

THE ARCHITECTURE OF COMMAND-AND-CONTROL SYSTEMS IN FUTURE MILITARY ACTIONS

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DOI: 10.55535/RMT.2025.3.02

Command-and-control systems are constantly adapting, resizing and developing in line with the technological evolution and the changes in the physiognomy of military operations. In this context, command-and-control systems become more complex and efficient, due to not only the quality of the military command personnel but also the systems architecture, which integrates and interconnects high-performance equipment. Moreover, the architecture of a complex command-and-control system is designed as a coherent integrator of sensors, decision-makers, executors and support capabilities, interconnected in subsystems to ensure the efficient planning, preparation, deployment and evaluation of military actions.

The main objective of the command-and-control systems is to obtain and maintain the informational decision and action superiority in the entire spectrum of military operations, which will guarantee the success at strategic, operational and tactical levels. Given the diversification of risks and threats in the multidimensional operational environment, the architecture of command-and-control systems must be permanently adapted in order to ensure real-time, horizontal and vertical communication between tactical level forces, operational and strategic command and support structures, as well as with the other institutions are also involved in the security and defence field.

Keywords: command-and-control systems; variable geometry; capabilities; technology; strategic, operational and tactical levels;

INTRODUCTION – STRUCTURES AND SYSTEMS OF COMMAND AND CONTROL

Military command-and-control systems, also known as C2 systems, are functional structures used by military structures to plan, conduct, assess and coordinate military operations.

In the past years, the way these systems are working has evolved in line with the changes in the conduct of military conflicts. The conflict with variable geometry, the most recent known type of conflict, has different forms, from “*peaceful revolution*”, “*civil war*”, “*war against terrorism*” and “*extended international conflict*”, involving multiple state and non-state actors (Revista Academiei de Științe ale Securității Naționale, 2019, p. 50). The Syrian conflict is the most recent example of a geopolitical and geo-economic conflict that started as a civil war (<http://www.contributors.ro/economie/energie-economie/razboiul-civil-din-siria-un-razboial-gazoductelor/>). The conflict was conducted on internal political level, with external foreign support, evolving to a conflict between super powers (the USA and the Russian Federation) in order to control the energy routes and resources. The conflict generated a huge humanitarian crisis, increasing migration and refugee flows towards neighbouring countries and the European Union. Some authors consider it as a “*4th generation conflict*”, at least one of the actors being a non-state entity (Impact strategic, 2017, pp. 56-57). This type of conflict generates multiple types of action – political, economic and military, that are conducted by combatants, insurgents, terrorist groups and civilians. This is an irregular and asymmetric conflict, using insurgent, guerrilla and terrorist TTPs against political, cultural, religious objectives or even against population.

Proxy war is another current concept. This is a conflict between two powers (armed forces, state actors) through interposed actors, on another state’s territory (Impact strategic, 2015, pp. 21-22). The parties do not directly engage each other, but interposed state and non-state actors are used.

In this context, we consider that expansion of command-and-control systems is necessary to manage both military operations and political-socio-economic-military operations specific to the new types of conflict. Command-and-control systems need to permanently adapt to new types of conflict and to the technological evolution.

All decision-makers need to be connected in real-time, both horizontally and vertically, facilitating the C2 of all conflict operations (at all levels – political, social, economic, military) based on an integrated situational picture. Both technology and an adequate C2 system facilitate a real-time response to dangers and threats.

There are three main trends in the evolution of C2 systems: technological developments, multinationalism and the expansion of operations in all areas.

Modern conflict environments are more complex, based on the evolution of technology and information. Non-military operations, diplomatic, political and economic actions have a certain position in the variable geometry of the conflict, but they are accompanied by complex, coordinated, planned military operations, more often than not at strategic level.

A C2 system vulnerabilities occur from within, while threats and risks are external.

Actions specific to modern conflicts represent a proof of the multidimensionality that generates a permanent shifting geometry along multiple axes (as a graphical representation of a conflict).

To each dimension of the conflict is corresponding a series of non-military operations like political-diplomatic ones (negotiation, inquiry, good practices, conciliation, arbitration, international judicial institution's decisions; UN Charter, Ch. 6), and economic (SMART sanctions – blocking personnel and institution assets, economic sanctions, embargo, blockade), as well as non-military actions (ethnic separatism, boycott, media attack) or military conventional operations (offensive, defensive, intermediate, stability, peace keeping, peace support and peace enforcement), unconventional operations (special ops, NBC), asymmetric operations (insurgent, organised crime, social unrest, revolution, civil war, guerrilla war, terrorism) and other types of operations (cyber, information, psychological, CIMIC).

