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Preface

Militarisation is a process that increasingly takes pace in various areas – territorial as well as systemic – in the wake of the ongoing re-definition of what is a ”global order”. The Arctic, the military strengthening of NATO, and efforts to update national military capabilities, are just some examples of this. In some cases, militarisation takes place almost from a zero level, in other instances it adds to existing capabilities as a response to technological developments.

For a *demilitarised* area, such as the Åland Islands, the (re-)militarisation of neighbouring geographical regions is an obvious development of concern, and the discussion about the impact of processes of militarisation – whether geographic or qualitative – upon demilitarised regions is bound to continue. The fundamentals of the regime of norms and practices of demilitarisation are challenged.

A related and at least partially demilitarised sphere of human activity also regulated by a regime, is Outer Space. It may appear to be a special case of conditions for regime building, but in reality, developments on Earth set the conditions under which a structured and non-coercive use of Space is possible. As the articles explain, what happens in Space is both a technological reflection of political conditions on Earth, and vice versa: developments in Space can take on their own momentum, seriously affecting global relations. What we see today is that global political trends are mirrored also in Space.

This Issue of Journal of Autonomy and Security studies (JASS) takes on the particular politico-technological relationship that exists between Space and Earth, by analysing a number of ongoing developments – technological as well as political. As will be explained, this Issue consists of research notes and is the result of a generous and productive cooperation, explained by Dr Katariina Simonen in her Introduction, between JASS and the Finnish chapter of *Pugwash Conferences on Science and World Affairs*.

To our Readers, we wish you an exciting change of perspective on the reality of demilitarisation!

Kjell-Åke Nordquist
Editor-in-Chief

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Research Note

Use of Armed Force in Outer Space: An Introduction

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Abstract

Space is increasingly a theater for States' and private companies' activities. Space as a normative environment faces multiple challenges. Some of these are innate to space law proper, such as the limited applicability of the Moon Agreement. Others emanate from the general erosion of international law and arms control, technological developments and innovation. The limits of accepted space behaviors need urgent clarification. Absence of clear rules is likely to contribute to further unilateralism, at the cost of existing multilateral rules like the UN Charter, and to increased risk of conflict. A clear normative environment in space provides an environment with predictability, clarity and risk-minimization for states and private actors alike. To achieve this, states and private actors may want to look for progressive soft law steps, starting by agreeing on gaps, on useful measures to promote, like the ENMOD Convention, and on priorities such as the clarification of the law of self-defense and its limits.

Keywords

Outer space, use of force, self-defense, international humanitarian law

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1. Introduction

A recent research webinar organized by Pugwash Conferences on Science and World Affairs and the Åland Islands Peace Institute discussed Outer Space Governance with a specific focus on weapons of mass destruction (WMD) and arms control in an era of eroding multilateralism.[1] The purpose of this research note is to provide some contextual concerns which contributed to the organization of the webinar in the first place.

The core concern is the erosion of rules on the use of armed force and its significance for outer space governance. The said rules regard the threshold for the use of force (*jus ad bellum*) and the conduct of actual hostilities (*jus in bello*). They provide also for the overall regulatory context for arms control and disarmament discourses taking place on supra-national and national levels.

Today's challenges to space governance are many, starting from the fact that key international agreements on space, such as the Outer Space Treaty[2] (hereafter OST) and the Moon Agreement[3], have limited applicability, either for their dominantly state-centric nature or their limited coverage by participants or by their contents. Recent years have seen the emergence of companies as space actors beside the classic ones, i.e. the US and Russia, and others (China, Europe, Japan, India *et cetera*), propagating easier and cheaper access to space, new satellite services in the communications and satellite sector or the exploitation of raw materials of other celestial bodies.[4] Moon Agreement has only 16 State Parties with none possessing significant space exploration capabilities. Rivaling soft-law arrangements are emerging, such as the Artemis Accords, raising concerns regarding the future of the Moon Agreement.[5]

Yet, international efforts at the United Nations (UN) level stall. The notion of the "Prevention of Arms Race in Outer Space" (PAROS) emerged already in 1978, and in 1982 PAROS was added as an item to the Conference on Disarmament's agenda. Since then, PAROS has been present on the agenda in multilateral discussions, becoming the umbrella term under which states discuss the maintenance and improvement of space security at

1 Webinar Report: Outer Space Governance. 2025. Sept. 1. https://pugwash.org/2025/09/01/webinar-report-outer-space-governance/.

2 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (1967), https://unoosa.org/oosa/en/spacelaw/treaties/introouterspacetreaty.html.

3 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (1984), https://unoosa.org/oosa/en/ourwork/spacelaw/treaties/intromoon-agreement.html.

4 Neuneck, Götz. 2022. "A New Arms Race in Space? Options for Arms Control in Outer Space." In *Security and Defence: Ethical and Legal Challenges in the Face of Current Conflicts,* edited by J. Cayón Peña. Springer Nature Swizerland AG, 23–36.

5 Artemis Accords are a non-UN but US-promoted soft law accord regarding the exploration of the Moon. Stefan-Wedenig, Michael & Nelson, Jack Wright. 2023. "The Moon Agreement: Hanging by a Thread?" *Institute of Air and Space Law (McGill),* January 6. https://www.mcgill.ca/iasl/article/moon-agreement-hanging-thread.

the United Nations (UN), so far with limited success.[6] At the core of PAROS is the desire to prevent arms racing, but states remain unable to agree on proper definitions for space arms or weapons, or even on the need for such definitions.[7] In an effort to define the terms more clearly, certain states, namely Russia and China, introduced to the Conference on Disarmament the draft treaty on the Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force against Outer Space Objects (PPWT) in 2008 and then again in 2014. Dual use capabilities have also prompted serious concerns and have led to attempts to regulate space behaviors, in addition to regulating specific capabilities (e.g. UNGA Res 75/36).

In addition to these open questions regarding space law proper, the general erosion of the rules on armed force and humanitarian law raises serious concerns as to the capability of such rules to provide guidance for states' space behaviors. This research note serves as an introduction to these open issues, hoping to pave way for further discussion on how to consolidate the normative environment.

2. Peaceful use, militarization and weaponization

The OST regulates in article IV.2 that "the moon and other celestial bodies shall be used by all States Parties to the Treaty exclusively for peaceful purposes". When the OST was drafted, "peaceful purposes" could be seen as a reflection of the efforts of détente during the Cold War.[8] Also, the Antarctic Treaty (1959) served as a model in the process.[9] Antarctica was preserved as a demilitarized zone, meaning 'non-military'. As to the OST, the exact meaning of peaceful purposes has been amply debated, due to the fact that outer space has been militarized since the earliest communication satellites were launched.[10] Military uses of outer space have also been accelerated in terms of both participating countries and technologies used.[11] And what of the void of outer space, considering that Art. IV does not explicitly establish limitation of exclusive use for peaceful purposes therein? Ortega and Koller argue that this obligation can be inferred from the applicability

6 Pobjie, Erin & Azcárate Ortega, Almudena. 2024. "Space Security Legal Primer 1 – Outer Space & Use of Force." *UNIDIR*. https://doi.org/10.37559/WMD/24/Space/02.

7 *Ibid*. 12–13.

8 Kopal, Vladimir. 2008. "Treaty on Principles Governing the Activities of States in the Exploration and the Use of Outer Space, Including the Moon and Other Celestial Bodies". *United Nations Audiovisual Library.*

9 Von Bonsdorff, Sara. 2024. "From satellites to battlegrounds: Use of outer space for peaceful purposes, the use of force and the right of self-defence in the modern space landscape". Master's Thesis, Åbo Akademi University, https://urn.fi/URN:NBN:fi-fe2024053041811, 15.

10 *Ibid.*

11 Su, Jinyuan. 2010. "Use of Outer Space for Peaceful Purposes: Non-Militarization, Non-Aggression and Prevention of Weaponization." *Journal of Space Law* 36(1): 253–272, 257. https://ssrn.com/abstract=1662238.

of general international law to the space domain, established in Art. III of the OST.[12] The said article stipulates that "States Parties to the Treaty shall carry on activities in the exploration and use of outer space, including the moon and other celestial bodies, in accordance with international law, including the Charter of the United Nations, in the interest of maintaining international peace and security and promoting international co-operation and understanding".[13] The regulation in the Moon Agreement differs from the OST in that it includes explicit prohibitions regarding the use of force, threat of use of force, other hostile acts or threats of hostile acts on the Moon or using the Moon to commit any such act or threat of such acts in relation to the earth, the Moon, spacecraft, the personnel of spacecraft or man-made space objects (Art III.2).

At this point, it is useful to note that the prohibition of the use of force does not explicitly ban specific space capabilities or space behaviors. In fact, the weaponization of space is not strictly prohibited by the OST, whose Art. IV.1 decrees only on *limited demilitarization*, as follows: "States Parties…undertake not to place in orbit around the earth of any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner" and "the establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military maneuvers on celestial bodies shall be forbidden". A similar logic is found in Articles 3.3–4 of the Moon Agreement: "States Parties shall not place in orbit around or other trajectory to or around the moon objects carrying nuclear weapons or any other kinds of weapons of mass destruction or place or use such weapons on or in the moon" and "The establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military maneuvers on the moon shall be forbidden. The use of military personnel for scientific research or for any other peaceful purposes shall not be prohibited. The use of any equipment or facility necessary for peaceful exploration and use of the moon shall also not be prohibited".

The Partial Test-Ban Treaty, in turn, bans nuclear weapon tests in the atmosphere, in outer space and under water.[14] Out of all these regulations, the most likely to affect potential means and methods of the use of force in outer space is the Convention on the prohibition of military or any other hostile use of environmental modification techniques (ENMOD)

12 Azcáte Ortega, Almudena & Lagos Koller, Hellmut. 2023. "The Open-Ended Working Group on Reducing Space Threats through Norms, Rules and Principles of Responsible Behaviours: The Journey so Far, and the Road Ahead." *Air and Space Law* 48: 19–40, https://doi.org/10.54648/aila2023029.

13 Legal scholars have amply debated the applicability of international law to outer space. However, many leading authors point out that a proper reading and understanding of Art. III of the OST makes *lex specialis* applicable to outer space, meaning that international law that is applied on Earth also applies to outer space and obliges states to carry out their space activities in accordance with the UN Charter. Von Bonsdorff, footnote 9, 26 and references therein.

14 Treaty banning nuclear weapon tests in the atmosphere, in outer space and under water (1963), https://treaties.un.org/pages/showDetails.aspx?objid=08000002801313d9.

whose usability is growing in importance due to technological advancements.[15] The ENMOD was the first instrument that dealt with deliberate destruction of the environment during warfare, and it also applies in time of peace.[16] The ENMOD treaty's Art. I states that 'Each State party to this Convention undertakes not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party'. The treaty is of particular importance to the use of force in outer space in that environmental modification techniques are defined to include 'any technique for changing – through the deliberate manipulation of natural processes – the dynamics, composition or structure of the earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space' (Art. II).[17]

To sum up, space law creates a limited demilitarization of outer space, leaving open the limits to other weapons than weapons of mass destruction. An interpretation further corroborated by the fact that both the US and the former Soviet Union had sent military satellites into orbit before the OST was even negotiated.[18] In the absence of an explicit prohibition, states have developed numerous forms of counterspace capabilities, ranging from debris-creating kinetic capabilities to non-kinetic counterspace assets which can deny, disrupt, degrade, damage, destroy or otherwise harm a system through electronic or cyber means.[19] An essential issue, then, that requires resolution is the regulation of legality of certain space weaponry.[20] However, the multilateral space security debates have not been able to produce tangible outcomes over the years due to the international community's inability to agree on which issues to tackle as well as how to best address them.[21] Risk of uncontrolled weaponization, even if allegedly non-aggressive, can easily shift into aggressive. Such risks are further exacerbated by the great complexity of today's eroded

15 McGee, Jeffrey, Brent, Kerryn, McDonald, Jan and Heyward, Clare. 2021. "International Governance of Solar Radiation Management: Does the ENMOD Convention Deserve a Closer Look?" *Carbon & Climate Law Review* 14(4): 294–305. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3806914.

16 Freeland, Steven. 2004. "Human Rights, the Environment and Conflict: Addressing Crimes against the Environment." *Sur – international journal on human rights* 2(2):112–139, 122. https://sur.conectas.org/en/human-rights-environment-conflict/.

17 Maogoto, Jackson & Freeland, Steven. 2007. "The Final Frontier: The Laws of Armed Conflict and Space Warfare". *Connecticut Journal of International Law* 23:165–195, 175.

18 Rodman, Lindsay R. 2021. "Orbiting Legal Analysis: Armed Attacks in Space." *NATO Legal Gazette* 42: 68–85, 72.

19 Weeden, Brian & Samson, Victoria. 2024. "Global Counterspace Capabilities." *Secure World Foundation*. https://www.swfound.org/publications-and-reports/2024-global-counterspace-capabilities-report.

20 Maogoto, Jackson & Freeland, Steve. 2010. "Space Weaponization and the United Nations Charter Regime on Force: A Thick Legal Fog or a Receding Mist?" February 26. http://dx.doi.org/10.2139/ssrn.1559922.

21 West, Jessica & Azcárate Ortega, Almudena. 2022. "Space Dossier 7 – Norms for Outer Space: A Small Step or a Giant Leap for Policymaking?" *UNIDIR*. https://doi.org/10.37559/WMD/22/Space/01.

arms control landscape.[22] Sufficient here is to refer to the 2nd Trump administration's plan regarding the Golden Dome missile defense system, still in the conceptual phase, which, if completed, would lead to the introduction of hundreds if not thousands of space-based sensors and missile interceptors, thereby destabilizing the already precarious strategic stability and heightening the risk of space becoming a war zone.[23]

3. Prohibition of the use of force

A recent study by UNIDIR on outer Space & Use of Force examines thoroughly the question of use of force in outer space and the contents of prohibited use of force, detailing the contextual requirements and elements that make the act a 'use of force'.[24] A key norm in this context is the UN Charter's Article 2.4, according to which "Members shall refrain in their international relations from the threat or use of force against the territorial integrity or political independence of any state, or in any other manner inconsistent with the Purposes of the United Nations".[25]

Not surprisingly, there has always been disagreement as to what is prohibited under the treaty (Art. 2.4), custom or general principles. According to Franck, the prohibition of the use of force is a so-called "idiot rule": it seems to enjoy high determinacy, but despite its superficial clarity, its compliance pull is feeble, especially as comes to the interpretation of the expressions "threat or use of force", "international relations" and the conditions under which force may be used without violating the injunction of the Article 2.4.[26] In fact, apart from self-help for the defense of legal rights (see *Corfu Channe*l 1949[27]), every phrase is amenable to interpretation.[28]

These controversies have led many states to interpret their right to use force autonomously, especially when their physical security was concerned. Hence, states have made the application of the article conditional upon the effective functioning of collective security, or argued for independent right to use force in cases of humanitarian intervention, rescue of nationals aboard, pro-democratic intervention, armed reprisals against the unlawful

22 Rose, Frank. (2025). "The Future of Arms Control: Time for a New Strategic Framework." July 11. https://www.justsecurity.org/116786/the-future-of-arms-control-time-for-a-new-strategic-framework/.
23 Kimball, Daryl G. (2025). "Golden Dome: Doubling Down on a Strategic Blunder." *Arms Control Association* June. https://www.armscontrol.org/act/2025-06/focus/golden-dome-doubling-down-strategic-blunder.
24 Pobjie & Azcárate Ortega, footnote 6.
25 United Nations Charter, https://www.un.org/en/about-us/un-charter/full-text.
26 Franck, Th.M. 1990. *The Power of Legitimacy Among Nations.* Oxford University Press. 50–66, 72–77, 88–90.
27 Corfu Channel (United Kingdom of Great Britain and Northern Ireland v. Albania), ICJ Judgement 1949, https://www.icj-cij.org/case/1.
28 Higgins, Rosalyn. 2004. *Problems and Process. International Law and How We Use It.* Clarendon Press, 239–242.

small-scale use of force and the like.[29] In fact, the growing number of breaches of the prohibition, such as NATO intervention in Kosovo (1999), US intervention in Iraq (2003), Russian intervention in Ukraine (2022) and Israel's interventions in Iran (2025) and several interventions over the years in Lebanon, Syria and Yemen are a cause for pessimism. Typical for the later breaches is that the states in question have not sought to appeal to exceptions within the rule (Art. 2.4) to justify their use of force, thereby undermining the rule in question.[30]

Space is not an environment apart. When the normative guidance provided by the UN Charter Art. 2.4 is not only open to interpretation but also weakened, states are more likely to interpret it according to their own interests, thereby lowering the threshold for unilateral uses of force short of armed attack, such as self-help, armed reprisals and the like, constituting for instance "harmful interference" under Art. IX of the OST, "unlawful intervention" under customary international law or a prohibited "threat of force " under Art. 2.4.

4. Self-defense

Self-defense in international law refers to the inherent right of a state to use force in response to an armed attack. Self-defense is one of the exceptions to the prohibition against use of force under article 2.4 of the UN Charter. According to the UN Charter Art. 51 (first phrase), "Nothing in the present Charter shall impair the inherent right of individual or collective self-defense if an armed attack occurs against a Member of the United Nations, until the Security Council has taken measures necessary to maintain international peace and security". Like Art. 2.4, the exact contents of Art. 51 are open to interpretation, and states have frequently justified unilateral uses of force by claiming self-defense. The Charter does not provide a definition of an armed attack. The implication is that even if a State uses force against another state's territorial integrity or independence, it does not necessarily in all cases constitute an armed attack, due to lack of force used.[31] The ICJ's judgment in *Nicaragua* provides for some guidance into the matter regarding the gravity, scale and effect for the use of force to be recognized as an armed attack.[32] In the *Oil Platforms* case the ICJ suggested that the cumulative nature of forcible actions could

29 Cassese, Antonio. 2001. *International Law*. Oxford University Press. 319–320.
30 The ICJ's approach in the Nicaragua case is that by appealing to exceptions within the rule, a state's justification implicitly reinforces the prohibition of the use of force in the first place. Military and Paramilitary Activities in and against Nicaragua (Nicaragua v. the United States of America), ICJ Judgement 1986, https://www.icj-cij.org/case/70.
31 Von Bonsdorff, footnote 9, 55–58.
32 Military and Paramilitary Activities in and against Nicaragua (Nicaragua v. United States of America), ICJ Judgement 1986, https://www.icj-cij.org/case/70, para 191.

possibly turn them into an armed attack.[33] In addition, as an interpretative environment space poses further challenges, such as the extent of self-defense (space as *res communis*), limits of self-defense and problems relating to the dual use of satellites.[34] When exercising the right of self-defense, states would also have to respect the demilitarization limitations imposed under space law (OST Art. IV and the Moon Agreement Art. 3.3-4). States also must adhere to additional duties of established principles of international law when exercising their right of self-defense as stated in Art. III of the OST.

In space, states retain ownership, jurisdiction and control over their space objects, including their satellites.[35] Satellites can, however, be 'attacked' by using kinetic and non-kinetic means. Destroying a satellite with kinetic means involves directly colliding with the satellite or in any other way 'hitting' it and causing significant destructive damage to it via high-speed impact.[36] Due to their destructive nature, these weapons are usually called anti-satellite weapons (ASATs). Non-kinetic means are slightly the opposite of the former. The purpose of non-kinetic means of warfare against a satellite is to alter the function of the satellite, not causing any permanent damage to it, but in the worst case causing the loss of the total function of the satellite.[37] Kinetic ASATs include high-altitude nuclear explosion, kinetic energy ASATs, direct-energy ASATs, microsatellites and ballistic missiles, for example intercontinental ballistic missiles (ICBM). Non-kinetic ASATs, or non-kinetic means of attacking a satellite include cyber-attacks, interference or jamming.[38] The establishment of the threshold for the use of Art. 51 in self-defense is quite complicated in the latter case, as targeted satellites would not be physically destroyed (as would be the case with kinetic ASATs) but temporarily disabled. There have been cases of satellites being jammed, which have not resulted in any military responses based on self-defense. For instance, Russia has actively been jamming GPS signals in Ukraine as they attempt to advance. The debate of cyber activities violating the principle of non-use of force and/or constituting armed attack is on-going.[39]

33 Oil Platforms (Islamic Republic of Iran v. United States of America), ICJ Judgement 1996, https://www.icj-cij.org/case/90.

34 Unfortunately, the Registration Convention does not distinguish between military, dual-use and civilian satellites in the international register for space objects. Jakhu, Ram S., Jasani, Bhupendra, McDowell, Jonathan C. 2018. "Critical issues related to the registration of space objects and transparency of space activities." *Acta Astronautica* 143:406–420. https://doi.org/10.1016/j.actaastro.2017.11.042.

35 Coglianti-Bantz, Vincent P. 2010. "Disentangling the Genuine Link: Enquiries in Sea, Air and Space Law." *The Nordic Journal of International Law* 79(3):383–432.

36 Koplow, David A. 2009. "Asat-isfaction: Customary International Law and the Regulation of Anti-Satellite Weapons." *Michigan Journal of International Law* 30(4):1187–1272, 1201.

37 Von Bonsdorff, footnote 9, 52–54.

38 *Ibid*.

39 See for instance Roscini, Marco. 2021. "Cyber Operations as a Use of Force'. In *Research Handbook on International Law,* edited by Nicholas Tsagourias and Russel Buchan. Edward Elgar, 233–254 and Schmitt, Michael N. 2011. "Cyber operations and the *Jus in Bello*: Key issues." *International Law Studies* 87:89–112, 96. Other principles of international law may also become implicated, such as the prohibitions of non-intervention and the inviolability of territorial sovereignty.

The threshold for self-defense becomes even more complicated with the deployment of weapons in space, advancement in technologies and innovation. Already in 1947, the advent of a new genre of weapons, atomic weapons, prompted the UN Atomic Energy Commission to note in its first report to the Security Council that "Interpreting its provisions [Article 51 of the Charter] with respect to atomic energy matters, it is clear that if atomic weapons were employed as part of an 'armed attack', the rights reserved by the nations to themselves under Article 51 would be applicable. It is equally clear that an 'armed attack' is now something entirely different from what it was prior to the development of atomic weapons. It would therefore seem to be both important and appropriate under present conditions that the treaty define 'armed attack' in a manner appropriate to atomic weapons and include in the definition not simply the actual dropping of an atomic bomb, but also certain steps in themselves preliminary to such action"[40].

The ensuing necessity for the flexibility in interpretation of Art. 51 opens up the argumentation to anticipatory or pre-emptive self-defense, departing from time-constraints imposed by Article 51 (ongoing or imminent armed attack). Counterspace technologies have already been developed faster than international space law, leaving states vulnerable for a surprise attack that would potentially harm a state's intelligence gathering, early warning systems and battlefield capabilities.[41] The right of true anticipatory self-defense has therefore arguably developed outside of article 51 in the light of new counterspace technologies and especially WMDs. Inevitably, first-strike capabilities have contributed to the necessity of the doctrine of 'anticipatory self-defense'".[42]

Pre-emptive self-defense, in turn, is not triggered by any event but comes from a general apprehension of being attacked ("the Bush doctrine of use of force against Iraq,[43] Russia's justifications for invading Ukraine"[44] or Israel's use of force against Iran[45]). The problem with pre-emptive self-defense is, according to Milanovic, that it is so boundless that it completely eviscerates the prohibition on the use of force – a state could act whenever it perceives an existential threat.[46] The doctrine is not endorsed by state practice.[47]

40 The 1st report of the Atomic Energy Commission to the Security Council (3 January 1947) UN Doc Nr AEC/18/Rev.1, for quote see UN Repertory of Practice, Article 51, vol. II (1945–54) chapter II.2 11–15.

41 Von Bonsdorff, footnote 9, 62.

42 Franck, Th.M. 2001. "When, If Ever, May States Deploy Military Force Without Prior Security Council Authorization?" *Washington University Journal of Law & Policy* 5:51–68, 57–58.

43 Milanovic, Marko. 2009. "The OLC Memoranda on Iraq: Revisiting the Case for War. *EJIL: Talk!* January 10. https://www.ejiltalk.org/the-olc-memoranda-on-iraq-revisiting-the-case-for-war/.

44 Milanovic, Marko. 2025. "Is Israel's Use of Force Against Iran Justified by Self-Defence?" *EJIL: Talk!* June 13. https://www.ejiltalk.org/is-israels-use-of-force-against-iran-justified-by-self-defence/.

