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A Fragile Frontier: Confronting the Space Debris Problem in Low-Earth Orbit and Exploring Partnership Opportunities with the EU

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EXECUTIVE SUMMARY

Decreasing launch costs and smaller, cheaper satellites have made it easier for states and private enterprises to launch spacecraft into low-Earth orbit (LEO), which has resulted in the creation of the New Space Economy as well as contributed to the mounting problem of space debris. Confronting the problem posed by this debris is fraught with legal, technological, and cooperative challenges. First and foremost, there is no internationally agreed upon definition of "space debris" and the exiting canon of space law, pursuant to the United Nations (UN) treaties and principles ratified in the 1960s and 1970s, does not make explicit mention of such debris. Additionally, modelling from both the European Space Agency (ESA) and the National Aeronautics and Space Administration (NASA) shows that even if all launches were ceased today, the number of debris objects would continue to grow because of the realization of the Kessler Syndrome in which debris collisions are producing additional fragments at a higher rate than those that decay. This indicates that in addition to mitigation measures, as outlined in the UN and the Inter-Agency Space Debris Coordination Committee (IADC) *Space Debris Mitigation Guidelines*, active debris removal (ADR) missions have become necessary to clean-up the space debris environment. However, the cost of engaging with and undertaking ADR missions is prohibitively high, and precludes states from acting unilaterally. Game theoretic analysis of ADR cooperation between states suggests, as is the case with the provision of many global public goods, that states are inclined to free-ride and not actively contribute to removal missions. Therefore, states are increasingly relying on private enterprises to provide both Earth- and space-based solutions to the debris problem. While confronting the problem of space debris seems dire, there have been positive inroads made on the part of the European Union (EU) through the ESA, which is paving the way for responsible norms of behaviour in space pursuant to the sustainability of Earth's orbital bands. There also exists a number of potential policy options available to Canada and other space-faring states that may further fuel cooperation and thoughtful launch and de-orbit behaviour. Indeed, Canada has the opportunity to both learn from the EU's actions in space as it pertains to tackling the problem of space debris, as well as engage in coalition building with the EU to ensure the responsible stewardship of this fragile environment.

PART I: INTRODUCTION

Space debris is defined by the United Nations Office of Outer Space Affairs (UNOOSA) in their Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space (COPUOS) as: "All man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional."[2] Similarly, NASA defines orbital debris as: "All man-made objects in orbit above the Earth, which no longer serve a useful purpose."[3] However, the definition of space debris remains contentious as there is no globally agreed upon definition. Moreover, the 1967 Outer Space Treaty only defines "space object" without any agreed upon definition of "space debris" as a subset of that term.[4] Herein lies the first of many problems related to confronting the problem of debris in low-Earth orbit (LEO), which is defined as the area between 150 kilometres and 2,000 kilometres in altitude above the Earth's surface. If there is no universal agreement as to what constitutes a piece of space debris, the very lack of a definition presents additional barriers for space-faring states, private enterprise, and international organizations to collaborate and effectively catalogue, target, and eventually clean up such debris.

This problem is further compounded by the technical limitations of the tools used to catalogue debris. The US Department of Defense Space Surveillance Network (SSN) currently maintains the world's pre-eminent database of orbital debris, but is only able to catalogue pieces of debris larger than 10 centimetres in diameter in LEO,[5] meaning the number of catalogued pieces of debris is much smaller than the total number of debris. The SSN has catalogued approximately 30,000 debris particles between five and 10 centimetres in size, however, it is estimated that there are more than 100 million pieces of debris larger than one millimetre in size.[6,7]

Decreasing launch costs and smaller, cheaper satellites have made it easier for states and private companies to launch spacecraft into LEO, which has resulted in the creation of the LEO Economy. The LEO Economy is defined by NASA as: "The production, distribution, and trade of goods and services within low-Earth orbit", which is growing to include more groups including, but not limited to government, the commercial sector, and academia.[8] The emergence of this new space economy has opened up a market potentially worth up to $3 trillion USD over the

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[2] "Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space," United Nations Office for Outer Space Affairs (UNOOSA), 2010, https://www.unoosa.org/pdf/publications/st_space_49E.pdf [accessed 10 June 2022].

[3] "What is Orbital Debris?" Astromaterials Research & Exploration Science Orbital Debris Program Office, NASA, accessed 10 June 2022, https://orbitaldebris.jsc.nasa.gov/faq/#.

[4] "United Nations Treaties and Principles on Outer Space," UNOOSA, 2002, https://www.unoosa.org/pdf/publications/STSPACE11E.pdf [accessed 10 June 2022].

[5] Peggy Hollinger and Sam Learner, "The Gathering Threat of Space Debris," *Financial Times*, 9 June 2022, 17, [accessed 10 June 2022].

[6] "Space Debris and Human Spacecraft," Space Station, NASA, 26 May 2021, https://www.nasa.gov/mission_pages/station/news/orbital_debris.html [accessed 10 June 2022].

[7] "What is Orbital Debris?"

[8] "LEO Economy FAQs," Low-Earth Orbit Economy, NASA, last modified 18 February 2022, https://www.nasa.gov/leo-economy/faqs [accessed 9 June 2022].

coming decades, and it is estimated that there will be in excess of 100,000 commercial spacecraft in orbit by 2030.[9]

Undoubtedly, the advent of the LEO Economy, and the new space economy more broadly, has given way to many of the technologies that humankind depends upon terrestrially for both commercial and military purposes. However, decreasing costs, ease of spacecraft manufacturing, and an influx of launch actors all but guarantees that the amount of debris in LEO will increase in the coming years as a result of increased launches, and further exacerbated by collisions between existing pieces of debris. The European Space Agency (ESA) estimates that if we maintain the current rate of 70 to 90 launches per year, injecting 30 or more satellites into orbit at once, and assuming future break-ups will continue at the mean historical rate of four to five per year, the number of objects in space—both operational and defunct—will continue to grow steadily.[10] This will inevitably be compounded by the rise of private actors in space, such as SpaceX and its planned Starlink project, which in its final form will comprise a mega-constellation of 42,000 satellites delivering high-speed Internet access across the globe.[11]

As the number of debris objects in space is expected to steadily increase, so too is the possibility of catastrophic collision. The increasing magnitude of space debris from new launches and the fragmentation of existing debris will lead to the realization of the Kessler Syndrome, whereby the density of existing debris in LEO is high enough to facilitate a chain-reaction of collisions that results in the creation of yet more debris, thus perpetuating an environment that can instantly destroy or disable space-based resources.[12] The realization of the Kessler Syndrome would all but guarantee that any new spacecraft launched into Earth's orbit will be struck and disabled by an existing piece of debris and thereby increasing the density of debris in LEO as a knock-on effect.

Terrestrial activity depends upon the structural and functional integrity of the satellites currently threatened by the debris found in LEO. Such activity includes, but is not limited to, telecommunications, weather forecasts, global navigation, banking and financial services, and a host of other services upon which we depend for commercial, private, military, and academic purposes. Similar to the provision of other global public goods, tackling the problem of space debris presents a unique challenge given the global commons environment it occupies. This is exacerbated by the fact that space, LEO or otherwise, is not under the control of any one nation, not subject to any tax-collecting authorities, and there exists a lack of global authority to impose sanctions or enforce action.[13] Nevertheless, terrestrial dependence on LEO and other orbits means that everyone is a beneficiary of the space systems that require a safe environment in

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[9] Hollinger and Learner, "The Gathering Threat of Space Debris," 17.
[10] "Mitigating Space Debris Generation," Safety and Security, European Space Agency (ESA), accessed 9 June 2022, https://www.esa.int/Safety_Security/Space_Debris/Mitigating_space_debris_generation.
[11] Adam Mann, Tereza Pultarova, and Elizabeth Howell, "SpaceX Starlink Internet: Costs, Collision Risks and How It Works, 14 April 2022, https://www.space.com/spacex-starlink-satellites.html [accessed 9 June 2022].
[12] "The Current State of Space Debris," Safety and Security, ESA, 12 October 2020, https://www.esa.int/Space_Safety/Space_Debris/The_current_state_of_space_debris [accessed 9 June 2022].
[13] Joseph N. Pelton, *New Solutions for the Space Debris Problem* (New York: Springer, 2015), 33.

which to operate. Action is needed urgently and presently to confront the problem of orbital debris in LEO. Indeed, internal studies by the ESA demonstrate that continuous removal actions that start in 2060 will be 25 per cent less effective compared to immediate action.[14] Undoubtedly, our current and future uses of space depend upon our stewardship of this fragile environment.

PART II: BACKGROUND INFORMATION

Before delving into the crux of the space debris problem in LEO, it may be useful to examine some key figures as reported by the ESA's Space Debris Office.

Table 1: Space Debris by the Numbers

Description of Debris	Amount of Debris
Number of rocket launched since 1957	~6,200 (excluding failures)
Number of satellites these rockets have placed into Earth orbit	~13,100
Number of these satellites still in space	~8,410
Number of these satellites still functioning	~5,800
Number of debris objects regularly tracked by the Space Surveillance Network and maintained in their catalogue	~31,450
Estimated number of break-ups, explosions, collisions, or anomalous events resulting in fragmentation	~630
Total mass of all space objects in Earth orbit	~9,900 tonnes
Pieces of debris by size	>10 cm: ~36,500 1cm – 10 cm: ~1M 1mm – 1 cm: ~130M

Data from "Space Debris by the Numbers," Space Safety, ESA, accurate as of 10 May 2022, https://www.esa.int/Safety_Security/Space_Debris/Space_debris_by_the_numbers.

