
Active Debris Removal: Assessing the Future Governance of an Emerging Technology

Chandaphan Suwijak* & P. J. Blount**

The proliferation of human activities in outer space has fostered technological progress while creating a serious challenge: space debris. This paper examines the legal complexities of active debris removal (ADR) as a means to reduce collision risks and ensure the long-term sustainability of space operations. ADR is now technologically feasible, but its implementation faces legal, technical, and economic hurdles. Current international law, notably the Outer Space Treaty and the Liability Convention, lacks explicit provisions on ADR responsibilities and liabilities, complicating cooperation and cost sharing. The absence of a universally accepted definition of space debris further hinders regulatory clarity and ownership issues. To address these challenges, the paper evaluates potential governance futures and proposes establishing a new international legal regime under the UN Committee on the Peaceful Uses of Outer Space. Modeled on institutions including the International Civil Aviation Organization, such a regime would clarify liability, set standards, and strengthen cooperation for sustainable space use.

Keywords

Space Debris, Active Debris Removal (ADR), International Space Law, Liability and Responsibility, Space Sustainability

* Lecturer in Law at the School of Law, Mae Fah Luang University. LL.B. (Mae Fah Luang U.), LL.M. (Chulalongkorn), Ph.D. (Beijing Institute of Technology). The author may be contacted at suwijak.cha@mfu.ac.th / Address: School of Law, Mae Fah Luang University, 333 Moo 1, Thasud Subdistrict, Mueang District, Chiang Rai 57100, Thailand.

** Assistant Professor of Space Law at Durham University. Ph.D./M.S. in Global Affairs (Rutgers U.), LL.M. (King's College London), J.D. (U. Mississippi), B.A./A.B.J. (U. Georgia). The author may be contacted at: percy.blount@durham.ac.uk / Address: Durham University Law School, Palatine Centre, Stockton Rd, Durham DH1 3LE UK.

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I. Introduction

In October 2000, Space Shuttle “Discovery” was completing the mission STS-92 to the International Space Station when it suffered the largest recorded impact of debris on a Space Shuttle windshield. A paint chip impacted the windshield, creating a “crater 10 mm diameter by 1.9 mm deep.”¹ Although this was a relatively small impact, capably mitigated by the shuttle’s outer pane of fused silica glass,² it is a chilling reminder of the power with which space debris moves. One can only imagine the momentary panic that an astronaut would experience if they happened to be admiring the view out the window at the moment of impact. Debris an order of magnitude larger could have catastrophic and deadly consequences.

It is a drama of human spaceflight that makes this topic compelling, but space debris is actually a threat to the entire orbital environment around Earth and a challenge for all operators. While human spaceflight takes place in a heightened risk-mitigation environment, not all operators can employ such mechanisms, meaning that destructive impacts on robotic missions are much more probable. The rapid expansion of human activities in outer space has ushered in an era of unprecedented technological advancement and scientific exploration, but it has also led to more opportunities for interference and conflict among space actors.

Satellites now facilitate crucial terrestrial functions, ranging from global communications and weather monitoring to navigation and scientific research. However, this flourishing space domain has inadvertently spawned a lesser-known yet increasingly critical challenge: space debris. The proliferation of debris not only endangers operational satellites, but also escalates the risk of collisions, generating further debris in a potentially catastrophic chain reaction known as Kessler syndrome.³ This phenomenon, if realized, could render vital orbits unusable for generations, thereby impeding future space activities and scientific endeavors. In response to this growing menace, the idea of active

1 J. Hyde et al., *A History of Meteoroid and Orbital Debris Impacts on the Space Shuttle*, in 3RD EUR. CONF. SPACE DEBRIS 2 (2001).

2 Karen Edelstein, *Orbital Impacts and the Space Shuttle Windshield*, 2483 SPACE ENVTL LEGAL & SAFETY ISSUES 1-2 (1995), <https://web.archive.org/web/20180721093749/https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19950019959.pdf>.

3 Julia Hudson, KESSYM: A Stochastic Orbital Debris Model for Evaluation of Kessler Syndrome Risks and Mitigations, (preprints) Authorea 1 (2022), <https://www.authorea.com/users/553563/articles/609031-kessym-a-stochastic-orbital-debris-model-for-evaluation-of-kessler-syndrome-risks-and-mitigations>.

debris removal (ADR) has been developing as a forward-thinking approach to reducing the dangers caused by space debris, which ensure the continued viability of outer space operations.⁴ ADR involves the deliberate removal of defunct satellites and debris from orbit to reduce collision risks and preserve the long-term sustainability of space activities. While technological advancements have made ADR feasible, its implementation raises complex legal, technical, and economic challenges that necessitate comprehensive international cooperation and regulatory frameworks.

This article will explore the proliferation of space debris as a pressing threat to space sustainability and examines the evolving landscape of ADR technologies and strategies. Furthermore, it delves into the legal considerations surrounding ADR, highlighting international legal frameworks and policy initiatives that aim to address this critical issue. By analyzing these dimensions, this research aims to contribute to a deeper understanding of the complexities associated with space debris mitigation and the imperative for concerted global action to ensure the future viability of outer space activities. This paper is composed of five parts including Introduction and Conclusion. Part II examines the growing problem of space debris and the development of active debris removal (ADR) technologies as a response. Part III analyzes the major obstacles to ADR, focusing on legal uncertainties, geopolitical tensions, and economic limitations. Part IV explores possible futures for governing ADR, evaluating models ranging from clear legal structures to contractual approaches and the continuation of the status quo. Part V concludes by highlighting the trade-offs among these options and offering recommendations to balance innovation, security, and sustainability in ensuring the long-term viability of space operations.

