Beatrice Nicolini

Reassessing Non-Proliferation in the Age of Autonomous Systems: AI-Enabled Weapons and the Future of UNSCR 1540

Abstract

This study examines the implications of artificial intelligence (AI) for international non-proliferation law, focusing on the inadequacy of United Nations Security Council Resolution 1540 (UNSCR 1540) in addressing emerging AI-enabled weapons.[1] While UNSCR 1540 was designed to prevent the proliferation of nuclear, chemical, and biological weapons to non-state actors, it does not account for intangible, dual-use AI technologies that increasingly shape modern warfare. Through conceptual analysis, case study from Libya and comparison with NATO principles, export-control regimes, and international humanitarian law, the research demonstrates that AI-enabled weapons represent a new domain of proliferation risk beyond the Resolution's scope. The study argues that AI's autonomous, digital, and commercially driven nature demands a new regulatory framework or a substantial update to UNSCR 1540. Without such reform, AI proliferation will continue to create legal, ethical, and security gaps that undermine international (in)stability.

Keywords: Artificial Intelligence; Dual-Use; Autonomous Weapons; UNSCR 1540; Non-Proliferation

1. Introduction

Artificial intelligence (AI) has rapidly evolved from a niche technological field into a central component of modern military and security infrastructures. Over the past decade, AI has been integrated into autonomous weapon systems, cyber capabilities, intelligence and surveillance architectures, targeting systems, and logistical military planning. While AI remains largely a dual-use technology, originating in commercial and civilian its military applications have profound implications for global security. States and non-state actors now have access to increasingly sophisticated AI-enabled tools with potential to cause large-scale harm, destabilise national infrastructures, and circumvent existing regulatory frameworks. This raises urgent questions about the adequacy of current arms-control and non-proliferation regimes. One of the most significant instruments in the global non-proliferation architecture is **United Nations Security Council Resolution 1540 (UNSCR 1540)**, adopted unanimously in 2004.[2] The Resolution requires all UN member states to implement domestic legislation to prevent non-state actors from acquiring nuclear, chemical, and biological weapons, as well as their means of delivery. UNSCR 1540 established a mandatory, binding non-proliferation framework to counter terrorism and illicit proliferation.[3] However, UNSCR 1540 was drafted at a time when artificial intelligence, autonomous weapons, and cyber-enabled warfare were not considered strategic threats. Its language reflects early-2000s technological assumptions and therefore does not address emerging technological realities. In particular, UNSCR 1540 makes no reference to AI, autonomy, digital systems, advanced algorithms,

[1] UNITED NATIONS (U.N.) SECURITY COUNCIL: RESOLUTION 1540 *(*Non-Proliferation of Weapons of Mass Destruction)*, International Legal Materials,* 43(5), 2004.

[2] Olivia, Bosch, and Peter Van Ham (Eds.). *Global Non-Proliferation and Counter-Terrorism: The Impact of UNSCR 1540.* The Hague: Clingendael Institute, 2007.

[3] Brian, Finlay. "UN Security Council Resolution 1540: The Next 10 Years," in *Southern Flows: WMD Nonproliferation in the Developing World. Stimson Center*, 2014.

data-driven weapons, software supply chains, cyber weapons, or private-sector digital innovation, domains that now sit at the forefront of security concerns.[4] This omission poses a significant challenge for global security governance. AI-enabled weapons defy traditional categories of "weapons of mass destruction" (WMDs) because they are not directly nuclear, chemical, or biological in nature. Yet they can amplify the effectiveness, delivery, coordination, and targeting of weapons in ways that may be just as dangerous. Moreover, AI systems are difficult to monitor, regulate, or classify because many of them originate in commercial industries, evolve rapidly through software updates, and can be acquired by non-state actors through legal and illegal channels with relative ease. Unlike fissile materials or nerve agents, AI models cannot be physically secured in the same way; they can be copied, transferred, or leaked globally at minimal cost. As AI systems gradually acquire more autonomous functions, including target identification and engagement, the boundaries between conventional weapons and autonomous digital systems become increasingly blurred.

Recent conflict in Libya has demonstrated that AI-enabled weapons, particularly loitering munitions, automated surveillance tools, and autonomous drones, are no longer theoretical.[5] They are being deployed, sometimes with minimal human oversight. This raises the question of whether existing legal instruments such as UNSCR 1540 can still adequately address the threats posed by rapidly advancing dual-use technologies.

This study examines the extent to which AI-enabled weapons challenge the conceptual and regulatory foundations of UNSCR 1540 and argues that the Resolution requires either substantial revision or supplementation through a new international framework.[6] Drawing on analysis of NATO standards, export control regimes, international humanitarian law (IHL), and recent wartime case studies, the study evaluates how governance systems treat AI and where gaps remain. It also explores policy options for modernising the global non-proliferation architecture and proposes a framework for integrating AI into future non-proliferation efforts.[7] The aim of this study is not to overstate the dangers of AI, nor to classify it as equivalent to WMDs. Instead, the objective is to demonstrate that the *dual-use* nature of AI, its ability to serve both civilian and military functions simultaneously, creates unique risks and regulatory gaps. These gaps undermine the preventive logic of UNSCR 1540 and require coordinated international action. Without an updated legal framework, AI-enabled weapons could expand unchecked, enabling new forms of violence and instability. As non-state actors gain access to increasingly powerful digital tools, the global community must reconsider how non-proliferation principles apply to emerging technologies.[8]

2. Research Question

The central research question guiding this study is: **to what extent do AI-enabled weapons create regulatory gaps within UNSCR 1540, and through what legal or political mechanisms can the Resolution, or a new UN framework, be updated to address emerging dual-use AI technologies?**

This question reflects three underlying concerns. First, the original language of UNSCR 1540 does not encompass AI, software, autonomous systems, or any digital technologies. Second, AI-enabled weapons increasingly empower actors, including non-state groups, who fall directly within the scope of UNSCR 1540's preventative aims. Third, AI's dual-use nature makes it difficult to track, control,

---

[4] Suren, Shirazyan. "Building a Universal Counter-Proliferation Regime: The Institutional Limits of United Nations Security Council Resolution 1540." *Journal of National Security Law & Policy*, 2019.

[5] *UN Panel of Experts on Libya. Final Report of the Panel of Experts on Libya Established Pursuant to Security Council Resolution 1973.* 2011. New York: United Nations Security Council, 2020; United Nations Security Council Resolutions 1970. 2011 and 2510. 2020*; European Union, "EU Launches Operation IRINI to Enforce Libya Arms Embargo*," 31 March 2020; International Crisis Group, *The Libyan Conflict and Prospects for Stabilisation*, 2020.

[6] Alexander, Hess. *Has UN Security Council Resolution 1540 Strengthened the International Nonproliferation Regime?* PhD Thesis, 2019.

[7] NATO. *NATO Artificial Intelligence Strategy. Brussels: NATO Headquarters, 2021; NATO. Principles of Responsible Use of Artificial Intelligence in Defence. Brussels:* NATO, 2021.

[8] Ben, Buchanan. "The New Era of Cyber-Enabled Strategy." *Survival* 61, no. 1 (2019): 27-48.

or classify under existing non-proliferation systems. Addressing these concerns is crucial for preventing new forms of destabilisation and violence.[9]

3. Research Objectives

The present study pursues four primary objectives: **1. To analyse AI-enabled weapons through the lens of dual-use technologies.** This entails examining how AI systems, algorithms, and digital infrastructures simultaneously serve civilian and military functions. It also involves assessing how AI-enabled weapons challenge traditional distinctions between civilian innovations and military capabilities. **2. To evaluate UNSCR 1540's conceptual and legislative limitations vis-à-vis AI technologies.** This includes a legal analysis of the Resolution's terminology, scope, and enforcement mechanisms, assessing whether AI-enabled weapons can be interpreted as covered under its existing provisions. **3. To compare UNSCR 1540 with other regulatory frameworks.** The study examines NATO standards, international humanitarian law (IHL), the Wassenaar Arrangement, the Missile Technology Control Regime (MTCR), the European Union's Dual-Use Regulation, and other frameworks to evaluate how AI is treated elsewhere and what lessons might be applicable to UNSCR 1540.[10] **4. To propose policy recommendations for updating international non-proliferation law.** The study offers two pathways: a) Updating the text of UNSCR 1540 to include AI, or b) Creating a new, independent UN resolution focused specifically on emerging technologies. Both options emphasise collaboration with the private sector, enhanced monitoring systems, and new definitions of threats in an AI-driven era.

