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The Role of AI Decision-Making for Land-Based Operations

FINABEL

European Land Force Commanders Organisation

WRITTEN BY:

Petar Petrović is a specialist in defence, security, and international relations, focusing on strategic analysis, hybrid warfare, and policy development. His expertise is in producing in-depth research and insightful publications addressing complex geopolitical challenges and emerging security threats.

Manuel Tavares Martins Dias is an MA student specialising in international security research with a focus on emerging and disruptive technologies. His fields of expertise are technical analysis, hybrid geopolitical environments and cyclic sustainability.

Niccolò Grasso is a defence and security researcher at FINABEL with a focus on European security policy, transatlantic relations and defence procurement policy. His academic research covers topics such as hybrid and covert warfare, NATO and EU relations with non-EU and non-NATO Eastern European countries and European defence collaborative projects.

Victoriano Vicente Botella Berenguer is a young Spanish security studies expert who specialises in European security and defence strategy, intelligence analysis, and strategic crisis management. His academic research interests include EU foreign and security policy, Middle East geopolitics, and migration governance, with a focus on incorporating intelligence frameworks into current security concerns.

Morgane Denieul is a legal researcher at FINABEL with an academic background in International and European Law. Her academic research interests cover EU strategic autonomy, international humanitarian law and the evolving legal frameworks shaping the NATO-EU defence cooperation in the aftermath of the 2022 Russian invasion of Ukraine.

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DIRECTOR'S EDITORIAL:

In today's increasingly complex and unpredictable global landscape, the role of artificial intelligence (AI) in military decision-making has become both a necessary tool and a transformative force. AI stands at the junctions of innovation and ethical complexity, capable of reshaping land-based military operations and enhancing operational efficiency, yet it also presents critical challenges to transparency and governance. In examining the role of AI in European land-based military decision-making, this paper routes the technological advances AI brings, the operational hurdles it addresses, and the caution required in its deployment.

The resurgence of large-scale land warfare, influenced by the ongoing conflict in Ukraine, has underscored the importance of robust, responsive, and technologically enabled military systems. AI has emerged as a fundamental component in this equation, enhancing real-time data analysis, predictive modelling, and situational awareness. This integration allows European land forces to maintain a competitive edge, addressing strategic necessities such as speed and interoperability in coalition operations. The development of AI-powered sensor-to-shooter systems and multi-domain operational capabilities promises to streamline decision-making processes, creating a more agile and responsive military force.

With these technological advancements come significant challenges. The dual-use nature of AI–that is, its applicability in both civilian and military realms–adds a layer of complexity to its adoption. European military forces face the challenge of integrating AI within their operational frameworks while upholding strict ethical and legal standards. The rapid pace of AI development, coupled with a fragmented global regulatory landscape, necessitates a cohesive governance structure. Without clear standards and international regulations, AI technology could exacerbate security risks, increase the potential for unintended escalation, and even challenge the foundational principles of humanitarian law.

Reliance on AI introduces ethical considerations, particularly when discussing autonomous systems capable of making life-and-death decisions without human intervention. Maintaining human oversight is crucial to avoid overreliance on algorithms that may lack transparency and accountability. For European land forces, the adoption of AI must be pursued with a commitment to ensuring ethical integrity, operational transparency, and a balanced approach to technological integration.

This paper reflects on AI's potential and responsibility in military decision-making. The path will require a delicate balance between embracing innovation and safeguarding humanity's ethical and legal foundations. The integration of AI into military frameworks represents a strategic advantage, yet it must be approached with foresight and caution to uphold the values that underpin our democratic societies.

Mario Blokken
Director

ABSTRACT

In an era of technological 'Oppenheimer momentum,' Artificial Intelligence (AI) has emerged as the new frontier in military decision-making, presenting enormous promises and challenges. This paper investigates the transformational impact of AI in the context of European land-based military operations, focussing on how AI may speed up decision-making, improve interoperability, and reshape traditional command and control (C2) structures. AI's unprecedented capacity to interpret large data sets in real time can improve battlefield responsiveness and operational efficiency, acting as a force multiplier in multi-domain operations.

In the current context of global military competition, AI's dual-purpose nature—its applicability in both civilian and military contexts—presents European ground forces with a competitive advantage, notably in sensor-to-shooter systems, predictive analysis, and autonomous decision-making. In addition to these improvements, this paper discusses the ethical, legal, and security problems connected with AI use for such purposes. As autonomous systems perform more complicated jobs, worries about accountability, transparency, and potential overreliance on opaque AI algorithms pose critical considerations about the future of combat and global security.

The present study not only emphasises AI's capacity to transform contemporary military decision-making mechanisms but also advocates for a strong governance structure that provides human supervision, ethical purity, and the preservation of international security standards in the context of unmanned conflict.

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
AI-DSS	Artificial Intelligence Decision Support System
ANTICIPE	Augmented Near Real-Time Instrument For Critical Information Processing And Evaluation
AWS	Autonomous Weapons System
C2	Command And Control
C4I	Air Command, Control, Communications, Computers And Intelligence
CCIRs	Commander's Critical Information Requirements
COP	Common Operational Picture
DIANA	Defence Innovation Accelerator For The North Atlantic
EDA	European Defence Agency
EDF	European Defence Fund
EDIDP	European Defence Industrial Development Programm
EDT	Emerging And Disrupting Technologies
EU	European Union
EW	Electronic Warfare
GDPR	General Data Protection Regulation
HAT	Human Autonomy Team
HAT	Human Autonomy Team
ICCPR	International Covenant On Civil And Political Rights
ICRC	International Committee Of The Red Cross
IDF	Israeli Defence Forces
IHL	International Humanitarian Law
IL	International Law
IS	Information Superiority
ISR	Intelligence, Surveillance And Reconnaissance
ISTAR	Intelligence, Surveillance, Reconnaissance And Target Acquisition
ISTAR Products	Real-Time Sensors And Fusion, C4i Generated Documents, Voice Communication & Control Systems
IT	Information Technology
LOAC	Law Of Armed Conflict

ML	Machine Learning
NATO	North Atlantic Treaty Organisation
NGBMS	Next Generation Battle Management System
NGVA	Nato Generic Vehicle Architecture
NLP	Natural Language Processing
OODA	Observe, Orient, Decide, Act
OPTS	Occupied Palestinian Territories
OSINT	Open Source Intelligence
PMSCS	Private Military And Security Corporations
SAPIENT	Sensing For Asset Protection With Integrated Electronic Networked Technology
TITAN	Tactical Intelligence Targeting Access Node
VUCA	Volatile, Unpredictable, Complex And Ambiguous
OSINT	Open-Source Intelligence

1. INTRODUCTION

The resurgence of major land warfare in Europe, triggered by Russia's full-scale invasion of Ukraine in 2022, has highlighted the need for European land forces to review their readiness for high-intensity battles. However, before this, many European nations assumed that conventional ground manoeuvre capabilities would become outdated in contemporary warfare (Barry et al., 2023). Even after the 2014 invasion of Crimea and the following conflict in Eastern Ukraine, there remained reluctance to completely restore these capabilities (Barry et al., 2023). Nonetheless, the 2022 North Atlantic Treaty Organisation (NATO) Summit in Madrid emphasised the importance of strengthening ground troops, citing Russia as the "most significant and direct threat" to NATO's security (Barry et al., 2023). This strategic change has put the recapitalisation of ground troops at the top of both NATO and European national priorities.

In today's operating environment, European land forces face considerable obstacles, including a lack of demographic superiority and decreasing industrial production capability. As global military rivalries heat up, Artificial Intelligence (AI) has emerged as a revolutionary dual-use technology with the potential to overcome these weaknesses. AI's potential to transform warfare is generally acknowledged, with researchers and military officials emphasising its importance in military intelligence, targeting and operational planning (King, 2024). According to US Colonel Andrew Cukor, the US is currently engaged in an "AI arms race" that will influence future military superiority (Gonzalez, 2022, as cited in King, 2024).

As Rob Murray (2020) argues, governments are rushing to harness these new disruptive technologies at scale and speed, recognising that success may depend on agility rather than having the greatest technology. Rapidly implementing these technologies can offer defensive capabilities at lower prices and faster decision-making cycles (Murray, 2020). For NATO, the pursuit of competitive advantage and innovation in emerging and disruptive technologies (EDTs) is vital. AI, autonomy and unmanned systems are rapidly evolving, changing both military capabilities and weaknesses (Csernatoni, 2024). As warfare progresses, incorporating AI into command and control (C2) systems will become critical to ensure interoperability and efficiency in decision-making processes. AI's dual-use potential is exemplified by its employment in predictive maintenance, automated aiming, and terrain modelling—capabilities that cross military and civilian realms.

Despite these advances, considerable hazards are involved when using AI technology for military applications. While AI systems are powerful tools, their use creates concerns about military safety, security, stability and accountability. As the Centre for a New American Security (2024) argues, the participatory nature of military rivalry necessitates strong AI assurance systems to prevent these threats. Failure to address these vulnerabilities might destabilise the national and international security climate.

Given the dynamic and competitive global context, this study will investigate the role of AI in improving decision-making and operational efficiency for European land forces. This research aims to give insight into how AI might assist European armies in maintaining a strategic edge in future wars by exploring its integration into military operations, such as information collection, combat operations like sensor-to-shooter systems and machine learning. Furthermore, this paper will address the legal, ethical and technological problems associated with the use of AI in military operations and decision-making, providing a balanced view of its promise and limits.

