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AI IN MILITARY C2-SYSTEMS

An Introduction and Recent Advances

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ABSTRACT

Recent advances in the integration of Artificial Intelligence (AI) into military Command and Control (C2) systems and procedures are transforming decision-making processes, enhancing situational awareness, and improving operational efficiency in a more complex operational environment.

This article traces AI's evolution from theoretical concept to practical military application, analyzing its role across the C2-cycle stages including data sensing, processing, sensemaking, and decision support. It introduces the reader to current AI developments such as Project Maven and (AI-driven) drone warfare systems, exploring how AI systems are revolutionizing target identification, intelligence analysis, and overall battlefield awareness, emphasizing the growing reliance on AI in military decision-making. It addresses critical challenges that include data quality issues, cybersecurity vulnerabilities, and the need for explainable AI systems in military contexts.

The authors advocate for a balanced approach to AI implementation that maintains human command authority while leveraging AI's advantages. AI's integration into military C2 represents an evolutionary rather than revolutionary change, requiring careful consideration of doctrinal adaptations, training requirements, and human-machine teaming approaches.

Keywords:
artificial intelligence, command and control, military decision-making, human-machine teaming, Project Maven, drone warfare

1. Introduction

Artificial Intelligence (AI) is rapidly taking over the world with large tech companies heavily investing in the practical use of the technology. It is probably the defining technology of the last decade, and perhaps also of the next (Boucher, 2020). It is of utmost significance to recognize and harness the potential that this innovative, groundbreaking, and rapidly evolving technology has to offer within a military context.

The term "AI," which serves as an umbrella term encompassing Machine Learning (ML) and Deep Learning (DL) (Frisoni, 2020), has been in use for some time. Early discussions regarding the concept of a machine capable of human-like thinking and actions, which had not yet been defined as AI, primarily took place within the realm of science fiction. It was not until 1955 that John McCarthy, a researcher at Dartmouth University, introduced the term Artificial Intelligence. Five years earlier, British researcher Alan Turing, widely regarded as both the "cracker" of the Enigma code and the "father of AI," discussed in his publication "Computing Machinery and Intelligence" the question of whether machines can "think" (Turing, 1950). This question became the cornerstone of years of research and technological development in many fields, from computing to philosophy.

If a machine can successfully convince an evaluator that it is a human being during a conversation, it is said to have passed the Turing Test. This would indicate that the machine possesses a level of AI that allows it to mimic human responses and behaviour effectively. The question raised by Turing that started it all led to a fundamental question: What is AI exactly?

Although AI is a term coined more than 70 years ago, it still does not have a generally accepted definition (Szabadföldi, 2021). From a broad perspective, AI is an algorithm that can carry out tasks that require intelligence, such as the ability to perceive, reason, and act. This includes activities such as learning, decision-making, and problem-solving (Bundy, 2016).

Technology has evolved since the time of McCarthy and Turing. Although advances were made in computing, the development of AI did not accelerate because the computing power was not yet sufficient to support it. Advances in the military were made in logistics and supply chain management, but these could not be labelled as AI assuming the stated definition. Computers gradually supported manual labor more and more in optimizing processes and operations, and continued doing so over time while improving at a faster rate. Computers showed their potential; however, technology was not yet able to truly have 'a mind of its own'. This changed in the late 1990s and early 2000s, when researchers broke down the main question raised by Turing into smaller problems that needed to be solved. This led to significant discoveries and the spread of AI, spanning from chess computers capable of outplaying grandmasters to medical computers adept at identifying anomalies in images.

Since then, AI technology cascaded and came under the close attention of many computer researchers as the technology supporting the Turing Test reached its intended level. Powerful computers, the accessibility and manageability of extensive data from diverse sources and continually advancing ML algorithms marked the early 2010s as a decade of discovery for researchers. The success rate of AI accelerated, and commercial companies, such as Google, Facebook, and Tesla, working with big data and AI flourished. These companies also made it clear that interacting with an AI or algorithm is a daily occurrence, even if users don't realize it.

Additionally, AI extended to military computers proficient in interpreting reconnaissance imagery. It allowed for more accurate targeting and could help reduce the risk for military forces and minimize collateral damage. Computers were finally able to analyze vast amounts of data and bring that data, now information, to the commander, who could make a well-informed decision.

This article examines the integration of AI into the military Command and Control (C2) Cycle, accentuating its role in enhancing decision-making, situational awareness, and operational efficiency while addressing its limitations. Section one introduces AI, providing a historical overview of its development from theoretical concept to a transformative technology. Section two explores the stages of the C2-cycle where AI-supported systems contribute, from improved data sensing to enhanced situational understanding. Section three examines current AI developments in C2, drawing on advancements in automation, machine learning, and decision support tools, with a focus on their role in recent research and conflicts, such as Project Maven and drone warfare, along with their implications. Section four evaluates whether AI in military C2 represents an evolutionary or revolutionary shift. In conclusion, the article reflects on AI's broader impact on the C2-cycle, advocating for a balanced, adaptive approach to its effective and responsible integration, a process that NATO has already begun by initiating the Data and Artificial Intelligence Review Board (DARB) (NATO, 2022).

