SPACE DEBRIS MITIGATION THROUGH DOMESTIC LEGISLATION

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1. INTRODUCTION

Fifty years of space exploration have revolutionized human activity, but they have also left a growing legacy of orbital pollution known as space debris. Space debris encompasses all non-functional, man-made objects orbiting Earth or re-entering its atmosphere, including defunct satellites, fragments from spacecraft, abandoned launch vehicle stages, and remnants from explosions or collisions.[1] The accumulation of this debris, particularly in crucial orbits like Low Earth Orbit (LEO) and Geostationary Orbit (GEO), brings on a significant and increasing threat to the safety and sustainability of space activities. These objects, traveling at hypervelocities, can cause catastrophic damage to operational spacecraft, including vital satellites used for communication, navigation, and research, as well as manned missions like the International Space Station. Events like accidental collisions, such as the 2009 Iridium-Cosmos incident, and intentional anti-satellite (ASAT) tests have amplified the problem to a greater degree than ever seen before creating thousands of new fragments.[2] This process becomes cyclical in nature and we become the instigators of our own impending doom. At one point, there will be so much space debris that the Earth's orbit will be blanketed by space debris. This leads to the Kessler syndrome. It is a theoretical concept wherein the cascade effect of collisions generates more debris, leading to further collisions and so on, rendering such regions of space unusable and making it unfit for future space exploration, defeating the goal of sustainable development as adopted in the Rio conference.

Space debris is defined by the Inter-Agency Space Debris Coordination Committee under

[1] Annie Handmer & Steven Freeland, *The Use of Law to Address Space Debris Mitigation and Remediation: Looking Through a Science and Technology Lens*, 87 J. AIR L. & COM. 375, 375 (2022).
[2] ANISH DEY & JITHIN JAGADANANDAN, *Study on Space Debris Mitigation Under the National Space* Laws, 9 U. BOLOGNA L. REV. 45, 48 (2024) (defining space debris).

its Space Debris Mitigation Guidelines[3], along with the UN's Space Debris Mitigation Guidelines[4], as all man-made fragments and elements thereof in Earth orbit or re-entering the atmosphere that are non-functional. It arises as both the National and International levels. Therefore, there are two questions that arise as to how to address and mitigate space debris from India's perspective.

1. Is the International Regulation on space debris sufficient and comprehensive enough to mitigate adverse effects in India?

2. Is there a need for domestic legislation on space debris for addressing liability, damages, and compensation?

2. ORIGIN OF SPACE DEBRIS

Space debris originates from various human activities in space since the beginning of the space age. Primary sources include inactive or defunct satellites and space crafts which have completed their mission, have run out of fuel or simply not operational anymore, launch vehicle stages which are upper stages of rockets and other components which are ejected during launch operations and during orbit, mission related debris which are objects intentionally or accidentally released during missions, fragmentation debris which has been discussed in the previous heading and other sources such as dust, particulate matter, coolant etc.[5] The sources are not exhaustive, and as technology steadily evolves, the sources of space debris will continue to increase. To combat it, one possible solution is to limit the number of detachable parts, have ejection limits, and to cap the number of moving parts in the spacecraft.

Fragmentation debris is the most serious of these aforementioned types due to the hyper velocity it attains in space, the sheer number of such debris, and the challenges in detecting and predicting the movement of the same. Accidental collisions between objects, such as the notable 2009 collision between the operational Iridium 33 satellite

[3] IADC Space Debris Mitigation Guidelines, IADC-O2-01, Revision 1, Sept., 2007, < ttp://www.iadconline.org/> no. 3.1
[4] UN Space Debris Mitigation Guidelines, Sept. 2007, as annexed to UN doc. A/62/20, Report of the COPUOS o. 1, para. 1.
[5] Stephan Hobe, *Environmental Protection in Outer Space: Where We Stand and What is Needed to Make Progress With Regard to the Problem of Space Debris*, 8 IND. J.L. & TECH. 1, 1 (2012).

and the defunct Cosmos 2251, can shatter both objects, creating thousands of fragments.[6] Intentional destruction, primarily through anti-satellite (ASAT) weapon tests conducted by nations like China, the US, India, and Russia, also generates substantial and long-lasting debris clouds.[7] It is caused by explosions, Collisions, and deterioration due to wear and tear and the harsh space environment.[8] Mandating thorough testing of the body of space crafts, authorizing space-safe paints, having an extensive and vast system for tracking space debris available to all states are essential to combat fragmentation debris and stop its proliferation at the source level.