Conflict's dimensions are evidence of operations conducted in all environments: physical (ground, air, maritime, space), cyberspace, information, giving to modern conflict its multidimensional character.

Command-and-control systems need to become a complex architecture entity, capable of managing full spectrum of operations, simultaneously, in all environments and dimensions.

Besides its interconnected elements (C2 structures, intelligence, communications and computer subsystems), command-and-control systems should include a variety of information management activities, procedures, equipment and other means used by commanders.

Conflicts with variable geometry require a modular C2 system with command, control, communications, computer, cooperation, intelligence, interoperability, surveillance and reconnaissance/C5I2SR (Lehaci, 2015, p. 65).

Therefore, it comes the requirements for new, unique infrastructure solutions, multiple multinational headquarters interconnectivity, adaptable and deployable modular C2 systems, sensors and base permanent monitor assets, based on modern technologies (identification, location and navigation) with discover, surveillance and target acquisition capabilities.

We consider that new services and new information may arise as a result of interconnection and/or integration of existing systems, included the use of artificial intelligence, with higher value and capabilities.

POSSIBLE ARCHITECTURE OF COMMAND-AND-CONTROL SYSTEMS IN CASE OF CONFLICTS WITH VARIABLE GEOMETRY

The roles, missions, objectives and C2 principles, the structural and functional interconnectivity/symbiosis of the system decision and operational command systems lead to an architectural C2 system according to the characteristics required to achieve the correct and efficient management of fluid/changing situations, specific to the conflicts with variable geometry (modular command-and-control systems as sum of systems and capabilities). The study of existing C2 systems, their evolution and trends represent an initial mark for a continuous structural development project, with the capability to rapidly adapt to any type of conflict or conflict combination. This undertaking is based on the permanent technological development and evolution.

The command-and-control concept has been continuously developed. In the first empirical approach, the concept evolved from C2 (command and control) to C3 (command, control and communications) then to C4 (command, control, communications and computers), to C4I (intelligence being added to this concept), eventually reaching to C4I STAR (command, control, communications computers, intelligence, surveillance and target acquisition). The C5ISR modular system of systems adds interoperability and cooperation. The two systems that have been most recently added (interoperability and cooperation) are absolutely required in conflicts with variable geometry that integrate and overlap all other known types of conflict, with multinational, state and non-state actors and different domains as economic, social, political, military etc. Therefore, the structure of the system of systems will permanently change by adding components, or by combining them

in a way that may generate another superior subsystem compared to those that generated it, based on the operational reality of a conflict with variable geometry. In our vision, this modular system of systems will change according to its needs, using its subsystems, and it can create in short time another structure fit to respond the next operational challenge. We would compare this modular system of systems to a Rubik cube. Using the same components, the Rubik cube can display multiple solutions by shifting its parts. Likewise, command-and-control systems will rapidly change their structure, using the same modules and generating the adaptability and capabilities required by the new challenge.

The technological evolution facilitates new C2 systems, superior to those previously mentioned. For example, Network Enabled Capability (NEC) is the NATO concept for a system of systems used for an enhanced military effect in an integrated use of computer systems, based on the *“right information, at the right time, at the right place – not in excess”* (Mihăescu, 2016, p. 23) principle. This system has been built integrating decision-makers, instruments and support capabilities in order to conduct more flexible and more efficient military operations.

The advanced C2 system (AC2S), developed by the Defence University in the Czech Republic in 2017, represent a concept using modern technologies in order to enhance military operations efficiency. This system uses relatively new system architecture, communications, computer and decision support. Tactical decision support system (TDSS) is used as part of AC2S. The purpose of this system is to support the commanders in their tactical decision process by using generated models. AC2S develops the concepts of computer support in the decision processes. The researches in the data analysis using AI based on a technological support allow increased command and control efficiency.

Decision support systems (DSS) represent a tool for commanders used for information/intelligence exchange, information analysis, a tool that can help in an efficient mission planning process. An advanced DSS is capable of giving options to a commander in order to assess the chances of success, options to warn him on possible threats (Farlík, Kratký, Časar, 2016, pp. 327-330).

