International Review of the Red Cross (2026), 1–31.
doi:10.1017/S1816383126101416

IRRC_

Beyond Earth: The perils of outer space for civilian safety and infrastructure

Jacqueline Reichhold
PhD Candidate, Institute of Air Law, Space Law and Cyber Law, University of Cologne, Germany
Email: jacqueline.reichhold@uni-koeln.de

Abstract

The increasing integration of outer space technologies into both civilian life and military operations poses significant challenges to the application of the principles of international humanitarian law. Although these technologies may strengthen military operations, the repurposing of civilian space assets for military ends increases their vulnerability to hostile actions, thereby creating risks that could ultimately impair the civilian infrastructure that is reliant upon them. The present article sets out to explore the growing reliance on space-based assets, such as satellites, for communication, navigation and surveillance purposes in modern conflicts, and explores the evolving role of outer space in armed conflict, emphasizing the humanitarian risks posed by its militarization and the absence of robust legal protections. The article puts forward that the international community's primary focus should be the protection of civilians, achieved through the safeguarding of space-based assets and the prevention of outer space's weaponization. Protecting these technologies from the effects of armed conflict is imperative for civilian safety as well as for maintaining global stability and ensuring that outer space remains a domain of peaceful cooperation.

Keywords: civilian infrastructure, dual-use technologies, international humanitarian law, outer space, space law.

: : : : :

Introduction

Current armed conflicts have resulted in significant challenges for international humanitarian law (IHL), leading to considerable legal uncertainties and the impediment of the development of robust protective measures.[1] These challenges are aggravated by interference with, or loss of, critical civilian and military space-based assets, causing harm to civilians and the infrastructure on which they depend. At the same time, outer space and space-based assets increasingly influence everyday life. This development is visible in the military field as well, as many military assets are supported by space technology, including satellite-based communication, navigation, early warning, and intelligence, surveillance and reconnaissance (ISR) systems.[2]

This trend is also reflected in multilateral processes, including the United Nations (UN) Open-Ended Working Group (OEWG) on Reducing Space Threats, and the Group of Governmental Experts (GGE) on the Prevention of an Arms Race in Outer Space (PAROS), as well as in recent UN General Assembly resolutions. Through these processes, States have articulated diverging positions on responsible military behaviour in outer space and the protection of space-based services that are essential to civilians.[3]

Additionally, outer space plays a significant part in the development of new multi-domain approaches, highlighting its importance in hostilities. However, not only militaries but also civilians worldwide are increasingly dependent on space services. This article will discuss the current development of the use of outer space in armed conflicts and the possible consequences of disregarding the deleterious effects that such hostilities can have on civilian use of outer space services. From the interruption of satellite-supported water treatment systems to power outages in hospitals or the loss of satellite-based navigation during aviation operations, civilian life and critical infrastructure rely heavily on space-enabled services, making them particularly vulnerable when these assets are disrupted during armed conflict.

1 International Committee of the Red Cross (ICRC), *International Humanitarian Law and the Challenges of Contemporary Armed Conflicts: Building a Culture of Compliance for IHL to Protect Humanity in Today's and Future Conflicts*, Geneva, September 2024.

2 North Atlantic Treaty Organization (NATO), "Joint Intelligence, Surveillance and Reconnaissance", 30 July 2025, available at: www.nato.int/en/what-we-do/deterrence-and-defence/joint-intelligence-surveillance-and-reconnaissance (all internet references were accessed in June 2026).

3 UNGA Res. 75/36, 7 December 2020; *Report of the United Nations Institute for Disarmament Research on the Open-Ended Working Group on Reducing Space Threats*, March 2024, p. 7. In these fora, States have expressed different opinions on whether responsible military behaviour in outer space should be defined by legally binding limits on counter-space capabilities or by voluntary behavioural norms, transparency and confidence-building measures. They have also discussed how far the military use of space should be restricted beyond existing international law.

Following this introduction, the article is structured in four substantive sections. The first section addresses the growing significance of outer space in armed conflicts; it begins by outlining current military uses, before considering likely future developments and assessing the consequences for civilians and civilian infrastructure. The second section shifts focus to the legal dimension, examining the discussions surrounding the application of IHL to outer space. This includes a review of academic commentary, relevant manuals, and the positions taken by the International Committee of the Red Cross (ICRC) and international bodies such as the OEWG on PAROS, and a discussion on the core IHL principles of distinction, proportionality and precaution. The third section proposes legal and practical approaches to guide the responsible use of outer space in the military context. Finally, the fourth section concludes with reflections on the legal and practical implications of space-based military operations in the context of the protection of civilians and civilian infrastructure.

The increasing use of outer space in armed conflicts

Although the military use of outer space has been developing for several decades, there has been a significant acceleration in the past decade, driven both by the further development of space technologies and by their growing use in hostilities. Even though the use of outer space has always been driven by military developments and State power,[4] only in recent years has it evolved into a domain with direct operational relevance for hostilities. Through this evolution, military and dual-use assets are now frequently placed in outer space,[5] and space-based assets play a major part in hostilities on Earth. This evolution has created structural interdependencies between civilian and military uses of outer space. In contrast to the terminology employed in space policy, IHL does not recognize "dual-use objects" as a separate category; instead, it requires a functional assessment of whether an object qualifies as a military objective at the time of attack.[6] These interdependencies directly affect the

4 Stephan Hobe, *Space Law*, 2nd ed., Nomos, Baden-Baden, 2023, pp. 29–39.

5 The term "dual-use assets" in outer space refers to technologies, systems, or infrastructure that serve both civilian and military purposes. Examples of such assets include satellites utilized for telecommunications, navigation or Earth observation, which may also support military operations such as targeting, surveillance or command and control. See "Dual-Use", *Space Security Lexicon*, available at: https://spacesecuritylexicon.org/terminology/dual-use.

6 While space policy and technology communities routinely describe satellites as "dual-use", IHL does not recognize "dual-use objects" as a separate category. Under IHL, an object is either a civilian object or a military objective, depending on its nature, location, purpose or use at the time of attack. This conceptual divergence is particularly significant in outer space, where most systems simultaneously support civilian and military functions, complicating the application of the principle of distinction. Oona A. Hathaway, Azmat Khan and Mara R. Revkin, "The Dangerous Rise of 'Dual-Use' Objects in War", *Yale Law Journal*, Vol. 134, No. 8, 2025; Svenja Berrang, "How Would IHL Apply to Hostilities in Outer Space?", *Humanitarian Law and Policy Blog*, 2 November 2023, available at: https://blogs.icrc.org/law-and-policy/2023/11/02/how-would-ihl-apply-to-hostilities-in-outer-space/; Laurent Gisel, *The Principle of Proportionality in the Rules Governing the Conduct of Hostilities under International Humanitarian Law*, Report of the International Expert Meeting, ICRC, Quebec, 2016, pp. 37–38.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

interpretation of the IHL conduct of hostilities principles of distinction, proportionality and precaution in contemporary conflicts. The following subsections will take a closer look at how space technology is used in current armed conflicts and what can be learned from past uses for addressing possible future uses of those technologies and their increasing effects on civilians and civilian objects.

Contemporary uses of outer space in hostilities

When analyzing the present utilization of outer space services in armed conflicts, recent hostilities such as those taking place in Russia/Ukraine and Israel/Gaza are frequently cited, particularly due to their reported extensive reliance on satellite-based communications and positioning systems, and the prominent role of (commercial) satellite imagery in documenting military operations and civilian harm.[7] The following will take a closer look at the different types of uses of space technology and their effects on Earth. These examples demonstrate how space-based capabilities have become integral to the conduct of hostilities, thereby increasing the likelihood of humanitarian consequences on Earth arising from military operations affecting space systems.

Non-kinetic capabilities and operations

Most uses of outer space services in hostilities are of a non-kinetic character; nonetheless, it is evident that such activities can significantly influence the conduct and outcome of armed conflict by enhancing a party's situational awareness, coordination and operational effectiveness.[8] For instance, the Houthi movement in Yemen has been reported to utilize satellite imagery and space-based communications to identify targets and coordinate attacks against its adversaries in the region.[9] A similar dynamic is observable in the ongoing conflict between Russia and Ukraine, where space-based ISR capabilities, particularly commercial Earth observation services, have facilitated the real-time monitoring of troop movements, the identification of

7 UNOSAT, "Gaza Strip Comprehensive Damage Assessment", 7 May 2025, available at: https://unosat.org/products/4130; RAND Corporation, *Lessons from the War in Ukraine for Space*, Santa Monica, CA, 2025; Human Rights Watch, "Gaza: Isreali School Strikes Magnify Civilian Peril", 7 August 2025, available at: www.hrw.org/news/2025/08/07/gaza-israeli-school-strikes-magnify-civilian-peril; Setsuko Aoki, "International Law of the Military Uses of Outer Space in Light of the War in Ukraine as the First Commercial Space War", in Shuichi Furuya, Hitomi Takemura and Kuniko Ozaki (eds), *Global Impact of the Ukraine Conflict: Perspectives from International Law*, Springer, Cham, 2023, pp. 313 ff.; European Union Aviation Safety Agency (EASA), "Global Navigation Satellite System (GNSS) Outage Leading to Navigation/Surveillance Degradation", Safety Information Bulletin No. 2022-02, Cologne, 17 March 2022, available at: www.easa.europa.eu/en/sib-2022-02.

8 Lonneke Peperkamp and Patrick Bolder, "The Space Domain and the Russia–Ukraine War", in Maarten Rothman, Lonneke Peperkamp and Sebastiaan Rietjens (eds), *Reflections on the Russia–Ukraine War*, Leiden University Press, Leiden, 2024, p. 270.

9 Stephen Bryen, "Houthis Using Commercial Satellites Combined with Radar to Target Ships in the Red Sea", *Weapons and Strategy*, 17 January 2024, available at: https://weapons.substack.com/p/houthis-using-commercial-satellites; Amila Prasanga, "Escalation Beneath the Waves: The Looming Threat of Houthi UUVs in the Red Sea", CIMSEC, 8 May 2024, available at: https://cimsec.org/escalation-beneath-the-waves-the-looming-threat-of-houthi-uuvs-in-the-red-sea/.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

artillery positions and the refinement of targeting decisions.[10] The role of private space actors has further expanded these capabilities: in the context of the ongoing conflict in Ukraine, SpaceX's provision of Starlink terminals has played a pivotal role in ensuring the continued operation of high-bandwidth communications.[11] This initiative has been particularly crucial in the face of reported Russian cyber operations and electronic warfare attempts to disrupt national connectivity.[12] These services have supported military command and control, enabled secure communication between dispersed units and maintained essential civilian communication networks.[13] When considered as a whole, these developments illustrate how access to space-based services has become an important factor in the contemporary shaping of military operations. At the same time, the dual-use nature of these systems makes it difficult to apply the principle of distinction, since the same satellite services may support both civilian populations and military forces simultaneously.

