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From Space Debris to Space Weaponry: A Legal Examination of Space Debris as a Weapon

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Abstract: Outer space represents an emerging and rapidly evolving domain that, until now, has remained free from armed conflicts. However, the stark reality is that the prospect of an arms race in space is no longer confined to dystopian imagination. This change in the environmental factual circumstances is substantiated by NATO's formal recognition of space as an operational domain and the renewed calls for a Treaty to Prevent an Arms Race in Space. Additionally, the symbolic characterization of space as the 'final frontier', as numerous scholars have described it, highlights the urgent need for analysis of the potential weaponization of the outer space domain.

Various potential weapons could be deployed in outer space. However, the primary objective of this paper is to investigate whether space debris in the highly commercialized and overpopulated Low Earth Orbit (LEO) could be weaponized. The example we focus on relates to the Kessler Syndrome and space debris generated by the use of (cyber) weapons.

The central message of this paper is that the potential triggering of Kessler Syndrome by creating space debris using space weapons should be considered an internationally wrongful act. Therefore, it should be taken into account during weapons reviews under Article 36 of Additional Protocol I to the Geneva Conventions (AP I). Moreover, the paper concludes that, in the context of the examined scenario and the rise of private entities within the space sector, it is also necessary to re-evaluate the legal framework regarding liability and responsibility in outer space as it relates to the triggering of the Kessler Syndrome.

Keywords: *space debris, weapon, outer space, liability, responsibility, Article 36 of Additional Protocol I*

1. INTRODUCTION

Outer space is garnering increasing attention as an operational domain. While the inherently curious nature of humanity is sometimes claimed to be the main driver for this, it is not the only one. Projection of power and spin-off technologies played a role in the past. Today, the increasing opportunities for commercial exploitation are also a factor. Space has become indispensable to the modern way of life.

Remarkably, since humanity's first venture into outer space in 1961, no active armed conflicts have occurred in this domain. The emphasis on peaceful activities in outer space within the Outer Space Treaty (OST) – the primary international law concerning space – has stood for almost 60 years.[1] However, terrestrial conflicts can extend into space, and the supposedly tranquil nature of the domain is slowly changing.[2]

Satellite infrastructure played a pivotal role in the early stages of Russia's blatantly unlawful full-scale invasion of Ukraine, manifesting in the cyber attack against the KA-SAT network in February 2022, which negatively impacted the situational awareness and communication capacities of the Ukrainian army and, thus, conferred an advantage to the Russian Federation.[3] Successful tests of kinetic anti-satellite

1 The OST has been in force since 1967. See Christopher Daniel Johnson, 'The Outer Space Treaty' *Oxford Research Encyclopedia of Planetary Science* (2018) <https://oxfordre.com/planetaryscience/display/10.1093/acrefore/9780190647926.001.0001/acrefore-9780190647926-e-43> accessed 13 March 2024.

2 Steven Freeland, 'The Peaceful Use of Outer Space: Protecting Life on Earth' (2023) Digital War <https://doi.org/10.1057/s42984-023-00065-w> accessed 13 March 2024.

3 'KA-SAT Network Cyber Attack Overview' (*Viasat*) <www.viasat.com/about/newsroom/blog/ka-sat-network-cyber-attack-overview/> accessed 10 May 2022; 'Case Study: Viasat Attack' (*Cyber Peace Institute*) <https://cyberconflicts.cyberpeaceinstitute.org/law-and-policy/cases/viasat> accessed 31 May 2023.

weapons (ASATs) carried out by China,[4] India,[5] and Russia[6] over the past few years are further demonstrations of the abovementioned changing dynamic.

Further evidence of the transformation discussed here can be found in official statements, international legal documents, and national space defence strategies that reflect these developments. Notably, the international community increasingly engages in discussions on outer space security and its implications in other areas. The United Nations General Assembly's First Committee on Disarmament and International Security adopted a resolution in November 2021 titled 'Reducing space threats through norms, rules and principles of responsible behaviours (L.52)'. This resolution advocates for a behaviour-based approach to addressing space security concerns and has led to the establishment of an Open-Ended Working Group (OEWG) to examine this issue. NATO has declared space an operational domain.[7] Moreover, various nations, including the US,[8] Germany,[9] and France,[10] have released space defence strategies declaring their interests in outer space.

Another factor to be taken into consideration is the increase in the pool of actors. Outer space is no longer the sole domain of nation-states. With the dwindling of funding for space programmes, the private sector has started to play an important role within the sector. This shift, accompanied by the proliferation of dual-use systems and an increasing number of commercial space objects in orbit, should be a driving force behind any discussion about the insufficiency of the existing legal framework.

The increasing traffic and a growing array of actors in outer space, coupled with the emergence of ASATs and cyber ASATs, necessitate a thorough examination of the

4 Brian Weeden, *2007 Chinese Anti-Satellite Test Fact Sheet* (Secure World Foundation 2010) <https://swfound.org/media/9550/chinese_asat_fact_sheet_updated_2012.pdf>; Shirley Kan, 'China's Anti-Satellite Weapon Test' (2007) CRS Report for Congress Order Code RS22652 <https://apps.dtic.mil/sti/pdfs/ADA468025.pdf>.

5 Ashley J Tellis, 'India's ASAT Test: An Incomplete Success' (*Carnegie Endowment for International Peace*) <https://carnegieendowment.org/2019/04/15/india-s-asat-test-incomplete-success-pub-78884> accessed 12 January 2024; 'India's Anti-Satellite Missile Test Is a Big Deal. Here's Why' (*Space.com*) <www.space.com/india-anti-satellite-test-significance.html> accessed 12 January 2024.