The general architecture of the AC2S is composed of three types of elements, as follows: the command point, the armed forces and robotic devices (systems), each with their role and missions. The command point is a main control centre with the following functions: situation assessment, operation planning and control, data collection and processing and analysis of available information, and dissemination through appropriate technical elements/equipment, command and control of forces, unmanned vehicles and robotic devices, communication with the upper

echelons. The forces are equipped with the tactical decision support system (TDSS). Unmanned vehicles and robotic devices can be included as long as they are compatible with the architecture (unmanned aerial vehicles/UAVs, unmanned ground vehicles/ UGGs, autonomous surface or underwater vehicles/AUVs). As for the high- precision hitting systems, they are connected through a wireless network so that they can benefit from the information and data from the command points.

AC2S's most important characteristic is that the system is modular. It can be configured for any type of military or non-military action/operation. Any available type or number of vehicles/assets can be included. Moreover, the militaries' number, together with their equipment for the following action/operation can be established according to the real requirements. The connecting wireless technology is compatible to all the elements. It comprises two independent networks, a short-range primary communication channel/network (messages, voice, images or video) and a long-range secondary channel/network (up to several kilometres), for back-up. The secondary channel/network is used when the primary network is no longer available. They are divided in underlets and interconnected elements. Even so, they can transmit only state information and control messages. That is why the system's capabilities must be enhanced.

The support of the decision-makers system (a subsystem of AC2S) is capable to understand the plan if there is an adequate model of tactics applied. The system is able to create optimal variants for problem solving by analysing the situation, the conditions and the effects. The courses of action are displayed for the commander in order to decide what solution to choose or the way in which to combine the courses. The subordinates and the robotic devices perform the decision. Each element knows its role and precise activity and tasks.

TDDS has the following capabilities: to prepare and to visualize the 2D geographical data, the operational areas' real time vectors and roasters, a real aid for several coordinate systems (geographical, WGS84/UTM, MGRS); it provides a basic geographical analysis (e.g. the topographical objects' analysis, direct and all round calculus visibility) (Rybanský, 2015, pp. 7049-7058) and also incorporates more advanced models of military tactics (5 advanced models of military tactics: the optimal manoeuvre for the units inside the area of operation, optimal model for monitoring systems' implementing, units' optimal logistic model, UAV optimal reconnaissance model and optimal land reconnaissance system).

More information about the TDDS can be found in *"Tactical Decision Support System to Aid Commanders in their Decision-Making"*, Modelling and Simulation for Autonomous Systems (Stodola, Mazal, 2016, pp. 396-406).

We have presented above a tactical model of a complex modular command-and-control system's architecture. However, when dealing with the threats and risks brought by a conflict with variable geometry, real-time communication, horizontally or vertically, between the national or multinational forces, command and support structures, as well as with the elements of strategic management or other elements with responsibilities in the field of security and defence is a decisive condition in obtaining the desired effects by executing the non-military or military operations. Tactical level modular systems must be operationally and strategically expanded so as to obtain the capabilities needed to effectively manage the challenges of extended conflict.

The news confirms that the technologies so far developed provide information flows in several areas like: the forces command and control, the common operational picture and common operational understanding, intelligence, surveillance, reconnaissance, strategic, operational and tactical planning, aerial situation and missile defence, joint fire, and air, naval and land target management, effects management, manoeuvre and synchronization, information operations, force protection, resource coordination, medical assistance etc.

The command-and-control system that is needed at the level of conflict with variable geometry must extend the interoperability, macro-surveillance and reconnaissance part at least at regional level, if not globally or extra terrestrially, in all conflict manifestation environments.

It is the moment when it becomes necessary to develop the artificial intelligence of cyber systems of systems based on integrated approaches of all the conflicting experiences developed over time that may generate, in advance, combined evolutionary conflict schemes in order to be managed before the real situation degenerate.

However, the context of technological development does not exclude the human element. It remains the most important element within the decision-making process supported by an adequate command-and-control system. Moreover, through the personnel who serves these technologies with their capabilities, the information becomes available to the decision-makers.