45 *Ibid*.

46 *Ibid*.

47 Byers, Michael. 2002. "Terrorism, The Use of Force and International Law After 11 September." *International and Comparative Law Quarterly* 51(2):401–414. doi:10.1093/iclq/51.2.401.

5. International Humanitarian Law (IHL)

The starting point for discussing the application of IHL is that neither the OST nor the subsequent international space treaties negotiated under the auspices of the UN (Rescue Agreement 1968, Liability Convention 1974, Registration Convention 1979 and the Moon Agreement 1979) provide further clarification regarding the placement of other types of weapons (other than WMD) in space. Regardless, as discussed above, Art. III of the OST confirms the application of international law into the outer space environment. Also, the applicability of international law to the space environment is highlighted in Art. I of the OST which indicates that the use and exploration of outer space shall be carried out “in accordance with international law”. Without going further into the problematics regulating space security (PAROS, PPWT) mentioned briefly in the introduction, from the point of view of IHL it is useful to note the potential dual-use of certain space objects, which have caused significant concern for the international community as well as the inclusion of behaviors (how capabilities are used) into discussions on how to reduce threats to space systems.[48]

The International Committee of the Red Cross (ICRC) has alerted the international community to this problematic of outer space uses of force, “making the potential consequences of attacks on space systems a matter of humanitarian concern”.[49] The ICRC highlights the substantial human consequences of deploying weapons in outer space, especially those capable of interfering with, harming, destroying, or incapacitating civilian or dual-use space assets. Civilian infrastructure, essential for various sectors such as health care, transportation, communications, energy, and trade, is strongly dependent on space systems that often have both military and civilian purposes; global navigation satellite systems, such as GPS, are essential for air traffic control, maritime shipping, and accurate time synchronization of crucial civilian infrastructure; weather, communication, navigation, and Earth observation satellites are crucial in humanitarian efforts for tasks such as needs assessment, emergency assistance delivery, catastrophe risk reduction, and conflict prevention.[50] Moreover, causing physical harm or destruction to things in space could result in more space debris, which could endanger other space objects that are crucial for safety-critical civilian operations and essential services on Earth.

48 OEWG on Reducing Space Threats through Norms, Rules and Principles of Responsible Behaviours, Threats to the Security of Space Activities and System, UNIDIR 23–27, U.N.Doc. A/AC.294/2022/WP.16 (12 Sep. 2022), https://documents.unoda.org/wp-content/uploads/2022/08/20220817_A_AC294_2022_WP16_E_UNIDIR.pdf.

49 International Review of the Red Cross, Position paper submitted by the International Committee of the Red Cross to the Secretary-General of the United Nations on the issues outlined in General Assembly Resolution 75/36 (2020), 102 (915), 1351–1356.

50 *Ibid*. and Von Bonsdorff, footnote 9, 66–67.

The 1977 Additional Protocol I to Geneva Conventions also prohibits the employment of means and methods of warfare which are intended, or may be expected, to cause widespread, long-term and severe damage to the natural environment. The term 'damage to the natural environment' could encompass negative environmental changes and accordingly space debris could fall under that notion.[51] States must also consider the environment and debris while evaluating necessity and proportionality. In the late 1970s, a NATO scientist named Donald Kessler proposed the hypothesis that the probability of satellite collisions rises as the number of satellites launched into orbit increases. Each collision would have a significant influence on the orbital environment. According to UNIDIR, "States have become increasingly concerned about the danger presented by space debris, and the ever-increasing potential for collisions, particularly in highly populated orbits such as low Earth orbit".[52]

In addition to space-specific concerns, the general erosion of IHL is likely to have an effect on how states interpret IHL, also in outer space. The President of the ICRC draws attention to the great number of conflicts and the complete disregard for IHL, as follows:

"The scale of human suffering, in Gaza, Myanmar, Ukraine, Sudan, Afghanistan, Syria and dozens of other countries across the world must never be accepted as inevitable. These are not unfortunate side effects of war, but consequences of a profound failure to uphold international humanitarian law. They are the results of political failure. When wars are fought with the mentality of 'total victory' or 'because we can' a dangerous permissiveness takes root – one where the law is bent to justify killing rather than prevent it. The Geneva conventions were created specifically to prevent senseless suffering and death".[53]

Last, there is the challenge that private actors pose from the point of view of attribution of responsibility. Article VI of the OST expresses that any act carried out by a non-governmental entity in outer space is imputable to the state as if it were its own, making the state directly responsible for such acts.[54] There are two aspects that warrant a short comment. One is the issue of commercial satellites becoming legitimate targets when used for intelligence-gathering in attack planning and the second one concerns the question whether Article VI could implicate states in violations of *jus ad bellum* rules with respect to activities of non-governmental entities in outer space.

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51 Von Bonsdorff, footnote 9, 69.

52 Open-ended working group on reducing space threats through norms, rules and principles of responsible behaviours, threats to the security of space activities and systems, UNODA (12 September 2022), A/AC.294/2022/WP.16 (12 Sep. 2022).

53 Speech given by Mirjana Spojaric, president of the International Committee of the Red Cross, on 18 August 2025 in Bangkok, Thailand and the 11th HRH Princess Maha Chakri Sirindhorn Lecture on International Humanitarian Law; https://www.icrc.org/en/statement/ihl-only-as-strong-as-leaders-will-uphold-it.

54 The OST's regulation is a unique development in public international law in that it differentiates itself from the regime of state responsibility applicable on Earth. The way many states implement their Art. VI responsibilities is through the enactment of national laws and regulations. Pobjie & Azcárate Ortega, footnote 6, 27.

Commercial satellites being used for intelligence-gathering is not a mere academic question as many nations, including the US, are using commercial satellite imagery in their defense enterprise.[55] According to Schmitt and Tinkler the US position in this regard is that the law of war treaties and the customary law of war are understood to regulate the conduct of hostilities, regardless of where they are conducted, which would include the conduct of hostilities in outer space.[56] They also point out that this is the ICRC's view as well, so that the law of armed conflict "applies to any military operations conducted as part of an armed conflict, including those occurring in outer space". [57] Hence, when commercial assets are used for military purposes, they become legitimate targets. Whether nations are likely to discriminate between military satellites and commercial satellites providing services to the government in the event of conflict is another open question.[58]

Another issue is the attributability of a commercial actor's acts to the state, making the latter party to the armed conflict. In Ukraine, due to Russian attacks on Ukrainian telecommunications infrastructure, Elon Musk offered Ukraine internet services through his constellation of 2,400 SpaceX Starlink satellites positioned in low Earth orbit and launched from the US. SpaceX made its highly effective services available first to the Ukrainian armed forces and emergency services, and then to the wider populace. Tara Brown discusses the Starlink case in detail, concluding, indeed, that the fact that the US bears international responsibility for the actions of commercial providers operating from within its jurisdiction under Article VI of the OST means that Musk's provision of Starlink services to Ukraine is attributable to the United States.[59] The subsequent question was, then, whether the traditional law of neutrality, under which the US assumes neutral obligation to abstain from providing material support to belligerent parties, was breached.

55 Dunlap, Charlie, J.D. (2021). "Are commercial satellites used for intelligence-gathering in attack planning targetable?" *Lawfire* 5 March. https://sites.duke.edu/lawfire/2021/03/05/are-commercial-satellites-used-for-intelligence-gathering-in-attack-planning-targetable/.

56 Schmitt, Michael and Tinkler, Kieran (2020). "War in Space: How International Humanitarian Law Might Apply. The Woomera Manual Project – Part 3." *Just Security* March 9. https://www.justsecurity.org/68906/war-in-space-how-international-humanitarian-law-might-apply/.

57 *Ibid*.

58 Colin Clark & Theresa Hitchens. 2019. "Commercial Satellites: Will They Be Military Targets?" *Breaking Defense* July 16. https://breakingdefense.com/2019/07/commercial-satellites-will-they-be-military-targets/.

59 Brown, Tara. 2022. "Ukraine Symposium – The Risk Of Commercial Actors In Outer Space Drawing States Into Armed Conflict." *Articles of War* Jul 8. https://lieber.westpoint.edu/commercial-actors-outer-space-armed-conflict/.

The response to this question warrants a complex review of concepts of traditional and qualified neutrality, exemptions thereto, as well as questions of co-belligerency.[60] According to Brown's analysis, the mere provision of enduring internet and communication services would not make the US a party, as facilitating the service does not demonstrate the intent to contribute to specific conduct of hostility operations.[61] The conclusion that follows is that the implication of states in an armed conflict would seem to depend on the degree of connection between the support and specific conduct of hostility operations and whether the actions of the commercial operator are under the "overall control" of the state.

6. Conclusions

As the above discussion shows, there are complex issues at play when deciphering the applicability of rules *jus ad bellum* and *jus in bello* in outer space. Even if space security debates at the UN level stall, there is no reason for states and private companies operating in space not to engage in clarifying the current interpretation of the rules governing the outer space environment. Soft law instruments are perfectly valid, and realistic, tools in such an enterprise. There is some urgency to such discussions too, concerning the breathtaking speed of counterspace capabilities, innovation and, at the same time, the erosion of arms control regulating the WMD. For instance, the development of first-strike capabilities has already obliged states to adopt an anticipatory stance instead of waiting for an armed attack prescribed by Art. 51 of the UN Charter. Technological advances may tip the balance in favor of pre-emptive action, so far not favored by states due to the high risks involved. It is for states and companies operating in space to assume a more proactive and innovative role in promoting space as a clear normative environment for the benefit of everyone.

60 For further reading, see for instance Nasu, Hitoshi. (2022). "Targeting A Satellite: Contrasting Considerations between the Jus ad Bellum and the Jus in Bello." *99 INT'L L. STUD.* 142:143–179; Schmitt, Michael N. 2022. "Providing Arms And Materiel To Ukraine: Neutrality, Co-Belligerency, And The Use Of Force." *Articles of War* Mar 7. https://lieber.westpoint.edu/ukraine-neutrality-co-belligerency-use-of-force/ and Gill, Terry D. 2022. "A Ukraine No-Fly Zone: Further Thoughts On Law And Policy." *Articles of War* Mar 23. https://lieber.westpoint.edu/a-ukraine-no-fly-zone-further-thoughts-on-law-and-policy/.

61 Brown, footnote 58.

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The Space-Nuclear Nexus and the U.S. Private Sector: A brief introduction

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Abstract

Outer space affairs have undergone many changes since nuclear deterrence last played a central role in great power competition. These changes in outer space affairs have been driven in great part by the private sector and its evolving role in this domain. This research note provides an introduction to the roles played by U.S. private actors in the space-nuclear nexus. It covers more traditional roles for private actors, such as constructing satellites, and potentially destabilising novel trends, namely the emergence of private companies as operators for military clients in space. Within these categories, launch services, satellite communications, remote sensing, satellite operations and space situational awareness, as well as warfighting itself are analysed. These discussions briefly consider the role of private companies as political players, economic actors, and members of the international community. The text concludes that the involvement of private actors within the space-nuclear nexus is neither inherently stabilising nor destabilising. However, far better governance and greater transparency will be necessary to ensure that this trend has a positive impact on nuclear strategic stability.

Keywords

Nuclear weapons, outer space, private sector, emerging technologies, arms control

1. Introduction

The link between space and the private sector is nearly as old as the relation between space and nuclear issues. Both relations have evolved significantly in the last decade. Innovations emerging from and applied by the NewSpace section of the space ecosystem have led to important changes in the space sector. These include cheaper access to orbit, wider provision of downstream services, greater availability of off-the-shelf components for satellites, among others. These changes have affected the relation of private space companies and nuclear strategic stability. Understanding the role of these private space actors in the space-nuclear nexus is increasingly important as the nuclear risk environment continues to deteriorate. This research note explores this relation by first defining the space-nuclear nexus, and then considering the impact of the private sector in this dynamic through a variety of roles. These roles may vary greatly between different nuclear weapon states and national space sectors. Given its prominence in defence, this research note focuses on the U.S. private space ecosystem. The text concludes with a set of recommendations for better managing the role of the private sector within the space-nuclear nexus.

2. The space-nuclear nexus

2.1 Space and counterspace capabilities

Before discussing the role of the U.S. private sector in nuclear issues linked to space, it is important to define the space-nuclear nexus. The space-nuclear nexus refers to the "multiple connections and interactions between the space and nuclear weapon domains"[1]. These connections include direct links between space and nuclear weapons including through missile early-warning systems, which are essential for enabling missile defence; satellite communications (SATCOM), a key asset for nuclear command control and communications (NC3); position, navigation and time (PNT) systems, which are important enablers for ballistic missile submarines (SSBNs) and missile navigation; and intelligence, surveillance and reconnaissance (ISR) satellites which, among other tasks, have a crucial role to play in threat assessment and target selection[2].

Although mostly non-nuclear, counterspace capabilities also fall within the space-nuclear nexus, as they can deny access to the previously mentioned key capabilities enabling nuclear deterrence. Harrison and colleagues divide counterspace weapons into

1 Nivedita Raju and Laura Grego, *The Space–Nuclear Nexus in European Security* (Stockholm: SIPRI, 2025), 1. https://doi.org/10.55163/GEPV2578.

2 Nivedita Raju and Tytti Erästö, *The Role of Space Systems in Nuclear Deterrence* (Stockholm: SIPRI, 2023), 2–10. https://doi.org/10.55163/NWLC4997.

kinetic physical, non-kinetic physical, electronic, and cyber. Kinetic physical counterspace weapons include direct-ascent anti-satellite (ASAT) weapons, co-orbital ASAT weapons, and kinetic attacks on ground stations. These weapons rely on direct strikes to affect their targets. In contrast, non-kinetic physical weapons seek to cause physical effects on space systems without the need of physical contact. These include high-powered microwave weapons, lasers, and the high radiation environment that a nuclear detonation in space would generate. Counterspace weapons also include electronic warfare capabilities, which seek to affect the electromagnetic spectrum employed by space systems to receive and transmit data through jamming or spoofing. The final category is cyber weapons, which target data itself and the systems that use, transmit, and control the flow of data[3].

2.2 Deterrence and entanglement

During the cold war, the close relation between space capabilities and nuclear deterrence helped dissuade adversaries from attacking each other's space systems[4]. These redlines are likely still clear in the case of attacks against particularly sensitive capabilities, such as NC3 systems. However, the entanglement between nuclear and non-nuclear capabilities in the space domain could lead to inadvertent escalation[5]. Entanglement refers to the increasing perceived or real threat posed to nuclear forces by emerging conventional threats. The term also refers to the increasing co-location of nuclear and non-nuclear forces, sometimes on board the same satellite, as well as to how certain capabilities, including NC3, early-warning systems and ISR, are increasingly used in both missions directly relevant to nuclear deterrence and non-nuclear missions[6]. This trend has been reversed in specific cases[7], but it remains widespread and may expand further.

Moreover, the continued integration of space assets as enablers for conventional warfighting has led to an increasing normalisation of counterspace operations short of

3 Todd Harrison, Kaitlyn Johnson, and Makena Young, *Defense Against the Dark Arts in Space: Protecting Space Systems from Counterspace Weapons* (Washington, DC: CSIS, 2021), 7–9. https://www.csis.org/analysis/defense-against-dark-arts-space-protecting-space-systems-counterspace-weapons.

4 Todd Harrison, "The Risks a War in Space Poses for Nuclear Stability on Earth", in *America's Nuclear Crossroads: A Forward-Looking Anthology*, ed. Caroline Dorminey and Eric Gomez (Washington, DC: Cato Institute, 2019), 30. https://www.cato.org/sites/cato.org/files/pdfs/americas-nuclear-crossroads-full.pdf.

5 Nivedita Raju and Wilfred Wan, *Escalation Risks at the Space–Nuclear Nexus* (Stockholm: SIPRI, 2024), 15. https://doi.org/10.55163/FZDW6296.

6 James M. Acton, Tong Zhao, and Li Bin, *Reducing the Risks of Nuclear Entanglement* (Washington, DC: Carnegie Endowment for International Peace, 2018). https://carnegieendowment.org/research/2018/09/reducing-the-risks-of-nuclear-entanglement?lang=en.

7 See Robert Samuel Wilson and Russell Rumbaugh, "Reversal of Nuclear-Conventional Entanglement in Outer Space", *Journal of Strategic Studies* 47, no. 4 (2023). https://doi.org/10.1080/01402390.2023.224962.

the use of kinetic physical weapons targeting these assets[8]. Along with entanglement, this trend opens the door for new escalation vectors which may, intentionally or unintentionally, eventually involve entangled or nuclear-specific space systems. As military operations are increasingly reliant on the private sector[9], private actors may find themselves in the middle of escalation ladders, including in regional conflicts that may turn nuclear[10]. Researchers and policymakers are becoming increasingly aware of this dynamic and its impact on deterrence. However, the role of private actors in the space-nuclear nexus is not well understood. The following sections provide an overview of this relation with the U.S. as a case in point.

3. The private sector as a builder of systems

3.1 Legacy space sector

The more traditional role of the U.S. private sector within the space-nuclear nexus is that of provider of systems. Companies build space systems and hand them over to the military, which then handles operations. Companies performing this role tend to be part of the legacy space sector and are also well established within the defence industry. Recent examples include crucial capabilities such as the Space-Based Infrared System (SBIRS) early-warning satellites developed by Lockheed Martin and Northrop Grumman[11], NC3 satellites commissioned to Boeing within the Evolved Strategic SATCOM (ESS) programme[12], and a variety of other systems. These satellites have traditionally been large, expensive, few in number, and vulnerable to attack, making them tempting targets in case of a nuclear confrontation due to their importance[13]. Similarly, there are companies

8 See Andrey Baklitskiy, *Strategic Stability in Outer Space After Russia's Invasion of Ukraine* (Washington, DC: CNA Corporation, 2023). https://www.cna.org/reports/2023/10/Strategic-Stability-in-Outer-Space-After-Russias-Invasion-of-Ukraine; Clémence Poirier, *Breaking the Final Frontier: Cyber Operations Against the Space Sector* (Zürich: Center for Security Studies, ETH Zürich, 2025). https://doi.org/10.3929/ethz-c-000787029.

9 Michael J. Mazarr, Krista Langeland, Anthony Atler, Alexis A. Blanc, Daniel Burkhart, Jordan Logue, Jonathan Tran, and Brett Zakheim, *The Space Enterprise and Integrated Deterrence* (Santa Monica: RAND Corporation, 2024), 12. https://doi.org/10.7249/PEA3183-1.

10 Baklitskiy, *Strategic Stability in Outer Space*.

11 Stephen Clark, *Lockheed Martin-Built Infrared Surveillance Satellite Launched Successfully* (SpaceNews, 2013). https://spacenews.com/lockheed-martin-built-infrared-surveillance-satellite-launched-successfully/.

12 Greg Hadley, *Space Force Awards Contract for New Nuclear Command and Control Satellites* (Air & Space Forces Magazine, 2025). https://www.airandspaceforces.com/space-force-contract-new-nuclear-command-control-satellites/.

13 Peter L. Hays and Sarah Mineiro, *Modernizing Space-Based Nuclear Command, Control, and Communications* (Washington, DC: Atlantic Council, 2024), 6. https://www.atlanticcouncil.org/wp-content/uploads/2024/07/Hays_-Miniero_-Modernizing-Space-Based-NC3-DRAFTJune25v2-2-1.pdf.

which supply counterspace systems. These range from inexpensive jammers[14] to strategic offensive capabilities, such as some systems developed by L3Harris[15].

The U.S. private space sector also plays a key role in preventing the proliferation of these and other capabilities. Said systems include dual-use technologies, such as space launch vehicles (SLVs). It is well known that, beyond their role in supporting access to space, SLV technologies can support the development of direct-ascent ASAT weapons or nuclear delivery vehicles to an extent[16]. The Missile Technology Control Regime, the Hague Code of Conduct and the Wiesbaden Process play important roles in controlling the proliferation of these technologies. Interest in small and micro launchers has increased the pool of companies with access to SLV technology[17].

3.2 NewSpace, new challenges

NewSpace companies are part of this expanding pool of actors. NewSpace operations are characterised by a fixed budget, for-profit model, with a more risk-tolerant approach to research and development than governments usually have. They tend to be startups. This model and the management style which dominates it have been adopted to promote innovation, lower costs, compress deadlines and yield faster returns on investment[18]. The entry of these companies into the market has led to new challenges for non-proliferation, in part due to a lack of awareness regarding export control duties[19], and also because these companies often lack the labour force and expertise needed to follow usually complicated export control regimes. This is because of their emphasis on lean organisational structures which tend to favour technical over legal savoir-faire.

Financial incentives and pressures from private equity and venture capital (VC) also introduce challenges. VC funds demand rapid scaling, big valuations and quick exits, which pushes startups working in dual-use technologies and defence to overpromise, chase hype,

14 Harrison, Johnson, and Young, *Defense Against the Dark Arts in Space*, 9.

15 Theresa Hitchens, *Space Force Takes Ownership of First Meadowlands Satellite Jammer* (Breaking Defense, 2025). https://breakingdefense.com/2025/04/space-force-takes-ownership-of-first-meadowlands-satellite-jammer/.

16 Johannes M. Wolff, "'Peaceful uses' of outer space has permitted its militarization – does it also mean its weaponization?" in *Making Space for Security?*, ed. Kerstin Vignard (Geneva: UNIDIR, 2003), 6, 10. https://unidir.org/wp-content/uploads/2023/09/making-space-for-security-en-346.pdf.

17 Kolja Brockmann and Dr Markus Schiller, *Small and micro launchers in the NewSpace era: New missile proliferation risks or more of the same?* (Stockholm: SIPRI, 2023). https://www.sipri.org/commentary/topical-backgrounder/2023/small-and-micro-launchers-newspace-era-new-missile-proliferation-risks-or-more-same.

18 Deganit Paikowsky, "What Is New Space? The Changing Ecosystem of Global Space Activity", *New Space* 5, no. 2 (2017): 86. https://doi.org/10.1089/space.2016.0027.

19 Kolja Brockmann and Lauriane Héau, *The Expansion of the NewSpace Industry and Missile Technology Proliferation Risks* (Stockholm: SIPRI, 2024). https://doi.org/10.55163/CZSK1790.

and rush "revolutionary" technologies into deployment before they are properly tested[20]. VC is not ultimately accountable to democratic publics either. This means that ethical and legal concerns about civilian harm, escalation or long-term stability can be easily sidelined whenever they conflict with profit[21]. Financial pressures, VC-caused or not, may drive failing NewSpace startups to unlawfully sell export-controlled military or dual-use technology to alleviate their financial situation; a growing concern given the weakening of the international arms control architecture[22].

However, NewSpace startups have made significant contributions to the space sector. These companies have spearheaded the mass production, miniaturisation, and simplification of space system components[23]. This has resulted in dramatic reductions in the cost and mass of satellites, as well as great improvements in their capabilities[24]. These technological trends, along with significant reductions in launch costs, have enabled the deployment of satellite constellations composed of thousands of satellites in low Earth orbit (LEO). No satellite believed to play a role in the transmission of nuclear launch orders or in missile early-warning is currently placed in LEO[25]. However, private sector LEO constellations may provide a platform for these capabilities in the future. Part of the following section will cover this possibility.

4. The private sector as a system operator

Utilising the private sector as operators in space is not new. For decades, U.S. private companies have supported the military through ground segment operations for satellites crucial to nuclear deterrence[26], as well as access to space[27], and commercial SATCOM

20 Elke Schwarz, *Unicorns for Uniforms: On the Problematic Allure of VC Investments in Defence* (Opinio Juris, 2024). https://opiniojuris.org/2024/09/18/unicorns-for-uniforms-on-the-problematic-allure-of-vc-investments-in-defence/.

21 *Ibid.*

22 Geneva Centre for Security Policy, *Militarisation of Space and the Private Sector's Expanding Role*, video, 1:36:37, published 02 July 2025, https://www.youtube.com/watch?v=RH5TIRCuejs.

23 Sébastien Moranta, *The Space Downstream Sector: Challenges for the Emergence of a European Space Economy* (Paris: IFRI, 2022), 18. https://www.ifri.org/sites/default/files/migrated_files/documents/atoms/files/moranta_space_downstream_sector_2022_.pdf.