4. Significance of the Study

The significance of this research derives from four key factors: **1. AI-enabled weapons pose an emerging security risk to global stability.** AI can accelerate conflict escalation, reduce reaction times, and automate critical decision-making processes. These risks require precise legal frameworks to ensure states and non-state actors do not misuse advanced technologies. **2. Current international law lags behind technological reality.** UNSCR 1540, one of the strongest global non-proliferation mechanisms, is outdated with respect to digital and autonomous weapon systems. Without reform, the Resolution risks becoming increasingly irrelevant. **3. Dual-use AI technologies complicate arms control.** Because AI systems originate in commercial innovation, regulating them requires cooperation between governments, international bodies, and private tech companies. This is fundamentally different from controlling nuclear materials or toxic agents. **4. Non-state actors can exploit AI weapons more easily than WMDs.** Non-state groups cannot easily acquire nuclear or chemical weapons, but they *can* acquire AI-enabled drones, cyber tools, targeting software, and autonomous capabilities. This reshapes global security assumptions. Given these factors, updating global non-proliferation strategies is not optional, it is essential.

5. Critical Literature Review

5.1 Overview of Contemporary Research on AI in International Security: The body of scholarship on AI and international security has grown significantly. Recent works focus on autonomous systems, ethical and legal concerns, military AI standards, and technological risk management. Notable contemporary authors include: Paul Scharre (autonomous weapons and

[9] Clara, Punz. "New technologies and AI: envisioning future directions for UNSCR 1540." (2024).
[10] Michael, Horowitz. *The Diffusion of Military Power: Causes and Consequences for International Politics.* Princeton: Princeton University Press, 2010; Michael, Horowitz, and Paul Scharre. "Meaningful Human Control in Weapon Systems: A Primer." *Parameters* 46, no. 3 (2016).

human-machine decision-making)[11]; Stuart Russell (AI ethics and safety)[12]; Kenneth Payne (AI and the future of warfare)[13]; Heather Roff (AI governance and IHL)[14]; Michael Horowitz (AI, military innovation, and power competition)[15]. Most of these authors highlight three themes: AI is transforming strategic competition. Autonomous weapons pose accountability and ethical challenges. Dual-use AI technologies complicate traditional arms-control measures. Yet despite robust debate on autonomous weapons, there is still limited literature on how AI interacts with UNSCR 1540 specifically. This represents a substantial research gap.

5.2 NATO Publications and Policy Guidance: NATO has published a number of significant documents, including: **NATO's 2021 Artificial Intelligence Strategy**; **NATO's Autonomy Implementation Strategy**; **Data Exploitation Frameworks (2020-2023)**; **Responsible AI Principles (2021).** NATO identifies AI as a "general-purpose, dual-use technology" and emphasises the need for reliability, human oversight, accountability, transparency, and traceability. These principles directly relate to how states perceive autonomous weapons and their regulation. NATO documents highlight: difficulty in verifying AI behavior; rapid software evolution; risks of unintended escalation; challenges of attribution in cyber and autonomous operations. This literature is critical for understanding western military governance of AI, yet it has not been integrated into UNSCR 1540 debates.

5.3 Export Control Regimes and Dual-Use AI: recent research also examines how export-control regimes attempt to regulate AI capabilities. Relevant publications include analyses of: the **Wassenaar Arrangement's controls on "intrusion software"**;[16] The **EU 2021 Dual-Use Regulation**,[17] which includes software categories; U.S. National Security Commission on AI (NSCAI) recommendations (2021).[18] These sources show increasing recognition that software and algorithms can function as weapons. However, export controls face challenges: AI is intangible and easily transferable; it is difficult to distinguish benign from malicious intent; many algorithms are open-source; private companies lead AI development. The available literature concludes that export control regimes are necessary but insufficient for addressing AI proliferation.

5.4 Academic Studies on Autonomous Drone Warfare: the chosen case study from Libya illustrates how AI-enabled systems have already shaped real-world conflicts. Scholars such as Dan Gettinger, Ulrike Franke, and Amos Fox[19] note: increasing autonomy in strike drones; AI-supported battlefield surveillance; risks of algorithmic targeting errors; proliferation of commercial-off-the-shelf drones used for military purposes. These analyses demonstrate that AI-enabled weapons are no longer speculative. They exist and are spreading.

---

[11] Paul, Scharre. *Army of None: Autonomous Weapons and the Future of War. New York*: Norton, 2018; Paul, Scharre. "The Role of Artificial Intelligence in Future Warfare." *National Security Journal* 3, no. 2 (2021): 1-22.

[12] Stuart, Russell & Peter, Norvig. *Artificial Intelligence: A Modern Approach*, Global Edition. Pearson Education Limited. 2021.

[13] Kenneth, Payne, and Jonathan B. How. "Artificial Intelligence and the Changing Logic of War." *International Affairs* 96, no. 5 (2020): 1369-1389; Kenneth, Payne & I., Warbot: *The Dawn of Artificially Intelligent Conflict*. London: Hurst, 2021.

[14] Heather, M. Roff. *To ban or regulate autonomous weapons*. 2016, *Bulletin of the Atomic Scientists*. Publisher: Informa UK Limited. https://doi.org/10.1080/00963402.2016.1145917.

[15] Michael, Horowitz, and Paul Scharre. "Meaningful Human Control in Weapon Systems: A Primer." *Parameters* 46, no. 3 (2016): 7-15; Michael, Horowitz. *The Diffusion of Military Power: Causes and Consequences for International Politics*. Princeton: Princeton University Press, 2010.

[16] Wassenaar Arrangement. *List of Dual-Use Goods and Technologies*. Vienna: Wassenaar Secretariat, 2022.

[17] European Union. *EU Dual-Use Regulation 2021/821*. Brussels: European Commission, 2021.

[18] U.S. National Security Commission on AI (NSCAI) recommendations (2021). https://reports.nscai.gov/final-report/.

[19] Dan Gettinger. "Drones and the Future of Air Warfare." *Air & Space Power Journal* 32, no. 4 (2018); Ulrike Franke. "Not Smart Enough: The Limitations of Artificial Intelligence in Weapons Systems." *Journal of Strategic Studies* 44, no. 6 (2021); Amos Fox C. "Precision Paradox and Myths of Precision Strike in Modern Armed Conflict." *The RUSI Journal* 169, nos. 1-2 (2024): 62-74. https://doi.org/10.1080/03071847.2024.2343717.

5.5 Digital Non-Proliferation and Cyber-AI Threats: a small but growing body of research examines digital non-proliferation, including governance of: autonomous cyber intrusions; malware enhanced through machine learning; algorithmic targeting of critical infrastructure. Scholars such as Ben Buchanan and P.W. Singer[20] stress that cyber-AI systems pose risks comparable to kinetic weapons. These studies, however, rarely connect their findings to UNSCR 1540.

5.6 Identified Gaps in the Literature: Ddespite significant scholarship on AI and warfare, three major gaps remain: **no comprehensive legal analysis of UNSCR 1540 in relation to AI exists.** Most authors focus on autonomous weapons under IHL or on ethics, leaving non-proliferation frameworks under-addressed. **Little work evaluates how AI challenges the definition of "weapons of mass destruction.** AI does not fit neatly into the nuclear/chemical/biological categories, but it can amplify or enable them. **There is insufficient analysis of private-sector roles in non-proliferation.** AI development is primarily commercial; the implications for regulation are not yet fully theorised. This study wishes to contribute to these faults.

6. Hypothesis and Limits of the Research

6.1 Research Hypothesis: the central hypothesis of this study is: **AI-enabled weapons constitute a new class of dual-use technologies that fall outside the scope of UNSCR 1540, creating a significant legal and security gap in the international non-proliferation regime.** The hypothesis asserts that: AI-enabled systems can be used by non-state actors; they can facilitate or enhance attacks on civilian or military targets; their proliferation cannot be effectively governed by existing UNSCR 1540 definitions; a new legal framework or revision is required to address these risks. This study argues that excluding AI from non-proliferation efforts is no longer viable.

6.2 Limits of the Research: this research has several limitations: **access to Classified NATO Material**. The analysis relies solely on publicly available NATO strategies, policy documents, interviews, and research. Classified assessments are not included. **Focus on Conventional Proliferation, Not WMD Enhancement**. Although AI can support nuclear, chemical, or biological weaponisation processes (e.g., optimisation models for dispersal or targeting), this study focuses on AI as an independent threat domain. **Focus on Documented Case Study**. Only publicly verified event (e.g., Libya 2020) is considered. **Technological Uncertainty:** the pace of AI development may render certain interpretations outdated over time. These limitations reflect the broader challenges inherent in studying emerging technologies and their impact on international law.

PART II - Conceptual Framework, Indicators, and Methodology

4. Conceptualisation

The global expansion of autonomous and AI-enabled weapons is reshaping modern warfare and intensifying long-standing ethical, legal, and humanitarian anxieties. Drones and other autonomous systems are increasingly capable of making targeting decisions without direct human intervention, and this acceleration in machine decision-making has unsettled diplomats, researchers, and civil society. While industry and military research programs advance at unprecedented speed, international lawmakers struggle to build guardrails strong enough to restrain technologies whose consequences are not yet fully understood.