2. STRATEGIC FOUNDATIONS FOR AI IN MILITARY DECISION-MAKING

The use of AI in military operations is changing traditional decision-making procedures worldwide. Historically, commanders depended on organised models to preserve a strategic advantage by shortening decision cycles. However, as contemporary warfare grows more complicated and data-driven, conventional frameworks are challenged by the massive quantity of information that must be analysed in real time. This section investigates both the long-term usefulness of traditional decision-making models and how AI is improving existing frameworks.

2.1. Traditional and Evolving Decision-Making Mechanisms in European Land Forces

European land forces have long used organised decision-making models, with the OODA Loop (Observe, Orient, Decide, Act) being one of the most well-known frameworks (Kerbusch et al., 2018). The OODA Loop emphasises quick decision cycles to achieve a strategic advantage by surpassing an adversary's decision-making (Daniels, 2024). The process includes assessing battlefield circumstances, orienting based on intelligence, making judgements and moving quickly to impede the enemy's reaction (Daniels, 2024). By completing these cycles quicker than opponents, troops obtain a strategic advantage by interrupting adversary activities before responding effectively (Daniels, 2024).

The OODA Loop is useful because it simplifies decision-making in fast-paced, dynamic contexts. It enables commanders to swiftly analyse complicated events and make decisions that improve military effectiveness (Daniels, 2021). However, as combat gets more digitised and complicated, the limitations of exclusively human-centred models such as the OODA Loop become more pronounced. Human operators might need help interpreting large amounts of data in combat settings, resulting in delayed decision cycles (Johnson, 2022a).

To address these issues, European land forces have begun incorporating AI into their traditional decision-making frameworks. AI can improve the OODA Loop and comparable models by automating and speeding up the data collecting and analysis stages. AI-powered decision support technologies may provide commanders with real-time intelligence to advise troop deployments, organise logistics and coordinate attacks, providing European troops with major operational advantages (Daniels, 2021).

One significant advantage of incorporating AI into these systems is its ability to handle one of the most fundamental issues in decision-making during armed conflicts: speed. It can be argued that the need to create a plan, disseminate it, and issue orders is one of the major sources of delay in combat operations (Colonel Antal, 1998). Indeed, the ability to make and implement decisions rapidly on the battlefield brings several advantages to a country's armed forces on both tactical and strategic levels (McNeilly, 2015), and together with the timely execution of a plan, it is a decisive factor contributing to victory (Sukman, 2013).

In modern warfare, maintaining a rapid decision-making process might be increasingly difficult. Modern surveillance systems such as drones or satellites produce higher volumes of information and intelligence, which is much more difficult to process than in the past (Sukman, 2013). Thus, improving intelligence collection and analysis becomes crucial to ensure a swift and efficient decision-making process (McNeilly, 2015). Rapid decision-making can allow the commander and the staff to visualise early decisive advantages on the battlefield while gaining agility over opponents (Colonel Antal, 1998). It also contributes to increasing the speed and tempo of combat operations, throwing the enemy off-balance and increasing the possibility of capitalising on new battlefield opportunities (McNeilly, 2015).

2.2. The Role of AI in Modern Military Operations

AI can be broadly defined as the ability of machines to perform tasks that normally require human intelligence, such as recognising patterns, drawing conclusions, making predictions or taking actions (USAF, 2019). The integration of AI into military operations has evolved significantly over time, shaping the way modern warfare is conducted. Historically, AI's military applications began in the mid-20th century with the adoption of early computational models for encryption, radar and missile guidance. These discoveries paved the way for the development of more sophisticated AI systems today, such as semi-autonomous drones, decision-support instruments and predictive algorithms that improve military operations' strategic and tactical capabilities (Roland, 2016). As computing power has expanded, AI technologies have become increasingly vital for C2, real-time intelligence analysis and automation of combat operations.

A key feature of AI is its dual-use nature, meaning that the same technologies can be applied to both civilian and military contexts. AI systems designed for civilian sectors, such as autonomous vehicles, cybersecurity and logistics optimisation, can be adapted for military applications like reconnaissance, target recognition and resource management (Brundage et al., 2018). As a dual-use technology, it has found its purpose in multiple peaceful applications, but it has also been at the forefront of a significant shift in weapons development (Ueno, 2024).

As the European land forces are facing an increasing need for improved decision-making capabilities to respond to rapidly evolving threats, the dual-use nature of AI can bring a significant improvement in this area. AI offers solutions by providing real-time data analysis, predictive modelling and enhanced situational awareness (Allen & Chan, 2017).

3. AI'S ROLE IN LAND-BASED OPERATIONS

Explaining how AI is currently used on the battlefield is a challenging endeavour for various reasons, the main one being the lack of consensus over what AI is and the scarcity of publicly available information (Konaev, 2023). Nevertheless, the ongoing conflicts in Eastern Europe and the Middle East have highlighted the importance of cutting-edge technologies on the battlefield, stimulating both the development and the debate around sophisticated weapon systems. Amid this complexity, understanding the various levels of autonomy inside these weapon systems is critical to comprehending the role of AI in modern combat.

There are three different levels of autonomy of weapons systems: semi-autonomous weapon systems, such as the 'fire and forget' missile which locks its target after being fired; human-supervised autonomous weapons systems, which independently attack targets under constant human supervision (good examples are the AEGIS, Patriot and the Iron Dome air-defence systems); and fully autonomous weapon systems, which do not require any human action or supervision to carry out missions (Schreiner, 2023). As of today, no military in the world is equipped with fully autonomous weapons systems, mainly because several countries and institutions prefer to keep human operators 'in the loop' to avoid losing control over the systems employed (Schreiner, 2023). Nevertheless, AI-supported systems are indeed a reality in today's battlefield, and they are used for a variety of military functions:

A. Command and Control

One of the fundamental functions of AI on the battlefield today is to collect and process large quantities of data to enhance situational awareness and decision-making. For instance, US cooperation with Ukraine provides a good example in this sense: Ukrainian forces and NATO advisors outside the country are using a tool called MetaConstellation, developed by the US-based company Palantir, to aggregate data collected by commercial satellites and create digital battlefield models (Konaev, 2023). Another example is offered by the US company Primer, which has reportedly provided Ukraine with AI-powered tools that are particularly effective at capturing, transcribing, translating and analysing Russian military communication (Konaev, 2023). However, Ukraine is not the only country using AI for C2 purposes. The US is currently using AI in the areas of logistics supply route planning, intelligence processing, information management and VR training simulation (Hunter et al., 2023). For example, C3 AI is a company active in military logistics that has applied its AI tools to the US military to aggregate data from inventories, service histories and sensors on US Air Force assets (Ro, 2023). The availability of this data can be extremely useful to predict and fix device failure before it even happens (Ro, 2023).

B. Manoeuvre

In addition to strengthening command and control, AI can be helpful in analysing locations or terrains to avoid obstacles and optimise deployment operations. Today, there are several projects under development in this area. However, some systems have reportedly already been used (Ro, 2023). The Israeli company ELBIT Systems has recently documented the capability of its new LANIUS system, a drone-based munition capable of autonomously mapping areas and buildings as well as classifying different items as threats, such as individuals carrying firearms (Automated Decision Research, n.d.). Moreover, as Hunter et al. (2023) report, Russia is using AI-piloted sea mines with auto-targeting capabilities, which would make the movement and transportation of naval assets far safer than it is now.

C. Intelligence

Transitioning to the intelligence domain, the use of AI helps gain a better knowledge of the enemy and its operational plans. AI can enhance one's military surveillance capabilities, and there have already been several applications in this sense. For instance, in 2022, a Polish news outlet reported that Ukraine was able to develop an AI tool capable of identifying camouflaged vehicles (Konaev, 2023). This tool was developed to be equipped with armed drones; nevertheless, the human operators would still oversee the decision to strike (Konaev, 2023). In addition, AI can be employed in conjunction with Open-Source Intelligence (OSINT) techniques to enhance intelligence collection and analysis (Lerner, 2024). OSINT is a method that uses open-source and mostly civilian tools to collect and analyse data for security purposes (Lerner, 2024). For instance, OSINT analysts can geolocate troops or military assets by using satellite imagery as well as photos on social media (Ntrepid, 2022). This function has been used extensively in Ukraine, where Ukrainian analysts could triangulate Russian soldiers' positions by using selfies they distractedly posted on VKontakte and other platforms (Krutov & Dobrynin, 2024). Integrating OSINT techniques with AI means further enhancing and automating data collection and analysis, geolocation and pattern recognition (Lerner, 2024), which translates into faster and more accurate intelligence.

D. Fires

Embedding AI in lethal weapons systems to enhance one's capabilities to inflict damage on adversaries is perhaps one of the most prioritised but controversial applications of this technology in the military sphere. Today's loitering munitions, drones equipped with destructive warheads, are probably the closest items to fully autonomous weapons systems: they are programmed by operators to attack specific targets and have considerable autonomous capabilities in carrying out such attacks; however, the operator can abort it if necessary (Schreiner, 2023). According to Ukrainian officials, drones with such capabilities have already been used on the battlefield against Russia, and they have been extremely useful in countering Russia's advanced electronic warfare capabilities (Mozur & Satariano, 2024). Indeed, a non-AI-guided drone requires constant contact with the operator. However, jamming devices can break this contact and render the drone ineffective. With AI-augmented drone systems, the connection between drone and pilot is not required anymore, as the pilot can lock onto a target, and the drone will autonomously reach it unless the operator decides to disengage it (Konaev, 2023; Mozur & Satariano, 2024). Russia has reportedly used its autonomous drone capabilities in Ukraine, such as the KUB-BLA and the Lancet, which are reportedly able to autonomously identify and strike targets using AI, although it is impossible to know whether they have been employed in this configuration on the battlefield or not (Konaev, 2023; Army Technology, 2024).

