



SPACE DEBRIS AND THE SUSTAINABILITY OF OUTER SPACE: ANALYSING THE ADEQUACY OF THE EXISTING INTERNATIONAL LEGAL FRAMEWORK

Siddhika Dhawan *

ABSTRACT

Within seven decades of the first satellite launch, outer space has moved from an unreachable frontier to a congested and increasingly commercial orbital environment. Alongside roughly 16,000 active satellites, tens of thousands of tracked pieces of debris and well over a hundred million smaller untraceable fragments now circle the Earth¹, threatening crewed and uncrewed missions alike and, in the worst case, risking a self-sustaining cascade of collisions known as the Kessler syndrome.² This paper examines whether the existing international legal framework, anchored in the five United Nations space treaties concluded between 1967 and 1979, is adequate to address the debris problem. It argues that while the treaties supply foundational principles of state responsibility, liability and registration, they were not drafted with debris specifically in mind and leave significant gaps: the absence of a binding legal definition of "space debris", a fault-based and causation-heavy liability regime for damage occurring in outer space, the non-binding character of the 2007 and 2019 United Nations guidelines, and jurisdictional obstacles to active debris removal arising from Article VIII of the Outer Space Treaty. The paper also considers whether general international environmental law, in particular the customary no-harm rule and the precautionary principle, can supplement these gaps through ordinary rules of treaty interpretation, and finds that it can inform but not replace binding reform. Drawing on the treaty texts, United Nations documents, state practice and recent scholarship, the paper concludes that incremental, guideline-based governance has slowed but not solved the debris problem, and it recommends a combination of harder technical standards, a clarified liability and salvage regime, an internationally coordinated debris-

*BA LLB, FIFTH YEAR, GOVERNMENT LAW COLLEGE, MUMBAI.

¹ European Space Agency, ESA's Annual Space Environment Report (Issue 10.0, GEN-DB-LOG-00288-OPS-SD, 1 May 2026) 5, 9-10.

² Donald J Kessler and Burton G Cour-Palais, 'Collision Frequency of Artificial Satellites: The Creation of a Debris Belt' (1978) 83(A6) Journal of Geophysical Research 2637.

removal financing mechanism, and market-based compliance tools, alongside stronger institutional coordination.

Keywords: Space Debris, Outer Space Treaty, Space Sustainability, Liability Convention.

INTRODUCTION

On 4 October 1957, the launch of Sputnik 1 opened the space age; by the close of 2025, humanity had placed tens of thousands of objects into Earth orbit, of which only a fraction remains functional.³ Every launch, every collision and every anti-satellite test leaves behind debris: spent rocket stages, defunct satellites, fragments of paint, bolts and shrapnel travelling at speeds of up to eight kilometres per second. At such velocities, even a centimetre-sized fragment carries the destructive energy of a hand grenade, and a piece the size of a marble can disable an operational satellite outright.

The problem is not merely technical. Outer space is governed by a distinct branch of public international law built around five multilateral treaties concluded between 1967 and 1979, together with a growing body of non-binding guidelines. These instruments were negotiated during the Cold War space race, at a time when the principal concerns were the peaceful use of space, non-appropriation of celestial bodies and superpower liability for accidents, not the slow, cumulative contamination of Earth orbit by debris.⁴ This paper asks whether that framework, designed for a different era, remains adequate to secure the long-term sustainability of outer space against the specific and growing threat of debris.

The paper proceeds in six further parts. Part II sets out the scientific and empirical dimensions of the debris problem. Part III examines the primary treaty framework. Part IV surveys the soft-law instruments and standards that have grown up around the treaties. Part V examines three case studies that illustrate how the framework operates in practice. Part VI analyses the structural adequacy of the framework as a whole, identifying seven gaps. Part VII offers recommendations for reform, before Part VIII concludes.

³ ESA Space Environment Report 2025 (n 1).

⁴ Diego Zannoni, 'Out of Sight, Out of Mind? The Proliferation of Space Debris and International Law' (2022) 35 Leiden Journal of International Law 295, 296-298.

UNDERSTANDING THE PROBLEM: THE SCIENTIFIC AND EMPIRICAL DIMENSIONS OF SPACE DEBRIS

Space debris is generally understood as any human-made object in Earth orbit, or re-entering the atmosphere, that no longer serves a useful function, whether an intact but defunct satellite, a spent upper stage, or fragmentation debris produced by collisions and explosions.⁵ No binding treaty defines the term, a gap discussed further in Part VI (1) below.

Kessler Syndrome: In 1978, NASA scientists Donald Kessler and Burton Cour-Palais theorised that, once the density of objects in low-Earth orbit passes a critical threshold, collisions between objects would generate new debris faster than atmospheric drag and other natural processes could remove it, producing a self-sustaining cascade that could render entire orbital bands unusable for generations.⁶ The theory, now known as the Kessler syndrome, is no longer merely hypothetical. The European Space Agency's 2025 Space Environment Report concludes that, even if all future launches were halted today, the debris population would continue to grow for more than two centuries, because fragmentation now outpaces natural decay.⁷

The Scale of the Problem, in Numbers: As of 31 July 2026, space-surveillance networks regularly track around 46,590 objects in Earth orbit, of which only about 16,000 are functioning satellites.⁸ Statistical models place the true population far higher: an estimated 1.2 million objects between 1cm and 10cm, and over 140 million objects between 1mm and 1cm, none of which can be individually tracked or catalogued with current sensors.⁹ The total mass of objects in orbit now exceeds 17,000 tonnes.¹⁰ More than 660 fragmentation events, explosions, collisions and other anomalous break-ups have occurred since the start of the space age, with

⁵ Committee on the Peaceful Uses of Outer Space, 'Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space' in Report of the Committee on the Peaceful Uses of Outer Space, Fiftieth Session (UN Doc A/62/20, 2007) Annex, paras 118-119; endorsed by UNGA Res 62/217 (22 December 2007) UN Doc A/RES/62/217, paras 26-27.

⁶ Kessler and Cour-Palais (n 2).

⁷ ESA Space Environment Report 2025 (n 1).

⁸ ESA Space Environment Report 2025 (n 1).

⁹ *ibid*; see also ESA Space Debris Office, 'Space Environment Statistics' (Space Debris User Portal, last updated 31 July 2026) <https://sdup.esoc.esa.int/discosweb/statistics/> (recording approximately 46,590 objects regularly tracked in Earth orbit, of which around 16,000 are functioning satellites, and a further approximately 54,000 objects larger than 10cm estimated by the MASTER-8 population model).

