SPACE SUSTAINABILITY AND THE GROWING THREAT OF ORBITAL DEBRIS: TOWARDS STRONGER GLOBAL GOVERNANCE

Vani Chaudhary, Christ (Deemed To Be University), Delhi NCR

ABSTRACT

The growing expansion of human activity in space has led to a dramatic increase in orbital debris. This debris is a grave threat to operational spacecraft, human spaceflight and the long term sustainability of the orbital environment. If left unmitigated, orbital debris could lead to the Kessler Syndrome events in which a cascading set of collisions renders critical orbits unusable for decades.

The research highlights the need for improved global governance to deal with the current orbital debris crisis as part of a broader concern for space sustainability. It begins with a discussion of orbital debris accumulation's scale, causes and consequences and highlights the associated environmental and economic concerns. The study further outlines the existing legal regime including but not limited to the Outer Space Treaty (1967), Liability Convention (1972), Registration Convention (1976) and United Nations Guidelines on the Long-Term Sustainability of Outer Space Activities. While these legal instruments indicate important guiding principles, they do not provide binding enforcement mechanisms, detailed debris mitigation measures or provisions for active debris removal.

The barriers to effective governance, which include limited technological capacity for small debris detection and removal, legal uncertainties surrounding jurisdiction and liability and the cost of mitigation are made worse by a fragmented jurisdiction between national policies and no consolidated international regime. To tackle these deficiencies, the study advocates for a multi- tiered governance scheme comprising inclusivity, transparency, accountability and enforceability. Some recommendations provided include negotiating a binding international treaty focused on debris mitigation and removal; establishing a Global Space Debris Management Authority; standardizing debris mitigation practices, enforced on all space actors; and finally, providing both incentives and penalties for compliance. The role of public-private partnerships is discussed as essential for advancing debris removal technologies and space traffic management.

Through case studies including the 2009 Iridium–Cosmos collision, China's 2007 anti-satellite test and the 2018 Remove DEBRIS mission, the research demonstrates the urgent need for collaborative governance. In part, it concludes that without enforceable, cooperative governance, the orbital environment will continue to degrade in an irreversible manner and future exploration will be threatened due to longer-term exploitation of orbital space. The initiative for enhanced global governance of outer space is therefore both a legal necessity and a practical necessity for the sustainable use of outer space for the benefit of humankind.

Keywords: Orbital Debris, Space Sustainability, Global Governance, Outer Space Treaty.

I. INTRODUCTION

Brief History of Human Activity in Space

The era of space could be traced back to the launch of Sputnik 1 by the USSR on 4 October 1957. This historic moment heralded the advent of mankind's engagement in outer space and marked an era of fast development mainly prompted by the dynamics of the Cold War between the USA and the USSR (Moltz, 2014).[1] Less than ten years following the launch of the first artificial satellite, both nations were capable of sending their people into orbit, with Apollo 11 successfully making a lunar landing in July 1969.

As time progressed, the value of space in terms of human activity has become increasingly evident. Satellites have been utilized to facilitate communication between countries all around the world and to monitor the climate. In addition to being used for intelligence gathering and missile tracking, military powers rely on satellite technology. When the twenty-first century began, there was another shift in the usage of space with its commercialization. Companies started launching rockets, creating satellite networks, and even conducting manned missions into orbit, bringing down the price of reaching space significantly (Bowen, 2020).[2] Nowadays, space is not reserved anymore exclusively for superpowers, with more than ninety countries and many private companies owning satellites in orbit of the Earth.

Nevertheless, this great expansion of space activity has brought along significant costs to it. With each rocket launched, satellite put into space, operation conducted there, and even with

[1] James Clay Moltz, The Politics of Space Security: Strategic Restraint and the Pursuit of National Interests (3rd ed. Stanford Univ. Press 2014).
[2] Brendan E. Bowen, War in Space: Strategy, Spacepower, Geopolitics (Edinburgh Univ. Press 2020).

each small fragment of paint, a piece of material remains in orbit. These various remnants form orbital debris, known as space junk, and pose one of the greatest risks to the continuous operation in outer space.

Emergence of Orbital Debris as a Major Threat to Space Sustainability

The problem of orbital debris became apparent to the efforts of scientists at NASA in the 1970s. In particular, Donald Kessler, working at the Johnson Space Center under NASA, together with Burton Cour-Palais published a significant paper in 1978 that stated that if the number of objects in low Earth orbit becomes critical, they can collide, creating even more debris and thus triggering a self-sustaining chain (Kessler & Cour-Palais, 1978).[3] Known as the Kessler syndrome, it is currently considered the most worrying theoretical result of uncontrolled debris growth.

In the time since the publication in 1978, the situation has only become worse. According to estimations made in 2024 by the European Space Agency (ESA), there were about 36,500 large objects measuring above 10 centimeters, as many as 1,000,000 medium objects, and more than 130,000,000 tiny objects smaller than 1 centimeter in orbit around our planet (ESA, 2024).[4] Regardless of their size, all objects have enough kinetic energy to destroy or seriously harm satellites moving through outer space. For instance, the International Space Station (ISS) performs several avoidance maneuvers each year.

The problem is well exemplified by two important events- the intentional destruction of the Fengyun-1C weather satellite by China in January 2007, creating over 3,000 debris pieces, and an accidental collision between the Iridium 33 and Cosmos 2251 satellites in February 2009, that resulted in 2,000 additional fragments (Johnson, 2010).[5] The mentioned accidents have substantially worsened the situation with debris in LEO and demonstrated the inefficiency of the current control measures.

Connection between Debris Mitigation and Long-Term Space Sustainability

Space sustainability refers to the ability of all states to engage in space activity in a sustainable

[3] Donald J. Kessler & Burton G. Cour-Palais, Collision Frequency of Artificial Satellites: The Creation of a Debris Belt, 83(A6) J. Geophysical Res. 2637 (1978).
[4] Eur. Space Agency, Space Debris by the Numbers (2024), https://www.esa.int/Space_Safety/Space_Debris.
[5] Nicholas L. Johnson, USA Collision with Russian Satellite: One Year Later, 14(2) Orbital Debris Q. News 1 (2010).

manner now and in the future. This ensures that the space environment remains accessible for future generations. The presence of space debris poses a direct threat to space sustainability. Failure to control the growth of orbital debris within critical orbitals will result in making particular altitude orbits unusable, which will threaten the existence of vital facilities such as GPS systems, weather satellites, broadband Internet and banking facilities.