E. Sustainment

Lastly, the distribution of resources on the battlefield to resupply forces is another military function that benefits from integration with AI. It can be leveraged to create predictive models to prevent equipment shortages in the frontline and ensure the availability of spare parts. This often involves the use of autonomous mobile robots which can transport gear, small arms, food and medical supplies (Rashid et al., 2023). For instance, the British company Alliance has designed a dog-like autonomous robot dubbed 'BAD One,' which can move through combat zones for detection and surveillance of the enemy or resupply of friendly forces (Dangwal, 2024).

General Remarks on AI's Role in Land-Based Operations

AI technology has found extensive applications on the battlefield. AI tools can be used for data aggregation and analysis to aid command and control functions, while AI-integrated weapon systems can provide support in surveillance, manoeuvre, fire and sustainment operations. This technological progress can already be considered as the 'Oppenheimer moment' in contemporary warfare. In the following sections, this paper will continue to investigate how AI can enhance military decision-making and, thus, evaluate its implications for European land forces.

4. AI'S IMPACT ON TACTICAL OPERATIONS AND INTEROPERABILITY

4.1. Enhancing Battlefield Responsiveness: AI in the Sensor-To-Shooter Loop

The essence is how quickly European land forces can process and act on data from intelligence, surveillance and reconnaissance (ISR) sources, speeding decision-making. In traditional operations, there is a time delay between target identification and engagement, which is typically attributable to the necessity for human analysis and decision-making (Correll, 2002). In this context, the 'sensor-to-shooter' systems seek to shorten this delay by streamlining information from the point of data collection to the action, using AI and automated procedures to allow for quick target acquisition and engagement with a minimal amount of human participation. This connection facilitates real-time analysis and decision-making, which can greatly improve responsiveness on the battlefield.

The sensor-to-shooter cycle focuses on intelligence, surveillance, reconnaissance and target acquisition (ISTAR) assets, as well as information processing, decision-making and the weapons systems deployed. The capacity to move quickly through the many stages of this process is crucial for contemporary armies, from tactical to strategic levels (Eshel, 2022). However, the effectiveness of the Sensor-to-Shooter loop is inextricably related to the interoperability of technology utilised by multinational coalitions. Understanding battlefield information has become increasingly difficult due to digitalisation, the proliferation of new sensors and expanding communication modalities (Fridbertsson, 2022). Consequently, providing weapons systems with relevant data to accomplish results within time is critical (Captain Kruger et al., 2020). This requires not just strong systems but also flawless integration and collaboration across allied forces, establishing the framework for a discussion of how AI may improve interoperability.

4.2. Enhancing Interoperability Through AI in European Land Operations

As European ground forces increasingly operate in mixed international coalitions, such as NATO and EU-led missions, smooth interoperability across C2 systems, communication platforms, and logistical networks is critical. However, because these systems differ from one another, they frequently struggle to collaborate. This lack of compatibility can cause uncertainty, decision-making delays, and operational inefficiencies during joint operations.

In this complex environment, AI continues to revolutionise military operations by acting as the major facilitator of Information Superiority (IS), which is critical for contemporary warfare (Pradhan et al., 2017). According to Pradhan et al. (2017), human and machine

dominance is no longer sufficient; IS has emerged as a critical aspect of coalition operations' effectiveness. AI's capacity to collect and share data across many platforms enables coalition forces to construct a Common Operational Picture (COP) in real time, resulting in quicker and more coordinated decision-making (Pradhan et al., 2017). This has become fundamental in an era where the pace of operations continues to accelerate.

In support of this, NATO's 'Duty to Share' principle mandates states provide each other access to important intelligence, which balances the traditional 'Need to Know' approach (Pradhan et al., 2017). Thus, AI helps by ensuring data is efficiently exchanged across several systems, laying the groundwork for a unified operational strategy (Pradhan et al., 2017). This integration reduces friction created by incompatible infrastructures, allowing European ground troops to collaborate more efficiently even in the most complex, fast-paced operating circumstances. By automating data standardisation and integrating information flows, AI guarantees that critical data is transmitted effortlessly across several national systems, making real-time interoperability a reality rather than a goal (Pradhan et al., 2017).

4.2.1. AI as a Force Multiplier for Interoperability

AI acts as a force multiplier by enabling the seamless integration of systems and platforms, hence improving operational coherence and tactical efficacy. AI's machine learning algorithms and natural language processing skills enable the standardisation and understanding of data formats across many communication protocols, allowing European ground forces to interact in real time despite varied technological infrastructures.

One of AI's most significant achievements is its capacity to handle large volumes of data and bridge gaps between various systems, resulting in a unified data architecture that allows for synchronised activities. A clear example is the NATO Generic Vehicle Architecture (NGVA), which provides a framework for interoperability amongst land vehicle platforms, establishing hardware and software interfaces to ensure that information is exchanged between various subsystems (Pradhan et al., 2017). AI allows real-time integration of sensors, subsystems and communication platforms, guaranteeing that coalition forces can communicate crucial information quickly, even in fast-paced battlefield conditions (Pradhan et al., 2017). Furthermore, AI's integration into a range of sensor and communication systems guarantees that units from various nations can work together (European Defence Agency, 2023b). The European Defence Agency's (EDA) INTERACT project, for instance, exemplifies how interoperability standards can improve the operational use, in this case of unmanned systems, by allowing various military units to deploy unmanned platforms in flexible configurations regardless of national origin (European Defence Agency, 2023a).

Integration of Remote and Self-Driving Sensor Platforms

AI enables the development of sensor networks that allow for the real-time collection and distribution of battlefield data across several platforms. These networks, which often include autonomous platforms, are critical for maintaining situational awareness and enabling smooth operational coordination among coalition troops. AI-enhanced sensor networks allow the continuous flow of ISR data from a wide range of unmanned platforms, including drones and self-driving cars (Pradhan et al., 2017). The challenge here is to integrate contemporary sensors with legacy systems, which is made easier by AI's capacity to do real-time data fusion and dissemination (Pradhan et al., 2017). This enables decision-makers to respond to ground-based threats more quickly and precisely.

This subsection has underlined how AI-powered autonomous systems allow interoperability by acting as force multipliers in joint operations. These technologies collect and analyse real-time sensor data distributed via a single network, enabling all coalition troops to act on the same information. AI guarantees that these platforms interact smoothly with human-operated systems, hence improving the operational capabilities of European ground forces. The European INTERACT project is a clear example of how AI-enabled autonomous systems across Europe may collaborate in swarm configurations or handover scenarios, resulting in a more flexible and responsive force (European Defence Agency, 2023a).

4.3. AI Accelerating Decision-Making and Multi-Domain Operations

AI can help to reduce interoperability issues, such as conflicting command formats and communication protocols, ensuring that cooperative activities go smoothly. By supporting multi-domain operations—where troops from various nations work across land, air and sea—AI allows for a robust and flexible response to new threats (Pradhan et al., 2017). It can optimise sensor data integration across many platforms, which will continue to improve European ground forces' combat readiness and agility in coalition missions.

Advanced AI detectors feature many sensors capable of detecting multidimensional information, as well as data processing systems that work like the human brain. Sensors on the battlefield encompass everything from satellites and unmanned aerial systems to ground-based radar and electro-optical sensors (Zhang et al., 2023). These sensors function in a variety of situations and platforms, producing distinct sorts of data, such as infrared imaging, acoustic signals, and electromagnetic data (Bin Rashid et al., 2023).

AI plays a critical role in analysing and combining this data in real time. AI algorithms can scan a variety of sensor inputs, find patterns, and integrate them to form a coherent operational picture (Chisan Hew, 2017). This capacity overcomes the limitations of single-sensor data, which may only provide a restricted or ambiguous view of the battlefield. AI-enabled data fusion benefits commanders by providing an integrated and complete perspective of the operational environment (Chisan Hew, 2017). AI must improve and promote interoperability among European land forces since they currently lack both demographic and industrial superiority, necessitating the development of disruptive technologies to compete with major powers.

Although the abundance of data might result in 'analysis paralysis,' which stymies good decision-making processes, AI can provide quicker and more accurate analysis, enabling comprehensive decision-making on the battlefield (McCullogh, 2022). Today's AI systems and the high-performance processors that support them can handle massive amounts of data at unprecedented rates. They can complete tasks that would ordinarily take people days or weeks in only a few seconds. AI can help lift some of the 'fog of war' with its ability to produce a comprehensive operational picture, hence significantly reducing the decision-making time loop. These productivity gains will ultimately enable more rapid and effective decision-making (Glonek, 2024). For instance, by searching non-governmental organisation databases, the computer can identify a targeted facility as a hospital rather than a rebel stronghold (Tudorache, 2021).

If used appropriately, such tools might make battlefield decision-making not only faster and more responsive in complex or ambiguous circumstances but also lower the likelihood of civilian deaths (Lewis et al., 2016). AI systems will accelerate military decision-making mechanisms by increasing situational awareness, rapidly processing large amounts of information, calculating decision options and automating operations (Glonek, 2024). With the ability to quickly absorb huge amounts of information and substantially accelerate processes like the OODA Loop, multi-domain sensors paired with a full AI system have the potential to be a game changer for European military forces.