¹⁰ ESA Space Environment Report 2025 (n 1).

non-collisional fragmentation, largely explosions of leftover propellant or batteries, now the single largest source of new debris.¹¹

The rapid growth of commercial satellite constellations compounds the problem. Industry estimates put the number of operational satellites, once around 6,500 in 2023, on course to exceed 27,000 by the end of the present decade.¹² Within certain popular low-Earth-orbit altitude bands, the density of active satellites is already of the same order of magnitude as the density of debris, meaning that collision-avoidance manoeuvres, once rare, are becoming a routine part of satellite operations.¹³

Major Debris-Generating Events: Three events illustrate how quickly a single incident can transform the orbital environment. On 11 January 2007, China destroyed its own defunct Fengyun-1C weather satellite in a direct-ascent anti-satellite (ASAT) test, generating upwards of 3,500 trackable fragments and an estimated 35,000 fragments larger than 1cm, the single largest debris-generating event on record.¹⁴ On 10 February 2009, the active Iridium 33 communications satellite collided accidentally with the defunct Russian Cosmos 2251 above Siberia, producing close to 2,300 trackable fragments and demonstrating, for the first time, that an intact collision between two full-sized satellites was not merely a theoretical risk.¹⁵ On 15 November 2021, Russia destroyed its own defunct Cosmos 1408 satellite in a further direct-ascent ASAT test, generating over 1,500 trackable fragments at an altitude close to that of the International Space Station, forcing the station's crew to shelter in their return spacecraft as the debris cloud passed.¹⁶ These three events, taken together, are estimated to account for a substantial share of all trackable debris currently in low-Earth orbit.

¹¹ ESA Space Environment Report 2025 (n 1).

¹² SatNews, 'ClearSpace to Launch the First Active Debris Removal Mission with Arianespace Vega C' (2023) <https://news.satnews.com/2023/05/21/clearspace-to-launch-the-first-active-debris-removal-mission-with-arianespace-vega-c/> (noting more than 34,000 debris objects larger than 10cm and roughly 6,500 operational satellites, with active satellite numbers projected to exceed 27,000 by the end of the decade).

¹³ ESA Space Environment Report 2025 (n 1).

¹⁴ NASA Orbital Debris Program Office, Orbital Debris Quarterly News, vol 26(1) (2022) 1-4 <https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/odqnv26i1.pdf> (the 11 January 2007 Chinese direct-ascent test on the Fengyun-1C satellite produced upward of 3,500 catalogable fragments).

¹⁵ Secure World Foundation, '2009 Iridium-Cosmos Collision Fact Sheet' <https://www.swfound.org/publications-and-reports/2009-iridium-cosmos-collision-fact-sheet> (the 10 February 2009 collision between the active Iridium 33 and the defunct Cosmos 2251 generated close to 2,000-2,300 trackable fragments).

¹⁶ James Murray and others, 'Observations of Small Debris from the Cosmos 1408 Anti-Satellite Test using the HUSIR and Goldstone Radars' (NASA Johnson Space Center, 2022) https://ntrs.nasa.gov/api/citations/20220011989/downloads/Obs%20Small%20Deb%20C1408%20ASAT_AMO_S_final_STRIVES.pdf (the 15 November 2021 Russian direct-ascent test destroying Cosmos 1408 produced upward of 1,500 tracked fragments within weeks).

THE PRIMARY (TREATY) LEGAL FRAMEWORK

International space law rests on five treaties concluded under the auspices of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS). None of them refers to "space debris" by name; their relevance to the debris problem must be extrapolated from broader provisions addressed to "space objects" and to state conduct in outer space generally.¹⁷

The Outer Space Treaty 1967: The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space (the Outer Space Treaty or OST) is the constitutional document of space law, with 118 States parties as of 2025, including every major spacefaring nation.¹⁸ Article I establishes that outer space is free for exploration and use by all states; Article II prohibits national appropriation of outer space or celestial bodies by claim of sovereignty, by means of use or occupation, or by any other means.¹⁹ Two provisions bear most directly on debris. First, Article VI makes states internationally responsible for national activities in outer space, "whether such activities are carried on by governmental agencies or by non-governmental entities", and requires authorisation and continuing supervision of non-governmental activity, the constitutional basis for domestic space legislation and licensing regimes.²⁰ Second, Article VII establishes that a state that launches, procures the launch of, or from whose territory a launch takes place, is internationally liable for damage caused by the resulting space object, whether on Earth, in air space, or in outer space, a principle later elaborated by the Liability Convention.²¹

Two further provisions are central to the debris debate, precisely because of their silence. Article VIII provides that a state on whose registry an object is carried "retains jurisdiction and control" over that object while in outer space, and that ownership of objects launched into outer space "is not affected by their presence in outer space".²² Because the Treaty does not distinguish a functioning satellite and an inert, uncontrollable piece of debris, jurisdiction and ownership persist indefinitely, even over an object that has not communicated with the ground

¹⁷ Zannoni (n 4).

¹⁸ United Nations Office for Outer Space Affairs, 'Status of International Agreements Relating to Activities in Outer Space' (UNOOSA) <https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties.html> accessed 29 August 2026; as of 2025 the Outer Space Treaty has 118 States parties, including every major spacefaring State, with a further 20 signatories that have not ratified.

¹⁹ Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (adopted 19 December 1966, opened for signature 27 January 1967, entered into force 10 October 1967) 610 UNTS 205 ('Outer Space Treaty' or 'OST') arts I-III.

²⁰ OST (n 1) art VI.

²¹ OST (n 1) art VII.

