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Enhancing Situational Awareness and Decision-Making: The Impact of Advanced ISR Solutions on Command and Control Systems[2]

Abstract

This document explores the transformative impact of advanced Intelligence, Surveillance and Reconnaissance (ISR) technologies on modern military Command and Control (C2) systems, particularly within NATO and EU contexts. It highlights how cutting-edge advancements like artificial intelligence (AI), machine learning (ML), edge computing and big data analytics enhance situational awareness, decision-making and operational efficiency. The transition from network-centric to data-centric warfare is examined, emphasising real-time data integration, autonomous systems and decentralised decision-making to address the complexities of modern combat. While these technologies offer unprecedented decision superiority and adaptability, challenges such as information overload and cybersecurity vulnerabilities are also discussed. The study underscores the need for continuous innovation and integration of emerging technologies to maintain a strategic advantage in dynamic military environments.

Keywords: situational awareness, Command and Control (C2) systems, Intelligence, Surveillance and Reconnaissance (ISR), data-centric warfare, edge computing, decision superiority

Introduction

Technological development has always played a key role in shaping the capabilities and efficiency of military organisations and alliances. This is no different for the

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North Atlantic Treaty Organization (NATO) and the European Union (EU), which heavily depend on robust Command and Control (C2) systems to maintain situational awareness and support decision-making. In recent years, rapid technological advancements have brought both new opportunities and challenges for these C2 systems. This document explores how these developments impact the current NATO and EU command and control systems, focusing on their potential to enhance situational awareness and decision-making.

Emerging intelligence, surveillance and reconnaissance (ISR) systems, open-source intelligence (OSINT), artificial intelligence (AI), machine learning, big data and data analytics have the potential to significantly transform military intelligence and analysis processes. As a result, they have a substantial influence on C2 processes, operational awareness, information superiority and decision-making. These advancements can also improve the speed and accuracy of information dissemination, enabling a quicker and more effective response to emerging threats.

Furthermore, integrating these technologies into C2 systems can enhance interoperability between NATO and EU forces, improving the overall coordination and efficiency of joint operations. Overall, the integration of advanced technologies into C2 systems can significantly boost military capabilities and contribute to mission success. By leveraging these developments, military forces can better adapt to evolving threats and achieve strategic objectives with greater efficiency.[3]

This article addresses the following research questions:
- How do advanced intelligence, surveillance and reconnaissance systems affect command and control systems?
- How do emerging and disruptive technologies, such as edge computing, artificial intelligence and machine learning, influence situational awareness and decision-making processes?

Materials and methods

In current military operations, there has been a significant shift from a network-centric approach to a data-centric approach to warfare. In data-centric warfare, the Army utilises advanced capabilities to enhance lethality, survivability and operational tempo. By providing timely access to critical information, leaders and soldiers can assess risks and optimise combat capabilities. Utilising analytical tools allows for effective understanding and response to dynamic situations, while integrated decision-driven capabilities promote informed decision-making and agile military operations.[4]

Achieving and maintaining informational and decision-making superiority has become critical to the effectiveness of modern military operations. This superiority enables the force to make decisions and manoeuvre ahead of its adversaries, increasing the likelihood of mission success while reducing the risks to personnel and assets. This evolution highlights the growing importance of data in ensuring the success of

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[3]   Tóth 2020.
[4]   Rey–Saie 2023.

military operations. In a data-centric context, the efficiency of military operations increasingly depends on the comprehensive collection of relevant information, its effective processing and timely sharing across different levels of command. Advanced data analytics, artificial intelligence and secure communication networks play a crucial role in supporting these processes. These technologies enhance the ability to analyse complex datasets, allowing military leaders to make informed decisions quickly. Moreover, access to accurate and relevant real-time information is not only essential for executing operations but also for dynamically adapting operational procedures to changing battlefield conditions. In recent years, several studies[5] have identified that military operations have transitioned from network-centric warfare to data-centric warfare, rooted in data-driven decision-making processes.[6]