Thus, debris removal is more than a scientific challenge; it is a necessity for states and other actors in space activity. In order to achieve space sustainability, there has to be the development of legal and policy frameworks that compel all actors engaged in space activity to behave sustainably.

Research Problem

Even after more than several decades of awareness, the international community still struggles to develop legally binding mechanisms to govern orbital debris. Most of the existing treaties were developed in the 1960s and 1970s when there was no full comprehension of the problem. In addition, there are obvious loopholes in the treaties when applying them to private players, non-state organizations, and new challenges resulting from mega constellations. Although voluntary guidelines have their usefulness, they cannot compel actors to follow them since they are not binding. This state of affairs, therefore, constitutes a typical tragedy of the commons where each participant has a personal gain of reducing mitigation costs but suffers collective effects from the act.

Research Objectives

This research identifies two major goals for the study. First, it intends to conduct a thorough analysis of the legal, technical, and policy obstacles involved in managing orbital debris. Second, it suggests new approaches that can be used to address the issues raised by developing international frameworks that are legally binding, technically sound, economically viable, and politically broad. It argues that space sustainability can be attained only when there is a fundamental transformation of the present international system.

II. LITERATURE REVIEW

Perhaps the key scientific input into the orbital debris research field comes from Kessler & Cour-Palais' seminal work from 1978, where they introduce what is known today as the collision cascade of orbital debris named after Kessler. Specifically, Kessler & Cour-Palais use mathematical models to predict the behavior of debris in the coming decades, concluding that beyond a certain density, there will come a time when the rate of creation of debris due to collisions would exceed the natural degradation rate, resulting in a self-reproducing chain reaction (Kessler & Cour-Palais, 1978).[6] This scientific article, highly cited and influential today, serves as the main starting point for discussions regarding the topic.

The next scientific breakthrough regarding the issue comes from Liou & Johnson (2006), who published an article in Science, arguing that the Kessler Syndrome is already occurring now, rather than being a future possibility. The authors modelled the behavior of the current debris population and found that, at the current state of affairs, the orbital population of objects is sufficient to sustain itself and continue growing via mutual collisions, without the need for any future missions. Hence, they conclude that the Kessler Syndrome is here now and it is necessary to find ways to stop the process - active removal.[7] This scientific work thus provided the foundation for the necessity of such a governance measure.

Further, the legal research on the issue of orbital debris regulation has developed simultaneously with scientific research, with researchers increasingly pointing at the inadequacy of the current system of treaties. The first scholarly work to articulate legal principles of international law governing outer space issues was written by Bin Cheng, who elaborated on the legal basis of the OST (Bin Cheng, 1965).[8] The common perception of the due regard obligation in Article IX of the OST formulated initially by Bin Cheng and then further developed by scholars like Frans von der Dunk is understood to represent an obligation to take into account the interest of other states, which cannot be described as a requirement to not cause space debris (von der Dunk, 2011).[9]

In his study, Listner (2012)[10] conducted a thorough analysis of space debris from the perspective of public international law, arriving at the conclusion that the responsibility of states for their nationals' activities under the OST, alongside the lack of a debris-related provision, creates an institutional gap which cannot be addressed by treaty interpretation and

---

[6] Kessler & Cour-Palais, supra note 3, at pg 9.
[7] J.-C. Liou & Nicholas L. Johnson, Risks in Space from Orbiting Debris, 311 Science 340 (2006).
[8] Bin Cheng, The Law of Outer Space: The Common Heritage of Mankind, 5 Colum. J. Transnat'l L. 1 (1965).
[9] Frans G. von der Dunk, International Space Law, in Handbook of Space Law 29 (Frans G. von der Dunk & Fabio Tronchetti eds., 2011).
[10] Michael J. Listner, The Debris Problem: Addressing the Legal Issues, Space Rev. (Mar. 12, 2012), https://www.thespacereview.com.

requires additional legislation. In turn, in his analysis of Article VI of the OST and its applicability to commercial space operations, Freeland (2015)[11] concludes that the discrepancy between national regulatory systems nullifies the article's meaning and allows companies to exploit regulatory arbitrage opportunities.

The edited book by Jakhu and Pelton (2017)[12] titled Global Space Governance: International Challenges and Solutions, brings together contributions of renowned scholars of space law, providing analysis of different governance challenges faced by international society, among which there are those related to debris regulation. In line with the claim put forward in the paper, the editors' conclusion states that the current system of international treaties is insufficient and requires major amendments to include a new agreement on debris management. Marchisio (2020)[13] evaluated the UN Long-Term Sustainability Guidelines for outer space and found them politically relevant but inadequate in terms of being binding enough for the solution of debris problems.

Further, the legal barriers to active debris removal were explored by Su & Lixin (2014).[14] In their study, the authors focused on the question of jurisdiction and ownership under the Outer Space Treaty (OST) in terms of its significance for third parties carrying out such removals. Three major legal obstacles to ADR were revealed in the paper, namely, lack of consent, no regulation for granting authorization of cross-border removal and ambiguity regarding liability for incidents involving debris removal activities. These concerns remain relevant to the present day. Marboe & Fiala (2015)[15] followed up on this research and performed an analysis of the Liability Convention, highlighting the shortcomings in the legislation that must be addressed via additional protocol.

Gaps in the Existing Literature

While the existing literature provides an extensive account of many aspects of the problem at hand, several gaps remain that must be addressed. For one, most of the academic literature on

[11] Steven Freeland, Fly Me to the Moon: How Will International Law Cope with Commercial Space Tourism?, 11(1) Melb. J. Int'l L. 90 (2015).
[12] Ram S. Jakhu & Joseph N. Pelton (eds.), Global Space Governance: An International Study (Springer 2017).
[13] Sergio Marchisio, The UN Guidelines for the Long-Term Sustainability of Outer Space Activities, in Routledge Handbook of Space Law 425 (Ram S. Jakhu & Paul S. Dempsey eds., 2020).
[14] Jing Su & Lixin Han, Legal Analysis of Active Debris Removal: In-Orbit Servicing Activities and International Space Law, 30(4) Space Pol'y 253 (2014).
[15] Irmgard Marboe & Andreas Fiala, Space Activities and Liability, in Handbook of Space Law 399 (Frans G. von der Dunk & Fabio Tronchetti eds., 2015).

governance of orbital debris focuses on analyzing the shortcomings of the existing regulatory framework without offering operational suggestions for change. Indeed, few scholars have offered detailed treaty reforms for dealing with the problem. Another major limitation of existing scholarly work on the problem is its failure to incorporate insights from multiple disciplines. While many authors are either legal scholars or experts in orbital debris modeling and engineering, relatively few have combined both legal analysis and scientific data. Indeed, the former may lack technical knowledge while the latter will likely not possess sufficient understanding of international law. This study seeks to address this gap by incorporating insights from multiple disciplines and synthesizing them in order to produce meaningful findings. Another important shortcoming of the available literature is the neglect of the viewpoints of emerging spacefaring nations. Given their potential roles in a new binding agreement, their perspectives should receive far more consideration than they currently do. The majority of existing papers were written by researchers of traditional spacefaring countries and thus reflect their interests and assumptions. An international agreement that does not take into account the valid interests of nations such as India, Brazil, Nigeria, and South Africa is unlikely to garner the required levels of participation. This paper seeks to address these gap in the literature.