²² OST (n 1) art VIII.

for decades. As Part VI (3) explains, this has become one of the principal legal obstacles to active debris removal. Article IX requires states to conduct activities "with due regard to the corresponding interests of all other States Parties" and to avoid "harmful contamination" of outer space, together with consultation where a state has reason to believe that a planned activity would cause potentially harmful interference.²³ The provision is widely regarded as too general, and too dependent on self-assessment by the acting state, to generate concrete debris-mitigation obligations on its own.²⁴

The Liability Convention 1972: The Convention on International Liability for Damage Caused by Space Objects elaborates Article VII of the Outer Space Treaty. It distinguishes two regimes. Under Article II, a launching state bears absolute liability for damage caused by its space object on the surface of the Earth or to an aircraft in flight, liability that does not depend on proof of fault.²⁵ Under Article III, however, where damage is caused elsewhere than on the surface of the Earth, that is, in outer space itself, liability attaches only where the damage is due to the fault of the launching state or of persons for whom it is responsible.²⁶ Where two or more states jointly launch a space object, they are jointly and severally liable.²⁷ Articles IX to XX establish a claims procedure through diplomatic channels and, failing settlement within a year, through a Claims Commission, whose decisions are binding only where the parties have so agreed; otherwise they are recommendations that the parties are merely to consider in good faith.²⁸

In practice, the Convention has been formally invoked only once. On 24 January 1978, the Soviet nuclear-powered reconnaissance satellite Cosmos 954 re-entered the atmosphere uncontrollably and scattered radioactive debris across some 124,000 square kilometres of the Canadian Northwest Territories.²⁹ Canada, invoking the Liability Convention, billed the Soviet Union C\$6,041,174.70 for the cost of the joint clean-up operation; after protracted negotiation, the two states settled the matter bilaterally for C\$3,000,000, without any formal decision of a

²³ OST (n 1) art IX.

²⁴ Zannoni (n 4).

²⁵ Convention on International Liability for Damage Caused by Space Objects (adopted 29 November 1971, opened for signature 29 March 1972, entered into force 1 September 1972) 961 UNTS 187 ('Liability Convention') art II.

²⁶ Liability Convention (n 8) art III.

²⁷ Liability Convention (n 8) art IV.

²⁸ Liability Convention (n 8) arts IX-XX.

²⁹ Alexander F Cohen, 'Cosmos 954 and the International Law of Satellite Accidents' (1984) 10 Yale Journal of International Law 78, 78-91.

Claims Commission and without any admission of legal liability by the Soviet Union.³⁰ Cosmos 954 remains, more than four decades later, the Convention's only tested precedent, and even that precedent was resolved diplomatically rather than through the Convention's own machinery, a point developed further in Part VI (2) below.

The Registration Convention 1975: The Convention on Registration of Objects Launched into Outer Space requires the launching state to maintain a national registry and to furnish the United Nations Secretary-General with specified information, including basic orbital parameters and the general function of the space object, as soon as practicable after launch.³¹ Registration is intended to identify which state is responsible for a given object for jurisdiction, liability and, potentially, salvage. In practice, registration is frequently late, incomplete or simply omitted, particularly for small satellites launched by commercial operators as secondary payloads; a 2007 General Assembly resolution recommended, but did not require, improved practice.³² Nor does the Convention require separate registration of debris created after a launch, so that once an object fragments, the resulting pieces are, for registry purposes, effectively unaccounted for.

The Rescue Agreement 1968 and the Moon Agreement 1979: The remaining two treaties add comparatively little to the debris framework. The Agreement on the Rescue of Astronauts concerns the return of astronauts and of space objects that land outside the territory of the launching state; it has limited direct relevance to orbital debris.³³ The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies extends the non-appropriation principle to the Moon and other celestial bodies, but has attracted only around 18 States parties, none of which is a major launching state, and in any event says little about debris in Earth orbit, where the overwhelming majority of the problem is concentrated.³⁴

³⁰ Protocol between the Government of Canada and the Government of the Union of Soviet Socialist Republics: Settlement of Claim for Damage Caused by 'Cosmos 954' (signed 2 April 1981), reproduced in UNOOSA, 'Bilateral and Multilateral Agreements' https://www.unoosa.org/oosa/en/ourwork/spacelaw/nationalspacelaw/bi-multi-lateral-agreements/can_ussr_001.html accessed 29 August 2026 (settlement of C\$3,000,000, against a Canadian claim of C\$6,041,174.70, in full and final settlement, without any admission of liability).

³¹ Convention on Registration of Objects Launched into Outer Space (adopted 12 November 1974, opened for signature 14 January 1975, entered into force 15 September 1976) 1023 UNTS 15 ('Registration Convention') arts II, IV.

³² UNGA Res 62/101 'Recommendations on Enhancing the Practice of States and International Intergovernmental Organizations in Registering Space Objects' (17 December 2007) UN Doc A/RES/62/101.

³³ Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (adopted 19 December 1967, opened for signature 22 April 1968, entered into force 3 December 1968) 672 UNTS 119.

³⁴ Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (adopted 5 December 1979, opened for signature 18 December 1979, entered into force 11 July 1984) 1363 UNTS 3 ('Moon

THE SOFT-LAW SUPPLEMENT: GUIDELINES, STANDARDS AND VOLUNTARY COMMITMENTS

Because renegotiating the 1967-1979 treaties has proved politically unrealistic, states have instead built an extensive but non-binding architecture of technical guidelines and voluntary commitments around them.

The IADC and UN COPUOS Mitigation Guidelines: The Inter-Agency Space Debris Coordination Committee (IADC), a technical forum of national space agencies, issued the first comprehensive set of debris mitigation guidelines in 2002, revised in 2007 and updated again in 2025.³⁵ Building on the IADC's technical work, COPUOS adopted its own Space Debris Mitigation Guidelines in 2007, endorsed without a vote by the General Assembly later that year.³⁶ The seven guidelines address, among other things, limiting debris released during normal operations, minimising the potential for on-orbit break-ups, limiting the probability of accidental collision, avoiding intentional destruction, minimising post-mission break-ups from stored energy, and limiting the post-mission lifetime of spacecraft and orbital stages in low-Earth orbit, commonly operationalised as a 25-year de-orbit rule.³⁷ Crucially, the guidelines are expressly voluntary; they create no binding obligation and no enforcement mechanism.

Technical standards: ISO 24113 and ITU regulation: The mitigation guidelines have since been translated into a detailed engineering standard, ISO 24113, first published in 2011 and updated in 2023, which sets specific technical requirements for limiting debris release, passivating stored energy and planning post-mission disposal.³⁸ The International Telecommunication Union separately regulates the geostationary orbit through Recommendation ITU-R S.1003-2, which calls on operators to manoeuvre satellites to a graveyard orbit at end of life to protect the limited geostationary arc.³⁹ Like the IADC and COPUOS guidelines, these are technical standards and recommendations rather than binding

Agreement'); UNOOSA (n 7); as of 2025 the Moon Agreement has only around 18 States parties, none of which is presently a major launching State.

