AERIAL SURVEILLANCE
– EVOLUTIONS AND ENDURING TRENDS –

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The scientific and technological progress registered in the last decades has contributed to the development of radars with supreme radar detection abilities to better detect the air attack means of the enemy. These means, in turn, have contributed to the improvement of the parameters of the airborne surveillance systems in order to detect and to counter aerial threats. The structural and functional dynamics of the aerial surveillance systems have pursued continuous adaptation to the complexity of the battlefield environment in modern warfare, ensuring the information necessary for the coherent and effective engagement of forces in the conduct of military operations.

Keywords: aerial surveillance; electromagnetic waves; aerial warning; complexity theory; Air Operations Centre;

INRODUCTION

Collecting information about the adversary has been an essential condition for the political, economic and military domination since ancient times. Surveillance, as a method of collecting information about the adversary, is considered a method used to know the specific situation of a certain area of interest or battlefield in order to obtain and maintain the initiative of forces during the fighting.

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The attempts of the great military powers of the beginning of the 20th century to design and create an airspace surveillance system yielded small results, the identified solutions proving to be inefficient in case of armed conflict. The outbreak of the First World War was the determining factor that contributed to the creation of an air surveillance system corresponding to the specific military requirements of each state involved in the conflict, which was capable to early detect and stand off the adversary's air attacks. The manner in which actions were carried out in air space during the Great War strongly demonstrated that the effectiveness of air defence was dependent on the sustainability of the surveillance and alarm system, which proved true not only during the mentioned conflict but also in the following conflicts.

BRIEF HISTORY

The first air battles took place in the First World War. The potential of the plane to penetrate deep into the adversary's territory, without the possibility of being detected, caused concern among the states participating in the conflict, intensifying the research to identify technical and organisational solutions that would allow the early detection and destruction of air assets. The existing technology at the outbreak of the conflagration did not allow the construction of the radar, and for the detection of air assets there was used optical and acoustic equipment for collecting vital information to defend against air attacks.

The air surveillance system designed by the belligerent powers was made by structures specialised in the identification of air assets called ambush and aerial warning structures, which had the mission of providing the information necessary to combat air attacks, its importance in air defence being highlighted by the large number of aircraft lost compared to the period prior to its establishment.

The continuous development of air assets by the belligerents contributed to the creation of combat aircraft, becoming, in this way, a permanent threat to the civilian population and the important objectives important in the war. The danger represented by air attacks led the authorities of the belligerent states to enhance the research in the field in order to identify solutions to neutralise the combat aircraft. In this respect, concrete actions were taken to create air surveillance systems in order to identify aircraft from a large distance as early as possible in order to combat them. The surveillance of the airspace against aircraft was carried out by all the European states participating in the conflict, according to similar concepts, which involved concentrating the effort towards the area of operations and enemy air attacks. The air surveillance system designed by the belligerent powers was made by structures specialised in the identification of air assets called ambush and aerial warning structures (Teodorescu, Neagoe, Munteanu, 2001, pp. 37-42), which had the mission of providing the information necessary to combat air attacks, its importance in air defence being highlighted by the large number of aircraft lost compared to the period prior to its establishment.

The end of the First World War did not bring major changes in the equipment used in the detection of aircraft. The metal body detection tool presented by the engineer Christian Hülsmeyer had no military relevance, the distance from which it could detect the metal bodies

in question being operationally insignificant. It is considered that the history of radar was dated in 1904 with the device made by the engineer Christian Hülsmeyer even if it did not allow determining the distance to the object, but rather determined the direction where the metal object was located. Insignificant detection compared to the technical characteristics of air-attack assets contributed to maintaining disinterest in this equipment, and the dissemination of scientific research related to the detection of metal objects with the use of electromagnetic waves within the scientific community failed in drawing the attention of the scientists.

