European Air C2 System National Requirements: Case Study of the Slovak Republic

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Abstract: *The end of the world bipolar division has reduced the likelihood of a threat of an atomic conflict, but at the same time it has released dormant conflicts. From that time, the phenomena that are not new, but their frequency, intensity, impact on human society have caused a change in the way they are perceived. In this context it is clear, that to ensure the sovereignty of the European airspace and specifically the one of the Slovak Republic, as a member of NATO, is the first priority task of the Air Force missions. To accomplish this, there will be significantly increased the requirements for processes automatization within Air C2 systems, in order to keep the necessary level of interoperability and to utilize and exploit both combat and reconnaissance unmanned aerial vehicles.*

Key Words: *Command, control, requirements, NATO, interoperability, armed forces*

1. INTRODUCTION

The processes of the globalization, the continuous rising of the society, as well as the information technologies, generate the inevitable changes in the environment in which we live. The world is being the witness of the conflicts that created a striking increase of the asymmetric threats in the 1990s. Especially the breakthrough of the 20th and the 21st centuries with the events from September 11, 2001, brought significant changes in the security system and in the understanding of the security threats and risks [1]. One of the NATO's main task, which is designed in accordance with the Washington Treaty from April 4, 1949, it is to ensure airspace protection. In order to guard the airspace of the NATO member countries, the integrated air defense system has been created, in which all the NATO European countries contribute with the relevant information from the radars and active defense elements. According to the third article of the North Atlantic Treaty, it is the obligation of each member to "individually and collectively, with the constant and effective self-help and mutual help to

maintain and develop the individual and collective ability to resist the armed attack" [2]. It is clear, to ensure the sovereignty of the airspace of the Slovak Republic, as well as a member of NATO, it is a priority task of the Air Force of the Armed Forces of the Slovak Republic.

In order to fulfil the above requirement, it is necessary to have a comprehensive command and control system. Its understanding and its correct application in the national units is a basic prerequisite for planning, preparing and implementing the fulfilment of strategic, operational, tactical and other tasks under the conditions of the Armed Forces during the time of peace, in times of crisis and in times of war.

At the present, there is a wide range of communication and information systems which are being used in the Armed Forces. Their ability to share information is largely limited due to the differences in the HW components, differences in the application of the SW packages and versions, differences in the formats, differences in the application of various exchange information protocols, missing of the requirement for the confidential definition as well as the absence of any standard (permanent) operational procedures and others. All these negatives affect the complexity and robustness of the command and control system and reduce the capabilities of the effective defense of the Armed Forces as a whole [3].

In near future there will be significantly increased the requirements for processes automatization within Air C2 systems in order to keep the necessary level of interoperability and to utilize and exploit both combat and reconnaissance unmanned aerial vehicles. The part of advanced Air C2 systems has to be algorithms for automation of operational planning including modelling and optimization of the air operational manoeuvre [4].

2. GENERAL ANALYSIS

The command and control system (C2) should be built on the operational requirements of the users within the Armed Forces and should be based on the military structure of the national defense system, which is an internally coordinated and interconnected summary of the forces as well as the resources which are involved to achieve the objectives of the Slovak Republic defense system in the following areas:

- command and control,
- comprehensive protection of the troops and defense facilities,
- ability to develop a war structure,
- securing of the allied troops on their own territory,
- means how to conduct, support and provide the combat activity,
- troop preparation,
- operational preparation of the state territory (building of the defense facilities),
- fire and electronic action,
- ensuring defense activities,
- defense and the protection of the population.

C2 systems, such as the bodies and processes of the command and control systems, need to be prepared to respond for a change of security environment, for the rapid technology development and increasing speed of the dynamic changes in the pre-combat, during and post-combat situations. These requirements place the high demands on the preparation of the command posts, the quality of procedures and development in the modern, secure and highly sophisticated technologies which are able to operate in the real time. To link the command and control systems in the horizontal and vertical lines within the national forces and NATO is and still will be an unconditional requirement for the ensuring of the effective decision-making and command, coordination and management processes during the preparation and

implementation of the national and international operations [5]. The military aviation legislation has its own specifics and principles. The civil and military legislative frameworks should operate in the close synergy and on the same footing. They use the same airspace. In general, in a peaceful time, the military flying objects using a general airspace are unconditionally governed by the civil aviation legislation. The exceptions are an emergency, crisis, or the QRA-quick reaction action against a potential threat where the designated military flights have the priority and may temporarily restrict civilian traffic, but under no circumstances the military action may not to threat the safety of the civil traffic.

