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Rethinking military command and control systems

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Abstract

The evolution of society and the new characteristics of armed conflict, as demonstrated in today's wars, highlight the need to adapt the military system to meet current and future challenges. In an increasingly complex and contested operational environment, command and control systems must be the first priority in this endeavour because of their impact on all other components of the military domain. Moreover, the technologization of society and the increased transparency of the confrontational environment place additional pressure on ensuring the effective protection and functionality of command-and-control systems.

This article explores the need to rethink the architecture and fundamentals of C2 systems, analysing the essential elements that support operational effectiveness: flexibility, modularity, survivability, small footprint and resilience. In the context of new multi-domain operational paradigms and accelerated technological progress, C2 adaptation involves the integration of emerging technologies such as artificial intelligence, automation and real-time response capabilities to optimize decision-making. In particular, it emphasizes the importance of modularity and redundancy to ensure the operation of systems under conditions of intense conflict, as well as reducing electromagnetic vulnerability and increasing mobility. The article's conclusions propose practical solutions for adapting C2 systems organized around the four components of people, processes, technology systems and command posts, highlighting their essential role in achieving decision advantage, a critical element of operational success on the modern battlefield.

Keywords:

C2 (command and control); decision; adaptation; technology; human factor.

Article info

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Today's operational environment is evolving into an integrated conglomerate of threats, assets and capabilities, extending beyond the traditional land, air and maritime domains into space, cyber, the electromagnetic spectrum or the information dimension. This increased complexity requires rethinking the way military operations are planned, conducted and managed, and poses new challenges to traditional command and control concepts. Against the backdrop of profound changes in the defence sector, but also against the backdrop of increasing great power competition, Western militaries are taking accelerated steps to adapt to the new demands and opportunities of contemporary armed conflict (Bailey 2023).

Modern approaches such as multi-domain operations, a concept developed by the US Army and also implemented by NATO, can provide solutions to these new requirements, demonstrating the need for greater convergence of capabilities and synchronization across the different domains of operations, but also with international partners. The challenges posed by major technological adversaries such as China and Russia underline the urgency of adapting armed forces to a new type of great power competition across the spectrum of conflict. This transition is not limited to matching military capabilities but involves a broad process of integrating advanced technologies, from artificial intelligence and automatization to satellite surveillance and digitized communications.

Research problem

In this context, rethinking command and control systems becomes a strategic imperative for any actor. However, implementing these changes is not without difficulties, as the evolving operational environment places multiple and often conflicting demands on these systems. This article analyses the implications of these changes for the Romanian Armed Forces, as the main target of this study, and explores possible directions for adapting command and control systems in an attempt to shape a viable command model in the face of the complex challenges of the future.

Research objective

For this reason, this paper aims to analyse the factors influencing C2 systems and to identify courses of action for the main target of this study, the Romanian Army, in its efforts to adapt to current and near-future challenges. The need for such an endeavour comes against the backdrop of changes in the way armed conflicts are understood and conducted, as well as the accelerated development of technological systems and their impact on the current mode of operation. Furthermore, given the importance of command and control as a central element in the process of military operations, it is imperative that the armed forces' approach to adaptation begin with an analysis of command-and-control systems.

Research methodology

The research carried out was **a qualitative** one, aimed firstly at understanding the specific nuances of command-and-control systems, and then at analysing the

challenges they face as a result of the nature and character of the conflicts and the trends in the evolution of the operating environment. In line with the qualitative approach adopted, we also opted for **inductive reasoning**, constructing our conclusions and findings from the available empirical data (Leavy 2023, 9; Creswell and Creswell 2023, 276).

Given the qualitative nature of the study, it did not aim to test and validate hypotheses. The paper was guided by the following **research questions:**

- What are command and control systems?
- What factors influence command and control systems?
- What aspects need to be taken into account for an effective adaptation of command-and-control systems?

The logical scheme of the research undertaken is shown in the figure below.