6 'Russian Direct-Ascent Anti-Satellite Missile Test Creates Significant, Long-Lasting Space Debris' (*U.S. Space Command*) <www.spacecom.mil/Newsroom/News/Article-Display/Article/2842957/russian-direct-ascent-anti-satellite-missile-test-creates-significant-long-last/> accessed 12 January 2024; 'Russia's Anti-Satellite Weapons: An Asymmetric Response to U.S. Aerospace Superiority' (*Arms Control Association*) <www.armscontrol.org/act/2022-03/features/russias-anti-satellite-weapons-asymmetric-response-us-aerospace-superiority> accessed 12 January 2024; 'Russia's Anti-Satellite Test Should Lead to a Multilateral Ban' (*SIPRI*) <www.sipri.org/commentary/essay/2021/russias-anti-satellite-test-should-lead-multilateral-ban> accessed 24 May 2022.

7 'Foreign Ministers Take Decisions to Adapt NATO, Recognize Space as an Operational Domain' (*NATO*) <www.nato.int/cps/en/natohq/news_171028.htm> accessed 12 January 2024.

8 '2020 Defense Space Strategy Summary' (*U.S. Department of State*) <https://media.defense.gov/2020/Jun/17/2002317391/-1/-1/1/2020_DEFENSE_SPACE_STRATEGY_SUMMARY.PDF>.

9 'The German Federal Government's Space Strategy' (*BMWK – Federal Ministry for Economic Affairs and Climate Action*) <www.bmwk.de/Redaktion/EN/Publikationen/Technologie/the-german-federal-governments-space-strategy.html> accessed 12 January 2024.

10 'Space Defence Strategy' (*Gouvernement*) <www.gouvernement.fr/sites/default/files/locale/piece-jointe/2020/08/france_-_space_defence_strategy_2019.pdf>.

associated legal ramifications. Our focus here is on an exploratory legal analysis of activities contributing to the escalating volume of space debris, which poses the risk of triggering the Kessler Syndrome.

The paper aims to investigate the evolving dynamics of outer space – particularly concerning space debris from (cyber) ASATs – and the potential triggering and damaging impact of the cascading effect of space debris known as Kessler Syndrome.[11]

Firstly, in Section 2, the paper introduces the requisite terminology and relevant legal frameworks. Secondly, Section 3 provides an in-depth examination of the area-denial capabilities of space debris. This inquiry is motivated by the realization that the repercussions of the proliferation of space debris, including that stemming from ASATs, have the potential to render outer space inaccessible to humanity – a circumstance incongruent with the established principles of international law. More specifically, the discussion focuses on the applicability of Article 36 of the AP I alongside the liability and responsibility regimes delineated within the framework of international law.

Building upon the discussion in this introduction, Section 4 provides an analysis of the different possible impacts of (cyber) weapons as regards the Kessler Syndrome and potential infringements upon international legal norms. The paper's central conclusion is that the existing scholarly literature pays insufficient attention to the Kessler Syndrome and its legal ramifications as they pertain to space-based weaponry. The paper's overarching aim is to offer new insights by not only recognizing the Kessler Syndrome as an undesirable outcome, a point well-documented in the existing literature, but also shedding light on its legal implications – a dimension that we contend has been underexplored.

2. SPACE DEBRIS

As humans, we are always concerned about what works and how it should work. We seem to be less concerned with things that used to work but are no longer needed. This is not meant as a critique; it is simply a consequence of the fact that in a modern and fast world, and especially today's world, we do not even have the capacity to be concerned. Space debris – meaning parts of old spacecraft, inoperable satellites, and human-made rubbish[12] but also natural objects such as meteoroids[13] – generally has no useful purpose. However, it is increasingly becoming a problem.

11 The Kessler Syndrome is discussed in detail in Section 2.

12 'Mission Monday: Five Fast Facts about the First American Spacewalk' (*Space Center Houston*) <https://spacecenter.org/mission-monday-five-fast-facts-about-the-first-american-spacewalk/> accessed 12 January 2024.

13 Linda Dawson, 'Space Debris as a Weapon' in Linda Dawson (ed), *War in Space: The Science and Technology Behind Our Next Theater of Conflict* (Springer International Publishing 2018) 46 <https://doi.org/10.1007/978-3-319-93052-7_4> accessed 12 January 2024.

The Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space defines space debris as 'all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional'.[14] NASA uses a similar definition, which states that 'orbital debris is the term for any object in Earth orbit that no longer serves a useful function. These objects include non-operational spacecraft, derelict launch vehicle stages, mission-related debris, and fragmentation debris.'[15] Throughout this paper, we will use NASA's definition because we believe that even functional but unused objects should be considered space debris.

As of December 2023, the European Space Agency (ESA) has identified 36,500 space debris objects larger than 10 cm, 1 million objects ranging from 1 cm to 10 cm, and a staggering 130 million objects measuring between 1 mm and 1 cm.[16] While larger objects are more concerning, this does not mean that small objects are not a threat. Due to their high velocities (reaching speeds of 17,500 kph at a minimum), even the tiniest pieces of debris possess enough kinetic energy to disrupt critical systems on satellites or spacecraft. Notably, the International Space Station (ISS) suffered damage from 'a paint flake or small metal fragment no bigger than a few thousandths of a millimetre'.[17] Such an occurrence underscores the severity of encounters with even minor debris.[18] Whether big or small, space debris and space debris fragments are a threat to our presence in space that could, especially, grow in significance in relation to global navigation services, telecommunication services, weather forecasting, or climate change research.