Each state has its own airspace structure, procedures and certain specifics which are affected by several factors. They are determined by the size and profile of the country and by the volume of the traffic. However, all these factors must be absolutely compatible with the internationally applicable standards set by ICAO. The issue of an interoperability at the civil-military level is the core of a number of ICAO publications that are updated according to the latest informations.

The interoperability in the command and control issues means the close synergies during obtaining information, exchanging it between military and civil sites, and providing the services needed for all the units. Communication, navigation, reconnaissance systems and some other advanced support technologies functionally combine and supplement "classic" ground and air systems into the one integrated air traffic system that is accessible to all users of general airspace. One of the main advantages of this interoperability is its modularity, which consists of collecting only the informations that are needed to conduct the activity.

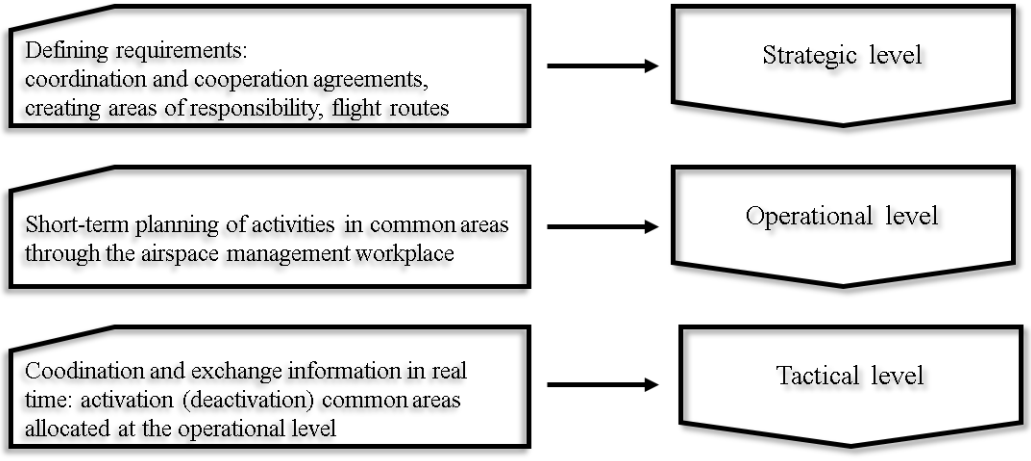

Figure 1: The scheme of the coordination levels between the civil and military parts

Only the synergy of all stakeholders, already during an early planning phase, optimizes an overall further action and reduces the cost of building a new common air traffic control system. In case of non-compliance with this particular principle between the civil air traffic control infrastructure and the military ground systems with the avionics equipment, the following problems may occur:

a) increased financial costs,
b) lack of support systems,
c) ungranted certification process,
d) lack of space in the cockpit for additional avionics,
e) security aspects (compatibility of the technical facilities and software applications),
f) limited further joint development.

In case of an extraordinary or emergency situation requiring take-off QRA aircraft and the subsequent interception, there is an increased level of exchange of necessary information between civil and military units which are using the same airspace. They both try not to influence the flight parameters (speed, flight level, heading) of the civil flights while leaving maximum of operational freedom to QRA aircraft when performing Air Policing procedures. However, in order to preserve security and depending on the nature of particular situation, there may be a partial, short-term limitation of the flight of some civil aircraft located in the vicinity of QRA aircraft's intended route. Any limitation of civilian traffic, as well as the direction of the flight route of interceptor, target and expected interception area are subject to close coordination between the ATC authorities. In order to quickly reach a specific target and minimize disruption to the flow of the civil aviation (the required level of interoperability), it is important to regularly conduct Air Policing missions by the joint efforts of civilian and military units. This is because the interceptors must choose the shortest possible route in order to reach the goal fastly and as safely as possible.

