guidelines, a UN document entitled Technical Report on Space Debris. The UN COPUOS guidelines, though voluntary and non-binding, outline fundamental principles without legal obligations for States and their nationals. These directives are specifically tailored to guide the mission planning and operational endeavours of newly engineered spacecraft and orbital stages. Still, they do not offer a solution to the space debris problem or stabilize the space debris environment. Unlike IADC guidelines, the UN COPUOS guidelines provide broader direction[17].

To facilitate these discussions, the United Nations Office for Outer Space Affairs (UNOOSA) has compiled a compendium of space debris mitigation standards, which is publicly accessible via their website at the request of Member States. The compendium aims to provide States with insights into current instruments and measures that States and international organizations adopt.

Moreover, alongside ongoing scientific and legal discussions, the recovery and return of space debris constitute integral aspects of the 1968 Rescue Agreement[18]. Under this treaty, state parties are obligated to return any "foreign" space objects found within their territories to their rightful owners. They are required to notify the Secretary-General of such discoveries. UNOOSA manages a registry of these recovery notifications.

The UN. Office for Outer Space Affairs in May 2023 generated a policy document called Our Common Agenda For All Humanity –The Future of Outer Space Governance to address the sustainable development of activities in space. This report tackled the remarkable transformations occurring in outer space, evaluating their implications for governance, sustainability, safety, and security. It further delineated key trends impacting the security of space activities and warned of potential risks to humanity if these challenges remain unaddressed. The document also gave recommendations to the member states, which included a proposal by the Committee on the Peaceful Uses of Outer Space

- to develop a unified regime for space sustainability, or

[17] Anirudh, *Legal Regime of Space Debris and Legal Proposals to mitigate the negative effects of Space Debris*, LEGAL SERVICE INDIA, (n.d), https://www.legalserviceindia.com/legal/article-3427-legal-regime-of-space-debris-and-legal-proposals-to-mitigate-the-negative-effects-of-space-debris.html
[18] The Rescue Agreement, April 22 1968, 19 U.S.T. 7570, 672 U.N.T.S. 119.

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- to develop new governance frameworks for various areas like Space traffic management, Space debris removal and Space resource activities

(C) India's Position on the Issue of Space Debris

Over the past six years, India has actively engaged in discussions within the COPUOS and the STSC regarding space debris and measures for its mitigation. As a longstanding member of the Inter-Agency Space Debris Coordination Committee (IADC) since 1996, the Indian Space Research Organization (ISRO) adheres to the guidelines set forth by the IADC and the United Nations (UN) for mitigating space debris, which include limiting the creation of debris, avoiding on-orbit collisions, and disposing of satellites post-mission.

All operational Indian geostationary orbit (GEO) satellites possess the capability for post-mission disposal. Upon completing their mission lifespan, these satellites are manoeuvred to super-synchronous orbits and undergo electrical passivation. Recent initiatives have focused on intentionally de-orbiting ISRO's low Earth orbit (LEO) satellites at the conclusion of their missions to minimize their post-mission orbital lifespan and reduce the risk of accidental break-up by depleting onboard residual fuel.

India actively participates in the International Academy of Astronautics (IAA) Space Debris Working Group and the International Astronautical Federation (IAF) Space Traffic Management (STM) working group, contributing to global efforts in this domain. Additionally, India regularly engages in discussions within the United Nations Committee on the Peaceful Uses of Outer Space and its subcommittees to help shape the evolution of space debris mitigation guidelines at the international level.

India is in the process of formally adopting a national mechanism for space debris mitigation. ISRO is working on finalizing Space Debris Mitigation Requirements aligned with IADC and UN guidelines to establish more effective implementation mechanisms and encourage compliance among Indian entities[19].