Comprehensive approach (CA) is the term that defines the need for joint effort to achieve governmental and nongovernmental goals when dealing with a conflict. To achieve this goal, simultaneous and convergent action is required on several directions of action: military, political (diplomatic), economic and civil.

Planning in order to achieve the common goal involves the information exchange, similar working methods and availability for joint planning sessions, which are more often than not carried out with difficulty. Planning in a multidimensional

environment and in the conditions of risks and threats specific to the conflict with variable geometry generates specific challenges for both civil and military actors. In open conflict situations, where the area of operations is assigned to a military commander, as well as due to the ability of the military system to plan actions of numerous forces, it is recommended that it should act as an integrator of the plans.

After completing the planning stage, the execution stage follows and automatically the implementation of the control measures of the operations/ actions. The success of the actions depends on the execution of synchronized, joint and coordinated actions, and the command-and-control system, interoperable or common, of the allied forces must meet this condition. Under these circumstances, some institutions might not be willing to formalize relationships and exchange information freely.

The global security environment creates challenges that are so wide, so complex, volatile and difficult to anticipate.

CRITERIA USED FOR THE OPERATION OF MODULAR AND FLEXIBLE COMMAND-AND-CONTROL SYSTEMS

The integrated systemic approaches in the art of operational planning capture aspects related to the fact that the technologies developed to date provide information flows in several areas such as: command, control of the forces, common operational picture and its interpretation, intelligence, surveillance, reconnaissance, strategic, operational and tactical planning, air situation and missile defence, joint fire, and air, naval and land target management, effects' management, manoeuvre and synchronization, information operations, force protection, resource coordination, medical assistance etc. (Roman, 2017).

Starting from the premise that the command-and-control system adaptable to the requirements of the conflict with variable geometry must extend the interoperability part, macro-surveillance and reconnaissance at least at a regional if not even global or extra terrestrial level, in all the conflict environments, we consider that the development of artificial intelligence of cyber systems of systems becomes mandatory, based on the integrated approaches of all the conflicting experiences developed over time, which can generate early evolutionary combined conflict schemes in order to be managed before the degeneration of real situations.

However, the context of technological development does not exclude the human element. It remains the most important in the decision-making process supported by an adequate command-and-control system. Moreover, through the personnel who serves these technologies with their capabilities, the information becomes available for the decision-makers.

In this context, it is necessary to identify the precise conditions in which the dynamics of the contemporary operational environment takes place (by studying the multidimensionality of the current operational environment), to identify the typology of the specific threats of the conflict with variable geometry, to study in depth the organization of the headquarters (with the C2 systems and the necessary technological support for them to function) in order to draw relevant conclusions regarding their ability to respond to the requirements of conflict with variable geometry.

Starting from the existing structures and analysing the requirements that a command-and-control system must meet in relation to the challenges of conflict with variable geometry, other architectures based on modular structures with higher efficiency and multiple capabilities in different areas of conflict manifestation are outlined. Equipment and technologies play an extremely important part in this equation. They, in addition to the missions they have now, will have to provide the technical support in order to ensure the modules' mobility, subsystems and systems within the command-and-control system and the cooperation and interoperability with other systems of the same type. In this direction, the equipment used is based on the latest technological discoveries and developments. We have previously exemplified by Network Enabled Capability (NEC) a term used at NATO level for systems of systems designed to achieve increased military effect through an integrated use of information systems. But things will not stop there. The concept of artificial intelligence is being increasingly used. Extremely complex computer systems are capable of learning by themselves from the situations that are managed with their help. The researches in this field have developed artificial intelligence on the principle of the human brain's functioning. They can algorithmically and synthetically analyse and can also generate absolutely necessary quick solutions for the lack of time in the decision-making process. The commander may be offered in a relatively short amount of time certain courses of action already analysed through the necessary variables, already introduced within the system, and using a comprehensive database. The decision will be made much faster regardless of whether a system-generated or intuitive or combined course of action will be adopted. However, the human factor plays the most important role.

In the decision-making process, it is important *to integrate and interconnect the subsystems and technologies* necessary for the command-control operation. The identification and/or the construction of instruments for analysing the operational environment and the identification of the action procedures necessary for the command-control when managing specific situations of the conflict with variable geometry becomes imperative.