³⁵ Inter-Agency Space Debris Coordination Committee, IADC Space Debris Mitigation Guidelines (IADC-02-01, first issued 2002, revised 2007, updated 2025); summarised in UNOOSA, 'Space Debris Mitigation Standards Compendium' <https://www.unoosa.org/oosa/en/ourwork/topics/space-debris/compendium.html>.

³⁶ COPUOS Space Debris Mitigation Guidelines 2007 (n 5).

³⁷ *ibid*, Guidelines 1-7.

³⁸ International Organization for Standardization, ISO 24113:2023 Space Systems - Space Debris Mitigation Requirements, discussed in Orbital Radar, 'Space Debris Mitigation Guidelines - UN, FCC 5-Year Rule, IADC & ISO 24113' (2026) <https://orbitalradar.com/regulatory/space-debris-mitigation-guidelines>.

³⁹ International Telecommunication Union, Recommendation ITU-R S.1003-2, 'Environmental Protection of the Geostationary-Satellite Orbit' (adopted 2010).

treaty obligations, though national regulators increasingly incorporate them into domestic licensing conditions.

The 2019 Long-term Sustainability Guidelines: After nearly a decade of negotiation beginning in 2010, COPUOS adopted, in June 2019, a preamble and 21 consensus, voluntary Guidelines for the Long-term Sustainability of Outer Space Activities, organised around four themes: national policy and regulatory frameworks; safety of space operations; international cooperation and capacity-building; and scientific and technical research.⁴⁰ The length of the negotiation, eight years to secure consensus on a non-binding text, is itself instructive: it illustrates how difficult it has proved for the international community to agree even on voluntary standards, let alone binding obligations, in this field.⁴¹

The Artemis Accords 2020: Outside the COPUOS process, the United States has led a parallel initiative, the Artemis Accords, first signed by eight states in October 2020 and by more than 65 states by 2026.⁴² Section 12 commits signatories to plan for the mitigation of orbital debris, including the timely and efficient disposal of spacecraft at the end of their mission, and to limit, so far as practicable, the generation of new, long-lived debris.⁴³ Because the Accords are a series of bilateral political commitments rather than a multilateral treaty, and because China and Russia are not parties, commentators note that section 12 raises the bar for signatories inter se without creating any universal obligation, and that its proliferation outside the COPUOS framework risks fragmenting, rather than unifying, global debris governance.⁴⁴

National and Regional Measures: States and regional agencies have also begun to harden these voluntary standards at the domestic level. In 2022, the United States Federal Communications Commission adopted a rule requiring FCC-licensed low-Earth-orbit satellites to de-orbit within five years of the end of mission, a significant tightening of the traditional 25-

⁴⁰ Committee on the Peaceful Uses of Outer Space, 'Guidelines for the Long-term Sustainability of Outer Space Activities' in Report of the Committee on the Peaceful Uses of Outer Space, Sixty-Second Session (UN Doc A/74/20, 2019) Annex II.

⁴¹ United Nations Information Service, 'Guidelines for the Long-term Sustainability of Outer Space Activities of the Committee on Peaceful Uses of Outer Space Adopted' (21 June 2019) UNIS/OS/518 <https://unis.unvienna.org/unis/en/pressrels/2019/unisos518.html>.

⁴² NASA, 'Artemis Accords' <https://www.nasa.gov/artemis-accords/> accessed 29 August 2026; as of 2026 more than 65 States have signed the Accords.

⁴³ Artemis Accords: Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids for Peaceful Purposes (signed 13 October 2020) s 12.

⁴⁴ cf Julia Selman Ayetey, 'The Artemis Accords: Evolution or Revolution in International Space Law?' (2022) 71 International and Comparative Law Quarterly 249, 258-260 (noting that, absent binding international law on space debris, section 12 of the Accords represents a significant elevation of signatories' obligations, albeit only among themselves).

year guideline, albeit binding only on FCC licensees.⁴⁵ That rule has since been enforced: in October 2023, the FCC fined DISH Operating LLC USD 150,000 and secured an admission of liability after the company left its defunct EchoStar-7 satellite roughly 122km short of its required disposal altitude, the Commission's first space-debris enforcement action and, on present evidence, the first such penalty imposed by any national regulator anywhere.⁴⁶ The European Space Agency has adopted its own "Zero Debris Approach", and reports that around 90% of its low-Earth-orbit rocket bodies now comply with the 25-year rule and around 80% with its newer 5-year internal standard, though these figures largely reflect the practice of established spacefaring actors operating under domestic licensing regimes, rather than the sector as a whole.⁴⁷ The rate is markedly lower for large payloads specifically: of large low-Earth-orbit satellites above 1,000kg reaching end of life since 2020, only around 57% are in orbits that will clear within twenty-five years, illustrating that aggregate compliance figures can conceal weak performance among precisely the largest and most dangerous objects.⁴⁸

The most significant recent development is regional rather than purely national. On 25 June 2025, the European Commission proposed the EU Space Act, a regulation that would harmonise authorisation, safety and debris-mitigation requirements across the Union, applying to EU operators and to third-country operators serving the EU market alike, the first binding, multi-state instrument of its kind anywhere in the world, though it remains under negotiation in the European Parliament and Council and has not yet entered into force.⁴⁹ India has taken a comparable domestic step: in April 2024 the Indian Space Research Organisation announced its Debris Free Space Missions initiative, committing all Indian governmental and non-governmental space actors to debris-free missions by 2030.⁵⁰ Technology is beginning to keep

⁴⁵ Federal Communications Commission, 'Mitigation of Orbital Debris in the New Space Age' (Report and Order, FCC 22-74, adopted 8 September 2022), reducing the post-mission disposal window for low-Earth-orbit satellites from 25 years to 5 years for FCC-licensed operators; discussed in Orbital Radar (n 14).

⁴⁶ Federal Communications Commission, In the Matter of DISH Operating LLC, Order and Consent Decree, DA 23-888 (2 October 2023) 38 FCC Rcd 8524, the first space-debris enforcement action taken by the Commission: DISH admitted liability for failing to move its defunct EchoStar-7 satellite to the disposal altitude required by its licence, and agreed to a compliance plan and a civil penalty of USD 150,000.

⁴⁷ European Space Agency, 'Zero Debris Approach' referenced in ESA Space Environment Report 2025 (n 20); see also the ESA Space Debris Office statement that roughly 90% of low-Earth-orbit rocket bodies now comply with the 25-year rule and roughly 80% with ESA's newer 5-year standard.