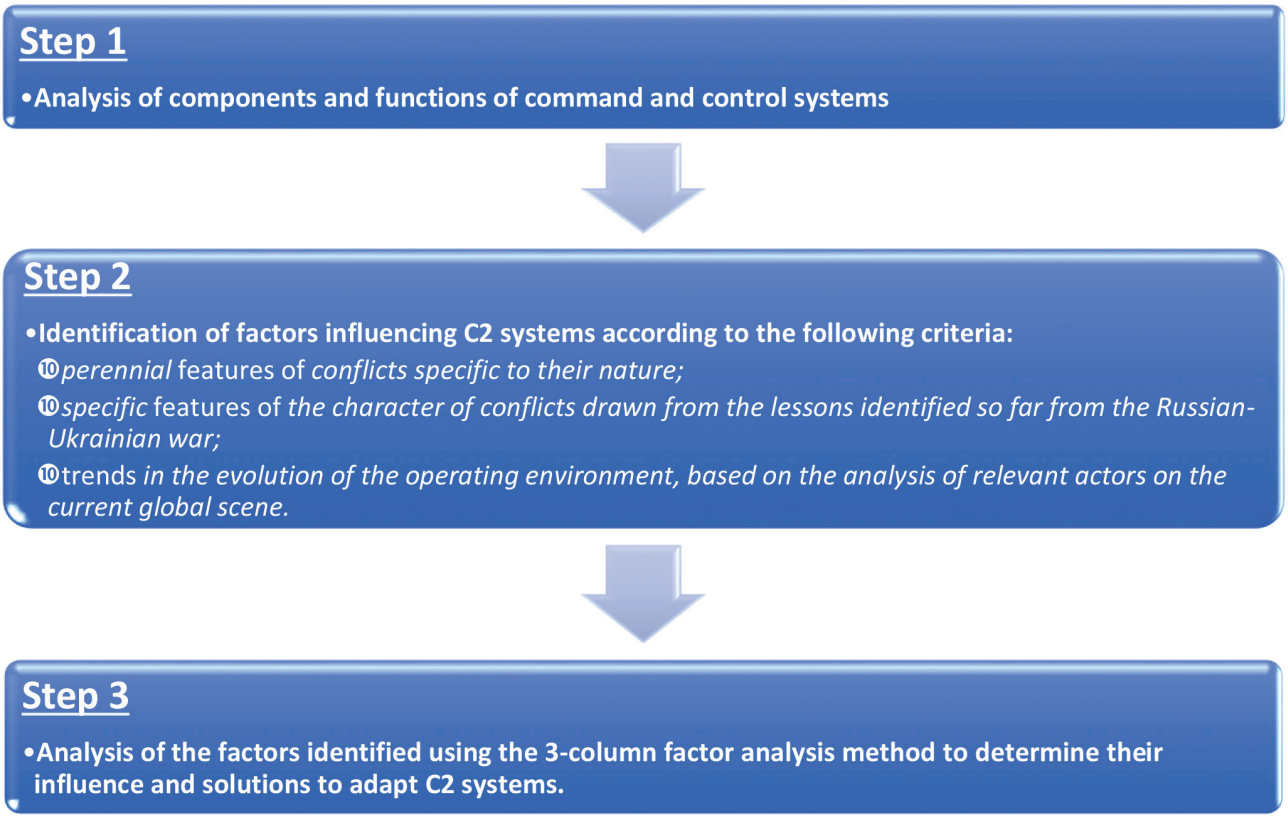

Figure 1 Logical scheme of the research
Source: author's conception

Figure no 1 - Both **primary and secondary data** were employed. For example, we used the results of previous research to identify those elements of the enduring nature of the conflict, its character as a result of the Russian-Ukrainian war, and the evolving trends in the operational environment that may affect command and staff systems. We collected these data using the method of documentary analysis to select

those most relevant to the purpose of the study and the research questions. **The sampling** of these data **was non-probabilistic** and based on three secondary data selection criteria:

- the perennial characteristics of conflicts, which are specific to their nature;
- the specific features of the nature of conflicts, based on the lessons learned so far from the Russian-Ukrainian war;
- the trends in the development of the operating environment, based on the analysis of the relevant actors on today's global scene.

The primary data used resulted from a proprietary process of inference on the results obtained from the analysis of the impact of the factors identified in relation to the three previous criteria on C2 systems, using the **individual brainstorming method**. The factors resulted from the application of the **comparative analysis method** to the previously selected documents to ensure their operational relevance.
In the final phase of the research, the **thematic analysis method** was used to identify the aspects necessary for the adaptation of command-and-control systems, coding the data and organizing them into the four specific components of any C2 system: people, processes, technological systems and command posts.

We do, however, recognize several **limitations to the results of our study**, arising either from the unclassified nature of the data used or from the methodological approach adopted. Given the high degree of researcher involvement in the conduct of the study, we were always aware of potential biases that could have influenced the results obtained, and we constantly took reflexive steps to reduce their influence.

Structure of the paper
The paper was divided into three main parts in order to answer the three research questions. Thus, in the first stage, we analysed the characteristics, components and functions of command-and-control systems, highlighting their operational relevance. In the second part, which is also the focus of the paper, we analysed the factors and how they can influence the functioning of the systems, as well as ways to counteract them from a C2 perspective. In the last section, dedicated to conclusions and proposals, we organized the results of the previous section according to the four components of any command-and-control system: people, processes, technological systems and command posts, and proposed relevant and coherent directions for their adaptation for the Romanian Army.

1. Operational relevance of command-and-control systems

For as long as humanity has existed, conflict has been a constant, reflecting the most violent expression of societies. Developing philosophies to manage them, to create the conditions necessary to ensure victory has been a constant human endeavour.
Nowadays we find ourselves at a turning point for everything that is the military

instrument of power. In an increasingly complex and dynamic environment (MCDC 2020, 1-2; TC 7-102 2014, 1-2; JCN1/17 2017, 1), the ability to ensure the operational coherence of forces has become critical to the success of military missions. Within this framework, it is necessary to develop and field advanced command and control (C2) systems to provide the engine for transforming the military system to meet the challenges of the operational environment. C2 systems are the operational core of a modern military force, enabling effective coordination of resources and rapid decision-making in critical situations, and are essential for the efficient and effective planning and execution of combat operations. These systems must be adaptable to rapid changes in the current operational environment and provide a complete picture and accurate understanding of the operational situation.

No activity in a military system is more important than command and control (MCDP-6 2018, 1-3). While it may not be able to carry out direct attacks on the enemy, influence the enemy's perceptions or provide the logistical support necessary for its own combat structures - all of which are critical to the success of military operations - none of these activities would be possible without command and control.

Although command-and-control is discussed in the literature (AJP-3 2019, 1-21 - 1-25) alongside the other functions of warfare, such as intelligence, manoeuvre, fire support, information activities, protection or logistic support, in reality, none of these functions would have a clear purpose without command and control. It encompasses all military functions and operations, giving them meaning and harmonizing them into a meaningful whole. For this reason, command and control systems are of paramount importance in a military context, ensuring the coordination and effectiveness of the actions undertaken by the armed forces. A thorough understanding of these systems is therefore critical to the success of military operations.
Command and control is the authority, responsibility and activities of military commanders in the effective direction and coordination of military forces and in the execution of orders relating to the preparation and conduct of military operations (ATP 3.2.2 2016, 1.1).

The commander is a critical element of the command-and-control system. His or her role is to oversee and direct a wide range of activities, including operational planning, organizing and directing resources, assessing threats, making decisions, and supervising and training troops. Through command and control, he ensures the cohesion and synchronization of military action, enabling the achievement of set objectives and effective mission accomplishment. A well-developed command and control system optimizes the use of resources, improves decision-making and enhances the ability to respond to critical situations. Command-and-control is, therefore, an essential element in the success of any military operation.
Although the central element of C2 is the commander, he or she cannot command and control forces and operations alone but needs support. Command-and-control,

therefore, involves more than the commander. The people involved, the processes used, the technological systems or the facilities from which it can be exercised (command posts) are elements of similar importance, as shown in Figure 2. It is impossible to talk about effective C2 without considering these four elements in addition to the commander. In the following lines, we will briefly analyse what each of them entails, in order to provide the framework for the analysis in the following sections on the adaptation needs of command-and-control systems.