Command and control NATO level

NATO Force Structure (NFS) consists of Allied, National and Multinational Forces and their headquarters, provided to NATO in a permanent or in a temporary disposition with the refined combat readiness criteria. The national contributions are made available to NATO through an approved Transfer of Authority (TOA), but also through the coordination and cooperation agreements which are enhanced by common resources for specific capabilities and opportunities.

The Alliance Command Structures are subject to ongoing reconstruction and restructuring. There have been made some changes in the NATO command structures in previous years, as well as the redistribution of individual command posts, followed by the current subordination of air operations command.

The military command structure consists of three levels: strategic, operational and tactical.

The Supreme Headquaters Allied Powers Europe (SHAPE), headquartered in Monse, Belgium, is the NATO's highest strategic body in Europe. It is headed by NATO's Allied Forces Headquarters in Europe – SACEUR and is responsible for military planning, including developing Armed Forces requirements to maintain stability, ensuring crisis management and effective defense. The operational level of command consists of three Allied Joint Force Command (JFC). Headquarters in Brunssum (Netherlands) and Naples (Italy) have resources and staff capable to lead one major and two minor joint operations. The Lisbon Headquarter (Portugal) is able to conduct two smaller joint operations. The JFC in Brunssume provides the operation headquarters for ISAF in Afghanistan, while JFC Naples provides command for NATO operations in the Balkans, Iraq and the Mediterranean. The Lisbon Headquarters commands in Somalia in all the anti-piracy operations.

The tactical level consists of six headquarters according to the focus - land, sea and air (three for North JFC Brunssum and three for South JFC Naples). Although these components are subordinate to the operational headquarters, they can be allocated as needed for operations under other command. The Allied Air Command (AIRCOM) headquartered in Ramstein, Germany, and in Izmire, the southern region of Turkey, are directly subordinated to the headquarter in Brunssum. Their main task is to plan and conduct all NATINAMDS peacekeeping operations. They are also involved in the submitting proposals for measures and requirements (e.g. for changing the allocation of forces), carrying out exercises for the benefit of subordinate units and carrying out a verification process. The basic AIRCOM tactical element of command and control is represented by two static (Torrejon in Spain and Uedem

in Germany) and one redistributable (also Uedem) multinational Combined Air Operations Center (CAOC). They are an essential building block in fulfilling Air Police tasks within their Area of Responsibility (AoR).

The CAOC is linked to its subordinate command and control systems (C2) representing the National Control and Reporting Centers (CRCs), which permanently exchange the relevant and up-to-date informations with each other to contribute to the creation of a joint picture of the air situation in the AoR. In the context of peaceful life, CAOC is the top decision-making authority of NATINAMDS.

Command and control national level

Area Control Centre - ACC Bratislava

ACC is a civilian radar control center in located in the SR. It controls and has an overview of all civilian aircraft located in the Slovak airspace. If an extraordinary or emergency situation arises, for example it means that the ACC unit has radio connection failrule with the controlled aircraft. It shall immediately inform the neighboring ATC unit in accordance with the procedures and rules for civil aviation. At the same time, it is mandatory to inform the CRC in Zvolen about the occurred situation.

Military Area Control Centre – OAT Bratislava

The OAT (Operational Air Traffic) unit is a military ATC component located in the ACC Bratislava. One of its main tasks, especially in relation to QRA, is to ensure the coordination of military flights with civilian traffic and vice versa. The OAT unit is responsible for in-time and accurate informing the CRC Zvolen about the emergency of a civil aircraft in the AoR of ACC Bratislava. In the opposite direction, it transfers the informations about the plans and activities of the CRC and QRA changes.

Control and Reporting Centre - CRC

The CRC, in cooperation with the declared forces and resources of the rest of the Air Forces through its sections, performs tasks which are aimed to ensure airspace sovereignty within the NATINAMDS (Weapons section), to conduct a continuous radar reconnaissance of the SR as well as to provide a full picture of the air situation to the designated units (Surveillance section). Members of the CRC are under the NATO command. The Weapons Management Section is responsible for the direct control and vectoring of QRA aircraft in the SR airspace, fulfills (or proposes) the instructions of the superior level and coordinates QRA flight with other ATC units according to needs and current situation. It gives an order to the QRA to follow the specified alert level procedures and immediately informs master controller of any change in the AoR. The objective of this section is to continuously monitor the airspace with the support of a dedicated radar technique, tracking and identifying flying objects over the territory of the SR. In addition, it must inform other positions within CAOC and in the case of international flights, the neighbouring states, through their CRC sections about activities, significant changes which have a potential impact on the airspace integrity and suverenity.