II. Space Debris and Active Debris Removal

The technical aspects of the problems addressed in this article are twofold. First, the proliferation of debris in the orbital environment must be understood as a technical problem in terms of mitigation and avoidance. Second, as a response to the problem, states and commercial companies have begun developing ADR, a

4 J. Liou, *Active Debris Removal-A Grand Engineering Challenge for the Twenty-First Century*, NASA Technical Reports Server (2011), at 1, <https://ntrs.nasa.gov/api/citations/20110011986/downloads/20110011986.pdf>.

technology that can remove debris from space.

A. Space Debris

Since the launch of Sputnik I in October 1957, marking humanity's initial venture into space, there has been a steady increase in the number of nonfunctional objects in Earth's outer atmosphere and beyond.⁵ The quantity of space debris orbiting Earth is rapidly increasing. Currently, space surveillance systems monitor around 35,000 objects, of which roughly 9100 are operational satellites and the remaining 26,000 are debris fragments larger than 10 centimeters.⁶ Nevertheless, it has been estimated that there are over 1 million pieces of space debris exceeding 1 cm in size which is sufficient to inflict severe damage.⁷ Over time, what was once an empty orbital realm is now becoming a repository for discarded objects. Ultimately, the proliferation of space debris threatens to restrict our future utilization of space.⁸

The term "orbital debris" refers to the accumulation of human-made objects in Earth orbit, especially low Earth orbit (LEO), that no longer serve any useful purpose.⁹ This debris is not visible from Earth, as it exists beyond the clouds in the realm of LEO, forming an extensive orbital junkyard. LEO is inundated with millions of pieces of space debris predominantly generated by human activity. These include fragments of spacecraft, minuscule paint flecks from spacecraft surfaces, rocket components, nonfunctional satellites, and debris resulting from in-orbit explosions. These objects travel at velocities of up to approximately 29,000 kilometers per hour, which is nearly seven times the speed of a bullet.¹⁰ The high velocity and substantial volume of debris present significant safety risks to current and future space-based services, exploratory missions, and operations, posing potential hazards to people and property in space as well as on Earth.¹¹ The development of LEO into an orbital graveyard can be attributed to various

5 Donald Kessler & Burton Cour-Palais, *Collision Frequency of Artificial Satellites: The Creation of a Debris Belt*, 83(A6) J. GEOPHYS. RES. SPACE PHYS. 2637 (1978).

6 Erica Marchand, *ESA Reports on Growing Space Debris and Mitigation Efforts*, SPACE DAILY (May 29, 2024), https://www.spacedaily.com/reports/ESA_Reports_on_Growing_Space_Debris_and_Mitigation_Efforts_999.html.

7 The European Space Agency (ESA), *ESA Space Environment Report 2024* (July 19, 2024), https://www.esa.int/Space_Safety/Space_Debris/ESA_Space_Environment_Report_2024.

8 J. Liou & N. Johnson, *Risks in Space from Orbiting Debris*, 340(5759) SCI. 311 (2006).

9 NASA, *Orbital Debris Management & Risk Mitigation*, at ¶1.1, https://www.nasa.gov/wp-content/uploads/2018/12/692076main_orbital_debris_management_and_risk_mitigation.pdf.

10 NASA, *Space Debris*, <https://www.nasa.gov/headquarters/library/find/bibliographies/space-debris>.

11 ESA, *Space Debris: Assessing the Risk* (Mar. 21, 2005), https://www.esa.int/Enabling_Support/Operations/Space_debris_assessing_the_risk.

unintentional and intentional events.

Unintentional incidents come in a variety of forms. In 2013, for instance, there was a collision between Ecuador's first and only satellite, Pegasus, and fragments from a Soviet rocket's fuel tank over the Indian Ocean.¹² The uncontrolled re-entries of NASA's Upper Atmosphere Research Satellite and Germany's ROSAT X-ray telescope in 2011 underscore the increasing issue of space debris posing risks to both Earth and crucial space assets.¹³ On February 10, 2009, the first incident of two intact spacecraft colliding took place over Siberia, involving the US communications satellite Iridium 33 and the decommissioned Russian satellite Cosmos 2251. This collision resulted in the dispersal of two debris clouds across a substantial area of LEO.¹⁴

While many accidental collisions, known as conjunctions, have occurred in space, the collision between the Iridium and Cosmos satellites was notable as the first involving two intact satellites, one of which was operational. This incident heightened public awareness of space debris more than any previous collision and received considerable media coverage.¹⁵ It also made clear how difficult the debris issue is, since the conjunction had not been predicted by the modeling of the Joint Space Operations Center (JSpOC), the US Air Force center that, at the time, distributed conjunction warnings to operators.¹⁶ Additionally, the recent spate of antisatellite (ASAT) capability demonstrations has had a negative impact on the space environment. In particular, China's deliberate destruction of its Fengyun-1C weather satellite in 2007 contributed significantly to cataloged fragmentation debris.¹⁷

Currently, the European Space Agency (ESA) is considering ADR for two old, uncontrolled satellites, ERS and Envisat, which have been drifting in LEO due to

12 *Ecuador Pegasus Satellite Fears Over Space Debris Crash*, BBC NEWS (May 24, 2013), <https://www.bbc.com/news/world-latin-america-22635671>.