⁴⁸ ESA Space Environment Report 2025 (n 1).

⁴⁹ European Commission, Proposal for a Regulation of the European Parliament and of the Council on the safety, resilience and sustainability of space activities in the Union (EU Space Act) COM(2025) 335 final (25 June 2025), arts 58-73, requiring launch and spacecraft operators to mitigate the generation of debris and imposing common environmental-impact assessment and end-of-life disposal obligations across the Union, with third-country operators serving the EU market also covered.

⁵⁰ Indian Space Research Organisation, 'India's Intent on Debris-Free Space Missions - Explained' (ISRO, April 2024) https://www.isro.gov.in/Debris_Free_Space_Missions.html committing all Indian governmental and non-

pace with these commitments. Japan's ADRAS-J mission, launched by Astroscale under a JAXA contract in February 2024, achieved the first close-proximity rendezvous and inspection of an uncooperative piece of debris, though the actual capture and removal of that same object awaits a follow-on mission not expected before 2027, underlining that operational active debris removal remains a demonstrated capability rather than a routine one.⁵¹

CASE STUDIES ILLUSTRATING THE FRAMEWORK IN OPERATION

Cosmos 954 (1978): The Limits of the Liability Convention: The Cosmos 954 incident, discussed above, remains the clearest illustration of the Liability Convention's practical limitations. Although the Convention supplied Canada with a formal legal basis for its claim, the matter was in fact resolved through direct diplomatic negotiation rather than through the Convention's Claims Commission procedure, and the settlement figure (C\$3,000,000) was roughly half of what Canada had claimed, with no admission of fault.⁵² Nearly fifty years later, and despite thousands of re-entries and close approaches in the interim, no other claim has ever been pursued through the Convention's formal machinery, a pattern most plausibly explained by the practical difficulty of proving fault and causation for damage occurring in outer space, discussed further in Part VI (2) below.

The 2009 Iridium-Cosmos Collision: The Absence of a Space Traffic Management Duty: The accidental collision between Iridium 33 and Cosmos 2251 in February 2009 exposed a different gap: neither the Outer Space Treaty nor the Liability Convention imposes any binding obligation on operators to share tracking data, to coordinate collision-avoidance manoeuvres, or to notify other operators of close approaches.⁵³ Both objects had been separately tracked by space-surveillance networks for years, yet no warning was issued, and no manoeuvre was attempted before the collision, because no legal duty required one. The incident prompted improved voluntary data-sharing arrangements, but two decades on, a binding, universal space traffic management regime remains absent from international law.

governmental space actors to debris-free missions by 2030, overseen by ISRO's System for Safe and Sustainable Space Operations Management.

⁵¹ Astroscale Japan Inc, 'Astroscale's ADRAS-J Mission Completes Operations, Begins Deorbit' (Press Release, 25 March 2026) <https://www.astroscale.com/en/news/astrocales-adras-j-mission-completes-operations-begins-deorbit>. Launched in February 2024 under Phase I of JAXA's Commercial Removal of Debris Demonstration programme, ADRAS-J achieved the first close-proximity rendezvous and inspection of an uncooperative piece of debris, a defunct H-2A rocket upper stage; actual capture and removal of the same object is deferred to the follow-on ADRAS-J2 mission, planned for launch in Japan's 2027 fiscal year.

⁵² Cosmos 954 Settlement Protocol (n 30).

⁵³ Secure World Foundation, 2009 Iridium-Cosmos Collision Fact Sheet (n 15).

The 2007 and 2021 ASAT Tests: The Unenforceability of Guideline 4: The Chinese test of 2007 and the Russian test of 2021 each involved the deliberate, kinetic destruction of a state's own satellite, precisely the conduct that COPUOS Guideline 4 recommends states avoid.⁵⁴ Because the guideline is voluntary, neither test breached any binding international obligation. The international community's principal response has been political rather than legal: in December 2022, the General Assembly adopted, by a recorded vote of 155 in favour to 9 against with 9 abstentions, a resolution calling on states to commit not to conduct further destructive direct-ascent ASAT tests.⁵⁵ China and Russia voted against the resolution; a number of other states, including India, abstained.⁵⁶ As a General Assembly resolution, it remains a statement of political commitment rather than a binding rule of international law, and by 2023 only around three dozen states had converted the resolution into a formal national pledge, illustrating the gap that persists between broad rhetorical support and binding legal commitment in this field.

ADEQUACY ANALYSIS: STRUCTURAL GAPS IN THE FRAMEWORK

Drawing together Parts III to V, seven structural gaps can be identified in the existing international legal framework as applied to space debris.

The Definitional Lacuna: No treaty defines "space debris". The Outer Space Treaty, Liability Convention and Registration Convention all speak only of "space objects", a term that on its face covers a functioning satellite and an inert fragment alike, but whose application to debris has never been authoritatively settled.⁵⁷ This ambiguity has real consequences: if a fragment is a "space object" for Article VIII of the Outer Space Treaty, it remains permanently owned and subject to the jurisdiction of the launching state, however small or however long defunct, which in turn complicates any attempt by a third party to remove it without consent (see (3) below). Commentators have consistently identified the absence of an agreed definition, whether within the treaties themselves or through a dedicated protocol, as a foundational obstacle to more effective regulation.⁵⁸ A workable definition already exists outside the treaty system: the

⁵⁴ NASA ODPO, Orbital Debris Quarterly News (n 14).

⁵⁵ UNGA Res 77/41 'Destructive Direct-Ascent Anti-Satellite Missile Testing' (7 December 2022) UN Doc A/RES/77/41, adopted by a recorded vote of 155 in favour to 9 against, with 9 abstentions.

⁵⁶ UN Press Release, 'Approving 21 Drafts, First Committee Asks General Assembly to Halt Destructive Direct-Ascent Anti-Satellite Missile Tests in Outer Space' (1 November 2022) UN Doc GA/DIS/3703.

⁵⁷ Zannoni (n 4).

⁵⁸ Fawaz Haroun, Shalom Ajibade, Philip Oladimeji and John Kennedy Igbozurike, 'Toward the Sustainability of Outer Space: Addressing the Issue of Space Debris' (2021) 9(1) New Space 63, 64-67.