A. Kessler Syndrome

The foremost concern linked to the proliferation of space debris is known as the Kessler Syndrome.[19]

14 United Nations Office for Outers Space Affairs, *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space* (United Nations 2010) <www.unoosa.org/res/oosadoc/data/documents/2010/stspace/stspace49_0_html/st_space_49E.pdf>.

15 Nicholas L Johnson, 'Orbital Debris Management & Risk Mitigation' (NASA) 6 <www.nasa.gov/wp-content/uploads/2018/12/692076main_orbital_debris_management_and_risk_mitigation.pdf>.

16 'Space Debris by the Numbers' (*European Space Agency*) <www.esa.int/Space_Safety/Space_Debris/Space_debris_by_the_numbers> accessed 12 January 2024.

17 'Impact Chip' (*ESA*, 12 May 2016) <www.esa.int/ESA_Multimedia/Images/2016/05/Impact_chip> accessed 12 January 2024.

18 ibid; Lizzie Plaugic, 'This Is What Happens When a Tiny Piece of Flying Space Debris Hits the ISS' (*The Verge*, 12 May 2016) <www.theverge.com/2016/5/12/11664668/iss-window-chip-space-debris-tim-peake> accessed 12 January 2024; Ted Muelhaupt, 'Space Debris and The Aerospace Corporation' (2015) 16 Crosslink 2–3.

19 Vilius Petkauskas, 'Why Hackers Destroying One Starlink Satellite Could Cause Orbital Armageddon' (*Cybernews*, 27 June 2022) <https://cybernews.com/editorial/why-hackers-destroying-one-starlink-satellite-could-cause-orbital-armageddon/> accessed 12 January 2024; Mike Wall, 'Kessler Syndrome and the Space Debris Problem' (*Space.com*, 15 November 2021) <www.space.com/kessler-syndrome-space-debris> accessed 12 January 2024; Francis Lyall and Paul Larsen, *Space Law: A Treaties* (2nd edn, Routledge 2018) 271.

As space debris collides with other objects, a cascading effect can be triggered that perpetuates the generation of additional space debris. This cascade effect, which is often likened to a domino effect or chain reaction, constitutes a pivotal aspect of the space debris issue. In theory, there is a potential scenario where the accumulation of space debris in our orbital vicinity reaches a critical mass, hindering the spacecraft's access to space. Compounding the issue is that the utility of satellites would also become severely constrained, thus imperilling their operational capabilities.[20]

This grim possibility is well illustrated by two notable events: The first was the People's Republic of China's ASAT test on Fengyun-1C in 2007. The test created more than 2,600 pieces of space debris over 10 cm across (over 100,000 in total), significantly accelerating the proliferation of space debris and, thus, further escalating the issue of orbital congestion.[21] The second was the 2009 collision between a U.S. satellite, Iridium 33, and a Russian satellite, Cosmos 2251,[22] which resulted in the creation of over 2,000 sizable fragments accompanied by numerous untraceable ones. Alarmingly, even three years post-collision, more than 90% of these fragments persisted in orbit, amplifying the hazards posed by an increasingly cluttered space environment.[23]

These events serve as harbingers, vividly illustrating the tangible consequences and potential ramifications of collisions or the use of weapons within the orbital realm.

As a worst-case scenario, the Kessler Syndrome could result in outer space becoming inaccessible to exploration and the cessation of vital space-related services, such as the Internet, telecommunications, or the global navigation satellite system (GNSS). Such an impact would effectively dismantle the contemporary world. The repercussions would extend beyond the loss of GPS navigation, impacting essential systems such as banking, and rendering the Internet unusable due to the absence of accurate time-stamping.[24]

20 Donald J Kessler and Burton G Cour-Palais, 'Collision Frequency of Artificial Satellites: The Creation of a Debris Belt' (1978) 83 Journal of Geophysical Research: Space Physics 2637; Jakub Drmola and Tomas Hubik, 'Kessler Syndrome: System Dynamics Model' (2018) 44–45 Space Policy 29; Donald J Kessler and others, 'The Kessler Syndrome: Implications to Future Space Operations' (*Semantic Scholar*, 2010) <www.semanticscholar.org/paper/THE-KESSLER-SYNDROME%3A-IMPLICATIONS-TO-FUTURE-SPACE-Kessler-Johnson/227655e022441d1379dfdc395173ed2e776d54ee> accessed 12 January 2024.

21 Leonard David, 'China's Anti-Satellite Test: Worrisome Debris Cloud Circles Earth' (*Space.com*, 2 February 2007) <www.space.com/3415-china-anti-satellite-test-worrisome-debris-cloud-circles-earth.html> accessed 12 January 2024.

22 RL Wang and others, 'Thinking Problems of the Present Collision Warning Work by Analyzing the Intersection between Cosmos 2251 and Iridium 33' *Proceedings of the 6th European Conference on Space Debris* (2013) <https://conference.sdo.esoc.esa.int/proceedings/sdc6/paper/45/SDC6-paper45.pdf>; Weeden (n 4).

23 Leonard David, 'Effects of Worst Satellite Breakups in History Still Felt Today' (*Space.com*, 28 January 2013) <www.space.com/19450-space-junk-worst-events-anniversaries.html> accessed 12 January 2024.

24 Charlotte Van Camp and Walter Peeters, 'A World without Satellite Data as a Result of a Global Cyber-Attack' (2022) 59 Space Policy 101458, 1–7.

