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Beyond Earth: The Legal Battleground for Outer Space Security

RISHABH PANDEY[1] AND DR MANISH BHARADWAJ[2]

ABSTRACT

This article is a critical examination of the changing nature of space law and the increasing challenge of space debris problems in space. Space infrastructure has become an essential part of our contemporary lives. Without satellites, one can hardly use a mobile phone or internet access nor can one benefit from Global Navigation System satellite signals nor use remote-sensing satellites that provide essential information for natural disaster prevention, forest conservation or weather forecasts. While the use of space technology has many benefits, the increases of space debris seriously impairs the security, safety and sustainability of space activities. The orbital domain has become a dumping ground for obsolete satellites and rocket bodies. It threatens the uninterrupted functioning of all man-made objects placed in space. This essay analyses the prominent legal frameworks provided under leading international treaties on Aerospace Law. It argues that they cannot be certainly applied to a complex legal regime of man-made objects, space debris, which remains a thorny issue of space operations needing continuous regulations and laws. The article illustrates the essential background of Aerospace Law in today's legal landscape and critically examines its challenges from the perspective of space sustainability, the new up-momentum in national legislation within the existing space treaty framework, and their imperative needs for vigorous international cooperation and normative regulations to cope with space debris.

Keywords: *Space Laws, Space exploration, Space debris, Utilization of Space Infrastructure.*

I. INTRODUCTION

It shows how space exploration and exploitation is now a key aspect of our modern life, turning into reality what was once a matter of science-fiction. This introduction examines the nature and importance of space infrastructure, the dual nature of space technology, and offers an introduction to space law. It is followed by a comprehensive legal examination of space debris. Space infrastructure and the modern world Space infrastructure contributes not only to the safe

[1] Author is a student at Law College Dehradun, Uttaranchal University, Dehradun, Uttarakhand, India.
[2] Author is an Assistant Professor at Law College Dehradun, Uttaranchal University, Dehradun, Uttarakhand, India.

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functioning of space objects such as satellites, but also paves the way for new applications and opportunities arising from the space environment. It reveals how space exploration and exploitation is now a component of everyday life, turning into reality what was once only a matter of science-fiction. The dual nature of space technology Space technology is characterised by its dual nature: it can be used for both civilian and military purposes. This public-private dualism allows for a shared approach to cooperative utilisation of space assets. It provides an introduction to space law.

Today, space infrastructure has become essential not just to modern science but also to life on Earth. Satellite technologies are crucial to numerous critical services such as global communications and internet connectivity, weather forecasting, navigation, Earth observation, among many others. These services are crucial both to the operation of different sectors of the economy, as well as to managing natural disasters and national security.

The rapid growth of space-based infrastructure has led to remarkable progress in scientific discovery and exploration; contributed to the globalisation of information; and has been a vital catalyst for social and economic development by such means as monitoring the Earth's climate, managing natural resources and improving productivity in the agricultural sector through the use of precision farming technologies. Space infrastructure is also deeply involved in international telecommunications, GPS systems and has become a strategic asset integral to military and security applications, thus ensuring the security of states worldwide.

As space technology continues to advance, it floods our world with both opportunities and problems. One of the defining features of space technology is that it tends to boomerang back to us. Although it is a technology for our use and our benefit, space technology has an acquired independence that allows it to have dual sociotechnical valences. While there are countless benefits to space technology, the potential for danger lurks everywhere it proceeds. In this way – and many others – technology has the power to disable our ambitions. Space technology has blazed a trail in the production of dangerous artifacts like space debris, an accumulation of material remnants of humanity. These artifacts threaten the operational safety of future space missions.

'Space debris' is a catch-all term for all spacecraft and fragments in orbits around Earth, including dead satellites and abandoned rocket stages, as well as fragments produced by the breakup, erosion, ageing and collision of objects After years in orbit, these pieces could exceed a vessel's design speed limit – accelerating the ageing process and the risk of impact, even for sturdy crafts. Space debris could cripple any operating satellite and could potentially collide

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with a crewed spacecraft such as the International Space Station (ISS). A special case that gives a sense of the dire potential is Kessler Syndrome. Kessler is a NASA scientist who has popularised a theoretical scenario in which the object density in LEO becomes so high that collisions cascade, propagating new debris up to an exponential increase in the risk.