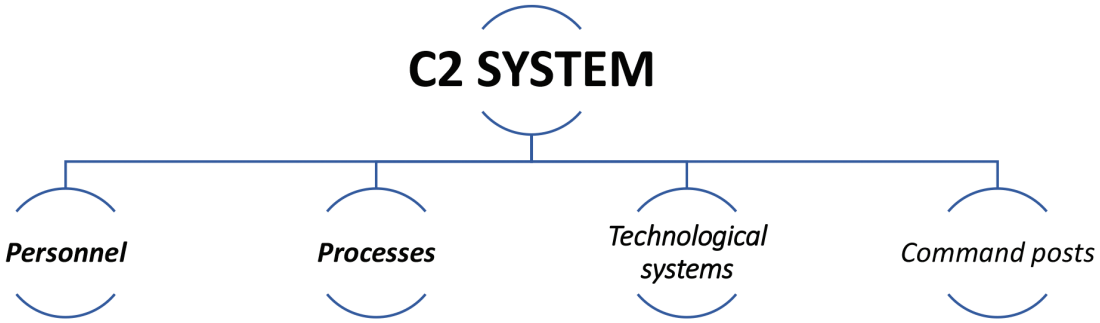

Figure 2 Command and control system elements (Wade 2023, 3-8)

From a C2 perspective, **personnel (Pe)** plays a key role in the effectiveness and coherence of the command-and-control system. Commanders, as mentioned above, are the central element in this process, having direct responsibility for decision making and command of forces. In addition, their authority and leadership style can make a significant contribution to enhancing the morale component of the combat power of armed structures (AJP-3.2 2022, 18). Their mere presence in certain moments and areas of battle can often have a decisive impact on the outcome. Historical examples abound to support this assertion. Given their crucial role in directing the course of operations and, consequently, the conduct of the conflict, commanders must manage their time between the CPs and the positions of subordinate units in order to understand the situation, observe operations and their effects at first hand, and motivate subordinates by personal example.

However, it is physically impossible for these measures alone to provide a comprehensive understanding of the operational situation. Time is a major constraint on the ability of commanders to be present throughout the theatre of operations. For this reason, the role of staff officers is extremely important. They must support commanders in making and implementing decisions by providing analysis and assessments in their specific functional areas that increase the effectiveness of the commander's decisions. Staff personnel are responsible for preparing plans, orders and assessments to ensure effective control of operations. They also contribute to the integration and synchronization of combat power by providing relevant information to facilitate situational awareness and mission progress.
When analysing the command-and-control system, emphasis should be placed on elements such as management style, leadership, or the way in which forces are

trained and educated to improve the performance of personnel involved in specific command-and-control system processes.

The second component of C2 systems are specific **processes (Pr)**. They are an essential element in the organization of activities within major nations. Coherent integration of these processes to facilitate timely decision-making and support effective coordination of combat resources and actions is achieved through the development of a well-articulated battle rhythm, integrated with that of the higher echelon and subordinate structures. Command and control processes play a vital role in ensuring the operational effectiveness of military systems. They enable the coordination and synchronization of actions during a military operation and contribute to its success. A crucial aspect of these processes is that they can provide the military structure with the framework to anticipate and respond rapidly to changes in the operational environment.

A key process is the operational process, which encompasses the core command and control activities carried out during the planning, preparation, execution and ongoing evaluation phases of the operation. This framework enables commanders to understand the operational environment, visualize and describe the end state of the operation, make articulated decisions and direct subordinate structures to achieve their own intent for how the operation should be conducted (ADP 6-0 2019, 2-14 - 2-16).

In addition to the operational process, commanders and staffs use integrative processes to synchronize various specific functions. These processes consist of a series of steps and activities that integrate warfighting functions by involving multiple disciplines to achieve a specific objective. Integrative processes include information preparation of the operational environment, intelligence gathering, targeting, risk management or knowledge management.

C2 processes are designed to be simple and fast, allowing commanders to operate effectively even under extreme stress. They must be efficient enough to increase the pace of operations and simplify staff planning sequences to facilitate rapid response. In addition, C2 processes must provide flexibility and adaptability in the face of changing circumstances and allow for continuous improvement to meet the increasingly complex challenges of the operational environment. Thus, the optimal implementation and exploitation of C2 processes can ensure efficient workflow and effective resource management in order to achieve the set operational objectives.

However, given the digital age we live in and the increased dynamics of operational change, commanders need advanced tools and technologies to enhance their ability to make real-time decisions and communicate them effectively and in a timely manner. For this reason, the third component of command and control, **technological systems (TS)**, is essential to ensure effective communication between the different levels of command and control, as well as to monitor and manage military resources in the

best possible way. The development and implementation of modern technologies and high-performance information systems are therefore essential to ensure the effectiveness and speed of military command and control processes.
The main components of technology systems include end-user applications, information services and data, and transport and digital information management. These elements work together to ensure efficient communication and information management, supporting the effective operation of the C2 system.

Time is a critical factor in modern military operations. Armed forces must work hard to ensure that they execute the action-decision cycle, also known by its inventor's name, the Boyd cycle (OODA - Observe, Orient, Decide, Act), faster and more accurately than the adversary. In this context, the ability to use technology to accelerate timely decision-making can ensure a decision advantage over the adversary.

The final component of the C2 system is the **Command Posts (CPs)**, which play a key role in ensuring the continuous coordination, synchronization and exchange of information between different structures. Their importance stems from the fact that they provide a physical location where people, processes and technological systems are integrated to assist commanders in understanding, visualizing, describing, directing, controlling, executing and evaluating military operations.

Functions common to all command posts include managing knowledge and information, developing and maintaining an accurate understanding of the situation, maintaining current assessments to support the commander's decision-making, controlling ongoing operations, evaluating ongoing operations and planning for the next phases of combat, and coordinating with internal and external organizations in the interest of accomplishing the assigned mission.

All these four elements are essential to the effectiveness of the command-and-control system. The ability to create a C2 system that outperforms the adversary's is a vital step in realizing the preconditions for operational success (ATP 3.2.2 2016, 1.1). In this approach, it is mandatory to identify solutions to streamline the **specific functions of any C2 system**:

- *developing accurate and timely situational awareness* – providing accurate and timely information about the enemy, terrain and own vulnerabilities;
- *developing clear and flexible objectives* – adjusting objectives as the situation changes;
- *establishing situationally appropriate actions* – directing and coordinating the efforts of forces for a harmonized and forceful action;
- *providing continuous monitoring* – so as to enable rapid adaptation to changes on the battlefield;
- *ensuring operational security* – so as to prevent the enemy from gaining information about the true intentions of his own forces;

• *generating a high tempo of action* - exploiting opportunities and ensuring a high tempo of military action to maintain the operational initiative.

2. Contemporary operational challenges to command-and-control systems and potential adaptation solutions

The purpose of this chapter is to identify the factors that may affect command and control in the current operational environment, an approach that is extremely important in determining the potential actions to be taken to adapt command and control systems. In addition, this section aims to draw inferences and conclusions relevant to command-and-control systems in relation to the factors identified, using a critical tool often used in the military operational planning process, the three-column factor analysis.

I would like to mention at the outset that the factors we have analysed in this chapter have only resulted from the analysis of open, publicly available, unclassified sources. In doing so, we acknowledge one of the main limitations of the results of the study undertaken, which results from the nature of the data collected and analysed. The sampling of the data used was non-probabilistic and was carried out in relation to three elements that we consider relevant to the process of adaptation of command-and-control systems:

- perennial features of conflicts specific to their nature;
- the specific features of the character of conflicts drawn from the lessons identified so far from the Russian-Ukrainian war;
- the trends in the evolution of the operating environment based on the analysis of relevant actors on the global scene today.