It is worth noting that the Kessler Syndrome is not a rapid event akin to a 'space gunshot'. Rather, it resembles the slow congestion of the space environment with what is essentially rubbish. Moreover, according to Doboš and Pražák, the low-intensity Kessler Syndrome threshold, which requires significant planning effort when deploying new spacecraft and satellites, has already been reached.[25]

B. Space Debris and International Law

Space law applicable to space debris is mainly constituted by the Outer Space Treaty (OST) and the Liability Convention (LC).

The cornerstone of the OST is Article IX, which delineates the principle of non-contamination of space and establishes guidelines for conducting outer space activities while duly considering the legitimate interests of other states.[26] This article urges responsible behaviour in space endeavours to safeguard against contamination and to ensure that activities in outer space align with the mutual interests of all participating states. Moreover, based on Article IX and customary law on state responsibility,[27] we conclude that states are responsible for the space debris they produce because of the due regard principle.[28] With regard to this, it is crucial to emphasize that a space object and any space debris that originates from it share jurisdiction, carrying with it the corresponding legal implications. For instance, if a space object is registered in State A, the state assumes liability and responsibility not only for the object itself but also for any space debris that may originate from it.

According to the OST, if space debris is repurposed to intentionally cause damage or harm by State B, the liability and responsibility still lies with the state that initially launched the space object from which the debris originated. Such a principle underscores the accountability of the originating state for any subsequent misuse of space debris, emphasizing the need for careful and responsible conduct of outer space activities.

Within the framework of the LC, a pivotal question arises as to whether space debris would be classified as a space object, thereby falling under the purview of the LC. Article I of the LC defines a 'space object' as including not only the primary object but also its constituent components and associated launch vehicles. Space debris that could be considered a component of launch vehicles would arguably be subsumed under this definition.[29]

25 Bohumil Doboš and Jakub Pražák, 'Master Spoiler: A Strategic Value of Kessler Syndrome' (2022) 22 Defence Studies 123, 123.

26 John S Goehring, 'Can We Address Orbital Debris with the International Law We Already Have? An Examination of Treaty Interpretation and the Due Regard Principle' (2020) 85 Journal of Air Law and Commerce 309, 310–312.

27 For example, ARSIWA or the International Law Commission's articles on state responsibility: introduction, text, and commentaries.

28 Goehring (n 26) 336–337.

29 Isabella Henrietta Philepina Diederiks-Verschoor and Vladimír Kopal, *An Introduction to Space Law* (3rd rev edn, Kluwer Law International 2008) 128.

The classification of space debris as space objects can be approached from two distinct academic positions: spatialist and functionalist. The former approach hinges on location, designating anything beyond the airspace boundary as a space object. Conversely, the latter conceives space objects as operational space instruments regardless of their location. Thus, on the functionalist view, space debris may not be considered a space object precisely because it has lost its functionality.[30] While the spatialist theory seems more intuitive, the absence of an international consensus weakens its validity.

The absence of any mention of space debris in the LC or the OST can be attributed to the historical context of these documents.[31] At the time of their inception, space debris was not a prevalent concern, as space exploration was still in its nascent stages. Pelton asserts that the categorization of space debris as space objects is not straightforward and may require an amendment to the LC.[32]

The tranquil environment of outer space is undergoing changes, necessitating consideration of whether International Humanitarian Law (IHL) is applicable in outer space, which is defined as a peaceful domain.[33, 34] The applicability of these rules derives from Article III of the OST, which states that international law applies to the use of outer space. The International Committee of the Red Cross (ICRC) emphasizes the relevance of Article 2 of the Geneva Conventions, asserting that it is applicable to any conflict.[35]

In summary, although IHL and general space law (including the OST and the LC) represent distinct legal codes, they are not in conflict per se. With regard to legal stability and continuity, if an armed attack were to occur in space, IHL would not terminate or suspend general space law but complement it.[36] Regarding Article 36 of the AP I and its status as IHL, Dienelt claims it also applies in peacetime.[37] For these reasons, we will delve further into both legal concepts.

30 Gordon Chung, 'Jurisdiction and Control Aspects of Space Debris Removal' in Annette Froehlich (ed), *Space Security and Legal Aspects of Active Debris Removal* (Springer International Publishing 2019) 34–36 <https://doi.org/10.1007/978-3-319-90338-5_3> accessed 12 January 2024.

31 Lyall and Larsen (n 19) 272.

32 Joseph N Pelton, 'Legal Challenges Related to Active Orbital Debris Removal' in Joseph N Pelton (ed), *New Solutions for the Space Debris Problem* (Springer International Publishing 2015) 73 <https://doi.org/10.1007/978-3-319-17151-7_6> accessed 12 January 2024.

33 Preamble OST, art IV OST.

34 Michael Schmitt and Sqn. Ldr. Kieran Tinkler, 'War in Space and International Humanitarian Law' (*Just Security*, 9 March 2020) <www.justsecurity.org/68906/war-in-space-how-international-humanitarian-law-might-apply/> accessed 12 January 2024.

35 *International Humanitarian Law and the Challenges of Contemporary Armed Conflicts – Recommitting to Protection in Armed Conflict on the 70th Anniversary of the Geneva Conventions, ref. 4427*, pp 32–34.

36 Article 3 of the draft articles on the effects of armed conflicts on treaties, with commentaries.

37 Anne Dienelt, 'The Shadowy Existence of the Weapons Review and Its Impact on Disarmament' (2018) 36 Sicherheit und Frieden (S+F) / Security and Peace 126, 126.

3. THE AREA-DENIAL CAPACITY OF SPACE DEBRIS

Currently, the generation of space debris in orbit is unavoidable. However, the increase in its amount and size distribution can be caused both intentionally and unintentionally, even to the point of triggering the Kessler Syndrome. In the scenario of intentional increase, space debris could be used as area-denial weapons, effectively rendering the 'ultimate high ground' useless. The proliferation of space debris, thus, poses a tangible threat that could possibly be used for geopolitical leverage, encapsulating the multifaceted risks associated with debris accumulation in outer space.

