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Mechanisms for Addressing Space Debris from the Perspective of International Law

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Abstract

This paper explores the various mechanisms available for addressing the issue of space debris through the lens of international law. As human activities in space continue to increase, so does the accumulation of space debris, posing significant risks to satellites, spacecraft, and overall space operations. International law plays a crucial role in governing space activities and managing the growing problem of space debris. This paper examines the legal frameworks and mechanisms established at the international level to mitigate, prevent, and manage space debris. It analyzes treaties, agreements, guidelines, and principles relevant to space debris mitigation and explores the roles of different actors, including space agencies, governments, and international organizations, in implementing these mechanisms. The paper also discusses challenges and gaps in current legal frameworks and suggests potential avenues for enhancing international cooperation and coordination in addressing the issue of space debris. Through this examination, the paper aims to contribute to the

understanding of the intersection between international law and space debris management and to inform future policy and decision-making in this critical area.

KEYWORDS *Space Debris, Guidelines, International Mechanism*

Introduction

Space debris, consisting of defunct satellites, spent rocket stages, and other fragments resulting from space missions, poses a significant threat to space exploration, satellite operations, and potentially, to life on Earth. As the volume of space debris continues to increase, there is a pressing need for effective mechanisms to mitigate its proliferation and prevent catastrophic collisions in outer space. Addressing space debris requires a multifaceted approach encompassing technological innovation, international cooperation, and legal frameworks to regulate space activities and ensure the sustainability of outer space operations.[1]

From the perspective of international law, mechanisms for addressing space debris play a pivotal role in governing the use and exploration of outer space while minimizing risks to space infrastructure and activities. This introduction explores the key legal principles and frameworks governing space debris mitigation, highlighting the role of international cooperation, customary law, and multilateral agreements in shaping strategies for managing space debris. By examining the intersection of space law and environmental sustainability in the context of space debris mitigation, this exploration seeks to elucidate the legal mechanisms essential for safeguarding the long-term viability of space exploration and utilization.[2]

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[1] Minghe Shan, Jian Guo, and Eberhard Gill. "Review and comparison of active space debris capturing and removal methods." *Progress in Aerospace Sciences* 80 (2016): 18-32; Howard A. Baker, "Space Debris: Legal Policy and Implication", *Thesis.* (Quebec Canada: McGill University Montreal, 1988).

[2] Diego Zannoni, "Out of sight, out of mind? The proliferation of space debris and international law." *Leiden Journal of International Law* 35, no. 2 (2022): 295-314; Lawrence Li, "Space debris mitigation as an international law obligation: a critical

Prior to the launch of Sputnik I by the Soviet Union, space-related issues had received minimal attention from humanity. The implications of human activities in space were not fully recognized in terms of their impact on terrestrial welfare and survival. However, following the launch of Sputnik I on October 4, 1957, by the Soviet Union, global scrutiny intensified across ideological, political, economic, cultural, and legal spheres. This seminal event prompted nations worldwide to question and evaluate the implications of space exploration, marking the dawn of a new era in space governance and international cooperation.[3]

In accordance with the agreement of the United Nations General Assembly, International Law and the Charter of the United Nations extend their jurisdiction to space, the moon, and other celestial bodies. This framework asserts that all nations have the right to freely explore and utilize these entities in accordance with established international law. Moreover, it explicitly prohibits any state from claiming ownership over space, the moon, or other celestial bodies. The launch and exploration of celestial bodies represent significant milestones in human technological advancement and have profound implications for life on Earth. Such endeavors signify progress in leveraging space for the benefit of humanity, facilitating advancements in science, technology, communication, and exploration.[4]

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analysis with reference to states practice and treaty obligation." *International Community Law Review* 17, no. 3 (2015): 297-335; Lawrence D. Roberts,"Addressing the Problem of Orbital Space Debris: Combining International Regulatory and Liability Regimes." *Boston College International and Comparative Law Review* 15, no. 1 (1992): 51-73.

3 Michael Sheehan, *The International Politics of Space*. (London: Routledge, 2007).

4 Stacey L. Lowder, "State's International Legal Role: From the Earth to the Moon, A." *Tulsa Journal of Comparative and International Law* 7, no. 1 (1999): 253-383; Nandasiri Jasentuliyana, *International Space Law and the United Nations*. (Leiden: Brill, 2023); Csabafi, Imre Anthony. *The Concept of State Jurisdiction in International Space Law: A study in the Progressive Development of Space Law in the United Nations*. (London: Springer, 2012); Jackson Nyamuya Maogoto, and Steven Freeland. "Space Weaponization and the United Nations Charter Regime on Force: A Thick Legal Fog or a Receding Mist?." *The International Lawyer* (2007): 1091-1119.