13 Tim Robinson, *Space Debris: The Legal Issues*, Royal Aeronautical Society (Jan. 3, 2014), <https://www.aerosociety.com/news/space-debris-the-legal-issues>.

14 Brian Weeden, 2009 Iridium-Cosmos Collision Fact Sheet (Nov. 10, 2010), <https://www.scribd.com/document/98094281/2009-Iridium-cosmos-Collision-Factsheet>.

15 Robinson, *supra* note 13.

16 John Wagner, *Beware the situation: how JSpOC tracks space debris*, 1(1) ROOM: SPACE J. ASGRADIA (online) (2014), https://room.eu.com/article/Beware_the_situation_how_JSpOC_tracks_space_debris. JSpOC was moved from the Air Force into US Space Force when it was established. These functions are now carried out by Space Forces Combined Space Operations Center. *See also* US Strategic Command, Fact Sheet: Combined Space Operations Center/ 614th Air Operations Center (2018), https://www.stratcom.mil/Portals/8/Documents/CSpOC_Factsheet_2018.pdf.

17 Leonard David, *China's Anti-Satellite Test: Worrisome Debris Cloud Circles Earth*, SPACE.COM (Nov. 17, 2021), <https://www.space.com/3415-china-anti-satellite-test-worrisome-debris-cloud-circles-earth.html>.

major failures. However, there is an absence of international legal frameworks mandating the cleanup of debris in LEO.¹⁸ The removal of space debris from LEO poses significant challenges due to the enormous quantity of debris, which amounts to nearly 9300 tons.¹⁹ The financial and technical demands of mitigating this issue are substantial, underscoring the need for comprehensive international cooperation and innovative solutions to address the growing problem of space debris.

B. Active Debris Removal

ADR is broadly defined as “an on-orbit service consisting of removing space debris into a graveyard orbit or to an earth return trajectory.”²⁰ The outer space environment is distinct in that the natural decomposition of debris occurs far more slowly than the decay of pollutants in other environments.²¹ The existing mitigation guidelines, which aim to limit the creation of new debris through operational and technical standards, appear to be insufficient to ensure environmental sustainability in outer space.²² Based on current research, collisions between existing objects will cause the LEO population to grow, even if no new satellites are launched in the near future.²³

ADR can come in a variety of forms, but at its most basic it involves the close approach of the ADR craft with a debris object and some sort of manipulation of that debris to remove it from its current orbit for safe disposal.

This is most often understood as proximity and rendezvous operations. Both the close approach and the manipulation of the debris object create risk that must be adequately addressed. The close proximity and rendezvous of the two objects could lead to a potential conjunction between the two objects and result in a debris creation event that could impact other space actors. Further, the capability of manipulation creates both risks of accidents as well as a capability for intentional interference with other operations. The technology creates not only significant

18 Numa Isnard, *Active Debris Removal: Mitigating Legal Barriers for Promising Technologies, Comparisons & Proposals*, in 8TH EUR. CONF. SPACE DEBRIS PROC. 1 (2021).

19 New Space Economy, *The Growing Threat of Space Debris: Challenges and Potential Solutions*, <https://newspaceconomy.ca/2024/04/15/the-growing-threat-of-space-debris-challenges-and-potential-solutions>.

20 Philippe Clerc, *French Law Approach Around the Topic “Legal Implications/Aspects of Active Debris Removal (ADR)”*, in SPACE SECURITY AND LEGAL ASPECTS OF ACTIVE DEBRIS REMOVAL 179-87 (Annette Froehlich ed., 2019).

21 Jack Beard, *Soft Law’s Failure on the Horizon: The International Code of Conduct for Outer Space Activities*, 38(2) U. PA. J. INT’L L. 339-40 (2016).

22 Melissa Force, *Active Space Debris Removal: When Consent Is Not an Option*, 29(3) AIR & SPACE L. 2 (2016).

23 Jinyuan Su, *Active Debris Removal: Potential Legal Barriers and Possible Ways Forward*, 9(2) J. E. ASIA & INT’L L. 405 (2016).

opportunities for cleaning up the space environment, but also a number of risks that will require a governance framework of some sort to address.