2.1. Analysing the nature of conflicts in terms of their influence on C2 systems

War is a social phenomenon, the most violent expression of society at any given time. According to most military theorists, it contains both some characteristics that have remained constant over the years and others that have changed with history. The nature of war is the timeless component; it is neither defined by when it takes place nor by the characteristics of the society at that time. Therefore, we can say that it has remained constant over time. Certain fundamental aspects of warfare, such as the role of the human factor, the violent nature of confrontations, their destructive impact on societies, and the constant uncertainty or friction, have remained constant over time and are considered to be essential features of warfare, regardless of how they will change. While all of these characteristics influence C2 systems to some extent, the greatest influence is undoubtedly **the level of uncertainty** specific to military confrontations. How it affects C2 systems, and possible solutions to limit its negative impact, can be found in the analysis in the table below.

TABLE NO. 1

Analysis of the level of uncertainty specific to the nature of armed conflict from the perspective of command and control systems

Factor 1 – *Level of uncertainty specific to the nature of armed conflicts*	
Deductions	**Conclusions**
1.1. Influencing decision-making (Increased risks)	**1.1.1. Decision-making under uncertainty (Pr, Pe)** - training staff in calculated risk acceptance and operational risk management; - effective integration of risk management into decision-making. **1.1.2. Developing staff critical thinking (Pr)** - use of analytical tools for analysing information (e.g. Red teaming, Alternative Analysis, etc.); - educating staff in the use of critical and creative thinking.
1.2. Difficulties in anticipating how the operational situation will evolve	**1.1.2. Opportunities to mislead the opponent (Pr)** - using uncertainty as a basis for constructing an operation to mislead the adversary. **1.2.1. The need to invest in emerging technology to enhance data collection and analysis capabilities. (ST, Pr)** - integration of emerging technology (e.g. Artificial Intelligence) in support of specific processes to achieve operational insight.

2.2. Analysing the nature of conflicts in terms of their influence on C2 systems

Although some aspects of conflict remain unchanged over time, as outlined above, it is the character of war that is constantly evolving. It has changed almost radically over time, depending on the circumstances at the time of the conflict. The main drivers of change are society, diplomacy, politics and technology (JP-1 2017, I-4). This metamorphosis of armed conflict thus depends primarily on technological and scientific innovations, demographic, political and even educational changes in a society at a given time, and to a large extent on the specific characteristics of the security environment at that time (UK Ministry of Defence 2020, 1).

In today's highly complex and rapidly changing world, command and control systems must keep pace with and adapt to these changes in order to maintain the viability of their essential functions for the effective conduct of combat operations. The first defining characteristic of contemporary society is its increasing **technologization** and the growing dependence of the human factor on such technologies, and the military domain is no exception. This presents a number of opportunities but also challenges for future C2 systems.

The ability to make decisions faster and more accurately than the enemy, coupled with advances in the accuracy of long-range weapons and reduced time to engage targets, are critical advantages on the modern battlefield. Current technology is having a profound impact on all branches of the military, "driving the adaptation of military art and existing doctrines, manuals and operational procedures". (Stanciu and Gimiga 2023, 159) Whether it is the process of detecting and engaging targets, gathering and analyzing intelligence, or communicating and maintaining the operational picture, technology has fundamentally changed the way armed forces operate and, by extension, command and control systems.

Technological development has also led to an expansion of the specific domains in which armed forces operate, with NATO's relatively recent recognition of cyberspace

and cyber warfare. As a result, armed confrontations have become much more complex, with multi-dimensionality being one of their most striking characteristics. Today, we talk about the need for a **multi-domain approach** to military operations in order to accomplish the missions entrusted to them. (Crilly and Mears 2022; Ellison and Sweijs 2023, 1; NATO 2022; NATO Parliamentary Assembly 2022, 3). Such an approach poses additional challenges for C2 systems, which must adapt to the complexity and integration of information from different domains (land, air, sea, cyber, and space).

In addition, the rapid development of **anti-satellite technology** and the increased ability to conduct extended hostile **operations in cyberspace** have added significant new dimensions to an already complex picture of how a possible future great power conflict might unfold (Nilsson 2023, 49). All of this has a direct impact on command-and-control systems, as today's armed forces rely heavily on satellites for navigation, communications, surveillance and reconnaissance, the loss of which could severely compromise the ability to coordinate, synchronize and execute operations across multiple theatres of operation. In addition, hostile operations in cyberspace have become increasingly sophisticated and widespread in recent years. These may include attacks on critical infrastructure, such as energy, transport, banking or defence systems, with the potential to have a significant impact on the effectiveness and security of C2 systems.

In addition, as a direct result of increased technological development, we are witnessing an increase in the technical capabilities of military sensors to collect information. This has led to greater transparency on the battlefield. A key element in supporting this, as demonstrated by the Russian-Ukrainian war (Gosselin-Malo 2024), is the use of drones. "The use of unmanned aerial systems has created a transparent battlefield in which there is no hiding place". (Collins 2023, 8)

Drones have revolutionized the way armed forces operate. Their versatility makes drones an extremely important weapon with the potential to support multiple combat functions. Originally used only for reconnaissance, drones have become lethal strike weapons for much more expensive armoured technology. Their operational relevance is evidenced by the nickname given to them in the literature: magic bullets (Hambling 2020). Their impact on command-and-control systems is also extremely high. Ensuring the protection and security of command-and-control centres is one of the greatest challenges facing an adversary's unmanned aerial systems. However, drones also have an extremely important role to play in supporting the development of deep situational awareness: "The information provided by drones and distributed through new digital battlefield command networks greatly increases the speed of decision and action". (Molloy 2024, 90)

Western militaries have enjoyed a superior position in all conflicts since the beginning of this millennium, but this is no longer the case. The world is in a state

of fierce competition, with **multipolarity** being the fundamental characteristic of today's society (IISS 2023, 27). The current situation demonstrates that the ability to operate freely with access to most technological and operational facilities is no longer valid. **The operating environment is highly contested**, with potential adversaries possessing qualitatively similar capabilities. This puts additional pressure to rethink command and control systems, from the specific processes to the technology used or the way command posts are organized. The classic format of the latter, specific to the conflicts of the early millennium, highly static, impressively large and with technology at their disposal, make these command posts a relatively easy target in the face of an extremely powerful adversary such as those of today (Nagl 2024, p. 24). Reducing and masking size, thermal and electromagnetic footprints, or increasing mobility **must be mandatory steps to ensure the survival of command-and-control systems** in today's operational environment (Beagle, Slider and Arrol 2023, 10). In addition, **increasing the accuracy and lethality of weapons, as well as the transparency of the battlefield and the reduction in the time required to identify and engage targets**, pose additional challenges to these systems and require the identification of viable solutions to enhance the protection of command posts in order to ensure the continued functionality of military structures and the operations they conduct.

