OPERATIONAL CONCEPTS APPLICABLE TO AIR SPACE SECURITY IN THE LAND FORCES' AREA OF RESPONSIBILITY FOR THE INTEGRATION OF VSHORAD, SHORAD, SAM AIR DEFENCE MISSILE SYSTEMS

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Airspace security is regulated at the level of each state according to the international treaties and conventions, in all possible situations, in times of peace, crisis or war, by integrating all the civilian and military air traffic control systems. The deep concern reaching the level of worry of the specialists in the field of airspace security is the reality of the complex operational environment of the land forces operations. In this context, due to the upgrades in the air space technology and the scale of the air actions at different altitudes, the need for the operational conceptualization of the air defence systems is well justified. For this, we redefined the airspace in the land forces area of responsibility from the perspective of two directions of research. The first direction of research is the threat and the aggression of a hypothetical air enemy, and the second direction of research is the conduct of the air defence response at different altitudes. In order to obtain results, in this article, we have developed several directions of analysis and conceptualization on the possibilities of integrating the VSHORAD, SHORAD, SAM air defence missile systems. Through this scientific approach, we consider to have opened new series of possibilities of planning the air combat and of probabilistic configuration on the notion of event of the air defence response, in a manner which is appropriate to the new challenges arising in the current airspace.

Keywords: aerial threat and aggression; air defence response; air defence event; air defence probability; operational art.

Conceptualizing the Negative Air Event in Redefining Airspace Security

The multidimensionality of the battle space is given by the resultant of the possibilities of employing a structure to counteract the means that a hypothetical adversary can use in a military conflict. In what the airspace security is concerned, this requires planning and implementing an integrated and interoperable airspace control system for all categories of forces. The purpose of such an airspace control system is to allow the actions of all the missile and air defence artillery structures to be synchronized with the operations of the other forces participating in the joint operation, in order to obtain the minimum level of operational risk. Establishing the security of any conflict environment is the first condition for achieving the freedom of action without the hazard of negative events caused by a hypothetical opponent. The definitions of the multidimensionality of the combat space and the expression of the notions of airspace security and airspace control system underline the importance and role of *the concept of negative event*. The object of study of the probability theory, the notion of *event* (as a result of an experiment), highlights the laws that manifest themselves in the field of random phenomena having a mass character. For argumentation, we will refer to the fundamental concepts used in the probability theory[1]:

- *a random experiment* is performed in order to collect the data necessary to establish the presence or the absence of a risk factor or to determine a simple status: positive or negative;
- *the test* is the method by which the experiment is obtained on an entity from the analyzed set;
- *the event* is the possible result of a test (an elementary event if it appears as a result of a single test);
- *the probability* is the possibility of the event to occur after a test.

Therefore, in the practice of probabilities, events can be of three types: certain, impossible and possible, which is why we chose to express airspace security from the perspective of conceptualizing the negative event, due to the limited knowledge of

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the actions of a hypothetical opponent, respectively a knowledge based on the estimates of the situation in the modern combat space[2]. *The estimate* as a separate document, as it appears in the operational art, is specific to military action planning and has two components: of *certainty* and of *uncertainty*. For the first direction of research (a topic of this article) which is the threat and the aggression of a hypothetical aerial enemy, we conceptualized the notion of negative event to show the impossibility of acquiring full knowledge on the actions of a hypothetical opponent. The actions of a hypothetical enemy can be interpreted and deduced following the processing of the data base prepared in peacetime or during the (airspace) reconnaissance operations. The creation of the data base is the result of the intelligence preparation of the battle space and of the war game (a tool specific to the military operations planning) which help identifying which of the total possible events are certain, impossible or possible. Thus, we will identify as certain events those that will mandatorily occur as a result of performing the war game (in this case, the war game is performed similarly to conducting an experiment).

After going through the war game in planning military operations, a combat situation can be interpreted as an experiment repeated under the same conditions or by changing certain circumstances, through which we can obtain, each time, new visions of the states of a system of forces and means. By this, we expect to identify the possible events that, following the determinations, are subject to certain laws, also called statistical laws. By applying the theory of probabilities we can obtain a new knowledge on the reality of the operational environment in the sense that they will allow us to predict the development of possible mass events such as: the imminence and the way of conducting an air strike. By applying the formula:

$$P(A) = \text{Number of favorable cases} / \text{Number of possible cases}$$

where P(A) is the probability of occurrence of the event, we obtain a factual situation in which P(A) is in relation $0 \leq P(A) \leq 1$, which in other words means that the relative frequency of the event that we analyze is equal to the ratio between the number of the tests in which event A occurred and the total number of the tests (repeated trials). Therefore, we will be able to express the state of affairs on the airspace security from a new perspective of the possibility of the occurrence of the negative event, which can be for example, a *surprise air attack*. The state of the airspace security, in this case, is expressed by analyzing three factors that give the resultant of the *air threat*, respectively: the composition, the disposition and the capabilities of the air enemy. Based on the three components of the air threat, we can build the model of the air aggression or the probable courses of action of the air enemy.