Such issues as ensuring that debris moves to a safe disposal orbit and that reentry into Earth's atmosphere does not pose risks remain among the most severe challenges for ADR technologies. Even though ADR exists, the operational procedures for these tasks are still in the early stages.²⁴ Debris removal on a small scale will not be enough to significantly lower the frequency of catastrophic collisions and future increases in fragments in LEO. In order to make LEO more safely, instead, large-scale debris removal is required, since statistical calculations show that a subsequent catastrophic collision will release as many fragments as the Iridium-Cosmos collision breakdown combined.²⁵ Collisions of this scale occur every 12 years, on average.²⁶

Concerning the removal of large debris objects in LEO, it is critical to recall that only larger objects (i.e., objects greater than 10 cm) are tracked, although satellites in LEO are susceptible to significant damage by objects larger than 1 cm. Additionally, oversized debris items may be incapable of avoiding collisions with other large debris objects, resulting in massive amounts of new debris.²⁷ Many proposals are being developed, especially in technology areas, to remove the largest and most harmful pieces of debris from space.²⁸ In March 2021, for example, End-of-Life Services (ELSA-d), a demonstration mission operated by Astroscale to test an idea for cleaning up space debris, was launched from the Baikonur Cosmodrome in Kazakhstan.²⁹ The mission attempted to demonstrate technology that could be used to capture space debris in the future.³⁰ In Canada, McDonald Dettwiler and Associates Ltd. has also attempted to develop autonomous robotic capabilities. As the essentials for carrying out such a mission are presently intended to be accessible, an object in orbit can be caught and

24 Committee on the Peaceful Uses of Outer Space, *Active Debris Removal-An Essential Mechanism for Ensuring the Safety and Sustainability of Outer Space*, UNOOSA Doc. A/AC.105/C.1/2012/CRP.16 (Jan. 27, 2012), at 23, https://www.unoosa.org/pdf/limited/c1/AC105_C1_2012_CRP16E.pdf.

25 Luciano Anselmo & Carmen Pardini, *Analysis of the Consequences in Low Earth Orbit of the Collision between Cosmos 2251 and Iridium 33*, ISTI-CNR (2009), at 1-2, https://www.issfd.org/ISSFD_2009/CollisionRiskI/Pardini.pdf.

26 *Id.* at 25.

27 *Id.* at 24.

28 T. Martin et al., *Active Debris Removal Mission Design in Low Earth Orbit*, 4 *PROGRESS PROPULSION PHYSICS* 1 (2013).

29 Astroscale, *Astroscale Celebrates Successful Launch of ELSA-d* (Mar. 23, 2021), <https://www.astroscale.com/en/news/astroscale-celebrates-successful-launch-of-elsa-d>.

30 ESA, *End-of-Life Service by Astroscale Demonstrator (ELSA-d) Satellite* (Dec. 13, 2018), https://www.esa.int/ESA_Multimedia/Images/2018/12/End-of-Life_Service_by_Astroscale_demonstrator_ELSA-d_satellite.

berthed automatically, then either transported to a graveyard orbit or deorbited using existing robotics.³¹

In light of improvements in the ADR technologies, the following critical questions must be addressed at the initiation of any ADR planning process: (1) What is the most crucial aspect of ADR?; (2) What are the short- and long-term mission objectives?; (3) What objects should be removed first?; (4) What are the benefits to the environment?; and (5) How will activities be carried out?³² The answers to these questions will serve to establish high-level requirements, stimulate the necessary technological development, and lead the implementation of ADR activities in their various forms and circumstances. Therefore, ADR can be more efficient when the following principles are applied for the selection of removal targets:³³

- The target debris should be of a high mass, since it has the most significant environmental impact in the event of a collision;
- It should have a high probability of colliding; for example, the debris should be located in heavily populated areas and have a large cross-sectional area; and
- It should be at a high altitude, where the orbital lifetime of the resulting fragments is long.

While ADR, as a technology, could have benefits for the space environment, it is important to understand that the core capability that enables ADR is valuable for other reasons. Most ADR projects focus on some sort of approach-and-rendezvous operation with the target debris. Such an operation would have significant military applications for a state intending to develop the capability to interfere with another state's space objects.³⁴ ADR is a dual-use technology, both of which can have a significant impact on the space environment.

31 *Id.*

32 J. Liou, *Active Debris Removal and the Challenges for Environment Remediation* (2012), at 2, <https://ntrs.nasa.gov/api/citations/20120013266/downloads/20120013266.pdf>.

33 ESA, *Active Debris Removal*, https://www.esa.int/Safety_Security/Space_Debris/Active_debris_removal.

34 P. Blount, *On-Orbit Servicing and Active Debris Removal: Legal Aspects*, in *PROMOTING PRODUCTIVE COOPERATION BETWEEN SPACE LAWYERS AND ENGINEERS* 179-82 (Anja Peculjic & Matteo Tugnoli eds., 2019).

III. Obstacles

A. Legal Issues in Establishing an ADR Regime

While it is evident that the proposed ADR methods require additional advancement to be technologically practicable and commercially viable, several legal issues can be foreseen. ADR technologies are not specifically contemplated in the international space law regime, but there are nevertheless a few provisions that are applicable to such activities. This section will sketch these provisions out, but it must be understood that these are for the most part unresolved legal issues that result from the complexity of contemporary space operations and the lack of any real interpretive practice connecting the text of the law to evolving technology.

First, the legal status of space debris is somewhat undefined. No existing space law mechanism specifically defines what constitutes “space debris.” This infuses ambiguity into which space objects should be considered space debris and therefore need to be removed from orbit.³⁵ In 1999, a term was used in a Technical Report on Space Debris (1999) by the Scientific and Technical Subcommittee (STSC)³⁶ of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS). This report defined space debris as “all man-made objects, including their fragments and elements thereof, in Earth’s orbit or reentering the atmosphere, that are non-functional.”³⁷ Although this is not a legal definition, it is evident that nonfunctional and non-maneuverable space objects could endanger functional space objects.³⁸ Nevertheless, no international consensus has been yet adopted on the legal definition, so that there remains significant uncertainty regarding what should be removed, how it should be removed, and by whom space debris ought to be cleared from outer space. The status of debris is a complicated question mainly due to the concept of a space object into which debris potentially fits. The term “space object” has never been clearly defined in space law. Pursuant to Article I of the Liability Convention, space objects are defined as including the “component parts of a space object as

³⁵ Su, *supra* note 23.