III. UNDERSTANDING ORBITAL DEBRIS AND SPACE SUSTAINABILITY

Definition and Types of Orbital Debris

Orbital debris or commonly called space debris and space junk is defined by Inter-Agency Space Debris Coordination Committee (IADC) as any man-made material revolving around Earth or falling back through the atmosphere and is no longer functional (IADC, 2007).[16] This definition includes many different types of items, both large and small. It consists of dead satellites, rocket stages, small paint flecks and metal shards.

There are different kinds of orbital debris. The first type of debris is launch related which is a part of rockets launched with their payloads. Mission-related objects include equipment released during missions such as camera covers, clamps, and separation bolts. Fragmentation debris is the largest group; it is formed when rocket stages explode due to leftover fuel, batteries fail, an anti-satellite test, and collisions between objects. Degradation debris is made up of tiny

[16] Inter-Agency Space Debris Coordination Comm., IADC Space Debris Mitigation Guidelines (2007), https://www.iadc-home.org.

pieces of material that have been chipped away from older satellites, such as paint chips and metal shavings.

Orbital debris is found in various orbital zones. Low Earth Orbit (LEO), which lies at about 200 to 2,000 kilometers, is the most congested one where the International Space Station, Earth observation satellites, and densely packed commercial constellations are located. Geostationary Orbit (GEO) is 35,786 kilometers where telecommunications and meteorological satellites operate. GEO is more threatening since the objects remain there for eternity unless disposed of. Medium Earth Orbit (MEO) is an orbital regime located between LEO and GEO where navigation satellites including GPS, GLONASS, and Galileo are positioned (Liou and Johnson, 2006).[17]

Causes of Orbital Debris Accumulation

There are several reasons for the formation of orbital debris. The primary reason is the exponential growth in the number of orbital objects lacking appropriate measures of disposal at the end of the mission. In previous decades, it has been quite typical to leave satellites and other rockets floating in space once they have reached the end of their operational life. While gravity acts on objects placed at lower altitudes and pulls them down into earth sooner, those located farther away will float for centuries, and sometimes even for millennia.

The explosion of satellites or rocket parts is a major cause of orbital debris formation. In many cases, the explosion was due to the presence of unused fuels in rockets and satellites, or pressurized tanks in some satellites. Since the beginning of the space era, over 250 explosions of satellites and rockets have occurred in outer space according to data from US Space Surveillance Network (ESA, 2024).[18] Another contributing factor to the problem is the anti-satellite weapons test performed in outer space by the United States (1985), China (2007), India (2019), and Russia (2021).

The introduction of mega-constellations by private entities in space has recently become an increasingly common occurrence. SpaceX launched a mega-constellation of satellites called Starlink that were estimated to comprise 42,000 units in total (McDowell, 2020). This number exceeds the current number of satellites in space by far. Even when assuming a small failure

[17] J.-C. Liou & Nicholas L. Johnson, supra note 7, at pg 11.
[18] Eur. Space Agency, Space Debris by the Numbers (2024), https://www.esa.int/Space_Safety/Space_Debris.

rate, the probability of collision increases dramatically because of the sheer number of objects.

The Kessler Syndrome and Cascading Debris Effect

According to Kessler and Cour-Palais (1978),[19] the Kessler Syndrome is defined as the scenario when there is such a high level of density of objects in LEO that when collisions occur between them, it produces debris that can collide again, creating a self-generating cascade of collisions. It will result in making some orbits unusable for generations in the future, even in case when no new space launches are made. The effect is often referred to as "ablation cascade" because the ablation process occurs during collisions of two objects, resulting in generation of smaller elements, which are capable of causing more harm as well.

Recent simulations prove that the Kessler syndrome might be already taking place in particular altitudes. According to NASA's Orbital Debris Program Office, even if no launches happen anymore, the present amount of orbital debris will grow in number for many decades due to mutual collisions among objects currently orbiting the Earth (Liou & Johnson, 2006).[20] The only way to stop it is by actively removing debris from orbit, especially large massive objects like defunct rocket stages.

Due to its nature, Kessler Syndrome creates an effect that makes the threat of orbital debris irreparable. While most pollution issues are solved relatively easily with reduction in the pollution source, in this case, reaching a point of no return might become quite problematic. Therefore, the only solution lies in preventing the occurrence of Kessler Syndrome.

Economic, Environmental and Security Implications/ Consequences

The continued build-up of space junk has serious economic implications. In 2023, the size of the global space economy was estimated to be approximately $630 billion, with the satellite sector accounting for most of this amount (Space Foundation, 2024).[21] Direct financial costs associated with insurance, hardening of spacecraft against collisions, and maneuvers to avoid conjunctions or collisions with debris add to the total economic burden. One geostationary communication satellite alone could generate insured losses in excess of tens of millions of dollars when lost to the effects of space junk and disrupt services for millions of people. As the

[19] Kessler & Cour-Palais, supra note 3, at pg 9.
[20] J.-C. Liou & Nicholas L. Johnson, supra note 7, at pg 11.
[21] Space Found., The Space Report 2024 Q2 (2024).

space junk situation worsens, space missions become more expensive and risky.

From the environmental perspective, the increased presence of metals from disintegrated satellites entering Earth's atmosphere could contribute to environmental issues, such as the formation of aluminum oxide or other compounds at higher altitudes within our planet's atmosphere (Ross & Toohey, 2019).[22] Though less developed as a research area compared to the physics aspect of space junk, it provides another way of conceptualizing the dangers it creates.