Therefore, we will express the state of the airspace security as the sum of all the possible negative events out of the totality of the possible events that can occur by the conduct of the air enemy's actions. Depending on the role and the destination of the means of air action, available to a potential aggressor, we can establish the multitude and the typology of the possible events that the enemy can achieve in the airspace. To provide an example, we shall refer to the action of the reconnaissance aircraft that can cause a negative event, namely, "disclosure of the friendly forces on the march or in the deployment area" or the actions of the attack helicopters that can cause the negative event from no. 68 by "hitting column 3 of tanks belonging to 22 Armor bat." and so on. The advantage of *conceptualizing the negative event* is that it establishes the state of affairs regarding the airspace security and offers the possibility to determine the number of negative events out of the total number of possible events that could occur in the airspace. Obtaining such a report on events or a report of the possible events of the enemy in relation to those of his friendly air defence forces, substantiates the determination of the balance of air superiority in an area of military conflict[3]. In other words, the expression of the level of security in the airspace is not only a regulation at the level of each state according to the international treaties and conventions through an integration of all civilian and military air traffic control systems, but rather, it can be expressed by the number of possible negative events in the airspace.

The air threat, as presented above, can be redefined as the sum of all possible negative events that an air enemy can generate at a given time. In this sense, we have decomposed the threat of a hypothetical enemy into three main

categories: the composition, the disposition and the capabilities. For clarification, we shall refer to the representation of each of the three levels, namely to their content expressed in terms of the negative event. *The composition of the air enemy* is the form of organizing the forces and means of action, leadership and logistical support necessary for planning and conducting an air event. In this regard, we have distinctly identified *the group of forces* and *the mission organization* which can consist of:

- manned reconnaissance means for gathering intelligence, surveillance, locating and engaging targets – fixed-wing (FW) and rotary-wing (RW) aircraft;
- ballistic missiles (BMs), weapons of mass destruction (WMDs) and means of information warfare – currently developing complex weapons systems;
- unmanned aerial vehicles (U [C] AVs) – with low and easily amortized costs;
- air-to-surface missiles (ASMs), cruise missiles (CMs) and large-caliber missiles (LCRs);
- high precision striking systems – of more recent development.

A first observation consists in the fact that, regardless of the composition and organization for the mission, planning and conducting an event in the airspace are actually done by the physical presence of that aircraft in the studied airspace. As the presence in the airspace is a flight path specific to the aerial system, we can deduce that the set of possible events in the airspace is the geometric place of all the points in the airspace where at least one aircraft can be located. If the aircraft are hostile, by the nature of their actions, they have the potential to generate negative events. In this sense, we can reformulate and make the following statement: "if the aircraft has the potential to perform a hostile action, then the geometric place occupied by the aircraft in the airspace or through each position on the flight path, is a *negative event*".

The second observation is related to setting in time and space the negative event caused by a hostile aircraft carrying combat potential, on its flight path. This tells us that in order to suppress certain negative events that could take place in the air one can intervene on each of the points on the hostile aircraft's flight path, but no later than it can achieve its own mission (ideally the aircraft should be destroyed on the ground or immediately after take-off).

The two observations prove that the conceptualization of the notion of *negative event* can be applied to expressing the state of security of the airspace. Based on this fact, we can reconsider the ways of developing risk management as a decision-making process which leads to expressing the situation estimates by describing the possibilities of the occurrence of the negative events and are closely related to the possibility of planning and designing air defence events.

Conceptualizing the Airspace in the Land Forces Area of Responsibility

Due to the technical and tactical capabilities of the air defence artillery systems of the land forces, there is a certain *action dimensionality in the airspace*. We define action dimensionality in the airspace as the totality of the geometric places in the airspace where the air defence artillery structures can plan and execute actions of reconnaissance, tracking and classification, identification, engagement and destruction, as well as evaluation of these actions against hostile aircraft or types of ammunition launched by air. After expressing the definition of action dimensionality in the airspace and by correlating the two types of events, namely the *negative air event* and he *air defence event*, it is possible to express the state of security of the airspace of responsibility and implicitly to conduct risk management. We define the *air defence event* as the possibility of executing any air defence action planned and carried out by the air defence artillery structures of the land forces.