³⁶ UN, Technical Report of the Scientific and Technical Subcommittee on Space Debris, U.N. Doc. A/AC.105/720 (1999), https://www.unoosa.org/pdf/reports/ac105/AC105_720E.pdf.

³⁷ *Id.* at 5. See also ESA, What is Space Debris, https://www.esa.int/Space_Safety/Clean_Space/What_is_space_debris.

³⁸ Su, *supra* note 23.

well as its launch vehicle and parts thereof.”³⁹ If space debris is a space object, then there is significant complexity in understanding who has the proper nexus to authorize its removal.

Second the question may arise of what actor can authorize the removal of an object. Although there will be certainly instances when such an actor can be clearly identified. The cooperative multinational nature of space operations may result in significant difficulties in finding a single actor with this power. The Outer Space Treaty adopts a complex system of accountability that identifies a number of types of states that have a nexus with a given object. First, to the extent that the space debris is connected to a space activity, the “appropriate state” under Article VI of the Outer Space Treaty 1967 (OST) may be responsible for the debris. Article VI requires the appropriate state to bear international responsibility for the space activities of both their governmental and non-governmental actors. This responsibility is mitigated through the obligation of the state to authorize and supervise space activities. Next, Article VII of the Outer Space Treaty identifies the states having liability for a space object as the launching states. These states “launch[es] or procures the launching of an object into outer space [...] and each State Party from whose territory or facility an object is launched.”⁴⁰ Liability is connected to the launching states despite the type of mission that is being carried, that is, whether the mission governmental or nongovernmental. Unlike Article VI, Article VII does not incorporate mechanisms to mitigate this liability, though the Liability Convention allows launching states to apportion liability amongst themselves through bilateral agreements. Finally, Article VIII OST states that the state of registry “shall maintain jurisdiction and control” and that ownership of a space object is not impacted by its presence in outer space. This article can be read as either a grant of jurisdiction or an obligation to maintain jurisdiction and control. This does not come with the burden of either responsibility or liability, but it does result in a clear nexus between a space object and the state that placed it in its national registry. It also though adds another layer by acknowledging that in addition to states with a nexus, there can be an owner of the space object who may be subject to the authorization and continuing supervision laid down in Article VI.

The network of actors that could have a potential nexus with a space object or piece of debris adds complexity when identifying which actor has the right to grant prior consent for the removal of debris. Even if it were to be accepted

39 Liability Convention art. 1.

40 OST art. VII.

that only the launching state can remove its own defunct space objects,⁴¹ for instance, there are potentially multiple states for any given space object. Unlike salvage law, in which a maritime legal principle asserts that anyone recovering another's property at sea merits a reward proportional to the property's value, in the context of outer space, this principle is not directly applicable, since salvaged satellites often hold value similar to museum artifacts. However, legally defining space debris could enable salvors to claim removal in the global interest without the owner's permission. This approach proves beneficial in cases involving unidentified debris or disputed ownership.⁴²

Next, and connected to this issue of who has the right to authorize the removal of an object, is the question of responsibility and liability. Accountability for such activities will be significant issue if these activities result in harm or damage to other actors. The Outer Space Treaty creates connections between states an object ensuring that there is accountability for space activities in order to better protect third parties. This means though that if one actor authorizes the removal of debris it could impinge upon the accountability of another state. If the appropriate state (Art.VI) authorizes the removal of an object, there could be implications for the launching state(s) especially if there is an accident during the operation. So, if an actor removes the debris of a third party, then the launching state(s) may want to protect themselves by requiring that the removing agency bear full responsibility for the removal.⁴³ Such indemnity agreements are allowed by the Liability Convention and serve as a key tool for allocating risk. It should be noted that this type of agreement might not shield a state from absolute liability for damage to the surface of Earth.⁴⁴

To address these issues, ADR operations will most likely be wrapped in a complex arrangement of bilateral international agreements and contracts among the various parties connected to an operation. Central to this web of public and private law are the notions of responsibility and liability and who bears them at what point in an operation. Since ADR technology involves approach and rendezvous operations, it presents major risks that all parties will need to mitigate. The higher potential for a collision that creates more debris and impacts the activities of other actors will be, the more governmental and non-governmental actors will want to ensure that there is sufficient clarity around the

41 JOSEPH PELTON, *NEW SOLUTIONS FOR THE SPACE DEBRIS PROBLEM* 36 (2015).

42 Ewan Wright, *Legal Aspects Relating to Satellite Constellations*, in *LEGAL ASPECTS AROUND SATELLITE CONSTELLATIONS* 36 (Annette Froehlich ed., 2019).