In 2008, during the conflict between Russia and Georgia, cyber operations were reportedly used to disrupt governmental communication channels and essential civilian services, including information flows and financial transactions.[14] Although the impact on military operations appears to have been limited, this incident demonstrated how cyber capabilities can create uncertainty, impose operational friction and expose the fragility of the digital and space-enabled systems that are relied upon by State authorities and civilians.[15] This use of non-kinetic means disrupted not just the function of the Georgian military, but also the country's civilian infrastructure. Thus, even without direct military confrontation, vital civilian infrastructure can still be affected.[16]

The effects of non-kinetic operations are felt on Earth, even when the affected infrastructure is located in outer space. Such operations are enabled by technologies used for cyber warfare, including, for example, jamming and data manipulation.[17] Of course, cyber warfare is also used on Earth, but it is important to note that it is now frequently used to disrupt or disable space-based assets that

10 Béatrice Hainaut, "Operational, Legal, Political and Strategic Implications of Using Commercial Satellites in War", in European Space Policy Institute (ESPI), *Space, Cyber and Defence: Navigating Interdisciplinary Challenges*, ESPI+ Report, Vienna, November 2023, p. 8; Marisa Torrieri, "How Satellite Imagery Magnified Ukraine to the World", *Via Satellite*, 24 July 2023, available at: https://interactive.satellitetoday.com/via/articles/how-satellite-imagery-magnified-ukraine-to-the-world.

11 B. Hainaut, above note 10, p. 9.

12 L. Peperkamp and P. Bolder, above note 8, p. 265.

13 B. Hainaut, above note 10, p. 7; L. Peperkamp and P. Bolder, above note 8, pp. 262–263.

14 Ketevan Chincharadze, "From Georgia to Ukraine: Seventeen Years of Russian Cyber Capabilities at War", Modern War Institute, 30 July 2025, available at: https://mwi.westpoint.edu/from-georgia-to-ukraine-seventeen-years-of-russian-cyber-capabilities-at-war/; Eneken Tikk, Kadri Kaska and Liss Vihul, *International Cyber Incidents: Legal Considerations*, Cooperative Cyber Defence Centre of Excellence, Tallinn, 2010, pp. 69–72, 77–79.

15 Ronald J. Deibert, Rafal Rohozinski and Masashi Crete-Nishihata, "Cyclones in Cyberspace: Information Shaping and Denial in the 2008 Russia–Georgia War", *Security Dialogue*, Vol. 43, No. 1, 2012.

16 NATO, "NATO Addresses Electromagnetic Interference Threats to Civil Aviation Safety", 8 May 2025, available at: www.nato.int/cps/en/natohq/news_235022.htm?selectedLocale=en; ICRC, *ICRC Observations on the Consultants' Report: Protecting Essential Civilian Services on Earth from Disruption by Military Space Operations*, Geneva, June 2024.

17 L. Peperkamp and P. Bolder, above note 8, p. 265.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

provide services to populations on Earth, both civilians and combatants; therefore, it can harm civilian infrastructure in a conflict, such as communication, internet and energy networks. A notable example is the cyber attack on the Viasat KA SAT network in February 2022, at the outset of the Russia–Ukraine conflict. This attack disrupted satellite broadband services across parts of Europe, affecting both civilian users and critical infrastructure.[18] Crucially, it is not cyber operations that have led to an increased reliance on space-based assets; rather, the growing dependence on space-enabled services for military operations has created the strategic incentive and vulnerability that make such assets attractive targets for cyber interference. Thus, no matter the size of the conflict or the geographical focus, with the growing use of such technologies for both strategic and tactical operations, the reliance on space capabilities in global conflicts is increasing. Non-kinetic uses tend to be more politically and diplomatically tolerated than kinetic actions because they are generally perceived as less likely to lead to escalation or cause long-term harm, such as through the creation of space debris. Nevertheless, even non-kinetic interference can have significant humanitarian consequences, highlighting the need for precautionary measures when military operations risk affecting the space-based services that civilians rely on.

Kinetic capabilities and space-related military actions

In addition to the non-kinetic applications outlined above, there is an emerging body of evidence suggesting a rise in the utilization of kinetic applications. These are military activities that result in physical damage or destruction. Since the start of the use of outer space in general, the placement of military satellites and other military assets in outer space has taken place. Provided that this does not have an effect on celestial bodies or their orbits, it is not prohibited under the Outer Space Treaty (OST).[19] These military assets can include reconnaissance satellites, communication systems and early warning devices, all of which are considered crucial for national security and defence.[20] The deployment of these assets gives rise to concerns regarding space debris, conflicts and the militarization of outer space when the number of such assets continues to rise. Due to their physical vulnerability, any kinetic action involving satellites risks generating long-lasting debris that can have indiscriminate effects on other space objects, including those used for essential civilian services.

18 Viasat, "KA-SAT Network Cyberattack Overview", 30 March 2022, available at: www.viasat.com/perspectives/corporate/2022/ka-sat-network-cyber-attack-overview/; Grace B. Mueller, Benjamin Jensen, Brandon Valeriano, Ryan C. Maness and Jose M. Macias, *Cyber Operations during the Russo-Ukrainian War: From Strange Patterns to Alternative Futures*, policy brief, Center for Strategic and International Studies, Washington, DC, 13 July 2023.

19 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, 610 UNTS 205, 27 January 1967 (entered into force 10 October 1967) (OST); Kai-Uwe Schrogl and Julia Neumann, "Article IV", in Stephan Hobe, Bernhard Schmidt-Tedd and Kai-Uwe Schrogl (eds), *Cologne Commentary on Space Law*, Vol. 1, Carl Heymanns Verlag, Cologne, 2009; S. Hobe, above note 4, pp. 123–131.

20 NATO, *NATO's Overarching Space Policy*, 2019 (last updated 24 June 2025), available at: www.nato.int/cps/en/natohq/official_texts_190862.htm.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

As emphasized in international discourse, it is imperative that responsible behaviour is upheld in order to guarantee that space remains a safe and sustainable environment for all actors.[21] A frequently cited recent example is the exo-atmospheric interception of a ballistic missile by the Israel Defense Forces in 2025.[22] Although the intercepted missile was not an orbiting space object, the operation demonstrates the growing integration of space-related sensors, tracking systems and intercept technologies into modern military operations. Therefore, even though the interception did not constitute a kinetic attack against an orbiting object, it reflects the growing relevance of space-enabled capabilities in kinetic engagements. As technology continues to advance, it is probable that a greater number of analogous examples will emerge, resulting also in the enhancement of space-based defence systems.[23] The future of military strategies could be significantly impacted by these developments, underscoring the significance of technological innovation and international regulations in the responsible management of kinetic space operations. These developments also raise questions about how the IHL principles governing the conduct of hostilities apply to kinetic operations that could have a ripple effect on civilian infrastructure which relies on space-based services.

One of the most notorious kinetic uses is the employment of anti-satellite (ASAT) weapons, whose destructive testing has become widely criticized due to the generation of long-lived orbital debris, the resulting risks to other space objects, and the destabilizing effects that such activities have on international security and emerging norms of responsible behaviour in outer space.[24] A notable example of this phenomenon is China's 2007 destruction of the Fengyun 1C weather satellite, which alone is reported to have generated more than 2,000 trackable debris fragments 10 cm or greater in size, and remains one of the most severe debris-producing events in history so far.[25] Several States, including the United States,[26] China,[27]

21 Ram S. Jakhu and Steven Freeland (eds), *McGill Manual on International Law Applicable to Military Uses of Outer Space*, Vol. 1: *Rules*, Centre for Research in Air and Space Law, McGill University, Montreal, 2022 (McGill Manual), p. 1.

22 "Israel Intercepts Iranian Missile in Space; What Is Exoatmospheric Interception, and Arrow 3 Features", *Economic Times*, 14 June 2025, available at: https://economictimes.indiatimes.com/news/international/us/israel-intercepts-iranian-missile-in-space-what-is-exoatmospheric-interception-and-arrow-3-features/articleshow/121842039.cms.

23 Donald J. Trump, *The Iron Dome for America*, Executive Order 14186, FR Doc. 2025-02182, 3 February 2025; Reuters, "Exclusive: Pentagon Golden Dome to Have 4-Layer Defense System, Slides Show", *US News*, 12 August 2025, available at: www.usnews.com/news/world/articles/2025-08-12/exclusive-pentagon-golden-dome-to-have-4-layer-defense-system-slides-show.

24 For more details, see G. Blair Kuplic and Jonathan Sawmiller, "Humanity on the Final Frontier: Challenges in Applying International Humanitarian Law to Modern Military Space Operations", *International Review of the Red Cross*, Vol. 107, No. 928, 2025, p. 207.

25 European Space Agency (ESA) Space Debris Office, *ESA's Annual Space Environment Report 2023*, Darmstadt, 2023, pp. 75–79; Nicholas L. Johnson *et al., The Characteristics and Consequences of the Break-Up of the Fengyun-1C Spacecraft*, NASA Johnson Space Center, Houston, 2007, available at: https://ntrs.nasa.gov/api/citations/20070007324/downloads/20070007324.pdf.

26 Nicholas L. Johnson, "Operation Burnt Frost: A View From Inside", *Space Policy*, Vol. 56, May 2021, p. 2.

27 Shirley Kan, *China's Anti-Satellite Weapon Test*, CRS Report for Congress, 23 April 2007.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

Russia[28] and India,[29] are reported to have developed technologies that are able to target and destroy satellites – however, it is important to note that no kinetic ASAT system has ever been used in an armed conflict. The consequences of the destruction of a satellite could range from the disruption of communication and navigation services to the degradation of early warning systems for missile launches. In this context, the ongoing development and testing of ASAT capabilities by major spacefaring States has consequently become a significant factor in discussions about a potential arms race in outer space.[30] In light of the long-term persistence of debris, kinetic actions in space give rise to acute precautionary concerns under IHL, as their effects may extend far beyond the immediate military objective and impact civilian infrastructure for extended periods of time.

Effects on terrestrial systems

Following the above examination of kinetic and non-kinetic operations, it is crucial to consider the secondary aspect: the consequences they engender. In addition to the developments occurring in the outer space environment, there is an affiliated development concerning the effects of those developments on Earth. It is evident that military infrastructure is increasingly reliant on space-based assets, with the Global Positioning System (GPS) being a prime example.[31] GPS satellites are of paramount importance for military operations as they provide critical data for navigation, communication and surveillance. Recent advancements in warfare strategies, particularly the emergence of multi-domain operations that also extend to the space domain,[32] have underscored the imperative for enhanced connectivity via satellite systems. This growing reliance reflects how dependent modern military operations are on uninterrupted access to space-enabled services. As a result of this interconnectedness, any disruption to such services may have immediate operational consequences on Earth, which must be considered when assessing the proportionality of attacks affecting space systems.

---

28 Robin Dickey and Michael P. Gleason, "Space and War in Ukraine", *Journal of Airpower and Spacepower*, Vol. 3, No. 1, 2024.