The agreement underscores the principle of common heritage of mankind, emphasizing that space and celestial bodies are to be accessed and utilized for the collective benefit of all nations. This legal framework promotes the peaceful and equitable exploration of space, fostering international cooperation and collaboration in space endeavors. Furthermore, it serves to prevent the monopolization or militarization of space, ensuring that access to its resources remains open and accessible to all nations. Thus, the exploration and utilization of celestial bodies not only represent technological progress but also embody the spirit of international cooperation and the pursuit of common goals for the betterment of humanity.[5]

The progress made in space exploration is evident through advancements in enhancing the quality of life and the conduct of diverse scientific research across various disciplines, alongside efforts to discover new natural resources through the exploration of celestial bodies. However, the utilization of space for improving human welfare can also entail various drawbacks, impacting not only terrestrial territories but also airspace and the space environment itself. These losses manifest as a consequence of competitive activities in space management.[6]

One notable concern revolves around the potential negative impacts associated with satellite launches, particularly those employing radioactive materials or nuclear technologies. In instances where satellite launches fail and debris falls onto the territory of other nations, significant losses may ensue for the affected countries. Moreover, the launch of space objects can pose risks to the ozone layer, a vital component of Earth's atmosphere that serves as a shield against harmful ultraviolet radiation. The disruption of the ozone layer due to space activities can exacerbate environmental challenges and contribute to broader ecological concerns. Thus, while

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5 Daniel Deudney, *Dark Skies: Space Expansionism, Planetary Geopolitics, and the Ends of Humanity*. (Oxford, USA: Oxford University Press, 2020); Mary Victoria White, "The Common Heritage of Mankind: An Assessment." *Case Western Reserve Journal of International Law* 14, no. 3 (1982): 509-542.

6 Chia-Jui Cheng, ed. *The Use of Airspace and Outer Space for All Mankind in the 21st Century*. (Leiden: BRILL, 2023); Christy Collis, "Res communis? A critical legal geography of outer space, Antarctica, and the deep seabed." *Palgrave Handbook of Society, Culture and Outer Space* (2016): 270-291.

space exploration offers immense opportunities for human advancement, it also necessitates careful consideration of its potential adverse effects and the implementation of appropriate safeguards to mitigate risks.[7]

Numerous celestial bodies launched by countries worldwide encounter malfunctions or failures, particularly notable during the launch of nuclear-powered satellites, often deployed in low-earth orbits where malfunctions are more common. Satellites have a finite lifespan, and upon expiration, they pose risks to operational objects and may even descend to Earth's surface. The repercussions of such incidents extend beyond the launching nations, affecting countries associated with the launch process and even those uninvolved in the initial deployment. These negative impacts underscore the interconnected nature of space activities and highlight the need for comprehensive risk management and international cooperation to address potential hazards stemming from space exploration.[8]

Under international law, a country can be deemed liable for the consequences of its celestial body's launch, particularly if the object becomes space debris and subsequently falls into another country, resulting in harm. This principle is enshrined in the Convention on International Liability for Damage Caused by Space Objects 1972, which outlines the legal framework governing liability for damages arising from space activities. According to this convention, nations are accountable for any damage caused by their space objects, emphasizing the importance of responsible conduct in space exploration and ensuring the mitigation of risks associated with space debris.[9]

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[7] Rada Popova, and Volker Schaus. "The legal framework for space debris remediation as a tool for sustainability in outer space." *Aerospace* 5, no. 2 (2018): 55.

[8] Eligar Sadeh, James P. Lester, and Willy Z. Sadeh. "Modeling international cooperation for space exploration." *Space Policy* 12, no. 3 (1996): 207-223.

[9] *See also* Kirsten Schmalenbach, "Convention on International Liability for Damage Caused by Space Objects." *Corporate Liability for Transboundary Environmental Harm: An International and Transnational Perspective*. (Cham: Springer International Publishing, 2022), pp. 523-536; W. F. Foster, "The convention on international liability for damage caused by space objects." *Canadian Yearbook of International Law/Annuaire canadien de droit international* 10 (1973): 137-185.

The topic of space debris was brought to the forefront during the 31st Session of the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) in February 1994, following General Assembly Resolution 48/39 of 10 December 1993. Prior to this, discussions regarding space debris had been conducted independently across multiple international forums. During the session, the Subcommittee recognized the significance of addressing the issue of space debris and acknowledged the necessity of international collaboration to mitigate its potential impact on forthcoming space missions. This marked a pivotal moment in the global dialogue surrounding space debris, underscoring the imperative for collective action and cooperation to safeguard the sustainability of space exploration and utilization.[10]

From a technical perspective, there are three primary approaches to managing space debris, namely:

1. Prevention: This entails implementing guidelines aimed at curbing the generation of operational space debris. Measures include minimizing the use of bolts, coating caps, ropes, pyrotechnic devices, and residues during spacecraft deployment and operations.
2. Satellite Protection: Measures are taken to shield satellites from the effects of debris impacts and the aging process. This may involve the installation of specific shields and other protective mechanisms, including materials with self-healing properties, to mitigate damage caused by debris collisions.
3. End-of-Life (EOL) Disposal: Disposal methods are employed to remove spacecraft from orbit once they reach the end of their operational lifespan. Techniques such as retrieval and descent technologies, such as tether-assisted deorbit systems, deliberate

[10] *See* Yunita Permatasari, and Antonia Rahayu Rosaria Wibowo. "International instrument relating to space debris: The value of environmental protection." *AIP Conference Proceedings*. Vol. 2941. No. 1. AIP Publishing, 2023; Ramona L. Walls, et al. "Assessing the IADC Space Debris Mitigation Guidelines: A case for ontology-based data management." *AMOS Paper* (2016).

spacecraft dismantling through controlled detonation, or placement into a designated "*graveyard orbit*," are utilized to safely remove spacecraft from active orbits and mitigate the accumulation of debris in space. These approaches aim to promote sustainable space operations and minimize the risk posed by space debris to future space missions and satellite operations.