2. AI-Supported Systems in Command and Control Cycle

NATO defines Command and Control as the exercise of authority and direction by a commander over assigned and attached forces to accomplish the mission (NATO, 2019). The term encompasses the two elements of Command and Control, hinting at a synergy between them. While Command connotes the human aspect of leadership, creativity, and flexibility, Control is more associated with strict rules, doctrine, predictability, and standardization (Balis & O'Neill, 2022).

The NATO standard definitions of both Command and Control are often critiqued in academic literature for their self-referentiality and heavy emphasis on control activities. McCann and Pigeau (1999) state that Command is often associated solely with authority, responsibility, initiative, courage, trust, and leadership. Control, on the other hand, is often associated with plans, procedures, Rules of Engagement, communications protocols, software, and equipment. The authors define the two terms as follows:

Command and Control: The establishment of common intent to achieve coordinated action. Command is defined as 'The creative expression of human will necessary to accomplish a mission,' and control as 'Those structures and processes devised by Command to manage risk' (Mccann & Pigeau, 1999)

One of the main focal points for commanders, and thus their C2 structure, is to maintain situational awareness and respond accordingly with (military) actions, if needed, to achieve strategic goals and whole-of-government objectives (Simpson et al., 2021). Military operations today are complex, with data and actions significantly affecting the battlefield. Military C2 must navigate a fast-evolving, multi-domain[1] environment. To remain effective, the military must evolve with technology and adapt it beneficially. AI, in particular, emerges as a transformative force as it enhances decision-making, operational efficiency, and strategic capabilities, yet its integration into C2 systems demands careful consideration. It is essential to remain cautious of technological solutionism, defined as the assumption that every challenge can be resolved solely through technology without considering the complex social, cultural, and political dimensions that influence military and security environments.

As the six-volume RAND report series points out (Menthe et al., 2024), commanders must understand AI's constraints in five key areas: cybersecurity, predictive maintenance, wargaming, mission planning, and constructive simulations. Addressing these five areas will be essential to strengthening AI's role as a dependable and effective tool in military operations. In addition, there are many significant factors affecting the acceptance towards the use of a network of various intelligent objects in the military (Saylam & Ozdemir, 2022). As a result, the application of AI in the military is also not as straightforward as it sounds due to the critical nature of military operations and their vulnerability to adversarial attacks (Frisoni, 2020). It is essential that AI is trained to cope with the complexity of military operations to gain the trust of the commander (Scherrenburg, 2022). It holds the capacity to improve the overall C2 framework and the entirety of the decision-making process, spanning all levels. However, this enhancement is not without limitations regarding decision-making authority. A study published by the NATO Command and Control Centre of Excellence (NATO C2COE) shows that although the technology for full autonomously (mainly tactical) military systems exist, the role of the commander remains essential as he or she wants to make the final decision. Trust in supporting systems, whether with human staff or different levels of AI algorithms, is essential for a commander. This also has implications for the delegation of authority and the assigning of tasks during the C2 process (Scherrenburg et al., 2019). Efforts are being made, such as DARPA's Explainable Artificial Intelligence Program (Gunning & Aha, 2019), which aims to enable commanders to understand, trust, and effectively use machine learning techniques.

To effectively integrate AI into command processes, a deeper understanding of decision-making models is essential.

Decision-Making Model - a component of C2-Cycle

The need for structured decision-making has been a fundamental aspect of human and organizational behavior throughout history. As societies and institutions grew more complex, individuals and leaders required systematic approaches to evaluating alternatives, allocating resources, and responding to uncertainties. Early decision-making models focused on maximizing efficiency and were often influenced by classical management theories and economic principles. However, real-world decision-making is rarely optimal due to

1 Domain: Critical macro maneuver space whose access or control is vital to the freedom of action and superiority required by the mission (Reilly, 2016).

constraints such as limited information, cognitive biases, and time pressures.

Herbert Simon, a pioneering figure in decision-making and artificial intelligence, defined decision-making as the act of selecting a course of action from multiple alternatives. He introduced the concept of bounded rationality, arguing that individuals make decisions within cognitive and informational limitations rather than achieving perfect rationality (Simon, 1965).