29 Vladimir Akhmetov, Vadym Savanevych and Evgen Dikov, "Analysis of the Indian ASAT test on 27 March 2019", *arXiv*, 22 May 2019, available at: https://arxiv.org/abs/1905.09659.

30 B. Hainaut, above note 10, p. 1; Jakub Pražák, "Dual-Use Conundrum: Towards the Weaponization of Outer Space?", in *Acta Astronautica*, No. 187, 2021; Brian Weeden, "The Rule of Law and Military Space Activities", Secure World Foundation, 5 July 2017, available at: www.swfound.org/publications-and-reports/insight—the-rule-of-law-and-military-space-activities.

31 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*, Oxford University Press, Oxford, 2021, p. 25; Valentina Chabert, "The Outer-Space Dimension of the Ukraine Conflict", *Journal of International Affairs*, Vol. 75, No. 2, 2023, p. 147.

32 James Black *et al., Multi-Domain Integration in Defence*, RAND Corporation, Santa Monica, CA, 2022; NATO, "Multi-Domain Operations in NATO – Explained", 5 October 2023, available at: www.act.nato.int/article/mdo-in-nato-explained/.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

The extensive reliance on outer space systems in military operations can also have direct consequences on civilians. As significant elements of civilian infrastructure are reliant on GPS signals[33] and satellite internet and communication systems, they are susceptible to disruptions in outer space. The impact of such phenomena can be observed in a variety of contexts, including financial markets and the domain of aviation.[34] Furthermore, the disruption of satellite communications has the potential to adversely impact emergency, transportation and daily digital activities, resulting in widespread inconvenience and safety risks:[35] during periods of conflict or cyber attacks targeting space-based assets, civilians may experience internet connectivity disruptions, navigation errors or compromised financial transactions. This highlights the interdependence of military and civilian systems, emphasizing the importance of safeguarding space-based infrastructure in order to minimize the impact on vital civilian services. The examples given here demonstrate that the incidental effects of military operations involving space systems may be severe and widespread, reinforcing the need for careful proportionality assessments.

Presently, utilization of outer space services in hostilities is predominantly non-kinetic in nature; such operations are already playing an important part in hostilities and may evolve to assume an even more significant role in the future. As space technologies evolve, however, it is important to note that such advancements may initiate a new arms race, thereby encouraging States to develop more destructive space-based weapons for kinetic and non-kinetic use. In this regard, the weaponization of low Earth orbit (LEO) could influence the future utilization of outer space. The unhindered use of LEO is vital for many space-based services,[36] and the accumulation of space debris as a consequence of destructive activities poses considerable risks to both current satellites and future missions, potentially hindering scientific progress and peaceful exploration efforts.[37] The long-term risks associated with debris-generating activities underscore the necessity of incorporating precautionary measures into military planning involving space systems.

33 Laurent Gisel, "The Weaponization of Outer Space Is Not Inevitable", statement, ICRC, 5 August 2025, available at: www.icrc.org/en/statement/weaponization-of-space-not-inevitable.

34 Michael A. Garcia, Giuseppe Sirigu and John Dolan, *Observations of Trend in GPS Anomalies Affecting Aviation*, white paper, Aireon, April 2025; EASA, "Global Navigation Satellite System (GNSS) Outages and Alterations", available at: www.easa.europa.eu/en/domains/air-operations/global-navigation-satellite-system-outages-and-alterations; London Economics, *The Economic Impact on the UK of a Disruption to GNSS*, final report, August 2023, pp. 4, 19, 41–43.

35 Gianluca Pescaroli *et al., Cascading Effects of Global Positioning and Navigation Satellite Service Failures*, UCL Institute for Risk and Disaster Reduction and Mullard Space Science Laboratory Special Report 2019-02, University College London, London, 2019, pp. 3–6.

36 ESA Space Debris Office, *ESA's Annual Space Environmental Report 2025*, Darmstadt, 2025, pp. 4, 25–26; NASA Orbital Debris Program Office, *Orbital Debris Quarterly News*, Vol. 26, No. 4, 2022, pp. 1–2, 5–6.

37 For the different possible scenarios, see Jakub Drmola and Tomas Hubik, "Kessler Syndrome: System Dynamics Model", *Space Policy*, Vol. 44–45, August 2018; for current space debris numbers, see ESA, "Space Debris by the Numbers", last updated 21 April 2026, available at: www.esa.int/Space_Safety/Space_Debris/Space_debris_by_the_numbers.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

Technological developments shaping contemporary armed conflict

Predicting the future use of outer space in armed conflicts seems almost impossible. Using outer space to the extent that it is used today seemed unthinkable even a few decades ago; today, almost every technology – even sanitation – depends on outer space.[38] Russia has reportedly developed a satellite that can "give birth" to another satellite in outer space.[39] China has demonstrated technologies in outer space that can refuel satellites in orbit.[40] Possible "repair stations" in outer space are opening new possibilities for the use of and need for "graveyard orbits".[41] The speed at which technology has developed since the launch of the first artificial satellite *Sputnik 1* enables a cautious look into the future; many lessons can therefore be learned from past developments. These technological trends also indicate that future armed conflicts may increasingly involve space-based capabilities, which renders the integration of IHL considerations into space operations ever more urgent.

Historical technological foundations of space capabilities

The transition from early dreams of space to modern achievements is a fascinating story of innovation and perseverance. A seminal moment in the history of space travel research was marked by the publication of Robert H. Goddard's groundbreaking 1919 work *A Method of Reaching Extreme Altitudes*, which laid the theoretical foundation for space travel and paved the way for future research in the field.[42] The application of "de Laval nozzle to liquid fuel rockets",[43] as pioneered by Goddard, demonstrated the feasibility of developing powerful propulsion systems capable of achieving the high velocities necessary for interplanetary travel. The subsequent transformation of the concept of extraterrestrial exploration into a tangible engineering challenge has had a profound impact on the field, inspiring generations of scientists and engineers to actualize these visions.

The twentieth century witnessed significant advancements in the field of space travel. The launch of the first artificial satellite, *Sputnik 1*, in 1957, signalled

38 ICRC, above note 16, p. 1.

39 Victoria Samson and Kathleen Brett (eds), *Global Counterspace Capabilities: An Open Source Assessment*, Secure World Foundation, Broomfield, CO, 2026, p. 02-17.

40 Todd Harrison *et al., Space Threat Assessment 2022*, Center for Strategic and International Studies, Washington, DC, 2022, p. 24; Hou-Yuan Lin, "BeiDou-G2: Past and Present", *arXiv*, 2022, p. 1, available at: https://arxiv.org/abs/2204.09258.

41 NASA, "Space Station Enables Tests of Technology to Capture, Refuel, Repair Orbiting Satellites", 21 July 2022, available at: www.nasa.gov/missions/station/space-station-enables-tests-of-technology-to-capture-refuel-repair-orbiting-satellites/; Douglas Gorman, "Spaceium is Building Service Stations in Space", *Payload*, 28 June 2024, available at: https://payloadspace.com/spaceium-is-building-service-stations-in-space/.

42 Robert H. Goddard, *A Method of Reaching Extreme Altitudes*, Smithsonian Miscellaneous Collections, Vol. 71, No. 2, Smithsonian Institution, Washington, DC, 1919, available at: https://iiif.library.cmu.edu/file/Posner_629.13338_G57M_1919/Posner_629.13338_G57M_1919.pdf.

43 ESA, "Solid and Liquid Fuel Rockets", available at: www.esa.int/Education/Solid_and_liquid_fuel_rockets2.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

the commencement of the first space age.[44] This historic event demonstrated that the launch of artificial satellites into orbit was not only feasible but also practical, thereby paving the way for the development of a wide range of applications, including navigation, communication, weather monitoring and scientific research. In a period spanning just over a decade, with the culminating event occurring in 1969, humankind accomplished another milestone, perhaps one of the most significant in history: the achievement of a lunar landing.[45] The Apollo 11 mission demonstrated that, given sufficient ingenuity and determination, reaching other celestial bodies was no longer merely a theoretical prospect but a tangible goal.

In addition to rockets and associated missions, the concept of space habitats emerged early on as a visionary idea. In 1929, the Slovenian officer Hermann Potočnik Noordung published his vision for a complete space station in his book *The Problem of Space Travel*.[46] The notion of a rotating space station to simulate gravity and support human life in orbit was remarkably advanced for its time. In the contemporary era, space-based facilities such as the International Space Station embody the principles established by Potočnik Noordung, functioning as both laboratories and habitats for astronauts engaged in scientific research in microgravity.[47] These developments demonstrate how initial ideas that were once considered science fiction have steadily become integral parts of our space exploration and use endeavours, thus illustrating the incredible progress made over the past century. These historical developments also established the foundations for the contemporary dual-use environment, as numerous technologies originally developed for exploration or strategic purposes have since become integral to essential civilian services.

Commercial actors and the transformation of space operations

A large proportion of the projects discussed above have been driven by military endeavours, while others have been driven by scientific thought. The majority of these undertakings have been characterized by an objective of showcasing the strength of a State. This ongoing development of projects is marked by significant investment of States in space technology for the purpose of maintaining or enhancing their strategic positions.[48] Nevertheless, there has been a notable increase in the involvement of private actors in space exploration. These private actors have already

44 S. Hobe, above note 4, 32.

45 NASA, "Apollo 11 Lunar Landing Mission", press kit, 6 July 1969, p. 3.

46 Hermann Noordung, *Das Problem der Befahrung des Weltraums* [*The Problem of Space Travel*], eds. Ernst Stuhlinger, J. D. Hunley and Jennifer Garland, NASA History Series, NASA SP-4026, Washington, DC, 1995 (first published 1919), available at: https://ntrs.nasa.gov/citations/19950015477. For more on Noordnung, see Katja Grünfeld and Stephan Hobe, "A Great Pioneer of Space Travel", *Journal of Air and Space Law*, Vol. 71, March 2022.

47 Melissa L. Gaskill, "Station Science 101: Research in Microgravity: Higher, Faster, Longer", NASA, 13 May 2024, available at: www.nasa.gov/missions/station/iss-research/station-science-101-research-in-microgravity-higher-faster-longer/.