Space debris primarily emanates from anthropogenic activities. Abandoned, non-functional, and deteriorating spacecraft and satellites are significant contributors to the amount of space debris. Moreover, the utilization of ASATs, when involving the interception of and collisions with operational satellites or other man-made objects, is a substantial generator of space debris. Testing of anti-satellite capacities (either kinetic or cyber) against existing space debris (such as largely compact defunct satellites) escalates the creation of space debris and poses a heightened risk in the orbital vicinity.

Cybersecurity considerations – or the lack of it – are an additional factor. The commercialized and arguably overcrowded LEO[38] hosts satellites and mega-constellations with notably subpar measures against cybersecurity threats.[39] In 2023, NIST published a relevant cybersecurity standard,[40] and IEEE initiated a working group aimed at creating one.[41] However, there is still a notable lack of internationally recognized soft laws as well as hard laws, leaving the ecosystem vulnerable to cyber attacks or the deployment of cyber weapons. Malfunctions via cyber means might escalate the generation of space debris and eventually trigger the Kessler Syndrome. In such an environment, malicious actors might deploy cyber ASATs as counterparts to kinetic ASATs. While kinetic ASATs are typically detectable within minutes of launch, the average detection time for a cyber data breach is approximately 200 days.[42]

38 Diederiks-Verschoor and Kopal (n 29) 21–22; Chitra Sethi, 'The Commercial Future of Low-Earth Orbit' (*Tech Briefs*, 1 August 2022) <www.techbriefs.com/component/content/article/46276-the-commercial-future-of-low-earth-orbit> accessed 12 January 2024; 'Low-Earth Orbits Are Getting Crowded' (*ESA*) <www.esa.int/ESA_Multimedia/Images/2022/04/Low-Earth_orbits_are_getting_crowded> accessed 12 January 2024.

39 'Satellites Are Rife with Basic Security Flaws' (*Wired*, 20 July 2023) <www.wired.com/story/satellites-basic-security-flaws/>; 'Cybersecurity Threats in Space: A Roadmap for Future Policy' (*Wilson Center*, 8 October 2020) <www.wilsoncenter.org/blog-post/cybersecurity-threats-space-roadmap-future-policy> accessed 13 January 2024.

40 Matthew Scholl and Theresa Suloway, 'Introduction to Cybersecurity for Commercial Satellite Operations (2nd Draft)' (National Institute of Standards and Technology 2022) NIST Internal or Interagency Report (NISTIR) 8270 (Draft) <https://csrc.nist.gov/publications/detail/nistir/8270/draft> accessed 29 May 2022.

41 'P3349 – Space System Cybersecurity Working Group – The Project' (*IEEE SA*) <https://sagroups.ieee.org/3349/the-project/> accessed 13 January 2024.

42 Brendan I Koerner, 'Inside the OPM Hack: The Cyberattack That Shocked the US Government' (*Wired*, 23 October 2016) <www.wired.com/2016/10/inside-cyberattack-shocked-us-government/> accessed 12 January 2024.

Advanced concealment methods and the already mentioned lack of cybersecurity standards create a vulnerable environment that provides opportunities to intentionally increase the amount of debris over time to deny important capabilities and cause chaos.

The deliberate or inadvertent initiation of the Kessler Syndrome, resulting from either the intentional or unintentional creation of an extensive volume of space debris – such as through a destructive directed cyber attack on multiple mega-constellations or numerous directed kinetic attacks on a group of satellites – constitutes an internationally wrongful act. The violation stems from the fact that such an attack would constitute a breach of obligations outlined in the OST – particularly Article I – contravening the principle of exploration and use of outer space for all. Additionally, Article IX of the OST establishes the principle of due regard, emphasizing that exploration and use of outer space should not lead to potentially harmful interference. Closing access to outer space by triggering the Kessler Syndrome would breach both provisions of the OST.

A. Liability and Responsibility Regarding the Kessler Syndrome

Two pivotal legal concepts demand attention when considering the matter of collisions between space objects and the Kessler Syndrome: responsibility and liability. It is important to underline that these concepts originate from distinct temporal and contextual backgrounds, thereby rendering their contemporary application challenging.[43]

Primarily, our attention will be directed towards the complexities pertaining to the concept of responsibility. Article VIII of the OST stipulates that no state has the authority to destroy objects outside of its jurisdiction unless an agreement for a justifiable cause is in place. The article embodies a customary law obligation and explicitly confers jurisdiction and control to the state of registration, which assumes liability for the space object. Notably, the legal provision does not set a time limit for sovereignty, effectively allowing the state of registration to retain it indefinitely.[44] Hence, if State A were to destroy a space object belonging to State B, it would constitute a breach of the OST. Consequently, if the act were attributable to State A, it would qualify as an internationally wrongful act for which State A would be held responsible. Furthermore, since the registration of space objects is non-transferable, even in the case of damage to a non-functional or inactive space object (like space debris), states could be held responsible if acting outside of their jurisdiction.

43 Frans G von der Dunk, 'Liability versus Responsibility in Space Law: Misconception or Misconstruction?' *Proceedings of the 34th Colloquium on the Law of Outer Space* (1992) 363–371 <https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1020&context=spacelaw>; Bartosz Ziemblicki and Yevgeniya Oralova, 'Private Entities in Outer Space Activities: Liability Regime Reconsidered' (2021) 56 Space Policy 101427.