One of Herbert Simon's earliest publications on the decision-making process stated that it consists of three phases: Intelligence, Design, and Choice (Simon, 1965). Within the C2-cycle, these basic steps are called Sensing, Sensemaking, and Deciding. Although a crucial element, the decision-making act itself is part of a larger process by which a commander leads an operation. Throughout the Operational Planning Process, there are specific points where the commander will approve planning products, provide direction and guidance to the staff, and make specific decisions. The so-called operational rhythm within this process is key to creating a Command Advantage, enabling more timely, coordinated, and effective actions across all levels of command. The Battle Rhythm (BR) is the method used to combine staff effort in analyzing relevant information and providing assessments and recommendations to the commander. The Battle Rhythm is a disciplined set of meetings, briefings, and gatherings used to maintain operational tempos for all levels of command. It is an essential mechanism for informed decision-making, maximizing joint activities, planning operations, and aiding (joint) operations synchronization.

As humans naturally tend to systematize their work, they are always searching for a decision-making model that is both ideal and suited to the situation. These models are constantly evolving to meet the needs of the modern battlefield. However, in a future volatile, uncertain, ambiguous, and complex environment, existing skills and insights alone will no longer be sufficient to achieve well-founded decisions. The growing reliance on vast amounts of data and the challenge of extracting relevant insights in real time demand new approaches to decision-making. As interconnected events unfold across multiple domains with unclear cause and effect relationships, it becomes essential to reconsider traditional decision-making processes.

One commonly taught and used model is the OODA (observe-orient-decide-act) Loop concept developed by military strategist and United States Air Force Colonel John Boyd in the 1950s (Osinga, 2007). According to Boyd, decision-making (and the action afterwards) occurs in a recurring sequence of observe-orient-decide-act, with some feedback and feedforward loops. It provides a global overview of the basic premise of effective C2, where an entity (whether an individual or an organization) can process the

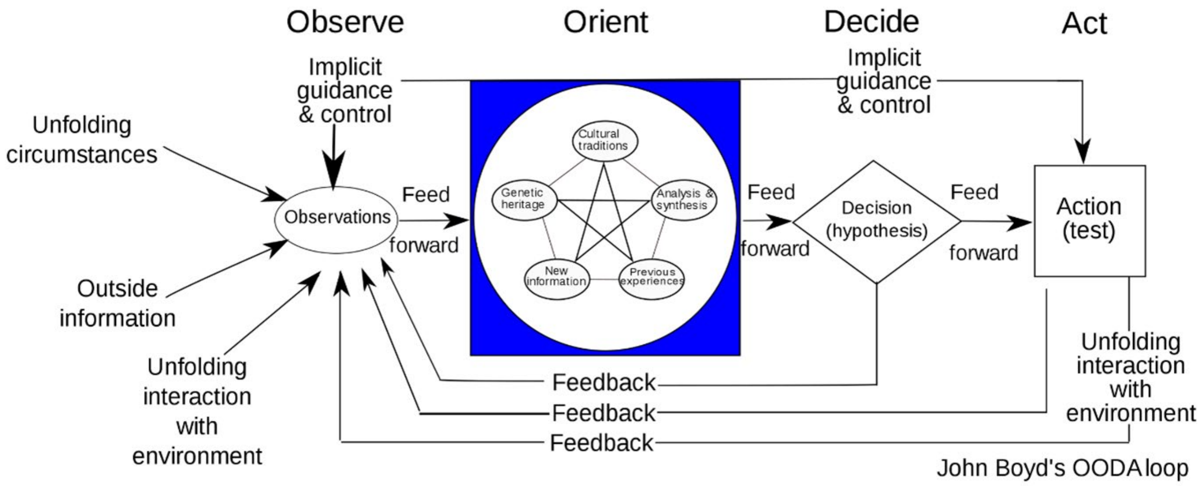

Figure 1. Boyd`s OODA Loop

cycle quickly, observing and reacting to unfolding events more rapidly than an opponent, thereby “getting inside” the opponent’s decision cycle and gaining the advantage. The OODA Loop (figure 1) shows that, prior to deciding (the Decide phase), the commander must first gather information (Observe) and determine its meaning and possible actions (Orient). ‘Shortening the Loop’ can make the difference between success or failure relative to the opponent.

On the other hand, the C2-Cycle (or NATO C2 conceptual model), developed as part of the C2 Capstone Concept (NATO Allied Command Transformation, 2018)(Scherrenburg et al., 2019), organizes the elements of C2 differently and offers a more relevant presentation of the steps involved than the OODA Loop. By breaking down Boyd’s broad and multi-interpretable concept, the C2-Cycle enables a more detailed analysis of its components and provides a clearer understanding of how emerging technologies such as AI, can enhance decision-making within the framework. Although the steps in the C2-Cycle are depicted as equal in Figure 2, not all parts of the cycle are equally relevant or require the same amount of time. The speed at which the entire C2-Cycle is completed is essential for gaining an operational advantage, just as it is with the OODA Loop.