Any military conflict, no matter how insignificant it may seem, in any part of the world, will not be managed as an isolated fact, as a matter that concerns exclusively those directly involved. Each of these conflicts will increasingly require, for its resolution, a global solution, which triggers the involvement of the international community. Military conflicts and wars will be exposed because of sensors of any kind and not only. However, they will also be covert, in the space where the information can be used as a weapon. The entire cyber, psychological and information spectrum will be used to penetrate all networks in order to use them to gain a position that allows them to follow the desired courses. The new strategies and conceptions regarding the unfolding of current and future military conflicts are directly influenced by: the complex causality of the conflicts, which is due to the incompatibility between the dictatorial or autocratic and democratic political systems; the very large gaps that have been created over time between rich and poor countries; the effects created by the technological differences; the different ways of applying force, which go from the use of extreme violence (terrorist attacks) to the strategies of containment, domination or imposition of a certain type of behaviour; dissymmetry and asymmetry; predominance of alliance and coalition strategies; the mandatory existence of the binomial action-reaction; prevention and primitive or repressive character; responsibility.

Making anticipatory and correct decisions is conditioned by the military action's adaptation to the real strategic situations and the approach of all the conflict areas with variable geometry in planning and management.

The current multinational operations require the development and implementation of strategies, doctrines, forms of preparation and common staff procedures, as well as adequate programs for forces' equipping and planning. The responsiveness and increased interoperability will be possible through organizational flexibility.

Modularity will lead to an increased structural and actional mobility. The use of high-performance technologies will lead to a significant increase in the decision-making and action capacity regarding: increasing the distance of action and the precision that will enhance the selective and punctual engagement of some objectives; the ability to choose the target effect from a wide range of non-lethal and lethal effects, which will give the military decision greater flexibility; achieving the state of confusion necessary to obtain surprise and victory through psychological, information and error-induced warfare procedures; increasing the reaction capacity, optimizing the management and achieving the viability of the technical systems.

The result of using the high-performance technologies, *their integration and interconnection together with the subsystems* at C2 level will materialize in: significant increases in the systems and subsystems mobility as well as the decision-making capacity; increasing the anticipatory potential; broadening the range of planned and conducted operations; diversifying decision-making processes and procedures and conducting military or non-military actions/operations; new solutions for multidimensional forces/objectives protection.

CONCLUSIONS

Military command-and-control systems, known as C2, are functional structures through which military organizations plan, conduct, evaluate and coordinate military actions or operations. Conflict with variable geometry is the most recent known type of conflict that can start from a certain form (peaceful revolution or revolution) later escalating to forms of civil war, and/or war against terrorism and eventually embracing the form of extended international conflict.

The technological evolution facilitates the establishment of control systems such as modular control structures on command, control, communications, IT, cooperation, intelligence, interoperability, surveillance and reconnaissance (C5I2SR) and even more.

Taking into account all these aspects, the command-and-control system must become an entity with a complex architecture capable of managing all types of actions/operations carried out simultaneously, in all areas of conflict and in all dimensions.

In the conditions of conflicts with variable geometry, we are dealing with the existence of a modularized command-and-control system on structures, on command, control, communications, IT, cooperation, intelligence, interoperability, surveillance, reconnaissance etc.

In addition to the already outlined issues, there is the problem of developing unique infrastructure solutions, the possibility of interconnecting several operational headquarters belonging to actors from different states, command-and-control systems that have deployable command modules and that are adaptable to changing situations with implementation of sensor systems and permanent monitoring of the deployment of forces based on modern identification, localization and navigation technologies that are capable of ensuring the detection, surveillance and acquisition of targets and beyond. We consider that by integrating and/or interconnecting the already existing systems with new ones, we can obtain higher-value services and information, without excluding the possibility of the inclusive use of artificial intelligence.

The system must be able function as an integrator of decision-makers, sensors, executors and support capabilities, in order to obtain flexibility and efficiency in performing military and non-military actions/operations.

Under the risks and threats of a conflict with variable geometry, real-time, horizontal and vertical communication, between national or multinational forces, command and support structures, as well as with strategic management elements or other elements having security and defence responsibilities, we meet a mandatory condition with a decisive role in obtaining the desired effects by performing non-military or military operations.

In conclusion, we consider that the future architecture of command-and-control systems will be one of the system of systems-type and will include the human component, the information and virtual infrastructure, the modules for planning, managing and evaluating military operations, along with equipment based on artificial intelligence.

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