44 Chung (n 30) 33–34.

Considering the challenging task of attributing cyber ASATs to the correct entities, as well as the responsibilities outlined in Article IV of the OST, helps us to recognize the possibility of a concerning scenario involving exploitation by malicious actors. In this scenario, owners of cyber ASATs successfully target a space object – potentially even space debris – belonging to State B, resulting in damage. In such a case, responsibility for the damage could fall upon State B (the affected state), the launching state, and the registrar of the targeted space object.

Furthermore, it is crucial to highlight that, under the current framework established in Article VI of the OST, states are responsible for the actions of both state and non-state actors. In light of the ongoing commercialization of outer space, this presents a significant legal concern. For instance, if a commercial entity that launched and registered its space object in State A triggers the Kessler Syndrome through testing a cyber ASAT on its own satellite, State A would bear objective responsibility.

While some states might have national space legislation to address such scenarios, international sanctions for wrongful acts primarily target states. Consequently, even if a state has laws to hold private companies accountable, it might face challenges in transferring the responsibility (or even liability, see below) on the level of national law to the private entity.[45]

Having considered responsibility, we turn to the concept of liability. If it is the case that the LC applies to space debris within space law, then liability is governed by two distinct regimes. The first is the absolute liability principle, as outlined in Article II of the LC, which applies to any damage caused to the surface of the Earth or to aircraft in flight. The second regime is fault-based liability, as detailed in Article III of the LC, which addresses damage occurring elsewhere than on the Earth's surface, particularly damage to space objects.

When considering the possibility of an intentional triggering of the Kessler Syndrome with respect to damages to other satellites hit, it is conceivable that the breach of the OST could be established. That means that if such a breach were attributable, it would constitute an international wrongful act. However, in assessing liability regimes, it is crucial to evaluate the potential impact of the Kessler Syndrome on the Earth's surface. Despite its monumental repercussions on space exploration and potential adverse effects on terrestrial living standards, that absolute liability would be invoked seems improbable. In terms of the fault-based regime, proving fault for the state that launched cyber ASATs that triggered the Kessler Syndrome and caused damage to other space objects poses what appears to be an insurmountable challenge because of

45 See Bartosz Ziemblicki and Yevgeniya Oralova, 'Private Entities in Outer Space Activities: Liability Regime Reconsidered' (2021) 56 Space Policy 101427; Paul Dempsey, 'National Laws Governing Commercial Space Activities: Legislation, Regulation, & Enforcement' (2016) 36 Northwestern Journal of International Law & Business 1.

the low probability that a strong causal link could be established or sufficient evidence found.

B. Weapons Review under Article 36 of the AP I

Under Article 36 of the AP I, 'new weapons, methods, or means of warfare' must be reviewed with due regard to the prevention of the use of weapons 'that would violate international law in all circumstances and to impose restrictions on the use of weapons that would violate international law in some circumstances'.[46] ASATs and cyber ASATs, which have the potential to significantly increase the amount of space debris and arguably bring the environment closer to triggering the Kessler Syndrome, require weapons review while taking into account their broader (potentially mid- to long-term) impact.

While the terms used in the wording of Article 36 of the AP I are not precisely defined, a weapon typically implies an offensive capability applicable against a military object or enemy combatant.[47] Since ASAT and cyber ASATs could be applicable in this context, we contend that both fall within this scope. As there is no specialized treaty or customary law that specifically addresses ASATs and cyber ASATs by formulating rules for their deployment or use, the subsequent evaluation focuses on general rules applicable to all weaponry.

Since the deliberate or inadvertent creation of space debris might lead to extensive, enduring, and significant harm to the natural environment and interests of humanity in outer space,[48] we posit that ASATs and cyber ASATs might infringe upon the prohibition on damaging the environment outlined in Article 35(3) and Article 55 of the AP I. Furthermore, contaminating outer space violates Article IX of the OST, which appears inevitable when creating a significant amount of space debris. Thus, we are convinced that the possibility that such environmentally destructive effects could be triggered must be considered within any review under Article 36 of the AP I.

ASATs and cyber ASATs are not new weapons; nevertheless, we claim that the use of ASATs or cyber ASATs to trigger the Kessler Syndrome and intentionally create space debris could be classified as a new means and method of warfare because doing so might alter such weapons' capabilities and effects.[49]

46 'A Guide to the Legal Review of New Weapons, Means and Methods of Warfare: Measures to Implement Article 36 of Additional Protocol I of 1977: International Committee of the Red Cross Geneva, January 2006' (2006) 88 International Review of the Red Cross 931, 4.

47 Justin McClelland, 'The Review of Weapons in Accordance with Article 36 of Additional Protocol I' (2003) 85 International Review of the Red Cross 397, 404.

48 Chung (n 30) 36–37.

49 Vincent Boulanin and Maaike Verbruggen, 'Article 36 Reviews: Dealing with the Challenges Posed by Emerging Technologies' (Stockholm International Peace Research Institute 2017) 4 <www.sipri.org/sites/default/files/2017-12/article_36_report_1712.pdf>.

While the argumentation is straightforward for kinetic ASATs, there are exceptions for cyber ASATs. Solely disrupting the functionality of a space object may not lead to its destruction and the generation of a large amount of space debris.[50] The outcome of the weapons review hinges on the distinction between traditional ASATs, potentially illegal due to their destructive nature, and cyber ASATs, which are primarily focused on disruption and so might be considered legal, thus influencing their regulatory status. The Kessler Syndrome depends on the density of space debris – and although non-functional space objects are, by definition, considered space debris, their impact on the environment can differ. Seizing control of satellites by cyber means and adjusting their orbits to create collisions is problematic regarding triggering the Kessler Syndrome, whereas shutting them down seems to be a preferable option for society with regard to the lower mid-term and long-term impact on the outer space environment.