Data-centric warfare is an evolving military strategy that emphasises the critical role of data and information technologies in modern combat operations. This approach leverages advanced data analytics, artificial intelligence and machine learning to enhance decision-making, situational awareness and operational efficiency on the battlefield. As military forces increasingly integrate these technologies, the concept of data-centric warfare has become a significant factor in shaping contemporary military strategies, reflecting a shift from traditional resource-based models toward information dominance and agile responses to emerging threats. The significance of data-centric warfare lies in the rapid processing of massive amounts of data collected from various sources, including sensors and reconnaissance systems. This shift not only increases battlefield efficiency but also presents numerous challenges, such as data quality, human–machine collaboration, and technical issues related to the military applications of artificial intelligence. Integrating advanced technologies allows military personnel to make informed decisions quickly and navigate the complexities of modern warfare, characterised by hybrid threats and multi-domain operations.[7] One of the core principles of data-centric warfare is a proactive approach to information operations, which has become an integral part of contemporary military strategies. Data plays a central role not only in coordinating operations but also in influencing the C2 capabilities of adversaries. This approach emphasises the importance of anticipating military requirements and the capabilities of adversaries, enabling decisive actions during information operations. The principle of "attack" as an information activity embodies an aggressive mindset aimed at achieving information dominance over the adversary. This involves not only protecting one's own information systems but also actively disrupting the adversary's capabilities, including command and control systems and information dissemination networks.

Bobenrieth and Watts emphasise in their article that cyber operations, which are a critical component of data-centric warfare and information operations, encompass a broad spectrum from data theft and system mapping to denial-of-service attacks. These actions do not always constitute an "attack" in the legal sense under the laws of war. Defining the threshold of attack is crucial in data-centric warfare, as many

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[5]   Skoryk et al. 2021; Mayer 2023; Bronk – Cranny-Evans 2022.
[6]   Milano 2023.
[7]   Fazekas 2024.

operations focus on disrupting, manipulating, or rendering enemy data and systems unusable without causing physical damage. Fundamentally, this can be described as an "offensive orientation", requiring military forces to respond immediately to threats in the information domain while adapting quickly to emerging challenges. This means military forces must act swiftly against newly identified hostile information platforms and adapt to constantly changing circumstances, neutralising potential advantages held by adversaries. This approach integrates information operations into the broader operational framework, making them a vital component of overall military capability. These emerging operational procedures demand the decentralisation of C2 systems. Instead of traditionally centralised decision-making, smaller, local units are empowered to execute data-driven decisions quickly. The importance of decentralisation is particularly evident in environments where communication systems may be unreliable or vulnerable. By enabling independent data analysis at the local level, even in peripheral areas, military organisations can significantly improve their adaptability and responsiveness, enhancing the quality of operational execution.[8]

Data-centric warfare relies heavily on data analysis, a critical component in enhancing decision-making within the combat environment. A network of strategically placed sensors gathers comprehensive data about environmental conditions, troop movements and enemy positions, creating a detailed picture of the operational environment and supporting decision-making. This data is then processed and analysed to generate actionable insights, enabling data-driven decision-making processes.

The iterative decision-making process is supported by the OODA Loop (Observe, Orient, Decide, Act). This model is designed to improve decision-makers' ability to assess dynamic situations and respond faster and more effectively than the enemy. Rapid execution of the cycle allows for outpacing the enemy in decision-making by creating a "shorter time cycle" than the enemy requires. This forces reactions from the enemy, ensuring proactivity and supporting anticipation. The OODA Loop also provides flexibility, enabling leaders to adapt to changing environments and new information. Overall, effective use of the OODA Loop can disrupt the enemy's decision-making processes, ensuring decision superiority. The components of the OODA Loop in a military context are defined as shown in Table 1.

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8   BOBENRIETH–WATTS 2024.