In terms of regulation, there are three compelling reasons why space debris necessitates regulatory measures:

1. Risks to Earth Orbit: The existing space debris environment poses significant risks to spacecraft operating in Earth orbit. Additionally, there is a concern regarding the potential damage to terrestrial structures and assets if space debris re-enters Earth's atmosphere.
2. Threats to Spacecraft: Space debris presents a tangible threat to spacecraft, with the potential to cause mission failures or even jeopardize the lives of crew members in the case of manned spacecraft. The collision between debris and operational satellites can lead to critical malfunctions, disruptions in communication, and loss of valuable resources.
3. Preservation of the Space Environment: Regulatory measures are essential to safeguard the space environment for future generations. By implementing effective regulations, such as debris mitigation guidelines and end-of-life disposal requirements, we can mitigate the accumulation of space debris and preserve the sustainability of space activities for generations to come. These regulations are imperative for ensuring responsible and sustainable practices in space exploration and utilization.

Stephen Hobe suggests that the supremacy of international space law is gradually diminishing, a trend attributed to the evolution of space law, which can be categorized into four distinct stages.

1. First Stage (1950-1979): This phase primarily involved the establishment of binding international agreements governing space activities. During this period, key treaties such as the Outer Space Treaty of 1967 and the Rescue Agreement of 1968 were

formulated, laying down foundational principles for space exploration and utilization.
2. Second Stage (1980-1995): In this phase, the focus shifted towards the enactment of United Nations General Assembly resolutions addressing specific aspects of space activities. These resolutions aimed to address emerging issues and challenges in space exploration and promote international cooperation in the peaceful uses of outer space.
3. Third Stage (since 1995): This stage is characterized by UN General Assembly resolutions aimed at interpreting and clarifying the provisions of existing international agreements governing space activities. These resolutions serve to ensure a common understanding of the rights and obligations outlined in space treaties and agreements, fostering harmonious implementation among member states.
4. Fourth Stage: The most recent stage encompasses the development of non-binding and technical provisions based on shared understanding and consensus among space-faring nations. These provisions complement existing legal frameworks by providing practical guidelines and best practices for addressing contemporary challenges in space exploration and management.[11]

These stages reflect the dynamic nature of international space law, which continues to evolve in response to technological advancements, emerging threats, and the growing complexities of space activities. While the supremacy of international space law may appear to diminish, the evolving legal landscape underscores the ongoing efforts to adapt legal frameworks to the changing realities of space exploration and utilization.

There are various international, regional, and national arrangements governing space debris, each aimed at mitigating the risks posed by orbital debris. Some of these key arrangements include:

[11] *See* Stephan Hobe, "Legal Aspects of Space Tourism." *Nebraska Law Review* 86.2 (2007): 439-456; Hobe, Stephan, ed. *Pioneers of Space Law: A publication of the International Institute of Space Law*. (Leiden: Martinus Nijhoff Publishers, 2013); Stephan Hobe, and Kuan-Wei Chen. "Legal status of outer space and celestial bodies." *Routledge Handbook of Space Law*. (London: Routledge, 2016), pp. 45-61.

1. UN COPUOS Space Debris Mitigation Guidelines (A/62/20): These guidelines, established by the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), outline measures for space debris mitigation to minimize the creation of new debris and reduce the risk of collisions in space.
2. IADC Space Debris Mitigation Guidelines (Revision 1): Developed by the Inter-Agency Space Debris Coordination Committee (IADC), these guidelines provide recommendations for space agencies on debris mitigation strategies and practices to ensure sustainable space operations.
3. NASA Procedural Requirements for Limiting Orbital Debris (NPR8715.6): NASA's guidelines detail specific procedural requirements and best practices for spacecraft design, operation, and disposal to mitigate the generation of orbital debris and minimize collision risks.
4. Process for Limiting Orbital Debris (VEIN-STD-8719.14): This standard outlines the process for implementing orbital debris mitigation measures, including spacecraft design considerations, operational procedures, and end-of-life disposal strategies.
5. European Space Debris Safety and Mitigation Standard: Established by the European Space Agency (ESA), this standard provides guidelines and requirements for managing space debris risks in ESA projects and missions.
6. ESA Space Debris Mitigation for Agency Projects (ESA/ADMIN/IPOL): ESA's policy document sets forth guidelines and practices for mitigating space debris risks in the planning, development, and operation of ESA-sponsored projects and missions.[12]
7. Russian Aviation & Space Agency Standard: General Requirements, Mitigation of Space Debris Population: This standard, issued by the Russian Aviation and Space Agency, outlines general requirements and procedures for mitigating the population of space debris.