Security considerations related to space junk are considerable as well. Space systems are crucial military infrastructure, providing essential military functions such as communication, intelligence, navigation, and early warning. This makes the presence of potential risks to satellites posed either by accidental events or attacks in space create strategic vulnerabilities and instability in international relations. A country fearing the loss of their valuable space assets due to debris created by other nations' satellites might choose to initiate attacks preemptively, leading to a chain reaction wherein each military action generates new space junk jeopardizing further objects and drawing other countries into the conflict (Harrison et al., 2017).[23]

IV. EXISTING LEGAL AND POLICY FRAMEWORKS

The Outer Space Treaty (1967)

Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, or more widely known as the Outer Space Treaty (OST) came into effect on 10 October 1967. So far, in 2024, it has been ratified by 114 states (UNOOSA, 2024).[24] This treaty represents the core legal document in international space law, setting out the main principles regulating outer space activities. According to Article I of this treaty, the outer space is defined as "province of all mankind" and cannot be claimed by any state. Article IV of the OST prohibits the placing of nuclear weapons and other weapons of mass destruction into orbit around the Earth and on celestial bodies. As per Article VI, the international responsibility for national activities in outer space,

---

[22] Martin N. Ross & David W. Toohey, The Coming Surge of Rocket Emissions, 100 Eos (2019), https://doi.org/10.1029/2019EO136263.

[23] Todd Harrison, Kaitlyn Johnson & Thomas G. Roberts, Space Threat Assessment 2017 (Ctr. for Strategic & Int'l Stud. 2017).

[24] U.N. Off. for Outer Space Affairs, Status of International Agreements Relating to Activities in Outer Space (2024).

including those carried out by non-governmental entities, shall lie with the appropriate State Parties to the treaty which must ensure supervision and authorization of such activities. Finally, Article IX of the OST stipulates a duty of "due regard" to the interests of other States parties to the treaty, and a duty to consult should there be potential for harmful interference with activities carried out.

Nevertheless, the Outer Space Treaty possesses some drawbacks as well. Namely, as far as orbital debris is concerned, there are no specific provisions concerning orbital debris in the treaty, which is a consequence of lack of predictability on part of its drafters at the time. Due regard duty of Article IX has been interpreted as a soft legal duty, meaning that it does not explicitly oblige States parties to take actions aimed at prevention of debris creation or removal of debris already created. Authorization and supervision requirements of Article VI of the OST leave discretion for states in elaboration of their domestic legislation without specifying what standard needs to be reached. Moreover, the commercial space era did not exist during the OST's drafting process.

The Liability Convention (1972)

Convention on International Liability for Damage Caused by Space Objects, henceforth, Liability Convention, came into force on 1 September 1972. This treaty regulates the responsibility of states for damage caused by the space object to either the Earth's surface or aircraft in flight (Article II) or damage caused by one space object to another while both are in outer space (Article III). Article II holds that a launching state should be absolutely liable for any damage caused by its space object, while article III imposes fault-based liability for damage occurring in outer space. Under the convention, "launching state" means both the state that launched a particular space object or the state from which that object was launched.

There was only one case of using Liability Convention, which occurred in 1978, when Canada filed suit against the Soviet Union because of the crash of Cosmos 954, a nuclear-powered space craft to the territory of Canada. Even though Liability Convention is an effective tool when it comes to filing damages, there are many drawbacks to applying it to orbital debris. The problem with determining the launching state is that a collision can involve various parts of different objects which cannot be recognized. Besides, it is rather hard to prove fault-based liability for damage in outer space, since negligence or intent are to be proven. Moreover, Liability Convention does not offer a procedure for the removal of debris by a launching state, thus making such a state liable for the damages it has caused but leaving its debris behind (Marboe & Fiala, 2015).[25]

The Registration Convention (1976)

The Convention on Registration of Objects Launched into Outer Space, more popularly known as the Registration Convention, came into effect on 15 September 1976. According to this convention, countries must keep a registry of all space objects launched by their countries and furnish the United Nations Secretary-General certain information about the space object such as the name of the launching country, its designation, the date and location of launch, important orbital parameters, and the purpose of the space object. The United Nations keeps a public registry of space objects.

The Registration Convention aids in the detection and monitoring of debris through a system of formal registry. However, the convention has some serious flaws. Firstly, launching countries are only required to register the objects that they launch, but not debris. Secondly, the information provided to the Secretary-General is very limited and often supplied after much delay. Thirdly, many countries have irregular and non-comprehensive registration practices. Fourthly, private operators are only required to register their space objects as per the licensing terms of the licensing country. Lastly, this convention does not require the registration of any space debris. Hence, the records maintained under this convention cannot be used to establish liability for any space debris (Tronchetti, 2013).[26]

UN Guidelines on Long-Term Sustainability of Outer Space Activities

The United Nations General Assembly endorsed the Guidelines for the Long-Term Sustainability of Outer Space Activities at COPUOS in June 2019 after seven years of negotiations. The guidelines include twenty-one recommendations covering a broad range of issues, such as space debris mitigation, space weather, space situational awareness, and regulation of commercial operations in outer space. As for space debris, several guidelines call on countries to implement debris mitigation practices in line with the IADC Space Debris Mitigation Guidelines and to explore ways to remove debris from LEO, for instance, by

[25] Irmgard Marboe & Andreas Fiala, Space Activities and Liability, in Handbook of Space Law 399 (Frans G. von der Dunk & Fabio Tronchetti eds., 2015).
[26] Fabio Tronchetti, The Exploitation of Natural Resources of the Moon and Other Celestial Bodies (Martinus Nijhoff 2013).

developing debris removal technologies.

The most significant drawback of the UN Guidelines is that they are not legally binding. They are presented as voluntary guidelines, which means that countries cannot be held accountable for compliance. The implementation of the guidelines is entirely dependent on the willingness of each government and is not supervised or enforced. Although the guidelines represent a diplomatic success story and can affect the policies of some countries, they have not significantly affected debris generation. Countries that do not choose to follow the recommendations will not be penalized legally, and the guidelines have not prevented an increase in the number of objects in LEO (Marchisio, 2020).[27]

National Policies and Legislations

There are no comprehensive binding international policies and guidelines for the mitigation of orbital debris. Different national policies regarding the mitigation of space debris have been established by individual states. For instance, the U.S. has always been a leading actor in the area of space debris mitigation since the early stages when NASA introduced debris mitigation guidelines in the 1990s. In 2019, an updated Orbital Debris Mitigation Standard Practices was released by the U.S. government. The FCC has recently introduced rules mandating satellite operators to de-orbit their satellites in five years after the end of their operational life; this represents an improvement over the 25-year period of time that used to be recommended (FCC, 2022).[28]

In Europe, debris-mitigation policies are embedded into the broader context of a national space sustainability agenda reflected in the Space Programme Regulation. Moreover, there is the European Space Surveillance and Tracking (SST) system that monitors debris objects. In addition, the European Space Agency has a specific Space Safety Programme that involves, in particular, debris mitigation and research into active debris removal methods. Japan has introduced the Act on Launching Spacecraft (2016), including debris mitigation requirements for satellite operators. JAXA is also working on developing active debris removal technologies through its CRD2 programme.