At the heart of the donut-shaped model (from the inner to the outer circle of the two-dimensional representation) is connecting, the enabling component of C2, which links and harmonizes the three phases of the C2 model: Collecting, Decision Making, and Effecting. In this context, AI offers functional capabilities that align with and enhance various aspects of C2-Cycle. AI systems can be utilized as decision support tools in three primary functional areas based on their core design functions: (1) description and analysis, (2) prediction and extrapolation, and (3) prescription. It can be concluded that the first and second functional areas primarily relate to the data sensing and processing phases, while the second and third functional areas are more closely associated with the sensemaking and decision-making phases of the C2-Cycle. While these areas are not strictly separate and may overlap, leading to many academic discussions on the levels of autonomy and the concepts of ’human on the loop’, ‘human in the loop’, and ’human out of the loop’ (Endsley, 2018; Naikar et al., 2023), they collectively encompass the core functions of AI systems (Nadibaidze et al., 2024).

Figure 2. C2-cycle

Improved Data Sensing and Processing

Whereas air superiority is essential to conduct the full spectrum of air operations, so is information superiority (or dominance) in the information domain. The utilization of AI plays a pivotal role in attaining this information dominance and in processing large amounts of data quickly and accurately. Adopting these technologies acquires and disseminates information more promptly among allies and partners (Aranake, 2022).

In the past, military commanders had to rely on labor intensive, manual information processing by their staff and their intuition and experience to make decisions. Most of these decisions were based on (relatively) limited data. The increased use of emerging technology in sensing and gathering data has led to a data overload that is difficult for humans to fully process. While having more insights is generally better, too much information can be overwhelming and lead to a kind of decision-making paralysis (Scherrenburg et al., 2019). AI can help address this problem by filtering, correlating, and fusing data. The application of advanced algorithms and machine learning techniques enables AI systems to discover connections and correlations that may go unnoticed by human analysts (Desclaux, 2018). By identifying patterns, detecting anomalies using current events and historical data, and uncovering insights that would otherwise remain unobserved or misinterpreted, AI would reduce the cognitive burden on human decision-makers. However, this also highlights the potential vulnerability of human analysis, making it the weakest link in the decision-making loop.

Data can come from a variety of sources in multiple domains, such as sensors, reports from lower and upper units of headquarters, or from open sources. Multi-sensor platforms, in combination with automated information processing, will optimize the information delivered to the commander. With the advent of AI, commanders can now access relevant data in near time and make more informed decisions.

AI relies heavily on the availability and diversity of data sources for successful implementation, particularly in machine learning applications. A broad and varied dataset enhances AI's ability to generate accurate insights and improve decision-making processes. However, this does not mean that the volume of unstructured data can be unlimited, as excessive workloads may surpass AI's capacity to process information effectively (Dunn-Potter, 2022).

Despite its advantages, AI still faces significant challenges that require further research. Coping with unstructured data (and so the unusable documents for AI-ingestion) is one of the key challenges in fully integrating AI in C2 systems, as well as mission uncertainty, probing interventions to assess adversary intent, small sample sizes, data inconsistencies, high-clutter environments, heterogeneous inputs, adversarial manipulation in contested and deceptive settings, explainability, and meaningful human control, all of which remain critical hurdles.

To make AI effectively cope with the large amount of data, it is necessary to prompt the AI on how to learn autonomously and deal with confidential data; how to scrape relevant data and transform it into usable information and intelligence with correct prioritization. One promising approach to addressing these needs is the use of Large Language Models[2] (LLMs). These models would continue to transform the military and defense sector by improving decision-making, such as providing creative Courses of Action suggestions (Solaki et al., 2024), situational awareness, and overall operational efficiency. They could combine data from various sources like text, images, and sensors to offer comprehensive insights by analyzing satellite imagery, interpreting intelligence reports, and monitoring social media for threats in real time. This holistic approach would aid defense personnel in making quick, informed decisions, enhancing response times and mission outcomes. Additionally, LLMs will improve communication and coordination among teams, ensuring critical information is conveyed accurately. Integrating multi-modal agents into defense operations would significantly advance AI's role in national security.

Just like humans, AI will also struggle with inaccurate and "dirty" data (Dunn-Potter, 2022). The accuracy of AI recommendations is directly proportional to the reliability of the data it receives during the ingestion process.

To ensure an effective decision-making process, data needs to be distilled down to the essentials without excluding relevant facts when transmitted up the chain of command (Scherrenburg et al., 2019). Therefore, Information and Knowledge Management (IKM) is an integral part of C2 in striving towards enhanced situational awareness.