[12] Heiner Klinkrad, et al. "The ESA space debris mitigation handbook 2002." *Advances in Space Research* 34, no. 5 (2004): 1251-1259.

These arrangements reflect the collective efforts of the international community and individual space agencies to address the growing challenge of space debris and promote the sustainable use of outer space. They emphasize the importance of proactive measures to minimize debris generation, safely dispose of defunct spacecraft, and preserve the long-term viability of space activities.

The development of space activities in space poses various problems in parts of the world, but all existing arrangements are a precaution for other serious problems to occur. In recent years, it has been seen that the Scientific and Engineering Subcommittee expressed its appreciation to several countries that have implemented space debris mitigation measures consistent with the Space Debris Mitigation Guidelines of the Committee on The Peaceful Uses of Outer Space and/or The Inter-Agency Space Debris Coordination Committee (IADC) Space Debris Mitigation Guidelines) or countries that have developed their own space debris mitigation standards based on these guidelines. In addition, other countries use the IADC Guidelines and the European Code of Conduct for Space Debris Mitigation as a reference in the regulatory framework established for national space activities. In addition, countries are also of the view that each of these guidelines can complement each other.

Space Debris: Limitation and Legal Aspects

In IADC guidelines the definition of space debris is all man-made objects including parts and elements inherent in them that are in earth orbit or enter the atmospheric layer, which are no longer functioning. The IADC version of the definition is also a reference in the discussion of the issue of space debris at the UNCOPUOS scientific and engineering subcommittee session. In the UN space debris mitigation guidelines, it is stated that the main sources of space debris in earth orbit include:

1. The intentional or accidental release of fragments into Earth's orbit, causing the formation of space junk over a long period.
2. Space junk released intentionally during the operation of spacecraft and launch vehicles enters orbit.

The existence of space debris began with the launch of the Sputnik satellite by Russia in 1957. Since then countries have been racing to master space technology and launch satellites into space. The existence of space objects can be grouped into types of orbits, namely:

1. Low Earth Orbit (LEO) is an orbit with an altitude of less than 5500 km and an orbital period of less than 225 minutes
2. Medium Earth Orbit (MEO) is an orbit with an altitude of 5,500-36,000 km, generally navigation satellites that occupy this orbit, such as GLONASS (Global Navigation Satellite System) and GPS (Global Positioning System)
3. Geosynchronous Earth Orbit (GEO) at an altitude of 36,000 km, generally communication satellites and weather observers occupy this orbit.

In general, the causes of space debris are grouped into 3 causes, namely; (a) Space missions, (b) Accidents, and (c) Willfulness. As it is well known that every space mission such as launching a satellite into orbit passes through the release stage. In the process of placing space objects / satellites there are several parts / components that accompany and detach at the time of launch, including former tanks, rocket fuel, rocket shells and so on. The detached part/component becomes space debris.

In addition to space debris caused by space missions, accidents are also one of the causes of space debris, collisions between space objects with one another and collisions between debris that already exist in space cause new debris fragments. Collisions between space objects have occurred on the Russian Kosmos satellite that hit the United States Iridium satellite in 2009, based on data obtained from NASA collisions between these satellites causing at least 1000 debris debris measuring 10 cm.

The cause of the existence of the last space debris is intentional, one concrete example is the test of anti-satellite weapons (ASAT) conducted by China which destroyed its own satellite. According to tracking results conducted by the United States, the impact of the ASAT test produced at least 2,087 large debris fragments, the worst numbers of debris.

Global Impact Space Debris

A. Space Security

The increasing number of space debris in space certainly has repercussions and threats, especially for space security. The existence of space debris threatens space security in terms of the space environment and also the sustainability of space use in the future. If the amount of space debris increases and is not immediately addressed, saturation will occur and allow the space environment to no longer be used in the future.

In addition, space debris also threatens the safety of astronauts in space. For example, in 2009, the International Space Station (ISS) was almost hit by a fragment of space debris which, although only 0.8 cm in diameter, had a speed of 30,000 km per hour. This certainly threatens the lives of astronauts who are in the space station.

The danger of space debris also threatens the safety and security of other space objects such as satellites that are still functioning. The risk of impact is one of the threats to the safety of other space objects in orbit. Space debris fragments that are very large and have high speeds certainly have the potential to hit other space objects, this will certainly be very detrimental to parties or countries whose satellites are threatened with collisions with space debris. The losses incurred are not only in terms of technological functions but also from the economic side.

China's Anti-Satellite (ASAT) test serves as a poignant illustration of how space debris fragments pose a threat to operational space assets. During this event, China conducted a test that resulted in the intentional destruction of one of its own defunct weather satellites, generating a significant amount of debris. These debris fragments, ranging in size from small particles to larger pieces, now pose a substantial risk to the operational satellites of at least 16 other countries.[13]

The ASAT test conducted by China exemplifies the potential consequences of reckless actions in space. The resulting debris cloud poses a hazard to satellites from various nations, including those involved in telecommunications, weather monitoring, and scientific research. The

[13] Gene V. Milowicki, and Joan Johnson-Freese. "Strategic choices: examining the United States military response to the Chinese anti-satellite test." *Astropolitics* 6, no. 1 (2008): 1-21.

proliferation of space debris fragments increases the likelihood of collisions with operational satellites, which could disrupt vital communication networks, compromise weather forecasting capabilities, and hinder scientific endeavors.