The increasing pace and complexity of military operations is also a key challenge today. Improvements in mobility, range and lethality are compressing the boundaries of time and space, requiring greater amounts of up-to-the-minute information and an increased operational tempo, putting additional pressure on the effective performance of certain command and control system functions. In addition, the increasing lethality of weapons requires forces to be more widely dispersed to ensure their survivability, pushing the limits of command-and-control systems and requiring a significant amount of technology and information to effectively coordinate forces and operations.
Coupled with the increased transparency of the confrontation environment, these factors severely limit the ability to conceal forces and conduct combat operations, requiring the identification of alternative solutions to achieve surprise of the adversary, but also to ensure the protection of one's own forces.

In addition, a mix of manned, unmanned and autonomous systems will bring a further shift in lethality and employability, while hypersonic, ballistic, long-range missile and space-based counter-operation capabilities will further extend the competitive domain. All these features of the current nature of armed conflict require us to rethink our own command and control systems in order to respond as effectively as possible to today's challenges.

In addition, the complexity and high dynamics of change in today's operational environment create entangled and hidden problems whose solutions are increasingly difficult to identify. Within this framework, the human side of C2 systems must

insist on the adoption and development **of a "red teaming" mentality** that ensures the development of critical and creative thinking among its own personnel (UK Ministry of Defence 2021, 1; JDP 0-01.1 2023, 50).

The commander remains a critical element of the command-and-control system, as the ongoing Russian-Ukrainian conflict demonstrates. The ability to inspire and motivate subordinates has proven to be a particular quality that has increased the resilience of the Ukrainian people, contributing to the morale component of combat capability. Leadership has been and will continue to be a defining element of conflict, with the potential to motivate and unite individuals and maintain the high operational capability of armed forces (MCDC 2020, 4). In addition, the same conflict demonstrated that the use of the concept of mission command was fundamental to achieving Ukrainian decision superiority over the Russians. Trusting subordinate commanders and giving them freedom of action to fulfil the intent of the higher echelon is the essence of mission command.

In addition, given Romania's position as a member of the North Atlantic Alliance, any military operations in which the Romanian military will participate will certainly be multinational. For this reason, the design of future C2 systems must take into account a crucial aspect of **multinational operations**, namely interoperability, in all its three dimensions: technical, procedural and human (AJP-01, 2022, 71).
The result of the analysis of the impact of the nature of the current conflicts on the command-and-control systems and the potential solutions to adapt them is shown in the next table.

2.3. Analysis of trends in the evolution of operating environment and their influence on C2 systems

Evolving trends in the operational environment are a critical factor in analysing how command and control systems adapt. In a context of rapid change and advanced technological developments, military structures must continuously adapt their C2 systems to meet new challenges. This adaptation involves not only the integration of new technologies but also the re-evaluation of decision-making processes in order to respond effectively to the complexity and dynamics of current and future conflicts.

To identify the influence of evolving trends in the operational environment on C2 systems, it is first necessary to understand what these trends are. We have therefore undertaken a comparative analysis of the evolutionary visions of three major actors in international relations who have recently published papers on the subject: the United States (TRADOC G2 2024), the United Kingdom (UK Ministry of Defence 2024) and NATO (NATO 2023).

All these analyses have one thing in common: technology. For the military, too, it plays a vital role in shaping the operating environment of the future. **New technologies** that combine processing power, connectivity, automation, quantum

TABLE NO. 2

Analysis of the impact of the current conflicts' character on command-and-control systems

Factor 2 – *Specific features of the character of current conflicts*	
Deductions	**Conclusions**
2.1. High transparency of the confrontation space due to the development of information collection systems	**2.1.1. Enhanced measures to protect C2 systems (ST, PC, Pe)** - development and deployment of network protection technology in cyberspace; - physical protection of command posts - dispersion, OPSEC measures, counter-drone systems (EW, AD systems, other types of weapons - e.g. lasers) etc. - training personnel on the use of OPSEC measures. **2.1.2. Advantages of situational understanding. (Pr, Pe)** - adjusting the JISR process to collect relevant data; - understanding the limitations of data collection systems in order not to fall into the trap of being misled (seeing is not synonymous with understanding).
2.2. Large volume of data due to the development of information collection systems	**2.2.1. The need to invest in emerging technology to increase collection capabilities and rapidly analyse large volumes of data. (ST, Pr, Pe)** - integration of Artificial Intelligence in support of specific processes of command-and-control systems; - technologizing collection systems to reduce their limitations (weather, electromagnetic spectrum, time - day/night) in an effort to ensure situational understanding; - it must be well understood what the role of the human factor will be and how much the decision should and can be automated. **2.2.2. Increased potential for errors due to inability to analyse relevant data (Pr, Pe)** - decision-making must necessarily include a risk management process; - training commanders and command staff in risk acceptance and risk management. **2.2.3. Increased chance of being misled (Pr)** - the inability to manage the large volume of data can contribute to misunderstanding the situation and create opportunities for the adversary to deceive us; - a process needs to be developed to counter misleading, with preparedness being an essential first element of this process.
2.3. Digitizing the battlefield	**2.3.1. Opportunities speeding up own decision-action cycle (Pr, Pe)** - implementation of artificial intelligence systems and analysis algorithms to manage the large volume of data; - developing mechanisms to prioritize information essential for decision-making in a short timeframe; - training staff to optimize the interpretation and use of digital information. **2.3.2. The need for advanced cyber security measures and protection against interference. (Pr, Pe, ST)** - implementation of a continuous monitoring and defence system against cyber-attacks; - Integrating redundancy and business continuity measures in case of cyber-attacks; - increasing resilience by training staff on cyber risks and security measures.
2.4. The operating environment is highly contested	**2.4.1. Creating more agile command structures capable of operating in contested environments. (PC, Pe, ST)** - optimizing communication networks for mobility and increased security; - adopting dispersed command post practices and using redundant systems; - training staff to operate in analogue mode as well; - introducing additional security measures to protect C2 sites against direct and indirect attacks (e.g. drones). **2.4.2. Implement passive and active safeguards to reduce footprinting and masking of command posts (ST, PC, Pe)** - development and use of equipment and technologies to reduce the thermal and electromagnetic footprint, including multi-spectral electromagnetic shielding and cloaking systems; - optimization of C2 architecture to allow modular and flexible configuration, reducing visibility and time required for installation/deployment in the field; - increased pre-emptive detection capabilities, identifying any adversary surveillance threat early.
	2.4.3. Increased mobility to avoid detection and attacks (Pe, Pr, PC) - introducing mobile command posts and small C2 equipment that can be quickly transported and installed in new locations. - the adoption of rapid relocation procedures to increase the difficulty of detection and tracking by the adversary. - train personnel to operate in high mobility scenarios, preparing rapid procedures and processes for disconnecting and reconnecting to communications and data networks.