Since 2007 there have been two significant debris-generating events that have greatly increased the amount of space debris currently in orbit: (1) On 11 January 2007 the Chinese government launched an inceptor missile to destroy the defunct Chinese weather satellite, Fen Yun 1C. They used an anti-satellite (ASAT) missile system launched from a location near the Xichang Space Center. This event generated 3,000 pieces of debris with a diameter of 10 centimeters or larger,

[14] "Mitigating Space Debris Generation."

and roughly 150,000 pieces of debris with a diameter larger than one centimeter. Many of these newly-created pieces of debris were launched into long-duration orbits, meaning they will remain in orbit for the better party of one century.[15] (2) On 10 February 2009 the US Iridium 33 communications satellite collided with the defunct Russian weather satellite, Kosmos 2251, and generated roughly 2,100 pieces of new debris measuring 10 centimeters or more in diameter.[16] These two events increased the amount of space debris catalogued by the SSN by one-third and have negated the results of more than 20 years of international compliance with space debris mitigation guidelines.[17] Most recently on 15 November 2021, Russia launched a direct-ascent ASAT missile against one of its own inoperative satellites, Kosmos 1408, which generated over 1,500 pieces of trackable debris and will likely generate hundreds of thousands of pieces of smaller orbital debris in the years to come.[18]

There are neither international space laws that govern the creation or clean-up of space debris, nor any legally binding mechanisms to hold launch actors to account. However, COPUOS and its Scientific and Technical Subcommittee facilitate annual discussions and exchanges of information between states and organizations related to space debris research. An important result of such information exchange was the creation of the COPUOS and Inter-Agency Space Debris Coordination Committee (IADC) *Space Debris Mitigation Guidelines*, which were endorsed by the UN General Assembly in 2007. While these guidelines are not binding under international law, they remain applicable to mission planning and engineering of newly-designed spacecraft. The *Guidelines* are as follows:[19]

> *Guideline 1:* Limit debris released during normal operations;
> *Guideline 2:* Minimize the potential for break-ups during operational phases;
> *Guideline 3:* Limit the probability of accidental collision in orbit;
> *Guideline 4:* Avoid intentional destruction and other harmful activities;
> *Guideline 5:* Minimize potential for post-mission break-ups resulting from stored energy;
> *Guideline 6:* Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission; and
> *Guideline 7:* Limit the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous Earth orbit (GEO) region after the end of their mission.

In addition to the scientific and technical research of COPUOS, the national and international legal aspects of space debris mitigation are also discussed by the COPUOS Legal Subcommittee. Indeed, in 2004 the EU released the *European Code of Conduct for Space Debris Mitigation*, whose objective is three-fold: the prevention of on-orbit break-ups and collisions; the removal

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[15] Pelton, *New Solutions for the Space Debris Problem*, 3.
[16] Steven A. Hildreth and Allison Arnold, "Threats to US National Security Interests in Space: Orbital Debris Mitigation and Removal," Congressional Research, 8 January 2014, 3, https://sgp.fas.org/crs/natsec/R43353.pdf [accessed 10 June 2022].
[17] Hildreth and Arnold, "Threats to US National Security Interests in Space," 3.
[18] Antony J. Blinken, "Press Statement: Russia Conducts Destructive Anti-Satellite Missile Test," Press Releases, US Department of State, 15 November 2021, https://www.state.gov/russia-conducts-destructive-anti-satellite-missile-test/ [accessed 10 June 2022].
[19] "Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space".

and subsequent disposal of spacecraft and orbital stages that have reached the end of mission operations from the useful densely populated orbit region; and the limitation of objects released during normal operations.[20] The *Code of Conduct* outlines management measures,[21] design measures,[22] and operational measures.[23] Moreover, in 2011 the International Telecommunication Union's (ITU) Radiocommunication Sector released its *Environmental Protection of the Geostationary-Satellite Orbit* which provides recommendations and guidance for the disposal orbits of satellites in the geostationary orbit, which is where many global navigation and meteorological satellites are found. The recommendations of the ITU are as follows:

1. That as little debris as possible should be released into the Geostationary Orbit (GSO) region during the placement of a satellite in orbit;
2. That every reasonable effort should be made to shorten the lifetime of debris in elliptical transfer orbits with the apogees at or near GSO altitude;
3. That before complete exhaustion of its propellant, a geostationary satellite at the end of its life should be removed from the GSO region such that under the influence of perturbing forces on its trajectory, it would subsequently remain in an orbit with a perigee no less than 200 kilometers above the geostationary altitude;
4. That the transfer to the graveyard orbit removal should be carried out with particular caution in order to avoid radio-frequency (RF) interference with active satellites.[24]

Of the five UN treaties on outer space, the 1968 *Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space* (the "Rescue Agreement") maintains, per Article V, that State Parties return any "foreign" space objects recovered in their territory to their owners and notify the UN Secretary-General of any such discovered object.[25] Likewise, three other treaties of the UN outer space treaty system maintain applicable tenets to the topic of space debris. These treaties include:

The 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (the "Outer Space Treaty")

The Outer Space Treaty (OST) serves as the starting off point for all current canonical space law. While it does not address space debris specifically, Article VI maintains that states party to the treaty bear international responsibility for national activities in outer

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[20] "European Code of Conduct for Space Debris Mitigation," UNOOSA, 28 June 2004, 1, https://www.unoosa.org/documents/pdf/spacelaw/sd/2004-B5-10.pdf [accessed 13 June 2022].
[21] "European Code of Conduct for Space Debris Mitigation," 3.
[22] "European Code of Conduct for Space Debris Mitigation," 5-7.
[23] "European Code of Conduct for Space Debris Mitigation," 8-10.
[24] "Recommendation ITU-R S.1003-2: Environmental Protection of the Geostationary Satellite Orbit," ITU-R Telecommunications Sector of ITU, International Telecommunications Union, 2011, 1, https://www.unoosa.org/documents/pdf/spacelaw/sd/R-REC-S1003-2-201012-IPDF-E.pdf [accessed 13 June 2022].
[25] "2345 (XXII) Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space," Resolution Adopted by the General Assembly, UNOOSA, 19 December 1967, https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/rescueagreement.html [accessed 13 June 2022].

space; Article VII maintains that each state from whose territory or facility an object is launched is internationally liable for damage to another state party to the treaty (the Liability Convention expands upon this); and Article IX maintains that "States party to the Treaty shall be guided by the principle of co-operation and mutual assistance and shall conduct all their activities in outer space, including the moon and other celestial bodies, with due regard to the corresponding interests of all other States party to the Treaty".[26] The OST does not mention space debris specifically, but rather uses the phrase "object launched into outer space" which includes "its component parts".[27] This is an important consideration when considering the legal status of space debris, as none of the three treaties discussed here make explicit mention of "space debris".

The 1972 Convention on International Liability for Damage Caused by Space Objects (the "Liability Convention")

Building on Article VII of the OST, the Liability Convention maintains in Article II that a launching state (defined as a state which launches or procures the launching of a space object, or a state from whose territory or facility a space object is launched) shall be "absolutely liable to pay compensation for damage caused by its space object on the surface of the earth or to aircraft flight".[28] Much like the OST, the Liability Convention does not explicitly mention debris, but rather uses the term "space object". As a conclusion on the legal status of space debris, pieces of debris may be considered "space objects" in their own right since they are "component parts" of the "objects launched into outer space". In this case, launch states would be liable for any damage incurred because of resulting debris from their spacecraft.

The 1976 Convention on Registration of Objects Launched into Outer Space (the "Registration Convention")

The Registration Convention was borne of a belief that a mandatory system of registering objects launched into outer space would assist in their identification and contribute to the application and development of international law governing the exploration and use of outer space.[29] Much like the OST and the Liability Convention, the Registration Convention uses the term "space object", whose definition includes

[26] "2222 (XXI) Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies," Resolution Adopted by the General Assembly, UNOOSA, 19 December 1966, https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html [accessed 13 June 2022].

[27] Louis de Gouyon Matignon, "The Legal Status of Space Debris," *Space Legal Issues,* 23 July 2019, https://www.spacelegalissues.com/the-legal-status-of-space-debris/ [accessed 15 June 2022].

[28] "2777 (XXVI) Convention on International Liability for Damage Caused by Space Objects," Resolution Adopted by the General Assembly, UNOOSA, 29 November 1971, https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/liability-convention.html [accessed 13 June 2022].

[29] "3235 (XXIX) Convention on Registration of Objects Launched into Outer Space," Resolution Adopted by the General Assembly, UNOOSA, 12 November 1974, https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/registration-convention.html [accessed 15 June 2022].

"component parts" of the space object as well as its launch vehicle and "parts thereof".[30] Pursuant to Article II of the Registration Convention, a space object requires registration: "When a space object is launched into Earth orbit or beyond, the launching State shall register the space object by means of an entry in an appropriate registry which it shall maintain. Each launching State shall inform the Secretary-General of the United Nations of the establishment of such a registry."[31] While the Registration Convention also does not explicitly mention space debris, its definition of "space object", which includes its "component parts" and "parts thereof", allows us to consider using the Registration Convention to keep track of space debris and launching States that still have jurisdiction and control over the space objects/debris.[32]

PART III: KEY CONSIDERATIONS

There are a number of technical difficulties and legal issues that arise when discussing space debris and how to best clean it up. First, as discussed in Part I, there is no international consensus on the legal definition of "space debris". While the OST and subsequent treaties apart of the UN canon of space law make use of the term "space object", whose definition includes "component parts" and "parts thereof", the lack of universal, or near-universal, consensus on an explicit definition of space debris makes it difficult to identify which objects currently in LEO would count as debris and would be subject to removal.[33] The second key consideration is the ownership of objects in orbit, which remains the prominent legal issue related to debris removal. Pursuant to Article VII of the OST, space objects are the property of the state(s) which launched them, and thus they retain jurisdiction and control over that object while it remains in outer space, on a celestial body, and upon its return to Earth. Thus, no other state has the legal authority to remove or interfere with said object without prior authorization of the launching state(s). Unlike in maritime law, there is no right of salvage in space, meaning that the launching state(s) retain all property rights over their space object even if it is non-functional. If we consider the legal status of space debris pursuant to the definitions of "space objects" as outlined in the aforementioned UN treaties, then any fragments or components of space objects, no matter how small, are considered space objects in their own right, meaning they also fall under the control and jurisdiction of the launching state(s).[34]

Related to the discussion of the Liability Convention in Part II, the third problem that arises in the context of space debris is the question of liability, particularly when an unintended collision occurs during the debris removal process. Pursuant to the 1972 Liability Convention, the launching state remains liable for damages should its space object collide with private property

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[30] "3235 (XXIX) Convention on Registration of Objects Launched into Outer Space."
[31] "3235 (XXIX) Convention on Registration of Objects Launched into Outer Space."
[32] Matignon, "The Legal Status of Space Debris."
[33] Hildreth and Arnold, "Threats to U.S. National Security Interests in Space," 11.
[34] Michael Listner, "Legal Issues Surrounding Space Debris Remediation," The Space Review: Essays and Commentary About the Final Frontier, *Space News*, 6 August 2012, https://www.thespacereview.com/article/2130/1 [accessed 14 June 2022].