[27] Sergio Marchisio, The UN Guidelines for the Long-Term Sustainability of Outer Space Activities, in Routledge Handbook of Space Law 425 (Ram S. Jakhu & Paul S. Dempsey eds., 2020).
[28] Fed. Commc'ns Comm'n, FCC Adopts New 5-Year Orbital Debris Disposal Rule (2022), https://www.fcc.gov/document/fcc-adopts-new-5-year-orbital-debris-disposal-rule.

India's Space Activities Bill, currently under development in 2024, is likely to contain clauses related to debris mitigation measures. ISRO uses national debris mitigation guidelines internally. China, a major contributor to orbital debris following its 2007 anti-satellite test, has never published national policies and guidelines for debris mitigation but has expressed in COPUOS a general commitment to the UN guidelines for debris mitigation. No such national policies exist in Russia either (OECD, 2020).[29]

Gaps in the Current Framework

The current international legal regime controlling debris in outer space has three principal flaws. To begin with, the most prominent one is the absence of any mechanism for enforcing compliance with international law. Instruments concerned with orbital debris do not specify how states could be held accountable for failure to comply with their obligations (the Outer Space Treaty); are not suitable for identifying and holding responsible those who failed to meet their obligations (the Liability Convention and the Registration Convention); or are merely recommendations without any obligation (the UN guidelines).

Secondly, there is no verification mechanism in place. Even assuming that states are required to take some measures aimed at reducing debris in outer space, there is no way to verify their compliance with the obligations in an international fashion. Satellite debris monitoring is carried out by national organizations, especially by the United States Space Surveillance Network, but not all information collected by it is made public. Absent an independent and open-source space situation awareness, there is simply no way to prove that states complied with their obligations and who was responsible for each incident of orbital debris.

Finally, there is absolutely nothing requiring states to deorbit existing pieces of space junk. There is nothing in the existing body of international law obliging states to remove already-existing space debris that poses a danger to others. The entire emphasis is placed on the mitigation aspect: stopping generation of additional debris. Although technical solutions for active debris removal exist – as proved by RemoveDEBRIS and other similar projects – they need an international legal and financial framework.

[29] Org. for Economic Co-operation & Development, The Space Economy in Figures: How Space Contributes to the Global Economy (2020).

V. CHALLENGES IN ORBITAL DEBRIS MITIGATION AND GOVERNANCE

Technical Challenges

Tracking of Small Debris

One of the main technical challenges that come along with debris mitigation relates to the tracking of small debris objects. The existing ground-based tracking radars and optical telescopes, predominantly developed and operated by the United States Space Surveillance Network, allow for the reliable tracking of the orbits of objects greater than about 10 centimeters in LEO and of objects greater than 1 meter in GEO. Smaller objects in the range from 1 to 10 centimeters, believed to exist in the hundreds of thousands, are too small to be reliably tracked but pose sufficient threats to cause catastrophic damage to spacecraft. Objects smaller than 1 centimeter, existing in hundreds of millions, might cause significant damage to unprotected spacecraft parts such as solar arrays and glass surfaces (Liou et al., 2013).[30]

Enhancement in tracking technology will require significant financial resources for new sensors development. Some promising projects are emerging, such as the commercial SSA providers LeoLabs and ExoAnalytic Solutions. However, it is still not feasible to perform an efficient tracking of all debris with existing technology, and information obtained by various national and commercial space object tracking facilities is not yet sufficiently coordinated or available publicly.

Limitations of Active Debris Removal Technology

Active Debris Removal (ADR) involves the utilization of spacecraft or similar technologies for either capturing, deorbiting, or removing debris. Several techniques have been developed and tested for implementing ADR and these include harpoons, nets, robotic capture tools, electrodynamic tethers, laser ablation, ion beam shepherd, and drag augmentation systems among others. The RemoveDEBRIS project, which was carried out through collaboration by a team of scientists in Britain, successfully captured simulated debris using a harpoon and a net in 2018 (Forshaw et al., 2017).[31]

---

[30] J.-C. Liou et al., Controlling the Growth of Future LEO Debris Populations with Active Debris Removal, 66(5) Acta Astronautica 648 (2013).

[31] J.L. Forshaw et al., RemoveDEBRIS: An In-Orbit Active Debris Removal Demonstration Mission, 127 Acta Astronautica 448 (2017).

Despite the success recorded above, active debris removal faces several technical challenges when scaled up. The process of locating a debris object, capturing, and then subsequently deorbiting the object is highly challenging. Large debris objects such as rocket bodies may not necessarily have been manufactured for easy capture; hence, they could be spinning in space or tumbling around. Approaching and capturing these objects require precise orbital dynamics and advanced autonomous operations. Additionally, performing an ADR on each targeted object will cost many millions of dollars making the elimination of all hazardous debris impossible without international funding efforts (ESA, 2021).[32]

Legal Challenges

Jurisdiction and Sovereignty Issues

Jurisdiction and sovereignty stand among some of the most complex legal challenges when it comes to managing the issue of orbital debris. As per Article VIII of the Outer Space Treaty, any state is entitled to jurisdiction over its space objects regardless of whether they have become non-operational. It means that, despite being labeled as orbital debris, a defunct satellite or spent rocket body still belongs to the launching country. Therefore, no other state can dispose of or alter an already existing space object of another country without the permission of the latter.

The above challenge creates significant hurdles for effective ADR activities. Despite having the ability to remove a threatening debris from the outer space, a state cannot do anything unless it receives permission from the launching state. Gaining such permission might be problematic considering political, military, and bureaucratic reasons. Moreover, the fact that active debris removal technology can be used not only for clearing orbital debris but also for launching anti-satellite weapons adds additional concerns for countries in providing consent for such actions.

Issues with Attributing Liability

Under the principles established by the Liability Convention, assigning liability for damages resulting from space debris is a problem fraught with practical difficulties. The impact of an operational satellite with an object in orbit that cannot be accounted for could prove nearly

[32] Eur. Space Agency, ESA's Annual Space Environment Report (2021), https://www.sdo.esoc.esa.int.

impossible to trace back to a specific entity or state that launched it into orbit. Even when identifying the debris object is possible, proving negligence on the part of the launching state to the required level of certainty required for the imposition of liability under Article III proves difficult. Often, the debris object causing damage could be a result of another collision of other space objects, thus complicating the chain of causation.