Table 1: OODA Loop procedures and tools

Phases	Objectives and procedures	Tools
Observe	This initial phase focuses on a comprehensive assessment of the current situation to gather a broad range of relevant information. In a military context, various intelligence, surveillance and reconnaissance tools are utilised, including unmanned aerial vehicles (drones), satellites and reconnaissance teams, to collect and distribute critical data. Observing enemy movements, such as troop deployments and tactical manoeuvres, is essential for identifying strategies and intentions. Sensors are employed to analyse terrain, weather conditions and other environmental factors that could influence military operations or provide strategic advantages.	Using advanced sensor systems that play a crucial role in detecting potential threats and movements within the area, employing state-of-the-art technology to capture even the smallest changes in the environment. Deploying radar systems for real-time observation of hostile forces' movements, providing situational awareness and supporting strategic planning efforts. Conducting visual observations by personnel, who meticulously monitor and document enemy activities, helping to create detailed records that can serve as the basis for future actions and decisions. Robust Big Data intelligence integrates large amounts of data from different sources, supporting identifying patterns and insights that improve decision-making and increase operational efficiency.

Phases	Objectives and procedures	Tools
Orient	The primary goal is to thoroughly analyse and interpret the gathered information to create a comprehensive overview that serves as a foundation for decision-making. Evaluating the enemy's tactics and intentions: Gather information about the enemy's recent actions and activity patterns. Assess their strengths, weaknesses and possible future intentions or moves to understand their behaviour in the current situation. Assessing our own forces: Examine the current capabilities and limitations of our forces, including personnel, equipment and logistical support. Identify strengths that can be utilised and vulnerabilities that need to be addressed in light of the present circumstances. Comparing the current situation to strategic objectives: Analyse how the current scenario aligns with overarching strategic goals. Determine whether the current operational approach effectively supports achieving these goals or if adjustments are needed. Integrating observed information: Combine new intelligence with knowledge, skills and insights gained from previous military operations. Use this integrated information to gain a more detailed understanding of the battlefield and to inform tactical decision-making.	Using analytical software to review large amounts of data and identify patterns. Employing strategic modelling techniques to simulate different scenarios and predict outcomes based on various courses of action. Seeking expert opinions from military analysts and experienced personnel to gain diverse perspectives on the given situation. Comprehensive Big Data analytics to identify actionable information to support informed decision-making and significantly improve the operational efficiency of all operations.

Phases	Objectives and procedures	Tools
Decide	The primary goal is to develop a detailed and feasible plan to effectively manage military operations. Making quick, well-founded decisions: It is essential to analyse battlefield situations rapidly while ensuring that the assessment is based on reliable and relevant intelligence data. This allows commanders to respond effectively to dynamic situations without unnecessary delays. Choosing the most advantageous option: Commanders must evaluate multiple courses of action available during operations. This involves considering enemy movements, strengths, weaknesses, immediate tactical decisions and overarching strategic objectives that align with the mission requirements. Prioritising actions that effectively counter enemy manoeuvres is critical, while optimising the use of available resources. The element of time also plays a key role, as timely decisions can capitalise on opportunities before the enemy can react. Effective communication: After a decision is made, it is vital to immediately and clearly convey the chosen course of action to all involved teams and units. This ensures that everyone understands their role and responsibilities, aligning efforts towards the shared objective.	The use of battle management systems that integrate real-time data from various sources and provide commanders with a comprehensive overview of the battlefield to support decision-making. The application of decision-support systems, where analytical tools assist in evaluating different tactical options and predicting outcomes based on current and projected scenarios, thereby improving the decision-making process. The implementation of reliable command and control communication channels. These trusted communication networks enable the swift dissemination of orders and information among military units while maintaining confidentiality and integrity, facilitating coordination and the execution of planned strategies.

Phases	Objectives and procedures	Tools
Act	The primary goal is the efficient execution of decisions made. Carrying out offensive or defensive operations: Executing military activities planned according to objectives, aimed at either attacking the enemy (offensive) or protecting our forces and assets (defensive). Rapid mobilisation and coordination of troops: Quickly assembling and organising military units to ensure they are ready for deployment. This includes deploying forces to designated locations and establishing clear communication and command structures to enhance operational efficiency. Continuous monitoring of operational outcomes: Regularly evaluating the results of operations to determine their effectiveness. This ongoing assessment allows for timely adjustments and the initiation of a new OODA cycle, thereby refining tactics and procedures based on real-time feedback.	The use of weapon systems, including a wide range of arms from small firearms and artillery to advanced missile systems, which are designed to meet specific operational requirements. The implementation of reliable and secure communication networks, which are crucial for maintaining contact between units and for transmitting critical information and commands. These systems also play a key role in sending reports that are important for the further planning processes. The availability of effective logistical support, which is essential for providing the necessary supplies, equipment and maintenance support to ensure that the forces are properly equipped and sustained during their missions.