3. INTERNATIONAL FRAMEWORK

The international framework addressing space debris consists of both binding treaties and non-binding "soft law" instruments, such as guidelines and standards. Currently, there is no single, comprehensive international treaty specifically dedicated to space debris.[9]

Binding Treaties

The foundational framework of international space law comprises five core United Nations treaties adopted between 1967 and 1979. However, these treaties were largely negotiated before space debris became a significant concern and thus do not explicitly regulate or define it. Through interpretation, some provisions can be interpreted to include space debris.

Outer Space Treaty (1967) : Article I guarantees freedom of exploration and use of space for the benefit of all countries in accordance with international law.[10] This implies that space shall be kept free of debris for the purpose of benefit of all the countries. International law here includes various environmental principles such as the sustainable development principle, the polluter pays principle, and the precautionary principle

[6] Handmer & Freeland, *supra* note 1 at 13
[7] Dey and Jagganathan, *Supra note* 2 at 87,92
[8] V. Balakista Reddy, *Problem of Space Debris: Developing Countries Point of View and Proposal of Global Convention*, 4 & 5 INDIAN J. AIR & SPACE L. 1, 12 (2017) (referring to inactive payloads).
[9] V. Balakista Reddy, *Problem of Space Debris: Developing Countries Point of View and Proposal of Global Convention*, 4 & 5 INDIAN J. AIR & SPACE L. 1, 4 (2017)
[10] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, Jan. 27, 1967, 610 U.N.T.S. 205 [hereinafter Outer Space Treaty] Art. I.

adopted at the Stockholm[11] and Rio conferences[12], respectively. The Stockholm Declaration laid foundational concepts integrating environment and development. Principle 2 states that natural resources ought to be safeguarded for present and future generations. Principle 8 requires planning to reconcile development and the environment. Principles 1,3, and 4 of the Rio Declaration put human beings at the centre of sustainable development to ensure that future generations have their needs met. Outer space full of space debris deprives the future generations of their freedom to explore space and hence is unsustainable. This goes against International Law. Article III of the OST mandates space activities to align with International law.[13] Taking no preventive steps and engaging in mitigation amounts to direct violation of Article III. Article IV imposes responsibility upon the states regarding their activities in outer space.[14] Article VII makes the launching state liable for damage caused by its space object.[15] This also serves as the basis for the Liability Convention. Article VIII ensures that the launching state retains jurisdiction over objects launched into space.[16] This raises issues regarding salvage rights and removing debris belonging to another state. Article IX mentions conducting activities in a way that does not lead to harmful contamination of space and cause adverse changes to the space environment.[17] This is the most crucial article in the entirety of the OST, and it has direct implications regarding space debris.

Liability Convention (1972): Article I(d) defines space object to include components, parts, and launch vehicles, which are forms of space debris.[18] Their fragments thereof would also be considered space objects. Article II imposes absolute liability on the launching state for damage caused by its space object on Earth's surface or to aircraft in flight.[19] This means that liability can be imposed when space debris causes damage to objects in space or objects on the surface of the Earth. Article III imposes fault-based

[11] Declaration of the United Nations Conference on the Human Environment, U.N. Doc. A/CONF.48/14/Rev.1, princs. 1–26 (June 16, 1972) [hereinafter Stockholm Declaration].
[12] Rio Declaration on Environment and Development, U.N. Doc. A/CONF.151/26 (Vol. I), Annex I, princs. 1–27 (Aug. 12, 1992) [hereinafter Rio Declaration].
[13] See Outer Space treaty, supra note 10 at Art. III.
[14] Outer Space treaty, supra note 10 at Art. IV.
[15] Outer Space treaty, supra note 10 at Art. VII.
[16] Outer Space treaty, supra note 10 at Art. VIII.
[17] Outer Space treaty, supra note 10 at Art. IX.
[18] Convention on International Liability for Damage Caused by Space Objects, Mar. 29, 1972, 961 U.N.T.S. 187 [hereinafter Liability Convention].
[19] Liability Convention, supra note 18 at Art .II.