24 Steve Fetter and Jaganath Sankaran, "Emerging Technologies and Challenges to Nuclear Stability", *Journal of Strategic Studies* 48, no. 2 (2024), 255–256. https://doi.org/10.1080/01402390.2024.2433766.

25 James M. Acton, "The Survivability of Nuclear Command-and-Control Capabilities", *Journal of Strategic Studies* 48, no. 3 (2025), 432. https://doi.org/10.1080/01402390.2024.2435957.

26 Roger A. Jernigan, *Air Force Satellite Control Facility Historical Brief and Chronology, 1954–Present* (Sunnyvale: Air Force Satellite Control Facility History Office, 1989). https://www.nro.gov/Portals/65/documents/foia/declass/WS117L_Records/266.PDF.

27 Joseph Bauman, *Hercules Pegasus Missile Puts Private Enterprise into Outer Space* (Deseret News, 1990). https://www.deseret.com/1990/4/6/18855201/hercules-pegasus-missile-puts-private-enterprise-into-outer-space/.

(COMSATCOM)[28]. However, these arrangements have seen a high level of government control up until recently.

Recent years have seen a wider shift in the space sector from a one-time purchase business model to "space-as-a-service" arrangements. Space-as-a-service refers to agreements by which the customer acquires a commitment from a provider to reach a certain outcome or complete a task, as opposed to purchasing a tangible item. The service provider retains far greater autonomy than in previous arrangements. At this time, the pipeline for selecting, purchasing, and deploying private space services militarily remains largely undefined in the U.S.[29]. In these arrangements, service providers and the government must establish a greater level of trust over longer periods of time for these commercial relations to succeed than what is usually required in a one-time purchase agreement[30], a task which may be difficult for NewSpace startups given their potential financial instability. Private equity is also seeking to profit from the "as-a-service" business model through the acquisition of a large tranche of the world's ground station capacity[31], a fundamental capacity for conducting space operations. These trends introduce a range of dynamics to the U.S. private sector's involvement in the space-nuclear nexus that will be briefly explored in this section.

4.1 Launch

NewSpace has had an enormous impact on launch services. SpaceX has managed to establish itself as a trusted launch provider, even delivering payloads directly relevant to advanced missile tracking[32]. This success was not achieved solely through technical excellence. SpaceX had to rely on lobbying and lawsuits to access an uncompetitive national security launch market[33]. SpaceX even attempted to curtail the production of its

28 USSC, *Operation Desert Shield and Desert Storm Assessment* (Washington, DC: USSC, 1992), 4. https://nsarchive2.gwu.edu/NSAEBB/NSAEBB235/25.pdf.
29 Clayton Swope, *Bringing the Private Sector to Space: Operationalizing Commercial Space for U.S. National Security* (Washington, DC: CSIS, 2025), 3–4. https://csis-website-prod.s3.amazonaws.com/s3fs-public/2025-01/250130_Swope_Operationalizing_Space.pdf?VersionId=AsmVA9a0uvtLtfNkSfJsc2A3eNot5sHA.
30 *Ibid.*
31 EQT Group, *As Satellite Launches Soar, Spotlight Turns to Stations Back on Earth* (EQT Group, 2025). https://eqtgroup.com/thinq/technology/as-satellite-launches-soar-spotlight-turns-to-stations-back-on-earth.
32 U.S. Space Force, *Space Development Agency Successfully Launches Tranche 0 Satellites* (U.S. Space Force News, 2023). https://www.spaceforce.com/news-events/space-development-agency-successfully-launches-tranche-0-satellites.
33 Aaron Mehta, *SpaceX, US Air Force Settle Lawsuit* (Defense News, 2015). https://www.defensenews.com/air/2015/01/23/spacex-us-air-force-settle-lawsuit/.

competitors through these tools[34]. These commercial disputes could have affected reliable U.S. access to space and, by extension, the country's capability to field satellites relevant to the space-nuclear nexus. This dispute could have also hindered the revolution in space launches which made the cost of access to LEO 30 times lower compared to the service provided by the NASA Space Shuttle[35]. This development, along with cheaper, smaller space system components, enabled the deployment of mega-constellations of satellites, which have important implications for the resilience of space capabilities. In turn, the provision of micro and small launch services can support resilience by allowing more responsive launch timings, from different locations. This capability could be used to restore or reconstitute degraded constellations promptly, including during times of conflict. This could support the replenishment of small ISR satellites[36], SATCOM constellations, among other capabilities.

4.2 SATCOM

Privately operated COMSATCOM services have become increasingly central to modern warfare and the operation of critical infrastructure. This trend has prompted SpaceX to create a military-focused version of its Starlink mega-constellation[37]. These systems have also become the target of certain counterspace capabilities in conflicts directly involving nuclear powers[38]. Presently, there are no plans to employ COMSATCOM mega-constellations as part of NC3[39] and it is unknown whether the risk introduced by employing these missions for NC3 would be tolerable[40]. However, this could be possible.

Starlink could be modified to serve as a back-up for current U.S. NC3 capabilities, which rely on a few large satellites that are vulnerable to counterspace weapons[41]. Employing a

34 Dave Mosher and Rebecca Harrington, *SpaceX and its biggest competitors are waging a space battle on Capitol Hill* (Business Insider, 2016). https://www.businessinsider.com/spacex-ula-competition-space-war-politics-2016-10.

35 James Pethokoukis, *Moore's Law, Meet Musk's Law: The Underappreciated Story of SpaceX and the Stunning Decline in Launch Costs* (AEI, 2022). https://www.aei.org/articles/moores-law-meet-musks-law-the-underappreciated-story-of-spacex-and-the-stunning-decline-in-launch-costs/.

36 Tim Vasen, "Responsive Launch of ISR Satellites: A Key Element of Space Resilience?", in *JAPCC Journal*, edition 27 (Kalkar: JAPCC, 2018), 17–21. https://www.japcc.org/wp-content/uploads/JAPCC_J27_screen.pdf.

37 Joey Roulette and Mike Stone, *Musk's SpaceX Is Building Spy Satellite Network for U.S. Intelligence Agency, Sources Say* (Reuters, 2024). https://www.reuters.com/technology/space/musks-spacex-is-building-spy-satellite-network-us-intelligence-agency-sources-2024-03-16/.

38 See Baklitskiy, *Strategic Stability in Outer Space*; and Poirier, *Breaking the Final Frontier*.

39 Acton, *The Survivability of Nuclear Command-and-Control Capabilities*, 435.

40 Jonathan P. Wong, Yool Kim, Krista Langeland, George Nacouzi, Krista Romita Grocholski, Jonathan Balk, Karishma V. Patel, and Barbara Bicksler, *Leveraging Commercial Space Services: Opportunities and Risks for the Department of the Air Force* (Santa Monica: RAND Corporation, 2023), 33. https://www.rand.org/pubs/research_reports/RRA1724-1.html.

41 Fetter and Sankaran, *Emerging Technologies and Challenges to Nuclear Stability*, 259.

COMSATCOM mega-constellation in a different orbit than NC3 capabilities as a back-up could increase the resilience of overall NC3 at a low cost. Moreover, having different operating systems complicates cyberattacks, and large constellations are more capable of surviving kinetic attacks than individual satellites or small constellations[42]. Additionally, Starlink satellites are inexpensive to produce in mass[43], and responsive launch capabilities could quickly help restore the constellation after the loss of a few satellites. Overall, employing a large constellation as a back-up to traditional NC3 could strengthen nuclear strategic stability by increasing the survivability of NC3[44].

However, employing this type of architecture would likely increase the risk of collisions and space debris formation by making its orbit more crowded, degrading the LEO environment[45]. These types of systems also needs to coexist with other LEO constellations, making their survivability partly contingent on the efforts to avoid debris generation by other constellation operators, including foreign governments and private actors. Experts argue that jamming would be a manageable issue for Starlink if appropriate measures are taken, but cyberattacks could still pose a threat[46]. Assessing the seriousness of this threat is difficult. Starlink has recently shown itself to be "remarkably resistant" to cyberattacks in the context of the Russia–Ukraine war[47]. However, adversaries could simply be choosing not to exploit certain cyber vulnerabilities at this time.

Certain states adversaries could alternatively choose to detonate a nuclear weapon in LEO to counter a proliferated constellation. This is not completely unrealistic, as Russia is rumoured to have recently launched a nuclear weapon to space[48] and Chinese experts adjacent to the People's Liberation Army have modelled the impacts of nuclear detonations in (near) orbit[49]. A nuclear detonation in LEO would be enormously escalatory and would cause significant indiscriminate damage, making it a suboptimal choice in most scenarios. Radiation shielding might be able to mitigate the non-kinetic effects of this type of detonation. However, this is not certain[50].

42 Acton, *The Survivability of Nuclear Command-and-Control Capabilities*, 445.

43 Dave Mosher, *Here's How Many Millions of Users Starlink May Need to Break Even if It Loses $2,000 for Every Satellite Dish It Sells, According to Experts* (Business Insider, 2020). https://www.businessinsider.com/spacex-starlink-terminal-cost-subscriber-numbers-years-return-investment-profit-2020-11.

44 Fetter and Sankaran, *Emerging Technologies and Challenges to Nuclear Stability*, 265.

45 Acton, *The Survivability of Nuclear Command-and-Control Capabilities*, 435.

46 Wong et al., *Leveraging Commercial Space Services*, 30–33.

47 Victoria Samson and Laetitia Cesari, *2025 Global Counterspace Capabilities Report* (Boulder, CO: Secure World Foundation, 2025), 14-07. https://www.swfound.org/publications-and-reports/2025-global-counterspace-capabilities-report.

48 Juliana Suess, *The Nuclear Option – Russia's Newest Counter Space Weapon* (RUSI, 2024). https://www.rusi.org/explore-our-research/publications/commentary/nuclear-option-russias-newest-counter-space-weapon.

49 Li Liu, Shengli Niu, Jinhui Zhu, Yinghong Zuo, Honggang Xie, and Peng Shang, "Numerical Simulation of Debris Motion from a Near-Space Nuclear Detonation", *Chinese Journal of Computational Physics* 39, no. 5 (2022): 521–528. https://doi.org/10.19596/j.cnki.1001-246x.8492.

50 Acton, *The Survivability of Nuclear Command-and-Control Capabilities*, 444.

Even if the counterspace risks of employing Starlink as an NC3 back-up would be deemed tolerable, trust between customer and operator would remain an issue. Elon Musk, owner of SpaceX, has garnered a reputation for unreliability. Musk has reportedly made the personal decision to shut down access of Starlink for the Ukrainian military on more than one occasion – due to fear of Russian nuclear retaliation – without consulting with the American or Ukrainian militaries[51]. This illustrates the sway that nuclear threats can have on certain private actors, and Musk's outsized power over military affairs. Musk's current adversarial relation with President Trump has further eroded trust between the U.S. government and SpaceX[52]. If Starlink were to be employed as a NC3 back-up, this dynamic would be destabilising, as it would reduce trust on the system's reliability and could be perceived as a vulnerability.

4.3 Remote sensing

Commercial proliferated constellations have a variety of uses beyond SATCOM. Private satellites are increasingly hosting military payloads. Constellations could host governmental payloads to confirm the outcome of mid-course missile defence hit-to-kill interception attempts[53], further entangling private civilian and nuclear-relevant capabilities, but potentially supporting resilience. Beyond data collection, it has been reported that a private company is developing AI tools to integrate data from existing and next-generation U.S. early warning satellites[54].

Commercial remote sensing-specific constellations are also impacting the space-nuclear nexus. Although there has already been free and open access to Earth observation (EO) data for over a decade through government-run programmes, commercial EO providers have democratised access to optical and synthetic aperture radar (SAR) data with high spatial and temporal resolutions. These data support the efforts of open-source intelligence (OSINT) analysts seeking to better understand nuclear programmes, thus bringing more transparency and scrutiny to nuclear issues[55]. Moreover, private EO constellations can support demonstrative verification in cases such as ensuring that limits on the deployment

51 Joey Roulette, Cassell Bryan-Low, and Tom Balmforth, *Musk Ordered Shutdown of Starlink Satellite Service as Ukraine Retook Territory from Russia* (Reuters, 2025). https://www.reuters.com/investigations/musk-ordered-shutdown-starlink-satellite-service-ukraine-retook-territory-russia-2025-07-25/.

52 Zack Stanton, *Trump vs. Musk: Inside a Feud That Could Define the Future of Space* (Time, 2023). https://time.com/7292326/trump-musk-feud-spacex-nasa/.

53 Fetter and Sankaran, *Emerging Technologies and Challenges to Nuclear Stability*, 259.

54 Geneva Centre for Security Policy, *Militarisation of Space and the Private Sector's Expanding Role*.

55 See Christina Krawec, *A Guide to Satellite Imagery Analysis for the Nuclear Age* (Washington, DC: Federation of American Scientists, 2025). https://www.fas.org/wp-content/uploads/2025/12/Satellite-Imagery-in-the-Nuclear-Age-1.pdf.

of silo-based missiles are respected or verifying whether stored nuclear weapons are being deployed[56].

However, these capabilities can also be used to observe states' nuclear assets without their consent. This type of intelligence gathering is not new, but the involvement of private actors has increased access to this imagery, allowing countries without EO capabilities to access imagery of other countries' nuclear assets. Moreover, procuring imagery from companies, such as Maxar, allows the U.S. to more readily share intelligence with partners and allies, compared to data acquired through national technical means[57]. Experts and the media have also used this to assess the impact of the Ukrainian drone attack on the strategic bomber component of Russia's nuclear triad[58]. Russia and China have previously stated concern regarding the involvement of private space actors in supporting military operations, although they have engaged in this practice as well[59]. The provision of these services raises the prospect of horizontal escalation if a third-country private satellite supports a state that is party to a conflict and a state on the opposing side of the conflict interprets this as an intervention by the third country[60].

The targeting of private EO constellations may become more commonplace if these are used to track mobile targets. The shorter revisit times and improved sensor suites of constellations allow expanded and enhanced data collection which, if paired with AI-enabled analysis, could help identify nuclear weapon launch platforms such as road mobile launchers or even SSBNs in certain cases[61]. However, skilful nuclear states could employ a variety of countermeasures, likely keeping EO from becoming a significant threat to their second-strike capabilities[62].

4.4 Satellite operations and space situational awareness

Private actors have broken the monopoly of large states on space situational awareness (SSA). SSA "refers to the capability or practice of tracking and characterising specific space objects and their operational environment in order to understand their current position, as well as to predict their future positions"[63]. This capability can help prevent

56 Tamara Patton and Pavel Podvig, *Verification Without a Treaty: Demonstrative Verification in Arms Control, Disarmament, and Space Security* (Geneva: UNIDIR, 2025), 12–21. https://unidir.org/wp-content/uploads/2025/09/UNIDIR_Demonstrative_Verification_Report.pdf.

57 Mazarr et al., *The Space Enterprise and Integrated Deterrence,* 12.

58 Paul Brown and Thomas Spencer, *How Satellite Images Show Scale of Ukraine's Drone Attack on Russian Bombers* (BBC, 2025). https://www.bbc.com/news/articles/cvg9zdxwk29o.

59 Raju and Wan, *Escalation Risks at the Space–Nuclear Nexus*, 21.

60 Geneva Centre for Security Policy, *Militarisation of Space and the Private Sector's Expanding Role.*

61 Fetter and Sankaran, *Emerging Technologies and Challenges to Nuclear Stability*, 261.

62 *Ibid.*

63 Almudena Azcárate Ortega and Victoria Samson, *A Lexicon for Outer Space Security* (Geneva: UNIDIR, 2023), 23. https://unidir.org/publication/a-lexicon-for-outer-space-security.

accidental orbital collisions, and detect, attribute, and deter attacks on satellites[64], including on satellites relevant to the space-nuclear nexus. The U.S. owns the most extensive SSA sensor network, but it has not established continuous surveillance of Earth's orbits[65].

Current gaps in SSA could allow for malicious satellite manoeuvres to go unnoticed or could foster the perception of such threatening movements happening. Private satellites serving military clients engage in unusual manoeuvres more often than other satellites[66], which, paired with the blurry line separating offensive and defensive rendez-vous and proximity operations (RPOs), creates room for uncertainty. Some private companies have the capacity to conduct RPOs at geosynchronous Earth orbit (GEO)[67], an orbit that hosts early-warning and NC3 satellites[68]. Researchers have argued that this capability could support a range of tasks, from targeting[69] to servicing[70] these satellites. SSA is a necessary enabler for type of operation[71]. The targeting potential of SSA is troubling, given that private actors have shown themselves to be very willing to publicly share SSA information. For example, a private SSA company confirmed that the Russian satellite believed to be a nuclear ASAT weapon had started to tumble in orbit[72].

A more robust SSA coverage could also help implement stabilising measures such as the introduction of off-limit areas for non-consensual RPOs around satellites that are critical to nuclear strategic stability[73]. Moreover, improving SSA by employing private capabilities could enhance transparency regarding satellite manoeuvres[74] and support efforts to establish an international space traffic management system[75]. In addition to data from SSA-focused missions, private actors could provide information regarding their satellites'

64 Mariel Borowitz, "Legal Considerations and Future Options for Space Situational Awareness", *Georgia Journal of International and Comparative Law* 48 (2020). https://digitalcommons.law.uga.edu/gjicl/vol48/iss3/5/.
65 *Ibid.*
66 Geneva Centre for Security Policy, *Militarisation of Space and the Private Sector's Expanding Role.*
67 Northrop Grumman, *Space Industrial Revolution* (Northrop Grumman, 2024). https://www.northropgrumman.com/what-we-do/space/space-logistics-services/space-industrial-revolution.
68 Acton, *The Survivability of Nuclear Command-and-Control Capabilities*, 433.
69 Sitki Egeli, "Space-to-Space Warfare and Proximity Operations: The Impact on Nuclear Command, Control, and Communications and Strategic Stability", *Journal for Peace and Nuclear Disarmament* 4, no. 4 (2021). https://doi.org/10.1080/25751654.2021.1942681.
70 NASA, *Satellite Servicing Project Report* (Washington, DC: NASA, 2011), 28. https://www.nasa.gov/wp-content/uploads/2023/10/nasa-satellite-servicing-project-report-0511.pdf.
71 Raju and Erästö, *The Role of Space Systems in Nuclear Deterrence*, 14.
72 Tim Fernholz, *Tumbling Russian Sat Highlights Counterspace Threat* (Payload Space, 2025). https://payloadspace.com/out-of-control-russian-satellite-highlights-counterspace-threat/.
73 James M. Acton, Thomas MacDonald, and Pranay Vaddi, *Reimagining Nuclear Arms Control: A Comprehensive Approach* (Washington, DC: Carnegie Endowment for International Peace, 2021), 63. https://carnegieendowment.org/research/2021/12/reimagining-nuclear-arms-control-a-comprehensive-approach?lang=en.
74 Borowitz, *Legal Considerations and Future Options for Space Situational Awareness.*
75 See COPUOS, *Legal Subcommittee: 2025* (Vienna: UNOOSA, 2025). https://www.unoosa.org/oosa/en/ourwork/copuos/lsc/2025/index.html#sessdocs.

orbital trajectory and planned manoeuvres to improve predictability of their movements[76]. The stabilising effect created by these actions would be contingent on this information's quality, as well as whether it is consistently provided and perceived as trustworthy. This practice could help establish a baseline for common operations and could help detect unusual manoeuvres[77].

4.5 Warfighting and hybrid warfare

The private sector has started to take a more active role in conflicts. States are contracting companies to perform hybrid attacks, such as cyberattacks against critical targets[78]. However, there is an appetite in relevant circles in the U.S. to employ private space actors in military activities beyond hybrid operations. Analysts have argued that "[i]n virtually every case that a commercial space solution can meet an operational requirement, the Space Force should favour that commercial option over one developed from scratch for the government"[79]. This expanded role will likely be an important component of the Golden Dome for America (GDA). Presently, there is no clear GDA architecture, but rather a loose concept of the system[80]. Of particular interest is the speculated space-based interceptor (SBI) layer of the system and its immediate enablers (e.g. sensors, communications, etc.). Analysts have argued that companies could fulfil every task except for the decision to fire SBIs under the GDA[81], placing private firms at the core of the space-nuclear nexus.

Even if this more extreme scenario does not come to pass, the private sector already has a significant role in deciding how GDA might be implemented. The architecture of GDA will largely determine its policy implications. Amidst an apparent lack of direction from the U.S. government, illustrated in an executive order that puts the purpose of GDA beyond any realistic scope[82], large defence companies and consultancies are scrambling to define

76 Kaitlyn Johnson, Thomas G. Roberts, and Brian Weeden, "Mitigating the Threat of Noncooperative Rendezvous and Proximity Operations in Space", *Æther: A Journal of Strategic Airpower & Spacepower* 1, no. 4 (2022), 88. https://www.airuniversity.af.edu/Portals/10/AEtherJournal/Journals/Volume-1_Number-4/Weeden_Mitigating_Noncooperative_RPOs_.pdf.
77 Geneva Centre for Security Policy, *Militarisation of Space and the Private Sector's Expanding Role*.
78 Victoria Samson and Laetitia Cesari, *2025 Global Counterspace Capabilities Report*, 14-11.
79 Clayton Swope, *Bringing the Private Sector to Space*, 5.
80 Jessica West and Kathryn Barrett, *The Golden Dome Explained: Ambition, Reality, and Risk* (Waterloo: Project Ploughshares, 2025). https://ploughshares.ca/golden-dome-explained-ambition-reality-risk/.
81 Clayton Swope, *The Golden Dome as a Service: Pushing the Envelope on DoD Use of Commercial Space Services* (Washington, DC: CSIS, 2025). https://csis-website-prod.s3.amazonaws.com/s3fs-public/2025-06/250604_Swope_Golden_Dome_0.pdf?VersionId=_BOCEYiEWS_3MUzF3s6yWjhrYbpLtiex.
82 The White House, *Executive Order 14186: The Iron Dome for America* (Federal Register, 2025). https://www.federalregister.gov/documents/2025/02/03/2025-02182/the-iron-dome-for-america.

its architecture[83] in an attempt to access the significant funds that would be necessary to implement GDA[84]. Lockheed Martin is one of the firms placing an emphasis on SBIs and it has proposed testing one of these systems against a co-orbital target by 2028[85]. Such action would make the U.S. private sector a central actor in the overt weaponisation of outer space, contributing to the breaking of a significant taboo.

The Vice President for Space AI at Booz Allen Hamilton, an established consultancy interested in developing GDA, has recently suggested that employing AI-enabled SBIs would not introduce significant risk. He stated that if the system would "blow up someone's climate satellite" the U.S. government could just reply "whoops, I guess we will buy you another one"[86]. This statement completely disregards the humanitarian impact of suddenly denying access to a crucial asset for disaster management, the creation of space debris caused by an event of this type, and the possibility of unintendedly targeting rockets during their boost phase. Statements such as this raise concern regarding the level of understanding that established space and defence firms have of the security implications of their actions on conventional security, let alone nuclear strategic stability. This apparent lack of knowledge may lead to recklessness and may influence adversary threat perceptions. NewSpace companies, a group that often operates under the premise "move fast and break things", likely also fail to understand the consequences of their greater integration in the military, including the heightened risk of being targets of attack. In a dangerous precedent, Russia has stated that it sees the targeting of private satellites supporting military operations as legitimate[87].

83 Geoff Brumfiel, *Trump Unveils Ambitious and Expensive Plans for 'Golden Dome' Missile Defense* (NPR, 2025). https://www.npr.org/2025/04/22/g-s1-61658/trump-golden-dome-america-iron-military-defense.

84 Todd Harrison, *Build Your Own Golden Dome: A Framework for Understanding Costs, Choices, and Trade-offs* (Washington, DC: American Enterprise Institute, 2024). https://www.aei.org/research-products/working-paper/build-your-own-golden-dome-a-framework-for-understanding-costs-choices-and-tradeoffs/.

85 Sandra Erwin, *Lockheed Martin Targets 2028 Demo of Space-Based Missile Interceptors* (SpaceNews, 2025). https://spacenews.com/lockheed-martin-targets-2028-demo-of-space-based-missile-interceptors/.

86 SpaceNews, *Golden Dome – Data and AI*, video, 58:51, published 31 July 2025. https://www.youtube.com/watch?v=RH5TIRCuejs.