(D) Technological Steps Taken To Remediate Space Debris

Since 2021, the ELSA-D (End-of-Life Services by Astroscale - demonstration) mission has been adopted in the aerospace industry, a pioneering method to safely remove space debris from orbit using magnetic retrieval. Successful trails of it have been carried out where it was able to track an object from a great distance and tackle an uncontrolled object. Astroscale developed this, and in May 2022, Astroscale announced it was partnering with the UK and European Space

[19] Geetanjali R Kamat, *Unraveling the Space Debris Enigma*, 1 CASL 1, 5 (2021)

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Agencies and OneWeb to launch a new mission - ELSA-M - at the end of 2024. In June 2022, the UK government launched a Plan for Space Sustainability, including a $6 million fund for Active Debris Removal (ADR)[20].

The NASA Debris Assessment Software (DAS) utility furnishes evaluations capable of substantiating the conformity of spacecraft, upper stages, and payloads with NASA's stipulations concerning the restriction of debris creation, spacecraft resilience, post-mission longevity, and entry safety. Attaining successful verification through DAS validates adherence to NASA's debris mitigation prerequisites. NASA periodically updates DAS to ensure alignment with the most current insights into the artificial debris environment within Earth's orbit. The majority of spacecraft enterprises rely on this software to ascertain alignment with international guidelines.

Inmarsat, a British satellite telecommunications company, came up with five principles in their report, which are a global level playing field for operators, a New regulatory framework with robust rules and penalties, Increased investment in data and analytical tools, to detach sustainability from national security concerns in such a manner that countries could be able to share the location of their satellites without revealing their purpose, the regulation must be imposed in a timely manner and then be improved when technological dynamics change which could be adopted while framing comprehensive guidelines for clearing up the space junk. Satellites are being designed with electric propulsion systems and plasma thrusters, which help reduce particle expulsion. The inoperative satellite will be pushed back into the Earth's atmosphere by installing end-of-life de-orbit thrusters.

Even experiments and research are being conducted in Japan about using wood in spacecraft to reduce toxic debris. Tohoku University in Japan is developing a solution where satellites will fire a particle beam at debris, which will cause the debris to slow down and lower itself to the earth's atmosphere and get burnt[21]. In May 2020, economists at the University of Colorado Boulder proposed attaching an annual fee, rising 14% per year, to each satellite put into orbit to discourage the unnecessary accumulation of space junk[22]. Alternative strategies suggested over time encompass the creation of self-disposing satellites and applying polymeric foam coatings

[20] Katharine Rooney, *Space junk: what it is and why cleaning it up matters*, WORLD ECONOMIC FORUM, (May 20, 2021), https://www.weforum.org/agenda/2021/05/space-junk-clean-satellite/

[21] Dr. Max Polyakov, *We're polluting our future home – before we even live there. Here's why we need to clean up our space junk*, WORLD ECONOMIC FORUM, (May 5, 2021), https://www.weforum.org/agenda/2021/05/why-we-need-to-clean-up-space-junk-debris-low-earth-orbit-pollution-satellite-rocket-noosphere-firefly/

[22] Charlotte Luke, *Explainer: What Is Space Junk and How Does It Affect the Environment?*, EARTH.ORG, (September 6, 2021), https://earth.org/space-junk-what-is-it-what-can-we-do-about-it/

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to facilitate their descent into Earth's atmosphere for incineration.

(E) The Imminent Need for Updated Regulations to Align with Technological Advancements

On the other hand, 7,000 out of 11,000 launched satellites in the past decade remain in space; they help optimise flight paths and reduce emissions, help measure global carbon emissions accurately, help farmers boost yields and much more[23]. Also, owing to the improved and numerous Earth observation satellites, people in remote areas can access the internet, leading to better monitoring of climate change.

So, satellites are essential for our development and cannot be ruled out. In order to continually get the benefits of such space-related technologies, it is crucial to tackle the challenge of balancing orbital space debris and sustainable development in such space activities for which the rules governing satellites must be revamped. The current regime of space law lacks proper leasehold and teeth. The law heavily relies on the willingness of the states or parties to be fair and implies no penalties. The potential risks may outweigh the benefits if the law is not revamped. At present, there are only principles that exist to be followed. Still, the lack of a binding regime coupled with the current gold rush approach to space exploration will only lead to more accumulation of space junk, as will the related problems and dangers.