liability for damage caused to another state's space object.[20] However, proving causation and fault for debris collision remains challenging due to numerous factors such as the unpredictable nature of space debris, poor tracking technology, lack of forecasting, scientific variables in space, etc.[21]

Other Space Laws: The Registration Convention (1975) requires states to register objects launched into space, providing basic orbital parameters.[22] However, the data required is often insufficient for precise tracking needed for collision avoidance with debris. An amendment has to be made to this convention, or an entirely new convention on space debris should establish an International authority on near-Earth space debris similar to the ICAO (International Civil Aviation Organization) to effectively monitor and keep track of space debris. The ICAO has been proven to be one of the most successful international efforts in history. Therefore, it is practicable for the International Authority on near-Earth space debris to be established. Furthermore, it is only the Near Earth debris that can be taken into account because jurisdiction cannot be exercised by any state in outer space. It is impossible at the moment, as policing and taking action are possible only if persons or technology can be stationed throughout outer space. It is simply impossible with our current technology. Perhaps an amendment to the applicability of the treaty will be added eventually when sufficient technology is developed and stationed. Still, an issue arises as to whether the human population on Earth has jurisdiction of space itself beyond the Karmin line as it would be in contravention of to bar on national appropriation given under the OST.

The Rescue Agreement (1968) facilitates the rescue of astronauts in space and ensures their safe return to their country of origin. It also mandates assistance provided to astronauts in need.[23] This includes assistance in times when space debris affects the safety and well-being of the astronauts. The Moon Agreement (1979) has stronger protection for the moon's environment and topography, but has been regarded as a

[20] Liability Convention, supra note 18 at Art .III.
[21] Joshua Tallis, *Remediating Space Debris: Legal and Technical Barriers*, 9 STRATEGIC STUD. Q. 86, 89 (2015).
[22] Convention on Registration of Objects Launched into Outer Space, Jan. 14, 1975, 1023 U.N.T.S. 15 [hereinafter Registration Convention].
[23] Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, Apr. 22, 1968, 672 U.N.T.S. 119

failed convention due to minimal ratification and almost negligible applicability, as space mining has not commenced yet.[24]

Soft Law

Since treaties and conventions have not specifically addressed space debris, the international community have resorted to non-binding standards and guidelines referred to as soft law. They are internationally recognized best practices that states and operators are encouraged to adopt voluntarily through incentives, domestic policies and MOUs.[25] The IADC space mitigation guidelines, revised in 2007, were developed by the Inter-agency space debris coordination committee to provide technical guidelines focusing on limiting debris release during normal operations, minimizing breakups, post-mission disposal mechanisms, and collision prevention.[26] The COPUOS space debris mitigation guidelines (2007) adopted by the UN Committee on the Peaceful Uses of Outer Space and endorsed by the UN General Assembly put out 7 key measures closely resembling the IADC guidelines regarding; limiting operational debris, minimizing breakups, limiting collision probability, avoiding intentional destruction, minimizing post-mission stored energy, limiting orbital lifetime in LEO, and limiting interference in GEO.[27] The COPUOS Guidelines for the Long-Term Sustainability of Outer Space Activities (LTS Guidelines) (2019) have 21 voluntary guidelines covering numerous aspects of space safety and sustainability, including space debris management. It requires sharing of orbital data, promoting debris monitoring, designing spacecraft for minimal debris generation, addressing uncontrolled re-entry risks, and investigating long-term debris-related issues.[28]

4. NEED FOR DOMESTIC LEGISLATION

While international guidelines exist,[2] effective management largely depends on implementation through national laws and regulations. Since India is a dualist country, international law cannot be applied directly and thus domestic-level policies are