Each air defence action is the result of specific activities, which are planned and carried out by each subsystem of the air defence response system (the reconnaissance subsystem, the command and control subsystem, the air defence firing subsystem and the logistics subsystem). Depending on the time and space classification of the air defence response actions, the algorithm for fighting the air enemy results, on distinct stages, as follows:

- reconnaissance of the airspace as a result of the actions of all sensors in the visible, infrared and electromagnetic spectra, which depending on the technical and tactical characteristics of the optical electronic means and devices, namely the radar stations, results in a shape and dimensionality of

the air defence surveillance area (depending on the enemy's jamming possibilities, the relief features, the weather conditions and the light or dark times resulting in different detection distances in the area of responsibility of the military operations);

- detection and classification of air targets (fixed or rotary wing aircraft, different types of ammunition launched by air);
- continuous tracking and establishing the identification of the aircraft (friend or foe);
- decision-making on engaging hostile targets (a task of the command and control subsystem, in compliance with the rules of engagement and the weapons control status);
- engagement with air defence fire or the execution of air defence fire (depending on the technical and tactical capabilities the air defence firing areas and the launch areas for the air defence missiles, which determines a certain dimensionality of the airspace, to combat and to destroy – a task of the air defence fire subsystem);
- evaluation of the effects of the air defence firing, a mandatory sequence depending on the air defence system and respectively, its ability to react to the actions of the hostile aircraft);
- cessation or resumption of one of the stages of the air defence algorithm until the objective of the air defence response is achieved.

Due to the high speeds of the aircraft, the deployment of the air defence response sequences is very fast, which implies the development of new technologies for informational connection of the air defence system subsystems. For clarification, we mention that each air defence missile or artillery system consistently covers the entire air defence algorithm as defined above, and the physical overlap of the firing areas and the launch areas is a *multiplication of the participation in performing the air defence event*. In other words, an air defence event may consist of the action of several air defence systems, but the intended objective is preserved in space and time, in the sense that the hostile aircraft will take countermeasures to achieve the negative air event. The major advantage of approaching the air defence response from the perspective of *the events occurring in the airspace* is the possibility of splitting the actions of the air defence response and thus achieving a significant economy of forces and means (of air defence potential). Splitting the air defence response actions means that all the air defence systems that achieve a dimensionality of the airspace take part in the air defence event singularly under the most optimal and favorable conditions for intervention to prevent the occurrence of the negative air event.

In the context of the joint achievement of the dimensionality of the airspace of several air defence missile or artillery systems, based on the principle of the common participation in the effort to carry out the air defence event, a series of specific lines result, as shown in Figure 1. Depending on the spatial positioning of the air defence systems, an air defence event, according to the practice of probabilities, is of three kinds: certain, impossible and possible. The description of the air defence response lines, as in Figure 1, implies the successive activation and deactivation of the air defence systems for the realization of the stages of the air defence algorithm, depending on the evolution of the aircraft on its flight path or