48 For current statistics on governmental investments, see Statista, "Government Expenditure on Space Programs in 2022 and 2024, by Major Country", 2025, available at: www.statista.com/statistics/745717/global-governmental-spending-on-space-programs-leading-countries/.

played a significant role in hostilities, as evidenced by the involvement of companies such as ICEYE and Maxar, which are reported to have delivered satellite imagery of the Ukrainian front line to Ukrainian forces in the Russian–Ukraine conflict, as previously indicated. It is thus notable that some private actors are able to facilitate development to a greater extent than States, due to the financial resources and strategic investments available to them.[49] The advent of private actors has engendered a novel dynamic, thereby effecting a shift in the balance of power and capabilities in outer space.[50]

While there has been a notable increase in the participation of private actors in space-related activities,[51] these entities are also assuming an increasingly prominent role in armed conflicts. The capacity to produce high-resolution images and real-time data has become of inestimable value to military operations, intelligence-gathering and strategic planning.[52] In contrast to State actors, private actors frequently exhibit greater operational flexibility and less bureaucratic oversight, enabling expedited deployment and innovation.[53] The financial resources and strategic investments of these entities have been instrumental in facilitating the rapid development of new technologies, thereby enabling the enhancement of capabilities in a more efficient and expeditious manner, as compared to the protracted processes typically associated with government-sponsored projects.[54] This influx of private capital and expertise has lowered barriers to entry in space activities, leading to a more crowded and "competitive environment".[55]

The increasing involvement of private actors in outer space carries profound implications for armed conflicts and international security. The increased capacity of actors to deploy and operate space-based assets may expand the scope of military applications, both defensive and offensive. Private actors have the capacity to develop and deploy advanced satellite systems, ASAT weaponry and other space-based instruments with the potential to influence the trajectory of conflicts.[56] Their involvement gives rise to a number of issues, including those of regulation, accountability and the possibility of escalation, as the boundary between civilian and military space activities becomes increasingly blurred.[57] Furthermore, the ease of access and

49 ESPI, *The Rise of Private Actors in the Space Sector: Executive Summary*, July 2017, available at: www.espi.or.at/wp-content/uploads/2022/06/ESPI-report-The-rise-of-private-actors-Executive-Summary-1.pdf.

50 *Ibid.*

51 *Ibid.*

52 G. K. S. Amruta, "The Role of Private Entities in Outer Space Activities", *International Journal for Multidisciplinary Research*, Vol. 7, No. 2, 2025, p. 1.

53 Mikko Punnala, Santeri Punnala, Arto Ojala and Heidi Kuusniemi, "The Space Economy: Review of the Current Status and Future Prospects", in Arto Ojala and William W. Baber (eds), *Space Business: Emerging Theory and Practice*, Springer Nature Singapore, Singapore, 2024, pp. 41 ff.; Zoe Szajnfarber, Matthew G. Richards and Annalisa L. Weigel, "Challenges to Innovation in the Government Space Sector", *Defense Acquisition Research Journal*, July 2011.

54 G. K. S. Amruta, above note 52, p. 2.

55 *Ibid.*, p. 5.

56 Clelia Iacomino, *Commercial Space Exploration: Potential Contributions of Private Actors to Space Exploration Programmes*, Springer, Vienna, 2019, p. 40.

57 B. Hainaut, above note 10, p. 11.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

rapid development facilitated by private investments signifies that space-based capabilities are no longer solely within the reach of powerful States, but are increasingly accessible to a broader range of actors. This democratization of space technology has the possibility to result in a more unpredictable security environment where conflicts may become more prevalent and intense, extending into the domain of outer space. In essence, private entities have profoundly transformed the dynamics of outer space, rendering it a more multifaceted, competitive and potentially hazardous domain within the context of armed conflicts. This shift also complicates the application of IHL, as private actors may operate systems that simultaneously support civilian and military functions, thereby raising questions regarding accountability and the protection of civilian infrastructure.

Prospective military uses of outer space

An examination of the advancements made in technology reveals that the utilization of outer space is set to witness a marked expansion, thereby becoming even more intertwined with our daily lives and military operations. As noted, the utilization of satellites has become imperative in contemporary society, with their function encompassing pivotal roles in various domains, including communication, navigation, meteorological forecasting and scientific research.[58] As technology advances, these functions are expected to become increasingly sophisticated and widespread, continuing to exert growing influence on a wide range of domains, from global commerce to personal devices. This growing reliance on space infrastructure gives rise to concerns regarding security and the possibility of conflicts spreading beyond Earth;[59] as space-based systems become increasingly vital, they also become popular targets in hostilities,[60] and this could result in a future where military actions are not confined to terrestrial battlegrounds but also involve space-based weapons and strategies. Such a development would inevitably intensify the legal and humanitarian stakes involved, as any interference with satellites risks cascading effects on civilian services far removed from the immediate military objective.

With respect to military applications, a number of trends indicate the potential for outer space to become a theatre of war for the attainment of strategic dominance in the future. The development of space-based missiles and orbital strikes represents a particularly concerning possibility. The employment of such armaments could result in the disruption or destruction of enemy satellites, which are indispensable for communication, navigation and intelligence. The notion of orbital strikes, whereby missiles are launched from outer space or are employed to target satellites, has the capability to profoundly transform the character of warfare, rendering

58 Su-Yin Tan, "Introduction to Meteorological Satellites", in Su-Yin Tan, *Meteorological Satellite Systems*, Springer, New York, 2013; ESA, "Satellite Frequency Bands", available at: www.esa.int/Applications/Connectivity_and_Secure_Communications/Satellite_frequency_bands.

59 ICRC, above note 16, p. 1.

60 *Ibid.*, pp. 7–8.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

conflicts more destructive and challenging to regulate.[61] Such developments may initiate a new arms race in outer space, with States allocating substantial resources to ASAT systems and space-based weaponry with the aim of safeguarding their interests or augmenting their global influence. The implementation of these advancements is also contingent on the geopolitical landscape on Earth – States will assess the risks and benefits of deploying such weapons based on their security needs and international relations, as with any weapon. Should these capabilities be realized, they would give rise to complex questions under IHL, particularly with regard to proportionality and the foreseeability of incidental harm to civilian infrastructure that is dependent on uninterrupted satellite services.

In considering the future of space exploration, it is evident that technological innovation and geopolitical challenges on Earth will play a pivotal role in shaping the course of events.[62] As States continue to develop their space capabilities, the potential for space-based weapons such as orbital strikes could become more realistic, raising serious concerns about stability and the risk of escalation. However, the actual implementation of such weapons will also depend on the global political climate, treaties, and the willingness of States to abide by international agreements aimed at preventing an arms race in outer space. The issue is further complicated by the increasing presence of humans in outer space, whether in scientific, commercial or exploratory capacities, which in turn expands the range of potential threats to life in that environment. The future of outer space utilization will be characterized by a multifaceted interaction between technological capabilities and the geopolitical dynamics that influence security strategies on a global scale. In light of these considerations, it is imperative that IHL be integrated into military planning, as the humanitarian consequences of space-based hostilities are likely to extend far beyond the immediate area of operations.

Effects of space operations on civilian infrastructure

Concerns pertaining to the long-term sustainability of outer space, particularly the risk that excessive space debris could render certain orbits unusable,[63] have been addressed above, but contemporary conflicts also demonstrate that activities affecting outer space have tangible consequences on Earth. As previously outlined, essential civilian services are heavily reliant on space-based systems, rendering them particularly vulnerable in dual-use and critical infrastructure contexts. These vulnerabilities imply that military operations affecting space systems have the potential to engender immediate and severe humanitarian consequences, even when civilians

61 Cassandra Steer, "International Humanitarian Law in the 'Grey Zone' of Space and Cyber", Cybersecurity and Outer Space Essay Series, Centre for International Governance Innovation, 29 January 2023, available at: www.cigionline.org/articles/international-humanitarian-law-in-the-grey-zone-of-space-and-cyber/.

62 S. Hobe, above note 4, pp. 29–39.

63 ESA Space Debris Office, above note 36; Organization for Economic Co-operation and Development (OECD), *Earth's Orbits at Risk: The Economics of Space Sustainability*, OECD Publishing, Paris, 2022.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

are not the intended target. These consequences will be discussed in greater detail below, after taking a closer look at dual-use infrastructure.

Vulnerabilities of dual-use infrastructure

It is no secret that many infrastructures in outer space are of dual-use character.[64] A significant proportion of satellite systems and space-based assets are designed for civilian application, yet they can also be utilized for military or strategic advantage.[65] The dissemination of such dual-use technologies has had a considerable impact on civilian infrastructure, both in terms of enhancing capabilities and introducing vulnerabilities. For instance, Global Navigation Satellite Systems such as GPS,[66] GLONASS,[67] Galileo[68] and BeiDou[69] are predominantly utilized for civilian navigation, transportation and logistics. These systems depend on a network of satellites orbiting Earth, providing precise positioning and timing information that is vital for various sectors, including aviation, shipping, agriculture and emergency services.[70] In a similar manner, Earth observation satellites that were initially developed for military reconnaissance[71] have become vital for civilian applications, including disaster management, environmental monitoring, urban planning and resource management. These satellites provide real-time data on weather patterns, deforestation, crop health and pollution levels, informing policy decisions and economic activities.[72] It is crucial to note that these systems serve both civilian and military functions; consequently, any interference with them risks blurring the line between civilian objects and military objectives, thus complicating the application of the principle of distinction.

Moreover, with the onset of the Russia–Ukraine conflict, there has been an increase in the publication of documents offering evidence of the interaction

64 Charlie J. P. Bennett, "The Dual-Use Conundrum of the Lisbon Treaty Regarding Space Governance: Solutions through International Legal Interpretation?", *Global Policy*, Special Issue, "EU Space Governance at the Threshold of a New Era", 2025; Linda Slapakova, Theodora Ogden and James Black, "Strategic and Legal Implications of Emerging Dual-Use ASAT Systems", *NATO Legal Gazette*, Vol. 42, December 2021.

65 ICRC, above note 16, p. 1.

66 Catherine G. Manning, "GPS", NASA, 25 September 2023, available at: www.nasa.gov/directorates/somd/space-communications-navigation-program/gps/.

67 Roscosmos, "About GLONASS", available at: https://glonass-iac.ru/en/about_glonass/.

68 ESA, "What Is Galileo?", available at: www.esa.int/Applications/Satellite_navigation/Galileo/What_is_Galileo.

69 ESA, "BeiDou General Introduction", available at: https://gssc.esa.int/navipedia/index.php/BeiDou_General_Introduction.

70 Alexis Topete *et al.*, "How Is GPS Used? Understanding Navigation System Use and Its Relation to Spatial Ability", *Springer Open Cognitive Research: Principles and Implications*, Vol. 9, No. 16, 2024.

71 European Defence Agency, *Civil-Military Synergies in the Field of Earth Observation: Final Report of the Joint Task Force*, Brussels, 26 November 2010, pp. 5–7.

72 Huadong Guo, Wenxue Fu and Guang Liu, "Development of Earth Observation Satellites", in Huadong Guo, Wenxue Fu and Guang Liu, *Scientific Satellite and Moon-Based Earth Observation for Global Change*, Springer, Singapore, 2019, pp. 34 ff.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

between military and civilian objects in both outer space and on Earth.[73] Although dual-use infrastructure offers significant advantages, it concomitantly engenders vulnerabilities. Due to the accessibility of these systems and their extensive utilization, adversaries have the capability to target them with the objective of disrupting civilian services. To illustrate, interference with GPS signals through jamming or spoofing has the potential to compromise navigation and timing accuracy,[74] thereby exerting a detrimental effect on various areas, including transportation safety, financial transactions and communication networks. Such vulnerabilities have been demonstrated in various incidents where GPS signals were reported to have been intentionally interfered with or manipulated.[75] These examples emphasize that even limited interference with dual-use systems can produce disproportionate effects on civilians, which must be carefully weighed in proportionality assessments.