[24] Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, Dec. 5, 1979, 1363 U.N.T.S. 3 [hereinafter Moon Agreement].
[25] Handmer & Freeland, *supra* note 1, at 385.
[26] Inter-Agency Space Debris Coordination Comm. [IADC], IADC Space Debris Mitigation Guidelines, IADC02-01 (Sept. 2007).
[27] COPUOS Guidelines, *supra* note 4, at 2–4.
[28] Handmer & Freeland, *supra* note 1, at 389–90.

necessary to have meaningful change. India is one of the biggest and most prominent players in spacefaring at present and therefore, is also responsible for a significant portion of space debris. Currently, India lacks a single, overarching national space law. Space activities are governed by various policies, guidelines set by the Indian Space Research Organisation (ISRO), and specific regulations under existing acts like the Foreign Trade (Development and Regulation) Act, 1992 for exports[29] A draft Space Activities Bill was introduced in 2017, which included provisions for licensing and mentioned limiting pollution, but it has not yet been enacted and lacks detailed debris mitigation specifics.[30] While ISRO adheres to international guidelines and manages its operations through frameworks like the ISRO System for Safe & Sustainable Space Operations Management (IS4OM), this does not serve as a suitable replacement for a legally binding framework applicable to all national actors, especially the up-andcoming private space industry.[31]

Domestic law on space debris would fulfil international obligations as mentioned in Article VI of the OST about authorization to private entities and state responsibility for continued supervision. It would bring legal certainty for ISRO, Private companies, Academic institutions, and foreign entities working for India's space sector. Codification would improve the safety of space resources of India by avoiding collision and providing for compensation. Insurance mandates would also benefit India in the same way. It would promote responsible behaviour from all state actors involved in space activities. It would incentivize indigenous industry, working in tandem with pre existing policies such as "Make in India"[32]

5. IMPLEMENTATION MECHANISM

The legislation must have clear definitions about activities such as launch, operation, and re-entry. It should also define objects such as satellites, launch vehicles, and components. These two categories of definitions must be inclusive and not exhaustive to allow future technologies to be added to the scope and applicability of this legislation,

[29] Dr. Sanu Rani Paul, *India's Entry into Missile Technology Control Regime: An Introspection*, 4 & 5 INDIAN J. AIR & SPACE L. 157, 165–67 (2017).
[30] Dey & Jagadanandan, *supra* note 2, at 68.
[31] Dey & Jagadanandan, *supra* note 2, at 69–70
[32] Dey & Jagadanandan, *supra* note 3, at 58-60

hereinafter referred to as "The Act". It is also essential to define actors such as ISRO, private companies, foreign entities launching from India, etc. It should mention the foreign entities in the schedule or through the government notification to ensure that the integrity and sovereignty of India are retained, free of foreign intervention. A specific authority on a National level must be established. They should be granted the powers for licensing, making rules, monitoring, inspection, data management, and enforcement. There must be a mandate for licenses or permits to engage in space activities. The application process must be outlined in the act and should be scrutinized due to the sensitive nature of space. It should contain information requirements (including detailed debris mitigation plans), and criteria for assessment and approval/denial.

Debris mitigation standards should be made mandatory. The provisions must mention; Strict limits on debris released during deployment and normal operations, Requirements for spacecraft and launch vehicle design to minimize the risk of accidental explosions, mandatory passivation procedures (venting residual propellants, discharging batteries, etc.) at the end-of-life, he 25-year maximum orbital lifetime rule for objects passing through LEO, Requirements for moving GEO objects to sufficiently high graveyard orbits, Controlled re-entry requirements where feasible, minimizing casualty risk on the ground, Mandate collision risk assessment throughout the mission lifetime and require operational satellites above a certain size/risk threshold to have maneuver capability for avoidance, Require operators to screen conjunction data and take action when necessary and establish extremely stringent conditions and authorization requirements for any activity designed to intentionally create debris.[33] [34] It is imperative to establish a comprehensive national registry of space objects under India's jurisdiction/control, potentially exceeding the basic requirements of the Registration Convention. Adhering to minimum standards alone is not enough to ensure maximum effectiveness and safety. Operators should be mandated to provide accurate, timely orbital data and information on mission status, maneuvers, and anomalies to the national authority/registry. There must be provisions about the domestic allocation of liability for damage caused by space debris originating from activities licensed by India. Adequate third-party liability