As outer space activities expanded, they were eventually governed by space law, a constellation of treaties, agreements and principles negotiated under the auspices of the United Nations (UN). The basis of modern space law was established by the Outer Space Treaty of 1967 (treaty). It delineated the founding principles of space law: that outer space is 'not subject to national appropriation by claim of sovereignty, by use or occupation, or by any other means' (Article II); that outer space is free for use 'exclusively for peaceful purposes' (Article IV); that, in principle, all states are equals (Article I); and that every state that engages in space activities is responsible for the actions of state, and non-state, entities in outer space (Article VI).

Later agreements, such as the 1968 Rescue Agreement, the 1972 Liability Convention, the 1975 Registration Convention and the 1984 Moon Agreement, elaborated the basic legal principles. Still, space debris remains an area of space law that has never developed obligatory legal standards, only non-binding guidelines.

II. THE EVOLUTION OF SPACE TECHNOLOGY AND ITS IMPLICATIONS

The history of spaceflight is the history of an intense human determination and technological genius. If its chronology was to be drawn, it would tell a tale of an evident dramatic shift and technological revolution in space technology. Registering the first molecule of that revolution would be the launch of the first artificial satellite in space, none other than the infamous Sputnik I, and settling its binary opposite, the first formal outer space legal document – Outer Space Treaty, 1967. Over the years, the same spirit has engendered mind-boggling quintessential questions of space law and space debris. In this section, we walk you through an abridged history of space technology that has led us here.

Looking outward is perhaps the most dramatic technological innovation of the 20th century: not only has it enabled a greater understanding of the cosmos by humans, it also led to a new territory that became the next arena of legal and geopolitical contestation. The space journey introduces four inflection points that have shaped the current landscape of space exploration and space law.

On 4 October 1957, the Soviet Union launched its first artificial satellite, the Sputnik I, into orbit around Earth. That first flight heralded both the dawn of the space age and the space race – the competition between the United States and the Soviet Union over who was capable of

conquering the realm of outer space. The successful flight of Sputnik I around Earth was a symbol of mankind's ability to travel towards outer space. Sputnik I's flight into space also gave birth to human-made space debris. The Sputnik I and its upper launch stage were among the first spacecraft converted into orbital debris after their demise. At that time, they were not particularly dangerous. However, as we started launching more and more spacecraft into orbit and into deeper space, we also found ourselves increasingly struggling with the problem of how we, as mankind, should seek to regulate the use of outer space. As interest in space exploration increased – and as tensions between the Soviet Union and the US suggested the possibility of conflict over resources in outer space – it became clear that there was a need for a set of rules to govern space activities. The actual result was the Outer Space Treaty of 1967, also known by its full title, the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies. The treaty established the core principles of space law, limiting state claims of sovereignty over outer space or celestial bodies, requiring that outer space be used exclusively for peaceful purposes, and establishing the principle of state liability for damage caused by space objects.

The general principle that pervades the first third of the treaty is that 'outer space shall be free for exploration and use by all States', and more specifically that 'outer space is not subject to national appropriation' by any country, no matter the level of its economic or scientific development. The treaty was pathbreaking in establishing the fundamental ethical principles upon which 'space law' was founded. But the treaty did not touch upon the issue of space debris – the question of the sustainability of space activities did not arise at the time. The creation and signalling of a norm against an arms race, and the commitment that 'activities in the exploration and use of outer space shall be carried on for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development' occupied centre-stage.

The Outer Space Treaty and the subsequent legal instruments regarding space debris have far-reaching, but complex, implications. The treaty became the foundation for international cooperation and the principles of peaceful use of outer space for all parties involved, but it left a lasting void by not including specific provisions on space debris in the treaty or other binding international maritime law instruments. This legal void – the lack of rules to govern space debris – complicates the ability to maintain space activities in a sustainable manner as space debris accumulates and threatens the safety of space operations and the long-term usefulness of important orbits.

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III. SPACE TECHNOLOGY'S DUAL USE: CIVIL AND MILITARY APPLICATIONS

From the beginning of space technology there has been a dual-use element, with many applications and problems having both civil and military uses. This dual-use property is relevant to international security, diplomacy and space law, including space debris. Plans for space arms also exist, as do geopolitical anxieties between countries, such as Russia at the critical 1996 UNCOPUOS meeting, which showcase the problems of governance of space activities. In this section, we discuss the problem of the dual use of space activities, including emerging space arms and weapons, space geopolitics and the international legal regime for space debris.