International Law Association's 1994 Instrument on the Protection of the Environment from Damage Caused by Space Debris defines debris as any man-made object in outer space, other than an active or otherwise useful object, and extends "damage" to cover significant adverse modification of the environment itself, not merely loss of life or property.⁵⁹ That text has never been taken up by states, but it demonstrates that the definitional gap is one of political will rather than technical difficulty.

Fault-Based Liability for Damage in Outer Space: Article III of the Liability Convention conditions liability for damage occurring in outer space on proof of fault, a standard that is difficult to satisfy given the practical realities of the orbital environment.⁶⁰ Of the estimated 1.2 million debris objects larger than 1cm, only around 46,000-54,000 are individually tracked and catalogued at all;⁶¹ the remainder cannot be traced to a particular launching state, let alone shown to have caused damage through that state's fault. Even where an object can be identified, establishing that a particular collision was attributable to fault, rather than to the ordinary, unavoidable risks of operating in a congested orbital environment, presents a formidable evidentiary burden. It is telling that, notwithstanding thousands of tracked close approaches and several confirmed collisions since 1972, no claim under Article III has ever been formally adjudicated.

The Ownership Problem and Obstacles to Active Debris Removal: Article VIII of the Outer Space Treaty provides that ownership of a space object is unaffected by its presence in orbit, and that the state of registry retains jurisdiction and control over it indefinitely.⁶² Because no procedure exists for a state to relinquish, or be deemed to have abandoned, ownership of a defunct object, a third party wishing to conduct active debris removal (ADR) must first secure the consent of the launching state, even where that object has been silent and uncontrolled for decades. This is not a merely theoretical difficulty: when the European Space Agency contracted with the Swiss start-up ClearSpace for the first dedicated ADR mission, ClearSpace-1, it selected as the target a piece of ESA's own debris (part of a Vespa payload adapter left in orbit since 2013), precisely because removing ESA's own object avoided the consent and

⁵⁹ International Law Association, International Instrument on the Protection of the Environment from Damage Caused by Space Debris (adopted at the 66th Conference, Buenos Aires, 1994) arts 1(c), 1(f), proposing a definition of space debris as man-made objects in outer space, other than active or otherwise useful objects, and extending the concept of 'damage' to include significant adverse modification of the environment.

⁶⁰ Liability Convention art III (n 26).

⁶¹ ESA Space Debris User Portal statistics (n 9).

⁶² OST art VIII (n 22).

liability complications that would arise from removing another state's debris.⁶³ The episode illustrates, in miniature, how Article VIII, designed to protect states' legitimate interests in their functioning space assets, now operates as a structural barrier to cleaning up the very debris those assets have left behind.

The Non-Binding, Voluntary Character of the Mitigation Guidelines: As Part IV showed, the entire technical apparatus for debris mitigation- IADC guidelines, the 2007 COPUOS guidelines, ISO 24113 and the 2019 Long-term Sustainability Guidelines- is voluntary. Compliance data, where it exists, is largely self-reported by established spacefaring actors operating under domestic licensing regimes; there is no independent verification mechanism, and no consequence for non-compliance beyond reputational cost.⁶⁴ For new and emerging space actors operating outside such domestic frameworks, the guidelines carry less practical force correspondingly.⁶⁵

Registration Gaps and the Challenge of Mega-Constellations: The Registration Convention's requirements are frequently honoured in the breach, particularly for the small satellites now launched in bulk by commercial mega-constellation operators; the 2007 General Assembly recommendations on improved registration practice remain, like the mitigation guidelines, non-binding.⁶⁶ With active satellite numbers projected to more than quadruple by the end of the decade, the volume of objects requiring accurate, timely registration and tracking is set to grow far faster than the institutional capacity currently available to record it.⁶⁷

The Absence of Institutional Enforcement and Compulsory Dispute Settlement: COPUOS operates by consensus, and its guidelines are, by design, recommendations rather than binding decisions. The Liability Convention's Claims Commission, the one quasi-judicial mechanism the framework provides, issues binding decisions only where the parties concerned have specifically agreed to be bound; otherwise, its findings are recommendations to be considered in good faith.⁶⁸ No compulsory international jurisdiction exists over debris-related disputes,

⁶³ European Space Agency, 'ESA Purchases World-First Debris Removal Mission from Start-up' (2020) https://www.esa.int/Space_Safety/ESA_purchases_world-first_debris_removal_mission_from_start-up.

⁶⁴ ESA Zero Debris Approach (n 47).

⁶⁵ Jacqueline H Smith, Minoo Rathnasabapathy and Danielle Wood, 'The Political and Legal Landscape of Space Debris Mitigation in Emerging Space Nations' (2024) *Journal of Space Safety Engineering* <https://doi.org/10.1016/j.jsse.2024.08.009>.

⁶⁶ UNGA Res 62/101 (n 32).

⁶⁷ SatNews (n 12).

⁶⁸ Liability Convention (n 8) art XIX (2), under which a decision of the Claims Commission is final and binding only if the parties have so agreed; otherwise, it is a recommendation which the parties consider in good faith.

and, as Cosmos 954 shows, states that do pursue claims have in practice preferred bilateral diplomatic settlement to the Convention's own procedure.⁶⁹

The Absence of a Binding Space Traffic Management Regime: Finally, as the Iridium-Cosmos collision illustrated, no binding international instrument requires operators to share conjunction (close-approach) data, to coordinate collision-avoidance manoeuvres, or to submit to any centralised space traffic management authority.⁷⁰ Coordination currently rests on a patchwork of voluntary bilateral and commercial data-sharing arrangements that, while valuable, fall well short of a comprehensive, binding regime capable of managing an orbital population now doubling within a decade.⁷¹

The Limited Gap-Filling Capacity of General International Law: A further question is whether general international law, applied through ordinary rules of treaty interpretation, can narrow the seven gaps identified above without any new instrument at all. Article 31(3)(c) of the Vienna Convention on the Law of Treaties requires a treaty to be interpreted taking into account "any relevant rules of international law applicable in the relations between the parties".⁷² On this view, Article IX's otherwise open-textured references to "due regard" and "harmful contamination" should be read together with the customary no-harm rule, first articulated in the Trail Smelter arbitration⁷³ and echoed in Corfu Channel's recognition of every state's obligation not to knowingly allow its territory to be used for acts contrary to the rights of other states,⁷⁴ and in the Lac Lanoux tribunal's insistence that a state undertaking works capable of affecting a shared resource must give genuine consideration to the interests of others.⁷⁵ The rule was framed in its modern, general form by the International Court of Justice in its advisory opinion on the Legality of the Threat or Use of Nuclear Weapons,⁷⁶ elaborated as an obligation of due diligence requiring a state to use "all the means at its disposal" in Pulp Mills on the River Uruguay,⁷⁷ and extended, in Certain Activities Carried Out by Nicaragua in the Border Area, into a freestanding duty to conduct an environmental impact assessment

⁶⁹ Cosmos 954 Settlement Protocol (n 30).

