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The C5ISR System Integrated with Unmanned Aircraft in the Large-Scale Combat Operations

Integrace bezpilotních letounů do systému C5ISR v rozsáhlých bojových operacích

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Abstract: The manner of conducting modern large-scale combat operations (LSCOs) is characterized by the increasingly frequent and diverse use of unmanned aerial vehicles (UAVs) integrated into the Command, Control, Computers, Communications, Intelligence, Surveillance and Reconnaissance (C4IRS) system. These aircraft are one of the most important types of weapons in modern LSCOs. Anyone that has the technology can process the latest information from the field and safely passes that information to the command center has a great advantage and a chance to cause great damage to units whose goal is to prevent further operational work. What is important is that UAVs must have some degree of self-protection through site selection action to reconnaissance and retreat routes. The paper presents the possibility of using UAVs for various missions in LSCOs, as well as a case study of their use in previous modern armed conflicts.

Abstrakt: Způsob vedení moderních rozsáhlých bojových operací se vyznačuje stále častějším a rozmanitějším využíváním bezpilotních vzdušných prostředků integrovaných do systému velení, řízení, výpočetní techniky, spojení, zpravodajství, sledování a průzkumu (C4IRS). Tyto letouny jsou jedním z nejdůležitějších typů zbraní v moderních rozsáhlých bojových operací. Každý, kdo disponuje technikou schopnou zpracovat nejnovější informace z terénu a bezpečně je předat velitelskému středisku, má velkou výhodu a šanci způsobit velké škody jednotkám nepřítele, jejichž cílem je zabránit dalšímu operačnímu působení. Důležité je, že UAV musí mít určitý stupeň vlastní ochrany spočívající v možnosti výběru místa působení, průzkumu a ústupových cest.

Key words: Command Center; C4IRS; Large-Scale Combat Operation; UAV; UCAV.

Klíčová slova: Středisko velení; C4IRS; rozsáhlé bojové operace; UAV; UCAV.

INTRODUCTION

The strong development of science and technology, especially significant achievements in the fourth industrial revolution, have created many changes in the areas of social life. It can be particularly highlighted in the area of defense and security, where there has been a significant improvement in combat activities and where the application of scientific and technological achievements significantly improves the efficiency of units. Modern combat operations require the use of the most sophisticated combat assets for the efficient execution of assigned tasks. The use of unmanned aerial vehicles is an indispensable segment of modern combat operations. Due to its versatile use and different structural and combat characteristics, it provides a wide range of possibilities to units equipped with this type of combat equipment. By using unmanned aerial vehicles integrated into the C5ISR system, it is possible to have a picture of the battlefield in real time with cyber protection, which provides the decision maker with the possibility of timely and effective command of forces in a combat operation. C5ISR is an acronym for Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance and Reconnaissance and an upgraded system of C4ISR that does not include a cyber element (Figure 1). In modern combat operations, various types of drones are used, from commercial ones to armed combat drones that transmit data to the command center. The use of unmanned aerial vehicles in modern combat operations is increasing, especially for reconnaissance, surveillance and targeting of targets on the ground. There are certain characteristics that must be fulfilled in order for an unmanned aerial vehicle to be effective in combat and meet the requirements of modern warfare.[1]

Figure 1: C5ISR system

[1] Long. N (2020). The usage of UAVs and requirements in modern combats. *Journal of Military Science and Technology*, *66*(4), 218–222. https://doi.org/10.54939/1859-1043.j.mst.66.2020.218-222

1 LITERATURE ANALYSIS

There are a large number of papers dealing with the problem of unmanned aerial vehicles, while there are very few papers analyzing the application of a C5ISR system integrated with unmanned aerial vehicles. In a certain number of works, the use of unmanned aerial vehicles in combat operations was analyzed. Milić et al.[2] analyze the possibility of using drones in operations in the urban environment. Radovanović et al.[3] are picturing the possibility of using civilian drones in the protection and monitoring of the terrestrial security zone. Adamski[4] analyzes the effectiveness of combat drones used in modern armed conflicts. Jović[5] shows the combat use of drones in a counter-terrorist operation. Petrovski and Radovanović[6] analyze the use of mandrels in cooperation with the C4IRS system for the needs of the army. Ilić and Tomašević[7] analyze the impact of the conflict in Nagorno-Krabakh on the perception of combat drones. Bares[8] performs interoperability modeling for the C4IRS system in the collective security system. Radovanovic et al.[9] analyze the possibility of implementing drones in mortar units in order to increase the efficiency of fire support units by applying a fire management system in cooperation with the C4IRS system. Petrovski et al.[10] analyze the application of GIS in cooperation with the C4IRS system in geography for the needs of the military. Cai et al.[11] shows small drones with future development trends. Horizon Global Partners develops

2 Milić, A., Ranđelović, A. & Radovanović, M. (2019). Use of drones in operations in the urban environment. in: 5th International Scientific conference Safety and crisis management – Theory and practise Safety for the future – SecMan 2019, 124-130, Belgrade: Regional Association for Security.