Space technologies would be 'dual use' – meaning they would be deployed in a civilian (i.e., non-military) context such as space science, security and foreign policy, and commercial uses. This would be the unique 'double-handed' deployment of space technology as opposed to technology in the terrestrial context, wherein civilian instrumentation would avert war but would inevitably become weapons of destruction; space technologies would be improved for use in international instruments that promoted the peaceful uses of outer space and the same technologies would further improve military capabilities, and covert space technologies would facilitate global surveillance, stealth warfare and the thwarting of global terrorism. International law and spatial governance would feature a careful calibration between competing interests and concerns with security enjoying primacy over the peaceful uses of outer space.

There is also growing alarm as space arms and weaponry creep onto the horizon of international relations and space law. Weapons orbiting or deployed in space as well as systems used to conduct military operations from space (e.g., from an orbiting satellite, outer space or from a space base) attract increasing attention. Such developments are interpreted as a straight pathway to the militarisation and potential weaponisation of outer space. The militarisation of outer space often refers to anti-satellite (ASAT) weapons that would seek to render a satellite's function ineffective or destroy it entirely. ASAT weapons are already driving debris risks in LEO and space. Testing and use of ASAT weapons was always understood to generate a debris field that endangers the safety of civilian and commercial satellite space operations and wider sustainable uses of space.

But to the extent there is a case to be made for space arms development, it is not just about weapons in space but about the sustainability of space use in general. The legal regime governing space use is exceedingly thin. The foundation is the Outer Space Treaty of 1967 that, in addition to stipulating that celestial bodies cannot be terraformed or occupied sovereignly by nations, prohibits nations from 'placing nuclear weapons or any other kinds of weapons of mass

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destruction' into Earth orbit, on the Moon, or other celestial bodies. However, the treaty is silent on conventional munitions or ASAT weapons testing in space.

Meanwhile, other states – including Russia – have raised concerns about the militarisation of space at the international level, calling for legally binding instruments to prevent an arms race in outer space. At the 38th session of the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) in 1996, Russia stated: '[W]hen … weapons are placed in outer space, global security will inevitably be placed at risk, along with the sustainable development of space,' and that '[a]n arms race in outer space is fraught with contamination of outer space by debris resulting from the destruction of spacecraft.' The meeting crystallised concerns about the potential for conflict in space – and the risks associated with such a scenario, including space debris from destroyed satellites or ASAT weapons.

Indeed, nothing else but this fact can explain Russia's proposal at the UNCOPUOS meeting to take the discussion further into the international arena of concluding and adopting legal norms and procedures aimed at control of the arms race in outer space and dangers related to space debris, as noted in Russia's statement for the record by the representative of Russia. During the recent years, discussions at UNCOPUOS and the subsequent legal initiatives aiming to expand the existing treaty of law in space affairs and prevent an arms race in space and ensure space security and prevent militarisation of outer space, as well as minimise the dangers of space debris demonstrate how activities in outer space are characterised by efforts to develop and enhance the legal regime of space activities as well as the efforts to ensure space security and prevent an arms race in outer space and/or reduce the dangers of space debris.

Taken together, they show that the two-faced nature of space technology, on the one hand, space arms, and on the other, the geopolitics of space security, on the one hand, emphasise the need for a robust law and regulatory regime on space, if we are to avoid the entrapment of space debris today, and in the future. It is time for a robust law and regulatory space regime on managing space technology, on regulating space debris today and in the future, and time to sustainably utilise and ensure that outer space remains as a global common, a peaceful resource shared by all humanity, now. The above historical trail of binding milestone markers, as well as the antecedent geopolitics of the cold-war dynamics that I brought up, surely demonstrates the complicated interplay of technology and law, and international relations to why we find ourselves here today, where our human activities in outer space are a knot-point where all those three strands are intertwined.

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IV. THE CHALLENGE OF SPACE DEBRIS

With more and more rubble floating around, there is also more and more risk of a satellite or space station colliding with one of these objects or with debris from another collision. Unlike many space-policy challenges, the problem of space debris is getting worse. It is a complex problem because it has multiple dimensions, touching not only on the safety and operational efficiency of future space missions, but also on the existing legal and regulatory frameworks that aim to put space activities on a safe and sustainable path.