Source: BREHMER 2005

By integrating data-driven elements into the phases of the OODA Loop, military commanders can navigate complex scenarios more effectively and enhance their overall operational responsiveness. Incorporating data-driven solutions into the OODA Loop can significantly improve the process's efficiency and accuracy. The use of data-driven technologies in each step allows for more objective decision-making, faster analyses and real-time responses. Figure 1 illustrates the data-driven OODA Loop processes.
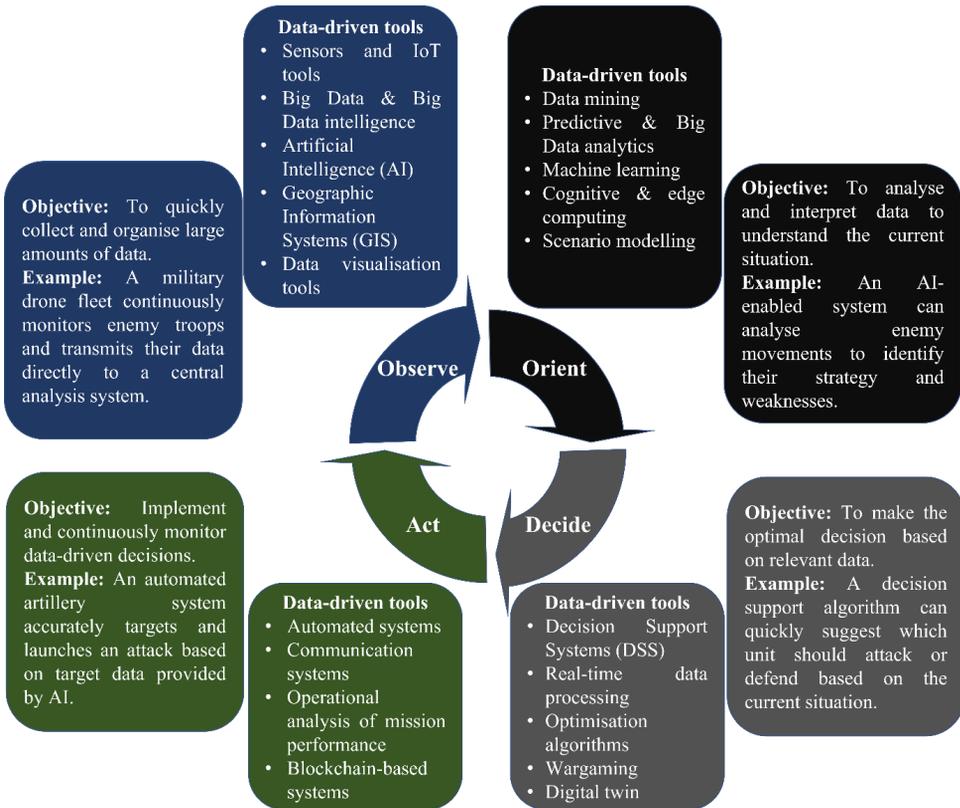
Figure 1: Data-driven OODA Loop processes
Source: compiled by the author

During the observe process, the sensors and IoT devices used include a variety of advanced technologies such as drones, satellites, radar systems, thermal cameras and other sensors, all designed for real-time data collection. These tools are crucial for accurate and timely information gathering across various fields, from environmental monitoring to tracking enemy activities. Big data technologies play an essential role in managing and organising the vast amounts of data generated by these sensors. Sophisticated intelligence systems are employed, using automated data collection and analysis methods that allow organisations to derive meaningful insights from large datasets. Artificial Intelligence enhances this process through automatic pattern recognition capabilities. By analysing data patterns, AI effectively identifies anomalies or deviations, such as unusual movements or behaviours, which can provide insights into enemy operational plans or potential next steps. For instance, computer vision technologies allow AI to interpret and understand visual data. At the same time, neural network-based object recognition algorithms are critical in the evaluation phase.