on Earth or interfere with aircraft flight.[35] However, when space objects collide in outer space, a fault standard is applied. Thus, if a collision occurs in outer space, the attribution of liability (and assessment of damages) only applies if negligence can be firmly established, which can lead to complicated fault assessments if such a collision occurs during the process of active debris removal (ADR) operations which involve multiple governments and stakeholders.[36] The final key consideration to be made is that states or private launch actors may be unwilling to cooperate in ADR, as the need for sharing technical and potentially proprietary or confidential information may arise. In such a case, the exchange of confidential or proprietary information may be necessary for the success of the ADR operation, which will require the negotiation of licensing and nondisclosure agreements between states and other actors.[37]

PART IV: POTENTIAL POLICY ACTIONS

There are two potential courses of action when it comes to addressing the problem of space debris: mitigation and remediation. In this context, "mitigation" refers to operational and design measures that limit the generation of debris for future launches, while "remediation" refers to the active removal of current pieces of debris.[38] However, it is important to note that these two paths are not mutually exclusive, but rather complementary and should be implemented in tandem to stabilize the debris environment in LEO and beyond. The ESA notes that ADR is necessary to assuage the growth of space debris, as long-term modelling shows that a "business as usual" approach will lead to the progressive and uncontrolled increase of space objects in LEO, wherein collisions become the primary source of debris. While mitigation measures, as outlined by the IADC *Space Debris Mitigation Guidelines*, can help reduce the rate at which space debris is generated, the rate of growth in the long-term is expected to rise even if all launch activities ceased today. This indicates that the density of large objects in LEO has reached a critical concentration, manifesting the realization of the Kessler Syndrome.[39] Even in ideal case scenarios, modelling by the ESA, NASA, and the IADC shows that without ADR, mitigation can only go so far. In one future scenario modelled by the ESA and NASA in which all new launches are halted and no new objects are added to the LEO environment, the number of debris objects will increase such that a collision between large debris objects can be expected once every 10 years. Similarly, an IADC study shows that even 90 per cent compliance with *Space Debris Mitigation Guidelines*, and assuming no in-orbit explosions, the density of debris would steadily increase such that collisions, again between large debris objects, could be expected every five to nine years.[40]

[35] "2777 (XXVI) Convention on International Liability for Damage Caused by Space Objects."
[36] Hildreth and Arnold, "Threats to U.S. National Security Interests in Space," 12.
[37] Hildreth and Arnold, "Threats to U.S. National Security Interests in Space," 12.
[38] Listner, "Legal Issues Surrounding Space Debris Remediation."
[39] "Active Debris Removal," Space Safety, ESA, accessed 15 June 2022, https://www.esa.int/Safety_Security/Space_Debris/Active_debris_removal.
[40] "Active Debris Removal."

Section i: Options for Mitigation

OPTION #1: The Club Model Approach

One potential option for the future mitigation of space debris is a three-pronged approach that facilitates international cooperation amongst space-faring nation states. First, the currently non-legally binding *Space Debris Mitigation Guidelines* promulgated by the IADC and UNOOSA are adapted into a legally-binding treaty that all space-faring nations must be party to in order to continue their launches. Second, a club similar to the WTO or NATO is created and partnership is extended to all space-faring nations. Third, all club members must uphold the newly-created treaty else be denied access to the club and its benefits, which would include technology and information sharing, the sharing of costs related to complex space launches and missions, and participation in future multilateral space missions to which all parties would benefit.

With regards to the first prong, Joseph N. Pelton, the former Dean of the International Space University and former Director of Strategic Policy at INTELSAT, suggests that transparency and confidence-building measures are key to the success of international cooperation on tackling the space debris problem. In fact, the UN Office of Disarmament Affairs (UNODA) has established a group of governmental experts on transparency and confidence-building measures in outer space activities. Pelton argues the need for an agreed upon norm of behaviour in regard to space debris that would be a net positive rather than zero sum game.[41] He suggests that space-faring nations including the US, Canada, Russia, China, India, Japan, and the EU agree that progress on the orbital debris problem is desirable, and if a norm of behaviour could be established and observed broadly over time, it would be sufficient as a space treaty to this effect.[42] He also advocates for an increased consideration of the role of private entities in the space arena. One approach he suggests is for launching states to agree to postpone launches until there is a binding contract to cover the due diligence related to debris at the time of launch, but also strict contractual terms that cover the right to sign-off on any subsequent sale of satellites and provisions for end-of-life disposal arrangements. He also argues for the installation of de-orbit systems on satellites that would remain under the control of the launching state.

In regards to the second and third prongs, the two key objectives of such a club model that would need to be attained for its success are: an agreed-upon and goal-oriented agenda; and the creation of interdisciplinary teams of experts who would work with key stakeholders to address the problem of space debris and devise solutions. Key parties of these teams would include: space agencies and defense-related ministries; relevant governmental agencies dealing with the international relations in this area; the various UN bodies dealing with disarmament and the peaceful and sustainable uses of outer space; aerospace, space-application and space transportation companies; and perhaps

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[41] Pelton, *New Solutions for the Space Debris Problem,* 34.
[42] Pelton, *New Solutions for the Space Debris Problem,* 34.

most significantly the insurance and risk-management industries. Some specific items on their action plan may include:

- Strengthening of the *Space Debris Mitigation Guidelines*;
- Developing new, efficient, and cost-effective technology for debris removal;
- Developing insurance arrangements and financial incentives for debris removal;
- Developing provisions related to orbital debris that are defined in codes of conduct, transparency, and confidence-building measures; and
- Creating a de facto basis of new procedures that cover registration of space objects, duties, and responsibilities of private entities designing, launching, deploying, operating, and owning space systems, and liability provisions through insurance and other risk-mitigation initiatives.

These conditions for cooperation and elements of agenda setting would undoubtedly be easier to implement under a club model of space-faring states.

The American economist Willian Nordhaus discusses the success of the club model approach as it pertains to free trade and the decline of war through the WTO and NATO, respectively. In his 2015 analysis, he outlines the conditions for a successful club model, which include: a public good-type resource that can be shared; a cooperative arrangement, including club dues, that is beneficial to each member; an arrangement in which non-members or non-compliant members can be excluded or penalized at a relatively low cost to members; and stable membership.[43] Space debris and the LEO environment appear to lend themselves well to these conditions: to the first condition, the maintenance of LEO and surrounding orbits can indeed be considered a global public good, and the orbits themselves fall into *res communis* territory. To the second condition, by cooperating to preserve the environmental integrity of LEO, all space-faring nations can ensure safe and effective launches. To the third condition, a club of space-faring states can easily exclude those states that, while space-faring, do not comply with the club's treaty by refusing to shoulder mission costs and share valuable technological information, and even going so far as to enact tariffs or other economic sanctions terrestrially. To the final condition, as space becomes an increasingly important forum for the future of military and commercial enterprise, it is in the best interests of all states to cooperate, space-faring or otherwise.

The club model approach has the potential to mark a mutually beneficial arrangement in which the costs of compliance are overshadowed by the benefits offered, with the added possibility of creating a framework for further regulation of future space activities. The creation of such a club endows legitimacy to the space debris problem and may help to foster cooperation between states. It would also make it easier to ensure compliance and dole out punishment for non-compliance. However, it is important to

[43] William Nordhaus, "Climate Clubs to Overcome Free-Riding," *Issues in Science and Technology* 31, no. 4 (2015), https://issues.org/climate-clubs-to-overcome-free-riding/ [accessed 16 June 2022].

note that this policy option would likely require an extended period of negotiation which may be vulnerable to competing policy agendas and interests. It is also worth noting Robert Keohane's and Joseph Nye's discussion of the club model of international cooperation in their seminal 2001 work. The introduction of private firms, NGOs, and various transnational and transgovernmental networks into the realm of global governance means that rule-making and rule-interpretation have become pluralized, and these non-governmental actors play a role alongside state authorities. As such, it behooves any sustainable mode of governance to institutionalize channels of communication between international organizations and domestic civil society institutions.[44] This is not to say that the club model of governance should be discarded, but rather, in the view of Keohane and Nye, modified. They caution that more weight should not be put on such institutions than they can bear and suggest that these multilateral institutions will only thrive when "substantial space is preserved for domestic political processes", similar to the concept of subsidiarity in the EU.[45] This delicate balance is observed within the WTO, which occasionally allows the domestic politics of member states to depart from international agreements without unravelling the entire systems of norms. Such a balance between integration at the global level and preserving the agency of domestic institutions is a key consideration for developing a club model of space-faring states.

OPTION #2: Implementation of Orbital Use Fees (OUFs)

The creation and implementation of orbital use fees (OUFs) seeks to address the lack of incentives for space-faring nations and commercial enterprises to account for the negative externalities of their use of orbital space. Similar to a carbon taxes, fisheries management systems, or cap and trade programs already in place within many space-faring nations, an internationally harmonized OUF would ratchet up over time to account for the long-term value of the satellite industry. As previously mentioned, current projections suggest that the industry will quadruple in value by 2030-2040 from roughly $600 billion USD to $3 trillion USD.[46] As it stands, the growing build-up of debris and the collision risks from this congestion are costly to satellite operations, yet they currently have no reason to account for such spillover costs. Since satellite operators cannot secure exclusive property rights to their orbital paths or recover collision-related damages, prospective operators are faced with the choice between launching profitable satellites which impose collision risks on others or not launching and leaving potential profits to competitors.[47] OUFs seek to provide an incentive-based solution to this problem.

[44] Robert O. Keohane and Joseph S. Nye Jr., "Between Centralization and Fragmentation: The Club Model of Multilateral Cooperation and Problems of Democratic Legitimacy," Faculty Research Working Papers Series, John F. Kennedy School of Government, Harvard University, February 2001, 25, http://dx.doi.org/10.2139/ssrn.262175 [accessed 16 June 2022].
[45] Keohane and Nye, "Between Centralization and Fragmentation," 25.
[46] Akhil Rao et al., "Orbital-use fees could more than quadruple that value of the space industry," *PNAS: Proceedings of the National Academy of Sciences of the United States of America* 117, no. 23 (2020): 12756 https://doi.org/10.1073/pnas.1921260117 [accessed 16 June 2022].
[47] Rao et al., "Orbital-use fees could more than quadruple that value of the space industry," 12756.