Furthermore, the emergence of new commercial space actors adds complexity to assigning liability. A satellite belonging to a company operating out of State 1, launched from State 2 into orbit with a rocket owned by Company 2, from a launching facility in State 3 could be classified by the broad definition of a "launching state" under the Liability Convention as a spacecraft belonging to all three states. Differentiating between the roles played by each of these entities in the case of damage would require a long and arduous legal process, potentially ending with no single state bearing full responsibility.

Lack of Binding International Obligations

Perhaps the most important aspect of this legal issue is the absence of binding international obligations to perform debris mitigation. As previously discussed, neither of the treaties mentioned obligate states to engage in such measures; the Guidelines, although highly detailed, are entirely voluntary. Furthermore, in many instances where nations do adopt domestic standards for dealing with debris, the differences in the strictness of said standards prove considerable, allowing companies to register themselves and license their launches from jurisdictions with relaxed laws. This idea bears resemblance to the flags of convenience approach employed in maritime transport (Freeland, 2015).[33]

Economic Challenges

High Cost of Debris Mitigation and Removal

The employment of debris mitigation techniques incurs some expenses that include the fuel that is to be used during the process of bringing down satellites in addition to the extra weight of the shielded components and the design cost of meeting the requirements of these measures. Despite the fact that the costs of employing mitigation measures have been declining with time

[33] Steven Freeland, Fly Me to the Moon: How Will International Law Cope with Commercial Space Tourism?, 11(1) Melb. J. Int'l L. 90 (2015).

because of increasing awareness of the issue, they still make up a substantial fraction of the total expenditure for both small satellites and new entrants into the business of launching satellites.

Active debris removal, however, comes with substantially higher costs, being of the order of magnitude greater than those of the former technique. It has been determined that removal of just the 50 biggest and most dangerous objects in LEO would require missions with the cost of 50 to 100 million dollars each, thus resulting in a program cost of 2.5 to 5 billion dollars for the first lot alone (McKnight et al., 2021).[34] Such a program would take many years and hence would need tens of billions of dollars, which no nation or international body has yet invested.

No Clear Funding Mechanism

At the moment, there is no internationally supported source of funding dedicated to the problem of orbital debris mitigation. While some national space agencies have financed research and development initiatives to promote ADR technologies, and while the European Space Agency contracted ClearSpace SA to conduct a demonstration mission to remove Vega rocket adapter from orbit, scheduled for the late 2020s, the lack of comparable source of financing remains a significant gap that can be likened to environmental clean-up or maritime funds (Weeden and Shortt, 2019).[35] As a result, the polluter pays principle, which forms the cornerstone of environmental legislation, fails to be successfully implemented in this case, thus ensuring negligible levels of liability among the states and operators of spacecraft that produce debris.

Incorporation of funding for debris removal into the current regulatory regime would face a number of obstacles in the political domain. Leading spacefaring nations might oppose the idea of paying contributions to the fund which will primarily benefit their economic competitors. Up-and-coming space powers might not approve of the contribution scheme that seems to reinforce the superiority of established space nations. Meanwhile, companies might object to internalizing the cost of removing debris from orbit if such a step will affect their competitiveness. Thus, developing an efficient and politically agreeable funding mechanism appears to be extremely difficult.

---

[34] Darren McKnight et al., Identifying the Large Debris Objects Most Likely to Collide with Other Objects in LEO, 189 Acta Astronautica 1 (2021).

[35] Brian Weeden & Victoria Samson, Orbital Debris: A Policy Primer (Secure World Found. 2019), https://swfound.org.

VI. TOWARDS STRONGER GLOBAL GOVERNANCE

Principles for an Efficient Model of Global Governance

To develop an efficient model of global governance on orbital debris issues, there should be a set of basic principles that will take into account the unique features of the environment in which the problem arises, as well as the heterogeneity of the actors involved in space operations. Based on examples of existing international legal regimes in the field of environmental law, maritime affairs, and arms control, some key principles can be identified.

First of all, it is necessary to put the principle of common heritage of mankind, expressed in the Outer Space Treaty, into practice by developing appropriate mechanisms. The principle that the creator bears the cost of cleanup should be implemented in the form of a polluter-pays principle from environmental law. The precautionary principle should stipulate that preventive measures be taken even when scientific uncertainty exists about potential threats. In addition, the principle of common but differentiated responsibilities, widely used in climate governance, implies a recognition of the historic role played by major space powers in the formation of space debris, although everyone has to cooperate in resolving this issue based on their capacities.

Proposed Measures

A Binding International Debris Mitigation Treaty

The primary proposal here is the negotiation of an entirely new binding international treaty focused on orbital debris mitigation and management. This document will include provisions for the adoption and implementation of the existing guidelines put forth by the Inter-Agency Space Debris Coordination Committee as mandatory baseline standards, a requirement for each state to adopt laws and regulations implementing these standards for both governmental and private organizations operating satellites, a mandatory post-mission disposal deadline of five years for all LEO objects, and passivation of all propulsion systems and pressurized containers to reduce explosion-generated debris.

Further, the treaty could mandate minimum standards for data-sharing on space situational awareness, requiring each country with a developed system to submit relevant data to an international registry. Another important provision would be the adoption of a phased-in approach to progressively tighter debris mitigation standards in line with the Montreal Protocol's timeline for the phasing-out of CFCs (Jakhu and Pelton, 2017).[36]

International Space Traffic Management Authority

An international STM authority, perhaps in the form of a specialized UN agency, can resolve the problem of coordination and enforcement identified above. The proposed entity would be responsible for maintaining an internationally recognized registry of all space objects and debris; sending out and coordinating conjunction warnings for satellite operators; drafting and enforcing standards for avoiding collisions; and resolving disputes involving space debris.

As a potential basis for such an authority, one may consider the International Civil Aviation Organization (ICAO), whose role in coordinating civil aviation in accordance with internationally agreed standards and procedures while recognizing states' sovereignty over airspace serves as a good example. Of course, such an organization must take into account that the legal status of space is different from airspace; however, the general principle of the institution's organization can easily be adapted to that purpose (Schrogl et al., 2015).[37]

Active Debris Removal Mandates and Financing

The governance framework also requires the provision for the removal of hazardous debris that already exists in space. This would involve an international mandate to actively remove the biggest and most hazardous objects currently orbiting above us, along with a financial mechanism to help pay for the task.