This incident underscores the importance of responsible behavior in space activities and the need for international cooperation to address the growing threat of space debris. Efforts to mitigate space debris must involve all stakeholders, including spacefaring nations, space agencies, and international organizations. By promoting responsible space practices and adhering to agreed-upon guidelines for space debris mitigation, the international community can safeguard critical space assets and ensure the sustainable use of outer space for future generations.

B. Earth Safety

Space debris not only impacts and threatens security in space but also security and safety on earth. Re-entry of uncontrolled space objects is one of the factors that can threaten and endanger human life and also the earth's environment. The lower the position of the space debris, the faster it will fall to the surface of the earth. The large debris includes defunct satellites such as NASA's UARS, Russia's Phobos-Grunt , and parts of satellite launch vehicles. Reentry is a recommended mission final disposal option for objects in LEO. This reentry is directed to a safe area, thus minimizing casualties. (William Ailor, 2012).

Space debris also has an impact on ozone depletion, this is caused by the charge of space objects. Research on the re-entry of space objects to earth has been carried out and research states that the material and chemical charge of space objects can cause ozone depletion.

C. Politics

In addition to having an impact on the security and safety of the earth and space. Space debris either directly or indirectly has an impact on the political situation. Examples can be seen of China's test firing of anti-satellite weapons (ASATs) that destroyed its own satellites and caused an increase in the amount of space debris in space. This event not only affects

the space environment but also becomes a polemic for countries, especially the United States.

This weapon test is believed to trigger an arms race in space. It also drew strong protests from countries with satellite programs affected by the shooting. Several countries such as Japan, Russia, the United States and Britain gave official responses to China's actions related to this satellite firing test.

The Debate of Space Debris Issues in International Forums

Since the emergence of space debris as a space problem, countries have made various efforts together in dealing with this issue. Discussion of Space debris as an issue that needs to be addressed by countries, international organizations and relevant stakeholders. Through the UN forum (UNCOPUOS) member states propose that the problem of space debris get attention.[14]

In 1993, recognizing the pressing issue of space debris, the United Nations took proactive steps by adopting Resolution No.48/39, which propelled the matter onto the agenda of the Scientific and Technical Subcommittee's session scheduled for 1994. Subsequently, during the Subcommittee's 1995 session, a meticulous work plan spanning the years 1996 to 1998 was meticulously devised. Crafted under the guidance of Niklas Hedman in 2009, this plan delineated a strategic roadmap for addressing the multifaceted challenges posed by space debris. The agenda for 1996 was marked by a concerted effort to refine methodologies for measuring space debris, deepen comprehension of collected data, and ascertain the ramifications of the debris-laden environment on space systems. Building upon this groundwork, the focus in 1997 shifted towards developing sophisticated models of the space debris environment and conducting comprehensive risk assessments to evaluate potential hazards to space operations and missions. This structured approach laid

[14] Peter Martinez, "The UN COPUOS guidelines for the long-term sustainability of outer space activities." *Journal of Space Safety Engineering* 8, no. 1 (2021): 98-107; Gérard Brachet, "The origins of the “Long-term Sustainability of Outer Space Activities” initiative at UN COPUOS." *Space Policy* 28, no. 3 (2012): 161-165.

the foundation for concerted international efforts to confront the escalating problem of space debris.

From this discussion produced the Technical Report on Space Debris which was later ratified in 1999. This report outlines measurements of space debris and a shared understanding of the term space debris. Further efforts to handle space debris at UNCOPUOS are the establishment of a working group that discusses space debris mitigation guidelines from 2004 to 2006 (Euis, 2011). In 2007, the Committee endorsed the Space Debris Mitigation Guidelines of COPUOS. These guidelines contain procedures and those that are seen as reducing the amount of space debris.

In addition to being discussed in UNCOPUOS, efforts to handle space debris are also realized in the IADC (Inter-Agency Space Debris Coordination Committee), an international forum whose members are space agencies of countries for coordination of activities related to debris in space. IADC was formed with the aim of sharing information in space debris research activities and facilitating cooperation opportunities in space debris research as well as reviewing the development of cooperation activities and identifying ways to mitigate space debris.

Within the IADC members share a number of common interests related to space debris research that can be developed into various research collaboration activities. IADC is intended to identify, plan and assist in the implementation of mutually beneficial cooperation activities.

In its development, efforts to handle space debris are not only carried out through UNCOPUOS and IADC but also by other international forums. UNOOSA (United Nations Office for Outer Space Affairs) through UNCOPUOS based on the contributions of Canada, the Czech Republic and Germany appeals to member states and international organizations to report a summary containing information on space debris mitigation arrangements and standards to UNOOSA collected in an overview / compendium.

The purpose of this compendium is to inform countries about space debris mitigation instruments and measures that have been implemented by countries and international organizations. In addition, the Compendium is expected to help those who wish to enact or develop similar standards with respect to this space debris topic.