[20] Ben, Buchanan. *The Hacker and the State: Cyber Attacks and the New Normal of Geopolitics*. Cambridge, MA: Harvard University Press, 2020; Ben, Buchanan. "The New Era of Cyber-Enabled Strategy." *Survival* 61, no. 1 (2019): 27-48. https://doi.org/10.1080/00396338.2019.1568043; P.W., Singer *Wired for War: The Robotics Revolution and Conflict in the 21st Century*. New York: Penguin, 2009; P.W., Singer *Cybersecurity and Cyberwar: What Everyone Needs to Know*. New York: Oxford University Press, 2014.

United Nations officials, together with many non-governmental organizations, caution that lethal autonomous weapons challenge core moral boundaries. They maintain that no machine should possess the authority to decide who lives or dies, and that such capabilities should be outlawed under international law.

Human Rights Watch has framed this trend within a broader arc of digital dehumanization, a world where algorithmic systems increasingly determine outcomes in policing, migration management, and eventually battlefield lethality.[21] The erosion of privacy in civilian life forms an uneasy backdrop to these developments. People surrender personal data to online platforms with little awareness of how information is harvested, monetized, or repurposed. International bodies now warn that such data could be exploited not merely to shape consumer behavior, but to identify individuals as military targets. Major powers, among them the United States, Russia, China, Israel, and South Korea, are investing heavily in autonomous weapons. Supporters of these systems argue that machines operate faster and more accurately under battlefield stress, while critics point to algorithmic bias, opaque decision-making, and the challenge of attributing responsibility when war crimes occur. Vulnerable groups stand at heightened risk, especially where facial recognition falters and misidentification can become fatal. Activists insist this path leads toward an ethical and legal collapse. The international community now confronts the problem of defining responsible military uses of AI. Even the meaning of the "military domain" varies by state: for some governments it includes disaster response and infrastructure protection; for others it applies only to wartime engagement.

Artificial intelligence enhances capacity across the spectrum of operations, decision support, intelligence processing, logistics, cybersecurity, simulation, and autonomous navigation. Used thoughtfully, it could reduce harm by improving legal compliance and strengthening proportionality assessments. Yet, as above described, deep uncertainty persists. Data limitations, embedded discrimination, unreliable models, and the vulnerability of AI to cyber manipulation introduce significant instability. Decision cycles accelerate to the point where misunderstanding and escalation become more likely, and risks multiply as advanced tools spread to non-state actors capable of deploying disinformation or conducting autonomous violence.

The core questions remain stark: **who is accountable, who controls the system, and how do states prevent their biases and blind spots from becoming automated?** In response, the United Nations and leading NGOs urge the creation of global regulations on lethal autonomous weapons. Negotiators are working toward a formal ban by 2026, building on conversations that began in 2014. Over 120 countries have now signaled their willingness to proceed with multilateral negotiations.

The UN Secretary-General has repeatedly called for prohibiting machines capable of killing without human supervision, insisting that such systems violate fundamental ethical norms and should be banned under international law. A recent informal meeting in New York showed cautious convergence around a possible two-tier structure that would combine outright prohibitions with regulatory measures for systems retaining meaningful human control.[22] Yet fundamental disagreements endure regarding definitions and technical boundaries, even as costs fall and proliferation becomes more likely.

In 2024, the General Assembly adopted resolution 79/239, the first instrument dedicated specifically to AI in defense contexts. The Secretary-General's 2025 report to the Assembly highlights mounting dangers: the speed of autonomous decision-loops lowers the threshold for conflict initiation, widens power disparities, and invites an AI-driven arms race. Technological vulnerabilities, system failures, unpredictable outputs, cyber infiltration, data poisoning, threaten operational reliability. Algorithmic bias risks discriminatory targeting. Automation bias fosters excessive trust in machine recommendations, eroding moral judgment and complicating accountability.

The specter of AI integration into nuclear command and control systems provokes some of the report's strongest warnings, with nuclear-armed states urged to preserve sole human authority over

[21] Human Rights Watch. *A Hazard to Human Rights: Autonomous Weapons Systems and Digital Decision-Making.* New York: Human Rights Watch, 28 April 2025.

[22] Interview with Senior Adviser to the UN Disarmament Commission. New York. 5/12/2025. Thank to L. Wallnoefer.

any decision to launch. The report also underscores that AI must not aid the development of biological or chemical weapons, and existing non-proliferation obligations remain intact. At its 9754th meeting, the Security Council acknowledged that scientific innovation must be incorporated into its oversight of global peace and security. Amin Awad, from the Geneva Centre for Security Sector Governance, described emerging technologies as a collective wake-up call, reminding delegates that artificial intelligence must be guided by the humanitarian tradition embodied in the Geneva Conventions.[23]
Switzerland noted that neurotechnology may soon enhance soldiers' capabilities, intensifying decision speed and altering battlefield realities. Delegates debated the ethical implications of cognitive manipulation, risks of power asymmetry, and the possibility that developing nations could become testing grounds for sophisticated tools created elsewhere. Some warned that recent conflicts illustrate how AI can magnify violence and worsen civilian suffering. Others stressed the need to bridge technological divides, accelerate accountability mechanisms, and ensure that innovation does not outpace law. A distinction emerged between AI decision-support systems, which aid human judgment, and autonomous weapons systems, which select and engage targets without it. Although built on similar architectures, their legal and moral profiles diverge sharply.
AI decision support can expand awareness and reduce uncertainty, but when integrated into lethal autonomy, it replaces, not assists, human agency. The dual-use nature of digital technologies complicates the landscape further. Tools developed for civilian logistics or research may be repurposed for surveillance, cyber aggression, or targeted violence.

Libya presents another case in which arms embargoes have been challenged by military flights and drone proliferation. Satellite imagery confirmed the delivery of Akinci UCAVs following a Libya-Turkey agreement, illustrating how supply chains adapt around sanctions. Investigations also uncovered UAV components disguised as wind-energy equipment, underscoring the difficulty of enforcement. The non-proliferation framework built by Security Council resolution 1540 continues to prohibit the transfer and weaponization of nuclear, chemical, and biological agents. States are expected to secure materials, enforce borders, regulate exports, and prevent non-state access to dangerous technologies. These obligations remain complementary to existing treaties, and a monitoring committee oversees implementation while encouraging cooperation and assistance.
Several export control regimes contribute to broader governance. The Missile Technology Control Regime[24] limits the spread of delivery systems capable of carrying nuclear payloads and has evolved to address chemical and biological threats. The Wassenaar Arrangement promotes transparency and responsible transfers of dual-use goods and conventional arms.[25] Both are voluntary, operating through consensus and regular updates to control lists.
International humanitarian law remains a constant reference point. The ICRC stresses that autonomous weapons must comply fully with the rules governing armed conflict, which require distinction, proportionality, precaution, and human accountability. Meaningful human control is essential; machines cannot bear legal or moral responsibility. The CCW provides the primary multilateral forum for addressing lethal autonomy, and its Group of Governmental Experts has examined definitions, prohibitions, lifecycle regulation, training requirements, oversight, and responsibility.
Sessions held in Geneva in 2025 advanced a rolling text structured around five thematic areas, exploring how to ensure reliability, predictability, traceability, human oversight, accountability, and

[23] United Nations Security Council. "*Meeting 9753 'Anticipating the Impact of Scientific Developments on International Peace and Security*." Statement by Amin Awad, President of the Foundation Council, Geneva Centre for Security Sector Governance (DCAF), 21 October 2024. S/PV.9753.
[24] Missile Technology Control Regime (MTCR). *Guidelines for Sensitive Missile-Relevant Transfers*. MTCR, 2020. https://www.nti.org/education-center/treaties-and-regimes/missile-technology-control-regime-mtcr/.
[25] Wassenaar Arrangement. Op. cit.

legal compliance. Despite divergence on key terminology, participants described the process as constructive, with further consultations planned before the 2026 review conference.

Across all discussions, a shared theme emerges: artificial intelligence may assist defense, but it must not supplant human judgment. Policy briefs recommend keeping AI in supportive roles, analysis, anomaly detection, simulation, while preserving human authority in nuclear and lethal decisions. Good governance requires risk review, cybersecurity protections, defined responsibilities, transparency, and systems designed to prevent automation bias. To sustain legitimacy, decision-making must incorporate public reasoning, reinforce international law, and maintain space for human moral agency. Education, red-team testing, and independent oversight are part of this effort.

4.1 Defining Artificial Intelligence in the Military Context: artificial intelligence is broadly understood as a class of computational systems capable of undertaking tasks that typically require human cognitive abilities, including pattern recognition, decision-making, data analysis, and prediction. Within military settings, the term encompasses machine-learning algorithms, computer-vision technologies, natural language processing tools, reinforcement-learning techniques, data-fusion platforms, and autonomous decision-support systems. NATO characterises AI as a "general-purpose, dual-use enabling technology" that can support autonomous platforms, enhance intelligence analysis, accelerate decision-making cycles, and improve operational coordination. At the same time, NATO emphasises that military AI systems must remain subject to meaningful human control and must be traceable, robust, and reliable. These principles delineate the boundary between acceptable uses of military AI and those that present heightened ethical or legal risks.