There could be two approaches to the problem of providing necessary funds for space debris removal, an international orbital debris removal fund paid for by governments and private actors according to the share of the overall debris population attributed to them, similar to the International Oil Pollution Compensation Funds of MARPOL Convention; and a market-oriented solution, which could involve charging an orbital debris fee or creating a cap-and-trade system for debris creation rights (Weeden and Shortt, 2019).[38] In any case, the combination of both solutions might prove more practical than implementing each one

[36] Ram S. Jakhu & Joseph N. Pelton (eds.), Global Space Governance: An International Study (Springer 2017).
[37] Kai-Uwe Schrogl et al. (eds.), Handbook of Space Security: Policies, Applications and Programs (Springer 2015).
[38] Brian Weeden & Victoria Samson, Orbital Debris: A Policy Primer (Secure World Found. 2019), https://swfound.org.

separately.

Enhancing Verification and Compliance Mechanisms

In order to increase compliance with debris mitigation requirements, it would be essential to introduce mandatory reporting and assessment procedures, where states and other commercial space actors provide information about the debris mitigation activities implemented, end-of-life disposal of satellites, and possible cases of unintentional fragmentation. An independent technical body could then examine the provided data and conduct its own verification using available tracking information.

As for the compliance enforcement process, it should include several stages, starting with offering assistance to countries unable to meet the requirements set. Next stage might imply diplomatic pressure and even public criticism of violations until the violation becomes a case of material non-compliance, allowing for sanctions and restrictive actions. It would be beneficial to apply lessons learned from multilateral environmental agreements, IAEA nuclear safeguards and IMO maritime safety enforcement mechanisms while designing a new space debris management regime (Harrison et al., 2017).[39]

VII. CASE STUDIES

Iridium–Cosmos collision (2009)

On 10 February 2009, the operational Iridium 33 communications satellite belonging to Iridium Communications (USA) collided with the decommissioned military satellite Cosmos 2251 over northern Siberia at an altitude of about 789 km. This incident is the first collision of two functioning satellites in human history, which resulted in 2,300 detectable pieces of space debris (Johnson, 2010).[40] This case showed a number of flaws in the existing governance regime of outer space.

Firstly, although the USA has a well-developed tracking system that could monitor both satellites, there was no notification to Iridium Communications of a possible collision. Second, the Cosmos 2251 satellite was decommissioned and incapable of any maneuvering, thus

[39] Todd Harrison, Kaitlyn Johnson & Thomas G. Roberts, Space Threat Assessment 2017 (Ctr. for Strategic & Int'l Stud. 2017).
[40] Nicholas L. Johnson, USA Collision with Russian Satellite: One Year Later, 14(2) Orbital Debris Q. News 1 (2010).

emphasizing the threat posed by inactive satellites moving around crowded orbital slots. Moreover, this collision highlighted the need for an international space traffic management regime, which would help coordinate and organize maneuvers to avoid collisions between satellites controlled by different countries.

This collision led to intensified discussion of the LSG within COPUOS, as well as to changes in the USA's policy to share conjunction data with commercial satellite operators through their online portal Space-Track. Still, this incident did not produce any binding norms, leaving some serious systemic risks associated with collisions of satellites unregulated. For example, the problem of accumulation of inactive satellites on congested orbits was still neglected.

China's Anti-Satellite Test (2007)

On 11 January 2007, China conducted a direct-ascent ASAT test, which destroyed its own Fengyun-1C weather satellite at an approximate altitude of 865 kilometers. As a result, the most extensive debris cloud ever observed was created with more than 3,000 observable fragments and some 150,000 unobservable fragments larger than one centimeter, ranging from 200 to 3,000 kilometers above Earth (Weeden, 2010).[41] It occurred at an orbit level sufficiently high for many fragments to linger for decades or even centuries.

The reaction to the Chinese test across the international community was strong and consisted largely of condemnations of the reckless and irresponsible nature of the test. Diplomatic protests were raised by the United States, European countries, and others. Initially denying the test, China later justified it as a sovereign action within the framework of their space exploration program. At the same time, the test highlighted both the military dimension of the problem of space debris and the lack of any binding ban on ASAT testing with the creation of debris clouds.

In the aftermath of the Chinese ASAT test, coupled with Russia's and US similar actions, there has been increasing pressure towards multilateral constraints. Proposals ranged from banning to moratoriums on destructive ASAT testing. Among those is the initiative put forward by the United States in 2022 for an international moratorium on destructive ASAT direct missile testing. A resolution endorsing such a moratorium unanimously passed in the United Nations General Assembly on 14 December 2022 with only nine states dissenting and 155 voting in

[41] Brian Weeden, 2007 Chinese Anti-Satellite Test Fact Sheet (Secure World Found. 2010), https://swfound.org.

favor. This marks a new precedent in regulating the military aspects of the debris problem (UNGA, 2022).[42]

RemoveDEBRIS Mission (2018)

In April 2018, the RemoveDEBRIS mission was transported to the International Space Station, where the project was then deployed as a free-flying satellite in June 2018. In total, the mission demonstrated four technological validations for active debris removal technologies; a net capture system that caught the target satellite deployed by RemoveDEBRIS, a harpoon that pierced the simulated debris, a vision-based navigation system that was able to identify and characterise tumbling debris, and a drag sail to deorbit the spacecraft upon the completion of the mission (Forshaw et al., 2017).[43]

The RemoveDEBRIS mission represents a milestone achievement in terms of active debris removal technology proof-of-concept, showcasing the feasibility of net- and harpoon-based active debris removal technology in outer space. However, the mission has also shown that there remains a gap between the demonstration of technological capabilities and actual operationalisation of said technology. First, the targets captured have been cooperative debris objects built specifically for this mission, while no actual large uncooperative tumbling debris have been captured and removed in the course of the mission.

The mission's significance in relation to governance is in that it serves as a proof of concept of active debris removal technologies and therefore directly challenges claims about the impossibility of implementing binding ADR legislation due to technical difficulties. Moreover, the mission has also helped stimulate commercial interest in the ADR sector, as multiple private actors have developed ADR concepts, with companies like ClearSpace SA, Astroscale, and D-Orbit entering into agreements with national space agencies. Commercial development of active debris removal technology can be considered important for governance purposes, since it might bring down the costs of the technology and create a financial incentive for debris removal.