Contextualization of the data involves integrating analyzed information within the broader framework

2 "Large language models (LLMs) are a category of foundation models trained on immense amounts of data making them capable of understanding and generating natural language and other types of content to perform a wide range of tasks." (IBM, 2023)

of the mission, objectives, and the operational environment. This step is vital to prevent the misinterpretation of raw data, ensuring that factors such as geography, weather, local customs, and cultural considerations are accounted for in information analysis. Collected data needs to be processed and analyzed to extract meaningful insights and identify patterns, trends, and potential threats, as well as evaluating the credibility and relevance of the information.

These processes are iterative and adaptive, meaning that as new data becomes available, analysis may need to be revised and updated. High-quality information processing and analysis contribute to enhanced situational awareness, information superiority, and decision-making.

Enhanced Situational Understanding

Situational Awareness (SA) is the recognition of what is happening in the environment, such as troop locations and current events. It is about knowing and provides the 'what' and 'where'. Situational Understanding (SU) goes deeper, analyzing this information to determine its significance, predict outcomes, and guide decisions. SU is about comprehending; it provides the 'so what' and 'what next' (Lovering, 2014).

Having a full understanding of the operational environment is not about having the most sensors or the biggest dataset. True cognitive advantage comes from the ability to make sense of data and project it into a specific context and mission framework thereby creating Situational Understanding. To achieve this, NATO doctrine recommends applying the Comprehensive Understanding of the Operating Environment (CUOE) process. This is a crisis-specific cross-headquarters process to develop a comprehensive understanding covering all political, military, economic, social, infrastructure, and information domains (PMESII), including associated potential threats, risks, and opportunities, in support of planning and the conduct of operations as part of a wider campaign.

Possessing information and knowledge superiority does not automatically lead to decision superiority. Organizational and doctrinal adaptation, relevant training and experience, and proper C2 mechanisms are needed. Decision superiority is achieved through a combination of superior information and knowledge in the hands of an experienced staff and a trained commander, applying wisdom and judgment, insight and expertise of the commander's staff and other supporting organizations, and an efficient set of associated decision-making processes (Jeffress, 2004). The speed of the decision-making process is a function of the speed at which the commander and his or her staff can operate (Fazekas, 2023). Operating under time constraints might compromise the decision's quality, yet generally, it is preferable to have a timely, satisfactory decision than a flawless one that's delayed.

As a result of the improved data sensing and processing, AI facilitates further analysis and, eventually, would provide a better understanding of the environment. AI could assist expert staff in enhancing the pace of their guidance, thereby aiding the commander in making well-founded and prompt decisions. These systems possess a robust knowledge repository (data lake[3]) derived from historical encounters and collaborative databases. The counsel or judgments they provide, rooted in the data repository, could bolster trust and comprehension.

When a reductionism doctrine is applied with deduction and over-simplification of data into intelligence, staff officers might risk excluding potentially relevant information or events. Even though experienced staff members know that the commander only needs information about what is important to him or her, there is a tendency to overload the commander's cognitive information absorption capacity. Questions may arise such as: who decides what information is presented to the commander? Is filtering the information prejudicial

3 A data lake is a data repository in which datasets from multiple sources are stored in their original structures. It should provide functions to extract data and metadata from heterogeneous sources and to ingest them into a hybrid storage system. (Quix & Hai, 2018)

to the commander? When the information sourced from AI presents an exceptional, unconventional, or divergent perspective from traditional human insights, it can pose a challenge for commanders. If commanders lack the means to verify the credibility or viability of such insights, they might hesitate to adopt or even disregard them altogether (Fazekas, 2023). If the information reaching the commander is too filtered, perhaps we are hindering his or her intuition.[4] It should be the commander who instructs his or her staff about the degree of detail in the information he or she wants to receive. By doing so, the commander sets his or her information filter threshold, and this will set the pace for the commander's Battle Rhythm.

Commanders need to have the capability to significantly decrease the duration spent on decision-making procedures while understanding the limited validity of specific systems. They can then take steps to minimize the impacts of potential mistakes. Responsibility for their decisions rests upon military leaders, and this responsibility remains unchanged even when AI-systems contribute to their decision-making. The use of AI will prominently influence the enhancement of human decision-makers' capability to process and amalgamate extensive and diverse information sources. However, irrespective of whether an approach from higher echelons or from lower levels is taken, it is humans who train these AI/ML systems and should ultimately be responsible (Nalin & Tripodi, 2023).