The technological evolution recorded by the air-attack assets, as well as the increasingly high possibility of the outbreak of a new war in Europe, generated a surge of interest of the military powers in the detection of air assets, many related studies being carried out, almost simultaneously and independently, in USA, UK, USSR, Japan, Germany, France and Italy. On 26 February 1935, it took place the Daventry Experiment (Malanowski, 2019, p. 5), demonstrating the possibility of detecting air assets with the use of radio waves, the experiment representing the high point of research carried out in electromagnetism. The experiment carried out in Daventry showed the British Army leadership the importance of a radar in the operations carried out against the enemy air-attack assets. The fact that the British Army leadership acknowledged the major importance of the radar led to development of the programme carried out on building it and creating an airspace surveillance system that became operational before the beginning of the Second World War. Even though radars became predominant elements in the air surveillance system, the optical and acoustic equipment used during the First World War continued to ensure the detection of air assets simultaneously with radars. The air surveillance radar system represented the finality of some research in science and technology, being also considered the result of some studies undertaken to identify the optimal solutions for its organisation, in order to obtain a decrease in the superiority of air-attack assets against air defence artillery. A strong and effective air defence system against the enemy's air attacks consisted in obtaining,

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in real time, the information about its operations in the airspace. The achievement of this goal required a continuous adaptation of the air surveillance system in order to combat enemy air attacks, characterised by a permanent structural and functional dynamic, which aimed to increase the efficiency of the process of obtaining and processing data and the ability to combat of the enemy air attacks by air defence artillery.

STRUCTURAL DYNAMICS

The new means of combat, the aircraft, demonstrated a high combat potential, being able to penetrate deeply into the opponent's territory. In order to reduce the impact of this new means of combat on the economic and military potential, the political-military authorities of the states involved in the conflict made sustained efforts in order to identify solutions that ensured the detection of these means of combat.

The First World War introduced a new means of warfare, which extended warfare into a new dimension, namely *airspace*. The new means of combat, the aircraft, demonstrated a high combat potential, being able to penetrate deeply into the opponent's territory. In order to reduce the impact of this new means of combat on the economic and military potential, the political-military authorities of the states involved in the conflict made sustained efforts in order to identify solutions that ensured the detection of these means of combat. The materialisation of these solutions was achieved by building specialised structures for the detection of air-attack assets, equipped with optical technology for sound detection suitable for long-distance monitoring of air assets. Those structures were part of a centralised system designed to provide the information necessary to carry out defence actions against the enemy aircraft attacks. The airborne early warning and control systems were connected with the military and civil protection command centres, through which the military and civil authorities were notified in time about possible air-based threats.

The results obtained by the belligerents in the actions to combat air-attack assets through the airborne surveillance systems confirmed the importance of this service, whose permanent improvement and modernisation constitute a relevant priority in air defence.

The First World War marked the beginning of airspace surveillance and the detection of air assets, being characterised, from the perspective of aerial surveillance, by the following aspects:

- the creation of the first aerial surveillance and information services;

- the development of the first concepts for the organisation of aerial surveillance systems;
- the organisation of training programmes for air surveillance specialists;
- the development and implementation of the tactical principles and norms for military and defence use of aerial surveillance systems (Teodorescu et al., pp. 44-47).

The Romanian Armed Forces, during the period of neutrality, received the general concepts for the operation of the air surveillance and warning service developed by the French, German and Belgian armed forces, which regulated the performance of aerial surveillance. Those documents constituted the necessary basis for the development of their own aerial observer techniques and training procedures to observe and identify the enemy air assets. The documents developed by the leadership of the Romanian Armed Forces settled the methods of obtaining and transmitting information to the military departments in order to achieve the protection of the main relevant objectives during the war and the civilian population. Thus, as a result of the actions undertaken by the leadership of the Romanian Armed Forces for the defence against enemy aircraft, it was established, on 15.08.1916, by the High Decree no. 2784 of 14.08.1916, the first airspace surveillance system, within the Anti-aircraft Artillery Defence, in order to inform the authorities about any possible air assault (Ib., p. 67).

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The interwar period was a prolific time for the scientific and technical development, which led to the creation of the modern radar. Technologically-advanced countries built radars capable of detecting air attack assets from long distances, allowing air defence forces to efficiently intervene against them. The radars built by both Germany and Great Britain allowed the production of aerial surveillance systems that played an essential role during the Second World War air battles. The technological evolution of aircraft of both sides involved in the conflict led to the continuous development of the radar that allowed more and more accurate aircraft detection. At the beginning of the war, Britain had an operational air surveillance system, called *Chain Home* (Toomay, Hannen, 2004, p. 3), capable of detecting German aircraft

at sufficiently large distances in order to ensure an effective response from the responsible structures for defence from air and missile attack.