87 Jon Brodkin, *Russian official says civilian satellites may be "legitimate" military target* (Ars Technica, 2022). https://arstechnica.com/tech-policy/2022/09/russian-diplomat-suggests-attacks-on-satellites-in-possible-reference-to-starlink/.

5. Conclusion

U.S. private companies have permeated a wide range of activities relevant to the space-nuclear nexus, including support of strategic assets and potentially direct operations through initiatives such as GDA, or decision-making through AI systems and lobbying. Their overall participation is neither inherently stabilising nor destabilising. There is a need to better understand how the role of these actors continues to emerge, including as political operators, economic players, and members of the international community. It will also be important to better understand the role of different national private sectors in other countries such as China, Russia, the EU, and India.

Present trends would suggest that the military-commercial integration described in this research note will expand in the U.S. As private companies gain greater responsibilities and autonomy within the space-nuclear nexus, it is increasingly important for these actors to better understand their role in nuclear issues as well as the risks and opportunities associated with their actions. This could be achieved by engaging with governments, international organisations, and civil society regarding their role in space security. Moreover, if firms are to continue performing the services described in this research note, they ought to be better integrated in military exercises to ensure appropriate responses during potential crises. These private actors should also be more careful in their public communications, as these could be interpreted as formal signalling by adversaries. Moreover, all private actors should support the creation and following of norms of responsible behaviour in space as well as applicable international law. There is also a need for greater transparency and accountability regarding the role of private actors in the space-nuclear nexus. States should agree on an explicit delineation of what represents a legitimate role for these actors[88].

88 Raju and Wan, *Escalation Risks at the Space–Nuclear Nexus*, 26.

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Research Note

Golden Dome for America and its Impact on Nuclear Strategic Stability: An event series report

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Abstract

This report examines the Golden Dome for America (GDA) and its potential implications for nuclear strategic stability. Drawing on insights from a three-event webinar series organised by International Student/Young Pugwash (ISYP) and Student/Young Pugwash UK (SYP UK) in late 2025, it reviews the initiative's conceptual scope, projected architecture, budgetary requirements, and technical feasibility, with particular attention to space-based sensors and interceptors, midcourse and boost-phase missile defence, and systems aimed at countering hypersonic glide vehicles. The report finds that GDA remains highly ambitious, politically significant, and conceptually fluid, while facing major technical, industrial, budgetary, and operational constraints. At the same time, the initiative is already shaping strategic perceptions among major nuclear powers. By extending US homeland missile defence aspirations beyond limited threats and toward peer competitors, GDA risks accelerating offensive and defensive arms competitions, intensifying counterspace developments, and undermining adversaries' confidence in the effectiveness of their nuclear deterrents. The report also briefly considers the limited conditions under which missile defence could have stabilising effects and identifies recommendations aimed at reducing misperception, improving transparency, strengthening pre-launch notification mechanisms, and grounding policy in realistic technical assessments.

Keywords

Nuclear deterrence, Golden Dome, strategic stability, outer space, missile defence, space-based interceptors, arms control

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1. Introduction

In January 2025 the Trump administration announced an ambitious initiative to protect the United States from all airborne threats. However, the Iron Dome for America, which would soon be renamed Golden Dome for America (GDA), brought with itself more questions than answers, including pressing questions on the future of nuclear strategic stability.

To explore this matter International Student/Young Pugwash (ISYP) and Student/Young Pugwash UK (SYP UK) organised a series of webinars focused on GDA in Q4 2025. The events initially covered the status of the GDA initiative, questions surrounding its budget, and the technical feasibility and effectiveness of some of the systems that may form part of its architecture. These sessions build a solid knowledge base on these topics, enabling an in-depth discussion on GDA's potential and current impacts on nuclear strategic stability during the final webinar. The experts leading these discussions were Dr. Laura Grego, Todd Harrison, Dmitry Stefanovich, Dr. Cameron Tracy, Dr. Jessica West, Robert "Sam" Wilson, and Dr. Tong Zhao. This report gathers the main insights shared during this three-event webinar series and includes complementary sources.

2. What is the Golden Dome?

Overall, information regarding GDA remains scant, be it because of the level of classification required to access it or because of a lack of concrete direction by the current US administration. It was said during the event series that GDA is best thought of as an overarching, ambitious vision for protecting the US from aerial threats. The initiative will seek to achieve this through an integration of old and new systems into a "layered, integrated, global missile defence architecture"[1]. The goal is to defeat not just intercontinental ballistic missiles (ICBMs), but also hypersonic glide vehicles (HGVs), cruise missiles, drones, and other airborne threats at any stage of flight. Said goal was initially planned to be achieved with a total amount of $175 billion[2]. President Trump announced that the system will be completed by the end of his second term and will have a near 100% interception success rate.

This is extremely ambitious and, at this fluid stage, no part of how this goal will be achieved is particularly clear; questions remain regarding, *inter alia*, technical feasibility, budgetary availability, and political will. For these reasons, GDA could very well be scaled

1 The White House. 2025. *The Iron Dome for America*. https://www.whitehouse.gov/presidential-actions/2025/01/the-iron-dome-for-america/.

2 Stone, M. & Mason, J. 2025. *Trump selects $175 billion Golden Dome defense shield design, appoints leader*. Reuters. https://www.reuters.com/world/us/trump-make-golden-dome-announcement-tuesday-us-official-says-2025-05-20/.

down in time. But across its possible incarnations, there are three functions which must be achieved in any architecture: detection and tracking, interception, and command and control[3]. To that end, GDA's layers will consist of sensors, including space-based sensors; kinetic interceptors that will likely be ground, sea, air, and space-based; and a partially autonomous command and control network.

Even if the vision of GDA remains conceptual, GDA has already unleashed strong political and economic forces taking on a life of their own. These include, as shared during the events, bipartisan support behind closed doors in some congressional subcommittees addressing the initiative, indicating that GDA may last beyond the Trump administration. There is also strong private sector interest to drive the design of GDA, caused in part by an apparent lack of clarity in the government regarding the specifics of the architecture and by the vast sums of money that have already been announced for GDA. Private actors are shaping the architecture themselves by announcing capability claims and partnerships, evangelising the feasibility of their GDA solutions, and positioning themselves as go-to partners. Multiple companies have announced future interceptor capabilities and demonstration tests in orbit, while others are designing sensor networks, tracking layers, and autonomous command and control systems. However, there is an opportunity cost in fixing the attention of the American defence-industrial base on GDA and in allocating huge sums to GDA, even if these have not been spent yet.

The urge to develop GDA is in part a response to the current strategic geopolitical landscape, in which existing defences may be tested by faster and more manoeuvrable missiles, hypersonic glide vehicles, advancements in drones, and other precision strike capabilities. In this context, GDA may require an important allied involvement, including the sharing of radar stations, data, and the protection of forward-deployed troops and bases in the Indo-Pacific. Canada has communicated its potential interest in joining GDA[4], and similar considerations are likely being contemplated in capitals across Europe as well.

Comprehensive defence is an alluring concept for certain American political circles, and the moniker of GDA evokes Israel's Iron Dome and its famed effectiveness. However, this serves as a false analogy. Iron Dome is a theatre missile defence system defending a specific area against short-range, low-altitude threats such as rockets and artillery, in contrast with the strategic scope of GDA. Technological realities are at odds with the ambitious promises of GDA, which could provide a false sense of confidence feeding into high-level US decision-making by invoking the image of an impenetrable shield defending the US. GDA also risks exacerbating the development of counterspace technologies, moving towards

3 West, J. & Barrett, K., 2025. *Golden Dome Explained: Ambition, Reality, Risk*. Project Ploughshares. https://ploughshares.ca/golden-dome-explained-ambition-reality-risk/.

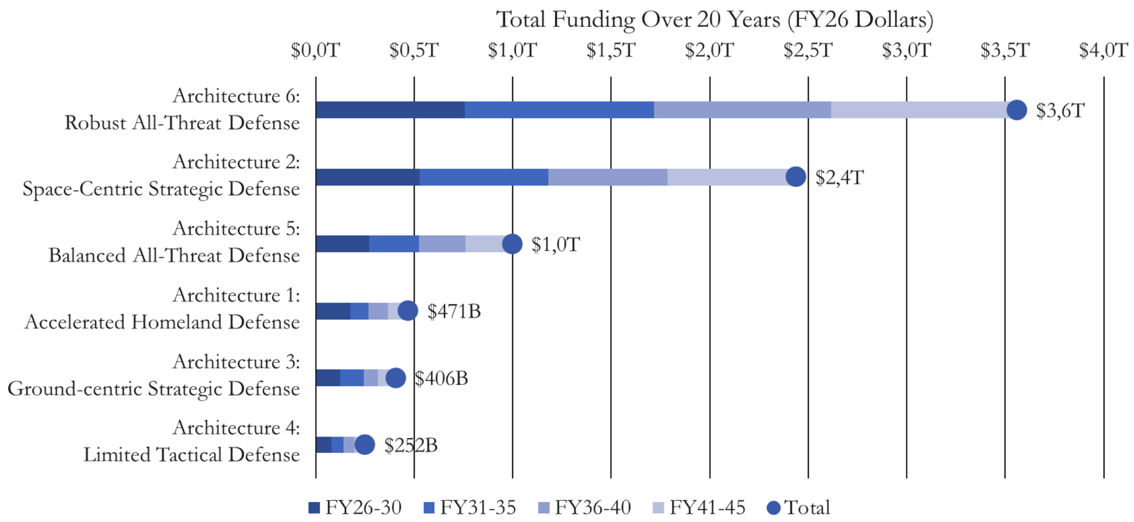
4 Panetta, A. 2025. *Canada wants to join Golden Dome missile-defence program, Trump says*. CBC. https://www.cbc.ca/news/world/golden-dome-trump-us-missile-defence-canada-1.7539390.

the normalisation of unambiguous, open weaponisation in orbit; a Rubicon that would be crossed if space-based interceptors were to be deployed and tested. GDA would also risk creating escalation pathways for conflict to potentially move into orbit, with potentially huge consequences for civilian life, as satellites that underpin navigation, communications, banking, and emergency services could be severely disrupted.

3. Budget

One of the few aspects of GDA about which there is concrete information is its budget. Harrison[5] has calculated the budget necessary for developing a set of possible GDA architectures (Figure 1), ranging from a fully-fledged system following President Trump's specifications, to more limited alternatives.

Figure 1: Projected budget for selected potential GDA architectures[6]



This analysis found that GDA would require a far greater budget than what was announced by the White House, and even with a budget of over $3.6 trillion, GDA would likely fall short of its stated goal of a near perfect interception rate for all aerial threats and would take far longer to implement than the stated three-year timeline. It was also stressed that developing a system of this magnitude on a politically driven timeline has failed in the past and will likely fail again, in part due to a lack of industrial capacity to produce space-

5 Harrison, T. 2025. *Build Your Own Golden Dome: A Framework for Understanding Costs, Choices, and Trade-offs*. AEI. https://www.aei.org/research-products/working-paper/build-your-own-golden-dome-a-framework-for-understanding-costs-choices-and-tradeoffs/.

6 *Ibid*.

based interceptors (SBIs) in sufficient numbers. These time and capability restrictions would also very much be the case with an architecture restricted to the budget announced by President Trump. The latest budget estimate of $185 billion shared by the Pentagon[7] places middle-term costs in line with Architecture 1 projections, which could include a boost phase SBI component theoretically capable of intercepting a five-missile salvo[8], but would fall short of GDA's stated aims.

Congressional budgetary documents can also provide information regarding the existing GDA budget. Wilson found that the Fiscal Year 2026 Reconciliation Act allocates $24.4 billion to elements that may be considered part of GDA[9]. The latest Reconciliation Act provides important information about the possible architecture of the system. $9.2 billion will be allocated to tracking threats pre- and post-launch from space, an expense likely related to improving satellites dedicated to HGV tracking. The Reconciliation Act also provides $5.6 billion to SBI development and $8.7 billion to non-space based potential elements of GDA. Previous budget documents have also provided details on the plans for proliferated sensor constellations, including the Next-Generation Overhead Persistent Infrared (Next-Gen OPIR) Missile Warning Satellites which would likely be considered part of the GDA architecture.

This is a significant resource allocation but falls far short of even the low budget provided by the White House. More budget may be allocated in the future. However, the tight deadline set by the current Trump administration would require funds to become available as soon as possible. It was also speculated at the events that, given the time, technical and budgetary constraints, the Trump administration will possibly claim that GDA has achieved its goal by testing an SBI in orbit by 2028.

4. Technical feasibility

In addition to questions regarding budget and industrial capacity, it is unclear whether GDA would be a technically sound initiative. The event series addressed this by exploring the technical dimension of a selection of capabilities that would arguably be part of most tentative GDA architectures. These include strategic terminal, midcourse, and boost phase ballistic missile defence systems, as well as HGV defence systems covering HGV's glide

7 Schepkof, V. 2025. *Golden Dome cost rises to $185 billion as new contractors join*. Yahoo News. https://uk.finance.yahoo.com/news/golden-dome-cost-rises-185-180611950.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAKW46xFQtgpn0uQBQHF4E3aOdEUn2GWjUTXgWan8M97Xgk680WarU2PEe0XVXiSq8I-7YXEO9DwaEeGRzuvEVIYod3ycZFmzott0F2-fSpQkqrKMciZvsNFITth5t97ylq-GgxrhSwwJNfsCgijbJPBvuH1JnPw2lyoMWzkkVPk9.

8 Harrison. 2025.

9 Wilson, R.S. 2025. *FY 2026 Defense Space Budget: Emergence of Golden Dome*. The Aerospace Corporation. https://csps.aerospace.org/papers/fy-2026-defense-space-budget-emergence-golden-dome.

phase. Successful interceptions in of all these cases are as reliant on sensor networks and communication links as they are on capable interceptors. It is also worth emphasising that these cases refer specifically to strategic missile defence, which represents a very different set of challenges compared to theatre missile defence. Therefore, the success rates of these two types of missile defence should not be conflated.

4.1 Midcourse missile defence

Strategic missile defence against ballistic missiles may take place during the boost, midcourse or terminal phases of missile flight. Midcourse missile defence (MMD) systems allow the defender to avoid the forward deployment of interceptors. This type of defence is enabled by a suite of land, sea and space-based sensors, and affords the defender a relatively generous timeline of 30–35 minutes for action[10]. However, there is a range of technologies which make midcourse interceptions particularly difficult, including multiple re-entry vehicles, launch debris, and countermeasures, which may include radar jammers, decoys, or high-altitude nuclear detonations. Countermeasures represent an important technical challenge for MMD[11]. Although there have been technological advancements in the last twenty years that support MMD's capability to surmount these challenges, the gap between defence and offence in this respect remains significantly large in favour of the attacker[12]. It was also highlighted during the event that current US MMD has an unreliable test record. US MMD capabilities are undergoing modernisation, including the Long-Range Discrimination Radar coming on-line, the likely inclusion of space-based sensors for tracking and discrimination, and the development of the Next-Generation Interceptor. However, even with this modernisation drive, interceptors remain scarce, expensive and difficult to manufacture, favouring the attacker's capacity to saturate the US MMD. This inability to cost-effectively and quickly expand interceptor inventories, as well as the technical difficulty of performing interceptions, make MMD vulnerable even to small, relatively unsophisticated attacks[13].

10 Lamb, F. K., et al. 2025. *Strategic Ballistic Missile Defense*. American Physical Society. https://res.cloudinary.com/apsphysics/image/upload/v1741185158/APS_BMD_Report_2025_qzgzaz.pdf.

11 Sessler et al. 2000. *Countermeasures*. Union of Concerned Scientists. https://www.ucs.org/resources/countermeasures.

12 Grego, L. 2025. *Do technology advances allow missile defences to make up ground?* Journal of Strategic Studies 48(2). https://www.tandfonline.com/doi/abs/10.1080/01402390.2024.2447306.

13 Lamb et al. 2025.

4.2 Boost phase missile defence

Boost phase is usually the most vulnerable phase of ballistic missile launch, as targets are relatively easily identifiable and are at the slowest moment of their trajectory. However, boost phase missile defence (BPMD) is not without significant technical challenges. These systems have a much shorter timeline for interception than MMD, at around 2–4 minutes[14]. It was argued that this compressed timeline would likely require significant AI involvement in decision-making, potentially increasing the risk of inadvertent escalation. Moreover, this time constraint limits BPMD systems to standoff distances requiring potentially vulnerable forward deployments on sea or land, while lacking the capacity to reach launch sites deep in enemy territory.

These spatial constraints make Low Earth Orbit (LEO) a potentially attractive location for the deployment of BPMD interceptors, as it allows proximity to launch sites that would be out of range for sea or land-based BPMD interceptors. However, it was explained that there are several setbacks related to BPMD SBIs. Orbital BPMD is even more vulnerable to being overwhelmed by salvo attacks than MMD due to the difficulty of having enough SBIs to cover a launch location at the same time. To defend, for instance, against a salvo of 10 solid-propellant ICBMs launched by North Korea against the US, the system would need 40,000 SBIs, with the generous assumption of only one SBI being needed per ICBM[15]. These SBIs would then need to be promptly replenished to avoid prolonged coverage gaps in the SBI architecture, facing potential bottlenecks due to launch and industrial capacity. These factors would make SBIs extremely challenging to use against large-scale attacks, or consecutive attacks through gaps created. These gaps in the architecture may also be created through the targeting of SBIs with anti-satellite (ASAT) weapons. SBIs may also be used as kinetic ASATs themselves, or they could support MMD. However, these two use cases where not explored at length during the event series due to limited time.

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14 *Ibid*.

15 Harrison, T. 2025. *Space-Based Interceptor Calculator*. AEI. https://toddsharrison.github.io/SBI/?sbiOrbitAltitudeKm=300&averageAccelerationG=15&maxDeltaVKmPerS=10&divertVelocityKmPerS=2.5&thrusterIspSeconds=240&killVehicleDryMassKg=25&interceptorBodyDryMassKg=25&supportModuleDryMassKg=50&sbiLifeExpectancyYears=5&killProbabilityPercent=80&compositeKillProbabilityPercent=96&salvoSize=900&interceptAltitudeKm=200&maxLatitudeCoverageDeg=90&flyoutTimeSeconds=480&nonRecurringDevCostMillion=7000&firstUnitInterceptorCostMillion=70&interceptorLearningPercent=85&operatingSupportCostPerYearMillion=450&costEstimatePeriodYears=20&payloadCapacityPerVehicleKg=45000&firstUnitLaunchCostMillion=150&launchLearningPercent=95.

4.3 Hypersonic glide vehicles

HGV defence is identical to ICBM defence during the boost and midcourse/re-entry phases. However, differences exist in the terminal phase and the HGV-specific glide phase. Short range interceptors placed close to the defended area can be used for terminal phase defence. As a rule of thumb, interceptors require a 3:1 acceleration rate compared to their targets[16]. Given their endoatmospheric trajectory and the potential slowdowns due to manoeuvres, HGV are slower than ICBMs in their terminal phase. Therefore, terminal-phase defence against hypersonic missiles is possible if attempted sufficiently late in the target's flight, but this remains a difficult and very complex action[17].

HGVs also have a specific endoatmospheric glide phase, during which they can fly under MMD system coverage areas[18]. In contrast to MMD, glide phase missile defence (GPMD) does not have to deal with decoys, as most decoys cannot survive the same aerothermal heating conditions as gliders, and the ones that can are almost as costly as gliders. Tracking for GPMD may be achieved through orbital sensors, including infrared, radar, and optical sensors. However, it was stated during the event series that GPMD would require new, more agile interceptors, as well as new seekers potentially based on radio frequency sensors. Considering these factors, the level of challenges and costs of glide phase missile defence can be considered as similar to MMD.

It was also emphasised that the capability to engineer a system does not guarantee that this system will have its intended strategic impact. Not impossible does not necessarily translate to operationally feasible or strategically sound. In the specific case of GDA, this means that the potential capacity to build effective strategic missile defence does not necessarily lead to a safer strategic situation for the US. This is because the announcement, development, and deployment of these systems may work against nuclear strategic stability by modifying adversarial threat perceptions and reducing adversaries' confidence in their nuclear deterrent.

5. Nuclear strategic stability

Even before the first SBI has been deployed, GDA has already had an impact in nuclear strategic stability by stoking the flames of the ongoing international nuclear modernisation drive. Whereas US missile defence previously focused on defending the homeland from

16 Palumbo, N. F., et al. 2010. *Modern Homing Missile Guidance Theory and Techniques*. Johns Hopkins Apl Technical Digest, 29(1).

17 Wright D. & Tracy, C. L. 2023. *Hypersonic weapons: vulnerability to missile defenses and comparison to MaRVs*. Science & Global Security 31.

18 *Ibid.*

limited threats (e.g., from a small number of North Korean ICBMs), GDA explicitly aims to address threats from peer competitors, representing yet another chapter in the missile defence saga involving the US, Russia and China[19]. Even if missile defence is likely to remain imperfect, to the extent that GDA is successful at damage limitation it raises the spectre of a pre-emptive first strike by the US and undermines Russia's and China's confidence in their second-strike capability. It was also stated in the events that these fears are further reinforced by left of launch and missile defeat concepts being increasingly promoted in certain American security circles. Therefore, GDA may trigger an arms race, qualitatively and quantitatively. Russia and China are likely to continue increasing their missile stockpiles and developing countermeasures such as novel delivery vehicles to circumvent GDA.

It was stated during the events that China is particularly likely to strongly react to the announcement of GDA, as even respected Chinese technical experts tend to be overly generous in their assessments of American capabilities. Moreover, it is a widespread assumption in Chinese strategic communities that in the case of a nuclear confrontation with the US, the US would opt for a comprehensive disarming strike against China.

Two examples were offered. In 2016 and 2017, prominent Chinese technical experts made sincere arguments that the Terminal High Altitude Area Defense (THAAD) system deployed in South Korea could distinguish between warheads and decoys on Chinese ICBMs. The concern was that this information would then be passed on for US homeland missile defence, weakening China's second-strike capability. Prominent and influential space experts in China simulated the US using Starlink to intercept hundreds of Chinese ICBMs even though this technical analysis was dismissed by most US and international experts[20]. As the political environment within China has become increasingly restricted, the scope for informed, free discussion within China among technical experts about US homeland missile defence has become narrower. This then increases the already-existing tendencies to exaggerate genuinely misplaced concerns and incorrect assessments of US missile defence capabilities.

With that said, it was recounted that there appears to be some Chinese understanding that President Trump's personal interest in GDA and his assumed lack of expertise on these issues may be causing counterproductive decisions on the US side. There has also been concern as to whether GDA is partly aimed at deceiving China, to mislead China into excessive countermeasures and responses which prove to be a waste of resources.

19 Zhao, T. & Stefanovich, D. 2023. *Missile Defense and the Strategic Relationship among the United States, Russia, and China*. American Academy of Arts and Sciences. https://www.amacad.org/publication/missile-defense-and-strategic-relationship-among-united-states-russia-and-china.

20 Yuangzheng, R. et al., translated by Cowhig. 2022. *The Development Status of Starlink and Its Countermeasures*. Modern Defense Technology 50(2). https://gaodawei.wordpress.com/2022/05/25/prc-defense-starlink-countermeasures/.

However, it is also possible that China will seek to develop its own orbital missile defence network, an endeavour which could be supported by Russia through data sharing and the deployment of sensors on Russian soil.

Overall, China is confident in its ability to outlast the US in an arms race due to the advantages provided by one party rule, increasing technological prowess, and a position of economic strength. Moreover, it was said that China is increasingly confident in its conventional military capabilities vis-à-vis the US and will aim to keep any confrontation below the nuclear threshold.

In Russia, GDA's announcement has validated a pessimistic branch of strategic thinking, rooted in the Star Wars-era, that saw the deployment of American SBIs as a matter of time. In response, Russia has been developing capabilities to defeat this type of system for decades.

In response to the Trump administration's announcement of GDA, Beijing and Moscow stated that the initiative creates "hardly surmountable obstacles to the constructive consideration of nuclear arms control and nuclear disarmament initiatives"[21]. Russia, China, and the US also rely on space-based assets for conventional intelligence, surveillance, reconnaissance, and command and control; as well as for nuclear early-warning, and command, control, and communications. SBIs orbiting above Russian and Chinese territories would be an unprecedented crossing of that line symbolically and operationally. Moreover, testing these interceptors would likely be perceived by other countries as the test of a co-orbital kinetic ASAT weapon. It was argued that in response, Russia and China are likely to accelerate the development of counterspace capabilities to both hold GDA at risk and to protect their own assets in space. In turn, the US is likely to develop capabilities to protect GDA from such countermeasures. In the worst case, Russia and China may plan to detonate nuclear weapons in space to wipe out GDA. Chinese experts associated with the People's Liberation Army and China's defence industry have simulated the effects of a nuclear explosion in space on satellites in low-earth orbit[22]. Additionally, Russia is allegedly developing a nuclear anti-satellite system which would use the explosion for weapons effects[23].