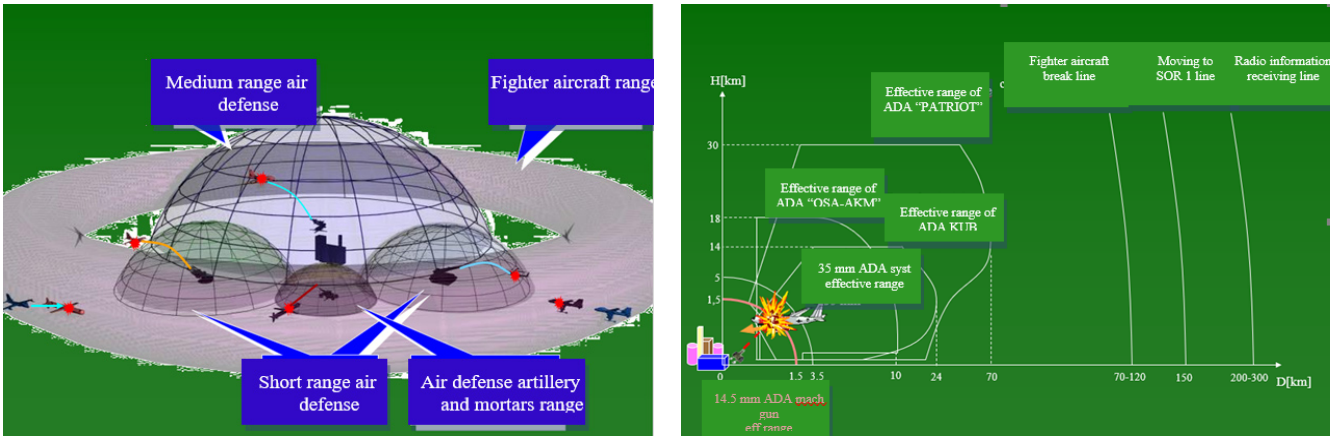
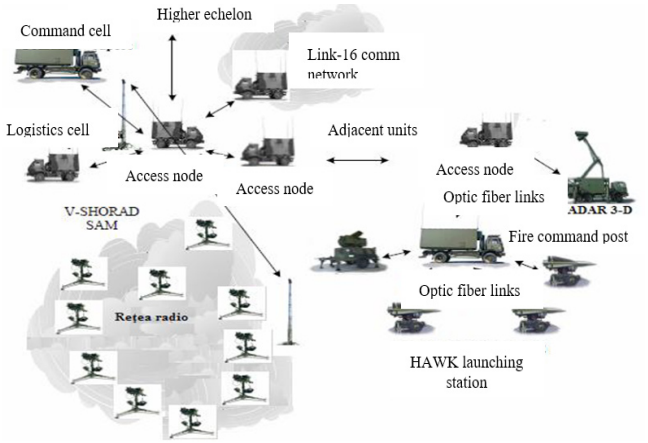


Figure 1 *Schematic representation of the action dimensionality in the airspace of responsibility*

the achievement of the air (negative) events. The disadvantage of activating and deactivating the corresponding stages on specific actions of the air defence systems, consists in the possibility of losing information about the evolution of the aircraft in the air, which causes a loss of precious reaction time to the negative air event. One solution to remedy this disadvantage may be to carry out air defence work in an air defence response network. The role of such an air defence network is to divide each sequence of the air defence response into discrete combat spaces in which only those systems that develop the maximum result per unit of air defence effort will operate. We define *the air defence performance* as the air defence end state pursued per unit of air defence effort. In other words, we aim to change in time and space the air defence efficiency depending on the contribution of each air defence system to the achievement of the air defence event. This means this can take place in a coherent expression of the contribution of each air defence system to the targeted event. Thus, for the same position and the coordinates of a hostile aircraft on the move in the airspace, the air defence systems in the same dimensionality of the airspace, will simultaneously encounter the three event situations: certain, impossible and possible. In this context, in order to obtain the optimal solution to solve the problem of the negative air event, an integrative control unit according to the model of *the collaborative work network* is necessary.[4]



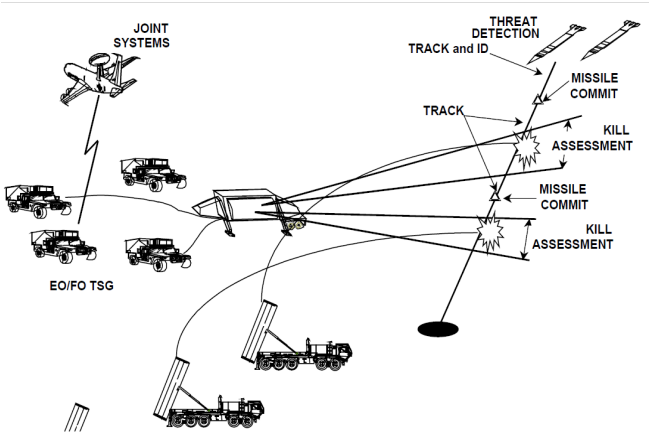


Figure 2 *Simplified scheme for representing a negative air event and the conduct of the air defence event*[5]

Integrating the VSHORAD, SHORAD, SAM Air Defence Missile Systems

The airspace defence involves the responsible joint action of the air defence missile and artillery systems within all categories of forces: air forces, land forces and naval forces. This implies analyzing, planning and decision-making on the employment in combat of all the air defence response capabilities depending on the degree of threat and aggression of a hypothetical air enemy. Decoding the level of air threat requires knowing and understanding the composition, the disposition and the possibilities of air action of a hypothetical opponent. The overlap of the air threat models on the geographical format of the area of operations together with the possibilities of occurrence of the other factors influencing the military actions (the existence of important objectives in the category of critical infrastructure, or the implications of signing international treaties, etc.) may lay the foundation of the development of the air aggression model. The conceptualization of the notion of negative air event opens new perspectives regarding the analysis, planning and decision-making of the air defence action, according to a network model, as in the graphic representation shown in Figure 2.

