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

Nicolas Ayala Arboleda

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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'

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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.