Deductions	Conclusions
2.5. The multidimensionality of confrontation	**2.5.1. Development of integrated and interoperable C2 structures (ST, PC, Pr, Pe)** - implementing multi-domain C2 architectures capable of simultaneously managing operations in land, air, maritime, cyber and space; - creating secure and fast communication channels among domains to enable the exchange of relevant information in real-time; - training C2 personnel to understand the specificities of each domain of operation. **2.5.2. Increased capacity to process and analyse data from different domains (ST, Pr, Pe)** - using artificial intelligence and advanced algorithms to integrate data from multiple domains, providing a coherent operational picture; - creating a system for automatically prioritizing information so that critical data from any domain is quickly flagged to decision-makers; - optimizing cross-domain coordination processes to ensure that actions in any operational space are synchronized and support overall mission objectives. **2.5.3. Flexibility and adaptability of C2 structures for efficient and coherent response in several areas (ST, PC, Pr)** - development of configurable C2 procedures and equipment to allow rapid adaptation to the specific requirements of each domain; - introduction of scalable command and control modules to enable effective responses at different levels of intensity and in a variety of operating environments; - ongoing training of personnel in adapting and coordinating responses to interdependent operations in multiple domains, thereby increasing operational resilience.
2.6. Multinational operations	**2.6.1. The need to achieve interoperability between C2 systems (ST, PC, Pr, Pe)** - adoption of common communication and security standards to enable connectivity between different C2 systems, facilitating information exchange and operational coordination; - development of standardized protocols and common formats for reporting and transmission of orders, which are user-friendly for all forces involved; - the implementation of interoperability programs to familiarize partner forces with allied equipment and procedures, thereby increasing operational cohesion. **2.6.2. Investment in staff training and joint training for multinational operations (PC, Pr, Pe)** - organizing regular multinational exercises to train C2 personnel from allied forces in working together; - creating common training manuals and procedures, including practices and protocols for rapid coordination in multi-nation operating contexts; - encouraging the exchange of personnel and experience between partner nations, thereby increasing mutual understanding and integrated responsiveness. **2.6.3. Developing a communications infrastructure tailored for multinational operations (ST, PC)** - ensuring deployment of interoperable, secure and efficient communications networks that support the rapid exchange of information between allied forces without security vulnerabilities; - investing in portable communications technologies and equipment compatible with partner forces' networks so that information is available to all parties involved.

computing, machine learning and artificial intelligence will enable not only a new generation of weapon systems but also new ways of waging war.

All of this has a direct impact on military-specific C2 systems. Innovative technologies can help to speed up the decision-making process by processing and analysing large amounts of data, providing the basis for a near-complete operational picture at all levels of conflict. The main benefits of integrating emerging technologies into C2 systems are recognized to include (NIAG 2022, 1-29 - 1-30):

- faster and deeper understanding of the operational situation
- faster targeting of forces relative to the enemy;
- increased synchronization of operational effects on the battlefield;
- improved processes, capabilities and effects realized through other

combat functions such as logistic support, protection, fire support or intelligence activities.

In support of command and control, technology has the practical ability to improve:

- the collection, analysis, fusion, sharing and, most importantly, exploitation of data from all relevant sources for all relevant domains to provide the best possible situational understanding and thus ensure the information advantage on the battlefield;
- the effective use of this information to make better-informed and better-calculated decisions, thereby ensuring decision advantage over the adversary;
- the synchronization of information and effects of operations across environments and theatres;
- the optimization of the tempo of battle to achieve superior enemy decision tempo.

Considering the increasing dynamics and growing complexity of military confrontations, it is expected that technology will be a primary factor in building new C2 systems. The analysis and impact of the main emerging technologies with relevance in this respect are presented in the table below (NIAG 2022, 3-106 - 1-115; NATO Science & Technology Organization 2020, 41 - 111).

TABLE NO. 3

Analysis of the impact of the main emerging technologies in the construction of new C2 systems

Technology	Details	How can it support the C2
Artificial intelligence	• Artificial intelligence (AI) is the ability of machines to perform tasks that typically require human intelligence. These tasks include recognizing patterns, learning from experience, drawing conclusions, making predictions, and making decisions or initiating actions. • AI mimics aspects of human cognition such as perception, reasoning, planning, and learning. This technology can autonomously perform tasks such as planning, understanding language, recognizing objects and sounds, learning, or solving problems. • It is considered by many experts to have the most revolutionary impact on society in general and military systems in particular. • Russian President. Vladimir Putin, estimated in 2017 that "artificial intelligence is the future... Whoever becomes a leader in this field will rule the world." (Russia Today 2017). • One advantage is that it is not influenced by factors such as stress or fatigue. (Dragomir and Alexandrescu 2017, 58)	- data analysis; - improving data collection capabilities; - developing strike systems and their effects; - performing specific tasks at command posts; - increasing disinformation capabilities (e.g., deepfake); - supporting the operational planning process by providing faster and more efficient methods for comparing and analyzing courses of action (war gaming).
Blockchain	• Blockchain is a distributed ledger technology that combines elements of cryptography, consensus, and distributed systems. It enables decentralized and secure data storage through a structure of linked blocks of information that are shared, replicated and synchronized among network members. • Blockchain ensures high data security by making it impossible to change an existing block without changing all subsequent blocks. The technology thus prevents retroactive alteration of data and ensures information integrity. • In a military context, blockchain offers the potential for coherent data exchange between different hierarchical structures, such as sensor networks or command posts. It enables a secure and synchronized flow of information in distributed and complex environments.	- increasing data exchange; - ensuring situational understanding; - ensuring data and communication security.