Case Study: Rafael Advanced Defence System – Fire Weaver

Fire Weaver is designed for combined missions ranging from special forces to joint operations, and it immediately closes an unlimited number of sensor-to-shooter loops. The system offers sophisticated management capabilities such as target selection, permits numerous precision strikes, optimises ammunition consumption through multiple targeting, gives complete information and aids decision-making (Rafael, 2024). Fire Weaver is a sensor-to-shooter system for moving troops that uses combat-proven technology and a distributed core to control the whole network and assault process, including force safety. The system connects all battlefield elements in real time and automatically picks the most applicable shooter for each target, allowing for comprehensive situational awareness and simultaneous precision attacks (Rafael, 2024). This networked sensor-to-shooter system connects intelligence-gathering sensors to field-deployed weapons, improving target recognition and engagement capabilities. It aims to improve the ability to function concurrently with several players working together to boost precision, decrease collateral damage and reduce the possibility of friendly fire (Dahan & Mimran, 2024). Fire Weaver utilises Rafael Advanced Defence System's superior AI algorithms to process, analyse and prioritise fire allocation (European Defence Review, 2021). The system connects sensors and shooters within a defined region, allowing AI algorithms to generate what Rafael refers to as target and weapon pairings. This implies that the system can identify a 'threat' and then select the appropriate weapon to combat it (Global Defence Technology, 2021). Because the technology was developed by an Israeli-based company, there have been serious allegations of the Israeli Defence Forces (IDF) employing this kind of technology during their operations in the Gaza Strip, where the intricacy of the terrain (urban) can benefit from AI aid (Ali, 2023). The Fire Weaver system may offer an excellent framework for overcoming some of the issues European ground forces face, as it connects sensor intelligence with field-deployed weapons. Despite the obvious potential of the system, many ethical and legal questions need to be answered before it is put to use.

Case Study: Palantir Technologies - Tactical Intelligence Targeting Access Node (TITAN)

The Tactical Intelligence Targeting Access Node (TITAN) is the first intelligence ground station enabled by AI. It is considered a key component of the service's multi-domain operations and joint all-domain operations vision (Seffers, 2023). It is designed to be deployable in a variety of operational environments. It can be fielded as a mobile or stationary unit, enabling commanders to establish intelligence hubs in forward operating areas and improving decision-making on the ground. TITAN will deliver a next-generation, expeditionary, scalable and manoeuvrable platform at the echelon that is purpose-built to address the army's number one gap in large-scale combat operations: deep sensing (PEO IEW&S, 2021). By accessing data from multiple sensors simultaneously across the spatial, high altitude, aerial and terrestrial layers, TITAN provides situational awareness and understanding across operations. Fusing that data and using advanced analytics to deliver targetable intelligence to lethal and non-lethal networks reduces the sensor-to-shooter gap and enables long-range precision fires, aviation and mission command (Johnson, 2024). While TITAN is primarily a US Army initiative, it enhances interoperability between US troops and its Western allies, resulting in a unified operating picture. This is critical for joint operations, in which many branches or foreign partners must coordinate their activities based on shared intelligence.

Case Study: Quantum Sensing

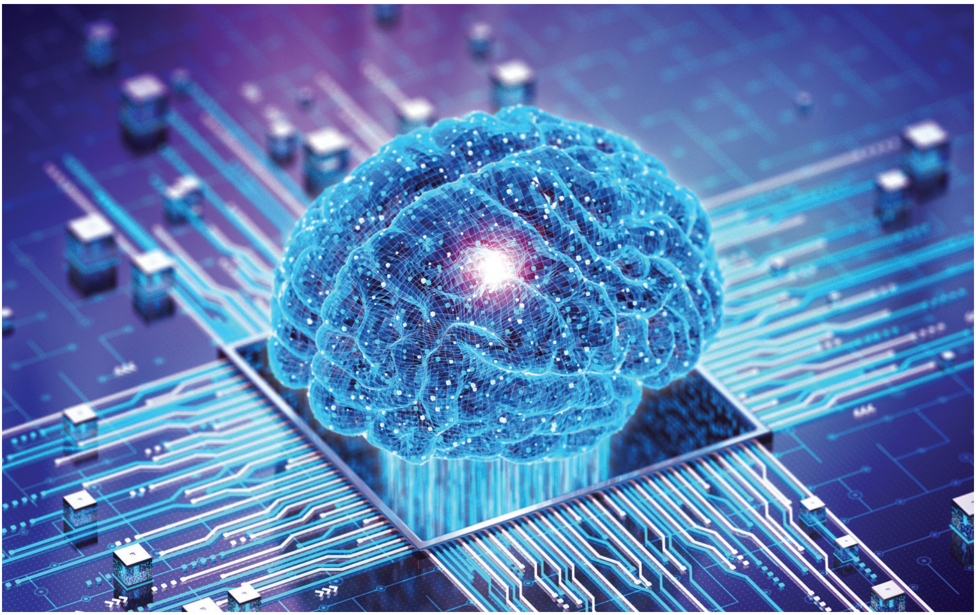
In its 2023 Action Concept for Quantum Technologies, the German Bundestag acknowledged quantum technology's transformational and disruptive potential (Swayne, 2023). Quantum sensing applies quantum physics ideas to sensors and might improve several military capabilities. For example, it can provide alternate positioning, navigation, and timing choices, allowing armies to continue to function at peak performance in GPS-degraded or GPS-denied conditions. Furthermore, quantum sensors may be employed in an ISR capacity (Sayler, 2024). Successful development and deployment of such sensors might lead to major gains in submarine detection, jeopardising the viability of sea-based nuclear deterrents. Quantum sensors provide vessels with extraordinary accuracy by carefully surveying the Earth's magnetic field. Unlike satellite navigation, these sensors are extremely resistant to disturbance (Weber, 2024). As they exhibit exceptional precision in positioning vessels, quantum sensors are already being leveraged by the British armed forces for the precise positioning of the ships (Weber, 2024). Quantum sensing has the potential to significantly improve European ground forces' capabilities, notably in navigation, ISR, communication security and threat identification. The technology might also promote interoperability among European ground troops, as quantum sensing provides a strategic edge on the battlefield.

5. MACHINE LEARNING AND FUTURE APPLICATIONS OF QUANTUM COMPUTING

5.1. Machine Learning and Military Decision-Making

Machine learning (ML) is one component of the overall field of AI and of the larger fields of computer and data science. This subject studies computational systems, information and automation. In this sense, it also processes, aggregates and analyses, in varying degrees and types, information and patterns. Within these types, ML stands out as using neural artificial networks (Lt. Col. Doll & Capt. Schiller, 2019) and being a type of AI that "allows machines to learn from data without being explicitly programmed" (International Organization for Standardization, 2024 para. 3). When specific ML algorithms are applied to datasets, the end products are ML models. Three main models exist within its domain: supervised (using identified datasets), unsupervised (using unidentified datasets) and reinforcement (trial and error with unidentified datasets) (International Organization for Standardization, 2024).

Supervised ML fits best military certainty and reliability requirements in air defence; for example, it focuses on training models to identify specific datasets and is more aptly applied to scenarios that require 'split-second' decision-making. These include identifying, intercepting and/or mitigating threats with short decision times and reliable accuracy (Dantas et al., 2022). In any case, their combined potential impact on autonomous complex decision-making has been a contested issue across



the military sector. In the cases where the human critical decision maker still has the final say, ML's use for immense data processing, as well as aiding in faster, more comprehensive decision-making, has been effectively verified (Robinson et al., 2023). Although AI and ML are not the same thing, it can be said that many of the recent advancements in AI have been made through ML (Brown, 2021). Because this sub-field of AI learns and improves with data, the more data, the better the overall system learning. As it has been seen in the public domain, the kind of data input will orient the operational framework and capacity of the given ML system (Marion, 2024).

5.1.1. Practical Applications of Machine Learning

ML stands as an operationally demonstrable intermediary support system for the enhancement of decision-making. Its capacity to process information already allows human decision-makers to achieve immense speed and complexity of data analysis that was previously impossible to achieve. The rate of progress should then follow the capacity of AI to make contextual 'out of the box' decisions that blend with human thinking. In other words, the first decisions that ML systems should be allowed to make are those that do not require employing human psychological — or, to a certain extent, philosophical capacities — and that prioritise speed. ML's use for voice-recognition software, already deployed in Ukraine (Wagstaff, 2023), as well as face-recognition software in the Occupied Palestinian Territories (OPTs) (Kwet, 2024), is of note in this context. These facial recognition systems, most recently the Blue Wolf and Red Wolf systems, have been employed by the IDF to compile mass datasets on Palestinian faces to be later used in operations for identification purposes; however, many errors in judgement have occurred where civilians have been mistaken for militants (Robins-Early, 2024). As a result, some have been denied access to their communities for not being recognised by the AI algorithms and, in certain cases, wrongfully targeted by the military, though these are just a few examples (Robins-Early, 2024).

The use of generative AI (supervised ML algorithms) in the US's Advanced Targeting and Lethality Automated System or ATLAS (Suárez & Baeza, 2023), but particularly in the Israeli Iron Dome (Pacholska et al., 2024), serves as the best examples of leveraging AI systems for identification, analysis and mitigation of threats. Such systems can provide unmatched accuracy and speed in this specific decision-making domain, which for this paper shall be referred to as *time-decisive micro-decision-making. Though recent studies have indicated the potential of AI can also be channelled for "better protection of civilians in urban warfare" (Greipl, 2024), this application is not without its ethical dilemmas (Raska, 2024). Collateral damage and potential prioritisation choices are just some of the present ethical issues (Anugrah, 2024). Additionally, although voice and face recognition are current uses of AI, most technologies still cannot distinguish between a soldier who is surrendering and one who is taking up arms (Anugrah, 2024). The applications of ML in land warfare are varied, but the increasing complexity of multi-domain threats is equally wide. The following section will present a case study on German AI applications for land warfare that illustrates this.*

The Tactical Unmanned Aircraft System (UAS) Battalion

The German Bundeswehr Army Concepts and Capabilities Development Centre has made an interesting contribution in the use of an AI-assisted 'Tactical Unmanned Aircraft System (UAS) Battalion' or swarm battalion to aid overall situational awareness, offensive and defensive capabilities and information distribution (Lt. Col. Doll & Capt. Schiller, 2019). This battalion has the goal of contributing to more comprehensive, efficient and effective decision-making in the field while considering new hybrid threats, namely electronic warfare (EW) and cyber-attacks (Lt. Col. Doll & Capt. Schiller, 2019). The application is grounded on the notion that communication infrastructures on the battlefield will become more saturated and more regularly subject to attack, and thus, the ability to quickly make decisions on available information will be progressively vital.