Near-misses and collisions – of spacecraft with spacecraft and spacecraft with debris – continue to underscore the growing menace of space junk. In one notable example from October 2009, space debris struck a satellite: an old, non-operational Russian satellite, Cosmos 2251, slammed into an operational Iridium communications satellite, raining thousands of pieces of debris down on a highly congested orbital regime and thereby considerably increasing the chance of further collisions. Such incidents point to the material threat of space debris that looms over space assets, whether those assets are already there or about to be deployed into the orbital vista.

These collision incidents not only cause immediate physical harm, but can also knock out vital networks that propagate across the globe, cause massive financial losses when important investments are lost, and even lead to the loss of human life (crewed missions would not be exempt from these accidents). Impacts between space debris and active satellites of course also impact a third realm beyond national security: international relations and security. Concerns arise that collisions between space debris might cause tensions between spacefaring nations to flare up, making it very difficult to implement certain cooperative measures aimed at mitigating the debris problem.

In fact, it's the growing mass of space junk – and the resulting increased probability of collisions – that raises a separate set of issues regarding the feasibility of future space missions themselves. If debris densities in critical orbital regions become even moderately large, they could preclude certain types of future space missions. This concern represents a worst-case scenario known as the 'Kessler Syndrome' (named after astronomer Donald Kessler, who posited the scenario in 1978). The Kessler Syndrome is usually described as creating a situation where the density of susceptible objects in a low Earth orbit is so high that objects in that orbit would collide with a non-negligible probability. If a collision did occur, the fragments that remained in orbit would collide with other objects with an even greater probability of creating additional debris. If the cascade were to grow large enough, it could make most if not all human-made objects in low Earth orbit unstable. Even if there were no collisions into operating satellites, such a scenario

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could jeopardise hundreds of existing missions and render certain orbits unusable for centuries, if not much longer.

As more debris accumulates, international efforts to manage the problem have drawn some shared wisdom from different entities, including the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS), the Inter-Agency Space Debris Coordination Committee (IADC), and various individual space agencies' guidelines. These include voluntary best practises to mitigate the formation of debris, such as the design of space objects to minimise debris production, end-of-life disposal strategies, and in-space debris removal technologies.

Such efforts notwithstanding, the legal and regulatory regime for space debris remains piecemeal and largely voluntary, and space-debris mitigation is jeopardised by the lack of binding international instruments addressing the overall management of space debris. This legal gap in the management of space debris underscores the necessity for enhanced international cooperation fostering the development of legally binding measures for the long-term sustainable conduct of outer space activities.

The problem of space debris is emblematic of the broader ramifications of changes in space technology: as humanity increasingly depends on space-based technologies, and extends those technologies into more and more-complex systems, so too will the responsibility of managing the space environment become a key priority. This will require not only technological innovation, but also legal and regulatory evolution in the space domain.

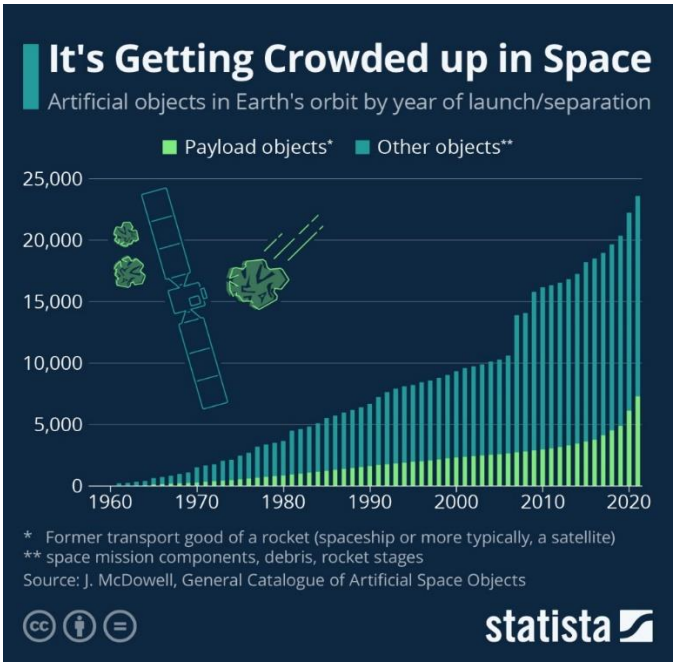

Fig 1. "Rising Tide of Orbital Debris: A Visual Overview of Artificial Objects in Space from 1960 to 2020"

The bar chart gives information about the growing number of payload and other debris objects launched in to space for flying purpose over past 60 years. It was observed that, incremental growth of space junk is much higher in compare to operational technology.