4.2 Defining "AI-Enabled Weapon": an AI-enabled weapon should not be understood as autonomous in the fully independent sense. For the purposes of this study, an AI-enabled weapon is defined as any system, platform, or weapon whose critical targeting, navigation, surveillance, analytical, or operational functions are supported, enhanced, or carried out by artificial-intelligence or machine-learning algorithms. This definition encompasses autonomous drones and loitering munitions, automated surveillance and target-identification systems, AI-supported cyber-intrusion tools, algorithmic battlefield-management systems, AI-enhanced missile-guidance capabilities, and data-driven targeting models. The crucial conceptual point is that AI need not constitute the weapon itself; rather, it may operate as the enabling layer that transforms a conventional system into one that is more capable and, potentially, more destabilising.

4.3 Autonomy vs Automation: a significant portion of scholarly and policy confusion arises from blurred **distinctions between autonomous and automated systems**. Automated systems operate on the basis of pre-programmed rules and do not adjust their behaviour when confronted with novel or changing environments; a missile that follows GPS coordinates without deviation exemplifies this category. Autonomous systems, by contrast, employ AI to perceive, interpret, and respond to environmental changes without human intervention; a loitering munition that identifies and engages a target based on its onboard AI illustrates this latter category. The distinction is critical: automated systems are generally addressed within existing arms-control frameworks, whereas autonomous systems fall largely outside them.

4.4 Dual-Use Technology: the notion of dual-use is central to this research. UNSCR 1540 traditionally employs the term to refer to materials or equipment with both civilian and military applications, such as biological agents that are legitimate research tools but also weaponisable. AI significantly amplifies this challenge because nearly all leading AI models originate within the commercial sector, most AI system components, GPUs, cloud-computing services, and software libraries, are inherently dual-use, and innovation is driven largely by private industry. AI therefore represents a novel form of dual-use technology that is far more difficult to track, regulate, and categorise than traditional dual-use items.

4.5 AI and Non-State Actors: the traditional logic of UNSCR 1540 focuses on preventing non-state actors, particularly terrorist groups, from accessing weapons of mass destruction. AI, however, lowers many of the barriers that previously restricted such actors. Unlike WMDs, AI-enabled capabilities do not require specialised materials; they can be developed using commercially available drones or

widely accessible AI tools. Open-source AI models and encrypted digital supply chains further facilitate this accessibility. Conceptually, this means that **AI-enabled weapons do not require a state-level industrial base** and may proliferate rapidly among groups historically excluded from advanced military capabilities.

5. Key Research Indicators: to analyse AI-enabled weapons within the framework of UNSCR 1540, this study identifies five categories of research indicators: proliferation indicators, autonomy indicators, supply-chain indicators, human-oversight indicators, and vulnerability indicators.

5.1 Proliferation Indicators: proliferation indicators concern the likelihood that a technology will diffuse beyond state control. In the case of AI, these indicators include the availability of open-source code, the use of cloud-based training platforms, the decreasing cost of commercial drones, the widespread availability of large-scale datasets, and the increasing accessibility of high-performance computing. Collectively, these factors indicate that AI may proliferate more rapidly and broadly than the traditional weapons systems addressed by UNSCR 1540.

5.2 Autonomy Indicators: Aautonomy indicators assess the degree to which AI contributes to a weapon system's functioning. They comprise the system's capacity for perception (such as computer vision and target detection), its decision-making functions (including target classification and engagement rules), its action components (such as autonomous launch, tracking, and engagement), and its learning capabilities (including the possibility of algorithmic adaptation or updates during deployment). Higher levels of autonomy correspond to more significant regulatory gaps.

5.3 Supply-Chain Indicators: AI supply chains diverge fundamentally from those associated with WMD-related technologies. Relevant indicators include reliance on commercial hardware such as consumer drones and GPUs, dependence on software components such as Python libraries and machine-learning frameworks, reliance on data inputs, dependence on cloud-computing infrastructure, and the rapid innovation cycles driven by private-sector developers. Because these supply chains are largely digital, they cannot be monitored using conventional export-control mechanisms.

5.4 Human Oversight Indicators: drawing on NATO's Responsible AI principles, the degree of human involvement provides a key indicator of legality, risk, and accountability. Human-in-the-loop, human-on-the-loop, and human-out-of-the-loop configurations correspond to decreasing levels of human oversight. Systems that operate without human involvement present significantly greater risks.[26]

5.5 Vulnerability and Misuse Indicators: indicators of vulnerability and potential misuse concern the system's susceptibility to harmful or unintended consequences. These include the possibility of weaponisation, the ease with which a system can be repurposed, the risk of algorithmic error, exposure to cyber vulnerabilities, and the difficulty of attributing actions during an attack. These indicators matter because **AI systems may cause harm even when they have not been designed as weapons**.

6. Methodology

This research employs a qualitative and legal-analytical methodology. Because AI-enabled weapons represent an emerging and rapidly evolving phenomenon, qualitative methods provide the necessary flexibility to examine conceptual developments, legal gaps, and policy implications in depth.

6.1 Qualitative Legal Analysis: the central methodological tool is a doctrinal legal analysis that examines the text of UNSCR 1540, its legislative history, subsequent interpretations issued by the 1540 Committee, related UN documents, and relevant Security Council debates and reports. The aim

[26] United Nations Security Council. *Letter dated 8 March 2021 from the Panel of Experts on Libya established pursuant to resolution 1970* (2011). S/2021/229*;* Zachary, Kallenborn. *"*Was a Flying Killer Robot Used in Libya? Quite Possibly*." Bulletin of the Atomic Scientists*, 2021*;* Michael N. Schmitt, and Jeffrey S. Thurnher. *"The Kargu-2 Autonomous Attack Drone: Legal and Ethical Dimensions*." Lieber Institute, West Point, 2021; *Project Ploughshares. "Kargu-2 Debate Raises Awareness of Autonomous Weapons,"* 2021.

is to assess the extent to which AI-enabled weapons may be interpreted within existing provisions and to identify areas requiring reform.

6.2 Comparative Analysis: the study also relies on comparative analysis across various regulatory regimes, including NATO standards and strategies, international humanitarian law, the Wassenaar Arrangement, the Missile Technology Control Regime, the EU Dual-Use Regulation of 2021, and U.S. and European export-control guidelines. This approach allows an assessment of legal coherence and helps identify potential models for regulating AI-enabled weapons.

6.3 Case-Study Method: the chosen case study provides empirical grounding by illustrating how AI-enabled systems function in real conflict environments. The case of Libya in 2020, involving autonomous drone engagements, demonstrates both the risks associated with proliferation and the ways AI can amplify the capabilities of conventional weapons.

6.3.1. Analysis of the 2020 Libyan Conflict: Weapons, Foreign Intervention, and the Legacy of the 2004 UN Resolution: the fighting that unfolded in Libya in 2020 was one of the most internationally saturated civil conflicts of the decade. It combined intense ground combat with heavy foreign involvement, turning the country into a stage for competing geopolitical agendas.

To understand this moment, it is crucial to look not only at the military dimension, especially the flow of conventional weapons and foreign support, but also at the broader international framework that shaped Libya's security environment.

In this regard, the 2004 UN resolution on Libya's renunciation of weapons of mass destruction, although unrelated to conventional arms, created conditions that had long-term consequences for what would later become one of the world's most heavily armed internal conflicts. By 2020, Libya had entered a particularly violent phase of its civil war. Power was split between two main blocs: the UN-recognised Government of National Accord (GNA) in Tripoli, and the Libyan National Army (LNA) led by the Lybian-american politician, military officer Khalifa Belqasim Haftar al-Ferjani (1943-), which controlled much of the east and parts of central Libya.

Early in the year, Haftar's forces intensified their push towards Tripoli, capturing Sirte and significantly weakening the GNA's position. Despite diplomatic attempts to stop the escalation, most notably the Berlin Conference in January, fighting only grew more intense.

The UN Security Council endorsed the Berlin conclusions through Resolution 2510, urging a ceasefire, but without solid enforcement mechanisms, the calls for de-escalation had little practical effect. Weapons supplies and foreign intervention were the driving forces behind the conflict's evolution in 2020. A wide range of military equipment poured into the country: heavy weapons, armoured vehicles, drones, anti-drone systems, surveillance technologies, and vast quantities of small arms. Among these, armed drones became especially important.

Turkish UAVs proved crucial for the GNA, while the UAE provided similar systems to Haftar's forces.[27] These competing technological capabilities helped shape the balance of power on the ground.

The conflict became a proxy battleground as foreign actors backed opposing sides. Turkey offered direct military support, including advisors and Syrian auxiliary fighters, while the UAE supplied Haftar with weapons and air power.