The UAS battalion, in this instance, would consist of over 5,000 units ready to deploy at a moment's notice. Upon field deployment, the swarm could then separate and regroup into smaller battalions with different purposes. For example, one unit could be equipped with sensors and cameras to serve as a sensor platform; another one to jam enemy drones as well as back information relays between friendly UASs; and another could be equipped with munitions to destroy enemy platforms or UASs and other potential purposes such as creating an 'anti-UAS barrier' or a "counter UAS swarm trained to intercept and destroy hostile UAS" (Lt. Col. Doll & Capt. Schiller, 2019). Operational landscape awareness would be enhanced and available to both the commander in question and the field operators through real-time 'sensor data fusion' (Lt. Col. Doll & Capt. Schiller, 2019, p. 4), depending on how many integrated units are available. Other than integrating the UAS swarm framework, AI is used to aid the identification and classification of hostile forces, but more importantly, to assess potential tactical formations and regularly update their presumed intent (Lt. Col. Doll & Capt. Schiller, 2019, p. 4).

Similar systems have been employed by Israel through their 'Ghost Unit,' also aptly viewed as an elite multi-dimensional unit, which is technically part of the 99th unit. The IDF established the Ghost Unit in 2019 as part of their larger project, Momentum, which was meant to integrate new technology into the frontline or urban warfare (Frantzman, 2024). This unit's main distinguishing feature is the application of more innovative technology in the frontlines of battle, namely unmanned aerial systems, which, like the UAS battalion, can at once be used for information collection or offensive purposes. The specific unit has killed at least 86 combatants in Gaza, which only makes up a part of the total confirmed kills by the 99th unit (Frantzman, 2024). Recently, in Gaza, the coordination between soldiers, different units and the Ghost Unit has allowed the IDF to expose secret Hamas tunnel networks as well as terrorist money stashes. The unit serves in this sense, both as a combat and as an information-gathering unit. Here, the fusion of data from cycling drone swarms with long-range targeting systems was most recently applied to the fighting in the Palestinian city of Jabalya in the Gaza Strip (Frantzman, 2024). The Ghost Unit coordinated with longer-range targeting systems, in this case, tanks and soldiers, to destroy a target inside a building where the tanks first destroyed the room, and the gunfire completed the job while the drone swarms monitored the situation (Frantzman, 2024).

On 19th October 2024, a probe was launched by the Belgian Federal Prosecutor into a Belgian citizen who had alleged ties to the Ghost Unit and is being accused of shooting unarmed civilians in Gaza, raising doubts as to whether such a unit was solely composed of Israeli nationals (or technology); in addition, three Americans, two French, a German and an Italian were also implicated in the operation (Barnea, 2024). This combination of technology and manned forces is becoming more prevalent in modern urban warfare, not only because it avoids needlessly exposing soldiers to potential danger but also because it adds efficiency to the overall targeting systems, diversifying and enhancing the resilience of the military information channels.

The importance of information and communication resilience in next-generation hybrid battlefield environments is also highly stressed in the Bundeswehr report. The report argues that hybrid attacks "will lead, almost invariably and with a high probability, to communications being disrupted in critical phases" and that critical decision-making superiority will depend on distributing information to as many units as possible while making the most of the limited "phases of connectivity" (Lt. Col. Doll & Capt. Schiller, 2019, p. 6).

In response to possible scenarios, the Bundeswehr has begun to study the need for a Next Generation Battle Management System (NGBMS) designed specifically for ground combat. This system would shift away from centralised command, focusing on quick modification of communication systems utilising existing technology. This new structure already assumes that it would be under intense electronic, cyber and overall hybrid attacks and would make use of smaller, mobile pieces of equipment that still held good C2 capabilities (Lt. Col. Doll & Capt. Schiller, 2019).

As modern warfare evolves, the advent of hypersonic weapons systems, particularly when integrated simultaneously with hybrid attacks, will increase the need for time-decisiveness in multi-contextual, multi-domain environments. This type, as opposed to time-decisive micro, can more aptly be described as multi-contextual complex decision-making. The Bundeswehr Tactical UAS Battalion somewhat fits this model already, but current ongoing projects that are also pertinent to this context, though with different multi-domain specificity, can be found worldwide. NATO's Augmented Near Real-Time Instrument for Critical Information Processing and Evaluation (ANTICIPE) (Marion, 2024), the UK's Sensing for Asset Protection with Integrated Electronic Networked Technology (SAPIENT) (Defence Science and Technology Laboratory, 2024) and China's 'Brain-Computer Codec Chip' or BC3 (Kania, 2021) are some examples.

Building on this, the long-term pattern for global military infrastructure seems to be following progressive AI integration in all domains and sectors of pertinence, where proof of concept has been validated, both for information aggregation and autonomous decision-making. However, one fundamental aspect to be acknowledged is that most of the data to back AI-based decision-making systems in *multi-contextual complex decision-making*, more so than time-decisive micro, has come from secure 'controlled environments,' without having been subject to real-world conditions and the threats therein (Suárez & Baeza, 2023, Figure. 1). Perhaps enhanced computing power will break new ground in overall learning systems capability, or in other words when one can go 'quantum.'

5.2. Going Quantum: Securing the Quantum-Classical Interface

Quantum technologies, under the current understanding of quantum physics, encompass three key areas of pertinence to military application: computing, communication and sensing (De Luca, 2024). Quantum information science succeeds traditional data science and revolutionises the way computers process information (De Luca, 2024). As touched upon in the previous section, cyber and electronic warfare threats will continually increase in complexity and target multi-domain assets. The capacity to deal with such threats effectively is limited by the current computational, communication and sensing infrastructure, which relies on both software and hardware. Currently, the applicability of quantum properties to military infrastructure will have to rely on mixed systems, for example, both using classical computer systems and integrating some quantum components (SEI Quantum Computing Team, 2023).

The importance of a quantum-classical computer interface stems from the basic premise that ML's operational framework needs large amounts of data to learn, and this capacity is also based on the computational power of the system that is being used. The more computational power a system possesses, the more information it can process in a shorter time frame, thus the more it can learn. This is where the importance of quantum computing emerges. While AI already provides the enhanced 'analytical' capacity to process information that is beyond the human brain, it is always limited by the physical (hardware) components that make it up. Classical AI interfaces are extremely fast compared to traditional computers but pale in comparison to the complexity of computations and the exponential increase in speed they could reach under quantum conditions (Szeleczki, 2021). In the context of information and communication tactical advantage, quantum key distribution presents a next-generation capability for unbreakable encrypted communications (De Luca, 2024). Additionally, the overall application of quantum technologies, when integrated with AI, promises to revolutionise aspects of ISR while having equally significant impacts on autonomous complex decision-making (NATO Allied Command Transformation, 2022).

ML has immense potential for military settings, particularly for the de-complexification of multi-domain information overloads, where it has already been employed. Although its use for actual decision-making — namely in interception and mitigation measures as seen with the Iron Dome — has been validated, the AI component of ML is currently more vital for the processing and aggregation of information that presents possibilities for decisions rather than making them. In this sense, it is also more ethically sound. In the future, ML has the potential to make complex decisions, but as of right now, it is only operationally efficient when integrated with human analysts who can provide better feedback on the context of a given problem. This goes in hand with the notion that hard decisions must be made in a warfare environment, and they are not always equivalent to an efficient outcome that can be encoded in algorithms. It is also important to distinguish between *time-decisive* micro decision-making and *multi-contextual* complex decision-making. The long-term potential for AI is that eventually, both types of decision-making can be performed interchangeably — as multi-contextual complex decisions might also be time-decisive.

There is no question that quantum technology poses a next-generation 'double-edged sword' that will revolutionise not just military warfare systems in general but societal apprehension and analysis of information, especially when integrated with AI. The immense amounts of power consumption that will take place because of increased AI use and the necessary infrastructure, namely data centres, must be considered. This also applies to the advent of quantum computing, particularly when coupled with AI. As more and more innovations are coming in this sector, solutions like mobile data centres, as well as mobile C2 structures, can be applied to land warfare scenarios. However, for efficient deployment and implementation of these systems, sufficient training must be undertaken with current military personnel and the new artificial systems beforehand. Additionally, natural language processing (NLP) systems for human-context comprehension need to be improved to reach full maturity status in decision-making.

There are natural aspects of human cognition that artificial systems still cannot emulate and can perhaps be enhanced by the increased integration of ML with human proxies, like the learning system seen under Open AI. In this sense, platforms that train AI with humans in simulation games will be of key importance for future autonomous multi-contextual complex decision-making. Specifically, where the parameters are not necessarily set for efficiency but to understand why a human might make a specific decision in each scenario. At the core of the incompatibility that AI might have with complex military decision-making is the unpredictable nature of warfare and the notion that artificial systems are based on sets of rules that they must follow. Inherently, war follows no rules. Unfortunately, the rate of technological advancement and its application to military environments cannot keep up with its ethical integration. This is something every military should prioritise, particularly when developing next-generation revolutionary technology, though the current global outlook is not encouraging.