The adverse conduct of the war affected the military operations or the military capacity of Germany, thus eliminating the danger posed by German bombers over England, the British surveillance system playing a secondary role in the British war effort. The emergence of a new threat in airspace through Nazi Germany's development of the V-2 ballistic missile contributed to increased interest in the development of aerial surveillance system. The new means of warfare was operating at high speeds and altitudes, making it impossible for the airspace surveillance system to detect them. Those new threats led to the reorganisation of the British air surveillance system so as to ensure the detection of V-2 missiles immediately after launch, informing the responsible structures for the protection of the population. The new air surveillance system was called *BIG BEN* (in *The Chain Home Radar System*) and was maintained until the end of the war, when the radars in its composition were organised into a new system, called *ROTOR* (in *Rotor radar system*), made for the detecting and tracking Soviet strategic bombers.

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FUNCTIONAL DYNAMICS

The European military powers intended, in the period preceding the outbreak of the First World War, the creation of functional aerial surveillance systems. The small number of countries possessing both aircraft and air assets contributed to maintaining a low interest in the creation of a viable air surveillance system, which would ensure the discovery, identification and transmission of the information necessary to combat air-attack assets. The First World War had a significant role in intensifying the efforts for the achievement of such system, laying the foundations of the process of processing the collected data and of a communication system for the transmission of information related to actions carried out in air space. The structure of this communication system was made in such a way as to ensure the connection between the ambush and aerial warning stations, as well as their connection with the command centres within the anti-aircraft defence system.

The information flows achieved were utilised by the units of anti-aircraft missile forces, responsible for the civil defence, as well as by other structures for combatting the aerial enemy. All belligerent powers had a similar architecture of the communications system, which ensured the information flow related to actions carried out in air space.

The period preceding the outbreak of the Second World War registered a significant technological development of air-attack assets, by improving their technical characteristics, as well as a series of important achievements in electronics, aiming at developing and improving communications equipment and making radars with high detection reliability and performance in any conditions. Using radar as a means of airspace surveillance contributed to changing the conception of the organisation of the air surveillance system by both Great Britain and Germany. According to this new organisational concept, a change was made to the architecture of the communications system and a new vision was emerging regarding data processing and dissemination. Great Britain created a centralised information system, in which the data collected by the radars of the aerial surveillance system were transmitted to a central command unit, where they were materialised on maps, establishing the objectives that could have become targets of the enemy's attack. The information provided by the radars was used to direct the fighter aircraft or the anti-aircraft battery.

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At the beginning of the war against Great Britain, Germany had an air defence system that consisted of sectors equipped with surveillance and fire control radars, searchlights and associated night fighters, the night fighter being directed into visual range with target bomber by the illumination of searchlights. Later, British countermeasures to annihilate that alignment consisted in the reorganisation of the air defence system by creating a radar network and coordinating fighters to targets (Murray, 1983, pp. 177-179). At the same time, Germany integrated the air surveillance systems of the allied states by operatively connecting the information flows provided by its own surveillance system with similar systems of the allied countries, thus establishing on the territory of Germany, *Information Monitoring Centres*

with the Allied Powers (Teodorescu et al., p. 154). The architecture of the British and German information system consisted of existing connections between radar stations and command units achieved through communication equipment that ensured the transmission of information about any potential enemy air threat.

After the war, the functional architecture of air surveillance systems did not undergo significant changes, having the role of optimising the activity in the command units.

The development of information and communication technology brought changes in the functional architecture of aerial surveillance systems. The use of computer networks has increased the ability to collect, process and disseminate data and information in real time, producing significant changes in the architecture of the system of transmission of information about any potential enemy air threat. The integration of these networks is carried out by the C4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance), that provides a clear picture of what is happening in the area of interest by collecting massive amounts of data from multiple sensors, in order to provide commanders with the information that is necessary to make key decisions that support mission outcomes (in *Control the Chaos. Control the Outcome*).

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The functional dynamics of the aerial surveillance system had as its purpose the adaptation to the valid operational requirements, constituting a true reflection of the organisation of the airspace radar surveillance system, which ensures the optimal development of the information processes.