Together, these technologies enable the precise identification and tracking of objects in complex environments, bolstering situational awareness and decision-making processes in military operations. Geographic Information Systems (GIS) are indispensable for processing and analysing spatial data, enabling the creation of detailed maps and visualising connections based on the collected data in military contexts. This supports the development of a common operational picture. These efforts are complemented by data visualisation tools, which transform complex datasets into easily understandable formats. Using graphs, charts and interactive dashboards, these tools help stakeholders make sense of complicated information, facilitating informed decision-making and strategic planning.

In the orient phase, data mining refers to the process of extracting valuable and relevant information from vast databases. This technique allows military organisations to uncover patterns and trends that can provide the necessary information for decision-making. Predictive and Big Data analytics are essential for forecasting adversary intentions and actions. These techniques enable military leaders to identify patterns and make informed predictions by analysing extensive datasets. By analysing past experiences, available relevant data, statistical algorithms and machine learning techniques, analysts can develop models that predict potential threats and hostile military movements. Machine learning techniques analyse historical data to draw lessons and conclusions from previous combat situations. By recognising patterns and outcomes, military forces can adjust their procedures and tactics based on strategies and techniques that proved successful in the past, ultimately improving decision-making during operations. Cognitive computing and edge computing utilise advanced AI-based systems to analyse data at the perimeter of the network. This enables real-time detection and interpretation of complex situations, even in remote or challenging environments. Such capabilities are vital for understanding operational contexts that may not be immediately obvious. The concepts generated by these technologies can be analysed through scenario modelling, which involves simulating various potential situations to determine the most effective course of action. By evaluating situations with different outcomes based on various variables, military planners can prepare for multiple possibilities and make informed decisions.

Decision support systems (DSS) play a crucial role in modern military operations because they integrate advanced artificial intelligence and analytical tools to help identify optimal strategies. These systems are designed to process large amounts of data in real time, allowing military leaders to quickly assess critical information and make well-informed decisions in time-sensitive situations. By using optimisation algorithms, DSS enables a systematic evaluation of different courses of action, taking into account factors like resource allocation, logistical constraints and the timing of various operational manoeuvres. This analytical capability ensures that military planners can develop plans that maximise efficiency while making the best use of available resources. Wargaming also supports this process, serving as a strategic approach that involves simulating military scenarios to analyse and predict possible operational and tactical responses from adversaries. Through wargaming exercises, military organisations can better understand the dynamics of a conflict and refine their strategies based on anticipated enemy actions. The concept of the digital twin

is another innovative tool in military decision-making. A digital twin is a virtual replica of real-world situations, allowing decision-makers to simulate various scenarios and test different military options in a risk-free environment. This virtual simulation enables commanders to explore the consequences of different decisions, enhancing their ability to adapt to changing circumstances on the battlefield and improving overall operational effectiveness.

In the act phase, automated systems utilise advanced technologies such as robotics, autonomous vehicles and drones, which can process information and make decisions at speeds surpassing human capabilities. These systems are designed to operate efficiently in dynamic environments, providing significant tactical advantages. Communication systems play a crucial role in these military operations, as they enable real-time coordination and facilitate command and control interactions between command centres and frontline troops. This ensures a seamless flow of information, keeping teams accurately informed about changing conditions and instructions. The operational analysis of mission performance focuses on continuously monitoring the effectiveness of various measures implemented during the mission. This real-time assessment allows military leaders to evaluate which strategies are working and quickly adjust plans if necessary, enhancing the overall success of the operation. In addition, blockchain-based systems offer robust solutions to ensure the authenticity and security of operations and commands. By using decentralised technology and encryption, these systems protect data integrity and prevent unauthorised access, which is essential for maintaining operational secrecy and the trust of military personnel.