To remove debris, new spacecraft could be launched into space to remove defunct satellites and other debris from orbit. However, this raises a legal dilemma: the question of permanent ownership rights over objects sent into outer space. This dictates that any other state or private entity from another state must refrain from touching, interfering with, or removing a space object without the explicit consent of the launching state. Another issue that might arise is compromising state security since these debris-cleaning satellites could be used for surveillance activities. Also, space debris, comprising derelict satellites and other objects, may be susceptible to reverse engineering upon re-entry into Earth's atmosphere. Thus, to implement this mechanism of debris removal, strict agreements would be needed between the “remover” and the owner/operator of the space object

Financing and international cooperation pose significant barriers to implementation and challenges such as defining 'space debris' and determining funding sources for missions. These issues must be addressed within any potential framework. A legally binding treaty at a global

[23]Rajjev Suri, *What's the environmental impact of space debris and how can we solve it*?, WORLD ECONOMIC FORUM, (July 13, 2022), https://www.weforum.org/agenda/2022/07/environmental-impact-space-debris-how-to-solve-it/

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level is required to hold the satellite makers and operators responsible for the hazard of space debris, and that is possible only by the collective cooperation of the states. They must be held obligated to implement de-orbiting defunct hardware in their spacecraft as a mandatory requirement and held responsible for cleaning up any debris created by that spacecraft during its orbit. The cost of delaying the protection of Earth's orbit should not be underestimated. It is imperative that states start taking initiatives to bring other states together to form treaties that will eventually share the global behaviour in the space industry.

III. WAY FORWARD - SUGGESTIONS

The United Nations Agency for Information and Communications (ITU) should be given the power to mandate and address issues of space sustainability. Countries with more giant footprints in space must work together with ITU to agree on some basic standards, such as a limit on the number of satellites in a given orbital shell, etc… Taking steps can also include setting specific percentages for post-mission disposal success rates, setting target number of years an object should remain in orbit at the end of its life as stated in the Space Industry Debris Mitigation Recommendations by the World Economic Forum, in collaboration with the European Space Agency[24].

Space should be considered a global commons, and the protection of the United Nations (UN) should be extended. Orbital space encircling Earth ought to be recognized as an ecosystem, warranting equivalent attention and regulatory measures akin to those applied to the atmosphere and oceans. It is essential to realise that any damage to the orbital space environment has a problematic impact similar to other environmental issues. If the UN does not take steps for interplanetary conservation, then national geopolitical and commercial interests will override it.

Another proposed measure is the creation of a global convention, such as the World Space Debris Congress convened by the United Nations Office for Outer Space Affairs (UNOOSA), involving state members of the UN General Assembly. The success of such a convention hinges on achieving consensus among nations regarding space debris management. Formulating the convention must incorporate the perspectives of space agencies, including NASA and ESA, astronautical societies, groups, associations, and experts.

[24] Nikolai Khlystov, *Space debris is a growing problem. These leaders have a plan to tackle it*, WORLD ECONOMIC FORUM, (13 June 2023), https://www.weforum.org/agenda/2023/06/orbital-debris-space-junk-removal/

IV. Conclusion

The space debris hazard is a multifaceted challenge that requires immediate action and attention. While analysing the complexities surrounding its definition and the current and potential impacts it has, it becomes quite evident that the existing legislative frameworks are inadequate in addressing the scale and urgency of the problem as highlighted by the study. But there is still hope for the better in the form of rapid technological advancements offer promising solutions through innovative debris removal techniques to enhanced tracking and monitoring systems. However, for these advancements to be efficient, it is essential for the legal framework to evolve with it. By fostering colouration on an international level and taking proactive approaches, we can ensure that we provide a safer and more sustainable space environment for future generations.

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V. REFERENCES

1. Outer Space Treaty of 1967
2. Moon Agreement of 1979
3. Liability Convention of 1972
4. Rescue Agreement of 1986

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