Russia's involvement, primarily through the Wagner Group,[28] added another layer of complexity, bringing mercenaries and additional military equipment into the country. These external interventions fuelled the conflict, prolonged hostilities, and made any progress toward negotiation extremely difficult.

---

[27] Dan, Gettinger. *"*Drones and the Future of Air Warfare*." Air & Space Power Journal* 32, no. 4 (2018)*;* Ulrike, Franke. *"*Not Smart Enough: The Limitations of Artificial Intelligence in Weapons Systems*." Journal of Strategic Studies* 44, no. 6 2021.

[28] European Union. 2020. "EU Launches Operation IRINI to Enforce Libya Arms Embargo." *Council of the European Union Press Release*, 31 March 2020, https://www.operation.eu/about-us/.

Meanwhile, the immense stockpiles of weapons inherited from the Muhammar al-Qaddafi era (1942-2011), many looted during and after 2011, continued circulating among militias, feeding both local and transnational criminal networks.
To make sense of the link between the events of 2020 and the 2004 UN resolution, it is important to remember what that resolution actually addressed. In 2004, Libya decided to dismantle its WMD programmes, and the UN Security Council responded by welcoming this move, encouraging monitoring and international cooperation.
Crucially, the resolution had nothing to do with conventional weapons or arms transfers. Its aim was to facilitate Libya's reintegration into the international community after decades of isolation. Nevertheless, the resolution had indirect but important consequences.
Once Libya abandoned its WMD ambitions, the EU lifted its conventional arms embargo later that year. This reopened Libya to international arms markets and allowed Qaddafi to rapidly rearm between 2004 and 2011. Those same weapons, never properly secured after the fall of the regime, spread widely across the country and beyond its borders, contributing to the chronic insecurity that later fuelled conflicts like the one witnessed in 2020.
In this sense, while the 2004 resolution did not shape the 2020 arms-embargo regime, it formed part of a broader chain of events that ultimately influenced Libya's long-term militarisation. Libya has technically been under a UN arms embargo since 2011, but by 2020 the restrictions were routinely ignored. UN experts documented continuous and blatant violations by multiple states.
The EU launched Operation Irini in March 2020[29] to strengthen embargo enforcement at sea, yet the mission had neither the mandate nor the capacity to monitor land and air routes, precisely the channels through which most weapons were entering the country. The inability to uphold the embargo contributed directly to the continuation of the conflict and to the suffering of civilians, who endured bombardments, mines, improvised explosive devices, and generalised insecurity.
Libya's conflict in 2020 demonstrates how decisive foreign intervention and weapons flows can be in determining the course and intensity of a civil war. The 2004 UN resolution, though focused exclusively on WMDs, indirectly shaped the trajectory that allowed Libya to accumulate enormous conventional arsenals, many of which fuelled later instability.
By 2020, Libya had become a heavily militarised arena where international actors routinely violated the arms embargo, undermining diplomatic efforts and prolonging violence.
Any long-term solution to Libya's instability must therefore go beyond political negotiations among Libyan actors. It must also involve credible, enforceable mechanisms to control the movement of weapons and hold states accountable for repeated violations of international law.

6.3 Actor-Based Analysis: given AI's unique development ecosystem, this research also analyses: state actors, non-state actors, private-sector companies, open-source communities, cloud infrastructure providers. This approach broadens traditional non-proliferation analysis to include entities that UNSCR 1540 did not originally consider.

6.5 Triangulation: the findings from doctrinal, comparative, and case-study analyses are integrated through methodological triangulation to produce robust conclusions. Triangulation mitigates the limitations of relying on a single method and ensures analytical consistency across conceptual, legal, and empirical data.

6.6 Why Quantitative Methods Were Not Selected:AI proliferation and governance currently lack: comprehensive datasets, global reporting mechanisms, transparent inventories of AI-enabled weapons, systematic documentation in conflict zones. Thus, a quantitative or statistical methodology would be unreliable and potentially misleading. A qualitative approach could be therefore more appropriate.

7. Predicted Outcomes

[29] Akram, Kharief. 2022. *Wagner in Libya – Combat and Influence.* Tunis: Rosa Luxemburg Stiftung, North Africa Office, January.

Based on the methodology and conceptual foundations, this research anticipates several outcomes: UNSCR 1540 is structurally incapable of addressing AI-enabled weapons under its current wording. Dual-use AI technologies will continue to proliferate rapidly. Non-state actors will increasingly exploit commercial AI capabilities. Without reform, the Resolution will be unable to mitigate emerging digital threats. International law must adapt to regulate intangible technologies, software supply chains, and private-sector innovation.
These predicted outcomes guide the transition to Part III.

PART III Analysis, Discussion, and Results

7. Analysis: Structural Limitations of UNSCR 1540 in the Age of AI

7.1 Textual and Conceptual Constraints of UNSCR 1540: UNSCR 1540 was adopted in 2004 in a security environment deeply shaped by fears that non-state actors, especially transnational terrorist organisations, might acquire nuclear, chemical, or biological weapons. It rests on three central obligations for states: to refrain from assisting non-state actors in acquiring weapons of mass destruction; to adopt domestic legislation criminalising WMD proliferation; and to implement measures to secure materials, equipment, and technologies associated with the production or delivery of such weapons.
The Resolution's drafting history reveals its reactive character, emerging from concerns about nuclear trafficking networks, unsecured chemical arsenals, and potential misuse of biological agents.
It was shaped by the post-9/11 geopolitical climate and the revelations surrounding clandestine proliferation networks. At that time, artificial intelligence was not an element of global security discussions, and digital technologies did not occupy the central role in military operations that they do today.
The Resolution is explicitly focused on materials such as fissile elements, toxins, and chemical precursors; equipment such as centrifuges, dispersal systems, and fermenters; technological expertise relevant to WMD development; and physical means of delivery, including missiles, aerosol devices, and contaminated vectors. This structure reflects a world in which weapons and proliferation risks were primarily material and therefore traceable.
By contrast, AI-enabled weapons are non-material, easily transferable in digital form, and blur the distinction between material and immaterial capabilities.
The Resolution makes no reference to artificial intelligence, autonomy, software, algorithms, cyber capabilities, machine-learning systems, cloud infrastructures, digital supply chains, or civilian technological innovation.
As a result, the conceptual framework of UNSCR 1540 does not encompass rapidly evolving digital technologies that have become central to contemporary military capabilities.
7.2 Why AI Cannot Be Interpreted as Implicitly Covered: some commentators have suggested that AI could be subsumed under the Resolution's references to "means of delivery." This interpretation is difficult to sustain. Artificial intelligence is not a delivery system in its own right, nor does it disperse nuclear, chemical, or biological agents. It is instead **a general-purpose technology that enhances delivery systems rather than constituting them**.
The Resolution's focus remains on physical proliferation risks, not on the digital enablers that may augment those risks. Moreover, state practice since the Resolution's adoption has never treated AI systems as falling within its scope. A further argument proposes that AI could be considered part of the category of "related materials" that states must prevent non-state actors from acquiring, but this category has always been understood to include items such as precursors, toxins, and specialised equipment.
AI does not fit within these definitions. For these reasons, the Resolution cannot be interpreted to include AI without substantial legal amendment.

7.3 The Practical Problem: AI's Intangible Nature: traditional approaches to non-proliferation focus on regulating physical objects that can be detected and monitored through export controls, customs inspections, intelligence assessments, satellite imagery, materials accounting, and laboratory oversight. AI-enabled weapons, however, exist primarily in the domain of software, open-source libraries, digital downloads, cloud-based services, and publicly shared algorithms.
Such components can be transferred instantaneously across borders without activating existing detection mechanisms. Even a broad interpretation of UNSCR 1540 would leave it without the operational tools necessary to regulate intangible technological proliferation.

8. Case Study of AI-Enabled Weapons in Contemporary Conflicts

8.1 Libya (2020): The Kargu-2 Autonomous Drone Incident: the following case study illustrates how AI-enabled systems are already employed in conflict settings, revealing the security challenges arising from their proliferation.
In March 2021, a UN Panel of Experts reported that, in 2020 during the Libyan civil conflict, Turkey's Kargu-2 loitering munition may have autonomously identified and engaged targets without human intervention. Although this conclusion remains contested, the incident is widely cited as the first documented instance of an autonomous lethal weapon operating independently. The drone employed machine-learning-based image recognition, selected targets using onboard sensors, and displayed autonomous "hunt and kill" behaviour.[30]
It was reportedly deployed by a non-state actor, namely Libyan militias. The implications of this episode are significant. An AI-enabled weapon produced by a state proliferated into the hands of non-state groups; it engaged targets without human oversight; and the entire event fell outside the regulatory reach of UNSCR 1540.
The case thus demonstrates how AI-enabled weapons can operate beyond the scope of existing non-proliferation mechanisms.
8.4 AI-Driven Cyber Operations: artificial intelligence is increasingly integrated into cyber weapons, enabling capabilities such as automated exploitation of vulnerabilities, intelligent propagation of malware, adaptive network attacks, rapid reconnaissance, data exfiltration, and disruption of critical infrastructure. AI-enabled cyber tools have been employed in attacks directed at defence networks in the Mena Region.
These tools are inherently dual-use, widely accessible, and virtually impossible to regulate under the framework established by UNSCR 1540.
8.5 Lessons from the Case Study: the Libyan case illustrates several broader trends. AI-enabled weapons are already deployed in active conflicts. Increasing autonomy reduces the level of technical expertise required to conduct sophisticated attacks. Private-sector actors play a central role in integrating AI into military systems. Non-state groups increasingly access commercially available AI-enabled drones. And AI complicates attribution, accountability, and escalation control.
Taken together, these trends underscore the urgency of developing legal frameworks capable of addressing AI proliferation.