3 Radovanović, M., Milić, A. & Ranđelović, A. (2020). Mogućnost upotrebe dronova u zaštiti Kopnene zone bezbednosti.In:15. Međunarodna konferencija rizik i bezbednosni inženjering, 303-311.Novi Sad:Visoka tehnička škola strukovnih studija u Novom Sadu i Fakultet tehničkih nauka.

4 Adamski, M. (2020). Effectiveness analysis of UCAV used in modern military conflicts. *Aviation*, *24*(2), 66-71.

5 Jović, Ž. (2016). Borbena upotreba dronova u protivterorističkimoperacijama SAD. *Bezbednost,* 58(3), 71-190.

6 Petrovski, A. &Radovanović, M. (2021). Application of detection reconnaissance technologies use by drones in collaboration with C4IRS for military interested.*Contemporary Macedonian Defence*, 21(40),117-126.

7 Ilić, D. & Tomašević, V.(2021). The impact of the Nagorno-Karabakh conflict in 2020 on the perception of combat drones. *Serbian Journal of Engineering Management,* 6(1), 9-21.

8 Bares, M. (2001).Interoperability Modeling of the C4ISR Systems. in: RTO SCI Symposium on "System Concepts for Integrated Air Defense of Multinational Mobile Crisis Reaction Forces".16-1 – 16-16. Valencia:North Atlantic Treaty Organization.

9 Radovanovic, M., Samopjan, M. & Petrovski, A. (2021).Possibility of Implementation of Drones in Mortar Units in Order to Increase the Efficiency of Fire Support Units. in:24. Međunarodna DQM konferencijaUpravljanjekvalitetom i pouzdanošću ICDQM -2021. 307-315. Prijevor: ICDQM.

10 Petrovski, A., Taneski, N. &Bogatinov, D.(2019). Geography in Geospatial Intelligence - C4IRS and Cyber Security. in: 5th International Scientific conference Safety and crisis management – Theory and practise Safety for the future – SecMan 2019. 64-72. Belgrade: Regional Association for Security.

11 Cai, G., Dias, J. & Seneviratne, L.(2014). A Survey of Small-Scale Unmanned Aerial Vehicles: Recent Advances and Future Development Trends.*Unmanned Systems*, 2(2), 1–26.

platforms that support C2, C3, C4, C5, C6 - ISR systems.[12] Halkis and Adha[13] analyze the C5ISR data link model of national defense in the face of cyber threats. Michaelis[14] analyzes explanatory systems to support IoT-based C5ISR applications on the battlefield. Radovanović et al.[15] analyze the choice of an unmanned aerial vehicle for the needs of tactical units of the army and the police by applying the fuzzy AHP - VIKOR multi-criteria decision-making model. Mahajan[16] analyzes the application of drones in construction. Mitka and Mouroutsos[17] performed a classification of drones according to purpose. In their work, Choi et al.[18] propose a multiple transmitter system composed of transmitter coils of different sizes for charging drones. Gupta et al.[19] presented a classification of unmanned aerial vehicles and analyzed the model of an unmanned aerial vehicle with its components. Žnidaršič et al.[20] shows several types of drones and anti-drone assets for the purpose of implementation in units of the Serbian Armed Forces. Petrovski and Toshevski[21] show the application of GIS in geo-reconnaissance and C4IS for military purposes.Žárský et al.[22]analyze the use of multicopters in the Czech army using the Delphi method.Colomina and Molina[23] analyze unmanned aerial systems for photogrammetry and remote sensing. When we talk about combat operations, Pytel and Cieśla[24]analyze

12 Available 22. October 2022.:https://www.horizonglobalpartners.com/

13 Halkis, M., Adha, I.R. (2019). C5ISR National Defense Data Link Model in the face of Cyber Threats. in: Proceedings 3rd Indonesia International Defense Science Seminar. 802-812.Jakrata.