C. The (Legal) Issues of Space Debris Weaponization via Triggering the Kessler Syndrome

Alongside the legal challenges – such as liability, responsibility, and the weapons review under Article 36 of the AP I – there are additional formidable obstacles. The first pertains to identifying the origin of space debris. The second revolves around the complexities of legitimizing the targeting of space objects.

The primary challenge in legally categorizing space debris as a weapon lies in detecting its origin.[51, 52] While it may be feasible but very difficult to trace the satellite or space object from which the debris originated – whether through kinetic or cyber means – identifying the creator of the debris presents a distinct challenge.[53] With kinetic ASATs, it is plausible that the state or entity that launched the object could be identified and the object's trajectory tracked. However, in the case of cyber attacks or cyber ASATs, attributing the attack to the correct entity becomes exceedingly difficult. This echoes the complexities encountered in identifying perpetrators within cyber attacks on Earth. A parallel issue emerges in pinpointing the state responsible for triggering the Kessler Syndrome.

The question is whether it is legitimate to target space debris under IHL. Article 52(2) of the AP I delineates military objectives, defining them as objects that, due to their nature, location, purpose, or use, contribute effectively to military actions, offering a clear military advantage in their destruction, capture, or neutralization. Given that space objects are predominantly dual-use in nature, they might be perceived as

50 James Pavur and Ivan Martinovic, 'The Cyber-ASAT: On the Impact of Cyber Weapons in Outer Space' *11th International Conference on Cyber Conflict (CyCon)* (IEEE 2019) 5–7 <https://ieeexplore.ieee.org/document/8756904/> accessed 12 January 2024.

51 Alessandra Celletti, Giuseppe Pucacco and Tudor Vartolomei, 'Reconnecting Groups of Space Debris to Their Parent Body through Proper Elements' (2021) 11 Scientific Reports 1.

52 Pelton (n 32) 73–74.

53 Di Wu and Aaron J Rosengren, 'An Investigation on Space Debris of Unknown Origin Using Proper Elements and Neural Networks' (2023) 135 Celestial Mechanics and Dynamical Astronomy 44.

legitimate targets.[54] On the other hand, since any space debris object is, by definition, a non-functional or unused space object, establishing that the conditions outlined in Article 52(2) of the OST are met could prove challenging.

4. DISCUSSION

A. The Illegality of Triggering the Kessler Syndrome

The triggering of the Kessler Syndrome is undesirable since it could violate Article I and Article IX of the OST due to its environmental consequences. Consequently, we contend that the triggering of the Kessler Syndrome could be construed as a violation of international law that leads to an international wrongful act. If this is indeed the case, considering the possibility that the Kessler Syndrome may have already commenced,[55] it would be plausible to apply international responsibility as stated in the Draft Articles on Responsibility of States for Internationally Wrongful Acts. Therefore, hypothetically, when states such as China or Russia tested their ASATs, they likely violated international obligations and thus committed an international wrongful act.

States need to consider the potential classification of triggering the Kessler Syndrome as a wrongful act on various levels, particularly concerning the development of new weapons. It is a crucial consideration when determining the area-denial capacity of space debris (via the Kessler Syndrome), influencing whether a space weapon can undergo a weapons review under Article 36 of the AP I. Consequently, failure to conduct a weapons review could be deemed a violation of IHL. However, given that space is designated as a peaceful arena in the preamble and Article IV of the OST, the question of whether IHL is applicable in this domain is pertinent.[56] Nonetheless, contemporary perspectives hold that 'peaceful' does not equate to 'non-military'.[57] This corresponds to Article III of the OST, which stipulates that activities in outer space should be conducted in accordance with international law.[58] Thus, it follows

54 Almudena Azcárate Ortega, 'Not a Rose by Any Other Name: Dual-Use and Dual-Purpose Space Systems' (*Lawfare*, 5 June 2023) <www.lawfaremedia.org/article/not-a-rose-by-any-other-name-dual-use-and-dual-purpose-space-systems> accessed 12 January 2024; Jakub Pražák, 'Dual-Use Conundrum: Towards the Weaponization of Outer Space?' (2021) 187 Acta Astronautica 397.

55 Andrea Gini, 'Don Kessler on Envisat and the Kessler Syndrome' *Space Safety Magazine* (Winter 2012) <http://www.spacesafetymagazine.com/space-debris/kessler-syndrome/don-kessler-envisat-kessler-syndrome/> accessed 12 January 2024.

56 Jasani Bhupendra and Maria A Lunderius, 'Peaceful Uses of Outer Space-Legal Fiction and Military Reality' (1980) 11 Bulletin of Peace Proposals 57.