9. Comparison with Other Legal and Regulatory Frameworks

This section analyses how existing governance mechanisms treat AI-related technologies and how their approaches might inform potential updates to UNSCR 1540.
9.1 The Wassenaar Arrangement: the Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods has attempted to regulate items such as intrusion software, sophisticated sensors, and digital surveillance systems.[31] However, it does not regulate AI algorithms,

[30] United Nations Security Council. 2021. *Letter dated 8 March 2021 from the Panel of Experts on Libya established pursuant to resolution 1970.* 2011. S/2021/229; United Nations Security Council. 2024. *Letter dated 13 December 2024 from the Panel of Experts on Libya established pursuant to resolution 1973.* 2011. S/2024/914.
[31] Wassenaar Arrangement. Op. cit.

covers hardware more effectively than software, and does not account for open-source AI or the role of cloud computing.
The Arrangement illustrates the inherent limitations of traditional export-control models when applied to rapidly diffusing digital technologies.
9.2 The Missile Technology Control Regime (MTCR): the MTCR regulates delivery systems capable of transporting WMDs. Although AI-enhanced navigation technologies may indirectly fall under some MTCR categories, the Regime does not address AI explicitly.
Two lessons emerge: technology-specific regimes tend to overlook digital enablers, and highly mobile, lightweight, commercially available systems such as drones evade traditional control mechanisms.
9.3 The European Union's Dual-Use Regulation (2021): the EU's Dual-Use Regulation is one of the most advanced international mechanisms for governing intangible technologies.[32] It covers certain forms of surveillance software, encryption systems, and cyber tools.
Yet it remains unable to govern open-source AI models, regulate algorithms trained on publicly accessible datasets, or ensure consistent implementation across member states. Its limitations show that even sophisticated regional frameworks are insufficient without global harmonisation.
9.4 International Humanitarian Law (IHL): International humanitarian law supplies principles such as distinction, proportionality, precaution, and accountability, all of which are relevant to the use of AI in conflict.[33]
However, IHL does not regulate weapons before their proliferation, cannot prevent acquisition by non-state actors, and applies only within the context of armed conflict. It therefore complements non-proliferation law but does not replace it.
9.5 NATO Principles for Responsible AI: NATO's 2021 AI Strategy articulates principles such as transparency, traceability, human oversight, reliability, governability, and bias mitigation. These principles stress the importance of maintaining human control and accountability and are directly relevant for contemplating the regulation of AI-enabled weapons.
9.6 Lessons for UNSCR 1540: numerous lessons emerge from this short comparative analysis. **AI must be regulated primarily as software rather than hardware**. Dual-use digital technologies require new forms of monitoring. The cooperation of private-sector actors is indispensable. International harmonisation is essential to avoid regulatory fragmentation. And definitions must be updated to incorporate autonomy, algorithms, and machine-learning systems. These insights serve as the foundation for the policy recommendations that follow.

10. Policy Recommendations: Updating UNSCR 1540 or Drafting a New Resolution

10.1 Option 1: Updating UNSCR 1540: one approach is to update UNSCR 1540 directly. Doing so would require amending the Resolution's definitions to include artificial intelligence, autonomous systems, machine-learning algorithms, AI-enabled weapons, and cyber-AI tools.
It would also require expanding the Resolution's scope to encompass digital proliferation pathways, mandating national legislation regulating AI-enabled weapons, and introducing reporting obligations concerning private-sector AI development that bears on national security.
Moreover, the 1540 Committee's mandate would need to be broadened to include digital technologies. The advantages of this approach lie in its reliance on an existing global framework, the

[32] European Union. *EU Dual-Use Regulation 2021/821*. Brussels: European Commission, 2021.
[33] D., Decker, & K., Rauhut. 2024. *The Implementation of UN Security Council Resolution 1540*. In A. Pytlak & J. Siebens (Eds.), *Advancing Accountability in Cyberspace: Models, Mechanisms, and Multistakeholder Approaches* pp. 34-45. Stimson Center. http://www.jstor.org/stable/resrep62165.5.

avoidance of political complexities associated with drafting a new resolution, and its use of obligations already understood by states.
Its disadvantages include probable political resistance from technologically advanced states and the risk of stretching the Resolution's original mandate beyond its intended limits.
10.2 Option 2: Creating a New UN Resolution on AI and Emerging Technologies: a more ambitious alternative is the **creation of a new UN Security Council resolution devoted specifically to emerging technologies.**
Such an instrument would define AI-enabled weapons, regulate dual-use software and algorithms, require states to control access to cloud-based AI training resources, create mechanisms for international oversight of private-sector AI development, establish norms for human oversight, and set standards for data access and model training with military implications.
This approach would be tailored to contemporary technological threats and would avoid distorting the conceptual structure of UNSCR 1540. However, it would require consensus within the Security Council and could take years to negotiate.
10.3 Cooperation Between the UN and Private AI Companies: given that AI originates predominantly in the commercial sector, effective regulation must involve systematic cooperation with private companies. Key mechanisms would include transparency agreements, mandatory risk assessments, reporting requirements, export controls for high-risk AI models, and frameworks governing the safe release of advanced systems.
10.4 New Definitions of "Threat" in the AI Era: a modernised non-proliferation regime must update its definition of threats to include autonomous targeting systems, AI-enabled cyber weapons, algorithmic decision-support systems used in kinetic operations, AI-directed drone swarms, and private-sector military AI platforms.
10.5 Monitoring and Verification Mechanisms: effective monitoring of AI proliferation will require tools distinct from those used in traditional arms control. These include software audits, the submission of model cards, digital supply-chain tracking, oversight of access to cloud-computing resources, and verification of autonomous functionalities. Although these mechanisms differ from established verification practices, they are indispensable in the digital domain.

Conclusion

In conclusion, the evidence demonstrates that the existing non-proliferation regime, exemplified by UNSCR 1540, no longer aligns with the technological realities driving AI-enabled warfare. The Resolution was designed to govern physical equipment, delivery systems, and traceable supply chains, yet AI-driven weapons derive their power from code, datasets, cloud infrastructure, and machine-learning models, elements that can be replicated, modified, and circulated far beyond the reach of traditional export controls.
At the same time, proposals for regulatory expansion, including the initiative introduced by Mexico and examined by the *Senior Adviser to the UN Disarmament Commission*,[34] reflect a shared recognition that governance must adapt to software-based military systems that proliferate with unprecedented speed. On biological and chemical weapons, the United Nations will also receive a forthcoming proposal from Washington DC to establish a verification system, with particular attention to the Mena Region. Regarding drone systems, consensus is emerging that AI-enabled drones require regulation across all sectors, as a fragmented or overly general solution risks becoming ineffective and subject to widespread criticism. This is especially true for developing countries, which fear being excluded from discussions on AI-based weapons despite being the regions where such systems are frequently tested.
Despite these challenges, multiple states converge on the need for a unified approach capable of protecting the international order from the destabilising risks posed by autonomous targeting,

[34] Senior Adviser to the UN Disarmament Commission. New York. Personal Interview 5/12/2025. Thank to L. Wallnoefer.

accelerated escalation cycles, and the empowerment of armed actors who previously lacked access to high-end capabilities. An effective framework must preserve the foundations of international law while integrating AI-specific mechanisms for transparency, traceability, human oversight, and accountability. Whether pursued through a structured amendment of existing resolutions or through the creation of a dedicated instrument, the overarching objective remains the same: preventing AI-enabled weapons from expanding unchecked into a regulatory vacuum.

Importantly, the debate must also acknowledge the many positive applications of AI within civil society. AI technologies already enhance healthcare, scientific research, environmental monitoring, public administration, disaster response, and economic development. These benefits demonstrate that AI is not simply a vector of risk but a powerful tool for human progress, provided that adequate safeguards, ethical norms, and democratic oversight are in place.