The structural and functional adaptation of the air surveillance system is a continuous process, which aims to improve the possibilities of discovery, tracking, identification, processing and dissemination of data and information about any potential enemy air threat, aiming to minimise or neutralise the technological advantages of the enemy. The technological innovations of the air-attack assets will require a reconfiguration of the architecture of the airspace surveillance system to further reduce its superiority. The detection of possible threats in the airspace and the avoidance of a surprise attack from the enemy

have led to development of the air surveillance systems. In order to achieve these goals, the states of the world have created sensor networks capable of maintaining under permanent surveillance a great volume of airspace, so as to ensure the detection of air assets from maximum distances and the timely reaction against them.

The high attack potential of aerial assets has required the development of complex sensor networks, capable of ensuring the surveillance of large geographical areas, having the effect of creating airspace surveillance systems with an increasingly complex architecture, for the purpose of achieving some higher operational requirements. The qualitative development of this system reveals the premise of achieving success in future aerial confrontations, its role in achieving the air power of a state being highlighted by the American General Henry H. Arnold, who stated that *"the first essential of airpower necessary for our national security is pre-eminence in research".* (Westenhoff, 1990, p. 50).

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ORGANISATION OF THE AIR SPACE SURVEILLANCE SYSTEM BY THE ROMANIAN ARMED FORCES

During the interwar period, Romania developed studies on ambush and air alert, bringing arguments in support of creating specialised structures in air surveillance since peacetime. Thus, in 1933, the General Ambush and Alarm Service was established (Teodorescu et al., p. 96), whose role was to ensure the surveillance of the national airspace and to collect the necessary information about any potential enemy air threat. The threat of a new war in Europe convinced the Romanian authorities to improve the country's ability to defend itself against air attacks. In this respect, on 28 October 1940, the Aerospace Defence Command was established, under whose subordination all the forces and means participating in the country's anti-aircraft defence were to function. With the same date, the newly established Passive Defence Service (AMR, collection 1376) was under the subordination of the new command. The technical means used for the detection of aircraft were similar to those of the First World War, the Romanian

state failing to purchase radars for the equipment of the anti-aircraft surveillance system. During the Second World War increased attention was paid to the ambush security system in order to protect important military targets from the enemy air and missile attack, such as the oil fields surrounding the city of Ploieşti. The importance of this oil region for the conduct of the war led Germany to establish a surveillance system based on radars of Freya and Wűrtzburg type, which provided the necessary information for carrying out the combat actions by fighter aircraft and anti-aircraft defence batteries. The air surveillance system established by the German armed forces for the air defence of the oil region of the city of Ploieşti was a part of a much larger system, built by Germany in the Balkan Peninsula, as follows:

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- a first alignment, between the Greek coast of the Mediterranean Sea and the Balkan Mountains, with an interception centre at Kalmuki, near Megara;
- a second alignment on the Danube, between Cernavodă - Turnu-Severin, on the Olt River, between Corabia and Braşov that continued with the Adjud - Galaţi alignment, being intended for the surveillance of the airspace against any potential enemy air threat, the provision of information necessary for the anti-aircraft batteries response in quick response of a bomber attack and for protection of the civilian population (AMR, collection 319).

The analysis of the surveillance system organised on the territory of our country reveals the fact that it was characterised by the coexistence between the air ambush system, specific to the First World War, and the surveillance system based on radars, organised by the German armed forces to ensure the information necessary for the defence of the oil fields. The two above-mentioned systems collaborated, ensuring the fulfilment of the assigned mission. Later, as a result of the unfavourable evolution of the war, Germany transferred the existing radar on the territory of Romania to the Romanian armed forces, in order to increase the capacity of the Romanian state to defend its own territory against the aerial enemy. The airspace surveillance

system built by the Romanian armed forces in the interwar period and during the Second World War, until 23 August 1944, had the following aspects:

- the organisation was similar to the first world conflagration, aiming at the surveillance of the main probable direction of attack of the aerial enemy and the provision of the necessary information for the anti-aircraft defence of important military objectives;
- the ambush and alarm units were equipped with optical and acoustic search equipment, similar to the armed forces equipment specific to the First World War;
- from an organisational perspective, the management of the Romanian armed forces identified the appropriate solutions to achieve the intended purposes, which was considered a major progress compared to the military organisation in the First World War, so that the existing air surveillance were developed considering the technical means available at the outbreak of the Second World War.