The present state of space technology and infrastructure development indicates an increasing reliance on satellite systems for both civilian and military applications. As these systems become more sophisticated and pervasive, their significance to daily life and national security is set to increase exponentially. As civilian infrastructure becomes increasingly dependent on space-based systems, any disruption – whether accidental or intentional – has the potential to engender cascading effects on transportation, communication, finance and emergency response.[76] The increasing sophistication of dual-use technologies necessitates international cooperation and robust security measures to protect these vital systems from emerging threats. These illustrations underscore the probable ramifications of vulnerabilities in space infrastructure, which possess the capacity to exert a profound and pervasive influence on the day-to-day functioning of society and the provision of essential services. This interconnectedness underscores the need for prudence in planning and executing military operations that may have space-based implications.

Risks to critical dual-use infrastructure

Following the general overview of the impact of hostilities on civilian infrastructure that is increasingly characterized as dual-use, the question of critical dual-use infrastructure remains unanswered. It should be noted that the term "critical" is used in this context to denote essential services;[77] it is therefore evident that critical dual-use

73 R. Dickey and M. P. Gleason, above note 28; Hellenic Air Force Academy, *Commercial Satellites in Crisis and War: The Case of the Russian–Ukrainian Conflict*, Occasional Paper No. 3, Dekeleia Air Base, 2023.

74 Gerard O'Dwyer, "Finland, Norway Press Russia on Suspected GPS Jamming during NATO Drill", *Defense News*, 16 November 2018, available at: www.defensenews.com/global/europe/2018/11/16/finland-norway-press-russia-on-suspected-gps-jamming-during-nato-drill/.

75 NETSCOUT, *DDoS Threat Intelligence Report*, No. 13, 2024, available at: www.netscout.com/threatreport/wp-content/uploads/2024/09/TR_1H2024_Web.pdf.

76 ICRC, above note 16.

77 Eirini Giorgou and Abby Zeith, "When the Lights Go Out: The Protection of Energy Infrastructure in Armed Conflict", *Humanitarian Law and Policy Blog*, 20 April 2023, available at: https://blogs.icrc.org/law-and-policy/2023/04/20/protection-energy-infrastructure-armed-conflict.

infrastructure refers to space-based systems that are deemed to be essential for the maintenance of infrastructure and public health and safety networks, as well as economic stability. These systems comprise high-precision navigation satellites,[78] Earth observation platforms utilized for disaster response,[79] and communication networks that support emergency services.[80] The potential consequences of their disruption or destruction are so significant that governments worldwide are compelled to prioritize their protection.

Given their critical importance, these systems are attractive targets for adversaries. ASAT weapons, cyber attacks and electronic jamming pose significant threats; furthermore, the increasing sophistication of cyber threats suggests the capability for malicious actors to hack into satellite control systems, manipulate data or temporarily disable services. The potential for deliberate interference with critical space-based assets gives rise to concerns regarding national security, economic stability and compliance with IHL. The latter emphasizes the protection of civilian infrastructure and the minimization of harm during conflicts.[81] Many States advocate for treaties and agreements to limit the deployment of destructive ASAT weapons and to promote responsible behaviour in space, aligning with principles of international law to prevent harm to civilians and civilian objects.[82]

The vulnerability of critical dual-use infrastructure highlights the need for international cooperation and the establishment of norms to prevent space conflicts. In order to protect these assets, it is necessary to implement redundancy measures, develop resilient systems and establish rapid response capabilities in order to mitigate possible disruptions. It is imperative that these measures comply with IHL to prevent escalation and ensure the protection of civilian populations. As reliance on space-based critical infrastructure grows, so too does the importance of safeguarding it against emerging threats, ensuring the stability of essential services that underpin modern civilization while respecting legal obligations to minimize harm to civilians during conflicts.

78 Zhetao Zhang *et al.*, "High-Precision and High-Reliability Positioning, Navigation, and Timing: Opportunities and Challenges", *Remote Sensing*, Vol. 16, No. 23, 2024.

79 Guy Jean-Paul Schumann *et al.*, "Assisting Flood Disaster Response with Earth Observation Data and Products: A Critical Assessment", *Remote Sensing*, Vol. 10, No. 8, 2018.

80 Qian Wang *et al.*, "An Overview of Emergency Communication Networks", *Remote Sensing*, Vol. 15, No. 6, 2023.

81 Especially relevant: Geneva Convention relative to the Protection of Civilian Persons in Time of War of 12 August 1949, 75 UNTS 287 (entered into force 21 October 1950); Protocol Additional (I) to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts, 1125 UNTS 3, 8 June 1977 (entered into force 7 December 1978) (AP I); Jean-Marie Henckaerts and Louise Doswald-Beck (eds), *Customary International Humanitarian Law*, Vol. 1: *Rules*, Cambridge University Press, Cambridge, 2005 (ICRC Customary Law Study), Rules 1, 7, 14–15, available at: https://ihl-databases.icrc.org/en/customary-ihl/rules.

82 UNGA Res. 76/231, 24 December 2021. On the banning of ASAT testing, for example, see Shannon Bugos, "Seven Countries Join ASAT Test Ban", *Arms Control Today*, November 2022, available at: www.armscontrol.org/act/2022-11/news-briefs/seven-countries-join-asat-test-ban.

Effects on civilian infrastructure and essential services

In the modern era, it is increasingly difficult to identify infrastructure that is exclusively utilized for civilian purposes. This challenge is especially salient in the context of armed conflict, wherein numerous services that are vital to civilians, including communication, navigation and environmental monitoring, are facilitated by space-based systems that concurrently serve military purposes. Consequently, the following paragraphs focus on those civilian services delivered via outer space that are most likely to be affected during hostilities, and on the implications that disruptions to such dual-use systems may have for civilian populations.

The significance of satellite-based communication systems in civilian life is indisputable, particularly in regions where terrestrial networks are either limited or vulnerable to damage. In the context of armed conflict, these systems frequently become indispensable when ground infrastructure is destroyed, overloaded or deliberately targeted. In situations of crisis, civilians have been shown to rely on satellite links for a number of purposes. Firstly, these links are used for emergency communications; secondly, they provide access to information; and thirdly, they facilitate the coordination of humanitarian assistance. Any disruption to these services, whether through jamming, cyber operations or physical attacks on space assets, can therefore directly impede the ability of affected populations to seek help, receive warnings or maintain contact with relief providers. Furthermore, satellites that facilitate meteorological forecasting and environmental monitoring also play a crucial role in ensuring the safety of civilian populations.[83] In situations involving armed conflict, the accuracy of meteorological data and environmental assessments remains paramount for the effective planning of evacuations, the management of humanitarian logistics and the mitigation of secondary hazards such as floods, wildfires or chemical releases.[84] The utilization of satellite imagery has become a customary practice in the assessment of damage, the identification of affected areas and the coordination of rescue operations in situations where ground access is restricted.[85] These functions assume even greater significance in situations of heightened conflict, particularly in circumstances where civilian mobility is significantly constrained and on-site assessments become unfeasible.

These civilian applications illustrate the extent to which essential services depend on space-based systems, and they highlight the risks that arise when such systems are disrupted during armed conflict. The utilization of outer space in hostilities has already demonstrated its capacity to exacerbate the effects of ground

83 Jun Li *et al.*, "Quantitative Applications of Weather Satellite Data for Nowcasting: Progress and Challenges", *Journal of Meteorological Research*, Vol. 38, No. 3, 2024.

84 World Meteorological Organization, *Atlas of Mortality and Economic Losses from Weather, Climate and Water-Related Hazards (1970–2021)*, Geneva, 2023, available at: https://wmo.int/publication-series/atlas-of-mortality-and-economic-losses-from-weather-climate-and-water-related-hazards-1970-2021.

85 Nasradeen Abdelrahman Hassan Gadallah and Ahmed Abdelrahman Hassan Siddig, "Space and Ground-Based Earth Observations for Hazards Valuation and Disaster Risk Management in the Era of Climate Change," in Rifaat Mahmoud Abdalla (ed.), *Revolutionizing Earth Observation: New Technologies and Insights*, IntechOpen, London, 2024.

operations: interference with satellite communications, navigation signals or Earth observation capabilities has the potential to hinder civilian transportation, health-care delivery and emergency response. These vulnerabilities imply that military operations affecting space systems have the potential to engender immediate and severe humanitarian consequences.[86] In the contemporary era of warfare, with its increasing incorporation of space-based technologies, the safeguarding of these assets has become imperative in order to protect civilian populations and maintain essential infrastructure. This underscores the necessity of interpreting IHL principles in a manner that fully accounts for civilian dependence on space-based systems, ensuring that military operations do not cause excessive harm to essential services.

Discussions surrounding the application of IHL in outer space

In recent years, there has been an increased level of discourse around the application of IHL in the context of armed conflicts involving outer space operations;[87] however, an under-estimation of the significance of the utilization of outer space remains. The recent directive issued by US president Donald J. Trump pertaining to the establishment of an "Iron Dome for America",[88] including the deployment of a new generation of military space-based assets, has heightened the attention directed towards the utilization of outer space in the context of armed conflicts. Nevertheless, there seems to be a lack of consideration paid to the potential impact on civilian infrastructure in outer space and on Earth, and the means by which such infrastructure might be protected. The following examples illustrate the main themes that currently shape discussions on this issue.

Academic discussions

The international legal framework governing activities in outer space, particularly IHL, remains a complex and evolving area of scholarly debate. Conventionally, the field of space law has been guided mainly by the OST, which emphasizes the peaceful use of outer space and prohibits the placement of nuclear weapons or other weapons of mass destruction in outer space.[89] However, the treaty does not explicitly address the application of IHL principles in outer space, thus prompting academic discussions on how those principles might extend to activities beyond Earth. It is the

86 International Telecommunication Union, International Civil Aviation Organization and International Maritime Organization, "Joint Statement on Protection of the Radio Navigation Satellite Service from Harmful Interference", March 2025, available at: www.itu.int/en/mediacentre/Documents/2025/ICAO-IMO-ITU-Joint-Statement.pdf.

87 S. Berrang, above note 6.

88 White House, "Fact Sheet: President Donald J. Trump Directs the Building of the Iron Dome Missile Defense Shield for America", 27 January 2025, available at: www.whitehouse.gov/fact-sheets/2025/01/fact-sheet-president-donald-j-trump-directs-the-building-of-the-iron-dome-missile-defense-shield-for-america/.