These OUFs would take the form of a fee or tradeable permits, and may also be orbit-specific, as satellites in different orbits pose varying degrees of collision risk. Further, the fee for each satellite would be calculated to reflect the cost of launching another satellite into orbit, including the projected costs of space debris production and collision risk. Rao et al.'s model projects an OUF that increases at a rate of 14 per cent per year, equal to approximately $235,000 USD per satellite-year in 2040.[48]

A number of conditions must be met in order for this option to be implemented successfully, namely: all launch states must participate in such an OUF regime, collect these revenues separately, and charge the same fee. Further, a bureaucratic secretariat—akin to one institutionalized in the aforementioned club model of space-faring nations, or the already established UNOOSA—must be wound up to dispense and collect the fees in addition to enforcement mechanisms that dole out punishment to those who fail to pay. The implementation of OUFs provides a tangible cost to the use of space to which states and private actors can respond. Such fees may crowd out smaller space actors by raising the cost of entry, and proceeds from the OUFs may eventually be used to finance ADR and cleanup efforts. Perhaps the most important consideration of the implementation of an OUF regime comes back to the problem of definitions. Insofar as the amount of the OUF is dependent upon the seriousness of the space debris problem, there would need to be a mutually agreed upon definition of what a "better" or "worse" orbital environment looks like, and to what degree the OUF will be adjusted in response.

Section ii: Options for Remediation

OPTION #1: Active Debris Removal (ADR)

ADR is perhaps the most discernible remedial solution to the space debris problem, and involves targeting current pieces of debris and either removing them via re-entry to Earth's atmosphere or re-locating them to a graveyard orbit. While there are currently a number of both government- and privately-backed remediation programs and initiatives in development, the launching state(s) jurisdiction over debris removal remains a significant legal barrier to be addressed. Legal challenges notwithstanding, the process of ADR can work in tandem with mitigation efforts and a space debris fund to encourage competition between both government and private entities, which can help facilitate a cost-effective and efficient system of ADR. This option deals directly with the existing problem and may spawn an economic sector responsible for debris cleanup that creates jobs (either at the state-level or by private companies that have been given express consent from the launching state(s) for cleanup). However, this option is fraught with legal considerations regarding jurisdiction over space debris, as well as the potential unwillingness of states to provide consent to have their debris collected. Further,

[48] Rao et al., "Orbital-use fees could more than quadruple that value of the space industry," 12756.

technologies developed for ADR, such as China's proposed laser-based systems,[49] may constitute an attempt to weaponize space, and such attempts may be so costly to develop and implement that it would be more cost-effective in the short-term to let the debris remain.

These challenges aside, there are two worthwhile ADR routes to examine. The first is government specific debris removal, in which the burden to engage in ADR falls to individual nation states and their governments. The second route is a global debris removal effort, which would see a globally designated international entity engage in ADR.

1.1: Government Specific Debris Removal Efforts

The enormous challenges of ADR underwrites the need for either national governments or an international body to assume the clean-up of orbital debris. Chief among these challenges are: the huge amount of debris that has now formed in LEO and other orbits; the complexity of the missions needed to remove the debris from orbit without risking a collision and thus the creation of more debris; and the high cost of such activities with no commercial market associated with them.[50] While meaningful progress on the problem of space debris has been made in previous decades with the creation of the IADC and UNOOSA *Space Debris Mitigation Guidelines* and the more recent work related to orbital debris and solar weather of the COPUOS Working Group on the Long-Term Sustainability of Outer Space Activities, there are no international agreements covering space debris or explicit sanctions to ADR. There have been no new or revised treaties, conventions, or principles since the original canon of space law entered into force in the 1960s and 1970s, and thus the expense—both political and financial—of creating a new international agency to undertake the task of ADR would be enormous.[51]

It appears likely that the task of ADR will fall to national governments themselves or to private companies subsidized by national governments. One of the most significant governmental efforts that sought to establish a process and legal regime to minimize space debris was the French Space Operations Act (FSOA) of 2008 and 2010.[52] More recently, the ESA announced in 2019 that it would launch the world's first ADR mission in partnership with the Swiss start-up, ClearSpace, which is set to launch in 2025-2026. The ADR mission will target the Vega Secondary Payload Adapter (Vespa) upper stage left, which has a mass of approximately 100 kilograms, a simple shape, and sturdy

[49] Quan Wen et al., "Impacts of Orbital Elements of Space-Based Laser Station on Small Scale Space Debris Removal," *Optik* 154 (October 2, 2017): 83, doi:10.1016/j.ijleo.2017.10.008 [accessed 12 July 2022].
[50] Pelton, *New Solutions for the Space Debris Problem,* 42.
[51] Pelton, *New Solutions for the Space Debris Problem,* 43.
[52] Pelton, *New Solutions for the Space Debris Problem,* 43.

construction, making it an ideal first candidate for an ADR mission before the ESA and other national space agencies embark on more complex clean-up efforts.[53]

Given that ADR missions remain in their nascent stages, it seems more plausible that funding for such missions will come from government budgets, likely as part of national defence spending as a response to debris threats against missile defence systems, missile launch detection systems, or to protect military space assets. Alternatively, funds may come from national space agencies to sustain governmental space programs, such as those conducted by the US Defence Advanced Research Projects Agency (DARPA), or from governmental legislative mandates as was seen with the FSOA.[54] Such national legislative action may serve to change the business case of ADR from a government-run, tax-funded removal program to an industry-led program that is largely self-funded, potentially creating a new commercial market for debris removal systems.[55]

1.2: Global Debris Removal Efforts

In contrast to having specific governments and private companies spearhead ADR operations, a new international organization could be formed to undertake these efforts. Such an organization may resemble the former International Telecommunications Satellite Organization (ITSO), or INTELSAT. Before it was privatized in 2001, INTELSAT was an intergovernmental consortium that owned and managed a constellation of communications satellites that provided international broadcast services. Throughout the process of creating such an organization there would have to be preliminary demonstrations of debris removal capabilities. Moreover, an amendment to the Liability Convention would have to be made and agreed upon, since currently only designated launch states are liable for any accidents involving space objects. Any new organizations charged with ADR would have to be included in the convention to assign damages should an accident occur during the course of debris removal.[56]

In addition to these considerations, a number of other concerns arise when discussing the creation of a new international entity. First, it is difficult to create and fund a new international organization, and even more difficult to dismantle such organizations should the need arise in the future. Second, there are a wide range of space- and safety-related issues under consideration by the global space community that have not yet reached consensus. These include the regulatory and legal arrangements for the oversight of commercial space tourism, hypersonic travel, and radiation exposure and stratospheric pollution, amongst others. Current discussions between existing international organizations such as the International Civil Aviation Organization (ICAO), the International Telecommunications Union (ITU), the World Health Organization

[53] "ESA Commissions World's First Space Debris Removal," Space Safety, ESA, 9 December 2019, https://www.esa.int/Safety_Security/Clean_Space/ESA_commissions_world_s_first_space_debris_removal [accessed 16 June 2022].
[54] Pelton, *New Solutions for the Space Debris Problem,* 43.
[55] Pelton, *New Solutions for the Space Debris Problem,* 44.
[56] Pelton, *New Solutions for the Space Debris Problem*, 44-45.

(WHO), the World Meteorological Organization (WMO), and the United Nations Environmental Program (UNEP) have been exhaustive, so the idea of creating an additional international entity solely responsible for orbital debris removal seems unlikely. Finally, there is the question of mission effectiveness and whether such a new organization would have access to the right technology, research, tracking systems, and financial resources to undertake debris removal operations in the most cost-effective manner.[57]

While individual space-faring states have their own space debris-specific policies and have, in some cases, undertaken their own ADR activities, the sheer cost and complexity of debris removal lends itself well to cooperation, as is the case with the provision of most global public goods from which everyone benefits. To better understand the likelihood of such cooperation, the ESA in 2016 released a game theoretic analysis of space debris removal between two players, the EU and the US. While an ADR mission produces a positive effect, or risk reduction, for all satellites in the same orbital band, it leads to a significant dilemma: each actor has an incentive to delay its actions and wait for others to respond. States can choose to undertake an individually costly action, which has a positive impact on all players, or wait until another state jumps in to undertake the action and free-ride. Of course, since all players are incentivized to delay their actions, a tragedy of the commons results.[58] The simulation in the 2016 ESA report uses a normal-form game in which *n* players each have a set of actions from which to choose. Without any prior communication, each player selects an action and the resulting combinations of actions by all players (i.e., the joint action) determines the payoff to each. Each player is assumed to be rational, meaning they will always seek to play their best response in terms of individual payoff to the joint action of all remaining players. In the space debris removal dilemma, the players are space actors, their actions are debris removal strategies, and the payoffs are derived from removal costs and collision risks.[59] For the initial simulation, the analysis focuses on a two-player game between the EU (represented by the ESA) and the US (represented by NASA). In subsequent analysis, a third player—China—is incorporated. Within the simulation, the players' actions are defined by the number of debris objects that will be removed per year. In this game, players can choose to remove 0, 1, or 2 debris objects every two years. Each player decides on their strategy at the beginning of the game and cannot change it at a later point, thus producing a one-shot normal form game.[60] Unsurprisingly, the modelling demonstrates that each player prefers to wait for others to remove debris objects, but that when all players cooperate to remove debris objects, the debris environment remains relatively more stable given the decrease in the number of collisions and resulting debris.

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[57] Pelton, *New Solutions for the Space Debris Problem*, 45.
[58] Richard Klima et al., "Game Theoretic Analysis of the Space Debris Removal Dilemma," ESA, 1, https://www.esa.int/gsp/ACT/doc/ARI/ARI%20Study%20Report/ACT-RPT-AI-ARI-15-8401-ActiveDebrisRemoval.pdf [accessed 23 June 2022].
[59] Klima et al., "Game Theoretic Analysis of the Space Debris Removal Dilemma," 9.
[60] Klima et al., "Game Theoretic Analysis of the Space Debris Removal Dilemma," 10.