⁷⁰ Secure World Foundation, 2009 Iridium-Cosmos Collision Fact Sheet (n 15).

⁷¹ Abid Murtaza, Syed Jahanzeb Hussain Pirzada, Tongge Xu and Jianwei Liu, 'Orbital Debris Threat for Space Sustainability and Way Forward (Review Article)' (2020) 8 IEEE Access 61000, 61001-61010 <https://doi.org/10.1109/access.2020.2979505>.

⁷² Vienna Convention on the Law of Treaties (adopted 23 May 1969, entered into force 27 January 1980) 1155 UNTS 331, art 31(3)(c).

⁷³ Trail Smelter Arbitration (United States v Canada) (1938 and 1941) 3 RIAA 1905.

⁷⁴ Corfu Channel (United Kingdom v Albania) (Merits) [1949] ICJ Rep 4, 22.

⁷⁵ Lac Lanoux Arbitration (France v Spain) (1957) 12 RIAA 281, 307.

⁷⁶ Legality of the Threat or Use of Nuclear Weapons (Advisory Opinion) [1996] ICJ Rep 226, para 29.

⁷⁷ Pulp Mills on the River Uruguay (Argentina v Uruguay) (Judgment) [2010] ICJ Rep 14, paras 101, 197.

wherever an activity risks significant transboundary harm.⁷⁸ The International Court had earlier held, in *Gabčíkovo-Nagymaros*, that new norms of environmental law must be taken into account even when interpreting older treaties silent on the environment,⁷⁹ a proposition of obvious relevance to a 1967 treaty being asked to govern a twenty-first-century debris problem it never anticipated.

These strands are reinforced by the Rio Declaration's antecedent, the 1972 Stockholm Declaration,⁸⁰ and by the precautionary principle in Principle 15 of the Rio Declaration itself, which the International Tribunal for the Law of the Sea has treated as an integral part of the general duty of due diligence and which, on this reading, would support proactive debris mitigation even in advance of conclusive proof that a given activity will cause harm.⁸¹ The Tribunal made the same point directly in its advisory opinion on the *Responsibilities and Obligations of States with respect to Activities in the Area*.⁸² The secondary rules needed to operationalise a breach of any of these primary obligations are supplied by the International Law Commission's Articles on Responsibility of States for Internationally Wrongful Acts, which govern attribution, breach and the consequences of an internationally wrongful act.⁸³ Most significantly, the International Court of Justice's advisory opinion of 23 July 2025 on the *Obligations of States in respect of Climate Change* confirmed that the customary duty to prevent significant environmental harm, together with the associated duty of due diligence, is not confined to the climate regime but forms part of general international law applicable wherever a state's activities risk significant transboundary harm, a holding with direct, if not yet tested, application to orbital debris.⁸⁴

⁷⁸ *Certain Activities Carried Out by Nicaragua in the Border Area (Costa Rica v Nicaragua)* (Judgment) [2015] ICJ Rep 665, paras 104, 153, 162 (requiring environmental impact assessment wherever there is a risk of significant transboundary harm).

⁷⁹ *Gabčíkovo-Nagymaros Project (Hungary/Slovakia)* (Judgment) [1997] ICJ Rep 7, paras 53, 140.

⁸⁰ Declaration of the United Nations Conference on the Human Environment (Stockholm Declaration) (16 June 1972) UN Doc A/CONF.48/14/Rev.1, Principle 21.

⁸¹ Rio Declaration on Environment and Development (14 June 1992) UN Doc A/CONF.151/26 (vol I), Principles 2 and 15.

⁸² *Responsibilities and Obligations of States with respect to Activities in the Area* (Advisory Opinion) [2011] ITLOS Reports 10, para 131.

⁸³ International Law Commission, Articles on Responsibility of States for Internationally Wrongful Acts, annexed to UNGA Res 56/83 (12 December 2001) UN Doc A/RES/56/83, arts 4-11 (attribution), 12 (breach), 30-31 (cessation and reparation).

⁸⁴ *Obligations of States in respect of Climate Change* (Advisory Opinion) [2025] ICJ Rep (23 July 2025), holding that the customary duty to prevent significant harm to the environment, together with the associated duty of due diligence, is not confined to the climate regime but forms part of general international law binding on all States in all domains where their activities risk causing significant transboundary harm.

This interpretive route has genuine value, and the recommendations in Part VII draw on it. But it cannot substitute for the reforms proposed there. The customary status of the polluter-pays principle in particular remains contested outside the specific treaty regimes, chiefly regional and domestic environmental law, where it has been codified, and none of these general or customary principles brings with it any dispute-settlement mechanism specific to outer space. Proving a breach of the no-harm rule in a debris-in-orbit context still confronts the same evidentiary and jurisdictional obstacles identified in sections (2) and (6) above: general international law can inform how Article IX is read, but it cannot by itself supply the binding technical standards, tracking capacity or liability clarity that the treaty framework presently lacks.

TOWARDS REFORM: RECOMMENDATIONS

Renegotiating the Outer Space Treaty itself is neither politically realistic nor, on balance, necessary; its foundational principles of freedom of use, non-appropriation and state responsibility remain sound. What is missing is the intermediate layer of binding, debris-specific rules that could be built without disturbing that foundation, together with complementary market-based tools that can accelerate compliance ahead of any binding instrument. Eight reforms follow from the gaps identified in Part VI.

First, a treaty-based definition of "space debris", distinct from "space object", would resolve the definitional lacuna identified in Part VI (1) and provide the conceptual foundation for every other reform proposed here.⁸⁵

Second, the core technical content of the 2007 and 2019 guidelines, limiting debris release, passivating stored energy and de-orbiting within a defined period, could be converted into binding obligations through a dedicated protocol to the Outer Space Treaty, on the model of environmental protocols such as the Montreal Protocol, rather than by reopening the Treaty itself.⁸⁶

Third, a clarified consent or "presumed abandonment" mechanism is needed to resolve the Article VIII problem identified in Part VI (3): for example, a rebuttable presumption that a

⁸⁵ Huma Parveen and Rajesh Kumar Verma, 'Orbital Debris Mitigation: Perspective from Environmental Law' (2024) ShodhKosh: Journal of Visual and Performing Arts <https://doi.org/10.29121/shodhkosh.v5.i6.2024.4491>.