89 OST, above note 19, Art. IV.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

contention of scholars that, in view of the increasing militarization of outer space and the development of satellite-based systems for strategic advantage, there is an urgent need to clarify how principles such as distinction, proportionality and precautions in attack apply to space-based assets and potential hostilities.[90] These discourses underscore the significance of interpretative frameworks that harmonize space law with IHL, emphasizing the need for explicit interpretation in order to forestall escalation and ensure the protection of civilian and civilian-associated objects in outer space.[91]

A substantial proportion of the academic discourse focuses on the applicability of IHL to space systems employed in armed conflict, whether they are affected by military operations intentionally or incidentally,[92] outlining that principles such as the prohibition of unnecessary suffering and the protection of civilian populations are universal.[93] Moreover, scholars have examined outer space as a warfare domain akin to land, sea or air,[94] thus raising questions about the ability of current legal regimes to prevent and manage such conflicts. The importance of establishing norms of responsible behaviour, transparency measures and confidence-building activities among spacefaring nations in order to reduce the risk of misunderstandings and accidental hostilities is emphasized.[95] Throughout the discourse, it is imperative to acknowledge the intricate and overarching network of norms that govern space activities. This network encompasses space law, particularly the OST, general international law (as exemplified by the UN Charter) and IHL, including the Geneva Conventions, their Additional Protocols and customary law.[96] In the present article, the focus lies on IHL alongside space law, without addressing in depth the complexities that may arise when these legal regimes apply concurrently.[97]

The academic discussion also considers the role of emerging technologies, such as cyber operations and directed energy weapons, that could have humanitarian implications and challenge existing legal boundaries.[98] The academic discourse

90 C. Steer and D. Stephens, above note 31.

91 S. Berrang, above note 6.

92 Michael N. Schmitt, Wolff Heintschel von Heinegg and Tetyana Krupiy, "War in Space: How International Humanitarian Law Might Apply," *Just Security*, 16 July 2020, available at: www.justsecurity.org/68906/war-in-space-how-international-humanitarian-law-might-apply/; S. Berrang, above note 6.

93 Henri Meyrowitz, "The Principle of Superfluous Injury or Unnecessary Suffering: From the Declaration of St. Petersburg of 1868 to Additional Protocol I of 1977", *International Review of the Red Cross*, Vol. 34, No. 299, 1994.

94 Tim Sweijs and Davis Ellison, "The Next Frontier: Strategic Theory for the Space Domain", in Saadia M. Pekkanen and P. J. Blount (eds), *The Oxford Handbook of Space Security*, Oxford University Press, Oxford, 2024.

95 Peter Martinez, *Transparency and Confidence Building Measures for Outer Space Activities*, Preprint Series PP23/06, Secure World Foundation, Broomfield, CO, 2023.

96 For discussion, see Kubo Mačák, "Silent War: Applicability of the Jus in Bello to Military Space Operations", *International Law Studies*, Vol. 94, 2018, pp. 10–15.

97 G. B. Kuplic and J. Sawmiller, above note 24, pp. 209 ff.

98 B. Hainaut, above note 10.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

emphasizes the necessity of developing a comprehensive, multilateral legal framework that integrates IHL principles into outer space governance, ensuring that space remains a domain of peaceful use and that any conflicts therein are conducted within clear, internationally accepted legal limits.[99]

Manuals on the military use of outer space

Besides the general academic discussion, manuals have already been drafted concerning this issue.[100] The legal and regulatory framework governing space activities, particularly in the context of armed conflict, is currently characterized by a combination of international treaties, customary law and specialist manuals developed by various organizations and national authorities. The OST is widely regarded as the cornerstone of space law, insofar as its Article IV establishes that outer space should be used for peaceful purposes and prohibits the placement of nuclear weapons and other weapons of mass destruction in outer space. Despite the fact that it does not explicitly address armed conflict scenarios, the OST creates the foundational principles that inform subsequent legal sources. These principles are further elaborated in a series of additional agreements, including the Rescue Agreement of 1968,[101] the Liability Convention of 1972,[102] the Registration Convention of 1976[103] and the Moon Agreement of 1984.[104] Collectively, these instruments establish the legal framework for all space activities, but they lack specific provisions for military conflicts or the weaponization of outer space. This has prompted the development of specialized manuals such as the *Woomera Manual on the International Law of Military Space Operations* (Woomera Manual) and the *McGill Manual on International Law Applicable to Military Uses of Outer Space* (McGill Manual),[105] with other manuals, such as the *Oslo Manual on Selected Topics of the Law of Armed Conflict* (Oslo Manual) and *Tallinn Manual on the International Law Applicable to Cyber Warfare* (Tallinn Manual), adding to the framework.[106] These manuals provide in-depth

99 Gershon Hasin, "From 'Space Law' to 'Space Governance': A Policy Oriented Perspective on International Law and Space Activities", *Harvard International Law Journal*, Vol. 64, No. 2, 2023; S. Berrang, above note 6; Jack Mawdsley, "Applying Core Principles of International Humanitarian Law to Military Operations in Space", *Journal of Conflict and Security Law*, Vol. 25, No. 2, 2020.

100 For the most specific, see Jack Beard, Dale Stephens and David Koplow (eds), *The Woomera Manual on the International Law of Military Space Operations*, Oxford University Press, Oxford, 2024 (Woomera Manual); McGill Manual, above note 21.

101 Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, 672 UNTS 119, 22 April 1968 (entered into force 3 December 1968).

102 Convention on International Liability for Damage Caused by Space Objects, 961 UNTS 187, 29 March 1972, (entered into force 1 September 1972).

103 Convention on Registration of Objects Launched into Outer Space, 1023 UNTS 15, 14 January 1976, (entered into force 15 September 1976).

104 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, 1363 UNTS 3, 18 December 1979, (entered into force 11 July 1984).

105 Woomera Manual, above note 100; McGill Manual, above note 21.

106 Yoram Dinstein and Arne Willy Darhl (eds), Oslo *Manual on Selected Topics of the Law of Armed Conflict*, Springer Open, New York, 2020 (Oslo Manual), Section I; Michael N. Schmitt (ed.), *Tallinn Manual on the International Law Applicable to Cyber Warfare*, Cambridge University Press, Cambridge, 2013,

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

analysis and recommended practices for conducting outer space operations in a responsible manner during conflicts, with a particular emphasis on the importance of protecting space-based assets and preventing unchecked militarization.

Furthermore, the manuals address the critical issues of conflict prevention and management in outer space, acknowledging that outer space is considered a new warfare domain. The importance of transparency, communication and international cooperation to minimize the risk of misunderstandings escalating into conflict is emphasized. In the event of armed conflict, the manuals examine how existing IHL rules, originally designed for terrestrial warfare, apply to space-based assets and activities. Satellites and other space infrastructure are vital for civilian life, military operations, scientific research and environmental monitoring, making their protection of paramount importance; the manuals stress that space-based assets must be shielded from intentional attacks, aligning with principles such as distinction and proportionality to avoid unnecessary harm to both space infrastructure and the broader environment. The manuals also explore possible scenarios involving offensive operations, ASAT weapons and cyber attacks, thereby highlighting the need for clearly defined legal boundaries and specific responsible behaviour norms.[107] The manuals consequently advocate for conflict prevention measures and responsible conduct,[108] with the objective of preventing the militarization and weaponization of space, thereby ensuring that outer space remains a domain of peaceful exploration and use.[109]

Moreover, these manuals explore the responsibilities of private actors, who are becoming increasingly involved in space exploration and use, space resource exploitation and space commercialization.[110] As commercial entities assume greater prominence in the space sector, the need for international regulation and accountability is becoming increasingly apparent. The manuals stipulate the necessity of establishing clear legal frameworks with a view to ensuring that private actors comply with IHL standards, prevent environmental contamination and avoid contributing to orbital debris accumulation.[111] It is asserted that sustainable practices are of paramount importance to safeguard future scientific and humanitarian missions

esp. pp. 270 ff.; Michael N. Schmitt (ed.), *Tallinn Manual 2.0 on the International Law Applicable to Cyber Operations*, 2nd ed., Cambridge University Press, Cambridge, 2017 (Tallinn Manual 2.0). On the non-binding legal status of such manuals and their role within informal international law-making, see Pauline Charlotte Janssens and Jan Wouters, "Informal International Law-Making: A Way Around the Deadlock of International Humanitarian Law?", *International Review of the Red Cross*, Vol. 104, No. 920–921, 2022; Liesbeth Lijnzaad, "Going for a Test Drive? Some Observations on the Turn to Informality in the Laws of Armed Conflict", *International Review of the Red Cross*, Vol. 104, No. 920–921, 2022.

107 Woomera Manual, above note 100, pp. 174–176; McGill Manual, above note 21, Rule 112, Oslo Manual, above note 106, pp. 19 ff.

108 Oslo Manual, above note 106, Introduction.

109 Woomera Manual, above note 100, Preface; McGill Manual, above note 21, p. 1.

110 Dale Stephens and Joanna Jarose, "The Woomera Manual and Military Space Activities and Operations", Lieber Institute West Point, 30 August 2024, available at: https://lieber.westpoint.edu/woomera-manual-military-space-activities-operations/.

111 See, for example, McGill Manual, above note 21, Rule 129.

and to maintain international peace and security.[112] The overarching objective of these initiatives is to cultivate responsible conduct among all stakeholders, thereby fostering stability and cooperation in the domain of outer space.

Military doctrines and national manuals on outer space further influence the legal landscape. A number of States, including the United States and Russia,[113] have promulgated space operation doctrines that encompass guidelines pertaining to the utilization of space-based assets during periods of hostilities. The development of the manuals is therefore indicative of efforts to establish comprehensive legal frameworks that integrate humanitarian principles into space law. It is evident that these manuals play a pivotal role in the harmonization of space law with IHL, and this process is central to ensuring that the exploration and use of outer space is conducted in a manner consistent with the principles of peace, sustainability and respect for international norms. As the threat landscape evolves, with concerns over ASAT weapons, cyber attacks and orbital debris, the above-mentioned manuals and guidelines need to be updated continuously. While initiatives such as the *Woomera Manual* and the MILAMOS project provide comprehensive guidance, they do not yet examine the practical and legal challenges that arise when applying IHL to outer space in depth. Nevertheless, the collective efforts of treaties, military doctrines and international guidelines contribute to shaping an emerging understanding aimed at ensuring that peaceful uses can continue even in situations where military operations extend into the space domain.[114]

Discussions by the ICRC and other international organizations

International organizations and their committees, such as the UN Committee on the Peaceful Uses of Outer Space, play a pivotal role in encouraging responsible conduct by formulating non-binding guidelines and best practices. UN initiatives such as the *Guidelines for the Long-term Sustainability of Outer Space Activities* promote transparency, responsible conduct and the development of norms to prevent conflicts and debris proliferation.[115] Additionally, the UN has established a number of processes that address the prevention of armed conflict in or through outer space in a more direct manner. The GGE on PAROS and the subsequent OEWG on PAROS have

112 Olga Stelmakh-Drescher, "How to Shape a Sustainable Future in Space through Responsible Action", World Economic Forum, 4 November 2024, available at: www.weforum.org/stories/2024/11/sustainable-space-through-responsible-action/?utm_source=chatgpt.com; University of Exeter, "Existing International Law Can Help Secure Peace and Security in Outer Space, Study Shows", *Phys.org*, 2 April 2025, available at: https://phys.org/news/2025-04-international-law-peace-outer-space.html.