From the analysis carried out on the evolution of the aerial surveillance systems in the interwar period and during the war, it results that the structural dynamics were consistent with the development of the air-attack assets, aimed at accomplishing the assigned missions by the aerial surveillance systems.

THE EVOLUTION OF THE AIR SURVEILLANCE SYSTEM DURING THE COLD WAR

After the end of the Second World War, aerial surveillance systems were adapted to face the specific threats of the post-war period, namely ballistic missiles, cruise missiles and bombers capable of carrying nuclear heads. Both the USA and the USSR developed airspace surveillance systems that provided the long-range detection of potential threats from airspace or outer space. In this regard, the USA and the USSR initiated programmes for the development of airspace surveillance systems that would ensure early warning, materialised in the establishment of complex radar networks, arranged over large

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geographical areas, made with the aim of detecting from a very long distance intercontinental ballistic missile launches and enemy's air attacks. The danger represented by the air-attack assets, ballistic and cruise missiles, had a strong impact on the political and military decision-makers of the two superpowers. In this context, there were designed aerial surveillance assets in order to neutralise the advantage registered by the two superpowers. The purpose pursued by the mentioned military powers was to include those aerial surveillance assets in sensor networks intended to ensure the detection of the air-attack assets from an as large as possible distance. These networks will contribute to the creation of airspace surveillance systems with a complex architecture, which will ensure the necessary informational support for defence actions. The technological evolution of air-attack assets has required the adaptation of the airspace surveillance system in order to combat them by creating complex networks of sensors that include land, naval, air and space (cosmic) components intended to provide the effective protection against anti-ballistic missiles.

After the end of the war, Romania continued the development of the air surveillance system through the acquisition of Soviet radars in 1949, in order to equip the Romanian armed forces. Therefore, the Romanian armed forces developed a system of aerial surveillance that included only ground-based technologies, having an architecture specific to company and battalion structures.

The high costs generated by the creation and use of a system of such complexity do not allow all states to include these components in the architecture of surveillance systems simultaneously. Depending on the economic realities, the existing threats, the possibilities of combating such threats and, last but not least, their geographical position, the airspace surveillance systems may include one or more of the aforementioned components.

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advancements in aviation industry, surface-to-air missiles and anti-aircraft artillery.

In conclusion, the airspace surveillance system had a structural dynamic adapted to the technological developments of the adversary's air attack assets. At the same time, the system was conceived as the main part of a much more complex system, intended to ensure the detection of ballistic and cruise missiles threats, providing the information necessary to counter and combat them.

THE SURVEILLANCE SYSTEM APPROACH FROM THE PERSPECTIVE OF COMPLEXITY THEORY

The dynamics of the aerial, structural and functional surveillance systems is generated by the need to identify technical or tactical solutions for the timely detection of air attack assets. Airspace surveillance systems are complex systems, within which there are numerous interactions between elements. Andrei Kolmogorov[1] set forth an interesting definition of complexity, in which he stated that *"the more complex a structure is the greater is the amount of information needed to describe it"* (complexity.ro, 2013). The difficulty in understanding the complexity of a system results from not knowing the internal mechanisms or the lack of information about the phenomena or processes produced inside it. The complexity of a system is described by the degree of uncertainty regarding its functionality and evolution, being generated by a multitude of interactions both between the elements of the system and between the system and the external environment (Stănciulescu, 2003, p. 44). An important role in the dynamics of complex systems is played by the study of networks, in the sense that the determination of their topology characteristics would lead to a better knowledge and understanding of them (Derzsy, 2012). By knowing the characteristics of these complex systems and the laws that govern them, we are able to understand

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[1] Andrei Kolmogorov, Russian mathematician, Professor at Moscow State University, contributed to the development of probability theory, statistics, mathematical logic, as well as to the development of complexity theory.

their operating mode and their future evolution, finding the optimal ways to develop them.