This compendium contains reports on countries on the mechanisms or standards that have been applied in dealing with space debris in their countries and how they are applied. The compendium also informs whether the national mechanisms applied refer to existing international mechanisms. So far, 24 countries have collected reports on their national mechanisms for mitigating space debris. These countries include Algeria, Argentina, Australia, Austria, Belgium, Canada, Chile, Czech Republic, France, Germany Indonesia, Italy, Japan, Mexico, Netherlands, Nigeria, Poland, Slovakia, Spain, Switzerland, Thailand, Ukraine, the United Kingdom, and the United States.[15]

The Urgency of the Establishment of a Special Agency for Space Debris Cleaning

The sovereign territory of the state also includes the air space above its territory. This area has long been discussed, especially in a postulate of Roman Law that reads "*cujus est solum, ejus est usque ad coelum*". This postulate means, whoever owns a piece of land thus also owns everything that is above the surface of the land up to heaven and everything that is in the ground.[16] According to international law, the territory of the country

[15] Kai-Uwe Schrogl, "The new debate on the working methods of the UNCOPUOS Legal Subcommittee." *Acta Astronautica* 105, no. 1 (2014): 101-108.

[16] "*Cujus est solum, ejus est usque ad coelum*" is a Latin legal maxim that translates to "*whoever owns the land, owns everything up to the sky.*" This principle reflects the concept of land ownership extending vertically into the airspace above the land. In essence, it suggests that landowners have rights to the space above their property, reaching all the way to the heavens. Originally formulated in medieval common law, this maxim established the idea that landowners possessed exclusive control over the airspace above their land, including the right to prevent others from encroaching upon it. However, with the advent of aviation and space exploration, the practical application of this principle has evolved significantly. In modern legal contexts, the concept of airspace ownership is subject to various regulations and treaties, particularly regarding air travel and space activities. National airspace is typically governed by aviation authorities, while international space law addresses issues related to outer space, satellites, and celestial bodies. Despite these developments, the principle of "*cujus est solum, ejus est usque ad coelum*" continues to influence legal discussions surrounding property rights and airspace use. *See*

consists of three dimensions, namely land, sea, and air. Sea area is an extension of land area, and a country's airspace follows the boundaries of the country's territory on land and sea. This is reflected in Article I of the Paris Convention for the Regulation of Aerial Navigation of 1919 which recognizes full state sovereignty in the airspace over its land and sea territory. Initially, state sovereignty was not determined by the distance limit vertically (*usque ad coelum*) which was later limited by the regulation of space.[17]

In recent times, the frequency of satellite launches has surged as nations engage in vigorous competition to expand their presence in space. The United States, notably through NASA, has developed advanced space shuttles capable of deploying multiple satellites into orbit in a single mission, with the ability to return to Earth for reuse. This technology enables the US to execute successive satellite launch initiatives efficiently. Concurrently, the Soviet Union made significant strides in space exploration with renowned projects such as Soyuz, Sputnik, and Cosmos, underscoring their active engagement in space endeavors. Indonesia, too, has entered the space arena, collaborating with the United States to launch its inaugural communications satellite, PALAPA A-1, during the 1970s, marking Indonesia's initiation into the realm of space utilization.[18]

Stuart Banner, *Who owns the sky? The struggle to control airspace from the Wright brothers on*. (Harvard, MA: Harvard University Press, 2009). *Also see* Stuart S. Ball, "The vertical extent of ownership in land." *University of Pennsylvania Law Review and American Law Register* 76, no. 6 (1928): 631-689; Sterling E. Edmunds, "Aerial Domain and the Law of Nations." *St. Louis Law Review* 8, no. 2 (1923): 88-97.

17 *See* Stuart Elden, *Terror and Territory: The Spatial Extent of Sovereignty*. (Minnesota: University of Minnesota Press, 2009); Olavo de Oliviera Bittencourt Neto, *Defining the Limits of Outer Space for Regulatory Purposes*. (London: Springer, 2015).

18 *See* Dodik Setiawan Nur Heriyanto, Yaries Mahardika Putro, and Haekal Al Asyari. "Space Diplomacy as A Way to Face The Era of Space Commercialization in Indonesia." *Seminar Nasional Kebijakan Penerbangan dan Antariksa III (SINAS KPA-III),* 2018. *See also* Ridha Aditya Nugraha, et al. "Air and Space Law Education: Preparing for the Future in China, Indonesia, Italy and Thailand." *Hasanuddin Law Review* 7, no. 3 (2021): 183-209; Harry Purwanto, "Safeguarding the National Airspace of Indonesia under the Framework of International Air Law." *Jurnal Hukum Novelty* 12, no. 2 (2021): 191-203; Adya

> Humans make garbage in large quantities not only on the earth where we live, but human makes garbage in space is also seen from the high activity of human space today. Many objects launched in space have become useless junk. Space junk is an artificial object that circles the earth in addition to a functioning satellite. It is estimated that space debris has fallen every day since the launch of satellites in 1957. This garbage is in the form of rocket and satellite waste that has burned up in the atmosphere. These objects generally fall in unpopulated areas so they are not dangerous.[19]

The occurrence of satellite collisions in space, coupled with the proliferation of defunct satellites that transform into space debris, poses significant threats to Earth and demands urgent attention from the international community. These incidents not only jeopardize the integrity of the space environment but also entail substantial risks to terrestrial ecosystems and human populations. In light of these escalating concerns, it is imperative for international governments to proactively engage in the development and implementation of robust environmental dispute resolution mechanisms. Such mechanisms are essential for mitigating the adverse impacts of space activities and safeguarding both the environment and human well-being on Earth.