The master controller in the CRC is responsible for communicating, executing instructions and solving of specific air situations with CAOC managers. In the case of national transfer of authority, he takes command of the QRA.

Operations Control Center

The Operations Control Center is also located in Zvolen. Its mission is to carry out active command and control of the Slovak National Air Forces. The priority task is to activate or increase the readiness level of the search and rescue service and to notify the relevant persons and institutions.

Wing Operations Center

The WOC collects and transmits informations regarding to the current status and capabilities of aeronautical and ground-based equipment at the airport. According to the CRC (Weapons Section) instructions, it orders the QRA in to the appropriate alert level. All the above informations are passed on not only to the CRC but also to the CAOC.

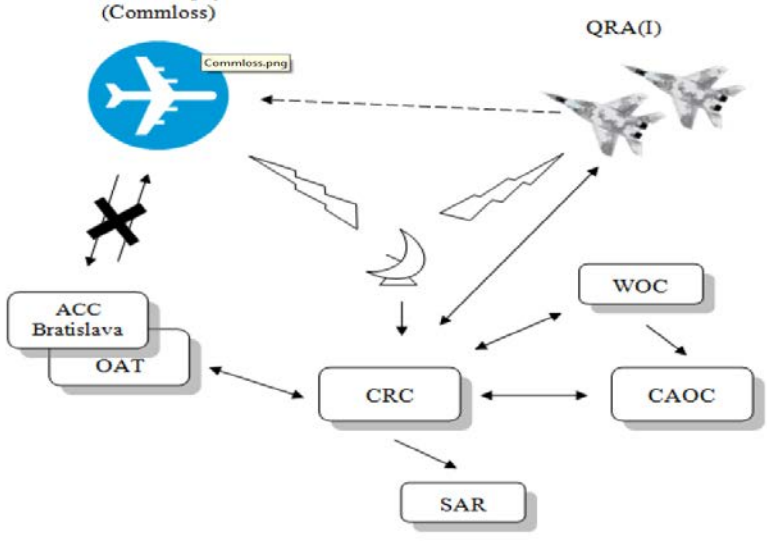

Figure 2: The communication flows while activating QRA on an aircraft with the radio communication failure

Figure 2 illustrates the main command and control entities which are entering the process of dealing with the commloss air situation, indicating the communication flows when activating the QRA. In this case, the primary impulse is a civilian aircraft with negative radio connection. However, only CRC, WOC, QRA and radars are assigned under the direct command of CAOC Uedem.

Figure 3 shows the scheme of the places of command and intersection within the transnational NATINAMDS system, as well as the interaction between the SR and NATO.