The fact that there have not been any significant developments to the canon of space law, no new space treaties, or any new international agreements related to space since the 1970s suggests that such a new international organization tasked with undertaking ADR operations may not be the most plausible option. This is further underlined by state actors' propensity to free-ride on the actions of others. Thus, the case for national governments acting in conjunction with private enterprise appears to be the more cost-effective and agile response to the ADR policy option.[61]

OPTION #2: Creation of a Space Debris Removal Fund

Pelton theorizes the creation of a space debris removal fund or a space debris insurance fund that operates similarly to current commercial space insurance protection against launch failures.[62] Such a fund may initially be created at the national, or regional level in the case of the EU, and operate parallel to technical demonstrations of ADR capabilities. Eventually, the fund may become universal and work in tandem with the aforementioned space-faring nations club. In theory, the creation of such a fund would work well with national governments and private enterprises undertaking ADR operations. The capital required to establish this fund would be collected prior to launches and follow a tiered model in which different orbits are charged different premiums. For example, the premium could be set to five per cent of the mission cost for GEO orbit, six per cent of the mission cost mission for MEO orbit, and seven per cent of the mission cost for a spacecraft launched into a Polar orbit or LEO.[63] Premiums would be collected over a period of 25 years with the understanding that if efforts for debris removal are successful within that period, the collection period could end prematurely in what Pelton refers to as the "sunset provision".[64] Further, rebates would be offered for "clean launches", which do not produce any debris, or when a satellite is successfully de-orbited back to Earth or sent into a graveyard orbit at its end of life. Payments into this fund would resemble the purchase of launch insurance for a space mission, and the fund could be administered by existing launch insurance companies,[65] such as Lloyd's of London, Munich Re, or Allianz Global Corporate and Speciality, amongst others. Similar to OUFs, this option levies a fee for the use of space that may incentivize states and other actors to more thoughtfully launch objects into orbit. It may also provide a long-term solution by collecting funds for future debris removal operations, as such a fund could seek to compensate those entities licensed under a regulatory framework for debris removal in LEO and beyond. The licensing process for entities designated to undertake debris removal, or even collision avoidance operations, could be formally assigned to UNOOSA or in time be assigned to a new international space regime.

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[61] Pelton, *New Solutions for the Space Debris Problem*, 45.
[62] Pelton, *New Solutions for the Space Debris Problem*, 46.
[63] Joseph N. Pelton, *Handbook of Cosmic Hazards and Planetary Defence* (Cham: Springer International Publishing, 2015), 868.
[64] Pelton, *Handbook of Cosmic Hazards and Planetary Defence*, 857.
[65] Pelton, *Handbook of Cosmic Hazards and Planetary Defence*, 858.

Additionally, other entities could be licensed by UNOOSA, or a future licensing entity, to undertake mitigation activities related to preventing the further creation of debris.[66]

In theory, the creation of such an economic fund mechanism would create a number of incentives, including rewards to launching states for clean launches; further rewards to operators for the proper removal of debris at the satellite's end of life; and the "sunset provision" creates a specific goal that space-faring nations can work towards. Moreover, this approach facilitates a competitive environment for the development of the best and most cost-effective technologies for active space debris removal.[67] Finally, the creation of such a fund and related rebate payments and sunset provision may work to reverse the current incentive that in some ways encourages the creation of orbital debris. Under the current space legal regime, owners and operators of space objects not only lack an incentive to remove their debris from orbit, but face substantial penalties, financial or otherwise, if the removal process results in adverse effects on other space objects covered under the Liability Convention.[68]

PART V: POSITIONS OF KEY STAKEHOLDERS AND GOVERNMENTS

Section i: Government Positions

Key space-faring actors, including the US, China, Russia, the EU, and Canada have made their positions against the growing problem of space debris clear in their domestic space policies, commissioned reports, and practices.

United States

The US in its *Outer Space Policy Directive-3* outlines in Section (3)(iii) that it will "Continue to develop and promote a range of norms of behavior, best practices, and standards for safe operations in space to minimize the space debris environment and promote data sharing and coordination of space activities,"[69] which lends itself well to the first mitigation policy option that calls upon space-faring states to adopt a collaborative and cooperative approach to addressing the space debris problem. Further, *Space Policy Directive-3* addresses the National Space Traffic Management Policy and outlines principles that the US recognizes and encourages other nations to recognize, the first of which states:

> *Safety, stability, and operational sustainability are foundational to space activities, including commercial, civil, and national security activities. It is a shared interest and responsibility of all spacefaring nations to create the conditions for a safe, stable, and operationally sustainable space environment.*

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[66] Pelton, *Handbook of Cosmic Hazards and Planetary Defence*, 858.
[67] Pelton, *Handbook of Cosmic Hazards and Planetary Defence*, 859.
[68] Pelton, *Handbook of Cosmic Hazards and Planetary Defence*, 858.
[69] "Space Policy Directive-3, National Space Traffic Management Policy," Infrastructure and Technology, Presidential Memoranda, 18 June 2018, https://trumpwhitehouse.archives.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/ [accessed 20 June 2022].

The Directive also outlines goals consistent with the principles aforementioned, guidelines in pursuit of these principles, roles and responsibilities in the furtherance of the aforementioned goals, and general provisions.[70]

NASA has also established a collection of standards, policies, and procedural requirements in three prominent publications, including the *NASA Handbook for Limiting Orbital Debris*, *Process for Limiting Orbital Debri*s, and *NASA Procedural Requirements for Limiting Orbital Debris and Evaluating the Meteoroid and Orbital Debris Environments*.[71] More recently, the Head of the US Delegation at the 61st Session of the COPUOS Legal Subcommittee underscored the US' commitment to preserving the space environment and the importance of engaging in debris removal.[72] The 2021 US Space Priority Framework lists a number of US space policy priorities, one of which is to "Foster a policy and regulatory environment that enables a competitive and burgeoning US commercial space sector".[73] Within this policy priority, orbital debris removal is listed as a non-governmental space activity for which the US is keen on providing authorization and supervision.[74] A second key priority listed in the Framework is the "[Prioritization of] space sustainability and planetary protection", for which the US plans to increase efforts to mitigate, track, and remediate space debris, in addition to advancing the development and implementation of domestic and international best practices to mitigate the creation of space debris.[75]

China

In 2021, the Chinese government released a white paper titled *China's Space Program: A 2021 Perspective* which outlines its space priorities. One of these priorities is the developing and testing of new space technologies, which includes new technology for the express purpose of the clean-up of space debris.[76] A second priority falls within the realm of space environment governance in which debris plays a significant role. Notably, China has applied upper stage passivation to all of its carrier rockets and has completed the end-of-life active de-orbit of the Tiangong-2 spacecraft, all of which are positive inroads for mitigating orbital debris. Further, in the next five years, China will seek to expand its system of space environment governance related to debris by improving its space debris monitoring system, cataloguing database, and early warning services; conducting in-orbit maintenance of spacecraft, collision avoidance and

[70] "Space Policy Directive-3, National Space Traffic Management Policy."

[71] Bill Keeter, "Space Debris," NASA Policies and Standards, NASA, 5 December 2018, https://www.nasa.gov/centers/hq/library/find/bibliographies/space_debris [accessed 20 June 2022].

[72] Emily Pierce, "2022 COPUOS LSC – US on Space Debris," US Mission to International Organizations in Vienna, 1 April 2022, https://vienna.usmission.gov/2022-copuos-lsc-space-debris/ [accessed 20 June 2022].

[73] "United States Space Priorities Framework," The White House, December 2021, 5, https://www.whitehouse.gov/wp-content/uploads/2021/12/United-States-Space-Priorities-Framework-_-December-1-2021.pdf [accessed 20 June 2022].

[74] "United States Space Priorities Framework," 5.

[75] "United States Space Priorities Framework," 7.

[76] "China's Space Program: A 2021 Perspective," The State Council Information Office of the People's Republic of China, China National Space Administration, January 2022, http://www.cnsa.gov.cn/english/n6465645/n6465648/c6813088/content.html [accessed 20 June 2022].

control; and space debris mitigation.[77] In addition to supporting the activities of such international organizations as the ITU, the IADC, and the International Space Exploration Coordination Group, it is also engaged in exchanges on space debris and long-term sustainability of outer space through mechanisms such as the Space Debris Work Group of China-Russia Space Cooperation Sub-Committee and the Sino-US Expert Workshop on Space Debris and Space Flight Safety.[78] Earlier this year, it was also reported that China appeared to have engaged in an ADR operation. In February 2022, ExoAnalytic Solutions, a private US-based company that tracks the position of satellites using a global network of optic telescopes, observed the Chinese SJ-21 satellite attaching itself to the decommissioned Compass-G2 (BeiDou-2 G2) satellite, altering its orbit, and eventually pushing it into a graveyard orbit.[79] Additionally, at the time of writing, China deployed a drag sail attached to a rocket component following a recent launch in an effort to de-orbit a piece of space debris. The 25-square-meter drag sail was onboard the Long March 2D rocket that was launched on 24 June 2022, and will assist with de-orbiting the rocket component in the next two years.[80] Such drag sails increase the surface area of the spacecraft to which they are attached, increasing the effects of atmospheric friction and consequently expediting the re-entry process back to Earth.

Russia

It is codified into Russian policy on space debris, pursuant to Section I Article 4 of its *Law on Space* that the harmful pollution of space leading to unfavourable environmental changes is prohibited. Russia also continues to independently adopt national mechanisms that abide by the UN and IADC *Space Debris Mitigation Guidelines* and has expressed that these guidelines are crucial to fostering cooperation and stability in space-related activities.[81] Further, Russia has drafted the National Standard “General Requirements on Space Systems for the Mitigation of Human-Produced near-Earth Space Pollution” which entered into force in 2009.[82] These measures further lend themselves to mitigation policy options, and suggests a willingness to consider other policy options of both a mitigation and remedial nature. Russia maintains a number of national mechanisms to assist in its debris mitigation standards. In terms of federal legislation, Russian maintains:

1. The Russian Federation Law “On Space Activity” dated 20 August 1993;
2. The Russian Federation Federal Law “On the State Corporation for Space Activities ROSCOSMOS” dated 13 July 2015; and

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[77] “China’s Space Program: A 2021 Perspective.”

[78] “China’s Space Program: A 2021 Perspective.”

[79] Esteban Pardo, “Chinese ‘Space Cleaner’ Spotted Grabbing and Throwing Away Old Satellite,” *Deutsche Welle*, 9 February 2022, https://www.dw.com/en/chinese-space-cleaner-spotted-grabbing-and-throwing-away-old-satellite/a-60658574 [accessed 20 June 2022].

[80] Andrew Jones, “China Deploys Deorbiting ‘Drag Sail’ to Aid Fight Against Space Junk,” *Space.com*, 11 July 2022, https://www.space.com/china-deploys-drag-sail-space-junk [accessed 13 July 2022].

[81] Yu Makarov et al., “Activity of Russian Federation on Space Debris Problem,” 54th Session of the Committee on the Peaceful Uses of Outer Space, Russian Federal Space Agency, 2011, https://www.unoosa.org/pdf/pres/copuos2011/tech-33.pdf [accessed 20 June 2022].

[82] Makarov et al., “Activity of Russian Federation on Space Debris Problem.”