Technology	Details	How can it support the C2
Human Augmentation	• Human augmentation refers to technologies used to enhance human performance. In the military context, it includes human physiological, social, and cognitive domains, as well as advanced human-machine interfaces. • Major categories of human performance enhancement include: - Enhanced/extended senses (e.g., augmented vision, hearing, taste, smell) that add new informational dimensions to C2 systems. - Enhanced cognition, achieved by identifying the human cognitive state and tailoring computerized feedback to the user's needs, thereby accelerating decision-making. - Augmented action, achieved by monitoring human actions and mapping them to local, remote, or virtual environments.	- increase situational understanding; - increase the efficiency of human data analysis and processing; - improve the speed at which people work; - revolutionize the way people share information; - improve decision-making by limiting the influence of cognitive biases.
Internet of Battle Things (IoBT)	• The basic idea of IoBT is to connect all elements available on the battlefield (vehicles, drones, soldiers, wearables, weapons, sensors, etc.) into a self-configuring network to facilitate the exchange of information. For example, the health status of soldiers can be shared via a monitoring system, images captured by a weapon's camera can be shared with intelligence structures at the command post, or video from a UAV, aircraft, or satellite can be transmitted to a reconnaissance patrol in the area.	- easy exchange of information; - supporting situation monitoring; - providing situational understanding; - supporting Battle Damage Assessment (BDA)
5G / 6G/ 7G Technology	• Cellular technology is used not only to connect people with handheld devices (e.g. smartphones) but also to connect almost all types of devices (computers, sensors, etc.). 5G technology will be available in the next 10 years, while 6G, currently in the definition phase, could be fully available by 2035, according to estimates, offering greater coverage, higher transmission speeds, centimetre-level location accuracy and edge computing. By 2040, 7G could be in the planning stages. Both technologies enable network slicing, which facilitates the deployment of "private" networks using commercial off-the-shelf equipment and commercial networks.	- securing transmitted data; - increasing situational understanding.
Quantum Technology	• Quantum technologies will play an important role in improving situational awareness, communications and cybersecurity capabilities. The categories into which quantum technologies can be divided in the C2 context are: sensing, communications, and computing. The major achievements in each category by 2040 could be: - Sensing: quantum sensors for C2 applications, portable quantum navigation devices. - Communications: Point-to-point secure quantum links, secure Internet for defence, the combination of quantum and classical communications. - Computing: Quantum computers will outperform classical computers.	- enhancing situational understanding; - ensuring cyber security.
Hyper-automation (robotization)	• To excel in automation, the combination of multiple technologies can help create smart spaces - physical environments in various domains where people and technology enable systems to interact, connect and coordinate, seeking to minimize human intervention and optimize effort. • Hyper-automation is expected to reach a profound level of expansion by 2040, with digital processes becoming an essential part of any military operation, including robotic process automation to reduce human intervention (especially in repetitive tasks) and AI-driven decision-making at all stages of OODA. Human intervention will be focused only on high-value activities in planning and tasking, as well as on key decisions (human-in-the-loop).	- reorganization of force structures; - reconfiguring how orders are transmitted; - increasing the efficiency of operational processes; - increasing lethality; - human-robot interoperability; - rapid decision making.

Although we are witnessing an unprecedented rephonologization of society, we believe that **decision-making will remain a human attribute**, at least for the foreseeable future. This statement is supported by the increasing uncertainty of the operational environment, but also by the fact that the way the brain works is prone to

systemic errors and biases (AJP3.10.2 2020, 42); thus, future C2 systems will have to adapt, with the commander still at the centre of the operational process. This means that they must be adequately trained and educated to effectively perform the specific functions of directing the entire military operation. Commanders must develop the ability to accurately understand the operational environment, visualize solutions to operational problems, effectively communicate those solutions to subordinates, direct execution in response to volatile and dynamic battlefield conditions, provide command and control of forces, and continuously assess progress to ensure timely adaptation to the challenges of the operational environment. In addition, commanders' training must include a component of internal reflection on their own cognitive limitations that may affect the quality of decision-making.

The rationale for including such an educational component is demonstrated by the flawed planning assumptions made by the Russians at the outset of the conflict, and the incalculable consequences of such decisions based on flawed prejudices. What was supposed to be a three-day special operation (Watling and Reynolds 2022, 1) turned into a nearly three-year conflict for the Russians, in which considerable resources and effort were invested.

Conclusions and proposals

In the information age, while some aspects of command and control (C2) remain unchanged, such as the nature of warfare, uncertainty and time pressure, technological developments have brought about fundamental changes. Today's world is characterized by instability and rapid change, and these characteristics are reflected in the military context. In such an era, C2 systems must be highly adaptable and perform effectively, regardless of the type of conflict or environment in which they operate. Technology has a critical role to play in enhancing C2 capabilities, but it also poses significant risks. On the one hand, technology can help to optimize decisions and make coordination more effective, but on the other hand, there is a risk of over-reliance on equipment and information overload. This can create a dangerous illusion that war can be fought with absolute precision, which is not realistic. In addition, as C2 systems become more sophisticated and interconnected, the risks of disruption, cyber-attack or information overload increase. Solutions must therefore be found to protect and optimize the data flows specific to command-and-control systems. Increasing the resources devoted to research and innovation in emerging technologies to ensure a competitive edge over adversaries can ensure breakthroughs that support more efficient C2 systems.

However, this article was not intended to be a roadmap for the adaptation of command-and-control systems, but it was rather meant to highlight some extremely important elements to be considered in the implementation of the transformation plan. The analysis of the immutable characteristics of the nature of conflicts, as

well as those of the current ones, and the trends in the evolution of the operational environment were the pillars on which we built the results presented.

Although we understand that the process of transforming the Romanian command and control system should not be an individual effort, but rather a collective one, well directed by the decision-makers at the highest level of the Romanian Army, we believe that this article can support this endeavour through at least two **extremely valuable elements**:

- the results obtained, which can be used as a basis for adapting C2 systems;
- the scientific way in which we have developed these results. Identifying, in the first phase, the factors that can influence C2 systems and how they can do so, and then, through a process of inference, determining how to adapt them, is what we consider to be the right approach for the transformation of command-and-control systems in the Romanian Army.

In the following lines, we will present **the main results of the scientific approach** undertaken, in the form of recommendations for the main target of this study, the decision-makers of the Romanian Army, organized by the four components of the command-and-control systems highlighted in the first section of this paper. These results emerged from a thematic analysis of the data derived from applying the "three-column factor analysis" method in the previous section. All the resulting data were subjected, at this stage, to a rigorous analysis process aimed at organizing them into broader themes, which were subsequently classified into the four major categories of command-and-control systems, according to the specific characteristics of each.