⁸⁶ Rada Popova and Volker Schaus, 'The Legal Framework for Space Debris Remediation as a Tool for Sustainability in Outer Space' (2018) 5(2) Aerospace 55, 55-60 <https://doi.org/10.3390/aerospace5020055>.

registered state has consented to removal of an object that has been uncontrolled and non-functional for a specified period, subject to prior notification and an opportunity to object.⁸⁷

Fourth, registration practice should be strengthened and extended to non-governmental mega-constellation operators, with real-time reporting integrated into the United Nations register, so that the framework can keep pace with the scale of commercial launch activity described in Part II (2).⁸⁸

Fifth, a binding space traffic coordination mechanism, plausibly developed jointly by COPUOS and the International Telecommunication Union, should mandate the sharing of conjunction data and establish minimum standards for collision-avoidance coordination, addressing the gap illustrated by the Iridium-Cosmos collision.⁸⁹

Sixth, the 2022 General Assembly resolution on destructive ASAT testing should be developed into a binding instrument, closing the gap between the broad political support the resolution attracted and the absence of any binding legal consequence for states that continue such testing.⁹⁰

Seventh, financing remains a binding constraint on remediation even once consent and liability rules are clarified. Sheer, Fatima, Farooqui and Kasuri have proposed an independent international space regime, coupled with a Global Debris Removal Fund financed by a per-launch orbital user fee, to coordinate space traffic and subsidise active-debris-removal missions targeting the legacy debris that no individual operator has an incentive to remove.⁹¹

Eighth, alongside binding legal reform, market-based tools can accelerate compliance ahead of it: the Space Sustainability Rating, developed by a consortium including the World Economic Forum, the European Space Agency and MIT, scores missions on debris-mitigation behaviour and lets insurers, licensors and customers price a mission's sustainability directly.⁹² The economic case for such measures is not speculative: a 2024 NASA cost-benefit study found

⁸⁷ Haroun and others (n 58).

⁸⁸ UNGA Res 62/101 (n 32).

⁸⁹ Murtaza and others (n 71).

⁹⁰ UNGA Res 77/41 (n 55).

⁹¹ Abbas Sheer, Sidra Fatima, Mohammad Owais Farooqui and Muhammad Ramzan Kasuri, 'A Panacea to Address the Legal, Administrative and Economic Aspects of Space Debris' (2023) *Advances in Space Research* <https://doi.org/10.1016/j.asr.2023.02.023>.

⁹² Space Sustainability Rating, 'Promoting Sustainable Behavior of Space Actors' (eSpace - EPFL Space Center) <https://spacesustainabilityrating.org/> accessed; developed by a consortium of the World Economic Forum, the European Space Agency, MIT, the University of Texas at Austin and BryceTech, and now administered by eSpace at EPFL.

that accelerating post-mission disposal produces benefits on the order of twenty to several hundred times the associated costs, chiefly through reduced collision-avoidance manoeuvring and fewer destroyed satellites.⁹³

None of these reforms is without difficulty. A binding mitigation protocol would need to accommodate the legitimate interests of new and developing spacefaring states, several of which have argued that stringent mitigation obligations, calibrated to the practice of established actors, risk entrenching the advantage of states that reached orbit first.⁹⁴ A presumed-abandonment mechanism would need careful drafting to avoid becoming a licence for unilateral interference with another state's functioning assets under the guise of debris removal, and any Global Debris Removal Fund would need a governance structure robust enough to survive the same geopolitical divisions that have stalled binding treaty reform. These are, however, problems of institutional design rather than reasons to abandon reform altogether; incremental hardening of the existing soft-law architecture, guideline by guideline, offers a more realistic path than wholesale treaty renegotiation.⁹⁵

CONCLUSION

The international legal framework governing outer space was not designed with space debris in mind, and it shows. The five United Nations treaties supply durable, foundational principles, freedom of use, non-appropriation, state responsibility and liability- that remain broadly fit for purpose as a constitutional framework for space activity in general. But when tested specifically against the debris problem, as Parts III to VI of this paper have shown, the framework reveals a consistent pattern: broad, general obligations (Article IX's "due regard"), a liability regime that is difficult to invoke in practice (Article III's fault standard), an ownership rule that obstructs remediation (Article VIII), and a decades-long reliance on non-binding guidelines in place of binding rules. The 2007 and 2019 guidelines, the Artemis Accords' orbital debris commitments, and the European Union's proposed Space Act represent genuine, if partial, progress, and missions such as ClearSpace-1 and ADRAS-J show that the

⁹³ Jericho Locke and Thomas J Colvin, Cost and Benefit Analysis of Mitigating, Tracking, and Remediating Orbital Debris (NASA Office of Technology, Policy, and Strategy, Report No 20240003484, 2024), finding that accelerated post-mission disposal produces benefits estimated at 20 to 750 times the associated costs, with net benefits over a 30-year horizon rising toward the upper end of that range as the disposal window is shortened.

⁹⁴ Walter Leal Filho, Ismaila Rimi Abubakar, Julian D Hunt and Maria Alzira Pimenta Dinis, 'Managing Space Debris: Risks, Mitigation Measures, and Sustainability Challenges' (2025) Sustainable Futures <https://doi.org/10.1016/j.sft.2025.100849>.

⁹⁵ Vishakha Gupta, 'Critique of the International Law on Protection of the Outer Space Environment' (2016) 14 *Astropolitics* 20, 22-30.

technical building blocks of debris removal are now within reach, even where full removal capability is not yet operational. But technical capability without a correspondingly robust legal framework for consent, liability and coordination will not, on its own, secure the long-term sustainability of outer space. The most realistic path forward lies not in reopening the 1967-1979 treaties, but in the incremental hardening of the soft-law architecture built around them: a binding definition of debris, binding mitigation and traffic-management obligations, and a workable consent mechanism for active removal. Absent such reform, the growth trajectories set out in Part II suggest that orbital congestion, and the risk of a self-sustaining Kessler cascade, will continue to outpace the law meant to prevent it.