3. The Russian Federation Federal Law “On Standardization in the Russian Federation” dated 29 June 2015.[83]

In terms of strategic planning documents on space activity, Russia maintains: *Federal Space Program of Russia for 2016-2025* and *Fundamentals of the Russian Federation’s State Policy in the Field of Space Activities for the Period up to 2030 and Beyond*.[84] Finally, in terms of standard technical documentation, Russia maintains “Space Technology Items: General Requirements for Space Vehicles for Near-Earth Space Debris Mitigation”.[85] All of these documents have provisions related to space debris. Notably, subparagraph D of paragraph 19 of Section VIII of the *Fundamentals* document states that one of the tasks on the provision of safe space activities is to ensure the environmental safety of space activities, and the adoption of technologies and designs that reduce space debris at launch and during operation of rockets and space equipment.[86]

While the mitigation of space debris features heavily in Russian space law and national legislation related to space, recent actions call to question the sanctity of such assertions. Notably, the November 2021 ASAT missile launch that destroyed that defunct Kosmos 1408 satellite, which threatened the lives of the crew of the ISS and produced an estimated 1,500 new pieces of orbital debris.[87]

European Union

The EU maintains a robust space policy and in April 2021 announced the adoption of a regulation establishing the new EU Space Programme for 2021-2027.[88] A key pillar to the EU’s policy on space debris specifically is the 2004 European Code of Conduct for Space Debris Mitigation, whose primary objectives are the prevention of on-orbit break-ups and collisions; the removal and subsequent disposal of spacecraft and orbital stages that have reached the end-of-mission operations from the useful densely populated orbit regions; and the limitation of objects released during normal operations.[89] At the 64th session of COPUOS in late-summer 2021, the EU revealed that its Space Surveillance and Tracking framework (EU-SST) would be evolving into a fully-fledged program as part of the Space and Situational Awareness (SSA) component of the recently-announced EU Space Programme and will extend its services to users beyond Europe. It was also stated that the upcoming EU-SST partnership has plans to

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[83] “Russian Federation National Mechanism,” Space Debris Mitigation Standards, UNOOSA, accessed 20 June 2022, https://www.unoosa.org/documents/pdf/spacelaw/sd/RF.pdf.
[84] “Russian Federation National Mechanism.”
[85] “Russian Federation National Mechanism.”
[86] “Russian Federation National Mechanism.”
[87] Tariq Malik, “International Space Station Dodges Orbital Debris from Russian Anti-Satellite Test,” *Space.com*, 20 June 2022, https://www.space.com/space-station-dodges-russian-satellite-debris [accessed 20 June 2022].
[88] “EU Space Programme 2021-2027,” EU Space Policy, Council of the European Union, accessed 22 June 2022, https://www.consilium.europa.eu/en/policies/eu-space-programme/.
[89] “European Code of Conduct for Space Debris Mitigation.”

"develop activities in preparation of future space safety services, in the realm of space debris mitigation and remediation".[90]

In addition to policy, the EU has also made concrete inroads to actively mitigate and remediate the debris situation. In 2019, it funded the REDSHIFT Project, which worked to develop new space debris mitigation guidelines and a web-based tool to protect people from debris re-entering Earth's atmosphere.[91] The EU, through the ESA, has also teamed up with the Swiss startup, ClearSpace, to launch the ClearSpace-1 mission in 2025-2026 that will clean-up a now-defunct payload adapter from its 2013 Vega rocket launch.[92] Previously, the EU funded a mission called RemoveDEBRIS in partnership with the University of Surrey in 2018 to test a harpoon and net contraption to target small debris objects.[93] While the upcoming ClearSpace-1 mission is set to clean a relatively small piece of debris (the adapter weighs just over 100 kilograms), ClearSpace has intentions to eventually scale up operations to remove larger pieces of debris.[94]

Canada

While a comparatively smaller space-faring power, Canada also recognizes the threat that space debris poses to its own spacecraft and space missions in which it participates. Canada maintains three key national mechanisms related to space debris: the Canadian Remote Sensing Space Systems Regulations of 2007, and the corresponding legal framework, *Canadian Remote Sensing Space Systems Act, 2005 (amended 2007)*; the Canadian Space Agency's (CSA) adoptions of the IADC *Space Debris Mitigation Guidelines* in 2012; and the Canadian Client Procedures Circular (CPC) for Licensing of Space Stations in 2014.[95] Pursuant to the *Remote Sensing Space Systems Act*, no person in Canada shall operate a remote sensing space system in any manner, directly or indirectly, except under the authority of a License. Further, such a License will not be issued unless a "system disposal plan" is provided. The requirements to be identified within such a disposal plan are:

a) Method of disposal that is proposed for each satellite and the reliability of that method;
b) Estimated duration of the satellite disposal operation;
c) Probability of loss of human life and how it was calculated;

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[90] "EU Statement at the 64th Session of the Committee on the Peaceful Uses of Outer Space," European Union, UNOOSA, 2021, 7, https://www.unoosa.org/documents/pdf/copuos/2021/statements/item_4_European_Union_ver.1_25_Aug_AM.pdf [accessed 22 June 2022].

[91] "Addressing the Danger of Space Debris," Success Stories, European Commission, 3 June 2019, https://ec.europa.eu/research-and-innovation/en/projects/success-stories/all/addressing-danger-space-debris [accessed 22 June 2022].

[92] Daniel Clery, "Europe Plans Space Claw to Capture Orbiting Junk," Science Insider, *Science.org*, 1 December 2020, https://www.science.org/content/article/europe-plans-space-claw-capture-orbiting-junk [accessed 22 June 2022].

[93] Clery, "Europe Plans Space Claw to Capture Orbiting Junk."

[94] Clery, "Europe Plans Space Claw to Capture Orbiting Junk."

[95] "Canada National Mechanism," Space Debris Mitigation Standards, UNOOSA, accessed 22 June 2022, https://www.unoosa.org/documents/pdf/spacelaw/sd/Canada.pdf.

d) Amount of debris expected to reach the surface of Earth, the size of the impact area expressed in square metres, and how they were calculated;
e) Confidence level of the determination of the boundaries and how the boundaries and confidence level were calculated;
f) Identity and quantity of hazardous material and dangerous goods contained in each satellite at the end of its mission life, the quantity expected to reach the surface of the Earth on re-entry and how the quantities were calculated;
g) Orbital elements and epochs of the proposed disposal orbits for each satellite;
h) An assessment of space debris expected to be released from each satellite during normal operations by explosions, by intentional break-ups and by on-orbit collisions, and the measures proposed to mitigate the production of space debris.[96]

The Act and its regulations are mandatory in Canada and are applicable to Canadian citizens, permanent residents, corporations that are incorporated or continued under the laws of Canada or a province, and to members of any prescribed class of persons having a substantial connection to Canada related to remote sensing space systems.[97] Additionally, in regards to the adoption of the IADC *Space Debris Mitigation Guidelines*, they are applicable to all CSA projects, missions, and activities.[98]

Finally, Section 3.3.3 Space Debris Mitigation Plan of the CPC 2-6-02—Licensing of Space Stations (satellites) requires that all applicants for space station spectrum and radio licenses submit a Space Debris Mitigation Plan as part of their applications. For geostationary satellites, the applicant must submit a plan for de-orbiting their satellite(s) in compliance with the International Telecommunications Union (ITU)—R S.1003-2 *Environmental Protection of the Geostationary Orbit*. For non-geostationary satellites, the applicant must submit a plan for de-orbiting their satellite(s) in accordance with best industry practices.[99]

Section iii: Private Enterprise Developments

In addition to state-level space debris policies and practices, there is an increasing number of private enterprise around the globe undertaking activities—ADR and otherwise—in this realm. The following list outlines a sample of commercial efforts from key space-faring states that are both publicly- and privately-funded. This list is not exhaustive and it should be noted that as the space debris problem grows, so too will the number of solutions generated by the private sector.

Rogue Space Systems Corporation – United States

Rogue Space Systems designs satellite vehicles and subsystems to provide on-orbit services to satellite operators. It is currently designing a fleet of orbital robots ("orbots"), one class of which will be used for transport and capture. This class of robots, called

[96] "Canada National Mechanism."
[97] "Canada National Mechanism."
[98] "Canada National Mechanism."
[99] "Canada National Mechanism."

"Fred", will be able to move satellites and other assets to and from different orbits.[100] In terms of funding, Rogue Space Systems has had 11 of its 13 Small Business Technology Transfer (STTR) Phase I proposals selected for up to $2.75 million USD in funding through the SpaceWERX Orbital Prime initiative by the US Space Force.[101]

NorthStar Earth & Space – Canada

NorthStar Earth & Space is currently building a 12-satellite constellation in partnership with Thales Alenia Space and LeoStella to provide the world's first space-based space traffic management platform called Skylark. Through a subscription, pay-for-use model, the service will alert users to potential collisions between satellites, both operational and defunct, and other large pieces of debris.[102] Once operational, Skylark will be able to provide users with a space object catalogue, space object tracking and identification, collision avoidance, on-orbit support, launch support, de-orbit support, event detection, and modelling and simulation services.[103] In terms of funding, NorthStar Earth & Space is funded largely by The Luxembourg Future Fund (LFF) and Telesystem Space. In December 2021, the LFF joined a $45 million USD investment round to help fund NorthStar's Skylark constellation and to help the company establish its European headquarters in Luxembourg.[104] The LFF co-invested €10 million in the project, with the Luxembourg government set to provide funding through the national space program LuxIMPULSE managed by the Luxembourg Space Agency (LSA).[105] The Canadian government also invested $13 million CAD into NorthStar Earth & Space in 2018.[106]

ClearSpace – Europe (Switzerland and UK)

ClearSpace seeks to provide in-orbit servicing and space debris removal services, and is currently working with the ESA and the UK Space Agency to launch ADR missions.[107] ClearSpace-1, in partnership with the ESA, is set to be the world's first debris removal

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[100] "Fred Transport, Capture and Robotics," Rogue's Orbital Robots—Orbots, Rogue Space Systems Corporation, accessed 27 June 2022, https://rogue.space/orbots/.

[101] "Rogue Space Systems Wins 12 United States Space Force SpaceWERX STTR Phase I Selections," Rogue Space Systems Press Releases, Rogues Space Systems Corporation, 9 May 2022, https://rogue.space/news/1135/rogue-space-systems-wins-13-united-states-space-force-spacewerx-sttr-phase-i-selections/ [accessed 27 June 2022].