The need for more satellite services and deepening interest in space might be raising awareness of the problem, which has grown acute over years; a little more than a week ago, a robotic arm of the ISS brushed against a piece of space junk. Plenty of spatial engineering has gone into the creation of space infrastructure and this mechanical arm didn't buckle under the impact. At worst, the thermal cover reportedly tore. Still, such incidents serve to emphasise the growing challenge of space management, according to the Canadian Space Agency, which issued a report on the collision.

More than 23,000 objects bigger than a softball now circle Earth, and the majority of those are no longer actively used, categorised instead as space debris: dead satellites, spent rocket stages and miscellaneous bits and pieces that once belonged to another spacecraft or that simply broke up. Since the scientific community began keeping count in the mid-1950s, the number of operational satellites has grown, and so has the amount of debris now present in space. The rate of debris currently increases faster than the rate of satellites, and space advocates cannot agree on just how we are perpetuating the problem.

The catalogue of objects – a list that chronicles all space objects from the moment of their arrival in orbit, from their launch or subsequent separation from other equipment – exhibits substantial increases in both satellites and debris since 1958. In total, it currently lists more than 58,000 space objects, of which approximately 23,000 are still in orbit.

V. SPACE LAW: FRAMEWORK AND CHALLENGES

Space law is the field of law that regulates human activity in outer space. It is curious and challenging from a historical point of view, but at the same time vital and still evolving. So much of our civilisation's future now depends on activities occurring significantly above Earth. This essay will therefore discuss the origins and development of space law, how space law is based on co-operation, and the effects of space law.

(A) The Role of United Nations and International Cooperation

Under much of this, and especially a significant part of the modern international space-law system, 1959 assembled something closely resembling an 'A-List' of space powerbrokers of old and new, and helped to inspire a restrictive bright-line regime as the minimalist norm applying and governing space activities, grounded in the opening, and the continued 'keeping'

of outer space for all forms of peaceful purpose(s), to be used by all States 'regardless of their degree of economic or scientific development'.

It was through it that states acted together under UN auspices, laying the foundations for the Outer Space Treaty of 1967 – the skeleton of space law, and for other space law treaties and instruments for which that skeleton was further fleshed out. Those treaties spell out, in what are now customary international law norms governing the behaviour of states in space: one promises that space will be 'the province of all mankind' while another vows that space 'is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means. They urge states to ensure that their space activities 'are carried out in conformity with the interests of all countries'. Space law was scripted at the dawn of what appeared to be a new era in international law, in the shadow of an existing Cold War driving the US and the Soviet Union into their Space Race, an arduous competition that coincidentally gave rise to the international space agency. It was legislated systematically, in hope that a new technological frontier in spaceflight activity would not mimic the nuclear antagonism of the two Cold War powers. And yet, even in the frame of negotiations for the rules of a piece of territory no state could rightly claim as its own, states approached the exercise of building space law as one they ought to view as a game of power politics into which they could expertly insert an agreement that they could justify for driving and accommodating all of their national space programmes.

(B) International Treaties and Their Limitations

Space law – perhaps one of the most grandly underappreciated terms of our day – is the legal framework of entities and diplomatic agreements and treaties that forms the foundation for activity in space. It is based largely around the Outer Space Treaty of 1967, with the Rescue Agreement of 1968, the Liability Convention of 1972, the Registration Convention of 1975 and – with respect rocky bodies – the Moon Agreement of 1984. These instruments established the grounds of international space law, and visionary at the time, international space law prohibited the national appropriation of space; prohibited weapons of mass destruction in space; and stipulated that states must avoid contamination of space and space bodies.

But these treaties leave many current issues – especially space debris – inadequately regulated, because they were written during the early days of space travel, before we knew that Earth's orbit would become so crowded. Key weaknesses include:

- Vagueness and broad terms: the treaties use undefined and at times overbroad terms such as 'harmful contamination' that might be interpreted differently and fail to capture

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the intricate nature of space debris.

- Lack of Specificity on Space Debris: None of the treaties directly addresses space debris, leaving a regulatory vacuum in terms of the identification, mitigation and removal of debris.
- Non-binding Nature of Subsequent Guidelines: The IADC guidelines and subsequent UNCOPUOS guidelines are also non-binding as states have to volunteers comply with them.
- Inadequacy of provisions for liability and compensation: The Liability Convention provides for a fault-based liability regime in respect of damage to the surface of the Earth and to aircraft, and an absolute liability regime in respect of damage elsewhere, but fault or liability for space debris, particularly fragments, is often hard or even impossible to allocate.