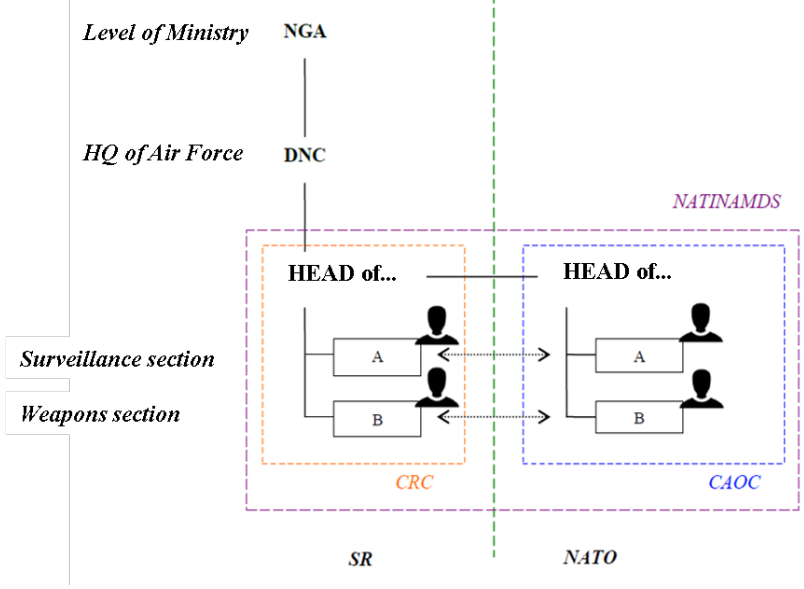

Figure 3: Scheme of command within the NATINAMDS system between the SR and NATO

3. INTEROPERABILITY

The interoperability at this level means the close synergies in obtaining information's, their exchanging it between military and civilian sites, and securing the services needed for both sites. Communication, navigation, reconnaissance systems and some other advanced support technologies functionally combine and support the "classic" ground and airborne systems into the one integrated air traffic system that is accessible to all users of the general airspace. One of the main advantages of this interoperability is its modularity, which consists of collecting only the information that is needed to conduct the significant activity. For interoperability issues, it is necessary to comply with the requirements of each unit involved at the national and international level. A significant part of C2 activities is already being carried out with the foreign partners. However, the interoperability conditions need to be fulfilled mainly in the area of systems, compliance with standards, data protocols, classification of secret level and so on. The systems used nowadays are based on the interconnection of several systems into a complex whole, which is aimed at command and control not only of aviation combat operations. This consists of the defined conditions. The interoperability of systems must fulfil the functions of planning, ordering and performing all the air operations [6].

From the point of view of modernization of the system, it is necessary to ensure the requirements for the protection of classified information up to the SECRET classification level. From a technical point of view, the proposed systems need to allow to operate the processes of Mode 4 and Mode 5 information. In terms of information transfer, it is important to focus on interoperability within NATO countries in systems FFI and MTF via JREAP format. In terms of geographic display support, the system needs to support the maps based on tactical and operational level in format NVG. The systems must be linked by Link 16 tactical data lines to allow the transmission of J-type messages that create a prerequisite for RAP creation and transmission.

4. RELEVANT REQUIREMENTS OF C2 SYSTEM

Interoperability requirements need to reflect the command and control systems in the developed NATO countries. The functional command and control system in the Slovak Armed Forces must be compatible and interoperable and it must follow the internationally defined requirements and standards.

The command and control system must ensure:

- requirement of exact classification level, up to level "Secret",
- requirement of a stable and functional operating system,
- possibility of Mode 5 and Mode 4 processing,
- enhancing interoperability within NATO (JREAP-C, NVG, FFI, MTF)
- support for NATO NVG tactical maps,
- support for Link 16 (J messages) processing,
- possibility to create and transfer RAP using Link16 messages,
- support for Friendly Force Tracking Systems (FFTS),
- Command support (orders and messages) in MTF format
- independence of an objective record of the operators' activities,
- centralization of the calculations,
- interconnectivity between the secret and non-secret network,
- time synchronization exchange,
- support for link 1 change to Link1overIP,

- building a Data Test Center (DTC).

The Support of the System Transfer to the Secret Classification

To support Mode 5 but also the need for data protection nowadays, it is essential that the system is fully implemented in the SECRET mode. This implies these requirements:

- prepare (configure, describe, certify) the operating system to work in the SECRET mode,
- changing the method of linking between the secret and non-secret networks,
- replacement of the serial connections for the data diodes,
- changing the L1 communication interface via serial to L1overIP.

Mode 5 Processing

Mode 5 provides an encrypted military version of Mode-S. Currently, as in the Mode-S civilian operation, the military Mode-5 is considered to be the main source of the information transmitted from the aircraft (secondary radar information from the aircraft on demand from the secondary radar).

The command and control system should be designed to handle the standard described by the EUROCONTROL (Asterix cat 48) and it is recommended that all the Mode 5 sources use this protocol.

Mode 4 Processing

Mode 4 is the forerunner of Mode 5 and in the future it is assumed that Mode 4 will be fully replaced. For the compatibility and support with some older devices, the system should also support the Mode 4 standard.

Increasing Nato's Interoperability Options (Jreap-C, Nvg, Ffi, Mtf)

Achieving interoperability within the NATO countries is one of the basic requirements of all partner Armed Forces. Therefore, when deploying a new system or upgrading the system, the functionality of connecting and sharing information should support:

- tactical maps - informations are shared by connecting to the NVG Information Service NATO Vector Graphics Format,
- datas from Link 16 - Informations are shared by using the JREAP transport protocol.