[102] Stuart Clark, "NorthStar Satellite System to Monitor Threat of Space Debris, Spacewatch, *The Guardian*, 29 October 2020, https://www.theguardian.com/science/2020/oct/29/northstar-satellite-system-monitor-threat-space-debris [accessed 27 June 2022].

[103] "Congestion in Space is a Clear and Present Danger to All Satellites," NorthStar Earth & Space, accessed 27 June 2022, https://northstar-data.com/space/.

[104] Jason Rainbow, "NorthStar Expanding to Luxembourg After $45 Million Funding Round," *Space News*, 23 December 2021, https://spacenews.com/northstar-expanding-to-luxembourg-after-45-million-funding-round/ [accessed 27 June 2022].

[105] "Clean, Secure and Equitable Access to Space," NorthStar Earth & Space, 16 December 2021, https://northstar-data.com/luxembourg-invests-in-northstar-earth-space-that-establishes-its-european-headquarters-in-the-grand-duchy-to-support-sustainable-space-activities/ [accessed 27 June 2022].

[106] "Government of Canada Invests in Innovative Satellite Technology Start-Up," News Release, Innovation, Science and Economic Development Canada, 15 November 2018,https://www.canada.ca/en/innovation-science-economic-development/news/2018/11/government-of-canada-invests-in-innovative-satellite-technology-start-up.html [accessed 13 July 2022].

[107] "About," ClearSpace Today, ClearSpace, accessed 27 June 2022, https://clearspace.today/about-clearspace/.

mission and is set to launch in 2025-2026,[108] using a four-armed claw-like robot to capture the Vega Secondary Payload Adapter (Vespa), which was left behind by the ESA's Vega launcher in 2013. The adapter is currently located approximately 800 kilometers above Earth and weighs about 100 kilograms.[109] In terms of funding, The ESA signed a €86 million contract with ClearSpace for the ClearSpace-1 mission in 2020,[110] and in 2021, ClearSpace secured an additional CHF 4 million from Swiss venture capitalist funds.[111]

Astroscale – Japan

Astroscale seeks to offer scalable on-orbit servicing solutions including life extension, *in situ* space situational awareness, end-of-life, and ADR. It is also working with government and commercial stakeholders to develop norms, regulations, and incentives for the responsible use of space.[112] In August 2021, Astroscale successfully demonstrated its End-of-Life Services by Astroscale-demonstration (ELSA-d), which is able to capture a client's spacecraft using a magnetic capture system. This successful demonstration was significant, as one of the primary challenges of ADR, and of on-orbit servicing in general, is the docking or capturing of an object.[113] Further, the Japan Aerospace Exploration Agency (JAXA) has partnered with Astroscale and will use Astroscale's Active Debris Removal by Astroscale-Japan (ADRAS-J) satellite for Phase I of its Commercial Removal of Debris Demonstration project (CRD2), which is set to launch in 2023. Phase I will be a precursor to a future ADR mission.[114] By the end of 2021, Astroscale had raised $300 million USD in capital from a broad range of global investors and venture capital funds, positioning it as the market leader in satellite servicing and long-term orbital sustainability in all orbits.[115] In May 2022, Astroscale announced that it had secured €15 million in funding from the ESA for a 2024 demonstration mission to remove a defunct OneWeb satellite.[116]

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[108] "ClearSpace-1," Space Safety, ESA, accessed 27 June 2022, https://www.esa.int/Safety_Security/ClearSpace-1.

[109] Samantha Matthewson, "ESA Partners with Startup to Launch First Debris Removal Mission in 2025," Spaceflight, *Space.com*, 16 May 2021, https://www.space.com/esa-startup-clearspace-debris-removal-2025 [accessed 27 June 2022].

[110] "ESA Purchases World-First Debris Removal Mission from Start-Up," Space Safety, ESA, 1 December 2020, https://www.esa.int/Safety_Security/ESA_purchases_world-first_debris_removal_mission_from_start-up [accessed 29 June 2022].

[111] Pierre-Yves Oehrli, "ClearSpace's Robot Cleaner Raises CHF 4 Million, *Switzerland Global Enterprise*, 7 July 2021, https://www.s-ge.com/en/article/news/20213-aerospace-clearspaces-robot-cleaner-raises-chf-4-million [accessed 29 June 2022].

[112] "About Astroscale," Astroscale, accessed 29 June 2022, https://astroscale.com/about-astroscale/about/.

[113] "Astroscale's ELSA-d Successfully Demonstrates Repeated Magnetic Capture," News & Resources, Astroscale, 25 August 2021, https://astroscale.com/astroscales-elsa-d-successfully-demonstrates-repeated-magnetic-capture/ [accessed 29 June 2022].

[114] "Active Debris Removal (ADR)," Services, Astroscale, accessed 29 June 2022, https://astroscale.com/services/active-debris-removal-adr/.

[115] "Astroscale Closes its Largest Funding Round to Date, Bringing Total Capital Raised to US $300 Million," Press Releases & Updates, Astroscale, 25 November 2021, https://astroscale.com/astroscale-closes-its-largest-funding-round-to-date-bringing-total-capital-raised-to-u-s-300-million/ [accessed 29 June 2022].

[116] Jason Rainbow, "Astroscale Gets Funds for 2024 Debris-Removal Mission," *Space News*, 27 May 2022, https://spacenews.com/astroscale-gets-funds-for-2024-debris-removal-mission/ [accessed 29 June 2022].

PART VI: CANADA-EU CONSIDERATIONS

Canada and the EU have a long and productive history of cooperation in the space sector, which began in the early-1970s with the joint development of the Communications Technology Satellite. Formal cooperation began in 1979 with the signing of the first Cooperation Agreement between the CSA and the ESA. This agreement has since been renewed five times, most recently in 2019, allowing Canada to contribute to ESA programs as a participating state and solidifying cooperation between the two agencies. Canada and the EU have made notable advancements in telecommunications, through Olympus, Artemis, and Advanced Research in Telecommunications Systems (ARTES); in Earth observation, through ERS, Envisat, and Global Monitoring for Environment and Security (GMES); in navigation, through Galileo; and in related technologies, through the General Support Technology Program.[117] The most recent Cooperation Agreement between the CSA and ESA will be in force until 2030 and supports the following objectives:

- Foster innovation and competitiveness by exposing companies from the Canadian space sector to ESA activities and programs dedicated to developing space applications, technologies, and systems.
- Maintain or increase the ability of the Canadian space sector to successfully contribute to Canadian space initiatives by providing access to ESA flight opportunities.
- Facilitate access to European space contracts and international public and private space contracts, if applicable.
- Keep abreast of European space policy directions and Europe's technological, scientific, programmatic, and commercial space environments to better guide the CSA's strategic planning process.[118]

The Canada-EU partnership in space extends beyond good cooperation and has seen the creation of strong alliances, teaming arrangements, and opportunities for new markets. The ESA and CSA are two of the five partners of the ISS, and key players in the International Charter on Space and Major Disasters, the Committee on Earth Observation Satellites (CEOS), and Global Earth Observation System of Systems (GEOSS).[119] The CSA and ESA were also key partners, alongside NASA, in the construction and launch of the James Webb Space Telescope, and both are key stakeholders in the upcoming Artemis Missions. Further, in May 2022, the CSA and European Commission signed the Copernicus Arrangement. Copernicus is the EU's Earth Observation program, and the aim of the Copernicus Arrangement is to share satellite Earth

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[117] "ESA and Canada Renew Partnership in Space Science and Technology," Agency Corporate News, ESA, 15 December 2010, https://www.esa.int/About_Us/Corporate_news/ESA_and_Canada_renew_partnership_in_space_science_and_technology [accessed 5 July 2022].

[118] "Canada-European Space Agency Cooperation Agreement," CSA, Government of Canada, last modified 23 October 2019, https://www.asc-csa.gc.ca/eng/funding-programs/canada-esa/about-cooperation-agreement.asp [accessed 5 July 2022].

[119] "ESA and Canada Renew Partnership in Space Science and Technology."

Observation data with one another. Access to Canadian space systems means Copernicus services will be more precise, and the Arrangement will more broadly reinforce cooperation between Canada and the EU, especially in the Arctic region and on climate action.[120] Canada is also an associated member of the European Cooperation for Space Standardization, which is an initiative to develop a coherent single set of standards for use in all European space activities.[121]

In a joint statement of Canada and the EU at the 2021 Canada-EU Summit in Brussels, Prime Minister Justin Trudeau reinforced the importance of cooperation in space with the EU: "We will continue to strengthen our space cooperation, including on satellite navigation services and applications, the exchange of Earth observation data, and responsible behaviours to ensure safety, security and sustainability in space in the UN and other multilateral settings, as well as consider new areas of cooperation."[122] In this vein, there are numerous opportunities for Canada and the EU to expand and strengthen their cooperation in the space sector by jointly confronting the growing problem of space debris. Inroads to such cooperation have already begun in the private sector following the partnership of Canada's NorthStar Earth & Space with the Franco-Italian aerospace manufacturer Thales Alenia Space in the construction of the Skylark satellite system (as discussed in Part V, Section iii above).

Since Canada's foray into the space arena with the launch of Alouette-I in 1962, it has established itself as a capable and technologically adept space-faring power. The Canadian satellite, NEOSSat, for example, is the world's first space telescope dedicated to detecting and tracking asteroids, comets, satellites, and space debris. Completing an Earth orbit every 100 minutes, NEOSSat observes satellites and debris as part of Canada's commitment to keeping the space environment safe for both Canadian and international space assets.[123] Canada's technological expertise combined with the EU's normative power may prove to be a winning combination in addressing the space debris problem through various avenues including:

- The reinforcement of norm building with adherence to existing treaties and guidelines, such as the OST, the Guidelines for the Long-Term Sustainability of Outer Space Activities, and the *Space Debris Mitigation Guidelines*.
- The pursuit of transparency and confidence-building measures through the exchange of information. Such exchanges could include the publication of national policies related to space and space debris, registration of space objects with the UN, and the advance notification of launches in accordance with the Hague Code of Conduct.