113 US Space Force, *The Space Force, Space Training and Readiness Command*, Space Force Doctrine Document No. 1, 9 April 2025; Russian Federation, *Military Doctrine of the Russian Federation, Approved by Presidential Decree No. Pr.-2976*, 25 December 2014, paras 12–32.

114 Tanja Masson-Zwaan and Roberto Cassar, "The Peaceful Uses of Outer Space", in Simon Chesterman, David M. Malone and Santiago Villalpando (eds), *The Oxford Handbook of United Nations Treaties*, Oxford University Press, Oxford, 2019, pp. 194–195.

115 UN Office for Outer Space Affairs, *Guidelines for the Long-Term Sustainability of Outer Space Activities*, June 2019.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

become central fora in which States articulate their positions on issues such as the definition of space weapons, the legality of kinetic and non-kinetic counter-space capabilities, and the scope of responsible military behaviour.[116] As evidenced by the proceedings of these bodies, there is a persistent divergence of opinion; for instance, China and Russia continue to advocate for a legally binding treaty prohibiting the placement of weapons in outer space,[117] whereas several Western States, including members of the European Union, favour non-binding norms and behavioural commitments rather than capability-based prohibitions.[118] The present OEWG on PAROS, incorporating its substantive April and July 2025 sessions in Geneva, is a reflection of these ongoing divergences. Despite the occurrence of a certain degree of progress during informal consultations, the sessions were ended without the establishment of an agenda or programme of work. This outcome serves to highlight the ongoing presence of both procedural and political challenges that continue to exert their influence on efforts to cultivate a shared understanding with the objective of mitigating risks in the domain of outer space.[119]

At the same time, the ICRC has become increasingly involved in deliberations concerning the applicability of IHL to activities in outer space. This engagement is a response to the rapid advancements in technology and the proliferation of space-based military and civilian assets. While IHL has historically focused on armed conflicts on Earth, the ICRC acknowledges that space activities, such as satellite deployment, military space operations and potential conflicts involving space-based assets, pose new challenges for IHL.[120] The ICRC is currently advocating for a clearer legal framework that ensures the protection of civilians and civilian infrastructure in outer space,[121] and it emphasizes that existing principles of IHL should be extended and adapted to address the unique environment of outer space;[122] this includes discussions on the relevance of principles such as distinction, proportionality and

116 UNGA Res. 78/20, 4 December 2023; *Report of the Group of Governmental Experts on Further Practical Measures for the Prevention of an Arms Race in Outer Space*, UN Doc. GE-PAROS/2024/CRP.4, 23 August 2024.

117 *Possible Substantive Elements of an International Legally Binding Instrument on the Prevention of an Arms Race in Outer Space, Including, Inter Alia, the Prevention of the Placement of Weapons in Outer Space*, UN Doc. A/AC.297/2025/WP.1, 26 September 2025.

118 *Joint Contribution of the European Union to the Work of the Open-Ended Working group on PAROS in All Its Aspects, Current and Future Threats by States to Space, Including to the Free and Unhindered Access to and Use of Space and the Long-Term Sustainability of Outer Space*, UN Doc. A/AC.297/2025/WP.4, 25 July 2025.

119 *Working Paper Submitted by Australia and Singapore*, UN Doc. A/AC.297/2025/WP.3, 25 July 2025; "Statement by Japan at the Open-Ended Working Group on the Prevention of an Arms Race in Outer Space (PAROS)", Substantive Session, Geneva, 23 July 2025; Jessica West, *Open in Name Only: The OEWG on PAROS Stumbles Through Its First Session*, Project Ploughshares, Waterloo, April 2025, pp. 2–3.

120 ICRC, above note 1, pp. 67–69.

121 ICRC, *Preliminary Recommendations on Possible Norms, Rules and Principles of Responsible Behaviours Relating to Threats by States to Space Systems*, working paper submitted to the OEWG on Reducing Space Threats, 27 January 2023, pp. 1–3.

122 ICRC, *Constraints under International Law on Military Operations in Outer Space during Armed Conflicts*, working paper, 5 May 2022, pp. 2–3.

precautions in attack within the context of space warfare.[123] In this domain, the destruction of satellites or space stations could have grave consequences for civilian populations on Earth, including the disruption of communication, navigation and the delivery of humanitarian aid. The ICRC has also emphasized the importance of transparency, accountability and rules of engagement in space conflicts, calling for international consensus to prevent the weaponization of outer space and to mitigate the risks of conflict escalation beyond Earth.[124]

The ICRC is an active participant in international fora and dialogues such as those organized by the UN Office for Outer Space Affairs and the Conference on Disarmament, with a view to promoting the integration of IHL principles into space law and policy.[125] It advocates for the development of legally binding treaties or protocols that explicitly address the conduct of hostilities in outer space, ensuring that even in the absence of specific treaties, existing legal norms are interpreted in a manner that safeguards human life and minimizes suffering.[126] The ICRC also underscores the significance of establishing safeguards for space objects designated for humanitarian purposes, such as Earth observation satellites utilized in disaster response, to avert their misuse or destruction during conflicts.[127] The ICRC's involvement in outer space discourse is indicative of its overarching mission to uphold humanitarian principles in all contexts of armed conflict, including emerging domains such as outer space. The ICRC seeks to promote international cooperation and legal clarity with a view to preventing the escalation of space conflicts and ensuring that space remains a domain that respects human dignity and security.[128]

Challenges to applying the core principle of distinction

One of the principles that is of great importance to the ICRC and academia, and which has also been reflected in State statements in multilateral fora as well as in the manuals, is also one of the "cardinal principles"[129] of IHL: the principle of distinction.[130] The principle of distinction is included in most IHL instruments and treaties, highlighting its importance.[131] IHL has been developed to provide protection for individuals and objects in the event of an armed conflict; the distinction

123 *Ibid.*

124 *Ibid.*, pp. 4–5.

125 See, for example, L. Gisel, above note 33.

126 ICRC, above note 122.

127 *Ibid.*, p. 3.

128 ICRC, above note 1, pp. 67–69.

129 International Court of Justice, *Legality of the Threat or Use of Nuclear Weapons*, Advisory Opinion, 8 July 1996, *ICJ Reports 1996*, para. 78.

130 AP I, Arts 48, 51(2), 52(2); ICRC Customary Law Study, above note 81, Rules 1, 7. For further examples, see Woomera Manual, above note 100, pp. 309 ff.; UNSC Res. 1265, 17 September 1999.

131 Emily Crawford, "The Principle of Distinction and Remote Warfare", in Jens David Ohlin (ed.), *Research Handbook on Remote Warfare*, Edward Elgar, Cheltenham, 2017, p. 51.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

between combatants and civilians and between civilian objects and military objectives is therefore its most essential element.[132] It is imperative that the principle be applied consistently and without exception, and consequently, any new weapon must be capable of distinguishing between these categories.[133] Nevertheless, the application of the principle of distinction is, unfortunately, not straightforward. This challenge has long been recognized, and with the rise of dual-use objects as described above, its practical application has only become more difficult.[134]

The principle of distinction in outer space presents further challenges in terms of its application. The advent of novel technologies and operational practices engenders further layers of complexity, thereby complicating an already complex principle. The application of distinction is increasingly stressed, as evidenced by several developments.

Firstly, it is important to note that cyber operations, which are now among the most frequently employed techniques, are generally non-kinetic, but may still constitute attacks under IHL.[135] As critical infrastructure is placed in outer space, cyber security and outer space will continue to be closely linked, and at the same time, States have assigned cyberspace a significant role. It is evident that the utilization of these systems is driven by two primary factors: first, there is the intrinsic necessity of their operation within the military organization, and second, there is the awareness of the vulnerability inherent in these systems, which presents a strategic opportunity to weaken the adversary.[136] The integrity of a satellite, inclusive of its system and data, can be compromised, impaired or destroyed through the implementation of cyber attacks.[137] The issue with cyber operations is that they are characterized by a certain number of unpredictable consequences, given the presence of indirect values. It is evident that cyber attacks have the potential to exert a significant influence on the domain of outer space; concurrently, the principle of distinction is jeopardized, as the majority of the systems targeted are dual-use systems, and attacking those systems can put civilians in a severe and dangerous situation. In addition, the majority of technology in space is vulnerable to cyber attacks, and

132 Fred Schreier, "Obligations of Private Military and Security Companies under International Humanitarian Law", in Benjamin Perrin (ed.), *Modern Warfare: Armed Groups, Private Militaries, Humanitarian Organizations, and the Law*, UBC Press, Vancouver, 2012, p. 183.

133 Eve Massingham and Annabel McConnachie, *Ensuring Respect for International Humanitarian Law*, Routledge, London 2020, p. 123.

134 Also on this topic, see G. B. Kuplic and J. Sawmiller, above note 24, pp. 218 ff.; ICRC, *International Humanitarian Law and the Challenges of Contemporary Armed Conflicts*, Geneva, September 2003, p. 11.

135 Michael N. Schmitt, "IHL and the Conduct of Hostilities", in Ben Saul and Dapo Akande (eds), *The Oxford Guide to International Humanitarian Law*, Oxford University Press, Oxford, 2020, p. 173; Heather Harrison Dinnis, *Cyber Warfare and the Laws of War*, Cambridge University Press, Cambridge, 2012, p. 197; Tallinn Manual 2.0, above note 106, Rule 14, para. 8; Knut Dörmann, *Applicability of the Additional Protocols to Computer Network Attacks*, 19 November 2004, p. 2, available at: www.icrc.org/en/doc/assets/files/other/applicabilityofihltocna.pdf.

136 William H. Boothby, "So, What Do We Make of All This?", in William H. Boothby (ed.), *New Technologies and the Law in War and Peace*, Cambridge University Press, Cambridge, 2018, p. 440.

137 S. Hobe, above note 4, p. 219.

consequently, any attack must be sufficiently specific to avoid infringing upon the principle of distinction.

Secondly, the involvement of private security entities in outer space further complicates the process of distinguishing between civilians and combatants.[138] Thirdly, autonomous weapon systems are playing an increasingly prominent role, but it remains uncertain to what extent they can meet the requirements of distinction or whether their capabilities may even extent the limits of human judgement.[139] These are just a few examples of issues that are currently challenging the application of the principle of distinction in outer space; in spite of such challenges, the effects of outer space operations on civilians and civilian objects must be constantly considered during armed conflicts.

Challenges to applying the core principles of proportionality and precaution

The obligation to account for the effects of attacks on civilians and civilian objects extends beyond the principle of distinction and is equally integral to the principles of proportionality and precaution. While the principle of proportionality focuses on minimizing damage to civilians by setting it in balance with military advantage,[140] the principle of precaution states that

> constant care must be taken to spare the civilian population, civilians and civilian objects. All feasible precautions must be taken to avoid, and in any event to minimize, incidental loss of civilian life, injury to civilians and damage to civilian objects.[141]

These principles face similar challenges as the principle of distinction, but there are also additional problems occurring which need attention in order to safeguard civilians and civilian objects. One major aspect that needs to be addressed is space debris.[142] As outlined earlier in this article, space debris is already endangering the use of outer space, and kinetic but also non-kinetic attacks can add to this problem. Damage caused by space debris could lead not only to issues for military activities in outer space but also to disruption of service for all space users, including civilian activities.