6. AI DECISION-MAKING FOR LAND-BASED OPERATIONS: THE ANTICIPE PROJECT

The ANTICIPE project is a new multi-domain prototype framework for the integration of AI, particularly the five AI types, which are explained in this section. ANTIC-

IPE allows for the integration of AI into the decision-making process of NATO multi-domain operational commands. In the context of this paper's focus, ANTICIPE represents the pertinent case study on the applicability of such systems to *multi-contextual complex* decision-making while maintaining human autonomy for final decisions. The conceptual framework pertinent to specific software and hardware components, as well as the actual infrastructure required for implementation, are also highlighted. What sets ANTICIPE apart from alternative AI implementation in the decision-making context is its innovative method for de-complexifying the analytical process that creates the commander's critical information requirements (CCIRs), allowing for faster, though nonetheless comprehensive, critical decision-making (Marion et al., 2019). The following section underlines ANTICIPE's conceptual and operational framework that allows for this innovation.

ANTICIPE integrates five characteristic types of AI in its framework: NLP, multi-criteria decision support, ML, decision management and a virtual assistant. These five types of AI are coupled with a *human* element, the human autonomy team (HAT). The four main aspects of HAT that allow for human-artificial cooperation and set the parameters for specific AI systems are "context sharing, rules, transparency and cooperation agreements" (Marion et al., 2019, p. 5).

The CCIRs represent the most pertinent information that is vital for high-level officials to make key critical decisions in a specific military operational context. Though they are the end-product the system is oriented towards, the final component post-CCIR is still the human critical decision-maker (commander in question). Traditionally, CCIRs have been sustained by manual means and kept small in numbers. In other words, these are the final products of information intelligence that are submitted to a critical decision-maker before an action is taken. They must be condensed into something sufficiently complex in its level of analysis to make an efficient, effective and informed decision whilst at the same time being simple enough to make a fast one (Lt. Giles, 2018). Anything that is not time or mission-sensitive to decide should not be included in the CCIRs (Marion et al., 2019). Though the exact definitions may differ from military to military, CCIRs are information points that are recognised while planning operations and which might fall under one of three types, consisting of those necessary for the anticipation of major decisions, those that make verifying assumptions possible and those that ensure the protection of one's forces and centre of gravity (Marion et al., 2019). Traditional multi-domain decision-making processes that employ AI (with HAT integration) and have multiple-domain source inputs, AI analysis and information aggregation systems already place the CCIR component at the centre. Being the end product — the CCIRs depend on the rest of the network framework and its units working in tandem.

The source input for the ANTICIPE project pulls from the renewed C2 structure, where 'Air Command, Control, Communications, Computers and Intelligence (C4I) Real-time Sensors and Fusion, C4I Generated Documents, Voice Communication & Control Systems (ISTAR Products)' and most importantly Open Sources (Twitter, Facebook, Dark

Net), are used to generate more comprehensive CCIRs (Desclaux, 2019, slide 11). Four key components constitute the operational and mostly AI-automated framework for information analysis: the crawler, the annotator, the miner and the CCIR manager (Desclaux, 2019). The process goes as follows: once the varied source inputs register something into the ANTICIPE network, they are oriented directly to the 'crawler,' which represents the first stage of information aggregation; this is where all sources are first registered in the system. The crawler then sifts through the information and directs it to the 'annotator' (Desclaux, 2019). By making use of substitutive AI, the annotator adds context to the specific source inputs, with the aid of human operators through a team-oriented process, creating annotated documents which are stored within the system database as 'knowledge artefacts,' thereby creating a more comprehensive 'profile' for each artefact and then sends it to the miner (Marion et al., 2019). Mining makes use of semantic models and ontologies (making use of collaborative AI) and uses this system to autonomously detect the cues and triggers (Marion et al., 2019), although a system is currently being designed to help integrate human curation if it is deemed necessary. For a more comprehensive graphic visualisation of this process, a consultation with Desclaux (2024) is recommended, particularly slide 10.

Having many traditional components within the decision-making process cycle, what makes ANTICIPE innovative in the process of decision-making is that it prioritises and targets the CCIRs, dividing them into two information units, the 'cues and triggers,' what the lead scientists of the project codename as 'weak signals' (Marion et al., 2019). The codename 'weak signal' also refers to the notion that some of these registered adversarial actions (cues) would otherwise not have been picked up by human analysis — and used for extrapolation and anticipation of a potential modus operandi (Marion, 2024).

The 'cues and triggers' are linked by set rules designed by human intelligence and are "identified by domain and sub-domain" (Marion et al., 2019, p. 4), which allows the CCIR manager (and HAT) to visualise the type of threat being faced and in what capacity of the multi-domain environment the enemy is operating (Desclaux, 2019). It is in this context that ANTICIPE allows the operator to 'read the enemy's thoughts.' At the same time, important questions can be answered constantly under this framework, such as "Status of my Vulnerabilities? Status of my Critical Capabilities? Are my assumptions still valid? What might cause key conditions to change? What may hurt most? How is the enemy conducting actions in multi-domains?" (Marion et al., 2019, p. 4). These pieces of vital information are directly linked to the final decisions, which are 'triggered' based on three colour levels representing different types of measures to be taken: yellow suggesting preventive action, orange for mitigation and red for a major decision needed (Marion et al., 2019). In this sense, the project reduces the 'information environment complexity' of the overall system (Desclaux, 2019, slide 8), but enhances the quality of the information being provided, making the most sense from the lowest possible inputs (Marion et al., 2019).

This 'agnostic' (Marion, 2024), malleable system can be applied to the "strategic, operational or tactical" levels of command (Marion et al., 2019, p. 4) and, indeed, to sectors outside of the military domain. The applicability of AI for decision-making in a specific context will always depend on the parameters and objectives set beforehand, particularly on the source inputs and overall information provided to the system. As explained in an interview with Dr Damien Marion, the lead scientist of the project, the underlying ANTICIPE framework has already been applied to measure depression levels during the COVID pandemic as well as aiding with monitoring and anticipating the Yellow Vest protests in France (Marion, 2024). Additionally, the potential mobility of ANTICIPE is also stressed as an added value for different operational environments (Marion, 2024). In this vein, the application of ANTICIPE for land warfare alone could be potentially more efficient if the parameters set were pertinent for land-based decision-making (which would reduce overall CCIR possibilities) and if land-pertinent sensors and source inputs were used.

Fewer CCIR possibilities and source inputs could mean faster CCIR proposals; however, these would likely be abdicating a more comprehensive information aggregation because these make use of multi-domain sensors. All of these can be said to be pertinent to land warfare, particularly in current hybrid warfare environments. What could also function in this context are multiple ANTICIPE frameworks tailored to each operational domain that work in tandem rather than one multi-domain framework. Here, the two main benefits would be the reduction of potential information overloads that can occur from multi-domain operations (maintaining individual domain security should the main system fail) and the ability to dedicate more computing power to one domain. In any case, it is not entirely clear that the benefits of this individual domain would outweigh the value ANTICIPE presents as an overall multi-domain system, particularly in being able to anticipate adversarial movements at all levels of military domains at once.

7. INTEGRATING THE SIXTH DOMAIN: CIVILIAN-MILITARY COLLABORATION IN AI DEVELOPMENT

In an era marked by both fast-paced technological advancements and shifting geopolitical landscapes, the participation of the private sector in AI development has never been more critical. As governments face increasing security challenges, the incorporation of civilian technologies into military applications presents revolutionary potential.

Nowadays, private enterprises are driving technical developments in the AI domain, and civilian ideas frequently make their way into military use. NATO, for example, through programs such as the Defence Innovation Accelerator for the North Atlantic (DIANA), has encouraged cross-sector cooperation (NATO, 2022). Meanwhile, the EU, in the same manner, through the European Defence Fund (EDF) and the European Defence Industrial Development Programme (EDIDP), is promoting innovation and development across its member states (European Commission, n.d.). The goal of DIANA is to encourage collaboration among universities, start-ups and existing technology businesses to create dual-use solutions that solve both civilian and defence concerns (NATO, 2022). By collaborating with civilian Information Technology (IT) businesses, NATO hopes to use cutting-edge technologies in military decision-making, data management and autonomous systems. In contrast, the EDF and EDIDP initiatives aim to develop new defence technologies and prototypes through co-financing to diminish reliance on non-European Union (EU) defence technology (European Commission, n.d.).

This 'spin-in' method, in which civilian technology is repurposed for military application, can enable European land forces to profit from advances in AI and related disciplines without relying primarily on traditional defence contractors. Civilian technology such as AI algorithms, edge computing and autonomous platforms can be quickly incorporated into military operations to improve capabilities like C2, information collecting and real-time decision-making (Csernatoni, 2024). Nonetheless, dual-use technology presents a significant difficulty regarding interoperability, given the multitude of European enterprises engaged in this sector. The reliance on technology or components that enable it, such as microprocessors, are mostly obtained from outside Europe. This reliance can create weaknesses in supply chains and intensify dependence on non-European suppliers, thus complicating the incorporation of civilian technologies into military operations. The dependency on exterior supplies can slow the adoption of advanced AI technologies and create potential vulnerabilities in European supply chains.

Furthermore, the defence industry's long-term, capability-driven approach may clash with the fast-paced civilian technology sector, which is frequently more adaptive and market-oriented. However, the private sector's leadership in AI is critical for driving innovation in both military and civilian spheres (Calcara, 2021). With security privatisation expanding — as proven by the increasing employment of private military and security corporations (PMSCs) for a variety of security duties — the trend towards automation in defence technology continues to minimise the necessity for human intervention in battle (Calcara, 2021). This transition is essential in modern combat since military troops are frequently deployed in isolated places with little logistical backup (Calcara, 2021).