Regarding space debris or space debris, this is very worrying because this problem threatens the safety of space as well as the possibility of falling to the surface of the earth. The lower the orbital position of the satellite or space debris, the faster it will fall to the surface of the earth. For example, the fall of the space junk Cosmos 954 owned by the Soviet Union in 1979 made the international community aware to further regulate in international law because it endangers anyone in the world and harms

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Paramita Prabandari, "Indonesia's Air Sovereignty Issues in the Global Era." *Diponegoro Law Review* 4, no. 2 (2019): 181-193.

[19] Alexandra Witze, "The quest to conquer the space junk problem." *Nature* 561, no. 7721 (2018): 24-26. *See also* Gabrielle Hollingsworth, "Space Junk: Why the United Nations Must Step in to Save Access to Space." *Santa Clara Law Review* 53, no. 1 (2013): 239-266.

other countries which can be in the form of environmental damage or human casualties.[20]

The crash of the Soviet Union's Cosmos 954 satellite in the Northwest Territories, Provinces of Alberta and Saskatchewan, Canada caused losses because radioactive properties are very dangerous for damage to the environment and public property around the area.[21] Cosmos 954 garbage weighs about 65 kg and contains about 3,500 radioactive particles. The radiation levels of these particles vary greatly from thousands to millions of X-rays/hour. Some of them have very deadly properties. One not-so-large fraction, 25 mm x 15 mm x 10 mm, has radiation up to 500 x-rays per hour which is enough to kill a human within hours of first contact.

The aforementioned data exclusively accounts for the direct impacts (*acute impacts*) resulting from the descent of Cosmos 954, with Canada yet to address the indirect impacts (*chronic impacts*).[22] For this problem, it is necessary to implement the real principle of prevention of pollution and contamination from space, including by space objects so that environmental sustainability is maintained (as stipulated in Article IX Space Treaty). Unlike the earth which has cleaners and garbage recycling sections, unfortunately in outer space there is no cleaning squad, garbage is left to orbit continuously in space. Although there is an international

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[20] *See* William B. Wirin, "The Sky is Falling: Managing Space Objects." *Proceedings of the Twenty-Seventh Colloquium on the Law of Outer Space, International Institute of Space Law of the International Astronautical Federation,* Lausanne, Switzerland, October 7–13, 1984

[21] *See* Ellen Power, and Arn Keeling. "Cleaning up Cosmos: Satellite Debris, Radioactive Risk, and the Politics of Knowledge in Operation Morning Light." *Northern Review* 48 (2018): 81-109; Joseph A. Burke, "Convention on International Liability for Damage Caused by Space Objects: Definition and Determination of Damages After the Cosmos 954 Incident." *Fordham International Law Journal* 8, no. 2 (1984): 255-285.

[22] *See* W. K. Gummer, et al. *Cosmos 954. The occurence and nature of recovered debris*. No. INFO--0006. Atomic Energy Control Board, 1980; Diego Zannoni, "Disaster management and international space law." *Disaster Management and International Space Law*. (Leiden: Brill Nijhoff, 2019).

law that regulates liability for damage caused by space objects, namely the Convention on International Liability for Damage Caused by Space Objects 1972, efforts are still needed to prevent damage that may be caused by space objects or spacecraft. Due to the increasing population of space debris, it is difficult to find the location of the fall of the garbage, so there is a need for prevention efforts with a mechanism carried out by humans to clean up the space debris. The spacecraft launch country must monitor the vehicle, because only the launch country knows the orbital period of each space object it launches.

The launch nation must constantly monitor the presence of space junk and map it. This effort can then be done by sending a mission, namely by forming a Space Debris Cleaning Agency to collect space junk and crush it into small debris so as to reduce its danger. More important is the cooperation among countries in reducing environmental impacts due to falling space debris, namely by transferring technology and contributing costs from developed countries to developing countries in order to preserve the environment on this Earth.

A. International Mechanisms as a Mirror of Liberalism

Along with the development of space technology and the increasing number of space objects in orbit, the space environment is currently experiencing saturation and this is directly proportional to the increasing amount of space debris in orbit. Space debris is not only a threat to the safety and security of the space environment, but also safety and security on earth and impacts various aspects of life.[23]

As the repercussions of space debris continue to reverberate globally, the matter has evolved into a prominent topic under discussion across various international space forums. Recognizing the urgency and complexity of addressing this challenge, both nations and international organizations have embarked on collaborative endeavors to tackle the issue

[23] Joseph N. Pelton, *Space Debris and Other Threats from Outer Space*. Vol. 331. (New York: Springer, 2013).

collectively. Through concerted dialogues and deliberations, stakeholders seek to devise effective strategies and mechanisms aimed at mitigating the impacts of space debris. This concerted effort underscores the collective commitment of the international community to confront and overcome the challenges posed by space debris, fostering a collaborative approach towards safeguarding the integrity of outer space and Earth's environment.