43 Paul Larsen, *Space Traffic Management-The Bin Cheng Model*, 44(2) J. SPACE L. 489 (2020).

44 Liability Convention art. II.

issue of the allocation of exposure through risk to third parties. It is presumed that cross waivers, which are commonly used in the space context, will be used to manage risks internally to the consortium of actors.⁴⁵

B. Geopolitical Issues

As noted above, ADR technologies have significant security implications which will impact the development of any legal regime intended to regulate these activities. Even if these technologies are developed commercially, assumptions will be made about the capabilities of their states of origin, and states tend to be reluctant to adopt new legal restraints that implicate their national security posture. In the context of current geopolitics related to space security and the development of its normative framework, two key observations can be made.

First, states seem to prefer a certain amount of ambiguity following the development of norms for emerging technologies.⁴⁶ This is because they do not want to foreclose access to strategically valuable technologies before the impacts of those technologies have been measured, and for similar reasons, states are reluctant to enter into agreements that could foreclose commercial opportunities for their nationals. An open normative regime is often linked to notions of enabling innovation and opportunity. It seems likely that states will be reluctant to develop new binding rules directly concerning ADR before it is deployed operationally, meaning that only in strategic and economic context will limitations be cognizable.⁴⁷

Second, the current framework of international law is stagnant in the area of space law and retrograde in many other areas. The development of law and governance has continued to slow in the United Nations Committee on the Peaceful uses of Outer Space (UNCOPUOS), and most recent governance-oriented mechanisms have emerged out of the STSC rather than the Legal Subcommittee. The fault lines in the framework of international law are being laid bare as noncompliant superpowers place pressure on the system. Outer space, due to its military implications, has faced deadlock in a number of areas which is expected

45 Paul Larsen, *Cross-Waivers of Liability*, IISL-92-0011, in 35TH COLLOQUIUM ON THE LAW OF OUTER SPACE PROC. 91-3 (1992), <https://ssrn.com/abstract=3787165>.

46 Martin Libicki, *Two Maybe Three Cheers for Ambiguity*, in CONFLICT AND COOPERATION IN CYBERSPACE: THE CHALLENGE TO NATIONAL SECURITY 27-34 (Panayotis Yannakogeorgos & Adam Lowther eds., 2013).

47 Oren Perez, *Normative Creativity and Global Legal Pluralism: Reflections on the Democratic Critique of Transnational Law*, 10(2) IND. J. GLOBAL LEGAL STUD. 25-64 (2003); Moshe Justman & Morris Teubal, *Innovation policy in an open economy: A normative framework for strategic and tactical issues*, 15(3) RES. POL'Y 121-38 (1986).

to continue until states find some impetus to solve the problems collaboratively.⁴⁸

C. Economic Issues

Today, a number of commercial companies are currently developing ADR technologies, but the economic value of such technologies in the open market might not be as clear as one might expect. The economics of launching something into space to remove something from space may not place these operations to a price point that makes the market viable. Granted, this will depend significantly on the technology and factors such as the number of removal operations that can be accomplished by a single craft and the weight of that craft.⁴⁹

Such a market might be developed through a state promulgating strong debris remediation regulations. However, these regulations could raise the cost of engaging in space activities in that state, which would result in a loss of market share as companies relocate to favorable regulatory jurisdictions. Currently, there is a global race among a number of states to capture the perceived economic benefits of the space industry. In this course, states may be likely to avoid measures that impose undue burdens on economic actors compared to other jurisdictions.⁵⁰

Another route is for a state to become the prime contractor for the ADR operators, buying the services to clean up debris resulting from state space activities. Recently, however, states who are enthusiastic to promote a space industry, are scaling back spending on civil space operations, meaning that budgets may not support such expenditures.⁵¹ This, of course, leaves the military

48 On the deadlock in space law at the international level, see P. Blount, *The Future of PAROS: Building a Framework to Reduce Strategic Risk*, XLVII ANNALS OF AIR & SPACE L. 93-130 (2023).

49 Toru Yamamoto et al., *Cost analysis of active debris removal scenarios and system architectures*, in 7TH EUR. CONF. ON SPACE AND DEBRIS PROC. 1-15 (2017); Christopher May, *Triggers and Effects of an Active Debris Removal Market*, Center for Space Policy and Strategy (2021), <https://aerospace.org/sites/default/files/2021-01/adr%20paper.pdf>; Sammie Graff et al., *Economic Impact and Feasibility of Active Debris Removal: Initial Results from the OPUS Integrated Assessment Model*, (Preprint) AAS 25-618, https://www.researchgate.net/publication/394518822_Economic_Impact_and_Feasibility_of_Active_Debris_Removal_Initial_Results_from_the_OPUS_Integrated_Assessment_Model#:~:text=Abstract,launch%20rate%20than%20removal%20rate.

50 Examples of this shift to commercialization include the “light touch” regulation movement in the US and the current regulatory review in the UK. See The White House, *Space Policy Directive-2, Streamlining Regulations on Commercial Use of Space* (Mar. 24, 2018), <https://trumpwhitehouse.archives.gov/presidential-actions/space-policy-directive-2-streamlining-regulations-commercial-use-space>; UK Department of Science, Innovation, and Technology, *Space Regulatory Review 2024 A targeted review of space regulations (2024)*, https://assets.publishing.service.gov.uk/media/6644d26fb7249a4c6e9d3597/space_regulatory_review_2024.pdf.