Linking the two types of achievable events, namely the negative air event and the air defence event, contributes to the creation of an air defence architecture based on an air defence algorithm, which is a correct and efficient tool for the air threat assessment and the activation of the TEWA[6] (Threat Evaluation and Weapon Allocation) weapons systems/ air defence forces and means of the land forces, air forces and naval forces alike. Based on the creation of such air defence architecture, a unitary integration of the actions of the VSHORAD, SHORAD, SAM air defence missile systems can take place according to the model in figure 3. Expressing the statement of the

air defence problem by conceptualizing the notion of air/air defence event implies the development of more solving variants where each variant has its own distinct results. As represented in the diagram in Figure 3, the contribution of the VSHORAD, SHORAD, SAM missile systems results in a new perspective of the operational art in the planning of air defence actions. In other words, there is a dissemination of the geometric locations of all the positions of the hostile aircraft on their flight path in the airspace, which implies a coherent activation/deactivation of the air defence missile systems, depending on the evolution of the air situation in the airspace of responsibility. Basically, a computer-assisted electronic ordering takes place in which successive missile launches are performed

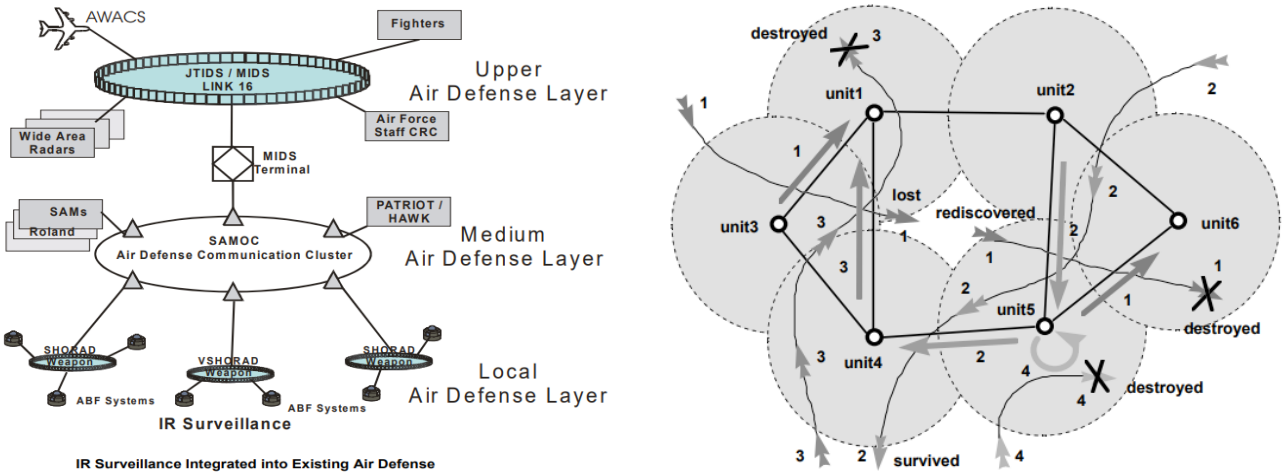


Figure 3 *Variant of schematic representation of the air defence architecture[7] for the unitary integration of the actions of the VSHORAD, SHORAD, SAM air defence missile systems[8]*

depending on the air event decomposed for each launching area of the VSHORAD, SHORAD and SAM systems as shown in Figure 3.

The result of such a collaborative air defence network depends on the speed of disseminating the information on the position of the hostile aircraft in the airspace and is one of the models resulting from overlapping the launching areas, at different altitudes of threat and aggression in the airspace. The actual creation of a collaborative air defence work platform implies the joint work of the subsystems of the air defence response system, so that all the sequences of the air defence response algorithm are carried out under technical interoperability conditions.

Conclusions and Suggestions

From the starting point of this scientific approach in which we tackled the deep concern reaching the level of worry of the specialists in the field of airspace security, we have developed a series of original ideas on the applicability of conceptualizing the notions of negative air event and air defence event. Following this conceptualization, against the background of the airspace technological development and the scale of the air actions at different altitudes, we have proven there is a justified need for the integration of the VSHORAD, SHORAD and SAM air defence missile systems in a collaborative air defence network following the operational model in Figure 3. For this, we redefined the airspace of responsibility of the land forces from the perspective of two research directions which we approached separately: the threat and the aggression of a hypothetical air enemy and the conduct of the air defence response at different altitudes.