The future security environment will depend on recognising AI as a primary vector of proliferation and embedding safeguards that govern both its development and its potential misuse. International law already applies to AI in warfare, and responsibility rests with humans throughout a system's entire lifecycle. While many states call for rapid movement toward a legally binding treaty, others favour gradual norm-building, concerned that overly rigid rules may fail to keep pace with technological change. Still, there is broad agreement that the debate must be inclusive, engaging technologically limited states and integrating scientific, industrial, and civil-society expertise.

States retain ultimate decision-making authority, and UN disarmament forums remain the most universal venue for negotiation. The Secretary-General urges all governments to act decisively at the next General Assembly to establish an institutional mechanism dedicated to military AI and its implications for global security.

Achieving this will require sustained cooperation at every level. Multilateral forums can maintain dialogue and advance norms. Regional organisations can adapt frameworks to local contexts. National strategies must strengthen legal review, accountability, data governance, and training for those who develop, operate, and supervise AI systems.

By integrating AI into military practice in ways that reinforce, rather than replace, human responsibility, the international community can anchor future security in ethics, law, and restraint, while simultaneously preserving the many constructive contributions that AI offers to civilian life.

Bibliography

Policy and Institutional Documents

"United States: Statement by the United States on the Twentieth Anniversary of UNSCR 1540." 2024. *MENA Report*, May 07. https://www.proquest.com/wire-feeds/united-states-statement-on-twentieth-anniversary/docview/3051743076/se-2.

European Union. 2020. "EU Launches Operation IRINI to Enforce Libya Arms Embargo." *Council of the European Union Press Release, 31 March 2020*, https://www.operation.eu/about-us/.

European Union. *EU Dual-Use Regulation 2021/821*. Brussels: European Commission, 2021.

Missile Technology Control Regime (MTCR). *Guidelines for Sensitive Missile-Relevant Transfers*. MTCR, 2020. https://www.nti.org/education-center/treaties-and-regimes/missile-technology-control-regime-mtcr/.

NATO. *NATO Artificial Intelligence Strategy*. Brussels: NATO Headquarters, 2021.

NATO. *Principles of Responsible Use of Artificial Intelligence in Defence*. Brussels: NATO, 2021.

U.S. National Security Commission on AI (NSCAI) recommendations (2021). https://reports.nscai.gov/final-report/.

UN Panel of Experts on Libya. 2020. *Final Report of the Panel of Experts on Libya Established Pursuant to Security Council Resolution 1973 (2011).* New York: United Nations Security Council.

UNITED NATIONS (U.N.) SECURITY COUNCIL: RESOLUTION 1540 (NON-PROLIFERATION OF WEAPONS OF MASS DESTRUCTION). (2004). *International Legal Materials*, *43*(5), 1237-1239. http://www.jstor.org/stable/20694499.

United Nations Security Council. “Meeting 9753 ‘Anticipating the Impact of Scientific Developments on International Peace and Security.’” Statement by Amin Awad, President of the Foundation Council, Geneva Centre for Security Sector Governance (DCAF), 21 October 2024. S/PV.9753.
United Nations Security Council. 2004. “Security Council Welcomes Libya’s Decision to Dismantle Weapons of Mass Destruction.” Press Release SC/8069, 22 April 2004.
United Nations Security Council. 2011. *Resolution 1970 (2011).* S/RES/1970. New York: UN (establishing the arms embargo).
United Nations Security Council. 2020. *Resolution 2510 (2020).* S/RES/2510. New York: UN (endorsing the Berlin Conference conclusions).
United Nations Security Council. *Security Council Resolution 1540 (2004)*. New York: United Nations, 2004.
Wassenaar Arrangement. *List of Dual-Use Goods and Technologies*. Vienna: Wassenaar Secretariat, 2022.

Bibliography – Kargu-2 Autonomous Drone Incident (Libya, 2020)

1. Primary / Official Sources

United Nations Security Council. (2021). *Letter dated 8 March 2021 from the Panel of Experts on Libya established pursuant to resolution 1970 (2011).* S/2021/229.
United Nations Security Council. (2024). *Letter dated 13 December 2024 from the Panel of Experts on Libya established pursuant to resolution 1973 (2011).* S/2024/914.
Organisation for the Prohibition of Chemical Weapons (OPCW). 2004. “Libya’s Accession and Destruction of Chemical Weapons.” OPCW Technical Report, The Hague.

2. Academic & Peer-Reviewed Literature

Hayir, N. (2021). “Defining Weapon Systems with Autonomy”. *Groningen Journal of International Law*, 9(1).
Oyewole, S. (2025). “Autonomous Weapons Systems in Africa”. *African Security Review*, 34.
Williams, P.R. (2025). “Laws on LAWS: Regulating Lethal Autonomous Weapon Systems”. *Journal of Indo-Pacific Affairs*, 8(3).

3. Legal and Policy Analyses

Schmitt, M.N., & Thurnher, J.S. (2021). *The Kargu-2 Autonomous Attack Drone: Legal and Ethical Dimensions.* Lieber Institute (West Point).
Kallenborn, Z. (2021). “*Was a Flying Killer Robot Used in Libya? Quite Possibly”. Bulletin of the Atomic Scientists*.
Nadibaidze, A. (2022). “Commitment to Control Weaponised Artificial Intelligence”. *Geneva Centre for Security Policy*.
Project Ploughshares. (2021). *Kargu-2 Debate Raises Awareness of Autonomous Weapons.*

4. Technical and Defence-Oriented Sources

Bronk, J., & Cranny-Evans, S. (2021). “Armed Uninhabited Aerial Vehicles and the Challenges of Autonomy”. *International Institute for Strategic Studies* (IISS).
Automated Research. (n.d.). *STM Kargu Loitering Munition.*
Autonomous Weapons Watch. (n.d.). *STM Kargu-2 UAV.*

5. Normative / International Humanitarian Law Frameworks

International Committee of the Red Cross (ICRC). (2021). “Libya: The Use of Lethal Autonomous Weapon Systems (LAWS)”. *ICRC Casebook on International Humanitarian Law*.

6. Broader Scholarly and Policy Context

Bode, I., et al. 2023. *Loitering Munitions and Unpredictability: Autonomy in Weapon Systems and the Challenge to Human Control.* University of Southern Denmark.
Kao, T.F. 2024. *Drones and AI in Modern Warfare: A Security Analysis.* SIT Digital Collections.
Wehrey, Frederic. 2018. *The Burning Shores: Inside the Battle for the New Libya.* New York: Farrar, Straus and Giroux. (Pre-2020 context on the militarisation of Libya.)

Zoubir, Yahia H., and Karim Mezran. 2020. *The Politics of Conflict in Libya.* Washington, DC: Atlantic Council.

Interviews

UN Senior Adviser to the UN Disarmament Commission. New York. Personal Interview 5/12/2025. Thank to L. Wallnoefer.

Secondary Sources

Andersson, J.J., & Cramer, C.S. 2023. Statistical Annex. In *EUISS YEARBOOK OF EUROPEAN SECURITY: 2023* pp. 108-115. European Union Institute for Security Studies (EUISS). http://www.jstor.org/stable/resrep52685.22.

Bertolini, Francesco, Wolfram Lacher, and Alaa al-Idrissi. 2020. *Foreign Intervention and Libya's Proxy War.* Berlin: Stiftung Wissenschaft und Politik (SWP).

Bosch, Olivia, and Peter Van Ham (Eds.). *Global Non-Proliferation and Counter-Terrorism: The Impact of UNSCR 1540*. The Hague: Clingendael Institute, 2007.

Buchanan, Ben. "The New Era of Cyber-Enabled Strategy." *Survival* 61, no. 1 (2019): 27-48. https://doi.org/10.1080/00396338.2019.1568043.

Buchanan, Ben. *The Hacker and the State: Cyber Attacks and the New Normal of Geopolitics*. Cambridge, MA: Harvard University Press, 2020.

Burian, P. (2007). "The Perils of Proliferation: Combating WMD in an Age of Terror". *Harvard International Review*, 29(3), 88-87. http://www.jstor.org/stable/43650223

Decker, D., & Rauhut, K. 2024. The Implementation of UN Security Council Resolution 1540. In A. Pytlak & J. Siebens (Eds.), *Advancing Accountability in Cyberspace: Models, Mechanisms, and Multistakeholder Approaches* pp. 34-45. Stimson Center. http://www.jstor.org/stable/resrep62165.5.

Dunnicliff, J., & Izewicz, P. (2015). "Civilian or military? addressing dual- use items as a challenge to the nuclear non-proliferation regime". *The Polish Quarterly of International Affairs, 24*(3), 21-II. Retrieved from https://www.proquest.com/scholarly-journals/civilian-military-addressing-dual-use-items-as/docview/1757725927/se-2.