Supporting Tactical Maps in NATO NVG Formating

The NVG service application is considered to be the main tool for exchanging information on a common operational picture of a battlefield situation. The tool enables mutual exchange of informations in the form of operational-tactical drawing of the situation. The goal is to render the objects in the geospace (zones, boundaries, direction of attack, minefield, ...) based on the NATO symbols according to the APP-6. The NVG protocol is based on the SOAP / WSDL web service, type Request / Response.

The system must allows:

- the connection to a third-party standard NVG server and get their tactical drawings,
- the creation of own tactical drawings,
- to provide information from own drawings to the third parties.

Link 16 Processing (J Administration)

GBAD (Ground Based Air Defense) network distinguishes 3 basic operating groups for Information Exchange Requirements (IERs):

- Common (Cmn) - this group includes IERs requirements common to all the C2 elements operating in the GBAD network.

- Air Surveillance (AirSurv) - this group includes IERs requirements for GBAD Air Surveillance reporting function. Like the Common IERs, AirSurv IERs are mandatory for every C2 element operating in the GBAD network.
- Command and Engagement Status (C&ES) - this group includes IERs requirements for GBAD units providing C&ES functions. C&ES combines the role of the Command Authority and the Weapons Unit under Command into the one functionality.

Creating and Transferring RAP with the Link 16 Management

The system should allow to contribute and create a common RAP within the Link 16 JREAP-C network. The RAP rules and correlations must comply with the NATO regulations related to the Link 16 (STANAG 5516). Informations need to be processed within the Minimum Link 16 requirements for the AirSurv. The information exchange must be done within the Link 16 (J-messages).

Friendly Force Tracking Systems Support (Ffts)

Tracking friendly units includes the ability to provide positioning informations about own and allied units. These informations are known as FFI (Friendly Force Information), and in a standardized form, they transmit an image of its own and allied units in the Situational Awareness (SA) of the NATO Force Tracking Systems (FTS), Command and Control Systems (C2) and other identification systems, including combat identification systems (CIDs), combat equipment and other units to reduce the risk of damage or destruction of allied forces.

Command Support (Orders and Reports) in the MTF Format

The Message Text Formats (MTFs) are used within the NATO operations and exercises to exchange a structured text information in between the coalition units. Many NATO reports are also exchanged within the national systems. The message list is published in APP-11 (NATO Message Catalog), where the latest version includes more than 400 message types covering all the aspects of the NATO operations.

Improving Operator Display Features and Adding New Functionalities

Upgrading to a modern operating system and the consequent use of current modern framework systems, especially its operator images, it can be enhanced and improved with a new functionality. The main areas are:

- Display multiple plots and local tracks simultaneously in any radar window.
- Support multiple projections with the different projection options in each radar window.
- Vector map support in the standard shapefile (.shp) format.
- Raster map support from the map servers.
- View tracks and all the datas obtained from the Link-16 data protocol via the JREAP-C.
- Transparency of the displayed graphics layers.
- Tools for conducting the combat operations in the Link-16 data protocol.
- A controlled mirrored directory from an unclassified network in a classified network used to transfer data (files) from an unclassified network to classified network.

Changing the Time Synchronization

It is currently time-synchronized with a GPS receiver, from which the data is processed and provided for the time synchronization and radar evaluation system (SDAA) as a source of reference data.

For this reason, the GPS processing for SDAA is no longer required. The time synchronization should be done by a professional device for that purpose. The device will also

allow time synchronization from another source (e.g., another time server on the classified network), not just the GPS. This will also result in a transition from special SW and HW to the COTS solutions.

Support for Changing Communication Link 1 To Link 1 Over Ip

To ensure the SECRET level of security, it is necessary to use a secure connection through the tactical data lines. At present, the only secure connection in Armed Forces via the tactical data lines is the Link 1 connection. Due to the transition of existing systems to the ethernet networks, providing communication via the IP protocol, it is necessary to modernize the used Link 1 line through an interface that allows the migration to Link 1 overIP.