The approach to battlefield from the perspective of complexity involves a high level of understanding it, by identifying both military and non-military interconnections between the parties involved. The increase in the complexity of military actions was generated by the scientific and technological evolution in the last century and their implementation in the military field, which led to an enhancement of military actions and a diversification of threats that modern armed forces had to face. The last decades development of information and communication technologies has contributed to the acceleration of the military transformation and adaptation process to the requirements of the high-tech battlefield, specific to the information society. The result of this process is *network-centric warfare (NCW)*, defined as *"a way to generate increased combat power by networking sensors, decision-makers, and shooters to achieve shared awareness, increased effectiveness of command (through speed, stability and strength), high tempo of operations (through appropriate rhythm, intensity and density), greater lethality, raised survivability, and a degree of self-synchronisation".* (Onișor, Moștoflei, 2003).

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The concept of *NCW – network-centric warfare* was first mentioned in 1998, in the work *Network Centric Warfare: Its Origin and Future*, written by Arthur K. Cebrowski and John J. Garstka (www.usni.org, 1998), in which it was presented as a new era of warfare, generated by the development of information and communication technologies and by the economic developments, being also considered a product of the information society. In this respect, the authors considered the following aspects:

"- the shift in focus from the platform to the network;

- the shift from viewing actors as independent to viewing them as part of a continuously adapting ecosystem;

- the importance of making strategic choices to adapt or even survive in such changing ecosystems" (Cebrowski, Garstka, 1998).

NCW was used on a large scale, in 2003, in the Gulf War, in which there were integrated very well, in a unique information flow, some structures belonging to all categories of military forces, thus allowing

the use of weapons specific to the missions assigned and the goals of the decision-makers. The integration of information flows ensured a high level of knowledge of the battlefield, which allowed the timely identification and quick reaction to operational changes leading to an increased combat effectiveness.

From the definition, we conclude that, through *NCW*, the information superiority over the opponent is transformed into combat power by interconnecting the battlefield entities (sensors, decision-makers, executors), allowing for freedom of action and a high ability of military forces to recognise and adapt to the actual conditions of combat. The interconnection of existing entities in the battlefield allows an increased capacity to disseminate the information necessary for the situational awareness in their operational tasks, obtaining the advantage offered by the permanent availability of information, which ensures the concentration of all available armed forces in order to act quickly, as well as a high level of cooperation, leading to an increased combat effectiveness.

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The sensor network is a battlefield entity with an important role in providing the data and information necessary for the battlefield surveillance. This will ensure the collection of data and information about the adversary and the real battlefield situation, which will be immediately transmitted for processing to the decision-makers, in order to take the optimal decision in a very short time. The existence of this network allows the superior knowledge and understanding of the complexity of the battlefield and the variables that cause the increase in the uncertainty level due to the unpredictable evolution of the operational situation.

The uncertainty generated by the complexity of the modern battlefield is based on the lack of information about the enemy, about its military goals and the way of carrying out its military operations. The uncertainty of the battlefield ensures a high potential for the asymmetrical use of force by state and non-state actors involved in the conflict. Reducing the level of uncertainty can be achieved by obtaining information corresponding to the area of interest so as to create a real image of the battlefield. The information plays an important role

in increasing the ability to influence the decisions taken by the adversary during the operation. The neutralisation of asymmetrical threats will require obtaining an information superiority over the opponent, which will be transposed into decision superiority in military combat operations. This information superiority will have as physical support a varied range of sensors deployed on space, air, sea and land platforms that will be used to find out information about possible hostile actions in order to counteract their adverse effects in time. The creation of complex sensor networks will contribute to the timely detection of threats, which allows to prevent or neutralise them altogether in order to conduct totally secure air operations. The effectiveness of the military combat operations conducted by the air force will be determined by an accurate visualisation of the battlefield, due to the battlefield surveillance missions that detect, locate, identify, and neutralise the threats identified in the area of interest. The sensor networks will be organised in the form of an air surveillance system responsible for providing land maritime and airspace surveillance. These systems will be designed with increasingly complex architectures, so as to meet, through specific parameters, the operational requirements of the battlefield and to ensure the adaptation of own military actions to the concrete situation of the operational environment.