The relationship between privatisation and technical progress is a complicated dynamic. On the one hand, privatisation has benefitted the defence sector by extending its engagement in the whole life cycle of defence equipment, from design to decommissioning. On the other hand, technologically driven automation, which occurs mostly outside the conventional military-industrial complex, has greater dual-use potential. Civilian breakthroughs in autonomous technologies are influencing military innovation, making them more significant than ever to military capabilities (Calcara, 2021).

Start-ups, in particular, are an important source of disruptive innovation, frequently upsetting existing standards and forcing bigger businesses to adapt (Murray, 2020). NATO's Innovation Fund, launched in 2021, provides financial support to early-stage tech enterprises developing dual-use technologies, ensuring that important defence breakthroughs remain under the Alliance's control (NATO, 2022). In this sense, the Euro-Atlantic Alliance is building a robust ecosystem of AI research that benefits both the defence and civilian sectors by stimulating competition and creativity in the private sector (NATO, 2022).

AI's dual-use approach ensures that military forces benefit from the latest developments while also aligning with the interests of governments, commercial corporations and research organisations. Startups are incentivised to create technology with both civilian and military uses, producing a win-win situation that pushes advancement in both sectors. By working with civilian tech entrepreneurs, European land forces can leverage cutting-edge technology innovations for better decision-making and overall military performance. Despite integration hurdles, ongoing collaboration between the corporate and public sectors will keep European land forces at the forefront of AI-driven innovation.

8. CHALLENGES AND POTENTIAL OF AI APPLICATIONS IN MILITARY OPERATIONS

The increasing adaptation of AI into military operations presents both revolutionary opportunities and major challenges. Although AI is transforming the way battles are conducted by allowing armies to operate more rapidly and efficiently, it also poses strategic and operational risks that must be managed appropriately.

AI has immense military application potential. It provides rapid outputs in combat scenarios as information flows from several domains, which is important in highly volatile, unpredictable, complex and ambiguous (VUCA) settings (Tudorache, 2021). Additionally, AI enables commanders to make more informed decisions, improving their cognitive abilities under high pressure. Lastly, it enables military personnel to perform at higher speeds and with more accuracy, ranging from increased situational awareness through machine learning-driven sensor fusion to improving logistics and maintenance operations using predictive models (Parly, 2019).

However, with these advantages comes the risk of over-reliance on AI. A fundamental concern is the increasing loss of *human judgment in decision-making processes*. The automation of the OODA cycle with AI may result in commanders relying too heavily on algorithmic outputs without fully grasping them (Johnson, 2022b). This reliance is jeopardised if AI makes mistakes, especially in the unpredictable and ethically complex environment of combat. For example, black box algorithms — AI systems with opaque decision-making processes — can produce errors that humans are unable to discover or correct until it is too late (Rashid et al., 2023). The fact that AI systems might occasionally provide outputs that are opaque or difficult to interpret complicates matters since human operators may be forced to trust a system that they do not fully understand (Szabadföldi, 2021).

Another significant concern of overreliance is AI's vulnerability to hacking and malicious manipulation. AI systems, which are deeply embedded in military infrastructures, may become targets for cyber exploitation (Rashid et al., 2023). Adversarial attacks, in which AI systems are affected by data inputs to produce incorrect outputs, can lead to catastrophic target misidentification or faulty battle decisions. In certain cases, opponents can take advantage of technology designed to provide military gains. Such threats emphasise the significance of robust cybersecurity measures, continual oversight, and putting human operators at the core of decision-making processes (NATO Allied Command Transformation, 2022).

The strategic implications of falling behind in AI adoption cannot be overstated. Nations that do not invest sufficiently in AI technology risk falling behind on both defensive and offensive capabilities. As AI advances, countries that excel in military applications may upend the current power balance. The AI arms race is about more than just technological dominance; it is also about maintaining strategic stability among world powers (Rashid et al., 2023). Failure to stay ahead of the curve might leave a country vulnerable to AI-enabled asymmetrical warfare, in which enemies utilise innovative AI tactics such as autonomous drones or deepfake-driven misinformation campaigns to disrupt established command structures and endanger global security (Lin-Greenberg, 2020). The dual-use nature of AI increases the likelihood of civilian advances being co-opted for military purposes, hastening the strategic race (Parly, 2019). This presents a scenario in which non-state actors and weaker countries may utilise AI to level the playing field with stronger adversaries, posing new and unexpected threats to international security.

Another key concern is AI's ability to disrupt critical digital infrastructure. As artificial intelligence systems become more integrated into military operations, their reliance on digital infrastructure grows, and so does their vulnerability. Deepfake technology, for example, might be used to manipulate command and control systems, spread misinformation or even disrupt entire military operations (Rashid et al., 2023). This raises the risk of biased early warning assessments and false alarms, leading to escalatory cycles based on erroneous data (NATO Allied Command Transformation, 2022). Furthermore, when quantum computing and AI collide, new security issues will arise, notably in missile defence systems that need rapid and precise data processing (NATO Allied Command Transformation, 2022). If the infrastructure designed to support AI-enhanced military capabilities is compromised, it might become a huge liability.

AI systems also face serious ethical and reliability challenges. Autonomous systems capable of making life-or-death decisions without human intervention create serious ethical considerations (Szabadföldi, 2021). The danger of biased or incorrect AI decisions in critical military scenarios, such as target selection, highlights the importance of including human supervision in the decision-making process. Furthermore, the quality and quantity of data used to train these systems determines the consistency of the AI outputs. AI models built on faulty or biased datasets may draw incorrect conclusions with potentially devastating consequences (Rashid et al., 2023). Given the irreversibility of many military decisions, it is vital to ensure that AI systems are trustworthy, transparent and free of prejudice. The battlefield's increasing complexity exacerbates AI's fundamental faults. The likelihood of arms-related rivalry and technological disruption grows as AI technologies advance rapidly. This disruption might occur on various levels, including pre-emptive strikes based on AI's swift decision-making abilities and AI-enabled disinformation operations that weaken coalition partner trust (Lin-Greenberg, 2020). Furthermore, AI's involvement in high-frequency cyber warfare and its potential to launch large-scale, coordinated cyberattacks constitutes a new frontier of conflict, with unanticipated consequences that are even more difficult to prevent (Parly, 2019).

9. LEGAL & ETHICAL ASPECTS OF AI IN MILITARY DECISION-MAKING

9.1. The Legal Vacuum and Absence of Harmonisation: The Challenge of Governing Military AI

The use of AI in military decision-making presents a substantial legal challenge due to the absence of a robust, universally accepted legal governance framework, escalating arms proliferation and challenging International Law (IL). Existing IL, including the Law of Armed Conflict (LOAC) and International Humanitarian Law (IHL), was crafted with human decision-making in mind. These frameworks lack specific provisions to regulate the deployment and use of AI in military contexts, creating a legal vacuum that leaves dan-

gerous ambiguities. While Europe's military AI industry is thriving, its political leadership has decided to turn a blind eye to its uses and the accompanying legal risks (Fanni, 2023). Indeed, the risk of mission creep, where AI systems originally designed for civilian purposes are repurposed for military use, adds a layer of unpredictability and danger. This absence of regulation places enormous strain on IL and ethical standards, creating a pressing need for the EU and other global bodies to take the lead in establishing a coalition for AI governance in military contexts—shaping safeguards with clear global norms and ethical standards (Csernatoni, 2024).

While there has been significant momentum in establishing AI regulatory frameworks, such as the G7 AI principles and the Hiroshima AI Process, these initiatives remain largely civilian-focused (Moutia-Bloom & Hickman, 2024). There is no comprehensive global agreement or legal framework that addresses military AI, creating a critical regulatory void. The emerging frameworks often exclude military applications of AI, leaving each state to define its approach to regulating the use of AI in warfare. This disparity in governance leads to fragmented policies and enforcement, increasing the risk of unintended escalations or violations of IHL.

On 1 August 2024, the EU's AI Act came into force, making it the first comprehensive horizontal legal framework for the regulation of AI systems in the EU, which have a global reach and affect actors across the AI value chain by prioritising human rights protection (EU Parliament & EU Council, 2024). However, several concepts set out in this AI Act will require clarification by courts and regulators to provide businesses with greater certainty regarding their compliance obligations. Alongside the AI Act, companies operating in the EU must still consider obligations under other applicable sector-specific instruments, such as the General Data Protection Regulation (GDPR), the Digital Services Act, and the forthcoming AI Liability Directive (EU Parliament & EU Council, 2016; EU Parliament & EU Council, 2022; EU Parliament & EU Council, 2022). Companies should also be aware of regulatory initiatives at the national level in the Member States in which they operate. For example, France's competition authority will investigate Big Tech's competitive functioning in the generative AI sector (Moutia-Bloom & Hickman, 2024).

While some regions, such as the EU, are making strides in AI regulation through the AI Act, this effort largely excludes military applications. The absence of comprehensive military AI regulation within such a landmark piece of legislation is not only problematic but reveals a broader failure. The EU's AI Act, while progressive in many areas, leaves military AI development to individual member states, perpetuating a fragmented legal landscape. This fragmentation is not only an issue for the EU but is a global phenomenon, as different countries adopt varying approaches to AI governance (Fanni, 2023). For example, the UK has declined to issue new legislation at this stage and has instead decided to adopt a flexible framework of AI regulatory principles that will be enforced by existing regulators (Moutia-Bloom & Hickman, 2024). The absence of a unified international framework allows powerful AI-driven military technologies to proliferate in legally uncertain spaces.