AI-supported systems could enhance our ability to properly command and deductively could be used as decision-makers; however, non-measurable human qualities play an important role in decision-making and should remain the commander's prerogative. (Scherrenburg et al., 2019)

From a NATO perspective, it is recognized that at the core of future military advantages one will find effective integration of humans and machines into warfighting teams. (NIAG, 2019) This will lead to fusion situations where both staff officers and/or AI-based systems, Non-Human Intelligence Collaborators (NICs) assess information within a certain area of interest to provide tangible insights for SU. Shared SA in Human-Machine Teaming (HMT) requires a process of dialogue between the human and the computer through intuitive interfaces. To cope with the data deluge involved in a military conflict, the human mental capacity is insufficient while computer algorithms are challenged due to uncertainty and ambiguity in data and decision-making. (NIAG, 2019)

Thus, an enhancement in the process would be to have dedicated tools for anomaly detection and to interlink or relate events across domains. NIC systems with humans-on-the-loop are required to provide situational understanding, operations assessments, and alternative analysis to support the commander in his or her CUOE. The development and management of a system for Intelligence Requirement Management and Collection Management (IRM & CM), including CCIRs (commander's critical information requirements), is critical in improving the military decision-making process.

The increased complexity of data emphasizes the need for skills of future commanders and staff officers to 'know what to ask', in other words, to focus on the correct information requirements for operations.

With this foundation in place, the next section presents examples of how AI is currently being applied within Command and Control.

3. Current AI Developments in C2

At the operational level, AI systems play an important role in streamlining target-related processes, including detection, validation, nomination, and prioritization. Advanced AI-

4 Humans have a skill, which, until now, is outside the range of technology: intuition. Intuition makes irrelevant information to be considered and to decide in an opposite way to the natural one.

driven platforms, such as Project Maven (USA), Palantir's MetaConstellation software (Ukraine), Griselda (Ukraine), Bylina EW Complex (Russia), Kropyva (Ukraine), Acacia-M (Russia), Alchemist (Israel), GIS Arta (Ukraine), Gospel (Israel), Lavender (Israel), and Where's Daddy (Israel), integrate real-time intelligence, sensor data, and pattern analysis to enhance situational awareness and optimize military decision-making. This distributed situational awareness, created by both humans and technology working together as a team (Salmon et al., 2017; Stanton, 2016), supports efficiency and effectiveness. These systems can identify and track potential targets, assess their relevance based on operational criteria, and prioritize them for engagement based on threat level and mission objectives. By processing vast amounts of data from multiple sources, such as satellite imagery, geolocation tracking, and drone reconnaissance, decision-makers leverage AI to identify objects, process data and intelligence, and assess the legality of potential targets (Cole et al., 2024; Nadibaidze et al., 2024).

Reports from ongoing conflicts, such as the Israel-Hamas war, the Russia-Ukraine war, and the Syrian conflict, highlight the expanding role of AI in military decision-making. Beyond active conflicts, Project Maven, a U.S. Department of Defense AI initiative, showcases the integration of AI-powered analytics in intelligence operations, enhancing target recognition and battlefield awareness and further reinforcing the growing reliance on AI in military decision-making.

Maven

At the tactical and operational levels of the C2-cycle, AI supports complex decision-making in force application by "integrating state-of-the-art computer vision and AI capabilities into analytic workflows." These workflows include tasks such as locating objects, identifying abnormal activities in near-real-time, detecting anomalies, and identifying targets. Given the impracticality of manually analyzing millions of visual records, AI applications at this stage are critical (NGA, 2024).

The targeting process (both sensor-to-shooter as well as notice-to-effect) in warfare evolved slowly in the past. Identifying and locating targets, tracking them, and relaying this information to weapons systems took significant time, especially during the Cold War. By the 1990s and 2000s, processing reconnaissance data typically required 15–20 minutes, with additional time needed to deploy firing platforms. By today's standards, under optimal conditions, the process can be completed in just a few minutes, although earlier methods required large-scale targeting centers and significant personnel. For example, during Operation Iraqi Freedom in 2003, a single targeting center employed over 2,000 staff members.

In response to the scale and speed demands of modern conflicts, the U.S. Department of Defense launched Project Maven in 2017 to shorten response times and enable simultaneous, parallel execution. By 2022, the U.S. National Geospatial-Intelligence Agency (NGA) assumed control of Project Maven, transitioning the program into an operational military capability (Tucker, 2024). This program aims to utilize computer vision and AI algorithms to identify targets in real time using pre-existing data, such as drone footage (U.S. Department of Defense, 2017), as well as social (online) presence (Sgro Jr, 2019). Maven processes incoming data, applies AI to detect points of interest, and generates battlefield overlays indicating potential targets, friendly forces, and civilian infrastructure. Human operators then make the final engagement decisions.