138 Benjamin Perrin, “Private Security Companies and Humanitarian Organizations”, in B. Perrin (ed.), above note 132, pp. 139–140.

139 Ian S. Handerson, Patrick Kean and Josh Liddy, “Remote and Autonomous Warfare Systems: Precautions in Attack and Individual Accountability”, in J. D. Ohlin (ed.), above note 131, p. 342.

140 AP I, Arts 51(5)(b), 57(2)(a)(iii); ICRC Customary Law Study, above note 81, Rule 14.

141 ICRC Customary Law Study, above note 81, Rule 15; AP I, Art. 57(1).

142 According to the Inter-Agency Space Debris Coordination Committee, the term “space debris” refers to “all human made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional. During the operational phases, a spacecraft or orbital stage can be considered as functional.” Inter-Agency Space Debris Coordination Committee, *IADC Space Debris Mitigation Guidelines*, 2020, p. 8.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

In relation to the generation and trajectory of space debris, it is challenging to predict the full scope of the consequences of an attack; the question therefore arises as to whether the principles of proportionality and precaution are subject to limitations imposed by the unique physics of outer space. This uncertainty can be attributed to the intricate and frequently disorderly nature of orbital mechanics, which undermines the feasibility of issuing effective warnings or calculating the full effects of an attack, thereby complicating compliance with IHL.[143] Space debris thus poses significant challenges to the application of IHL in outer space, particularly regarding collateral damage and the long-term effects of military operations. The generation of debris threatens civilian space assets and the sustainability of space activities; the destruction of satellites, whether intentional or accidental, can trigger a cascading effect, where resulting debris endangers other operational spacecraft, including those used for humanitarian, scientific and commercial purposes. This issue was highlighted in 2019 when India's ASAT test destroyed one of its satellites, creating a debris cloud that endangered the International Space Station.[144] While the 2019 Indian ASAT test was conducted in the absence of an armed conflict, it serves to illustrate how the generation of space debris can be exacerbated by certain activities, thereby increasing the risks associated with civilian space operations and jeopardizing the long-term sustainability of outer space.

The international community is heavily reliant on outer space and therefore seeks to ensure the applicability of IHL in this domain, marking an important step in space governance. However, the insufficient attention being paid to the issue of space debris – an anthropogenic challenge – poses a significant risk, potentially undermining the effective enforcement of IHL in outer space. It is therefore vital to employ a nuanced understanding of the immediate and long-term ramifications of military operations in the space domain, with a view to ensuring that proportionality and precaution are upheld.

The influence of the outer space domain on IHL

The increasing militarization and commercialization of outer space have significant implications for the application and evolution of IHL. As space becomes more and more important for global communications, navigation and surveillance, the traditional frameworks of IHL, which were primarily designed for terrestrial conflicts, face new challenges in addressing the unique characteristics of space operations. The employment of dual-use satellites serves to

143 Jacqueline Reichhold, *How Space Debris Impacts the Implementation of IIHL in Outer Space*, IISL Colloquium on the Law of Outer Space, 76th International Astronautical Congress, Sydney, 2025.

144 Sarah Thiele and Aaron C. Boley, "Investigating the Risks of Debris-Generating ASAT Tests in the Presence of Megaconstellations", *Journal of the Astronautical Sciences*, Vol. 69, No. 4, 2023, pp. 1807, 1811; Sinéad Baker, "'A Terrible, Terrible Thing': NASA Said India's satellite Destruction Created So Much Space Junk It Threatens the Safety of the International Space Station", *Business Insider*, 2 April 2019, available at: www.businessinsider.com/nasa-space-junk-india-destroying-missile-threaten-international-space-station-terrible-thing-2019-4.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

complicate the principle of distinction, while the long-term and often unpredictable effects of operations that generate debris strain the concepts of proportionality and precaution. It is imperative that IHL assessments take into account not only immediate effects but also cascading risks to essential civilian services and the sustainability of the orbital environment. In consideration of the interdependence between space-based and terrestrial critical infrastructure, the protection of civilians necessitates the provision of more explicit directives concerning the application of IHL principles to space operations. Furthermore, there is a requirement for military actors to devise and implement plans for such operations that prioritize the minimization of humanitarian harm. This necessity forms the basis for developing more concrete approaches to guiding the use of outer space in armed conflicts.

Guiding the use of outer space in armed conflicts

The utilization of outer space in armed conflicts has become an increasingly significant aspect of modern warfare, yet it remains a relatively under-regulated domain. Despite its critical role in a range of activities, critiques concerning the indiscriminate use of outer space, and regulation of outer space activities during armed conflicts, have been limited. It is evident that disruption caused by attacks on space-based assets, whether kinetic, non-kinetic or harmful interference, can have consequences that are comparable to those observed in attacks on terrestrial systems. As Rodenhäuser has outlined, "[f]or the civilian population, it makes little difference whether water supply or medical treatment is cut through bombing or disabled through cyber operations";[145] the same logic applies to space-based operations. The legal challenges posed by dual-use technologies and the risks associated with space debris are well documented, and the current framework offers several avenues for addressing these concerns and adapting the law to the specificities of space warfare. It is therefore vital that IHL principles such as distinction, proportionality and precaution be interpreted and operationalized for outer space in order to ensure civilian protection. A key area that requires further development is the clarification of the application of IHL to dual-use space assets;[146] this includes the development of clearer criteria for determining when a satellite, despite its dual-use character, qualifies as a military objective under IHL, the establishment of procedures for the disablement of space systems that minimize collateral effects, and the promotion of transparency measures such as notifications prior to potentially harmful operations in order to reduce the risk of miscalculation.[147]

145 Tilman Rodenhäuser, "ICRC Calls on States to Affirm Civilians and Civilian Infrastructure Must Be Protected against Cyber Operations", ICRC, 29 September 2020, available at: www.icrc.org/en/document/icrc-calls-states-affirm-civilians-and-civilian-infrastructure-must-be-protected-against.

146 G. B. Kuplic and J. Sawmiller, above note 24, pp. 218 ff.

147 ICRC, above note 122, pp. 3–4; *Report of the Group of Governmental Experts on Transparency and Confidence-Building Measures in Outer Space Activities*, UN Doc. A/68/189, 29 July 2013; Peter Martinez,

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

A more systematic approach to the regulation of military space operations is predicated on the recognition of the profound interdependence between space-based and terrestrial critical infrastructure. A wide range of critical infrastructure is reliant on satellite services, including but not limited to communication networks, financial systems, transportation management and emergency response.[148] The targeting of such systems in armed conflict has the potential to have catastrophic consequences for civilians, thus making strict adherence to IHL imperative. The enhancement of space traffic management, the refinement of satellite registration practices and the augmentation of the visibility of dual-use assets have the potential to facilitate compliance with IHL by enabling more precise targeting decisions and reducing the risk of inadvertent harm.[149] Concurrently, the incorporation of IHL considerations into emerging space governance initiatives, in conjunction with the advancement of proposals for space traffic management or updated registration mechanisms, would assist in ensuring that military operations do not impede the safe and sustainable utilization of outer space.[150]

It is evident that in order to achieve the objective of safeguarding civilians in the space domain, multilateral cooperation is essential. Existing treaties, including the OST, provide a foundation for the peaceful use of outer space, but their implementation in conflict settings remains insufficiently robust. It is recommended that States consider the harmonization of space law with IHL, the updating of existing instruments where necessary, and the development of new mechanisms for accountability, monitoring and dispute resolution. The international community is able to promote responsible behaviour, reduce humanitarian risks and ensure that the benefits of outer space are preserved for future generations by embedding IHL principles into the governance of military space operations.

Conclusion

In conclusion, the evolving landscape of armed conflicts underscores the urgent need to address the complex interplay between IHL, civilian safety and the strategic use of outer space. As reliance on space-based assets for communication, navigation and surveillance grows, their misuse or accidental damage during hostilities poses serious risks to civilian infrastructure and daily life. Recent conflicts have shown how attacks on critical infrastructure, such as water supplies, hospitals and

Transparency and Confidence-Building Measures for Outer Space Activities, Preprint Series PP23/06, Secure World Foundation, Broomfield, CO 2006.

148 G. Pescaroli *et al.*, above note 35.

149 Michael N. Schmitt, "International Law and Military Operations in Space", *Max Planck Yearbook of United Nations Law*, Vol. 10, 2006, pp. 116 ff.

150 For current discussion, see *Proposal for a Study Group on Perspectives for Space Traffic Management, Committee on the Peaceful Uses of Outer Space: Paper Submitted by Germany*, UN Doc. A/AC.105/2024/CRP.21, 20 June 2024. For academic discourse, see Stephan Hobe, *The Cologne Manual on Space Traffic Management*, Institute of Air Law, Space Law and Cyber Law, University of Cologne, and German Aerospace Center, Cologne, 2025.

https://doi.org/10.1017/S1816383126101416 Published online by Cambridge University Press

power grids, can cause extensive civilian suffering. If space-based assets are targeted or inadvertently affected, the resulting disruptions may include polluted drinking water, blackouts during medical procedures or the loss of essential navigational systems for transportation and emergency response. Such consequences demonstrate how deeply modern societies depend on space-based technologies and how severely civilians can be affected when these systems are compromised.

Furthermore, the militarization of outer space, in conjunction with its integration into multi-domain strategies, has the potential to engender conflict escalation and collateral damage to space-based assets that underpin civilian life. While the establishment of clearer legal frameworks and measures to address issues such as dual-use systems and space debris would undoubtedly lead to a more responsible conduct of space operations, progress in this area is impeded by significant political divisions. Recent UN processes, including the OEWG on Reducing Space Threats, have demonstrated that member States continue to hold divergent views on the optimal form of regulation, with some favouring binding treaties, others non-binding norms, and others voluntary confidence-building measures. The question of whether to impose new legal obligations in this context is a contentious one – some argue for such measures, citing the long-standing difficulties in achieving broad multilateral space treaties and the technological challenges of the present day as reasons to proceed, while others view such instruments as politically unrealistic or technologically premature. In this context, any movement towards enhanced protection, whether through binding rules or incremental cooperative measures, must navigate these divergent positions, even as the need to reduce risks to civilians and safeguard the peaceful use of outer space becomes increasingly urgent.

The development and deployment of space technology in armed conflicts present both opportunities and challenges. While these technologies have the possibility to enhance military capabilities, there is a pressing need for a cautious and responsible approach, given their significant potential to cause widespread civilian harm. It is imperative that policy-makers, military strategists and international organizations prioritize the protection of outer space and space-based assets, and uphold the principles of IHL, in recognition of the critical dependence of civilian infrastructure on space-based assets. It is only through concerted endeavours that continued accessibility of outer space can be ensured for the benefit of all humanity, despite the complexities of modern warfare.