(C) The Issue of Space Debris and Legal Gaps

And the increasing presence of space debris is perhaps the greatest threat to the sustainability of space activities. Space debris includes defunct satellites, burnt-out rocket stages and any other debris that is orbiting the Earth's equatorial plane. This debris remains in orbit at high orbital speeds and has the potential to damage other operational satellites, space stations or spaceflight crews.

Although it lays down the fundamental principle that space is open to exploration and non-appropriation, the framework of the existing space treaties is simply too rudimentary for the complex problem posed by space debris.

- Scattered legal provisions: There is no uniform, overarching legal instrument that specifically addresses the generation, mitigation and remediation of space debris. The legal regime already in place is spread across a series of treaties, and none of them were explicitly designed to address the debris problem.
- Voluntary Guidelines: IADC's Space Debris Mitigation Guidelines, endorsed by UNCOPUOS and widely considered the global standards on mitigation, are in fact voluntary guidelines, meaning that adherence to them is uneven and there are no repercussions for non-compliance.
- Problems of Enforcement and Compliance: Space activities are international and very collaborative in nature. Enforcement of any legal regime concerning space debris is not straightforward. The absence of a binding, enforceable and enforceable mechanism to

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ensure adherence to debris mitigation guidelines further increases the likelihood of liability creation from additional debris.

- Ambiguous Fault Allocation: The liability regime provided in the Liability Convention is impractical for space debris where often the debris pieces cannot be identified and traceability (i.e., causation) for damage would be difficult to ascertain. This further complicates the process of compensation and makes risk mitigation, touted as an important aspect of the scheme, somewhat perfunctory and thereby deterrent to the culture of maintaining and removing space debris.

The legal shortfalls we have described also emphasise another very important disconnect – between the rapid rate at which space technologies are developing, and the far slower rate at which a commensurate set of legal norms (and corresponding regulations) are being crafted to govern outer space activities. As the stock of space debris continues to expand, these legal and regulatory shortfalls will lead to greater and greater risks to the safety, security and sustainability of space activities. Overcoming them will require revising existing treaties, developing new forms of international law, and enhancing international cooperation in order to create a more encompassing, enforceable legal regime for the mitigation and management of space debris. That legal regime must be clear and precise and enforceable so as to match the evolving nature of competing and collaborative space activities relevant to the goal of making outer space a safe and secure environment for generations to come.

VI. WEAPONS IN SPACE: A LEGAL QUANDARY

Although the Outer Space Treaty bans nuclear weapons and other weapons of mass destruction in orbit or on celestial bodies, it leaves the status of conventional weapons and ASAT technologies ambiguous, leading to both a legal and a security dilemma. ASAT weapons can generate large quantities of space debris, potentially creating another insurmountable obstacle to space sustainability.

The debate over ASAT missiles and the broader question of space weaponisation touches on the tension between the ideal of space as a peaceful, shared domain and more Earthly issues of security. When countries such as India and the US test ASAT weapons, the problem of space debris worsens, but so do fears of space weaponisation and the militarisation of space, and a return to the otherwise nonviolent battles and zero-gravity fighting depicted in films such as Gravity (2013) and Moonraker (1979).

As they showcased how ill-prepared the existing framework of space law in its agreements and accords before the late 1960s is to deal with the present changes to space activities as

demonstrated by the challenges of space debris, military weapons in space and their actual use and advertising offensive capabilities in space, in breach of the basic principles on which the Outer Space Treaty continues to rest. What is clear is that the current framework of space law needs to be updated and adapted, in the coming year or so, with new treaties and regulations for existing treaties to ensure that space activities continue to be sustainable, prevent the buildup of more debris and other risks to space activities, and stop adding any further provisions that would bring us closer to an arms race in space. To do that, international cooperation must be increased; creative legal solutions must also be found; but, above all, space-faring nations and other entities must now begin to commit themselves to the long-term sustainability of outer space activities.