Results

Improving situational awareness (SA) and decision-making is crucial in various dynamic environments, particularly in military operations and the management of complex systems. SA refers to the perception, understanding and projection of elements within the environment, forming the foundation of effective decision-making processes. By integrating advanced ISR solutions, organisations are better equipped to obtain a comprehensive understanding of their operational environment. This is vital for C2 systems in high-stakes operations. The integration of technologies such as edge computing, artificial intelligence (machine learning), unmanned aerial vehicles (UAVs) and real-time data sharing through tactical data links significantly enhances the tactical-level situational awareness of military personnel on the battlefield. Tools like rugged mobile devices, tablets and augmented reality (AR) glasses help soldiers in the field process this information more effectively. Advanced helmet displays provide vehicle operators and pilots with critical tactical data, further improving their operational efficiency. Tactical data links, including radios and satellite communications (SATCOM), are essential for maintaining situational awareness. These systems distribute audio, video and sensor data, ensuring that teams have access to relevant information regardless of their circumstances.[9] As military operations evolve,

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[9]   LOMBARDO 2024.

the integration of advanced ISR solutions continues to enhance SA by delivering a comprehensive situational picture. This supports command and control decisions with reliable and verified information, often cross-validated from multiple sources, ensuring that decision-makers are equipped with all the critical data they need.[10]

These developments allow commanders to receive timely information and make well-informed decisions, which can significantly contribute to the successful execution of missions. With the continuous advancement of technology, the ongoing research and development of SA methods remain essential, especially as organisations strive to stay ahead of emerging challenges in both military and civilian contexts. The challenges related to data integration and the risk of information overload particularly highlight the complexity of enhancing situational awareness. Addressing these issues is crucial to ensuring that operators can effectively utilise advanced ISR technologies to make sound decisions in increasingly interconnected and dynamic environments.[11] The impact of advanced ISR systems on C2 operations in military activities is one of the central themes of this study, significantly influencing modern warfare. Advanced ISR technologies have revolutionised how military organisations collect and process information, enabling superior situational awareness and more informed decision-making in dynamic settings. This transformation is noteworthy as it enhances operational efficiency and decision-making superiority, providing commanders with comprehensive insights that greatly influence tactical outcomes on the battlefield.

A July 2024 analysis revealed that recent conflicts have underscored the need for C2 systems to adapt to the complex challenges of modern warfare, such as asymmetric threats and cyber operations. Russia's operations against Ukraine highlighted the importance of adaptability in hybrid warfare. Drones, satellite imagery and artificial intelligence play key roles in improving situational awareness and facilitating rapid decision-making. These technologies are fundamental for effectively adapting to various operational scenarios. Future C2 systems will rely on technological advancements such as data analytics, artificial intelligence and cloud computing. The rise of hybrid warfare demands abandoning traditional hierarchies and adopting more flexible, decentralised models and data-driven operations. The rapid data analysis capabilities of artificial intelligence, real-time multi-domain operations and coalition interoperability are becoming critical priorities.[12]

One of the deepest impacts of advanced ISR on C2 is achieving decision superiority. This concept refers to the military's ability to maintain better situational awareness and make faster, more informed decisions than their adversaries. By leveraging advanced ISR technologies, commanders can gain comprehensive insights into enemy movements, assess the efficiency of friendly forces and identify emerging threats in real time. This provides a critical advantage, allowing forces to manoeuvre better than the enemy on the battlefield. Further research has shown that autonomous systems are set to play a key role in military decision-making processes, fundamentally transforming these processes and enabling faster and more effective decision-making, thus

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[10]   Tóth–Farkas 2023.
[11]   Green et al. 2023.
[12]   Total Military Insight 2024.