However, it was also stated in the events that the asymmetry brought about by GDA may create opportunities for arms control discussions and threat reduction measures.

21 Office of the President of the Russian Federation. 2025. *Joint statement by the Russian Federation and the People's Republic of China on Global Strategic Stability*. http://en.kremlin.ru/supplement/6310.

22 Liu, L. et al. 2022 *Numerical Simulation of Debris Motion from a Near-space Nuclear Detonation*. Chinese Journal of Computational Physics 5. https://cnki.net/kcms/detail/detail.aspx?filename=JSWL202205003&dbcode=CJFQ&dbname=DKFXTEMP&v=.

23 Samson, V. et al. 2025. *FAQ: What We Know About Russia's Alleged Nuclear Anti-Satellite Weapon*. Secure World Foundation. https://www.swfound.org/publications-and-reports/faq-what-we-know-about-russias-alleged-nuclear-anti-satellite-weapon.

Additionally, effective missile defence capable of defeating a limited nuclear attack could prove stabilising. For example, if it effectively defends against a small number of missiles, it may dissuade countries from launching a limited nuclear attack. However, it may also increase the likelihood of limited nuclear strikes, as it would allow the attacker to communicate its resolve while facing more limited retaliation, based on the expectation that most of its nuclear missiles will be defended against.

In acknowledging the potentially positive aspects of missile defence, it was noted that for missile defence to be stabilising, there need to be predictable limits on the capability. This was akin to the role played by the Anti-Ballistic Missile Treaty during the Cold War. In the events unilateral limits, if not formal limits, were suggested.

On the topic of arms control, the point was raised that China is increasingly emerging as a somewhat equal player to the US and Russia in terms of missile defence and nuclear weapons capabilities. China is increasing its focus on research and development in missile defence, including in layered missile defence systems for purposes ranging from key point to homeland defence. It was also noted that Russia is helping China to develop early warning systems which support these efforts.

Finally, it was also said that the American development of GDA is a rich opportunity for China to monitor technical developments, and to implement lessons learned from the initiative, taking advantage of China’s industrial and engineering capability. It was mentioned in the events that if the relationship among these three major powers becomes increasingly symmetric, perhaps more opportunities could emerge for arms control, or at least cooperative threat reduction mechanisms. For example, if China develops its own missile defence network relying on a Chinese fleet of early warning satellites, that may spur mutual understanding that no countries should attack each other’s early warning satellites.

6. Recommendations

During the three webinar events certain recommendations were made to prevent or minimise the possible destabilising effects of GDA on nuclear strategic stability. This includes conducting technical, scientific studies regarding the actual capabilities of missile defence, which must inform policy. Moreover, it was said that more research is needed on the impact that different configurations of GDA may have on strategic stability.

Another recommendation focused on strengthening pre-launch notification. This would involve strengthening and universalising the Hague Code of Conduct, including by working with commercial space companies. As SBIs would need to be launched almost immediately upon detecting a plausible enemy threat, notifications could help to avoid the accidental interception of space launch vehicles or missile tests.

Additionally, states developing missile defence capabilities should be more transparent about what it is they wish to achieve in specific terms. In this respect, more transparency from the US on the rationale behind the GDA and its specific objectives, including how it relates to responsible space behaviours and nuclear strategic stability, would improve the quality of discussion and potentially assuage worst-case fears and concerns. Similarly, it was said that there needs to be better alignment between different states regarding honest threat perceptions to prevent inadvertent escalation.

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The Continued Entanglement: The Nuclear Impact on Space Governance

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Abstract

This research note argues that the regime of space governance has emerged and changed across time in part due to its close connection with strategic nuclear weapons. It charts this coexistence and entanglement across the Cold War development of space governance, the post-Cold War shift away from nuclear strategy, and the contemporary return to great power competition.

Keywords
Space law, nuclear weapons, space exploration, international law

1. Introduction

In 1953, United States President Dwight D. Eisenhower set out his Atoms for Peace plan in a speech before the United Nations General Assembly.[1] As nuclear weapons rose to prominence in the wake of World War II, the US administration sought to build a normative framework around this technology. The Atoms for Peace plan sought to establish a framing norm that nuclear technologies would be used for peaceful purposes.[2] The Soviet Union, the prime target of this plan, rejected the proposal.[3] This came in the wake of their rejection of the Baruch plan due to their resistance to verification by on-site inspection in disarmament regimes.[4] A line can be drawn from the failed proposed nuclear regime to the governance regime that would soon be established for outer space. The opening up of space was transformative in many ways, but one of the most important was the way in which it transformed the pre-existing nuclear technology.

This research note will trace the historical entanglement that space and nuclear technologies have had and bring that narrative forward to demonstrate that they are still linked in the contemporary context. This exercise will show how nuclear capabilities are still influencing how we approach the governance of space. The core claim is that nuclear capabilities historically shaped and are still shaping the rules that govern space security. This is due to the significant issues caused by the cross-domain context and the way in which space capabilities transform the strategic value of nuclear armaments. This is not to say that the two governance regimes are entangled, but rather that the infusion of nuclear technologies and space capabilities pose significant issues that must be accommodated for in the context of space governance.

This research note will first give an account of the historical linkage of the space domain to nuclear technology. It will then trace these through the post-Cold War shift and into the contemporary world. It will use this analysis to create a narrative that demonstrates the proximity of space governance to strategic restraint. It will be looking at this specifically through the lenses of both normative and deterrent structures as complimentary methods of limiting state action.

1 See "Atoms for Peace," Dwight D. Eisenhower Presidential Library (n.d.), https://www.eisenhowerlibrary.gov/research/online-documents/atoms-peace accessed 28 November 2025.

2 Dwight D. Eisenhower, "Atoms for Peace," (8 December 1953), paras. 70–71., https://voicesofdemocracy.umd.edu/eisenhower-atoms-for-peace-speech-text/ accessed 28 November 2025.

3 Leonard Weiss, "Atoms for peace," *Bulletin of the Atomic Scientists* 59, no. 6 (2003): 34–44, 40.

4 *Ibid*., 37.

2. History: Article IV and National Technical Means of Verification (NTM)

The notions of verification and peaceful purposes in the nuclear regime would be drawn forward into the space regime, and these two touchpoints will be used to frame the historical analysis deployed in this section as they both became important in the initial normative development surrounding space.

After the US attempt to effectuate disarmament through a verifiable regime failed, the Eisenhower Administration sought to use the Atoms for Peace plan to create a normative framing around nuclear technology. Space presented a second opportunity to curb the potential use of nuclear weapons. In 1949 Vannevar Bush[5] wrote that there is "less reason to be terrified by the thought of the A-bomb delivered by fleets of bombers" in light of current defense technology.[6] Bush's in-depth analysis of the state of military technology at the time reveals that a nuclear weapon, while massively destructive, still needed to get to its target, so it was only as good as its delivery system. Delivery by air, which had been the method for the two atom bombs that closed out World War II, was highly susceptible to interception considering contemporary air defense technologies. Space launch technology would change the potential for the delivery of these weapons, upsetting any stability premised on delivery by air. This section suggests that the initial normative order surrounding space was an attempt to govern the potential delivery system as an indirect way of governing the weapon itself. Interestingly, with space the notion of normative framing of peaceful purposes would come first as a way to preserve the potential for verification that space presented.

A. Peaceful Purposes

Though peaceful purposes were rejected in the nuclear context, the idea would be reheated for the space context.[7] Framing space as a domain of peaceful action was core to the United States' early strategy at establishing a normative construct for the domain, and this is directly linked to an aspiration of reducing the nuclear threat that space launch technology enhanced. In 1955, the United States announced its plans to launch a scientific

5 Vannevar Bush was the head of the U.S. Office of Scientific Research and Development during World War II and was a key player in the development of the Manhattan Project. 'Vannevar Bush' (*The Manhattan Project: An Interactive History*, n.d.), https://www.osti.gov/opennet/manhattan-project-history/People/Administrators/vannevar-bush.html accessed 1 December 2025.

6 Vannevar Bush, *Modern Arms & Free Men* (MIT Press 1968), 100–101.

7 The notion of peaceful purposes is found in a number of areas of international law and has variable meaning across its applications. It would become part of the nuclear regime with the *Treaty on the Non-Proliferation of Nuclear Weapons* (adopted 1 July 1968, entered into force 5 March 1970) 729 UNTS 161: Preamble & Article III.

satellite for the International Geophysical Year (IGY).[8] The announcement emphasized the scientific purposes of this launch as a framing for space activities. This framing was then taken up by the Soviet Union as it followed suit and made a similar announcement, also with science as the emphasis, several days later.[9] To be clear, there was never the illusion that these technologies would not be used for military applications, but the pre-emptive framing in the context of science and peace may have had an ameliorating effect on future discussions concerning governance. One can imagine that if these states had both made announcements that they were launching spacecraft for military purposes, this would have foreclosed a number of discussions. The IGY announcements helped to ensure that the initial forays into space were not shows of force but rather displays of scientific prowess. They were at once competitive (i.e. between the superpowers) and cooperative (i.e. as part of the global IGY).

The United States' emphasis on science for its first launch was followed through with its insistence that its first launch would not be by the military.[10] In a meeting in the White House four days after the launch of Sputnik, US Secretary of Defense Donald A. Quarles told President Eisenhower that the Army could likely have "orbited a satellite a year or more ago," but there was a policy decision to wait for a civil launch "to stress the peaceful nature of the effort."[11] The United States' commitment to peaceful purposes as framing norm for space went so far as to include this framing in the national law establishing the National Aeronautics and Space Administration (NASA), its civil scientific space program. This 1958 law states that "Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind."[12] This normative framing was then infused into the international framework through the United Nations General Assembly and the Space Treaty regime. It is found in United Nations General Assembly (UNGA) Resolution 1348, which is the first UNGA resolution and which established the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS), though only as an ad hoc committee at the time.[13] The framing is used

8 NASA, 'International GeoPhysical Year--US Announcement' (*National Aeronautics and Space Administration*, 2 February 2005), https://www.nasa.gov/history/sputnik/usannounce.html accessed 1 December 2025.
9 David SF Portree, *NASA's Origins and the Dawn of the Space Age* (NASA 1998), https://www.nasa.gov/history/monograph10/korspace.html accessed 1 December 2025.
10 For a fuller account see PJ Blount, 'Peaceful Purposes for the Benefit of All Mankind: The Ethical Foundation of Space Security' in Cassandra Steer and Matthew Hersch (eds), *War and Peace in Outer Space* (Oxford University Press 2021).
11 Memorandum of Conference with the President (8 October 1957), https://www.eisenhowerlibrary.gov/sites/default/files/research/online-documents/sputnik/10-9-57-early-memo.pdf accessed 30 November 2025 [hereinafter Quarles Memo].
12 National Aeronautics and Space Act, Pub. Law 85–568 (1958), sec. 102.
13 United Nations General Assembly, Resolution 1348(XIII): Question of the Peaceful Use of Outer Space (13 December 1958).

consistently in UNGA resolutions and is a framing principle in the preambles of all the space treaties.[14]

The normative content of peaceful purposes was interpreted to mean nonmilitary for a brief time, but this meaning soon eroded to some form of nonaggression, reflecting a baseline from the UN Charter.[15] The goal was likely never to demilitarize space, as both superpowers were already pursuing military applications, but instead to open up space for normative development that could produce stability instead of conflict. If space launch was the key enabler of the nuclear threat, then opening up the opportunity for discourse and negotiation through a normative framing of peaceful purposes was key. The weapon itself resisted governance, but the system and domain of delivery seemingly did not. The peaceful purposes-framing helped to slow these states in their deployment of such technologies by pushing them in a different direction. The outcome being the public-facing civil space race between the United States and the USSR.

A clear outcome of this are also the two limitations on the use of nuclear weapons in the space domain. The first of these is the Limited Test Ban Treaty which bans the testing and detonation of nuclear weapons in outer space.[16] Early on in the space age both the United States and the Soviet Union detonated nuclear weapons in space. The destructiveness of these tests and the rising importance of human space exploration led states to ban these types of explosions.[17] The treaty did not need verification as it was assumed that the forbidden detonations would be obvious and open, making the treaty self-verifying.

The second outcome is Article IV of the Outer Space Treaty, which bans the placement of nuclear weapons in orbit. This is a fascinating treaty provision in that it is a substantive arms limitation that is not matched with verification measures. The provision is based on the significant risk of instability connected to the placement of nuclear weapons in orbit. Such placement reduces the attack time to such a minimum that it would be nearly impossible to defend against. A first deployer, then, would be incentivized to strike before its adversary could deploy a similar capability. Whereas nuclear ICBMs are an effective deterrent against attack, nuclear weapons in orbit around the Earth did not have the same

14 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (27 January 1967) 18 U.S.T. 2410, 610 U.N.T.S. 205; Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (1968) 19 UST 7570, 672 UNTS 119, 7 ILM 149; Convention on International Liability for Damage Caused by Space Objects (29 March 1972) 961 UNTS 187; Convention on Registration of Objects Launched into Outer Space (1976) 1023 UNTS 15; and Agreement governing the Activities of States on the Moon and Other Celestial Bodies (Dec 18, 1979) 1363 UNTS 3.

15 PJ Blount, 'The Shifting Sands of Space Security: The Politics and Law of the Peaceful Uses of Outer Space' (2019), *Indonesian Journal of International Law* 17(1), 4–5.

16 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space, and under Water (10 October 1963).

17 For a detailed discussion of this see James Clay Moltz, *The Politics of Space Security: Strategic Restraint and the Pursuit of National Interests* (Stanford Security Studies 2008), 42–66.

deterrent effect since they incentivized offensive action over strategic defenses. The two superpowers at the time were able to agree that this should be avoided, and Article IV was deployed as law without verification. Arguably such an extraordinary provision could not have been achieved outside of the peaceful purposes-framing.

B. Verification

The Soviet Union's rejection of on-site inspections made any sort of arms limitations talks untenable because there was no means to verify any agreed upon limitations. US intelligence on Soviet armaments at the time was based primarily on highly illegal overflights by the high altitude U2, which would end in 1960 with the shooting down of one of these aircraft.[18] The verification problem would be solved, in part, with the launch of Sputnik, which established free overflight of another state's territory. In the same White House meeting in the aftermath of the launch of Sputnik referenced above, Secretary Quarles told President Eisenhower "that the Russians have in fact done us a good turn, unintentionally, in establishing the concept of the freedom of international space."[19] What Quarles meant is that by overflying states around the world without those same states objecting, Sputnik showed that orbital movement did not violate the sovereignty of others in the same way that a reconnaissance flight violated sovereign air space. Shortly after this exchange, President Eisenhower inquired about the possibility of the development of a reconnaissance vehicle to take advantage of this vantage point.[20]

Whereas space launch capability was a key enabler of nuclear technologies by providing a system of delivery, the orbital movement it enabled was an antidote for this by providing the possibility of verification as it allowed observation without the need to enter the sovereign territory of the observed state. Both the US and the Soviet Union began to pursue remote sensing capabilities in the early 1960s to get a bird's eye view of each other's military deployments and infrastructure.

Once attained by both states, remote sensing capabilities gave the two nuclear powers the opening needed to engage in arms limitations talks connected to their nuclear arsenals. This would lead to the collection of bilateral treaties, such as the Anti-Ballistic Missiles Treaty (ABM Treaty), that served to structure the strategic stability between the US and the USSR.[21] These bilateral agreements incorporated the notion of National Technical Means

18 'U-2 Overflights and the Capture of Francis Gary Powers, 1960' (*Milestones in the History of U.S. Foreign Relations*, n.d.), https://history.state.gov/milestones/1953-1960/u2-incident accessed 1 December 2025.

19 Quarles Memo, *supra* n.11.

20 Ibid.

21 Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missile Systems (3 October 1972) 23 UST 3435, TIAS No. 7503 [hereinafter ABM Treaty].

of Verification (NTM) as a way to include verification without revealing the specificities of state capabilities in detail. Though not exclusively, NTM were primarily constituted by remote sensing satellites.[22] The ABM Treaty is indicative. It adopts NTM as the means of verification and then obliges that parties do not interfere with the others' NTM.[23] This same pattern would be repeated in a number of these bilateral agreements. The NTM provisions served as a significant guarantor of security in space despite being only bilateral agreements. Due to the inability to be certain what capabilities were on board a given satellite platform, the states were forced to consider that any satellite in Earth orbit could have some NTM function.[24] This meant that these provisions went significantly further than intended in structuring the governance of outer space. In the Cold War context, the alignment of much of the world was structured around the binary of the superpowers and the risk of catastrophic conflict, meaning that multilateral extension of such norms was not necessary.

3. The Post-Cold War Shift

At the end of the Cold War there was a significant shift in the structure of global politics and in international peace and security. As the world transitioned from bipolarity into a moment of unipolarity and then settled into multipolarity, the way in which states approached security issues changed dramatically. In the immediate aftermath of the Cold War the enmity between the US and the former Soviet states seemed to dissolve almost immediately as the West pursued projects for democratization in these states. While nuclear threats were still a significant concern for states, in the post-Cold War period the nuclear threat faded into the background and terrorism and the threat of the non-state actor rose to prominence. This change was predicted by some commentators,[25] but it was truly solidified by the 9-11 attacks on the United States and the subsequent initiation of the US War on Terror.[26]

The shift in focus in international security created significant changes in how states approach their security stances during this time. The nuclear threat itself changed from

22 Jimmy Carter, Remarks at the Congressional Space Medal of Honor Awards Ceremony. Kennedy Space Center Florida (October 1, 1978).

23 ABM Treaty, Art. XII.

24 Roger G. Harrison, *Space and Verification, Volume. 1: Policy Implications* (Colorado: United States Air Force Academy, Eisenhower Center for Space and Defense Studies), 9.

25 For example, Alexandre de Marenches & David Andelman, *The Fourth World War: Diplomacy and Espionage in the Age of Terrorism* (Morrow 1992) and Samuel P. Huntington, 'The Clash of Civilizations?' (Summer 1993), *Foreign Affairs* 72(3), 22–49.

26 Ivo H. Daalder and James M. Lindsay, 'Nasty, Brutish and Long: America's War on Terrorism,' Brookings Institute (1 December 2001), https://www.brookings.edu/articles/nasty-brutish-and-long-americas-war-on-terrorism/ accessed 1 December 2025.

a strategic threat wielded by states to one of the dirty bomb in the suitcase delivered to a city center by a terrorist.[27] One of the impacts of this shift was a retraction from the bilateral agreements that underpinned the nuclear arms limitations between Russia (as the primary successor to the Soviet Union) and the United States. The 2001 US withdrawal from the ABM treaty is indicative of this. The withdrawal, under the George W. Bush Administration, was clearly premised on the notion that the strategic threat had waned and a new non-state threat had emerged. In his speech on the withdrawal President Bush stated that "the greatest threats to both our countries come not from each other, or other big powers in the world, but from terrorists who strike without warning, or rogue states who seek weapons of mass destruction."[28]

The net effect is that the protections granted by the NTM provisions have eroded significantly as these bilateral agreements have fallen to the wayside. While these are only bilateral agreements and thus binding on a limited number of parties, the changed context can be felt in the uptick in state demonstrations of capabilities to interfere with space activities. Most notable are the four kinetic anti-satellite weapons (ASAT) tests since 2007 by China (2007),[29] the United States (2008),[30] India (2019),[31] and Russia (2020).[32] In addition to these tests by the four major spacefaring nations, other states have begun to develop a variety of documented counterspace capabilities.[33] The foundation for this shift in the United States was established in the 2001 Rumsfeld Report, which explicitly called for the development of offensive space weapons.[34] Published just 8 months before the 9-11 attacks, the Rumsfeld Report signalled a change that, in the short term, would be dampened by the shift to terrorism and its intelligence driven security paradigm, which is significantly reliant on space assets. The same US administration would adopt a policy opposing any new restrictive rules in space and deadlock the Conference on Disarmament over the same

27 '"Suitcase Nukes:" A Reassessment,' James Martin Center for Nonproliferation Studies (23 September 2004), https://nonproliferation.org/suitcase-nukes-a-reassessment/ accessed 1 December 2025.

28 'U.S. Withdrawal from the ABM Treaty: President Bush's Remarks and U.S. Diplomatic Notes,' Arms Control Association (n.d.), https://www.armscontrol.org/act/2002-01/us-withdrawal-abm-treaty-president-bushs-remarks-and-us-diplomatic-notes accessed 1 December 2025.

29 'China confirms satellite downed,' BBC (23 January 2007), http://news.bbc.co.uk/2/hi/asia-pacific/6289519.stm accessed 1 December 2025.

30 Dwayne Day, 'Burning Frost, the View from the Ground: Shooting down a Spy Satellite in 2008,' *The Space Review* (21 June 2021), https://www.thespacereview.com/article/4198/1 accessed 1 December 2025.

31 Ajey Lele, 'Indian ASAT: Mission Shakti Should Be a Comma, Not a Full Stop,' *The Space Review* (27 March 2023), https://www.thespacereview.com/article/4556/1 accessed 1 December 2025.

32 Fabian Hoffmann, 'Russia Conducts Direct-Ascent Anti-Satellite Test,' International Institute of Strategic Studies (25 November 2021), https://www.iiss.org/online-analysis/online-analysis/2021/11/russia-conducts-direct-ascent-anti-satellite-test/ accessed 1 December 2025.

33 See Victoria Samson and Laetitia Cesari, eds., *2025 Global Counterspace Capabilities Report* (Secure World Foundation 2025).

34 Donald Rumsfeld and others, 'Report of the Commission to Assess United States National Security Space Management and Organization' (2001), 70.

issue.[35] As states shifted their focus to the threat of non-state actors, the rules connected to the space-nuclear nexus were neglected at best and actively dismantled at worst.

The transition from the Cold War security paradigm based on nuclear parity to the multipolar terrorist threat coincided with what is arguably an era of stagnation and erosion in international space law making. As the nuclear threat was being reimagined as one delivered by an individual dragging a wheelie case on the metro rather than a volley of missiles over the North Pole, the norms connected to the strategic threat became less important to states in this changing context.[36] Norm-building stagnated as states sought to adapt to the new threats that had come to center stage, and the normative structures that emerged from the Cold War were perceived to be a blockade to dealing with this new threat.

4. Great Power Competition and Space Deterrence

The stagnation and in some respects outright opposition to enhancing the normative order bore the fruits of the contemporary approach to space security. As terrorism receded into the greater milieu of international security, commentators began to discuss the return to great power competition.[37] This shift focuses on the return of superpower politics with a focus on China, Russia, and the United States. This superpower-based perspective brought strategic nuclear threat back into the fore as a core international security challenge. This can be seen in the uncertainty that Russia has sought to infuse into its own nuclear stance in the wake of its invasion of Ukraine[38] – specifically, its withdrawal from the Limited Test Ban Treaty.[39] Similarly, President Trump recently suggested that the United States

35 U.S. National Space Policy (31 August 2006), Sec. 2,, https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/national-space-policy-2006.pdf accessed 1 December 2025. See also Rebecca Johnson, 'Conference Remains Deadlocked after First Part of 2002 Session' (May–June 2002), *Disarmament Diplomacy* 64.

36 This is evident in the close cooperation on counterterrorism between Russia and the United States after the 9-11 attacks. See Philip H. Gordon, 'Bush-Putin: The End of the End of the Cold War,' Brookings Institute (November 13, 2001), https://www.brookings.edu/articles/bush-putin-the-end-of-the-end-of-the-cold-war/ accessed 13 December 2025.

37 Jonathan M. DiCicco and Tudor A. Onea, 'Great-Power Competition', *Oxford Research Encyclopedia of International Studies* (2023), https://oxfordre.com/internationalstudies/display/10.1093/acrefore/9780190846626.001.0001/acrefore-9780190846626-e-756 accessed 1 December 2025.