57 Tinkler (n 34).

58 Cassandra Steer and Dale Stephens, 'International Humanitarian Law and Its Application in Outer Space' in Cassandra Steer and Matthew Hersch (eds), *War and Peace in Outer Space: Law, Policy, and Ethics* (Oxford University Press 2020) 51–53 <https://doi.org/10.1093/oso/9780197548684.003.0002> accessed 12 January 2024.

that if the use of force occurs in outer space, IHL will apply in full, regardless of time and place.[59]

B. The Differences between ASATs and Cyber ASATs and Their Legal Implications

The militarization of outer space, once considered dystopian, is now a reality as spacefaring nations seek to deploy weapons beyond Earth's atmosphere.[60] A recent successful ASAT test, despite its achievements, underscores the significant hazards of generating extensive space debris and the problems with the lack of enforceable international law. Since ASATs are inherently destructive, so, too, they inherently contribute to the risk of triggering the Kessler Syndrome. In recognition of this concern, there is an ongoing discussion about the prohibition of such weapons led by the United States.[61]

An alternative worth exploring at this juncture is cyber ASATs. These possess unique advantages, particularly in terms of cost-effectiveness and the difficulty of attributing them to the correct entity.[62] From an environmental and legal standpoint, a key feature of cyber ASATs is their ability to 'turn off' satellites through various means, mitigating the risks of the creation of space debris.[63] However, cyber ASATs are not without their challenges – unintended impacts on multiple satellites within a mega-constellation and their potential availability to countries without established space capabilities are notable concerns. When considering cyber ASATs, it is also necessary to highlight that there is a greater chance that they would be owned or supported by non-state actors and private entities. This is an important difference compared to ASATs, which are mostly state-driven projects.

Given their destructive nature and the risks associated with triggering the Kessler Syndrome, ASATs could be deemed illegal. In contrast, cyber ASATs, which focus on disruption, might contribute less to the Kessler Syndrome and could possibly be considered legal. Hence, a shift in focus from the conventional arms space race to a cyber arms space race may be prudent.

59 *International Humanitarian Law and the Challenges of Contemporary Armed Conflicts – Recommitting to Protection in Armed Conflict on the 70th Anniversary of the Geneva Conventions, ref. 4427*, pp 32–34.

60 David E Sanger and Julian E Barnes, 'U.S. Fears Russia Might Put a Nuclear Weapon in Space' *New York Times* (17 February 2024) <www.nytimes.com/2024/02/17/us/politics/russia-nuclear-weapon-space.html> accessed 10 March 2024.

61 Theresa Hitchens, 'Debris from ASAT Tests Creating "Bad Neighborhood" in Low Earth Orbit: Analyst' (*Breaking Defense*, 16 June 2023) <https://breakingdefense.sites.breakingmedia.com/2023/06/debris-from-asat-tests-creating-bad-neighborhood-in-low-earth-orbit-analyst/> accessed 12 January 2024; Jeff Foust, 'More Countries Encouraged to Commit to Halt Destructive ASAT Tests' (*SpaceNews*, 15 June 2023) <https://spacenews.com/more-countries-encouraged-to-commit-to-halt-destructive-asat-tests/> accessed 12 January 2024.

62 Pavur and Martinovic (n 50) 5–7.

63 ibid 6.

C. The Fault-Based Nature of Traffic in Outer Space and the Production of Space Debris

The surge in the number of private entities for which states bear responsibility and liability presents numerous challenges. The existing legal framework, grounded in Article VI of the OST, asserts that states are responsible for national activities conducted by governmental or non-governmental entities. However, as the intentions of states and private companies may be inherently incompatible and distinct, there is a growing call for a re-evaluation of the relevant legal framework.[64]

Concerning the generation of space debris and the potential triggering of the Kessler Syndrome, the approaches of states and private companies could not be more different. Consider a hypothetical scenario where a private entity competitively destroys a space object launched and registered in a different state, yet due to the absence of adequate regulation, it is not held liable or responsible. Even if the company's motive was not to trigger the Kessler Syndrome but to gain a competitive advantage, it could inadvertently do so. Under the current legal framework, the relevant states would be held accountable. This possibility, as well as analogous scenarios likely to emerge with the burgeoning space industry, necessitates a re-evaluation not only of liability in general but also in the light of the possibility of triggering the Kessler Syndrome.

5. CONCLUSION

The escalating cyber threat in outer space raises significant concerns, particularly regarding the potential deployment of ASATs, which increase the amount of space debris and may, thus, conceivably trigger the Kessler Syndrome.

The looming threat of the Kessler Syndrome provides a compelling argument for the prohibition of ASATs, as assessed through a weapons review under Article 36 of the AP I, and for greater attention to the broader issue of space weaponization. It is crucial to differentiate between traditional ASATs and cyber ASATs. While the former would likely fail weapons review due to the substantial environmental consequences of their use, the latter, which could have a comparatively smaller environmental impact, might pass such assessments. This distinction prompts a re-evaluation, shifting our focus from an arms race in outer space to a cyber arms race in the same domain.

Moreover, the examination of liability and responsibility with respect to the Kessler Syndrome reveals the challenges of attributing (cyber) ASAT attacks to the correct entities and holding states accountable. This paper underscores the imperative need

64 Alexander P Reinert, 'Updating the Liability Regime in Outer Space: Why Spacefaring Companies Should Be Internationally Liable for Their Space Objects' (2020) 62 William & Mary Law Review 325; Ziemblicki and Oralova (n 45); Biswanath Gupta and Raju KD, 'Understanding International Space Law and the Liability Mechanism for Commercial Outer Space Activities – Unravelling the Sources' (2019) 75 India Quarterly 555.

for an updated legal framework capable of addressing the evolving landscape of space activities, especially considering the increasing participation of private entities that have different intentions from state actors.

In summary, the creation of space debris and the potential triggering of the Kessler Syndrome through the use of weapons in space represents an unregulated issue that is insufficiently covered within the current literature. This discussion opens a dialogue on the existing legal framework, treating the Kessler Syndrome not merely as a remote possibility but as an undesirable condition that could effectively 'close outer space' for humankind. Importantly, each step towards such a state should be viewed not just as a negative factual development but also as an internationally wrongful act, emphasizing the need for proactive legal measures and international cooperation in preserving the peaceful use of outer space.

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