[33] U.N. Off. for Outer Space Affs., *Guidelines for the Long-Term Sustainability of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space*, Guideline B.9 (2021).
[34] COPUOS Guidelines, *supra* note 2, Guideline 1; JOHNSON, *supra* note 7, at 6-7

insurance as a condition for licensing and specifying minimum coverage levels based on risk assessment is also required.[35] [36]

6. CHALLENGES

Despite growing international recognition of the threat posed by space debris, efforts towards effective mitigation and regulation face significant challenges across multiple domains such as the legal field, technical field, and political field.

Legal challenges

As mentioned before, the OST and other international conventions lack an explicit definition and mention of space debris. The interpretation of articles to include space debris remains ambiguous and contested. The Liability Convention's framework is difficult to apply due to the immense challenge of identifying the source state of small debris fragments, especially for fault-based liability claims in space.[37] The current guidelines are nonbinding on a dualist country such as India, and they are based on voluntary self-compliance. There is no legal obligation to adopt them, resulting in inconsistent application and enforcement. Due to article VIII of the OST regarding retention of state jurisdiction, space debris clean-up becomes impossible, and such debris would be deemed to be the property of another state, and one state cannot intrude on the property of another state. This is a barrier to ADR – Active Debris Removal. Furthermore, there is no clear international consensus on when a non-functional object legally transitions from a protected space object to debris that could potentially be salvaged or removed by others, nor are there established salvage rights in space.[38] Achieving the political consensus needed to create a new, binding international treaty specifically for space debris has been quite difficult. This is because most states have not carried out a single space mission, and it is not a priority at the moment. There is also not enough activity in space for space debris to be a real threat yet.

[35] Hobe, *Environmental Protection in Outer Space: Where We Stand and What is Needed to Make Progress With Regard to the Problem of Space Debris*, 8 IND. J.L. & TECH. 1, 2 (2012)
[36] KAITLYN JOHNSON, *Space Sustainability and Debris Mitigation*, *in* KEY GOVERNANCE ISSUES IN SPACE 5–6 (Ctr. for Strategic & Int'l Studies 2020)
[37] Outer Space Treaty, *supra* note 10, art. VIII
[38] Tallis, *supra* note 21, at 94.

Technical Challenges

While Space Situational Awareness (SSA) capabilities are improving, debris as small as 1-10 cm could still be lethal to operational satellites. The cost of designing debris resistant spacecraft and also debris-free spacecraft is astronomically high! ADR testing of technology such as nets, harpoons, or robotic arms is extremely expensive, with high mission risks and low effectiveness based on current technology.[39]

Political Challenges

Technologies such as ADR are inherently dual-use objects and can be repurposed as anti-satellite weapons. It will no longer fall under the ambit of International Space Law but rather International Humanitarian Law. It will raise National security concerns and prevent widespread usage of valuable technology such as ADR.[40] Despite acknowledging the problem, securing sustained political will and funding for debris mitigation enforcement and ADR development is difficult, especially when weighed against other national priorities. Remediation efforts often lack clear timelines or assigned agency responsibility within national policies. There is significant international disagreement on who should bear the responsibility and financial burden for cleaning up existing debris. There would be an issue as to which principle would apply (polluter pays or common but differentiated responsibility). concerns about imposing "undue costs" on developing space programs further complicate this issue.[41]

8. KOSMOS CASE

The Kosmos program represents an important part of history regarding space exploration, space debris, and its consequences. Kosmos 954, launched by the Soviet Union in 1977, was a reconnaissance satellite powered by an onboard nuclear reactor containing approximately 50 kilograms of highly enriched uranium. A critical malfunction occurred, preventing the intended safe separation and boosting of the reactor core into a higher disposal orbit at the end of its operational life. As a result, the satellite made an uncontrolled re-entry into the Earth's atmosphere on January 24, 1978.

[39] Ibid.
[40] Handmer & Freeland, *supra* note 1, at 400–01.
[41] JOHNSON, *supra* note 36, at 17.