[42] U.N. Gen. Assembly, Resolution 77/41: Destructive Direct-Ascent Anti-Satellite Missile Testing (2022).
[43] J.L. Forshaw et al., RemoveDEBRIS: An In-Orbit Active Debris Removal Demonstration Mission, 127 Acta Astronautica 448 (2017).

VIII. RECOMMENDATIONS

Legal Recommendations

First and foremost, it can be said that one major legal recommendation from this study is the signing of a comprehensive and legally binding international treaty on space sustainability by all member states within the United Nations Organization. This particular international treaty would entail the codification of currently used and implemented voluntary guidelines on the mitigation of debris into mandatory and universal minimum standards that will apply to all state and corporate activities in space. Specifically, the treaty must impose strict end-of-life obligations on all spacecraft and rockets. That is, any object that has entered Low-Earth Orbit must be taken out of service and brought down to the Earth within five years after its end-of-life stage, while objects in Geostationary Orbit must be shifted to graveyard orbit at least 300 kilometers above Geostationary Orbit. Moreover, the treaty must include a passivation requirement of all propulsion systems and pressurized objects to mitigate damage arising from explosions. Also, the international treaty must include a binding ban on debris-causing experiments in anti-satellite weapons, in accordance with United Nations General Assembly resolution in 2022.

It can be argued that liability reform is imperative in order to address the issue of space debris. The Liability Convention needs to be updated or supplemented through a new protocol, which would define standards of liability for the use of debris in outer space, adopt a strict liability standard for all damage caused by debris regardless of fault, and formulate a claims procedure that is efficient and effective. It is suggested that the idea of launching-state responsibility should be expanded to encompass continued obligations imposed on all states regarding the maintenance and control of space objects during their lifetime and their proper end-of-life disposal.

Policy Recommendations

States should establish debris mitigation standards that are either the same as or higher than those set forth by IADC and ensure that these standards are applied equally to all satellite operators within its jurisdiction, including foreign companies requesting launch authorization or radio frequency authorization. The five-year deorbit requirement imposed by FCC for LEO satellites should be made an international standard that addresses the entire lifecycle of the mission, encompassing the design, launch, operations, and decommissioning phases. Mega-constellation operators should be mandated to carry out environmental impact assessments before issuing launch authorizations taking into consideration the production of debris, possibility of collisions, atmospheric pollution via re-entering materials, and disruptions to astronomy.

States need to give top priority to the establishment of an international space traffic management system as one of their policy priorities. In the short run, states having superior technology should considerably increase the exchange of conjunction information with satellite operators without discrimination. States should establish a multilateral space traffic management center, which can either operate under UNOOSA or be an independent institution to coordinate space traffic activities such as maneuvering to avoid collisions, managing radio frequency interference, and maintaining a central register of space objects. UNOOSA should be granted increased resources and mandate to coordinate international efforts towards sustainability in space.

Technical Recommendations

Increased funding is needed for space situational awareness capabilities both nationally and internationally. Nationally, nations with space situational awareness capabilities, particularly the United States, need to make available more timely and extensive data about debris to all users, including commercial users and users from developing countries. Internationally, a network of ground sensors needs to be built to track debris smaller than 10 centimeters, through a system governed multilaterally and with open access to data generated. Research should focus on space-based sensors which can track objects in GEO and in deep space over the medium term.

Active Debris Removal (ADR) R&D programs need to be scaled up significantly. Technologies to remove debris should focus particularly on large, tumbling, and uncooperative objects such as spent rocket bodies, which are responsible for most debris. Standards for ADR should be defined in order to ensure interoperability between ADR efforts made by other space agencies or commercial actors, through standardization of communications protocols and technical interfaces. Internationally funded demonstration projects should seek to remove the 50 most dangerous objects in LEO by 2030 to demonstrate the ability of ADR to operate on an operational level, while spurring the development of the commercial market for ADR.

Regulators need to make it mandatory for satellite manufacturers to include standardizable components that enable ADR.

IX. CONCLUSION

Debris in orbit poses a significant problem for modern international environmental governance. Historical uses of outer space have created an expanding and more dangerous population of derelict satellites, expended rocket bodies, and other fragmentation products, threatening the sustainability of the space environment as a global commons. The Kessler Syndrome, proposed originally in 1978, has shifted from speculative theory to concrete concern; modeling suggests that chain reactions may have already commenced in the most crowded orbital regions. Time for preemptive action is running out.

International systems of governance, which are based on treaties developed in the 1960s and 1970s and supplemented by multiple codes of conduct, cannot solve the problem under current conditions. Requirements concerning the duty to take into account interests of other countries stated in Article IX of the Outer Space Treaty, responsibility in cases of space debris generation based on fault according to the Liability Convention, and registration of objects in outer space according to the Registration Convention were developed before the introduction of mega-constellation systems, debris removal programs, and anti-satellite weapon testing. Despite being non-binding, UN Guidelines for the Long-Term Sustainability of Outer Space Activities should be considered an important diplomatic success. Yet, they have not been supported by enough states to prevent the formation of new space debris.

As evident from the described cases, the problem is extremely serious, no existing solutions can be effective, and the technical possibilities of debris removal are obvious. First, the collision between two satellites emphasized that there was neither space debris nor proper STM regime able to reduce risks of such incidents. Second, China's anti-satellite weapon testing showed that the problem is strongly connected with the militarization of space and proved the necessity of introducing mandatory international prohibitions of weapon testing with the generation of space debris. Third, RemoveDEBRIS project demonstrated that ADR could be technically possible provided appropriate financial resources and political support were available.

The suggested recommendations are ambitious but essential in the current state of affairs. It is unlikely that humanity will survive without an international treaty, which would limit the amount of generated debris; an international body, responsible for the space traffic control; amendments to the systems of liability and registration; compulsory participation of countries in international ADR procedures; and universal implementation of the best practices in relation to satellite launches. In spite of their initial unfeasibility, practical examples prove the possibility of their successful implementation. The steps to be taken are both practicable and feasible. The only prerequisites for their fulfillment include political will and appropriate investments, which would become inevitable, given the possible consequences of inaction in this area.

Outer space regulation is one of the most vivid examples of a collective-action problem. Space is a global good, which will inevitably suffer because of its excessive exploitation. The tragedy of the commons will be prevented not because of the goodwill on the part of countries but due to institutional arrangements, which make them act in accordance with their mutual interest. As experience shows, mankind is able to rise above the interests and establish organizations that help mitigate the threat. The Montreal Protocol, the Nuclear Non-Proliferation Treaty, and the Law of the Sea Convention are good examples of such endeavors. The current situation is serious enough to initiate such activities in relation to space.