(A) The Impact of a Deficient Legal Framework

The evolution of space law has neither followed the pace of technological progress nor kept pace with the developments of the space environment. The result is a slew of legal deficiencies and numerous gaps in the ability of space law to effectively govern space activities. Compounding these issues is the ambiguity of key terms used in the existing treaties and the possibility of different interpretations of many of the rules found in the Outer Space Treaty. At the heart of these considerations is how they apply to the management and mitigation of space debris. We examine them here to illustrate the adverse impact of the shortcomings in the legal regime to the sustainability of space activities.

(B) The Misalignment Between Space Technology Development and Legal Progress

Space technology has transferred the way we communicate, navigate and observe the world around us to the same level as or beyond Earth's atmosphere, advancing the frontier of human knowledge and capacity. While the pace of innovation soars, however, governance frameworks struggle to catch up. A major mismatch is emerging between technological development and legal evolution. This is illustrated perfectly by the realm of space debris.

However, while technologies for space activities have evolved to the point that thousands of satellites can be launched, operated and deorbited by states and non-state actors, the applicable legal framework has largely relied on concepts developed in an age when space was much less crowded and contested. That relative stability is unravelling as a growing number of satellites, mega constellations and commercial space activities are rapidly expanding at a pace that the supportive legal and regulatory mechanisms have not been able to keep up with – resulting in a vacuum where indispensable space practices such as space traffic management, debris mitigation standards and end-of-life disposal practices in space are largely governed not by laws, regulations and obligations, but by voluntary guidelines and 'best practices'.

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(C) The Vagueness of Legal Terms and Its Consequences

The problem is that such terms are vague, and their vagueness inevitably gives rise to interpretive ambiguities. Terms like space debris, due regard and harmful contamination are not defined in the Outer Space Treaty (or in any of the other agreements), and so there's plenty of room for disagreement about their contours and application between interested States in the present context of space debris.

But there are other unintended consequences to this ambiguity in the legal terminology: it hampers the development of common standards for the design, operation and de-orbiting of space objects, which are necessary to reduce space debris in the first place; it raises uncertainty over whether entities in space will face greater legal liability and responsibility to prevent the creation of space debris and assist with its removal; and it remains unclear whether the informal framework for cooperation and coordination between space-faring States can be formalised with hard rules and obligated by binding treaties or agreements.

(D) The Outer Space Treaty: Interpretations and Implications

The treaty is the foundation of international space law, establishing the basic principles upon which states may conduct activities in space. Technically speaking, its provisions are merely guidelines available for interpretation. The two interpretations of the space debris and weaponisation provisions that stand out the most are the 'freedom of manoeuvre' interpretation and the 'highly condemned' interpretation.

For instance, Article VI of the treaty announces that states assume international liability for national activities in outer space, whether governmental or non-governmental. But it's far from clear what activities qualify as 'national', and how far the state's liability extends beyond its own governmental services. This ambiguity matters greatly with respect to space debris, because commercial space has increased the likelihood that any piece of debris might not originate from a governmental body and, if so, to which one?

In similar fashion, Articles IV and V of the treaty, which ban the placement of nuclear weapons or any other kinds of weapons of mass destruction in orbit around the Earth, on the Moon, or on any other celestial body, are silent on issues of conventional weapons deployment or the use of conventional anti-satellite (ASAT) technologies, which also generate space debris. The lack of clarity on these issues gives rise to ambiguities and, ultimately, challenges questions about how future conduct in space will continue to conform to the language of the treaty. Key aspects of the treaty make it ill-equipped to deal with contemporary issues of space security and sustainability.

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(E) Toward a Revised and Dynamic Legal Framework

The rise in space debris and the vision of long-term sustainability in outer space activities calls for a revised, dynamic legal framework in the context of fast developments in space technology and a growing space debris problem. Such a framework would require a progressive approach of construing existing norms under treaties, development of national space legislation and complement international space treaty regimes, and elevate the control of space activities under international community and organisations to a higher level.

(F) The Need for Progressive Interpretation of Existing Treaties

The founding documents of space law – the Outer Space Treaty and the other space laws of that time – were drafted in an epoch when the issues of space debris and the possible complexity of modern space activities were not yet foreseen. They need to be interpreted through a spirit of progressive interpretation to handle the realities of current and future space activities.

A more progressive reframing would entail reformulating the principles, consistent with the agreements made in the treaties, to respond to concerns of the day. For example, 'the exploration and use of outer space … shall be carried out for the benefit and in the interest of all countries, irrespective of their degree of economic or scientific development' might be expanded to read 'the exploration and use of outer space … shall be carried out for the benefit and in the interest of all countries, present and future, irrespective of their degree of economic or scientific development' – implicitly extending to the space environment the goals of the Convention regarding minimising future pollution; or 'states Parties to the Treaty undertake not to place in orbit around the Earth … objects or space vehicles the [orbits of which] would … jeopardise safe flight of space objects' could be reformulated and interpret explicitly to include space debris.