Personnel

- The commander will continue to be at the centre of the decision-making process. This requires continuous training. In addition, creating a system for transferring institutional memory from one generation to the next, from one commander to future commanders, can make training more effective.
- Leadership must remain the fundamental element of military command.
- The need to adopt a "red teaming" mentality to ensure the development of critical and creative thinking in one's own staff.
- The development of critical and creative thinking focused on producing effects that slow down the enemy's decision-action cycle.
- The need to train personnel to operate digital systems amidst the technologization of command-and-control systems.
- Training personnel to operate in analogue mode, given the increased possibility of operating in a contested environment against an adversary with enhanced electronic warfare capabilities.
- Staff training should focus on *how* to think, rather than *what* to think. Such an approach can provide staff with the necessary mental flexibility to adapt and respond effectively to the challenges that may arise in the increasingly volatile and uncertain operating environment.

- Understanding how the human brain works in decision-making and the errors in judgment that can occur as a result of one's own cognitive biases.
- Implementation and training of the Mission Command concept must begin in peacetime. If it is not implemented in day-to-day operations, it is unlikely to be effective in war.
- The need to achieve human interoperability between own and allied C2 systems in the context of the increasing likelihood of military operations in multinational environments.

Processes
- Adapting unit battle tempo to reduce decision time by incorporating new technologies.
- Shorten your own decision-action process.
- Optimize operational processes through the use of emerging technologies.
- Ability to communicate the full operational picture to the lowest echelons in real time and automatically update it at all levels of command.
- Reducing the size of transmitted orders or using emerging technologies to ensure rapid understanding. For example, NATO corps-level operational orders routinely run to 750 pages and joint-level orders to a thousand pages. Few people in a command read them in their entirety (Storr 2023, 87).
- The need to achieve procedural interoperability between national and allied C2 systems as the likelihood of conducting military operations in multinational environments increases.

Technological systems
- The digital transformation of command centres by integrating new technologies to support the rationalization of processes specific to the functions of command and staff systems (situational awareness, decision-making, etc.).
- The use of high-performance technological systems to facilitate the rapid generation, transmission, reading and understanding of written orders. This can reduce the planning time for new operations, with a direct impact on reducing the OODA cycle.
- The need to identify technical solutions to protect C2 systems: reducing cyber, electromagnetic and thermal footprints, etc.
- Dependence on technology can also create vulnerabilities in a contested environment and in the face of an adversary with enhanced electronic warfare capabilities.
- The need to achieve technical interoperability between one's own and allied C2 systems, given the increased likelihood of conducting military operations in a multinational environment.

Command posts
- Provide increased protection: physical and electromagnetic.
- Rethink the way command posts are organized (their current size is far too large

and they are far too static, making them extremely vulnerable in an era of increased remote weapon accuracy and reduced time between detection and engagement to minutes) to meet the increasing challenges of the operational environment and to ensure their survivability and continued C2 functionality (e.g. adopting command post dispersion practices and using redundant systems. Integrated and functional modules may no longer need to operate from the same location, and when we talk about the Basic Command Post, we no longer mean a single location, but a variety of locations/modules that together, with technology support, fulfil the functions of that command point).
- Implement additional security measures to physically and electromagnetically protect C2 sites from direct and indirect attack (e.g. from drones or enemy EW systems).
- Reduce and mask the size, thermal and electromagnetic footprint of command posts. (e.g. investing in silent batteries to allow PC-based technical systems to run for as long as possible, replacing noisy generators and identifying solutions to replace noisy air conditioning systems that can give away the location of command posts). "The war between Russia and Ukraine makes it clear that the electromagnetic signature emitted by command posts over the past 20 years cannot survive against the speed and precision of an adversary with sensor-based technologies, electronic warfare, unmanned aerial systems or access to satellite imagery." (Nagl 2024, 24)
- The use of measures to mislead the adversary by creating false command posts can be a solution in the effort to increase the protection of C2 systems (Nagl 2024, 242).
- Increase command post mobility to avoid detection and attack. The constant movement of PCs to avoid detection with continuous realization of C2 functionality.
- The need to achieve interoperability between own and allied C2 systems, given the increased likelihood of conducting military operations in a multinational environment.

Furthermore, the principles that must underpin new command and control systems, in order to ensure a high degree of adaptability to the current and future operating environment challenges, are flexibility, modularity, survivability, small footprint and resilience.

Flexibility implies the ability of the command and control (C2) system to adapt rapidly to changes in the operational environment. This principle includes both adaptable structures and procedures and the use of technology to enable rapid responses to unforeseen challenges. The flexibility of the C2 system is essential to respond quickly to new threats or opportunities and to adjust priorities and resources as the battlefield evolves.

Modularity means building the system from independent but interoperable components that can be combined and reconfigured as required. In the C2 context, this principle allows the creation of tailor-made structures for each mission and facilitates modernization by integrating new technologies without affecting the

whole system. Modularity enables armed forces to optimize resources and improve operational efficiency.

Survivability refers to the ability of the C2 system to operate under adverse conditions, including contested environments. This principle can be achieved through appropriate dispersion, small size, redundancy, mobility, manoeuvrability, camouflage, deception, OPSEC measures, and the integration of anti-drone systems and other defensive technologies to provide adequate physical and cyber protection. The goal is to reduce vulnerability to enemy attack and ensure continuity of operations.

Reducing the ground footprint means minimizing the physical size and electromagnetic signature of command posts, thereby reducing the chances of being detected and hit by the enemy. (One solution may be to disperse and conduct operations from multiple remote locations that operate as a whole.) A reduced-footprint C2 system is more difficult to identify and locate, contributing to the safety of personnel and equipment. This principle is essential against adversaries with advanced surveillance and attack capabilities.

Resilience refers to the ability of the system to recover quickly from a disruption or attack and maintain long-term functionality. Resilience includes system redundancy, backup procedures, and continuity plans to enable operations in the event of loss or disruption. This principle ensures that in the face of attack or failure, C2 systems can continue to perform their essential mission without compromising the overall effectiveness of operations.

To summarize, adapting command and control systems to meet the challenges of today's operational environment requires a holistic and integrated approach that takes into account both technological evolution and changes in global conflict dynamics and evolving trends in the operational environment. In this regard, C2 systems must strike a balance between the use of technology and human adaptability. It is also crucial to develop and implement flexible strategies that allow for rapid adaptation to unforeseen changes, as well as mandatory testing in different contexts of potential adaptive solutions for command-and-control systems. This will ensure coherent and flexible operations, which are essential in the face of the complex and dynamic challenges of modern warfare.

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