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[120] "Signature of a Copernicus Arrangement Between the Canadian Space Agency and the European Commission," Defence Industry and Space, European Commission, 16 May 2022, https://defence-industry-space.ec.europa.eu/signature-copernicus-arrangement-between-canadian-space-agency-and-european-commission-2022-05-16_en [accessed 5 July 2022].
[121] "Members," Organization, European Cooperation for Space Standardization, accessed 5 July 2022, https://ecss.nl/organization/members/.
[122] "Canada-European Union Summit—Joint Statement," Prime Minister of Canada Justin Trudeau, Government of Canada, 15 June 2021, https://pm.gc.ca/en/news/backgrounders/2021/06/15/canada-european-union-summit-joint-statement [accessed 5 July 2022].
[123] "NEOSSat: Observing Asteroids, Space Debris and Exoplanets," CSA, Government of Canada, last modified 23 June 2022, https://www.asc-csa.gc.ca/eng/satellites/neossat/ [accessed 5 July 2022].

- The recognition of the importance of verification to international peace and security, in which space domain awareness (SDA) and space surveillance and tracking (SST) are important components of verification.
- The expansion of existing expertise, which may come from the work of COPUOS and the IADC, as well as examining the development of norms and principles of responsible behaviour in other related fields, such as maritime and cyberspace, for the development of comparable norms for the space domain.[124]

PART VII: CONCLUSION & POLICY RECOMMENDATIONS

In much the same way that the first century of Canada's statehood was marked by innovation in rail and telegraphy, the second century of its statehood has been characterized by progress in outer space. Canada has remained a key player in the space arena since the establishment of COPUOS in 1959, and was the third nation in space with the launch of its first satellite, the Alouette-I, in 1962.[125] Today, Canada is one of five international partners in the ISS and a key contributor to the upcoming lunar and Mars exploration missions in partnership with NASA and the ESA.[126] This early and sustained involvement in space has enabled Canada to become a leader in both the commercial manufacture of spacecraft components, and the political sponsorship of outer space codes of conduct, norms, and legal obligations pursuant to the five outer space treaties in existence. As Canada and other space-faring nations ramp up their activities in space, it behooves Canada to forge and maintain partnerships with like-minded allies in the space realm. Indeed, as a middle power, it is in Canada's best interest to insert itself in the future of space rather than let this task fall to greater powers. As the northern neighbour of the world's superpower and space hegemon, Canada undoubtedly depends upon a rules-based international system that eschews unilateral manoeuvres. Understanding this, the following is a list of potential policy recommendations that Canadian leadership may consider.

1. **Formalize and endorse its stance on the space debris problem**
   While Canada's space policy document, *Exploration, Imagination, Innovation*, advocates for a "vibrant and sustainable space sector"[127] it makes no explicit mention of space debris or what Canada's official position is on this problem. In contrast, a number of Canada's allies including the EU, the US, and Japan—as discussed in preceding sections—have formalized their positions on the topic of space debris and have actively made inroads both politically and operationally to confront the problem. In order to keep pace and promote cooperation with its allies, Canada should consider issuing an addendum to *Exploration, Imagination, Innovation* or a separate policy document that outlines its

[124] "Canada's Views on Reducing Space Threats Through Norms, Rules and Principles of Responsible Behaviour," United Nation Office for Disarmament Affairs, Government of Canada, accessed 5 July 2022, https://documents.unoda.org/wp-content/uploads/2022/05/EN-Canada-working-Paper-on-Norms-75-36.pdf.
[125] Sylvain Laporte, "Canada UNISPACE+50 Statement," UNOOSA, June 2018, 3, https://www.unoosa.org/documents/pdf/copuos/2018/hls/04_05EF.pdf [accessed 13 July 2022].
[126] Laporte, "Canada UNISPACE+50 Statement," 3.
[127] "Exploration, Imagination, Innovation: A New Space Strategy for Canada," CSA, Government of Canada, 2019, 9, https://www.asc-csa.gc.ca/pdf/eng/publications/space-strategy-for-canada.pdf [accessed 13 July 2022].

stance on space debris. Ideally, such a stance would align with that of our allies, recognizing the threat that space debris poses to active spacecraft, human life, and Earth-based assets, and support pro-remediation and mitigation efforts to address the problem. The prohibitively high transaction costs of space operations prohibits Canada from operating unilaterally in this domain. Therefore, by making its position on the space debris problem clear, Canada can position itself as a partner and facilitator to space debris remediation and mitigation activities, entrenching itself as a responsible and steadfast space-faring actor.

2. **Increase participation in multilateral space debris remediation and mitigation efforts**
   As a founding member of COPUOS and an influential presence in the creation of the IADC's *Space Debris Mitigation Guidelines*, Canada has a long and productive history working within the organizations and agencies currently in place to deal with the space debris problem. Canada has also carved out a niche for itself within the space domain as a technological leader, and could engage in global space debris remediation and mitigation efforts through the provision of SSA data using its NEOSSat and Sapphire satellites. Canada may also work to strengthen the international legal regime on space debris action. By working with like-minded actors, such as the EU, Canada may find itself in a position of coalition building to strengthen the current space legal regime, including the various space treaties and principles, and the *Space Debris Mitigation Guidelines*. One such opportunity for strengthening exists within the Registration Convention. In its current form, Article IV(2) of the Registration Convention permits launch states to provide additional details on registered objects in orbit.[128] As such, through a coalition of like-minded states, Canada could push for the modification of Article IV to have states indicate objects that are available for salvage or removal. This would then permit states or commercial actors to de-orbit the object and return it back to the launch state or propel it into a graveyard orbit. Such coalition building and increased participation in multilateral space debris activities has the potential to pave the way for the creation of a space-faring nations club, as discussed in Part IV, Section i.

3. **Develop and contribute to a space debris economic fund mechanism**
   As outlined above in Option #2 of Part IV, Section ii, Canada may consider becoming one of the first nations to establish and actively contribute to a space debris economic fund mechanism. As Pelton suggests, these funds should ideally start at the national or regional level to levy a cost for the use of space that may incentivize states and other actors to more thoughtfully launch objects into orbit. It may also provide a long-term solution by collecting funds for future debris removal operations, as such a fund could seek to compensate those entities licensed under a regulatory framework for debris removal in LEO and beyond. Canada, through the Department of Finance, Innovation, Sciences and Economic Development (ISED), and DG Space through the Department of National Defence, could work to develop its own national-level fund or work with the US through bilateral arrangements to develop a regional fund. The Canadian space

[128] "3235 (XXIX) Convention of Registration of Objects Launched into Outer Space."

transport services company, Maritime Launch Services, already uses the US-based launch insurance provider, XL Catlin,[129] lending support for bilateral cooperation between Canada and the US for the purposes of establishing such a fund mechanism. Further, given its productive working relationship with the ESA, Canada may also be able to broker dialogue between itself, the US, and the EU to promote transatlantic cooperation in the development of an inter-regional economic fund. This would undoubtedly strengthen Canada-EU relations in the space sector and underscore Canada's commitment to international cooperation and the construction of a rules-based international regime.

4. **Increase investment and engagement with the private sector**
   Despite increased efforts on the part of national space agencies, it appears that the most significant inroads are being made by the private sector, and through public-private partnerships, to combat the growing space debris problem. ADR technologies have been developed expeditiously in the private sector, such as Rogue Space Systems Corporation's "orbots", NorthStar Earth & Space's Skylark constellation, ClearSpace's four-armed robotic claw, and Astroscale's ELSA-d's magnetic capture system and ADRAS-J satellite, largely given the growing space and LEO economies. Indeed, many of Canada's allies such as the ESA and JAXA have increased their partnerships with private sector actors as evidenced by the upcoming ClearSpace-1 mission and Commercial Removal of Debris Demonstration project (CRD2), respectively. While Canada continues to support the work of NorthStar Earth & Space through ISED funding, it would behoove Canada to increase investment in the private sector to stimulate innovation and development of ADR technologies and other space debris solutions. In March 2022, nine Canadian space companies established Space Canada, a national industry association whose mandate is to position Canada at the forefront of the global space economy.[130] The nine founding members include Calian, GHGSat, Magellan Aerospace, Maritime Launch Services, MDA, Mission Control, NorthStar Earth & Space, SpaceBridge, and Telesat. However, the association is seeking to expand to include the full breadth of Canadian space companies and associated firms. This new association presents a host of partnership opportunities for the CSA and the Canadian government, the first of which is the association's call for the government to create a National Space Council akin to those in the US and the UK.[131] An increase in investment and engagement with the private sector would allow Canada to keep pace with the actions of its allies and their cooperation with commercial actors.

Undoubtedly, the sustainability of LEO and successive orbital bands will depend upon our collective stewardship of this increasingly fragile environment. While space-based assets have

[129] Will Koblensky, "Covering Canada's First Spaceport," *Insurance Business Canada*, 28 March 2017, https://www.insurancebusinessmag.com/ca/news/breaking-news/covering-canadas-first-spaceport-63848.aspx [accessed 13 July 2022].
[130] "About Us," Space Canada, accessed 13 July 2022, https://space-canada.ca/team.
[131] "Nine Canadian Space Companies Create the Space Canada Association," *SatNews*, 20 March 2022, https://news.satnews.com/2022/03/20/nine-canadian-space-companies-create-the-space-canada-organization/ [accessed 13 July 2022].

become vital to daily life in their provision of data and services for private, commercial, military, and academic use, we need to be mindful that the debris generated by now-defunct spacecraft threatens these very assets we have become so dependent upon. While mitigation efforts have seen some success, through adherence to the UN and IADC *Space Debris Mitigation Guidelines*, it is clear that ADR efforts to clean-up LEO are crucial to preserving the functional integrity of this global commons. While inter-state cooperation presents its challenges, both financial and political, inroads made in the commercial sector through public-private partnerships have been encouraging. Amongst the world's space-faring powers, the EU in particular has made meaningful progress in confronting the problem of space debris. In addition to mandating responsible norms of behaviour in space, including launch activity, the EU through the ESA is prepared to embark upon the world's first ADR mission in the coming years. Despite this progress, there is much work to be done. Canada, as a leading technological space power, is well poised to strengthen its partnerships with like-minded space allies, such as the EU, and facilitate a number of Earth- and space-based solutions to the debris problem. Indeed, given the prohibitively high transaction costs of operating in space, such cooperation will be necessary to operate within this new domain. Our preservation and maintenance of LEO is not simply a question of morality but is vital to our existence here on Earth. The realization of the Kessler Syndrome in which the debris environment reaches a critical mass poses grave danger to both human life, including those aboard the ISS or any other spacecraft, and the functional integrity of the systems that we all critically depend upon here on Earth. There are a number of policy options available to Canada and its allies that should be considered if we are to maintain the integrity of LEO and ensure that it is not the final frontier in our collective exploration of the cosmos.

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