This will imply that significant day-to-day changes in circumstances will not have to be the justification for revisiting the core treaties, a process that would be arduous. But it will be actual international agreement among the world's spacefaring nations to actually stick with these interpretations that will make tenth-amendment-style (progressive) interpretation actually work for real policy and practice.

(G)National Legislation as a Supplement to International Treaties

Therefore, although international treaties establish the general legal framework for space activities, it is at the national level, with the adoption of domestic legislation, that the specifics of space debris management can be of real use. Space farer nations can adopt domestic legislation that fills the gaps left by the international treaties, and provide some specificity to

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the general obligations.

National law can require the design, operation and disposal of satellites to be as free from the creation of space debris as possible, set licensing and regulatory regimes for commercial space operators that require them to operate in conformance with best current debris mitigation practices, and incentivise or even require technologies for the removal of existing debris from space, either actively or passively.

Putting economics aside, developing and enacting a national law for space activities – something that only a few nations have accomplished so far – can help mitigate and regulate the problem of space debris and symbolise a country's commitment to responsible space activities. That law can also serve as an example for others, and help norms harmonisation to cascade to more countries.

(H)The Role of International Community and Organizations

These could include the international community more broadly and the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) and the Inter-Agency Space Debris Coordination Committee (IADC), among others. These bodies will need to participate in the governance of space activities and debris mitigation through the creation of a system of international standards and guidelines for debris mitigation practices, the sharing of best practices and technologies, and cooperation among states and private actors.

Furthermore, international organisations can also facilitate discussions and negotiations over treaty revisions or new space debris treaties, or function as institutional hubs for educating and raising awareness of the problem.

Thus, the imperatives of the international community obligate to provide for the adjudication of legal disputes or a more effective enforcement regime to combat space debris. By both providing regulation and mechanisms for accountability and redress of grievance,

VII. CONCLUSION

What once was pure science fiction is now a core part of modern life. Despite its gravity, space existence. From smartphones to weather forecasting to satellites that track global shipping – our lives are enriched by space. The known benefits of space technology far outweigh the negatives. However, space activity generates a lot of rubbish, both figuratively and literally. Every day, debris is being strewn in space, whether accidental or intentional, and this derelict architecture isn't going anywhere soon. There are several threads of law that, woven together, could be relied on to ensure that space debris mitigation practices change for the better.

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Following the Outer Space Treaty of 1967, supplemented by other legal instruments in the subsequent decades, space law has been built on the principles of the peaceful use of outer space, and principles of state responsibility in outer space. These regulatory standards were groundbreaking when they were conceived in the early 1960s, allowing for manned space travel and the safe use of space for rocket launches, space research, and space stations. However, these instruments are now clearly outdated in addressing such things as space debris. Today, nearly 100 million fragments of space debris are estimated to be orbiting Earth, many of which could cause serious injury to astronauts and damage their space vehicles. Despite the existence of decades of non-binding 'best practice' guidelines for mitigating the creation of debris, and voluntary measures to survey and catalogue debris, there is no comprehensive and enforceable international regime in place for dealing with debris production, mitigating space debris, or removing it.

Space debris are not only perilous to space activities, their numbers are likely to increase. Collisons and the growing risk of Kessler Syndrome warn us of trouble ahead. Addressing the space debris issue will require more than technological ingenuity; it will involve a radical transformation in space domain governance, through rulemaking and lawmaking.

By that reckoning, what's needed is a new and living doctrine to fill that critical gap between technological and legal progress – a doctrine offering a modern and dynamic approach to the application of current treaties, as well as nationally formulated and legally implemented rules to supplement the treaties, alongside a stronger role for the international community and its organisations to formulate and apply rules for debris mitigation.

The path to getting there is also clear. We need to foster stronger international cooperation, devise creative legal solutions, and adapt processes to ensure the long-term sustainability of outer space, for the benefit of all nations and generations to come. The interconnectedness of space technology, law and international relations in this moment signal a critical test for the sustainable management of space, an urgent call to action that demands a collective effort to ensure that outer space continues to be the common heritage of humankind.

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