ensuring the potential for achieving decision superiority. These systems integrate modular applications of artificial intelligence, data analysis and precision weapon technologies, reshaping the global balance of power and the functioning of C2 systems. By accelerating the OODA Loop, autonomous systems enable more efficient operations, particularly at the tactical level, where self-improvement and adaptation are also realised. The three levels of autonomous weapon systems – human-controlled, human-supervised and fully autonomous – require decreasing amounts of human intervention, creating information dominance. The authors point out that AI facilitates forecasting and provides unexpected suggestions, as it can process vast amounts of data. With these capabilities, autonomous systems enhance the speed, efficiency and complexity of warfare while demanding new approaches to cooperation between commanders and AI solutions.[13]

Regarding the impact of enhanced situational awareness and better decision-making processes on C2 systems, the conclusion can be summarised as follows: the integration of advanced ISR systems has transformed traditional C2 paradigms, enabling unprecedented levels of situational awareness and decision-making accuracy. Real-time data collection and analysis provide commanders with a comprehensive view of the operational environment, allowing them to anticipate enemy actions and make well-informed decisions with greater efficiency. This enhanced capability facilitates decision superiority, granting a strategic advantage on the battlefield. However, the massive influx of data also presents challenges, such as the risk of information overload and potential decision paralysis. To mitigate these issues, artificial intelligence and machine learning have become indispensable, streamlining data processing and enabling actionable insights at unparalleled speed. This evolution is also reshaping C2 systems by integrating data-driven operations that emphasise collaboration, interoperability and rapid adaptability.[14] Moreover, it has become evident that analysing the information collected by advanced ISR systems as early as possible is essential. Edge computing offers an excellent solution for this, enabling decentralised data processing at or near its source instead of relying solely on centralised systems. This technology is particularly critical in military operations, where rapid data processing and real-time decision-making are fundamental to success. Edge computing minimises latency, allowing military personnel to respond effectively, even in environments with weak or intermittent connectivity. As a result, frontline platforms can independently analyse and process data, significantly improving information flow and the speed of decision-making. Local data processing is especially advantageous in time-sensitive situations, eliminating delays caused by central command communication. Additionally, edge computing enhances operational resilience by reducing dependency on centralised data centres, which is vital in combat scenarios. By decentralising data processing, military units can manage sensitive information more securely, as it remains within the tactical environment. This approach not only strengthens security but also ensures that critical information for decision-making is always available in a timely manner. In conclusion, edge computing significantly contributes to the

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[13]   Simonetti–Tripodi 2020.
[14]   Tóth 2021.

speed, efficiency and resilience of military operations. This technology plays a vital role in modern military contexts, where rapid reactions and real-time data provide a decisive advantage.

Conclusions

This document investigates the transformative impact of advanced ISR systems, alongside emerging technologies such as edge computing, artificial intelligence and machine learning, on modern military C2 systems. The analysis provides insights into two critical areas:

1. Effects of Advanced ISR on C2 Systems: Advanced ISR systems, including drones, satellites and real-time data analytics, significantly enhance situational awareness by offering comprehensive and timely insights into the operational environment. This capability empowers military leaders with decision supe-riority, enabling them to anticipate threats, make informed choices rapidly and maintain a strategic advantage. The integration of ISR with C2 systems has revolutionised traditional paradigms, fostering improved interoperability, operational efficiency and mission effectiveness. However, challenges such as information overload necessitate the adoption of AI and ML to streamline data processing and ensure actionable insights.
   For example, ISR drones and satellites can utilise advanced AI to identify enemy artillery positions by analysing heat signatures, muzzle flashes and gunfire acoustics. They predict firing patterns based on terrain and past actions, quickly transmitting coordinates to command posts for precise counter-battery strikes. This system directs munitions such as artillery, missiles and kamikaze drones while continuously monitoring enemy movements to ensure effective suppression and strategic advantage.
2. Influence of Emerging and Disruptive Technologies on Situational Awareness and Decision-Making: Technologies like AI, ML and edge computing are reshap-ing situational awareness and decision-making processes. AI and ML enable predictive and Big Data analytics, pattern recognition and rapid processing of vast datasets, enhancing decision-making speed and accuracy. Edge computing decentralises data analysis, allowing real-time decision-making at the tactical level, even in environments with limited connectivity. This decentralisation strengthens operational resilience and security while reducing latency, thereby ensuring that commanders and field units can act swiftly in dynamic combat scenarios.
   For example, the disputed area's forward operating base (FOB) requires strong surveillance to detect and neutralise threats before they reach the perimeter. Traditional surveillance methods, such as handheld surveillance cameras or UAV imagery, can cause serious problems with operator fatigue, delayed response times and centralised data processing that can be disrupted in contested environments. AI surveillance cameras and UAVs use ML models trained to identify enemy movements, unusual activities or potential threats. Pattern