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The development of the aerial surveillance system in order to ensure some parameters of the surveillance area that are superior to the existing ones is characterised by the following aspects:

- improving the sensor network by developing, acquiring and deploying radars on land, air and sea platforms with superior target detection capability;
- improving the sensor network through the development, acquisition and deployment of small ground surveillance radars, which allow increased measures for the protection of the military force, as well as the completion with information of the unsupervised areas in the immediate vicinity of the combat team;

- creating a network-based passive radars, which ensures the detection of air assets by processing reflections from the illuminators of opportunity;
- developing some technical means that could be incorporated into the surveillance system for the detection of orbiting space objects of a potential adversary.

The development of the aerial surveillance system architecture ensures its adaptation to the existing threats in the modern battlefield, contributing, in this way, to an increased efficiency of the air force. The combat capabilities of the enemy air-attack assets lead to the configuration of the architecture of the air surveillance system for their detection at maximum range.

An evolution marked by the increase in the complexity of the battlefield can thereby be seen at the Air Operations Centre (AOC). The Air Operations Centre has under its command and control the aerial surveillance, the aviation and ground-based air defence of air bases. The Air Operations Centre, analysed from the perspective of this study, represents the final structure intended for the processing of data and information provided by the other elements of the airspace surveillance system architecture, allowing military forces, geographically dispersed, to have a real image of the battlefield. The AOC is a vital air operation centre responsible for controlling and monitoring air forces.

The Air Operations Centre represents the final structure intended for the processing of data and information provided by the other elements of the airspace surveillance system architecture, allowing military forces, geographically dispersed, to have a real image of the battlefield.

The organisation of the AOC, whether it was established at the national level or serving as the land component command, was created to perform the mentioned functions in accordance with its existing operational requirements. For example, in the Vietnam War, the Tactical Air Control Centre reflected, from an organisational perspective, the existing divided command structure by which air operations were divided according to geographical and organisational criteria (operations carried out in the south, in order to support the commanders of the land forces, and air denial missions carried out in the north for the bombing of the military objectives). Even if the organisation of the AOC is different, and doctrinally several organisational models can be established, an element of analysis

of this model is the existing relationship with the Air Force General Staff. Regardless of its organisational model, in essence, the role of the AOC is to plan, monitor and coordinate the execution of air operations.

The last decades technological development and the increased complexity of the battlefield require the AOC to undergo transformations to ensure its rapid adaptation to the operating environment requirements. Colonel Frederick Coleman, in the article *Beyond the AOC-Building the Next Generation of Operational Command and Control*, identifies four lines of effort that can be used to drive change, namely: distribution, system, organisation and manning. The progress in the field of communications allows the distribution of command-control warfighting functions, the leadership being able to command from anywhere, from a single location or from several places simultaneously, to several units, resulting in a greater resistance of the system to the enemy's operations, especially if the operational command and control functions are located outside the range of its attack assets. The future of the AOC depends on how quickly fixed hardware-based systems are replaced with cloud-based automated systems that will allow the architecture to be reconfigured based on the mission or tasks at hand, instead of being anchored in a single position, thereby increasing the agility of the system. *The organisation*, in the future, must correspond and reflect the operational requirements of the battlefield, having the effect of increasing the efficiency of the AOC. And, last but not least, the creation of a professional command-control system requires the creation of a group of *command-and-control centre specialists* (Coleman, 2021).

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The major challenges of national or multinational air operations centres, regardless of their operational-level command and control (Air Operations Centre, Combined Air Operations Centre) consist in: the existence of an aerospace strategy, the way of solving the problems represented by the time sensitive targets, the integration of ISR, the problems arising in a coalition war and the ability of the operations centre to expand during the operations. The way in which these problems will be solved in the future will determine the ability

of the operations centre to exercise command and control functions, having the effect of increasing the efficiency of the military operations carried out by the air force and achieving decision-making superiority over the adversary.

CONCLUSIONS

The structural and functional dynamics of the architecture of the air surveillance system highlights the technical and organisational solutions identified at a given time, which contribute to ensuring the information support necessary for planning and carrying out military combat operations. The link between the combat capabilities of aerial assets and the architecture of the aerial surveillance system is revealed by the permanent effort made by the relevant military powers for the structural and functional adaptation in order to diminish the technical or operational advantages of the enemy's air-attack assets. Consequently, a priority of the military decision-makers has been the creation and development of an air surveillance system intended to ensure the detection of the enemy's air-attack assets and the provision of the necessary information support for ensuring air sovereignty and air defence of the airspace of states.

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