As part of this project, the U.S. military began testing an AI-driven targeting system in 2020 for reconnaissance data analysis. Unlike traditional methods, this system compares newly captured imagery with existing databases to identify targets, even in imperfect data conditions. While human operators remain integral, AI enhances the speed and precision of targeting decisions. Project Maven functions similarly to a large-scale facial-recognition system, processing video feeds to identify and track targets, distinguishing real threats from decoys (Mohsin, 2024).

Maven has been trained on millions of reference

points from diverse reconnaissance settings, allowing it to make predictions and calculate probabilities. Integrated into battlefield command systems, it now processes supplementary data streams from commercial satellite imagery, military sensor networks, and intelligence databases to provide recommendations on target engagement strategies. In 2020, Maven demonstrated its capability by identifying and targeting an object in under a minute, previously a task that required 12 hours using traditional methods (South, 2024). Since the Russian invasion of Ukraine in 2022, Project Maven has been instrumental in processing satellite-gathered visual information, which has been shared with Ukrainian forces. Additionally, the conflict has provided a valuable testing ground for the system, with Project Maven underwent 50 rounds of improvements during the war (Manson, 2024a).

Despite its success, Project Maven's AI still faces challenges and its development is ongoing, with further improvements expected in the coming years. In 2023, U.S. Central Command's Chief Technology Officer Schler Moore acknowledged that Maven's AI underperformed in determining the optimal sequence of attacks and selecting the most appropriate weapon. While AI excels at target identification, decision-making remains a challenge due to the need for creativity and human judgment. As a result, officials continue to assert that AI will not be granted autonomous authority to make firing decisions (Manson, 2024b).

In the overall C2-cycle, there are no plans to delegate the deciding phase to such systems, as the objective is to assist in identifying targets. It is therefore important to note that these systems remain part of the data sensing and processing phases and do not go beyond the decision-making stages, ensuring as well that all critical decisions remain under final human authority and are guided by current ethical, moral and legal frameworks.

Drone Warfare

In recent years, unmanned aerial vehicles (UAVs) have gained significant attention, particularly through real-time video streams shared on social media. Conflicts such as the Second Karabakh War and Ukraine's defense against the Russian invasion have highlighted UAVs' battlefield impact. In contrast, AI systems in military operations, despite their growing integration, remain less publicly documented; most information comes from reports, news articles, and official statements. Several emerging media outlets detail AI's battlefield role in the Ukraine-Russia conflict, providing insights into the development and deployment of AI-driven first-person view (FPV) drones. (Hambling, 2025) These developments signal an increasing shift toward autonomous and AI-assisted drone warfare.

AI-driven FPV drone warfare is emerging as a game-changer, not just in the Ukraine-Russia conflict but also in ongoing operations in northern Syria. The growing prominence of AI-driven drone swarms, along with cutting-edge cyber and electronic warfare (EW) capabilities, has become a central pillar of modern military operations. As these technologies evolve, so too do the measures required to counter these threats.

For example, to counter the dual threat of cyber and drone attacks, Ukraine is testing the "Hitchhiker" counter-drone system, developed by two leading American tech companies: IronNet (an AI-based cybersecurity firm) and Asterion Systems (specializing in counter-UAS technology). The system can detect drones, classify them, track their movements, disrupt counter-UAS networks, and destroy target drones (Rahman, 2024).

In 2024, Ukraine deployed around 1.5 million drones, with domestically produced AI-based systems integrated into these UAVs. AI is primarily used to enable drones to reach targets autonomously, without direct piloting, allowing them to remain effective even in areas with extensive electronic jamming. This number is expected to surge in 2025, accompanied by the deployment of the first AI-driven drone swarm on the battlefield (Balmforth, 2024).

While achieving 100% accuracy in target identification remains unlikely, an 80% to 90% success rate could still significantly impact large-scale conflicts, especially when thousands of targets are engaged simultaneously. Combined with mass-produced, low-cost missiles and FPV drones, such as those increasingly utilized in the Ukraine-Russia war, AI-driven targeting systems have the potential to revolutionize modern combat. Both the United States and China are leveraging commercial industries to dramatically expand their stockpiles of missiles and FPV drones to unprecedented levels (Konaev et al., 2023).

However, AI's role in military operations is not limited to these early phases; it also extends into adaptive decision-making, operational planning, and execution. As AI continues to evolve, its integration across the entire C2-cycle, including predictive modeling, automated response recommendations, and mission adaptation in real time, is set to redefine the future of command and control. While human oversight remains essential, AI's expanding capabilities are transforming military decision-making, making operations faster, more precise, and increasingly autonomous.

Indeed, current AI applications, such as Project Maven and UAVs in conflict zones, primarily focus on data analysis, processing, and sensemaking-support during the initial stages of the C2-cycle. These AI systems are trained to identify targets, process vast amounts of sensory data, and assist with decision-making. However, as depicted in the C2-cycle framework in Figure 2, AI's influence extends beyond sensemaking into decision-making, acting, and assessing, reinforcing superiority in information, execution, and overall operational effectiveness.