recognition algorithms detect anomalous behaviour, such as when a person moves inappropriately near the perimeter or in a way that indicates a reconnaissance attempt. Instead of transmitting the raw video feed to a centralised command centre, edge computers (e.g. robust mini servers located at the FOB) process the data locally. Instant classification of potential threats provides real-time alerts, reduces latency and enables immediate response. AI-enabled automated response systems can trigger alerts and deploy countermeasures (e.g. automated turrets or drones).

Table 2 illustrates the effects found in the studies. The table shows the impact of each of the disruptive technologies on the areas under study.

Table 2: Impact of disruptive technologies on command and control systems, situational awareness and decision-making

Area of impact	Impact on command and control systems	Influence on situational awareness and decision-making
Advanced ISR Systems	Enhances common operational picture by providing real-time data and insights; improves interoperability and operational efficiency; challenges include information overload. Provides a unified operational picture through real-time data integration; enables enhanced coordination across multi-domain operations.	Improves decision superiority through real-time, comprehensive insights; supports proactive responses to threats. Supports the integration of augmented reality tools, improves real-time battlefield visualisation and enhances collaborative decision-making among units.

Area of impact	Impact on command and control systems	Influence on situational awareness and decision-making
Artificial Intelligence (AI) and Machine Learning (ML)	Enables predictive and Big Data analytics, rapid data processing, and pattern recognition; supports informed and real-time decision-making; mitigates risks of data overload and decision paralysis. Facilitates adaptive command structures by leveraging AI for scenario simulations and decision recommendations; supports enhanced human–machine collaboration in complex operations.	Accelerates decision-making processes by analysing complex datasets; supports forecasting and scenario modelling. Supports the integration of augmented reality tools, improves real-time battlefield visualisation and enhances collaborative decision-making among units. Facilitates autonomous decision-making systems, reducing the cognitive load on operators; enables real-time adaptation to emerging threats and enhanced multi-domain coordination. Enhances predictive situational analysis through machine learning models trained on historical data; supports the development of intelligent warning systems to prevent threats.
Edge Computing	Decentralises data analysis, allowing real-time decision-making even in low connectivity environments; enhances operational resilience and reduces latency. Strengthens tactical decision autonomy by decentralising critical data analysis; improves system resilience against cyber and connectivity disruptions.	Facilitates rapid and secure information flow; strengthens decision-making speed and efficiency in dynamic environments. Supports the integration of augmented reality tools, improves real-time battlefield visualisation and enhances collaborative decision-making among units. Allows for decentralised data sharing between units, enhancing local decision autonomy; provides redundancy and resilience in environments with disrupted central communication. Improves battlefield agility by processing environmental data in real-time; enables integration with wearable technologies for on-the-ground personnel, ensuring continuous situational updates.

Source: compiled by the author

Future research initiatives will concentrate on a thorough investigation of the limitations and challenges encountered in implementing advanced Intelligence, Surveillance and

Reconnaissance (ISR) systems alongside cutting-edge technologies such as Artificial Intelligence (AI), Machine Learning (ML) and edge computing. This comprehensive research will involve detailed quantitative analyses designed to assess measurable improvements in critical performance metrics, including response times, accuracy rates and overall operational efficacy, in real-world and simulated scenarios. Moreover, the research will aim to identify specific technological advancements, such as enhanced sensor capabilities, data processing speeds and decision-making algorithms, as well as operational enhancements related to teamwork and information sharing among various military units. By translating these technological and operational insights into actionable strategies, this work will provide valuable guidance on best practices, ultimately contributing to creating more resilient and effective command and control systems tailored for modern military operations.

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