Finlay, B. (Ed.) (2014). In *Southern Flows: WMD Nonproliferation in the Developing World* pp. 184-188. Stimson Center. http://www.jstor.org/stable/resrep11012.14

Finlay, B. (Ed.) (2014). UN Security Council Resolution 1540: The Next 10 Years. In *Southern Flows: WMD Nonproliferation in the Developing World* pp. 153-160. Stimson Center. http://www.jstor.org/stable/resrep11012.11

Finlay, B., Bergenas, J., & Tessler, V. (2010). Diversifying Capacity-Building Assistance: United Nations Security Council Resolution 1540. In *Beyond Boundaries in the Middle East: Leveraging Nonproliferation Assistance to Address Security/Development Needs with Resolution 1540.* pp. 22-23. Stimson Center. http://www.jstor.org/stable/resrep10895.7.

Fox, Amos C. "Precision Paradox and Myths of Precision Strike in Modern Armed Conflict." *The RUSI Journal* 169, nos. 1-2 (2024): 62-74. https://doi.org/10.1080/03071847.2024.2343717.

Franke, Ulrike. "Not Smart Enough: The Limitations of Artificial Intelligence in Weapons Systems." *Journal of Strategic Studies* 44, no. 6 (2021): 921-945.

Gettinger, Dan. "Drones and the Future of Air Warfare." *Air & Space Power Journal* 32, no. 4 2018: 55-72.

Van Ham, Peter, Bosch, Olivia. "Global non-proliferation and counter-terrorism: The impact of UNSCR 1540" (2007). *Arms Control Today, 37*(6), 48. https://www.proquest.com/scholarly-journals/global-non-proliferation-counter-terrorism-impact/docview/211264597/se-2.

Hess, A.A.C. 2019. *Has UN Security Council Resolution 1540 Strengthened the International Nonproliferation Regime?* (Order No. 22583556). (2305945548). https://www.proquest.com/dissertations-theses/has-un-security-council-resolution-1540/docview/2305945548/se-2.

Holmes, John and Detlof Winterfeldt. (07/2025). "Evaluating Compliance with UN Security Council Resolution 1540 on Nonproliferation of Weapons of Mass Destruction." *Risk Analysis* 45 (7): 1766-1791. doi:10.1111/risa.17697.
Holtom, P., & Bromley, M. (2011). International reporting mechanisms on arms transfers and transfer controls. In *Implementing an Arms Trade Treaty: Lessons on Reporting and Monitoring from Existing Mechanisms* pp. 4-19. Stockholm International Peace Research Institute. http://www.jstor.org/stable/resrep19195.7.
Horowitz, Michael and Paul, Scharre. "Meaningful Human Control in Weapon Systems: A Primer." *Parameters* 46, no. 3 (2016): 7-15.
Horowitz, Michael. *The Diffusion of Military Power: Causes and Consequences for International Politics*. Princeton: Princeton University Press, 2010.
Hughes, C.T. (2023). "Advanced reactors and nuclear terrorism: Rethinking the international framework". *Journal of National Security Law & Policy, 13*(3), 521-551. Retrieved from https://www.proquest.com/scholarly-journals/advanced-reactors-nuclear-terrorism-rethinking/docview/2839711064/se-2.
Human Rights Watch. *A Hazard to Human Rights: Autonomous Weapons Systems and Digital Decision-Making.* New York: Human Rights Watch, 28 April 2025.
International Crisis Group. (2020). "The Libyan Conflict and Prospects for Stabilisation". Brussels: ICG *Middle East & North Africa Report*.
Jones, S. (2006). "Resolution 1540: Universalizing Export Control Standards?". *Arms Control Today*, *36*(4), pp. 18-22. http://www.jstor.org/stable/23627676.
Kharief, Akram. 2022. *Wagner in Libya – Combat and Influence.* Tunis: Rosa Luxemburg Stiftung, North Africa Office, January.
Khripunov, I. (2014). "Looking Back: A Work in Progress: UN Security Resolution 1540 After 10 Years". *Arms Control Today*, *44*(4), 39-43. http://www.jstor.org/stable/24336466.
Lacher, Wolfram. 2020. *Libya's Fragmentation: Structure and Process in Violent Conflict.* London: I.B. Tauris.
Lee, M., & Nacht, M. (2020) Challenges to the Nuclear Non-Proliferation Treaty. *Strategic Studies Quarterly*, *14*(3), 95-120. https://www.jstor.org/stable/26937413.
Megerian, Anna. (2020). "Arms Proliferation in Libya: Dynamics and Regional Spillover." *Journal of Strategic Studies* 43(7): 1-23.
Ogilvie-White, T. (2006). "Non-proliferation and counter-terrorism cooperation in Southeast Asia: Meeting global obligations through regional security architectures?". *Contemporary Southeast Asia, 28*(1), 1-26. doi:https://doi.org/10.1355/CS28-1.
Payne, Kenneth, and Jonathan B. How. "Artificial Intelligence and the Changing Logic of War." *International Affairs* 96, no. 5 (2020): 1369-1389.
Payne, Kenneth. *I, Warbot: The Dawn of Artificially Intelligent Conflict*. London: Hurst, 2021.
Pézard, Stéphanie, and Michael Shurkin. 2015. *Arms Trafficking and Insecurity in Libya.* Santa Monica, CA: RAND Corporation.
Punzi, Clara. "New technologies and AI: envisioning future directions for UNSCR 1540." *arXiv preprint arXiv:2410.08216.* (2024).
Rehman, H., & Qazi, A. (2019). Significance of UNSCR 1540 and emerging challenges to its effectiveness. *Strategic Studies, 39*(2), 48. Retrieved from https://www.proquest.com/scholarly-journals/significance-unscr-1540-emerging-challenges/docview/2333580107/se-2.
Ricardo Gosalbo Bono, 'Some reflections on the CFSP legal order', (2006), 43, *Common Market Law Review, Issue* 2, pp. 337-394, https://kluwerlawonline-com.ezproxy.unicatt.it/JournalArticle/Common+Market+Law+Review/43.2/COLA2006023.
Roff, Heather. "Lethal Autonomous Weapons and the Future of Jus Ad Bellum." *Ethics & International Affairs* 31, no. 3 (2017): 275-291.
Roff, Heather. *Autonomous Military Robotics: Risk, Ethics, and Design*. Cambridge: Cambridge University Press, 2019.

Rosand, E. (2009). *Global Implementation of Security Council Resolution 1540 - An Enhanced UN Response is Needed*. Global Center on Cooperative Security. http://www.jstor.org/stable/resrep20364.
Russell, Stuart. *Human Compatible: Artificial Intelligence and the Problem of Control*. New York: Viking, 2019.
Scharre, Paul. "The Role of Artificial Intelligence in Future Warfare." *National Security Journal* 3, no. 2. (2021): 1-22.
Scharre, Paul. *Army of None: Autonomous Weapons and the Future of War*. New York: W.W. Norton, 2018.
Shirazyan, S. (2018). "'Synergies of Strengths': A Framework to Enhance the Role of Regional Organizations in Preventing WMD Proliferation". *Arms Control Today*, *48*(7), 16-22. https://www.jstor.org/stable/90024650.
Shirazyan, S. (2019). "Building A universal counter-proliferation regime: The institutional limits of United Nations Security Council Resolution 1540". *Journal of National Security Law & Policy, 10*(1), pp. 125-170. https://www.proquest.com/scholarly-journals/building-universal-counter-proliferation-regime/docview/2230660483/se-2.
Shirazyan, S., Conant, C.M., Dunnmon, J., Ensley, D., Green, A.E., Lissner, R.F., Menke, H., Van Dine, A., Washington, B., Wellington, T.A., & Wiener, R. 2017. Combatting WMD Terrorism: Law, Politics, and Flexibility of the UN Security Council Resolution 1540. In M. Cancian (Ed.), *Project on Nuclear Issues: A Collection of Papers from the 2016 Nuclear Scholars Initiative and PONI Conference Series*. pp. 85-100. Center for Strategic and International Studies (CSIS). http://www.jstor.org/stable/resrep23162.10.
Singer, P.W. *Cybersecurity and Cyberwar: What Everyone Needs to Know*. New York: Oxford University Press, 2014.
Stimson Center. 2016. Second Place: The United States of America National Action Plan for Implementation of Resolution 1540 (2004). In *COUNTERING WMD PROLIFERATION: THE NEXT GENERATION'S IDEAS: Results of the UN Security Council Resolution 1540 (2004) International Student Essay Competition* pp. 19-25. Stimson Center. http://www.jstor.org/stable/resrep10907.8.
Thomas Renard, "Partnering for Global Security: The EU, Its Strategic Partners and Transnational Security Challenges" (2016), 21, *European Foreign Affairs Review*, Issue 1, pp. 9-33, https://kluwerlawonline-com.ezproxy.unicatt.it/JournalArticle/European+Foreign+Affairs+Review/21.1/EERR2016003.
Vaseashta Ashok, Khudaverdyan Surik (Eds.). 2013. *Advanced Sensors for Safety and Security*. Dordrecht: Springer.