The first aspect resulting from the analysis of the airspace security is the redefinition of the *dimensionality of the airspace* and the possibility of a coherent integration of several air defence missile or artillery systems. Thus, new possibilities are opened for the creation of the air defence event through the selective participation of the VSHORAD, SHORAD, SAM air defence missile systems corresponding to the combat possibilities in coordination with a series of specific alignments as shown in figure 1. Depending on the air defence formation, an air defence event can be, according to the mathematical expectation of the theory of probability, of three kinds: certain, impossible and possible. The advantage of such an approach is the achievement of a significant economy of forces

and means of the air defence response. Another advantage results from the perspective of splitting the air combat, a period of time in which the forces can maneuver in order to get out of the enemy's line of fire.

Another important aspect regarding the creation of a collaborative air defence response platform is related to the nature and manner of conducting negative air events, which results in an air defence structured on tiers and on heights, depending on the technical and tactical capabilities of the air defence missile and artillery systems. The strategy of such collaborative networks is to deal with threats through gradual countermeasures for various intervals of interception of the hostile aircraft. In this way, an air target is forced to gradually cross the air defence fire of several air defence systems, leaving little chance of achieving the air threat against the land forces. In a conventional battlefield situation, this air defence strategy can be successfully applied. If a coordinated air raid from *a previously known direction* is expected, then several medium-range air defence systems such as PATRIOT and HAWK can be deployed and massed in the area of the contact line, providing air defence in depth but also exposing these systems to the enemy artillery or infantry fire. The integration of SHORAD air defence systems with SAM surface-to-air missile systems, such as ROLAND or air defence cannon systems, such as GEPARD[9] (German air defence system) or ZSU-23[10] (Russian air defence system), can generate an air defence combat formation much more effective based on splitting the air defence algorithm and a much more organic self-defence. However, in the current operational environment of the military missions carried out mainly outside the militarized area or the deployment areas, the situation of the land forces structures becomes problematic from an air defence point of view. In the case of the forces deployed in regions with limited conflict and crisis, as well as in peacekeeping missions, the notion of contact line loses its significance and the hostile areas become arbitrarily distributed among the areas of responsibility of the allied forces. Based on a complete aerial image, as in the case of the collaborative network integration of the air defence systems, *the air defence actions can be carried out as previously planned missions*.

The two resulting aspects lead to suggesting that the communications technological compatibility of the VSHORAD, SHORAD, SAM missile systems should be identified in order to create a typical structure of collaborative air defence network (as in Figure 3). A second suggestion, arising from the first, is to design the procurement of air defence weapons systems in accordance with the principle of the technological interoperability. In this way, the modern short-range systems (VSHORAD), easily deployable and highly mobile in the tactical field, based on the information received from the SHORAD and SAM systems, can achieve a much more effective air defence response against the threat of the air enemy found in the vicinity of the friendly troops. This method aims to increase the value of the capability of the VSHORAD radar-based air defence systems to counter cruise missiles (CM) or unmanned aerial vehicles (UAVs) which due to the use of terrain lines where the radar cross sections are quite weak, are impossible to detect on the radar (hence an impossible air defence event). Following the results of the analysis of the air defence response in the context of the new security environment from the perspective of conceptualizing the notion of negative air event, respectively air defence event, the arguments related to how an air surveillance system (the information subsystem) should be equipped to be able to meet the challenges of a future extremely dynamic battlefield, are as follows:

- it is necessary to create and provide a unitary real-time air picture in order to report without delay all the aerial surprise actions;
- it is necessary to conduct covert radar operation because many missions require surveillance in stealth mode to avoid detection by the enemy;
- the air insecurity situations should be solved through previously prepared plans based on anticipated negative air events, without the existence of a complete air picture, when a continuous 24-hour coverage is needed, during which air attacks can occur from anywhere and anytime;
- in order to ensure the quality of the air defence fire command/control data, the performance of the radar systems must be improved appropriately to each air defence system by data on the coordinates of the current position of the target detected in the air and its speed, respectively the future position coordinates of the air target.

In conclusion, although we have not expressed all the suggestions that may result from the conceptualization of the notions of negative air event or air defence event, we are convinced that the decision-makers' adopting an appropriate attitude on the implementation of the air defence response in the area of responsibility of the land forces increases the airspace security and limits casualties and property damage in the event of a contemporary military conflict.

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