9.2. Human Rights, Ethics and Data Privacy: A Cross-Border Legal Challenge

The integration of AI into military systems raises significant ethical, human rights and privacy concerns, particularly regarding the collection and use of sensitive data. AI-driven military systems heavily rely on the collection, analysis and use of large datasets, which include personal information, to enhance decision-making. AI Decision Support System (AI-DSS) tools can simplify a widespread and quick collection and analysis of information on civilians to enable better decisions during conflict when it comes to minimising the risk for civilians (ICRC, 2021). Nevertheless, this raises crucial questions about data privacy, particularly in cross-border military operations, where differing national standards can create legal uncertainty and friction. While the GDPR is a robust tool for civilian protection in Europe, it includes exceptions for national security and defence, which allows military AI operations to bypass some safeguards. As AI gathers intelligence in conflict zones, monitoring civilian communications or movements, such actions may infringe on the right to privacy, protected under the International Covenant on Civil and Political Rights in Article 17 (ICCPR, 1966).

Beyond privacy, the ethical implications of AI in military decision-making are vast and troubling. Autonomous systems capable of making life-or-death decisions without human intervention challenge established moral frameworks and legal principles, such as those outlined in the Martens Clause, which emphasises humanity and public conscience in warfare (Ticehurst, 1997). Maintaining human judgment in decisions that risk the lives and dignity of those affected by armed conflict is crucial for upholding ethical values and ensuring compliance with applicable laws, including IHL (Zhou & Greipl, 2024). Even the assertion that the arrival of new technologies in warfare will reduce civilian harm is not always true in practice (Copeland & Sanders, 2021). Excessive trust in AI potentially increases the probability of outcomes that diverge from the original intention of human decision-making, resulting in accidental escalation, which upsurges the risk for civilians in warfare (Stewart & Hinds, 2023). New military technologies, particularly those used for autonomous targeting or decision-making, both exacerbate the risks of civilian harm and increase the likelihood of unintended consequences (Crootof, 2022). Indeed, they can lead to discriminatory outcomes or mistaken targets, including the wrongful targeting of civilians. As militaries integrate AI and advanced algorithms into their systems, they introduce new types of errors specific to this technology (Scharre & Horowitz, 2018). Therefore, any AI-DSS output should be verified to prevent biased or inaccurate information. However, this double-check effort appears to become almost impossible when AI is used for complex tasks using multiple layers of analysis (Stewart & Hinds, 2023). Besides, these systems also bring vulnerabilities that adversaries can exploit through hacking, manipulation or other forms of exploitation (Brundage et al., 2018). As a result, beyond AI-DSS's potential to aid in mitigating civilian harm during targeting processes, militaries should prioritise investing in AI-DSS specifically designed to enhance civilian protection, a current gap in development. Such advancements are essential for improving compliance with IHL obligations to continuously safeguard civilians and take all feasible precautions in attacks (Zhou & Greipl, 2024).

While AI offers significant economic and societal benefits, there are growing concerns that it may disadvantage certain individuals and communities, potentially infringing on their rights and expectations (Mantelero & Esposito, 2021). Accordingly, the use of AI in military contexts raises significant questions about human rights protections. Facial recognition systems used for military surveillance, for example, may disproportionately misidentify individuals from certain ethnic groups, raising concerns about racial and gender biases (Zhou & Greipl, 2024).

9.3. Responsibility and Accountability: A Critical Gap in AI Governance

Finally, one of the most pressing concerns with the use of AI in military decision-making is the issue of accountability. As AI systems assume more responsibility for decision-making, the traditional frameworks for assigning blame or responsibility in cases of misconduct or errors become increasingly inadequate. The deployment of autonomous systems in warfare raises questions about the legal chain of responsibility. However, it should be underscored that responsible AI is not about AI being responsible. It is about humans and the "human responsibility for the development of intelligent systems along fundamental human principles and values" (Dignum, 2018, p.1). Under IHL, accountability for violations rests with the parties involved in the armed conflict, who are, ultimately, human beings (Zhou & Greipl, 2024). On top of that, new military technologies create new accountability gaps in armed conflict, expanding familiar sources of error and complicating causal analyses, making it more difficult to hold an individual or state accountable for unlawful, harmful acts.

On one hand, this is not a situation where new technology is creating a new problem. In expanding unintended harm to civilians, both incidental and accidental, new technology has made an older problem more salient. Therefore, it highlights the fact that there is no international accountability mechanism for most unintended harm to civilians in armed conflict. While individuals who intentionally target civilians or commit serious violations of IHL can face criminal liability for war crimes, "a system can take harmful action without anyone acting with the requisite mens rea for criminal liability" (Crootof, 2022, para. 15). In scenarios where AI systems operate with significant autonomy, attributing responsibility becomes murkier, and AI could potentially shield human actors from accountability. Consequently, under IL, no entity can be held legally accountable for the harmful consequences of lawful actions during armed conflict (Crootof, 2022). For example, while intentionally targeting civilians is forbidden, an attack that incidentally results in civilian harm may be lawful. New weapons technologies exacerbate this tension since they have narrowed the list of protected civilian objects. Technology has not only driven the shift to urban warfare (Schmitt, 2006), but the incentives to network and link military systems have also turned civilian infrastructure, such as telecommunications systems and internet services, into dual-use targets (Shue & Wippman, 2002).

On the other hand, how we frame corporate responsibility and accountability in cyber conflict is at stake today. Indeed, boundaries are blurred between national and corporate responsibilities since legal and technical experts, civil society, states, and private sector actors urgently need to work together to better understand, mitigate and regulate the harmful impact of adversarial data manipulation. Nevertheless, the most efficient and scaled-up technological capabilities in AI and cybersecurity are the intellectual property of private companies. As AI enhances the speed, stealth, and autonomy of cyberattacks, public sectors and civilian protection actors will become increasingly dependent on the cutting-edge expertise of AI and cybersecurity companies. This asymmetry grants private sector actors worldwide unprecedented influence and a significant potential role in civilian protection (Pauwels, 2022).

Finally, as the development and deployment of AWS (Autonomous Weapons System) have become one of the most pressing concerns in the absence of a military AI framework, a large call for clear regulation has been made. Indeed, as their use in warfare becomes more common, the international legal community will need to establish clear guidelines on how responsibility is assigned. However, since there has been little progress in creating binding international treaties to govern their use, this legal grey zone has incentivised the development of weapons. Therefore, this phenomenon has exploited loopholes in existing IL and increased this critical accountability gap where human rights violations could go unpunished.

10. FINAL REFLECTIONS AND FUTURE DIRECTIONS IN AI-DRIVEN MILITARY DECISION-MAKING

This paper has investigated the transformative role of AI in military decision-making, particularly for European ground forces. It has addressed the potential of AI use in military operations, a consistent feature in both present and future warfare scenarios, with its development for military purposes proceeding at a high pace. The findings show that AI technologies have the potential to greatly improve decision-making efficiency, speed and accuracy while simultaneously posing serious concerns about governance, ethical norms and security. This paper aims to analyse how AI may be used to give operational benefits to land forces while limiting dangers. This has been investigated using examples of AI's function in decision-making cycles, sensor-to-shooter systems, and machine learning.

A key finding is AI's capacity to rapidly fuse sensor data, helping to clear the 'fog of war' and offering a decisive advantage in modern combat by accelerating the OODA Loop. These technologies continue to reduce the delay between target detection and engagement, allowing forces to outpace adversaries in decision-making cycles. The proliferation of sensors, combined with AI's analytical power, has fundamentally reshaped how military forces perceive, understand and respond to complex environments. Furthermore, advances in ma-

chine learning and quantum computing are set to improve these capabilities by allowing for quicker data processing and predictive analytics, making future military systems even more responsive and accurate.
However, this study acknowledges some limitations. Despite the current benefits, the long-term impact of AI use for combat operations, which will affect decision-making, is questionable due to the technology's continuous evolution. The ability of AI to synthesise and analyse enormous amounts of data can speed up decision-making, allowing commanders to outperform opponents in high-stakes missions. AI-powered sensors enhance situational awareness and combat response, whilst decision-support systems optimise C2 activities. These advancements make the force nimbler and more interoperable, but they also highlight flaws, such as over-reliance on opaque AI systems and an increased danger of cyberattacks.
The findings of this paper suggest that while AI can be a force multiplier on the battlefield and support a wide range of activities in combat operations, without proper regulation, it could have dangerous and potentially uncontrolled destructive effects on the battlefield and beyond. One must be aware that the use of AI in military decision-making processes is notably hindered by the absence of specific legal provisions regulating its deployment. This lack of regulation introduces additional layers of unpredictability and risk. The resulting legal vacuum underscores the urgent need for global norms and ethical standards to mitigate potential breaches of human rights and address data privacy concerns. Consequently, the accountability gap created by this lack of harmonisation exacerbates existing loopholes in IL, allowing human rights violations to go unpunished. Soon, international organisations need to define the extent to which AI can be used in combat operations, following the logic and model of arms control treaties that have regulated the proliferation of new military technologies in the past, such as nuclear weapons and long-range missiles.
Looking forward, the next phase of military innovation will be shaped by the integration of quantum computing, increased cybersecurity measures, and enhanced human-AI collaboration. As AI technologies evolve, future research and policy initiatives must combine operational efficacy with ethical responsibility, ensuring that the use of AI in conflict fits with humanitarian norms and legal requirements.

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FINABEL
Quartier Reine Elisabeth
Rue d'Evere 1 box 44
B-1140 BRUSSELS

Tel: +32 (0)2 441 79 05 – GSM: +32 (0)483 712 193
E-mail: info@finabel.org

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