51 E.g., Briana Alvarado & Matthew Glasser, *Bill Nye Asks Congress to Push Back against “extinction-Level” NASA Budget Cuts*, ABC News (Oct. 6, 2025), <https://abcnews.go.com/Politics/bill-nye-asks-congress-push-back-extinction-level/story?id=126264405>; Pallab Ghosh, *UK Independent Space Agency Scrapped to Cut Costs*, BBC News (Aug. 20, 2025), <https://www.bbc.com/news/articles/c4gmjm8z47jo>; Eugene Gerden, *Russia’s Space Program Is Another Casualty of the War in Ukraine*, SCI. AM. (June 30, 2025), <https://www.scientificamerican.com/>

as a viable customer, with much of the expenditure and technology classified and in the black. As of today, it is unclear whether there will be a clear market for the ADR technologies in the future.

4. Possible Futures

A. Clear Legal Structure: An ICAO Model

At one end of the spectrum is the development of a clear legal structure with institutionalization of decision-making and some level of dispute resolution capability. For example, scholars have suggested the establishment of an ICAO model for space to solve a variety of legal issues.⁵² A primary responsibility of ICAO is to develop international standards (also known as standards and procedures) for international civil aviation.⁵³ It is a UN sub-agency but was established by a separate treaty, the Convention on International Civil Aviation (Chicago Convention).⁵⁴ The Chicago Convention was signed in 1944 to address new political and technological issues and regulate civil air transport following World War II. Basic international civil aviation standards and recommended practices can be found in annexes.⁵⁵ The main responsibilities of ICAO include: advancing the principles and methods of global air navigation; promoting the development of international air transport to ensure its safe and organized evolution; facilitating the establishment of air routes, airports, and navigation systems crucial for international civil aviation; fostering the development of all facets of global civil aviation; and ensuring the safe and orderly development of international civil aviation.⁵⁶

An institutional authority, similar to ICAO, could establish international minimum standards for ADR, which would necessitate engagement with technical experts in the areas for which norms are to be established. Such expert

article/russias-space-program-is-another-casualty-of-the-war-in-ukraine.

52 See, e.g., Varlin Vissepo, *Legal Aspects of Reusable Launch Vehicles*, 31(1) J. SPACE L. 165-217 (2005).

53 Chicago Convention art. 44.

54 ICAO, The History of ICAO and the Chicago Convention, <https://www.icao.int/about-icao/history/pages/default.aspx>.

55 Ferhan Sengur, *Air Traffic Management*, in *ENCYCLOPEDIA OF TOURISM MANAGEMENT AND MARKETING* 117-9 (2022).

56 Richard Gariepy & David Botsford, *The Effectiveness of the International Civil Aviation Organization's Adjudicatory*, 42(2) J. AIR L. & COM. 353 (1976). See also Chicago Convention art. 44.

communities could advocate the establishment of decision-making processes built on international standards, comparable to the ICAO system.⁵⁷

The establishment of an international organization or other type of institution to govern ADR provides an elegant solution to establishing clear rules for space debris and its removal. Such legal certainty could be a boon to civil, commercial, and military activities by creating predictability in the system, which can be a desirable feature for structuring transactions. Simultaneously, such an emerging industry may be skeptical of regulations that they perceive as potentially stifling innovation. An example of such skepticism can be seen in the US's human space flight requirements that adopted a permissive regulatory regime in response to concerns about the stifling effects of premature regulation.⁵⁸ Furthermore, although military and security actors benefit from predictability, this is often countered by a desire to maintain freedom of action in any given area. Depending on the details of such an institutionalized authority, space-enabled militaries will likely oppose the development of norms in this area before the deployment of the technology.⁵⁹

B. Geopolitical Status Quo

At the other end of the spectrum is the continuation of the status quo, characterized by stagnant rules and even potentially negative normative development.⁶⁰ In this scenario, legal uncertainty persists, but the commercial goal of uninhibited innovation and the military goal of freedom of action are achieved. It does not mean that these activities lack a normative structure; both hard law and soft law governing outer space activities generally is still applicable to the ADR operations. Nevertheless, a specific regime for ADR still remains lacking, leaving the legal issues outlined above unresolved. Such a system would support a recognizable framework for coordinating activities among actors based on their duties to cooperate and to share information as embedded in the Outer Space Treaty. This basic structure may be used to reduce risk through communication and ad hoc coordination, without imposing predetermined regulatory outcomes.⁶¹

57 The notion of expert engagement is similar to Haas' epistemic communities. See Peter Haas, *Introduction: Epistemic Communities and International Policy Coordination*, 46(1) INT'L ORG. 1-35 (1992).

58 Timothy Hughes, *Space Travel Law (and Politics): The Evolution of the Commercial Space Launch Amendments Act of 2004*, 31(1) J. SPACE L. 1 (2005).

59 On the resistance to the establishment of norms surrounding security aspects of space, see Blount, *supra* note 48.

60 On negative norm development, see P. Blount, *The Shifting Sands of Space Security: The Politics and Law of the Peaceful Uses of Outer Space*, 17(1) INDON. J. INT'L L. 1-18 (2019).