38 Katarzyna Zysk, 'Russia's Nuclear Doctrine Amendments: Scare Tactics or Real Shift?', *United States Institute of Peace* (29 January 2025), https://www.usip.org/publications/2025/01/russias-nuclear-doctrine-amendments-scare-tactics-or-real-shift accessed 1 December 2025.

39 Andrew Osborn, 'Putin Revokes Russian Ratification of Global Nuclear Test Ban Treaty,' *Reuters* (2 November 2023), https://www.reuters.com/world/europe/putin-revokes-russias-ratification-nuclear-test-ban-treaty-2023-11-02/ accessed 1 December 2025.

could resume nuclear weapons testing amongst numerous provocative statements about the United States' nuclear posture.[40]

This shift can be felt in space in the actions of these three competing great powers. China has reportedly deployed a fractional orbital bombardment system (FOBS) in the form of some sort of hypersonic weapon.[41] Russia has been accused of deploying nuclear ASAT capability.[42] The United States has announced its planned deployment of Golden Dome, a space-based missile defense system.[43] The return to these strategic technologies as the center-piece of state power has been felt in the system of space governance as well.

The degradation of the space normative regime that resulted from its sidelining allowed for the previously voluntary moratorium on ASAT testing to be brought to an end through the series of tests by China, the United States, India, and Russia. This was complemented by a shift towards more military-dominated stances as nations sought to more overtly define their space capabilities as seen in the trend toward the establishment of space forces. At the same time, there has been some return to a normative discourse around these technologies, a stalemated one, but a discourse nevertheless. One way to look at this is a divide on the form of the security arrangement. On one side is China and Russia with their desire for a legally binding arrangement represented by the introduction of the draft Prevention of the Placement of Weapons in Space Treaty (PPWT) in the deadlocked Conference on Disarmament.[44] Standing in opposition is the Western-led push for norms of responsible behavior, embodied in the UK's UN General Assembly resolution.[45] The opposition of these two stances is significantly centered on what form any adoption of rules should take. While both contingents are putting forward proposals, these proposals for the most part remain accepted only within their respective blocks.

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40 Georgia Cole, 'Russia and the US Put Nuclear Testing Back on the Table. Is Time Running out for Arms Control?', *Chatham House* (3 May 2024), https://www.chathamhouse.org/2025/11/russia-and-us-put-nuclear-testing-back-table-time-running-out-arms-control accessed 1 December 2025.

41 Dawn Stover, 'Orbital Hypersonic Delivery Systems Threaten Strategic Stability,' *Bulletin of the Atomic Scientists* (13 June 2023), https://thebulletin.org/2023/06/orbital-hypersonic-delivery-systems-threaten-strategic-stability/ accessed 1 December 2025.

42 Christopher J Borgen, 'Russia's Alleged Nuclear Anti-Satellite Weapon: International Law and Political Rhetoric,' *Lieber Institute West Point* (31 July 2024), https://lieber.westpoint.edu/russias-nuclear-anti-satellite-weapon-international-law/ accessed 1 December 2025.

43 Mike Stone and others, 'Trump Selects $175 Billion Golden Dome Defense Shield Design, Appoints Leader,' *Reuters* (21 May 2025), https://www.reuters.com/world/us/trump-make-golden-dome-announcement-tuesday-us-official-says-2025-05-20/ accessed 1 December 2025.

44 'Letter Dated 10 June 2014 from the Permanent Representative of the Russian Federation and the Permanent Representative of China to the Conference on Disarmament addressed to the Acting Secretary-General of the Conference Transmitting the Updated Russian and Chinese Texts of the Draft Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force Against Outer Space Objects (PPWT) introduced by the Russian Federation and China', UN Doc CD/1985 (12 June 2014).

45 See PJ Blount, 'The Future of PAROS: Building a Framework to Reduce Strategic Risk,' (2023) XLVII *Annals of Air and Space Law* 93.

A second way to view this is to see it from a perspective of strategy. The PPWT does not make kinetic surface-to-space missiles illegal, to which the United States objects.[46] However, China and Russia, the sponsoring states, are not contemplating a ground war in the US. They are contemplating US action inside of their claimed borders. The communications and intelligence that a forward deployed US military requires from the space segment is very vulnerable, and they can supply their military the same with ground infrastructure if needed. It does, however, seek to outlaw orbital weapons, which the US Golden Dome project would fall into. The US desire for missile defense is connected directly to its need to fortify itself from strategic arms while at the same time wielding them as a symbol of might in its global reach. The Golden Dome system could be vulnerable to kinetic ASATs depending on the orbital specifications.

The turn to great power competition has put strategic arms back in the forefront of international security, so the return to discourse at the normative level is not surprising. However, this is coming at a time when these same superpowers are challenging the bounds of international law and eroding core concepts. China's claims to the South China Sea,[47] Russia's invasion of Ukraine,[48] and the United States' undermining of international institutions[49] all reflect aspects of a core problem with international law. Legal systems depend on the governed society's belief in them. Powerful actors have the ability to demonstrate their disbelief in the system. Thus, the return to the strategic state coupled with vastly changed technologies opens significant uncertainty as states try to reconfigure their deterrence posture among these changing circumstances. Nevertheless, while states figure out how to maintain stability, there is still significant risk. When the law runs out, deterrence takes over, but if the deterrent lines themselves are blurry, then deterrence is uncertain. Cyber is a key example of this. Just as individuals in the modern world, states may run the risk of being "terminally online."

46 'Note Verbale dated 2 September 2014 from the Delegation of the United States of America to the Conference on Disarmament addressed to the Acting Secretary-General of the Conference Transmitting the United States of America Analysis of the 2014 Russian-Chinese draft treaty on the prevention of the placement of weapons in outer space, the threat or use of force against outer space objects', UN Doc CD/1998 (3 September 2014).

47 Krista E. Wiegand, 'International Law and Conflict Disputes: The Case of the South China Sea,' *Perry World House* (19 May 2025), https://perryworldhouse.upenn.edu/news-and-insight/international-law-and-conflict-disputes-the-case-of-the-south-china-sea/ accessed 1 December 2025.

48 John B Belinger, 'How Russia's Invasion of Ukraine Violates International Law,' *Council on Foreign Relations* (28 February 2022), https://www.cfr.org/article/how-russias-invasion-ukraine-violates-international-law accessed 1 December 2025.

49 White House, 'Withdrawing the United States from and Ending Funding to Certain United Nations Organizations and Reviewing United States Support to All International Organizations,' *The White House* (5 February 2025), https://www.whitehouse.gov/presidential-actions/2025/02/withdrawing-the-united-states-from-and-ending-funding-to-certain-united-nations-organizations-and-reviewing-united-states-support-to-all-international-organizations/ accessed 1 December 2025.

This has implications for both nuclear deterrence and space governance principles. This is indicated by the three incidents referenced above. The Chinese FOBS system is a throwback to a Soviet tested system from the 1970s.[50] While it was agreed that this technology was legal at the time, the Soviets never made it an operationally deployed system. The Chinese technology adds a twist by bringing the payload in on a "hypersonic missile."[51] This would allow the craft to deorbit a state's radar fence and then fly into an adversary's territory at a low altitude. This changes the nature of FOBS as a warhead delivery system, challenging the settled structure of deterrence. If Russia is thinking of deploying a nuclear anti-satellite weapon, this challenges the rules established in space law that impact nuclear deterrence. Russia's withdrawal from the Limited Test Ban Treaty means that it has withdrawn from the central rule banning the detonation of a nuclear device in space. If such a device were orbital it would violate the core nuclear limitation in Article IV. While Golden Dome would certainly add to the United States' overall deterrence posture, it would upend the decades-long structure in which states – except for very few occasions – have refrained from actually openly orbiting a clear weapon in the space domain. Though Golden Dome would be a significant undertaking in both development and costs, constellation technology and launch technology have changed significantly since the Reagan Administration looked at Brilliant Pebbles as part of the Strategic Defense Initiative (SDI) in the 1980s.[52] In their nuclear posturing, these states are explicitly flexing space technology and disrupting both the normative and deterrent realms.

This could not be more clearly stated than the adoption of the notion of "space as a warfighting domain."[53] This rhetorical and semi-policy device legitimates military exploitation of space and in space in a seemingly wider array of technologies beyond those that are only supportive of terrestrial military action. The past stability in the space domain resulted from its perceived technological limitations and the legitimacy of the intertwined normative structure. As these capabilities have changed, so too has the normative structure. Nevertheless, at the core of much of this process is space's ongoing entanglement with the strategic nuclear activities of states.

50 See R.L. Garthoff, 'Banning the bomb in outer space' (1980), *International Security*, 5(3), 25–40.
51 Stover, 'Orbital Hypersonic Systems'.
52 See David Wright et al., *The Physics of Space Security* (American Academy of Arts and Sciences, 2005).
53 Everett C. Dolman, 'Space Is a Warfighting Domain' (2022), *Æther: A Journal of Strategic Airpower & Spacepower* 1, 82.

5. Conclusion

Space has always been intertwined with nuclear technologies. Indeed, the normative regime for space certainly impacts nuclear stability. It remains uncertain how far these structures will be eroded in the current geopolitical context and what chance there will be for re-establishing them. The current trajectory is not necessarily a rosy one. While space war is not "inevitable," the conditions that keep it that way can change dramatically. Artificial intelligence technologies are soon to be, if they are not already, part of the mix of strategic technologies complicating the uncertainty of states as they seek stability and/or dominance.

While changing technology often challenges existing normative structures, this is not the only source of normative decay. The de-legitimation of international law and international institutions is also stressing the system. The primary agents within the tripolar politics at play are undermining the system of which they are the architects and – as permanent members of the Security Council – in which they hold significant power. Space is not the only component in these changing circumstances, but it is a significant one.

We should, however, remember that space war in and of itself is not the danger. It is its deep connection with nuclear technologies that infuses the threat. It leads one to question whether a space war may necessarily be a nuclear war. One could potentially see a state detonating a nuclear device in orbit as the first wartime nuclear usage since 1945. This would be a dramatic occurrence and challenge the traditional reluctance to deploy these weapons due to the extreme cost in human life. Detonation in space would impact human life, but not directly (outside of a handful of astronauts). Such an act would rewrite our understanding of norms and deterrence in nuclear and space domains and risk opening up a new era of nuclear brinkmanship.

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Targeting a Satellite: Electronic Warfare and International Humanitarian Law

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Abstract

Satellite signal interference is a core component of electronic warfare. It has become a daily phenomenon in today's conflict zones, considering that most military systems are electric and thereby potential targets of electronic warfare. However, electronic warfare is rather indiscriminate. Its effects are often felt by civilians in third countries, with increasing risks to civil aviation, navigation, telecommunications and humanitarian operations. International humanitarian law sets several requirements for targeting during electronic warfare operations. Yet many legal ambiguities remain, hampering not only the full protection afforded under international humanitarian law but also blurring the threshold of armed conflict. In today's context of erosion of international humanitarian law, there is a pressing need to co-operate on a wide front and inclusively, in order to strengthen and clarify norms on electronic warfare and, thereby, acceptable space behaviors.

Keywords

Electronic warfare, international humanitarian law, targeting, obligation to discriminate

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1. Introduction

The erosion of rules on the use of armed force discussed in the introductory research note to this special issue led to several legal questions in the realm of the law of armed conflict. This follow-up research note intends to discuss more in depth some of those questions when targeting a satellite with the purpose of signal interference or jamming.

There are several Global Navigation Satellite Systems (GNSS) in operation, including China's BeiDou Navigation Satellite System (BDS), Europe's Galileo, Russia's Globalnaja Navigatsionnaja Sputnikovaja Sistema (GLONASS), the USA's Global Positioning System (GPS), India's Regional Navigation Satellite System (IRNSS), and Japan's Quasi-Zenith Satellite System (QZSS). Satellites transmit precise navigation, positioning, and timing information, making them vital for civilian and humanitarian purposes worldwide.

The concept of GNSS interference has been a core component of electronic warfare (EW) for decades. Interference with a GNSS is relatively easy. There are four types of counter-space capabilities: kinetic physical, non-kinetic physical, electronic, and cyber. Kinetic physical operations and capabilities cause permanent and irreversible destruction of a satellite or ground support infrastructure through force of impact by an object or detonation of a warhead. These technologies include direct-ascent anti-satellite (ASAT) missiles and co-orbital systems. ASATs are essentially meant to destroy hostile satellites through the sheer use of high speeds and kinetic energy on impact.[1] Co-orbital systems are satellites placed on similar orbits and can be directed to intercept or interfere with other satellites through close orbital rendezvous operations.

Non-kinetic physical operations involve the use of technology to interfere with or damage space systems without physical contact. Technologies in this category include electromagnetic pulses and directed energy (laser beams or microwave bombardments). A third category is the focus of this note, i.e. electronic warfare (EW) capabilities, using radiofrequency to interfere with or to jam communications to or from satellites but without causing permanent physical damage. The last category is cyber warfare technologies which use software and network techniques to compromise, control, interfere with or destroy computer systems linked to satellite operations. It is important to note that the use of electronic and cyber means have become preferred methods of attack since their use can be plausibly denied. These counter-space capabilities can be used to deny, degrade, disrupt, or destroy space systems. What is more, the requisite technology for electronic and cyber warfare is becoming ubiquitous and diverse, accessible even to non-State actors.[2]

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1 Kuplic, Blair Stephenson. 2014. "The Weaponization of Outer Space: Preventing an Extraterrestrial Arms Race." 39 *N.C.J. INT'L L. 1123,* https://scholarship.law.unc.edu/cgi/viewcontent.cgi?article=2011&context=ncilj.

2 Rajagopalan, Rajesvari Pillai. 2019. "Electronic and Cyber Warfare in Outer Space*." Space Dossier 3,* UNIDIR https://unidir.org/wp-content/uploads/2023/05/electronic-and-cyber-warfare-in-outer-space-en-784.pdf.

During the Cold War, outer space utilization was primarily for strategic operations, such as strategic intelligence gathering, nuclear attack early warning and executing arms control agreements. Today, space also has a far more important role to play in conventional military operations.[3] What's more, offensive and defensive counter-space operations today would impact not just the security sector but also social and economic sectors across continents because of large-scale civilian dependency on space-based applications. The fact that space is vital to both civilian and military operations increase the danger of inadvertent escalation and conflict if there is, for instance, a disruption or denial of service during a period of heightened tensions. Also, there appears to be a greater willingness to engage in the development and possible use of new offensive counter-space capabilities than those available during the Cold War era. All these developments highlight also the need for clear rules that create the normative context for permissible space behaviors.

2. Defining the context

Electronic attacks are usually done by targeting signals, either through jamming or spoofing. Jamming is a kind of electronic attack that interferes with radiofrequency communications by creating noise in the same frequency band and within the field of view of the antenna of the satellite or receiver it is targeting, thus disrupting communications. Jamming causes temporary disturbance and disruption and is thus reversible. Once the jammer is turned off, the communication can return to normal. Spoofing is another form of electronic attack where a fake signal is produced by the attacker's device. In this case, if the spoofing attack targets the downlink data from a satellite to the ground, it could end up feeding false or corrupt data into the ground receiver system. Hijacking a satellite command and control and feeding it with such data are well-known means of disruption.[4] Satellites are controlled from ground stations through electronic signals, and they pass their data back to ground stations, so attacking those uplink and downlink linkages electronically can render satellites ineffective.[5]

With a satellite's signal interference, we enter the realm of EW, which involves the exploitation of the electromagnetic spectrum (EMS) to disrupt, disable or destroy an adversary's ability to use the EMS. The EMS spans a wide range of wavelengths which provides maneuver space consisting of all frequencies of electromagnetic radiation,

3 *Ibid.* 3.

4 Poirier, Clémence. 2025. "Electronic and Cyber Operations Against Space Systems". *Policy Perspectives* Vol. 13/1, https://css.ethz.ch/en/center/CSS-news/2025/01/electronic-and-cyber-operations-against-space-systems.html.

5 Harrison, Todd, Johnson, Kaitlyn and Roberts, Thomas G. 2019. *Space Threat Assessment 2019.* Center for International and Strategic Studies, https://aerospace.csis.org/wp-content/uploads/2019/04/SpaceThreatAssessment2019-compressed.pdf.

including radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, x-rays and gamma rays.[6] For instance, military operators use a host of equipment including receivers, transmitters, and satellites to communicate within the EMS operating environment, thus enabling the "command and control" warfighting function in military operations.[7] In fact, EW is no new phenomenon on the battlefield. To the contrary, different types of activities in the electromagnetic spectrum have been an integral part of warfare and other military activities since the early part of the 20th century – first as a means of intercepting enemy communication, later also in the shape of offensive and defensive interference with different types of weapons, communication and positioning systems, often in support of kinetic operations.[8]

Technological development has led to a situation where most military systems on the battlefield are electric and thereby potential targets of electronic warfare. The ongoing conflict in Ukraine serves as an illustration of the prominent – albeit in many cases invisible – role of EW. Both sides of the conflict have used EW for various purposes including targeted information campaigns against enemy soldiers and spoofing and jamming of enemy weapons systems.[9] Given the key role communications equipment and sensors play in military operations, it is unsurprising that electronic warfare is an important aspect of joint military operations for purposes of interference with an adversary's sensing, communication, and navigation capabilities.[10]

The ITU (International Telecommunications Union) Radiocommunication Bureau has noted rising electromagnetic interference since 2019 and previously warned about risks to global navigation services in 2022.[11] Russian EW operations such as jamming and spoofing have been interfering with non-military activities in northern Norway and in Finland even before ITU's recent reports. For instance, in 2017 Russia's EW interfered with NATO exercises in the region (Trident Juncture).[12] In this case, the EW signal emitted by Russia also served as 'signaling' to NATO its discontent with the large-scale exercise taking place near the Kola Peninsula – home to Russia's Northern Fleet and other strategic units.[13] Nowadays, such electromagnetic interference has also become a daily occurrence

6 Lawless, Robert and Nasu, Hitoshi. 2024. "Electronic warfare and the law of armed conflict". *Articles of War.* Lieber Institute, West Point, https://lieber.westpoint.edu/electronic-warfare-law-armed-conflict-2/.

7 *Ibid.*

8 Graff, Ulrik and Iben, Yde. 2023. "Elektronisk krigsførelse i folkeretligt perspektiv". University of Copenhagen, iCourts, https://jura.ku.dk/icourts/research/intermil/legal-aspects-of-electronic-warfare/.

9 *Ibid.*

10 Lawless and Nasu, footnote 6.

11 Poirier, footnote 4.

12 Harvey, James. 2025. "The Russo-Ukrainian war's expansion into the High North poses electronic warfare challenges for NATO". *The Barents Observer,* https://www.thebarentsobserver.com/opinion/the-russoukrainian-wars-expansion-into-the-high-north-poses-electronic-warfare-challenges-for-nato/431197.

13 *Ibid.*

in northeastern Europe. From the airport of Gdansk through the busy shipping lanes of the Baltic Sea and all the way to the airspace of Estonia and Finland, these interferences have been recorded almost daily since Russia's full-scale invasion of Ukraine in February 2022.[14] Recently, civilian aviation, satellite navigation and other GPS users in Norway's East Finnmark region have been particularly affected by Russian EW activities.[15] Russia's increased EW activity in the region since late 2024 seems to be a response to Ukrainian long-range drone attacks on the strategic weaponry Russia has based in the Kola peninsula.[16]

In terms of international humanitarian law (IHL), military objectives of the opponent (like the Ukrainian drones) are legitimate targets in armed conflict. However, non-belligerents also suffer from Russian EW activities. From the point of view of third states affected, Höller's short article questioning the official narrative of regional states regarding Russia's EW operations as hybrid warfare is interesting.[17] According to Höller, the official narrative regarding Russia's EW operations in the Baltic might not count as hybrid warfare, due to lack of intention to harm. Accordingly, the interference over the Baltic Sea and in neighboring NATO states could be largely collateral, and not the point of the operation itself.[18] Considering that the obligation of distinction between military and civilians is a core rule of IHL, Russian EW operations pose interesting challenges from the point of view of targeting, attack, and its intended or foreseeable consequences, which shall all be discussed below.

3. International humanitarian law and targeting

3.1 Applicable rules

As with all military operations, the use of EW capabilities during armed conflict must comply with the law of armed conflict (*jus in bello*). As the law of armed conflict is framed in terms of people and objects, any analysis of legal requirements regarding military operations in the EMS sphere must appreciate the extent to which such operations impact people and objects.[19]

14 Höller, Linus. 2025. "Researchers home in on origins of Russia's Baltic GPS jamming". *Defense News Europe,* https://www.defensenews.com/global/europe/2025/07/02/researchers-home-in-on-origins-of-russias-baltic-gps-jamming/.

15 Harvey, footnote 14.

16 Staalesen, Atle. 2024. "Governor: Murmansk is under drone attack". The Barents Observer, https://www.thebarentsobserver.com/news/governor-murmansk-is-under-drone-attack/102409; Nilsen, Thomas. 2025. "Successful and devastating: Massive drone attacks on Olenya airbase". *The Barents Observer*, Successful and devastating: https://www.thebarentsobserver.com/security/successful-and-devastating-massiv-drone-attacks-on-olenya-airbasenbsp/430777Massiv drone attacks on Olenya airbase.

17 Höller, footnote 14.

18 *Ibid.*

19 Lawless and Nasu, footnote 6.

The key norms for our purposes are codified in Parts III and IV of the Additional Protocol I to the Geneva Conventions.[20] Parts III and several chapters of Part IV (Arts. 35–60) deal with the conduct of hostilities, i.e. questions which hitherto were regulated by the Hague Conventions of 1899 and 1907 and by customary international law. Their reaffirmation and development were important considering the age of the Hague conventions. Among the most important Articles are those on the protection of the civilian population against the effects of hostilities. They contain a definition of military objectives and prohibitions of attack on civilian persons and objects.

The very core norm regarding means and methods of warfare (Part III) is article 35, which stipulates as a basic rule that the right of the Parties to the conflict to choose methods or means of warfare is not unlimited. Prohibited means and methods are those which are of a nature to cause superfluous injury or unnecessary suffering, or which are intended, or may be expected, to cause widespread, long-term, and severe damage to the natural environment. As far as new weapons (their study, development, acquisition, or adoption) are concerned, Article 36 obliges the High Contracting Parties to determine whether their employment would, in some or all circumstances, be prohibited by AP I or by any other rule of international law applicable to the High Contracting Party.

In turn, the very basic rule for the protection of civilians and their distinction is confirmed by Article 48. It is the very foundation on which the codification of the laws and customs of war rests[21]: the civilian population and civilian objects must be respected and protected in armed conflict and for this they must be distinguished from combatants and military objectives.[22] This obligation of distinction applies at all times and it is noteworthy that it concerns all civilians, also civilians of the non-belligerents, like civilians of states affected in the Baltic and High North regions.

Article 49 defines 'attacks' as acts of violence against an adversary, whether in offence or defense. Civilian population is defined in Art. 50 by exclusion of members of armed forces as defined in Article 43 and Article 4 A (1)–(3) and (6) of the Third Geneva Convention. In case of doubt whether a person is civilian, that person shall be considered to be a civilian.

Article 51 specifies that the civilian population, as well as individual civilians, shall not be the object of an attack; also, acts or threats of violence with the primary purpose of spreading terror among the civilian population are prohibited. The said article further

20 Protocol Additional to the Geneva Conventions of 12 August 1949, and relating to the Protection of Victims of International Armed Conflicts (Protocol I), 8 June 1977, International Humanitarian Law Databases, https://ihl-databases.icrc.org/en/ihl-treaties/api-1977.

21 Sandoz, Yves and Swinarski, Christophe and Zimmermann, Bruno (eds.). 1986. Commentary on the Additional Protocols of 8 June 1977 to the Geneva Conventions of 12 August 1949, International Committee of the Red Cross, 1875.

22 Commentary of 1978 – Article 48 Basic Rule, International Humanitarian Law Databases, https://ihl-databases.icrc.org/en/ihl-treaties/api-1977/article-48/commentary/1987?activeTab=.

prohibits indiscriminate attacks. Points a–c are relevant from the point of view of evaluating the legality of EW operations:

a) those which are not directed at a specific military objective;
b) those which employ a method or means of combat which cannot be directed at a specific military objective; or
c) those which employ a method or means of combat the effects of which cannot be limited as required by this Additional Protocol I; and consequently, in each such case, are of a nature to strike military objectives and civilians or civilian objects without distinction.