5. RECOMMENDATIONS AND CONCLUSIONS

The command and control of the NATO air operations in and outside the Europe, require the integration of multiple components and services at all the command levels to effectively use combat and support aircraft, unmanned aerial vehicles and ground-to-air missiles.

The NATO's command and control system must provide a backbone that supports planning, tasking, and execution of all air operations. The NATO's peripheral and older systems must complement NATO's comprehensive command and control system at the higher levels. For this reason, it is essential that all the member states are fully system-compatible and interoperable.

The ensuring the sovereignty of the area of responsibility also creates increased demands for the personnel training [7]. This is a key element in achieving and sustaining command and control success. It is very important that the harmonized planning, implementation, development and support of individual C2 systems and other programs connected to this complex environment meet the operational requirements and minimize military risks with regard to the NATO's political, economic and timetable requirements [8].

Command and control in the Armed Forces of the SR as an active NATO member, its effectiveness and the level of security of service provided by the military professionals is a complex matter that is directly proportional to the quality of the education provided and the training of that staff from the initial phase to the obtaining or maintaining a valid license. Whether at the level of technological progress in the application of new, ever-evolving sophisticated tools or at the human resources level, it is evident that the process of preparing professionals which are entering to the command and control process is very lively. To maintain security in this area of the preparation, it is advisable to create a synthetic environment - a training element (simulation environment) that will keep pace with the current NATO requirements for the safe and flexible provision of the services [9, 10]. To reach this goal, such an element must first and foremost have a well-trained and experienced staff who transform their knowledge through the use of sophisticated tools that are continually refined and applied in the training of other professionals, thus achieving a constant level of demand and need. Regarding to the means of command and control in the Armed Forces of the SR, it is appropriate to respect the currently established trend, which is applied in the NATO environment. In terms of economic possibilities, it is necessary to look for the most effective technical solution of the system with the possible integration of already established national systems. The transition to a new command and control system requires considerable effort in the preparation and training of all the staff involved [11].

From the reason of the NATINAMDS system integration, the Command and Control System in the Armed Forces of the SR is unique. In contrast with C2 ground forces and other

staff systems, the C2 system of the Slovak Armed Forces at the national level needs to address the issue of its integration into the NATO system. In terms of the ATP-86 dealing with the NATO GBAT concept of the operations using JREAP-C and Link 16 messages, the main mission of the GBAD's purpose grouping in the NATO operations is to prevent and to disarm airborne threats from any direction, such as fixed wing and helicopter aircraft, unmanned aerial vehicles, missiles, artillery and ensure the protection of their own forces and collateral losses during the execution of these operations. Air threats can occur against the NATO's static installations, maneuvering forces or missile defense forces not only within NATO but also at the deployed places. [12, 15] The use of the multinational GBAD of a dedicated grouping is recommended wherever a local or sectoral area of the operations requires integrated defense to fill a gap in the coverage of resources tailored by a specific air threat. This concept allows understanding of the integration and needs of the Slovak national C2 system into the overall NATO and NATINAMDS operations system, as well as its linking to the NATO operations (possible operation in case of activation of Article 5 of the Washington Treaty).

The concept of these operations is based on the interoperability of the systems. The permissible combination of the organizational elements (hardware, software, personnel) in GBAD dedicated groupings is a real-time challenge for interoperability. And in this case, it is necessary to link not only to engage in operations, but to interconnect the systems and keep them running within the NATO's reaction system. The solution of this challenge is that the rules and the procedures will focus on the level of command and control between C2 elements or Tactical Operations Centers (TOC) rather than at the components level. It is a multinational mix of the C2 elements that communicates through the JREAP-C, which is a surveillance and command network. Along with the proper use of the messages that are compatible with the Link 16, this network is the basis for the interoperability and integration features that are needed. Recognizing that some components, such as individual weapons or sensors, may be the only contributions that some states may offer, it is the contributor's task to ensure that such components are accompanied by the appropriate C2 facilities, software and personnel to implement agreed procedures to support the intended contribution to the local surveillance and command network. In view of these facts, it is necessary to define the requirements for the integration into the NATINAMDS and the integration of allied partners whose capabilities are limited to low-level image interface (LLAPI), Link 11B or single component posts [13, 14].

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