61 For a detailed look at this structure, see P. Blount, *Space Traffic Coordination: Developing a Framework for*

The problem with this path is that if technology proves to be economically viable, the need for a governing regime will grow stronger as states seek to shield themselves from liability and interference. This pull toward regulation often becomes irresistible in the wake of an incident, like an accident, that forces the hand of rule-makers. Unfortunately, in the space domain, such an accident could have significant, long-lasting consequences if it results in a debris-creation event. Charting a course through the status quo requires careful consideration of when regulation becomes appropriate to avoid such an outcome.⁶²

C. Strong Contractual Law

Assuming that ADR proves to be commercially viable, an ad hoc legal framework would likely emerge based on international agreements and contracts surrounding operations. ADR vendors, their customers, and the states involved may establish a network of agreements to define relationships and allocate risks associated with the activity. This approach is consistent with typical commercial interaction and often preferred by commercial actors, as it allows them to negotiate and structure deals that best meet the parties' needs. Over time, such practices have the potential to take on the characteristics of a *lex mercatoria* if they become widely accepted as standard practices.⁶³

An example of this type of structure can be seen in the Three Country Trusted Broker (TCTB) initiative, which seeks to serve as an intermediary among China, Russia, the US, and ADR contractors for facilitating debris removal.⁶⁴ It aims to foster trust for the ADR system within the realm of geopolitics where trust is often lacking.⁶⁵ The TCTB structure seeks to introduce bilateral agreements among the three states involved, which are combined with contractual relationships between states and private actors themselves. The broker sits in the middle of this arrangement and, in theory, serves as a trusted entity that can engage in

Safety and Security in Satellite Operations, SPACE: SCI. & TECH. (May 23, 2021), <https://spj.science.org/doi/10.34133/2021/9830379?permanently=true>.

⁶² *Id.* at 7-8.

⁶³ Yun Zhao & Yanru Chen, *The Evolving Lex Mercatoria: A Game-Changer for Transparency in International Commercial Arbitration*, 16(3) J. INT'L DISP. SETTLEMENT 1-18 (2025); David Hyland-Wood et al., *Lex Mercatoria Deal-Making Between Small Spacecraft in the Outer Solar System*, in 4TH COSPAR SYMP. (2019), https://www.researchgate.net/publication/337033751_Lex_Mercatoria_Deal-making_Between_Small_Spacecraft_In_The_Outer_Solar_System.

⁶⁴ Three Country Trusted Broker, Home, <https://threecountrytrustedbroker.com>.

⁶⁵ On trust in the system, see P. Blount, *Space Traffic Management: Standardizing on-Orbit Behavior*, 113 AM. J. INT'L L. UNBOUND 120-4 (2019).

decision-making in debris removal⁶⁶

Profit-driven enterprises may adopt risk when facing uncertainties beyond what the law explicitly permits. As noted earlier, this could impact the space domain by contributing to debris proliferation rather than remediation as such decisions are based on economics rather than prescriptive rules. Private law often integrates regulatory and governance frameworks to select obligations and to define the boundaries of private law arrangements. As mentioned above, economic ordering could create significant potential for the security capture of capabilities through military procurement contracts.⁶⁷

5. Conclusion

The management and mitigation of space debris present critical challenges that demand focused attention and international cooperation. The rapid growth of space activities and the resulting increase in space debris highlight the urgent need for effective ADR strategies. While technological advancements in ADR offer promising solutions to debris, the legal frameworks governing these efforts remain insufficiently specialized for the ADR task. The lack of a universally accepted definition of space debris complicates regulatory efforts with significant implications for liability, ownership, and operational jurisdiction in space. Current international space law, primarily governed by the Outer Space Treaty and the Liability Convention, does not explicitly address the removal of debris generated by nonfunctional satellites or abandoned launch vehicles. This legal gap raises concerns about responsibility, cost sharing, and the authority to conduct ADR missions.

Filling the gaps in the legal regime faces significant obstacles rooted in the existing legal framework for space activities, the geopolitical dynamics shaping state engagement in space, and the commercial viability of ADR technologies. To overcome these challenges, policymakers must recognize the trade-offs involved when moving along the spectrum from the status quo to full institutionalization.⁶⁸

⁶⁶ Chuck Dickey et al., *Cooperative Debris Remediation: Ready for Action!*, in PROCEEDINGS OF THE INTERNATIONAL INSTITUTE OF SPACE LAW 2023, 383 (P. Blount et al. eds., 2024).

⁶⁷ Ingo Baumann, *Contract Law*, in ELGAR CONCISE ENCYCLOPEDIA OF SPACE LAW 39 (Mahulena Hofmann & P. Blount eds., 2025).

⁶⁸ On these dynamics, see Brian Israel, *Treaty Stasis*, 108 AM. J. INT'L L. UNBOUND 63-9 (2014).

Balancing the risks and opportunities presented by ADR technology will be complex, given its significant dual-use nature. While ADR offers a valuable opportunity to promote the long-term sustainability of the space environment, it also represents a novel form of the ASAT technology with important strategic implications.

While technological innovations continue to advance, the development of legal frameworks is indispensable for effectively addressing the growing threat of space debris and safeguarding the orbital environment for future space endeavors. At the same time, States are reluctant to engage in regulatory structures that preconceive technologies, coupled with a more general degradation of international legal structures. International collaboration is essential to achieving proactive regulatory measures that strike a proper balance between innovation, security, and sustainability.⁶⁹

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⁶⁹ Blount, *supra* note 65.