Space debris, originating from technological progress, has become a collective challenge requiring united action. Nations now realize that addressing this issue in isolation is futile, prompting the need for cooperation and transparent information sharing among countries and stakeholders. This necessity underscores the interdependence among nations and international organizations, emphasizing the shared responsibility for preserving outer space. Institutions like UNCOPUOS and IADC play crucial roles as platforms for collaborative efforts between countries and space agencies in addressing space debris challenges. As a result, the establishment of international mechanisms, encompassing comprehensive regulations for space debris mitigation, signifies a global effort to uphold the integrity of outer space.[24]

Several international mechanisms in handling space debris are realized in the form of guidelines. In the liberal perspective, rationality is an unequivocal universal feature of the individual. Countries and international organizations that are part of the international community realize that space debris is a common problem and the international community essentially has the mindset to act in accordance with reason in overcoming and solving this space debris problem.

Individuals rationally pursue their own interests, but there is a potential alignment of interests between individuals. The rationality of the international community is basically driven by the interests of countries in the use of technology and the space environment to support their national

[24] Benjamin Adams, "Cooperation in space: An international comparison for the benefit of emerging space agencies." *Acta Astronautica* 162 (2019): 409-416. *See also* Daniel Lambach, and Luca Wesel. "Tackling the Space Debris Problem: A Global Commons Perspective." *Proceedings 8th European Conference on Space Debris*. 2021; Eligar Sadeh, "International Space Governance: Challenges for the Global Space Community." *Recent Developments in Space Law: Opportunities & Challenges* (2017): 43-59.

interests. And referring to this, space debris is a threat to the sustainability of space use that can interfere with a country's national interests. So, solving the space debris problem becomes the common interest of the international community in supporting their respective interests.

Based on this, countries and international organizations carry out a series of cooperation, this is realized by discussion of space debris in international forums continuously and the establishment of a series of international mechanisms, which are manifested in the form of Guidelines, which are a set of arrangements that contain guidelines in dealing with space debris which can be used as a reference or basis for countries to be applied in their national mechanisms in efforts to mitigate space debris.

B. Effectiveness of Guidelines

Space debris mitigation guidelines are the result of agreement with countries in handling space debris. An international mechanism established based on common needs and interests. The form of cooperation in solving space debris reflects that liberalism opposes the division between domestic and international areas, this can be seen in the existing guidelines that the problem of space debris and its solution is no longer a problem faced by only a few countries, but all space actors.

The set of arrangements contained in the guidelines advocated by international institutions such as COPUOS, IADC and EU, is a universal arrangement that can be applied by all countries and therefore guidelines are seen as arrangements that transcend national borders and other states and space actors lose some of their independence in handling space debris. And in this case indirectly countries are forced to participate in a more intensive form of cooperation. This is illustrated by the call on countries to report their national mechanisms to UNCOUPUOS.

The existing guidelines are a major step for countries and space actors in working together to mitigate space debris. Measures such as preventing and limiting the formation of more space debris through the design of space vehicles and their operation international institutions have succeeded in calling on countries to play a role in handling space debris. Several reports on national mechanisms are compiled in the

UNCOUPUOS compendium, countries have participated in reporting on their national mechanisms and most countries have made these guidelines as guidelines in their national mechanisms, both in the form of regulations and operational standards.

Conclusion

Human activities in space have led to the creation of a significant amount of debris, mirroring the waste generation observed on Earth. The proliferation of satellites and space missions has contributed to the accumulation of space junk, consisting of defunct satellites and rocket remnants. Since the launch of the first satellite in 1957, space debris has been steadily accumulating, with objects re-entering the Earth's atmosphere and burning up on a daily basis. While these re-entries typically occur in uninhabited areas, the risks associated with collisions between satellites or the transformation of operational satellites into space junk pose grave concerns for international governments. Given the potential environmental and human impacts of such activities, there is a pressing need for robust international mechanisms to address the issue of space debris.

In the realm of international relations, the formulation of guidelines for managing space debris reflects a liberal perspective, wherein the international community recognizes the shared interest in mitigating this common challenge. Cooperation in addressing space debris transcends national boundaries, with international institutions assuming a central role in facilitating collaboration among states and space agencies. By engaging in discussions and crafting solutions together, countries demonstrate a commitment to resolving the space debris issue collectively. This cooperative approach is exemplified by the deliberations held in international forums and the development of universally applicable guidelines agreed upon by all stakeholders.

Among the various international mechanisms established, the Space Debris Mitigation Guidelines of UNCOPUOS and the IADC Space Debris Mitigation Guidelines stand out as dominant frameworks. These guidelines, endorsed by countries worldwide, serve as reference points for both international and national efforts to address space debris. By adhering

to these guidelines, countries and space actors can contribute to the preservation of outer space and mitigate the risks associated with space debris accumulation.

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