The Article provides further examples of types of attacks that are to be considered as indiscriminate due to lack of proportionality vis-à-vis the military advantage anticipated. According to point 5.b of Article 51 (which is again relevant for EW and third states), an attack that is considered indiscriminate is:

b) an attack which may be expected to cause incidental loss of civilian life, injury to civilians, damage to civilian objects, or a combination thereof, which would be excessive in relation to the concrete and direct military advantage anticipated.

Article 52 (General protection of civilian objects) further dictates that attacks shall be limited to strictly military objectives. In so far as objects are concerned, military objectives are limited to those objects which by their nature, location, purpose or use make an effective contribution to military action and whose total or partial destruction, capture or neutralization, in the circumstances ruling at the time, offers a definite military advantage.

Article 57 includes an obligation of constant care in the conduct of military operations to spare the civilian population, civilians, and civilian objects as well as a set of precise obligations of precaution (including *incidental* loss of life and evaluation of proportionality vis-à-vis military necessity):

a) for those who plan or decide upon an attack to do everything feasible to verify that the objectives to be attacked are neither civilians nor civilian objects and are not subject to special protection but are military objectives;
b) take all feasible precautions in the choice of means and methods of attack with a view to avoiding, and in any event minimizing, incidental loss of civilian life, injury to civilians and damage to civilian objects;
c) refrain from deciding to launch any attack which may be expected to cause incidental loss of civilian life, injury to civilians, damage to civilian objects, or a combination thereof, which would be excessive in relation to the concrete and direct military advantage anticipated.

Also, the Article requires that an attack shall be cancelled or suspended if it becomes apparent that the objective is not a military one or is subject to special protection or that the attack may be expected to cause incidental loss of civilian life, injury to civilians, damage to civilian objects, or a combination thereof, which would be excessive in relation to the concrete and direct military advantage anticipated. In point 4 of the said Article, it is required that in the conduct of military operations at sea or in the air (relevant, again, for EW operations), each Party to the conflict shall, in conformity with its rights and duties under the rules of international law applicable in armed conflict, take all reasonable precautions to avoid losses of civilian lives and damage to civilian objects.

Hence, AP I sets several requirements for distinction between civilian and military, a prohibition of specific means of warfare as well as principles of proportionality and precaution for those planning and conducting attacks.

3.2 Testing the limits of Additional Protocol I – Attacks

The intriguing challenge is the application of AP I rules just described above to the realm of EW. The legal evaluation of EW under AP I is related to the concept of attack and its threshold, whereas operations below such a threshold are more problematic. It is also important to note at this point that the concept of attack for purposes of targeting is different from the concept of attack under the law of self-defense in UN Charter Article 51 and customary law.

Now, when considering the law of targeting under humanitarian law, weapon systems that cause physical harm, injury or death usually raise no critical legal questions about the attack threshold. Hence, the attack threshold is defined by its consequences, rather than by means or intent.[23] Indeed, the EMS may be used to inflict concrete damage in this sense, by means designed to cause physical destruction such as directed energy weapons like high-energy lasers and high-power microwaves.[24] Many jurists would agree that the use of EMS can be deemed an attack when it is reasonably expected to cause an injurious or damaging effect.[25]

The attack assessment becomes more difficult when an EW capability is designed to cause temporary, non-kinetic effects while creating a risk of potential physical damage. According to Graff and Iben, most EW means "only" temporarily jam the system targeted by the attack or cause it to function in an unintended manner for a certain time, so that

23 Graff and Iben, footnote 8.
24 Office of Naval Research. "Directed Energy Weapons: High Power Microwaves", https://www.onr.navy.mil/organization/departments/code-35/division-353/directed-energy-weapons-high-power-microwaves.
25 Lawless and Nasu, footnote 6.

most actions carried out in the EMS are not considered attacks.[26] However, when EW operations cause physical consequences (death, injury or destruction), the attack threshold may be crossed. For instance, this might be the case if jamming causes the collision of an aircraft or spoofing causes a ship to run aground. In such cases, EW operations need to comply with basic rules of the AP I regarding distinction, proportionality, and precaution. The said applies to operations that are intended or can be reasonably expected (foreseeable result) to cause destruction. The opponent's military targets (AP I Art. 52.2) are *per se* legitimate targets for an adversary's attack operations.

When discussing the effects of EW operations on civilians and civilian objects, AP I articles of distinction (Art 48), proportionality and prohibition of indiscriminate attacks (Art. 51), legitimate military targets (Art. 52.2) and principle of precaution (Art. 57) find full application. The principle of distinction under Art. 48 includes all civilians, also those of non-belligerents. Hence, the effects of signal jamming and interference in conflict zones by High Contracting Parties' military planners need to incorporate the evaluation of EW operations' foreseeable effects to all civilians, include a proportionality check of effects of military operations versus gained military advantage, and take all precautionary measures to protect the civilians and civilian objects. The attack must be directed at legitimate military targets and the incidental harm it is expected to inflict upon civilians and civilian objects must not be out of proportion to the anticipated military advantage.[27]

So far there is relatively little professional analysis of EW operations and requirements stemming from international humanitarian law, but the rules on cyber warfare in *Tallinn Manual 2.0* (which, by the way, also uses the EMS) as well as discussions regarding electromagnetic microwave counter-IED (improvised explosive devices) weapons in Additional Protocol II environments (i.e. in cases of non-international armed conflicts) provide for useful analogies, especially when analyzing whether the military capability is employed in conformity with the targeting rules, including precautions in case of an attack.[28] Also, in the commentary to Art. 36 of the AP I (New Weapons), experts raised concerns regarding the indiscriminate character of EW (amongst others), as follows:

> "Quite independently of the problems of atomic (nuclear), bacteriological and chemical warfare, or space war, which have not been included in this context, the experts were concerned with geophysical, ecological, electronic and radiological warfare as well as with devices generating radiation, microwaves, infrasonic waves, light flashes and laser beams. The use of long-distance, remote-control weapons, or weapons connected to sensors positioned in the

26 Graff and Iben, footnote 8.

27 Lawless and Nasu, footnote 6.

28 Schmitt, Michael N. (ed.). 2017. *Tallinn manual 2.0 on the international law applicable to cyber operations.* Cambridge University Press N.Y., p. 373–562; Boothby, William. 2016. *Weapons and the Law of Armed Conflict (2nd ed.).* Oxford University Press, p. 346–365.

> field, leads to the automation of the battlefield in which the soldier plays an increasingly less important role. The countermeasures developed as a result of this evolution, *in particular electronic jamming (or interference), exacerbates the indiscriminate character of combat.* In short, all predictions agree that if man does not master technology, but allows it to master him, he will be destroyed by technology."[29]

The question remains, then, whether EW operations can be executed in a discriminate manner or not. If not, the contradiction with the very basic rule of discrimination becomes evident.

3.3 Special challenges arising from EW

One challenge arises from military operations using EW below the attack threshold. As already mentioned above, most EW operations "only" temporarily jam the target system or cause its unintended function for a certain time. Due to their non-violent and often temporary effect, such EW operations cannot be considered attacks. International law on operations below the attack threshold is less clear.[30] However, Art. 48 basic rule on the protection of civilians has wider applications in that its applicability extends beyond attacks. The Article speaks of "military operations" which must be directed only against military objectives. With regard to EW, this means that many activities fall within the scope of Art. 48 even if they cannot be considered attacks.[31]A further challenge arises from the fact that military operations are not defined in AP I (or AP II or the Geneva Conventions). However, contextual reading of the entire Section IV on the protection of the civilian population refers to military operations in which violence is used, and not ideological, political or religious campaigns.[32]

Some military operations may not include violence, though, for instance attempts to influence the opponent and/or civilians. In such cases other rules of international humanitarian law may apply, such as the prohibition to threaten the adversary that there shall be no survivors (Art. 40 of AP I).[33] Other EW operations are more difficult to evaluate, especially if these are EW operations in support of military operations without being directly linked to such military operations. As examples, Graff and Iben cite interfering with civilian communications in order to prevent civilians to give warning of

29 Commentary of 1978 – Article 36 New Weapons, International Humanitarian Law Databases, https://ihl-databases.icrc.org/en/ihl-treaties/api-1977/article-36/commentary/1987?activeTab=1949GCs-APs-and-commentaries, 1476.
30 Graff and Iben, footnote 8.
31 *Ibid.*
32 Sandoz et al., footnote 21, 1875.
33 Graff and Iben, footnote 8,

troop movements in a specific region or the establishment of so-called ECM (electronic countermeasure) bubbles around military objectives; the principle of distinction may apply depending on the circumstances, the former example being the more problematic one as these are acts that target civilians directly.[34]

Another issue concerns the prohibition of perfidy under Art. 37 of AP II. Acts that invite the confidence of an adversary, leading him to believe that he is entitled to, or is obliged to accord, protection under the rules of international law of armed conflict, with the intent to betray that confidence. Such acts may involve, for instance, the feigning of an intent to negotiate under a flag of truce or of a surrender, the feigning of an incapacitation by wounds or sickness, the feigning of civilian, non-combatant status or the feigning of protected status by the use of signs, emblems or uniforms of the United Nations or of neutral or other States not parties to the conflict.[35] However, ruses of war are permitted. Article 37.2 of AP I specifies that ruses are acts which are intended to mislead an adversary or to induce him to act recklessly, but which infringe no rule of international law applicable in armed conflict and which are not perfidious because they do not invite the confidence of an adversary with respect to protection under that law.[36] Examples given by the article include the use of camouflage, decoys, mock operations and misinformation.

In case of EW operations, it is obvious that they need to respect the prohibition of perfidy under Article 37.1 of AP I. At the moment, there is an ongoing discourse in naval warfare that includes aspects that may be relevant for EW. The question is whether the right to sail under false flag may be interpreted to cover the sending of false radar and acoustic signals.[37]

A third issue concerns special protection afforded under international humanitarian law, such as medical establishments, units, and personnel.[38] The importance of their protection during both international as well as non-international armed conflict is evidenced by extensive protection rules both in the Geneva Conventions II as well as AP I–II.[39] Relevant for our discourse is the fact that belligerent parties are not only prohibited from making hospitals and mobile medical units objects of an attack but also from interfering with their work. Hence, the question is whether the use of EW, for instance, to disrupt communications can be construed as interfering with medical services or unnecessarily preventing their

34 *Ibid.*
35 Additional Protocol I, Article 37.1.
36 *Ibid.*, Article 37.2.
37 Graff and Iben, footnote 8, with reference to *Militærmanual om folkeret for danske væbnede styrker i internationale militære operationer* 2020, https://www.forsvaret.dk/da/publikationer/militarmanual/, p. 580–581.
38 Civil defense organizations are also awarded special protection under AP I Articles 61–66.
39 See for instance Geneva Convention I, Ch. III, Arts. 19–23 regarding medical units and establishments; Ch. IV, Arts. 24–32 regarding personnel; Ch. V, Arts. Arts. 33–34 on buildings and material; Ch. VI, Arts. 35–37 regarding medical transports and Ch. VII, Arts. 38–44 regarding the distinctive emblem.

proper functions, even if an attack threshold is not crossed? According to Lawless and Nasu, communications used for medical services are technically indistinguishable from other communications taking place in the conflict zones, as hospitals do not emit a special kind of electromagnetic wave and they do not necessarily transmit on a special frequency which would allow military operations immediately to identify them as hospitals.[40]

Regardless, a recent commentary regarding Art. 19 of the 1st Geneva Convention on protection of medical units and establishments extends the obligation to respect and protect military medical establishments and units to the prohibition of an intentional disruption of these units' ability to communicate for medical purposes with other components of the armed forces.[41]

The risks of harmful interference for humanitarian assistance vehicles were also underlined in a recent joint statement issued by three UN agencies, the ITU, the ICAO (International Civil Aviation Organization) and the IMO (International Maritime Organization), as follows:

> "NOTING with grave concern the increasing number of cases of harmful interference in the form of jamming and spoofing affecting the Radio Navigation Satellite Service (RNSS), which is critical for navigation of civil aircraft, maritime vessels, humanitarian assistance vehicles, as well as for time synchronization of telecommunication networks…
>
> ITU, ICAO and IMO jointly and urgently call on their respective Member States to protect the RNSS from transmissions that can adversely cause harmful interference degrading, interrupting or misleading signals used for civilian and humanitarian purposes."[42]

As noted above in the previous section, EW is bound to exacerbate the indiscriminate character of conflict. Hence, the challenge lies in the distinction of civilians from the military in the EMS in general, and the identification of hospitals based on EMS activity in particular.

40 Lawless and Nasu, footnote 6.

41 Convention (I) for the Amelioration of the Condition of the Wounded and Sick in Armed Forces in the Field. Geneva, 12 August 1949, Commentary of 2016, Article 19, https://ihl-databases.icrc.org/en/ihl-treaties/gci-1949/article-19/commentary/2016?activeTab=#_Toc452045289,1804.

42 Joint Statement by the Secretary General of the International Telecommunication Union, the Secretary General of the International Civil Aviation Organization, the Secretary General of the International Maritime Organization regarding PROTECTION OF THE RADIO NAVIGATION SATELLITE SERVICE FROM HARMFUL INTERFERENCE, 25 March 2025, https://www.itu.int/en/mediacentre/Pages/PR-2025-03-25-radio-navigation-satellite-service-harmful-interference.aspx.

4. Concluding remarks

The EW environment is quite challenging for military planners. Regardless, efforts need to be made to create a better understanding of the requirements for EW planning stemming from IHL. Making sure that key concepts of distinction, proportionality and precaution as well as special protections afforded under IHL (medical units, personnel, equipment *et cetera*) are part of the military planning is the responsibility of every High Contracting Party.

The realm of EW is under-researched terrain in terms of international law. As evidenced by the discussion above, topics for further research are many: the concept of attack in all cases of EW (also when physical consequences are not easily foreseeable), EW operations under the threshold of attack and the applicable legal framework, the concept of military operations, the principle of distinction and third states and so forth.

The threshold of (armed) EW attack from the point of view of self-defense, especially by third states, also needs clarification, considering that armed forces of states may relatively easily find themselves in opposition in the realm of EW. One needs only to think of NATO's developing EW capabilities and their potential use against Russian EW interference. The threshold of armed conflict becomes an interesting question for legal advisors in such a quite foreseeable situation. Prudence would seem to dictate that interpretative questions are to be solved sooner rather than later.

These interpretative challenges occur in a time and context which is very challenging from the point of view of IHL's continued respect by states. International Committee of the Red Cross (ICRC) published last December its *Humanitarian Outlook 2026: A World Succumbing to War* -report with alarming humanitarian tendencies.[43] One of these is the erosion of IHL evidenced by on-going conflicts and complete disregard for IHL by states and non-state actors. This situation does not change the conclusion regarding the importance of working to clarify the legal interpretation of IHL for EW operations, but rather strengthens it and underlines the need for enhanced co-operation in diverse formats. For instance, ITU, mandated to act on electronic operations against satellites, could join forces with the ICRC and provide the technical advice needed for clarifying different facets of EW operations under IHL.[44] Also, States that are known defenders of human rights and humanitarian law (Switzerland, Ireland, Norway, Austria, Mexico *et cetera*), NGOs, and academia have joined forces before to accomplish significant humanitarian conventions like the Mine Ban Treaty (1999), the Convention on Cluster Munitions (1999) and the Treaty Prohibiting Nuclear Weapons (2021). A similar effort for the defense of

43 ICRC. 2025. *Humanitarian Outlook 2026: A world succumbing to war,* https://www.icrc.org/en/article/humanitarian-outlook-2026.

44 Poirier, footnote 4.

international humanitarian law and for strengthening its application in fields like EW would be a welcome initiative.

On a grassroots level, the use of military capabilities depends on military advisors. Several states have published military manuals for their armed forces, but most states have not (like Finland, Sweden, or Russia). There are also overarching military manuals for specific environments like the *Tallinn Manual 2.0* for cyber operations[45] and the *Woomera Manual* of military space operations[46], which have been prepared by experts in consultations with States. Similar initiatives could be one possibility to harness the legal expertise of different states to forge an understanding of the application of IHL in diverse EW operations. If inclusive, meaning the inclusion of experts of all willing states, such exercises could have significant power to affect the applicability of rules of IHL to EW operations.

Finally, we shall be heading back to space. Fundamentally, the question is of acceptable space behaviors. Targeting a satellite with civilian functions should be deemed highly condemnable, and space-faring nations should aim to forge a consensus on this point. Dual-use satellites are evidently more problematic, but the respect for IHL should be enhanced in such cases. Hence the importance of inclusion of IHL in relevant discussions in Geneva and Vienna. Purely military satellites are another matter, as these are a military target *per se*. However, they are not a military target if they are operated by a non-belligerent. Hence, the pursuit of a consensus on acceptable space behaviors, better understanding of IHL requirements, along with technological developments to allow for better protection and attribution in cases of illegal targeting, are concrete steps necessary for a rule-based order in international relations.

45 Schmitt, footnote 28.
46 Beard, Jack and Stephens, Dale (eds.). 2024. *The Woomera Manual on the International Law of Military Space Operations.* Oxford University Press, https://doi.org/10.1093/law/9780192870667.001.0001.

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Research Note

Reshaping a Balanced Context of Space Arms Control: From Sustainability and Threat to Stability and Deterrence

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Abstract

In the discussions on space arms control, the terms of space sustainability and space threat are frequently mentioned. Space sustainability has been taken as the objective for space arms control negotiation, and the recognition of space threat is always deemed as the prerequisite for such rules-making processes. By contrast, space stability and space deterrence are seldom mentioned on purpose or as an omission. However, the recognition and determination of these two terms will be critical and even decisive for space security rules-making. When addressing all kinds of counter-space capabilities in the process of Prevention of an Arms Race in Outer Space (PAROS), it is always associated with the concept of space threat, in particular kinetic weapons, for instance Anti-Satellite (ASAT) tests. Subsequently, this brings about discussions on how to limit or ban such threats. It cannot be denied that these capabilities, when being defined as threats, are also the main sources of strategic or tactical deterrence. An arms control strategy involves interpreting an adversary's deterrence as a threat to the international community, thereby weakening or even prohibiting the adversary's deterrence through arms control initiatives. Space deterrence does not solely, or even necessarily, aim to deter space operations; rather, it may combine with nuclear, conventional, and informational deterrence capabilities to shape an adversary's overall perceptions and behavior. The complex interactions among space threats, deterrence, and threat perception shape international strategic dynamics, exerting significant influence on the international security landscape and policymaking. Therefore, it is imperative to foster a shared and balanced understanding of these interrelated concepts among states, so as to minimize the risk of misperception and miscalculation and thereby develop more balanced and practical rules for space arms control.

Keywords

Space sustainability, space stability, space threat, space deterrence, DA ASAT test, PAROS

1. Introduction

Security is the foundation of development, while international security reflects the collective capacity of nations to address shared risks through cooperation and governance. As a vital frontier of human activity, outer space plays an increasingly critical role for global strategic stability and technological advancement, warranting focused international attention. However, there are still obvious political contests and divisions in the field of arms control in outer space. Pursuing a balanced space security global governance (SSGG) through space diplomacy is the most urgent goal for all countries to address amid these challenges to pave the way towards space stability and sustainability.[1]

Since the beginning of the 21st century, initiatives such as "Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force Against Outer Space Objects (PPWT)" put forward by China and Russia have gained widespread support from developing countries, while the United States firmly opposes them. Most of the European countries have tried to remain as neutral as possible. The situation was somehow changed at the seventy-fifth session of the UN General Assembly in 2020. The "New Initiative for Responsible Space Behaviours" put forward by the United Kingdom, the United States, and other states, has won the support of a certain number of developing countries.

In the future, the game of space security and arms control in outer space will become increasingly complex and fierce. From the perspective of space global governance, this is conducive to neither alleviating tensions in space or enhancing mutual trust among major powers, nor effectively responding the challenges to the long-term sustainability of outer space activities.[2] In December 2024, the Open-Ended Working Group on the Prevention of an Arms Race in Outer Space in all its aspects was established under UN General Assembly Resolution 79/512. Its first and second substantive sessions were intended to mark a turning point in space diplomacy, a chance for states to move beyond disagreements in approach between legal and nonlegal measures, and regarding behaviors and weapons capabilities. It was intended to be a chance to begin meaningful work on a comprehensive approach to space security, arms control, and conflict prevention.[3]

Distinct rationales of sustainability and stability determine different contexts and approaches for space arms control negotiations. In practice, concepts such as space

1 Wang Guoyu, "Space Sustainability: Balanced Space Security Global Governance," in *The Oxford Handbook of Space Security*, ed. Saadia M. Pekkanen and P.J. Blount (Oxford: Oxford University Press, 2024), https://doi.org/10.1093/oxfordhb/9780197582671.013.35.

2 Guoyu Wang and Junzhe Chen, "On the New Initiative for Responsible Space Behaviors Proposed by United Kingdom, United States, and Other States," *Space: Science & Technology* 3 (2023): 4, https://doi.org/10.34133/space.0033.

3 Jessica West, "Open in Name Only: The OEWG on PAROS Stumbles Through Its First Session, Special Report" (Project Ploughshares, April 2025), https://cdn.prod.website-files.com/63e066081ef50cb16a3f4157/67feab07b5610b53378bcde0_OEWGFirstSessionRecap2025.pdf.

sustainability and space threats are frequently discussed and often adopted either as goals for space arms control negotiations or as prerequisites for rule-making, associated with the topics of space debris mitigation and space environmental protection. In contrast, notions like space stability and space deterrence receive considerably less attention, whether intentionally sidelined or inadvertently overlooked. Nevertheless, clearly recognizing and precisely defining these terms is crucial, and may even prove decisive, in establishing effective space security governance. It is therefore imperative to foster a balanced and shared understanding of these interrelated concepts among states, so as to minimize misperception and miscalculation risks, and support the development of more balanced, coherent, and practical rules for space arms control.

In the current Prevention of an Arms Race in Outer Space—hereinafter PAROS—discussions, the identification of space threats is often regarded as a prerequisite for the formulation of relevant arms control rules, but the threat itself should not simply and directly become the object of arms control rules, in the context of the current four classifications based on anti-space capabilities. The object of arms control rules should instead be specific space behaviors, and the three elements of subjective intention, the behavior itself, and the consequences of the behavior should be considered when formulating the corresponding prohibition or restriction rules. Space threat and deterrence are two sides of the same coin. However, regarding the relationship between space threats and space deterrence, the international community has not yet given a definitive conclusion. They are both a tool of a state to pursue the sense of strategic security or superiority and a tool of strategic interactions among states. This means that the various space threats, which are deemed as negative factors to the safety of space activities and environment, might be simultaneously taken as positive elements for national security and necessary measures to preserve balanced, stable space relations.

2. From Space Sustainability to Space Stability

The word sustainability is derived from the Latin verb *sustinere* and is usually used in the context of being able maintain an activity at a certain rate or level. Since the 1970s, the concept of sustainability has been applied to human habitation and the equitable utilization of planet Earth and its resources.[4] According to the *Oxford English Dictionary*, the term “sustainable” refers to “the capacity to be upheld or defended”.[5] From an ethical

4 P. Martinez et al., “The IADC Space Debris Mitigation Guidelines and Supporting Documents,” *Space Policy* 43 (2018): 5–8, https://doi.org/10.1016/j.spacepol.2018.01.002.

5 *Oxford English Dictionary*, 3rd ed., s.v. “sustainability (n.),” accessed November 30, 2025, https://www.oed.com/dictionary/sustainability_n?tl=true.

standpoint, a third dimension in defining "sustainability" is self-restraint. This can be viewed as a subsequent requirement of the first two elements, suggesting that one is not supposed to always exploit one's space rights to the fullest extent. Even in the absence of explicit prohibitions or restrictions under international law, space activities ought to be justified on ethical grounds.[6] Space sustainability is frequently underscored in various international platforms and discussions, with numerous concepts and initiatives, such as space environmental protection, space traffic coordination, the threat posed by space debris, and the ban on anti-satellite (ASAT) tests being rooted in or justified by this rationale.[7]

Taking the perspective of international security and strategy, it is "stability" rather than "sustainability" that should be the key rationale. From an objective perspective, space stability means the status deviating from space conflicts, particularly space armed conflicts and space warfare, under which any of the stakeholders in the space military/security game lack motivations to change the existing equilibrium through proposing new arms control initiatives. However, from a subjective perspective, the connotation of strategic stability may vary due to different stages and status with respect to the capability development of states. To an existing superpower, super priority might mean the most acceptable strategic stability. For emerging superpowers, the more urgent and practical objective is to pursue and maintain strategic equilibrium and at least keep a safe and secure distance from the leader.[8]

Space stability should be regarded as the ultimate objective of space security governance, serving as the primary standard for assessing the value of international initiatives on the PAROS—namely, whether they contribute to achieving or maintaining this stability. Furthermore, compared to the concept of sustainability, stability offers a distinct, subjective lens for re-examining perceived threats. It posits that genuine stability exists when no actor is truly willing to alter the *status quo* of space relations or seeks to aggressively pursue absolute superiority, thereby uncovering the real, often less visible threats, such as an arms race driven by ambitions like a "golden dome" strategy.