Traveling north-eastward over western Canada, Kosmos 954 disintegrated, scattering hazardous radioactive debris across a vast area spanning approximately 600 kilometres from Great Slave Lake to Baker Lake in Canada's Northwest Territories.[42]

This case represents the first and only known instance of a state making a formal claim against another state for damage caused by a space object. The crash resulted in a 2year-long clean-up operation named Operation Morning Light. It was a joint effort between Canada and the US. Canada incurred 6 million dollars. The claim was based on the Liability Convention of 1972. After diplomatic negotiations, Canada and the Soviet Union reached a full and final settlement of 3 million Canadian dollars.[43]

On February 10, 2009, the orbital environment witnessed the first accidental hypervelocity collision between two intact satellites, a significant event that occurred at an altitude of approximately 789 kilometers above Siberia. The collision involved an operational U.S. commercial communications satellite, Iridium 33, and a defunct Russian military communications satellite, Kosmos 2251, which had been nonoperational since 1995.[44] The impact generated a substantial amount of long-lasting space debris, initially estimated by NASA to be at least 1,000 pieces larger than 10 centimeters, with the U.S. Space Surveillance Network cataloging over 2,000 large fragments by July 2011. The Russian Federation argued that it had no legal obligation to actively deorbit Kosmos 2251 after its operational life ended and suggested that fault might lie with Iridium LLC for not having maneuvered its operational satellite to avoid the collision. Iridium LLC, on the other hand, reportedly contended that it had no obligation to avoid the collision even if it was aware of the potential for such an event.[45] neither the United States nor Russia pursued a formal legal claim against the other under the 1972 Liability Convention.

Another and a more recent incident is related to Kosmos 2499, a Russian satellite launched in May 2014 with an officially undisclosed purpose, which broke apart in

[42] Lee, Edward G., and D. W. Sproule. "Liability for Damage Caused by Space Debris: The Cosmos 954 Claim." *Canadian Yearbook of international Law/Annuaire canadien de droit international* 26 (1989): 273–279. Web.
[43] Ibid.
[44] Foreign Press, *So What's the Problem With Space Junk*, FOREIGN PRESS – JOURNALISM RESOURCES (Apr. 15, 2025), https://foreignpress.org/journalism-resources/so-whats-the-problem-with-space-junk.
[45] Tereza Pultarova, *ISS Dodges Its 39th Piece of Potentially Hazardous Space Junk; Experts Say It Won't Be the Last*, LIVE SCIENCE (Apr. 16, 2025), https://www.livescience.com/space/space-exploration/iss-dodges-its39th-piece-of-potentially-hazardous-space-junk-experts-say-it-wont-be-the-last.

Earth orbit on January 4, 2023. The breakup was confirmed by the U.S. Space Force's 18th Space Defense Squadron, which reported the generation of at least 85 pieces of trackable debris. This cloud of space junk is orbiting at a high altitude of approximately 1169 kilometres, an altitude at which atmospheric drag is minimal, suggesting that the debris could remain in orbit for a century or more.[46] The breakup of Kosmos 2499 showcases the previously discussed challenges of preventing space debris generation, even from satellites that are no longer operational, and highlights the ongoing lack of transparency surrounding the purpose and capabilities of certain space objects launched by various nations.

9. CONCLUSION

Addressing the escalating challenge of space debris through comprehensive domestic legislation is not merely a technical or legal mandate, but a profound responsibility we owe to ourselves and future generations on the basis of the principle of sustainable development. Recognizing space as a shared human endeavour, the proactive mitigation of orbital debris reflects a commitment to the sustainable exploration and utilization of the cosmos. It reflects our capacity for foresight and our ethical obligation to safeguard this valuable environment, ensuring that the boundless potential of space remains accessible and beneficial to all, rather than becoming a junkyard that limits our aspirations and endangers our future in the cosmos.

[46] Tariq Malik, *Mysterious Russian Satellite Breaks Up in Earth Orbit*, SPACE.COM (Apr. 16, 2025), https://www.space.com/russian-satellite-kosmos-2499-breakup-earth-orbit.