4. Discussion: Revolutionary or Evolutionary?

Predicting the outcomes of AI's future and its potential for military applications is a challenging task and open to debate. Will the development and practical use of AI in the military lead to a Military Revolution, as was the case during the Industrial and Nuclear Revolution? Or does it indicate more of a continuation of thinking and acting with new technology? As directly quoted from Bates (2017): "The difference that is measurable is whether the change is being driven internal to military organizations, or whether it is happening externally to the military but applying an irresistible force onto the organization".

The main difference between Military Revolutions (MR) and Revolutions in Military Affairs (RMA) is their scale and impact. Military Revolutions are much more disruptive, and have a much greater impact on society as a whole, and can start outside the military realm. RMAs are smaller-scale changes that do not have as much of a societal impact. Military Revolutions are often driven by external factors, such as the development of new technologies or the emergence of new threats. RMAs, on the other hand, are often driven by the military itself, as it seeks to find new ways to fight wars more effectively.

AI promises to (partly) lift the fog of war, making von Clausewitz relevant in this matter once again. As it shifts the military discourse, it also brings a new algorithmic fog of war, as AI introduces new vulnerabilities limiting human control and

decision-making regarding the use of force (Bode et al., 2021). Amidst these changes, the military's core values of adaptivity, adaptability, and flexibility remain pivotal, in utilizing this new technology to the fullest. It will not make conventional warfare in the acting stage of the C2-cycle obsolete; rather, it will enhance efficiency and minimize costs. Technology alone cannot eliminate the fundamental uncertainties, frictions, and human dimensions of warfare (McMaster & Biddle, 2003).

Some best-practice initiatives show that it is beneficial to initiate technology-based projects to support officers and provide new concepts. In retrospect, these officers were aware of the availability of commercial tools but could not envision military applications. Providing them with a demonstration enhanced the out-of-the-box thinking.

As expressed in the Art of War (Tzu, 6th century B.C.), operational art is a key aspect in any commander's decision-making process. This is not a new insight, but it is even more important in a complex environment.

The expected impact of AI on C2 today is mostly evolutionary, and relies heavily on technological advancements outside the military sphere. In the long run, it may gradually become more revolutionary and change the way things are done, how information is approached, and how operations are performed. For these reasons, it is important to continue to monitor, investigate, and experiment with advances in the field of AI and learn how to most effectively deploy the new technology (Aranake, 2022).

5. Conclusions

AI-enabled decision-making is not merely a technological advancement; it necessitates alterations in command structures, doctrines, and processes. In addition, it demands a renewed skillset from operators. Only when these aspects are addressed can AI-enhanced command and control truly fulfill its potential to transform military operations. Currently, AI serves mainly as a tool to elevate armed forces' capabilities, provided that its utilization is optimized for efficiency, effectiveness, and agility. However, challenges of military innovation still apply in the case of AI. Future research could focus on addressing the current challenges in using AI for military purposes.

AI enhances decision-making by accelerating the C2-cycle, and improving intelligence analysis, operational planning, and data processing. To fully harness its potential, armed forces must integrate AI efficiently and effectively, ensuring that it serves as a force multiplier, rather than a replacement for human judgment. This requires a shift in mindset from scepticism or partial adoption to proactive adaptation, in which traditional methods are refined to incorporate AI-driven insights. However, the integration of AI requires an entirely new type of workforce, for which current contractor and consultant support roles are not directly fit-for-purpose, particularly to enable sovereign-controlled AI and supporting data systems.

For successful implementation, military personnel must develop data and tech literacy, a new sense of trust in digital systems, algorithmic reasoning, and AI-assisted decision-making skills, ensuring that AI-generated outputs are interpreted correctly and integrated into command processes. For adoption by staff officers of future decision-making support products, platforms such as drones and the Maven program, and (near) real time simulations, the solutions provided should be available on demand, with a low threshold for actual use. Attention should be given to the short time required to activate the system, authenticate, and operate in a standards-based environment, while ensuring that final responsibility remains a human endeavor.

To fully leverage technology-enabled decision-making support systems, achieving true interoperability of processes and procedures is essential. While an ideal solution may take time to develop, NATO and its allies should focus on practical implementation strategies that enhance coordination and operational efficiency. Developing effective modus operandi and utilizing available tools will help build confidence in integrating technology to support the art of command through the science of control and the power of technology. As AI technology evolves, armed forces must remain adaptable and open to refining their approaches. Integration should be an ongoing process. By embracing this technological evolution and fostering open debates, armed forces can harness AI's transformative power to (r)evolutionize their operations and maintain their strategic advantage.

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