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6 Wang Guoyu, "Space Sustainability: Balanced Space Security Global Governance," in *The Oxford Handbook of Space Security*, ed. Saadia M. Pekkanen and P.J. Blount (Oxford: Oxford University Press, 2024), https://doi.org/10.1093/oxfordhb/9780197582671.013.35.

7 *Ibid.*

8 *Ibid.*

3. From Space Threat to Space Deterrence

When used in the context of space security, the term "threat" generally refers to the danger to the security of a space system or any of its components.[9] More specifically, it denotes a status arising from intentional behaviors that may cause adverse impacts to the space assets, activities and/or security interests of another country. It comprises three essential elements: intention, behavior, and adverse impacts.[10] To draw an analogy, if space threat is likened to an aircraft, behavior represents the core element, corresponding to the fuselage, whereas intention and adverse impacts serve as the two critical supporting factors, akin to the wings.

Intention. Threats in the space security domain are supposed to focus on intentional behaviors, which are distinct from risks that affect the safety of a space system or any of its components. Some definitions, as found in dictionaries and adopted by some countries, typically encompass both natural causes and man-made factors. However, it is neither appropriate nor necessary to include natural phenomena—as well as negligence, unintentional actions, or accidents—, within the scope of space threats. For instance, risks associated with space debris during normal operations, such as break-ups or uncontrolled re-entries, should not be classified as threats in the space security context. Instead, the intention in space threats encompasses unfriendly, provocative, or malicious behaviors. It may manifest in specific space operations, including electromagnetic interference, co-orbital attacks, and unauthorized use of cyber capabilities to seize satellite control. The intention can also extend to certain space security strategies or policies, such as public declarations identifying specific countries as primary threats or explicit designation of space as a warfighting domain, since they may increase the risk of misperception and miscalculation, thereby escalating tensions among states. Furthermore, the presence of hostile intention *per se* constitutes a potential threat to a certain extent.

Behavior. Space technologies and capabilities are inherently neutral and do not constitute threats *per se*, although they could be used to deny, disrupt, degrade, damage, destroy, or

9 Almudena Azcárate Ortega and Victoria Samson, eds., *A Lexicon for Outer Space Security* (Geneva: United Nations Institute for Disarmament Research, 2023), https://doi.org/10.37559/WMD/23/Space/05.

10 Guoyu Wang, "The Recommended Definition of 'Threat' in the Context of OEWG" (working paper presented to the Open-ended Working Group on Reducing Space Threats, New York, September 12, 2022, https://documents.unoda.org/wp-content/uploads/2022/09/20220912GW-The-Recommended-Definition-of-Threat-in-the-Context-of-OEWG.pdf.

otherwise harm a system, infrastructure, or person. Under specific circumstances, certain space behaviors utilizing these technologies or capabilities may pose potential threats. These behaviors can generally be categorized into two main categories. The first refers to behavior resulting from actions, such as jamming, spoofing, and rendezvous and proximity operations, which can directly impair space assets or operations, albeit in a potentially reversible manner. The second refers to behavior resulting from omissions. For instance, a commercial satellite is operated under the jurisdiction of State A and its collision warning services are also provided by State A. However, upon identifying potential in-orbit collisions or hazardous conjunctions between this satellite and a satellite operated by State B, State A does not promptly provide the necessary space situational awareness information to the commercial operator responsible for the satellite. In addition to the aforementioned behaviors that directly target space systems, there are other existing behaviors pertaining to space security, such as national space strategies and policies, serving as underlying drives of space threats. These behaviors are often less conspicuous and tend to be overlooked in discussions on space threats; they are, however, closely associated with weaponization and the emergence of an arms race in space.

Adverse impacts. Pursuant to "Draft Articles on Responsibility of States for Internationally Wrongful Acts"[11], injury includes any damage, whether material or moral. The latter, also referred to as non-material damage, can broadly be defined as the opposite of financial or any other form of tangible damage.[12] The adverse impacts of space threats encompass both material and non-material dimensions. Material consequences are akin to the damage defined in the Liability Convention[13], which means loss of life, personal injury or other impairment of health, or loss of or damage to property of States or of persons, natural or juridical, or to property of international intergovernmental organizations. These consequences include the impact in space, such as the degradation or loss of satellites and orbital resources, as well as impacts on Earth, such as the damage or destruction of critical infrastructure and services. Non-material consequences not only involve general interference during space operations, such as temporary sensor dazzling, but also pertain to perceptions of insecurity or misunderstanding, which may heighten tensions and potentially trigger or escalate arms races and conflicts in space. Additionally, both material and non-material consequences may be characterized as either reversible or irreversible from the perspective of technology.

Together with space threat, the concept of space deterrence must be examined simultaneously. Deterrence theory is deeply rooted in the nuclear domain but is not

11 Adopted by the UN International Law Commission in 2001.
12 Stephan Wittich, "Non-Material Damage and Monetary Reparation in International Law," *Finnish Yearbook of International Law* 15 (2004): 321–68.
13 See the UN Convention on International Liability for Damage Caused by Space Objects, adopted 1971.

necessarily limited to this domain. This theory also applies to and is reflected in space practice.[14] Deterrence is central to the national security policy throughout history, and is still achieved through, on most occasions, military measures[15]. As far as the author is concerned, from the perspective of game theory, deterrence is the tool of one party in the game to inflict the perceptible, foreseeable costs or negative consequences to the other party, in order to pursue maximum benefits through minimum cost.[16] Deterrence can be either a threatening initiative or a responsive one. Then, based on the perceptions to the category and extent of the deterrence inflicted by the other, the parties in the game would lay down their respective follow-up measures and plans to gradually, pertinently, and systematically degrade and even eliminate the effects of the deterrence it suffered.

The complex interactions between space threats, deterrence, and threat perception shape international strategic dynamics, exerting significant influence on the international security landscape and policymaking. It is therefore crucial to consider the balance of interests and stability among states while defining space threats and deterrence. Many delegations have expressed the view that kinetic weapons and destructive and ascent anti-satellite tests are major space threats, prompting calls for restrictions or prohibition, without appropriately mentioning that these capabilities and associated activities also serve as essential tools for maintaining strategic deterrence.

An arms control strategy involves interpreting an adversary's deterrence as a threat to the international community, thereby weakening or even prohibiting the adversary's deterrence through arms control initiatives. This is the essence of the United States' commitment not to conduct destructive, direct-ascent anti-satellite (DA ASAT) missile testing. Although the U.S. has made this commitment, it will have little impact on its own deterrence system. The impact of such a commitment on a State depends on the composition of its overall deterrence system. Some states might also wave the flag of environmental protection to cover their real intention to mitigate or degrade the strategic deterrence they have suffered. It is difficult to distinguish between threat and deterrence, in particular after the historical development of the great power games. Assuming that the national security concerns and the relevant strategic needs are not duly considered and only exploring space threats from the perspective of space environment protection, it becomes very difficult to achieve practical and effective solutions to deal with threats to space systems and their consequences for both space and Earth.

14 Wang Guoyu, "Space Sustainability: Balanced Space Security Global Governance," in *The Oxford Handbook of Space Security*, ed. Saadia M. Pekkanen and P.J. Blount (Oxford: Oxford University Press, 2024), https://doi.org/10.1093/oxfordhb/9780197582671.013.35.

15 Michael Krepon and Julia Thompson, *Anti-satellite Weapons, Deterrence and Sino-American Space Relations* (Washington, DC: Stimson Center, 2013), https://www.jstor.org/stable/resrep10894.

16 *Ibid.*

The current discourse unilaterally emphasizes space threats while neglecting space deterrence. When discussing various counter-space capabilities, particularly kinetic weapons and ASATs, they are invariably framed as space threats, followed by proposals to restrict or prohibit them, ignoring how these capabilities simultaneously serve as strategic or tactical deterrents. Calls for "threat reduction" may simply mean constraining or weakening an adversary's deterrence. The space threat debate focuses disproportionately on space sustainability while overlooking stability. In fact, misunderstandings, misperceptions, and tensions in outer space pose risks no smaller than those of space threats and their consequences, perhaps even greater. Lose sustainability, lose a lot; lose stability, lose everything. Deterrence cannot be eliminated; the optimal approach is to regulate it systematically. Clarifying the concept of space deterrence and its relationship with space threats is essential.

4. Case Study: The DA ASAT test from the perspective of space deterrence and space stability

As mentioned in the introduction, the initiative to partially ban anti-satellite (ASAT) testing is becoming the spotlight in the international discussions on space security and space arms control. It seems conducive to preserving the space environment, but it's also a game among space powers.[17]

In April 2022, the United States committed not to conduct destructive, DA-ASAT (Direct-Ascent Anti-Satellite) missile testing, and sought to establish this as a new international norm for responsible behaviour in space.[18] In September, the United States first proposed a draft resolution on "Destructive direct-ascent anti-satellite missile testing" at the UN Open-ended Working Group on Space Responsible Behaviour. In October, it submitted the draft resolution to the UN General Assembly (UNGA) First Committee together with 11 other countries, including Canada, the United Kingdom and Germany. The draft resolution was adopted by the First Committee on November 1 and was approved by the UNGA on December 7 with 155 votes in favour, 9 against and 9 abstentions. This resolution calls upon all states to commit not to conduct destructive direct-ascent anti-satellite missile tests and considers such a commitment to be an urgent, initial measure aimed at preventing damage to the outer space environment, while also contributing to the

17 *Ibid.*
18 The White House, "FACT SHEET: Vice President Harris Advances National Security Norms in Space" (news release, Washington, DC, April 18, 2022), https://bidenwhitehouse.archives.gov/briefing-room/statements-releases/2022/04/18/fact-sheet-vice-president-harris-advances-national-security-norms-in-space/.

development of further measures for the prevention of an arms race in outer space.[19] As of March 2025, 38 countries (including all member states of the European Union) have made a commitment not to conduct destructive DA-ASAT missile tests.[20] Although it is widely known that ASAT capabilities and related tests pose great risks to space environment, unfortunately, they are simultaneously important means for a state to safeguard its own security and maintain external deterrence capability.

The forms of ASAT deterrence. ASAT deterrence can be further divided into different forms, for instance, deterrence with ASAT capabilities, deterrence through conducting ASAT testing, and deterrence through possible ASAT testing. The deterrence of ASAT capabilities generally needs to be perceived through conducting ASAT tests. In addition, ASAT deterrence can be divided into two categories: capability-deterrence and intention-deterrence. Deterrence through conducting ASAT tests belongs to the former, and deterrence through the possibility of conducting ASAT tests belongs to the latter. For States that have not yet conducted ASAT tests, once they make the same initiative as the United States, it is tantamount to giving up capability-deterrence and subsequent intention-deterrence. For States that have already conducted tests to verify and demonstrate ASAT capabilities, once they make the same initiative, it means they have given up intention-deterrence. These States may seek to retain the tactical option of conducting ASAT tests, in other words, reserving the space for intention deterrence to maximize the space-strategic value brought by ASAT capabilities.

The effectiveness of ASAT testing. Pursuant to the concept of traditional deterrence theory, effective deterrence requires three elements: certain strength, determination to use strength, and effective information transmission.[21] Based on research on deterrence, Kissinger recognized the important role of psychological and cognitive factors in deterrence, and believed that deterrence requires a combination of strength, the willingness to use that strength, and potential attackers' assessment of the combination of these two factors. Meanwhile, deterrence is the product of all these factors, not the sum of them. If any one of these factors is zero, deterrence would fail.[22] This theory has a prominent performance in the nuclear field. Yang stated that if the number of nuclear weapons does not reach the threshold of assured destruction, the effectiveness of deterrence cannot be recognized. However, some believe that this exaggerates the significance of assured destruction

19 United Nations General Assembly, Resolution 77/41, "Reducing space threats through norms, rules and principles of responsible behaviours," December 7, 2022, https://undocs.org/A/RES/77/41.

20 Guoyu Wang and Chengyun Zhang, "Analysis of the Proposed Initiative on the Partial Ban or Restriction of ASAT Tests," in *2025 International Arms Control and Disarmament* (Beijing: World Knowledge Press, 2025), 109–131.

21 Gao Yangyuxi, "The Historical Evolution of American Deterrence Strategy in Space", *International Studies Reference*, no. 6 (2017): 27–34.

22 Henry A. Kissinger, *Nuclear Weapons and Foreign Policy* (New York: Routledge, 1984), 12, https://doi.org/10.4324/9780429046902.

to deterrence since some other related factors are ignored, such as the credibility of commitment.

Similarly, the credibility of deterrence capability is proven by the successful test of ground-based kinetic ASAT testing. The credibility of the threat intention is the extent to which a State believes its adversary would use the ground-based ASAT capability under certain conditions. In theory, the deterrence of ASAT tests, particularly tests that can generate debris, has strong strategic deterrence effect, and its deterrence capability is directly proportional to the degree of damage generated by debris. Therefore, the deterrence of theoretical ASAT capability without any demonstration is not the same as that which has been perceived via demonstration. The latter may have a stronger and more direct deterrence effect due to the selection of different targets—for instance, those in low Earth orbit (LEO) or high LEO.

Meanwhile, the ASAT test itself is an effective means to seek and enhance the deterrence effect of ASAT capability, namely the credibility of ASAT capability. ASAT tests that destroy real targets (space objects) obviously generate stronger deterrence than tests that validate the capability through virtual targets. Once a state has successfully conducted a similar test, it has less incentive to continue to prove the credibility of its deterrence capability. Nevertheless, it cannot be ruled out that it would continue to conduct such tests, including the destruction of real targets. On the one hand, it may stem from the demand for its capacity system construction and/or for better capacity building. On the other hand, such tests are tactical or strategic options to send a strong signal, especially debris-generating tests, which have stronger deterrence effect due to the realistic threats they may pose.

Moreover, if a state already has the credibility of deterrence capability, the evaluation of its deterrence capability at this time mainly depends on the credibility of its deterrence intention, in other words, whether a state has the determination to conduct such tests again. It is undeniable that the cost of conducting such tests to achieve desired effects must be high, and this state would be liable under international law if the debris causes damage or loss to the space assets or to personnel of a third party. However, it is precisely the high costs and risks that may let states determine whether to conduct such tests or not, in order to be in a better position in the game. In other words, whichever side of the game is willing to take greater risks of losing control would be able to force the other side to concede.[23] It is possible that one party of the game may prefer to take the risk of losing control to prevent a war in space, that is, to deter adversaries' attempts to directly attack its space targets by conducting a debris-generating ASAT test, or to deter adversaries in other areas involving national security, so as to avoid the escalation of conflicts. Therefore, the credibility of the

23 Schelling, 1966, pp. 92–105.

deterrence intent of such ASAT tests depends, on the one hand, on the determination of the testing party, and on the other hand on whether the testing party has the technical ability to effectively avoid the in-orbit collision risks caused by its debris.

Such DA ASAT initiatives directly affect the effectiveness of deterrence. Obviously, U.S. commitment and related ASAT initiatives are not only aimed at capability-deterrence, but also intention-deterrence. For countries that have developed ASAT capabilities, they would lose the tactical option to implement intention-deterrence once they have made similar commitments or signed relevant international documents. For countries that have yet to develop ASAT capabilities, they would lose the option to implement intention-deterrence, and the space for them to demonstrate ASAT capabilities might be greatly compressed.

If a state faces serious external challenges to its national security—for instance, in the event of a geo-political crisis—, a debris-generating ASAT test alongside missile tests, sea and air cruises and military exercises may not be ruled out to deter powerful adversaries and demonstrate its determination for war. Once a state is forced to abandon this strategically deterrent option due to pressures from the international community, it must actively seek alternatives to achieve equivalent capabilities, which would lead to another round of an arms race in space, exacerbating misunderstandings and tensions among spacefaring nations. The United States has made this commitment, possibly due to its reduced demand for conducting similar ASAT tests, considering the rapid development of its other counterspace capabilities, such as co-orbital technology, jamming technology, and the deployment of mega-constellations, etc.

In conclusion, from the perspective of space and its overall security situation, if states lack other appropriate means of space deterrence, they are still not precluded from conducting similar tests when under serious threat or in a geo-political crisis. The issue of space security has never been just about space but is rooted in geo-political tensions. Therefore, seeking a geo-political equilibrium among major powers and reaching an overall strategic understanding may eliminate the space risks caused by ASAT tests to the greatest extent possible. However, the project of "Golden Dome for America" announced in January 2025, which is described as an executive branch initiative to develop an integrated air and missile defense system for the United States' homeland, brings more uncertainties and destabilizing effects to the existing fragile strategic stability. This historic investment builds on two of the three main objectives of the U.S. Department of Defense: rebuilding military capability and re-establishing deterrence. It aims to protect the United States from aerial attacks from any foe and use next-generation technology to defend against the evolving and complex threat landscape.[24] The project's explicit focus on "defending

24 United States, Department of Defense, "Secretary of Defense Pete Hegseth Statement on Golden Dome for America" (news release, July 15, 2024), https://www.war.gov/News/Releases/Release/Article/4193417/secretary-of-defense-pete-hegseth-statement-on-golden-dome-for-america/.

against peer adversaries" and its intention to "develop and deploy proliferated space-based interceptors" represent its two most contentious aspects.[25] Some experts have pointed out that its unilateral conception and rollout, without prior consultation or engagement with allies or competitors, signals a breakdown in the cooperative ethos that traditionally underpins arms control.[26] This move can also be considered as severely undermining global strategic stability, trampling on the principle of peaceful use of outer space, and further destabilizing an already turbulent world.[27] Whether the DA ASAT tests and the deployment of space-based interceptors could be handled in a package solution in the forthcoming PAROS discussions is still to be observed.

5. Conclusion

Space is a shared and finite resource. The evolving landscape of space-related threats demands a multifaceted and adaptive governance framework in a more balanced and proportionate way. Effectively addressing these challenges requires a holistic approach that prioritizes both immediate risk mitigation and long-term stability and sustainability in space. The weaponization of, and an arms race in, outer space are the most severe threats to space security, capable of causing long-term damage to the space environment. This calls for a renewed multilateral commitment from the international community to safeguard the stability, security, and long-term sustainability of outer space as a guiding objective.

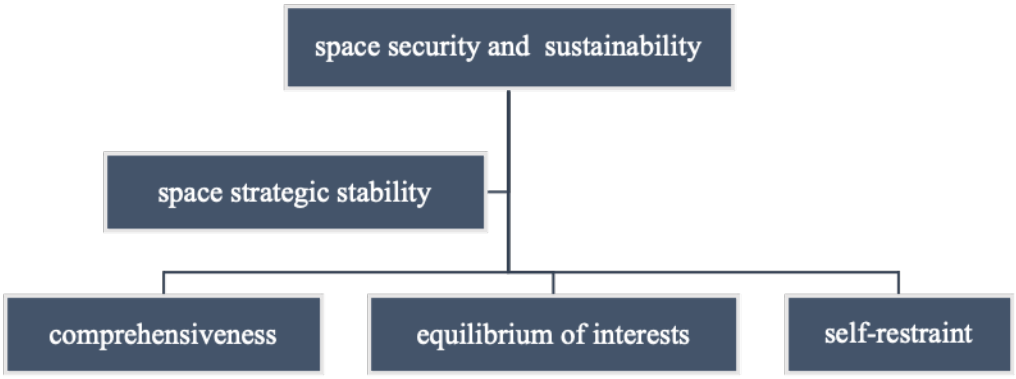
Space security governance would then have to aim at maintaining space strategic stability, following the principles of comprehensiveness, equilibrium of interests and self-restraint. (See Figure 1).

25 Zhang Ming, "U.S. Plan to Deploy Weapons in Outer Space Draws Criticism," *China Daily*, June 10, 2025, https://www.chinadaily.com.cn/a/202506/10/WS68479fdda310a04af22c42b8.html.

26 Xu Ying, "U.S. Golden Dome: A Glimmering Shield or a Blow to Global Stability?" *China Global Television Network (CGTN)*, May 23, 2025, https://news.cgtn.com/news/2025-05-23/U-S-Golden-Dome-A-glimmering-shield-or-a-blow-to-global-stability--1DAmfYsWNxe/p.html.

27 Guo Xiaobing, "U.S. Accused of Planning to Deploy Offensive Weapons in Outer Space," *People's Daily Online*, June 10, 2025, https://en.people.cn/n3/2025/0610/c98649-20325832.html.

Figure 1: The principles to be established for strategic space stability



The *comprehensiveness* principle means that the international community needs a comprehensive solution rather than a proposal about a single issue, like placing weapons in space, testing certain ASAT weapons, or other military space behavior. All these concerns should be taken care of in a comprehensive solution because they interact with each other in the game of space security. Considering that the precariousness of space security is the result of various reasons, such as the lack of strategic understandings, necessary mechanisms, and common recognition of *lex lata*, etc., an international initiative cannot be effective if it only reflects one of the above elements. States should positively work together on all of these matters in parallel. One small step in any of these fields might promote the process of the others. For instance, establishing a bilateral space traffic coordination mechanism might pave the way for achieving strategic understanding between countries. This is another requirement of the comprehensiveness principle.

The *equilibrium of interests* principle requires that any international solution for space governance reflect the appeals and interests of the relevant parties in a balanced way. International initiative in space security should not be taken as a tool to seek the superiority of one State which suppresses its adversaries. Such an initiative would sooner or later be trapped in political debates, and such negotiations are liable to cause nothing but high costs to the whole international community. The more comprehensive and compromised the positions one initiative holds, the less costly the negotiation, and the more practical and effective the final solution would turn out.

The *self-restraint* principle is the subsequent requirement of the above two principles. But it applies to the formulation of international rules or solutions and to every stage of security practices. Self-restraint requires all stakeholders to be appropriately and fairly engaged in space competition and contests in space security. A state should refrain from excessively provoking or threatening its adversaries, or taking other extreme actions, even if these behaviors are not expressly prohibited by international law. In any case, the actors in a space contest should do everything possible and practicable to avoid space (armed) conflict. When a conflict is inevitable or already occurring, each party in the conflict must prevent its escalation and try to contain the conflict on a small scale and at a low intensity. If it fails again, then the actors have to put the deteriorated conflict in a legal order and try to ensure a controlled result; otherwise, it would be a disaster for the space environment, and it would be the last picture we'd like to see.[28]

Finally, a commonly recognized rationale should be jointly explored by the international community to maintain space stability. To achieve this goal, it is recommended that existing space law is strictly interpreted while new normative frameworks to improve the current situation are proactively developed. Specifically, this includes two key points: (a) reinforcing the existing legal regime through refined interpretation of the Outer Space Treaty (OST) and related legal instruments, to clarify acceptable peacetime conduct and define unacceptable activities; and (b) developing new norms of behavior in order to address regulatory gaps and breaking the current diplomatic stagnation caused by uncertainties in the applicability of existing law (*lex lata).* These efforts must be guided by a shared vision and understanding, enshrining core principles such as comprehensiveness, equilibrium of interests, and self-restraint. The resulting framework should be substantiated by specific norms, verification mechanisms, and technical standards to ensure its effectiveness. States should work together, compromise and be pragmatic to work on a resolution to not only reflect the demands of all parties in a balanced manner, but also effectively prevent an arms race and conflicts in space.

28 Wang Guoyu, "Space Sustainability: Balanced Space Security Global Governance," in *The Oxford Handbook of Space Security*, ed. Saadia M. Pekkanen and P.J. Blount (Oxford: Oxford University Press, 2024), https://doi.org/10.1093/oxfordhb/9780197582671.013.35.

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