14 Michaelis, J.(2020). Explanation Systems for Supporting IoBT-based C5ISR Applications.*Artificial Intelligence and Machine Learning for Multi-Domain Operations Applications* II, *SPIE,* 11413, 114131B-1 - 114131B-7

15 Radovanović, M., Petrovski, A., Žindrašič, V. & Ranđelović, A.(2021). Application of the fuzzy AHP -VIKOR hybrid model in the selection of an unmanned aircraft for the needs of tactical units of the armed forces. *Scientific Technical Review*, 71(2),26-35.

16 Gayatri Mahajan, "Applications of Drone Technology in Construction Industry: A Study 2012-2021", *International Journal of Engineering and Advanced Technology (IJEAT),* Vol. 11, No.1, 2021, pp. 224-239.

17 Mitka, E. &Mouroutsos, G.S.(2017). Classification of Drones.*American Journal of Engineering Research (AJER)*, 6(7),36-41.

18 Choi, S., Huh, S., Lee, S., Kim, H., Woo, S. &Ahn, S.(2021). Drone Wireless Charging Station using Multiple Transmitter Coils of Different Sizes with Degrees of Freedom in the Air gap.In: 24th International Conference on Electrical Machines and Systems (ICEMS). 722-726.Gyeongju, Korea.

19 Gupta, G. S., Ghonge, M.,Jawandhiya, P. (2013). Review of Unmanned Aircraft System (UAS).*International Journal of Advanced Research in Computer Engineering & Technology (IJARCET),* 2(4),1646-1658.

20 Žnidaršič, V., Radovanović, M., Stevanović, D. (2020).Modeling the, Organisational Implementation of a Drone and Counter-Drone Operator into the Serbian Armed Forces Rifle Section.*Vojnodelo*, 72(3),84 -109.

21 Petrovski, A. & Toshevski, M. (2016). GIS in Army: Application of GIS in Geo-Reconnaissance and C4IS in Army Purposes. in: 2nd International Scientific Conference GEOBALCANICA, 153-160. Skopje.

22 Žárský, P., Hlavizna P. & Hnidka, J. (2022). Využitelnost multikoptér v Armádě České republiky. *Vojenské rozhledy.* 2022, 31 (2), 106-120, *DOI: 10.3849/2336-2995.31.2022.02.106-120*

23 Colomina, I. &Molina, P. (2014). Unmanned aerial systems for photogrammetry and remote sensing: A review. *ISPRS Journal of Photogrammetry and Remote Sensing*, 92(June) 79–97.

24 Pytel, M. & Cieśla, M.(2021). Use of Territorial Defense Forces (TDF) in combat operations.*Scientific Journal of the Military University of Land Forces*, 53(1). 61-72.

the use of territorial defense forces in combat operations. Wrzosek[25] analyzes the challenges of modern command and future military operations. Horyń and Tomasik[26] analyze territorial defense forces in hybrid warfare in the light of the experience of the conflict in Ukraine. Selmy[27] analyzes the use of drones in search and rescue operations. Watts et al.[28] analyze drones in remote sensing and science. Nohel et al.[29] select a tactical unmanned aerial vehicle for the Czech Armed Forces. Mitrović and Bojanić[30] analyze the battalion tactical groups of the armed forces of the Russian Federation in the changed physiognomy of modern conflicts. Terzić et al.[31] define the intelligence preparation of the battlefield and the modeling of the use of forces in operations in an urban environment. Ilić et al. analyze force modeling on the example of battalion tactical groups of the Russian Federation in the modern armed conflict on the territory of Ukraine.[32] Radanović et al.[33] analyze the concept of financial security for the operations of the Serbian Army. Hlavizna et al.[34] analyze approaches to conducting electronic warfare to support joint operations.

Slavković et al.[35] describe the maneuver in the attack operation of the ground forces. Marinković and others define aerial fire support for ground forces in an offensive operation.[36] Hlavizna in the article examines the different approaches of the North Atlantic

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25 Wrzosek,M. (2022). Challenges of contemporary command and future military operations. *Scientific Journal of the Military University of Land Forces*,54(1), 35-51.

26 Horyń, W. & Tomasik, R.(2022). Territorial defense forces in hybrid warfare in the light of experience of the conflict in Ukraine.*Scientific Journal of the Military University of Land Forces,* 54(1), 81-95.

27 Selmy, S.(2015). Role of an Unmanned Aircraft System for search and rescue (AUS - SAR) operations. in: The International Maritime Rescue Federation World Maritime Rescue Congress Conference Bremerhaven. 1-19.Germany.

28 Watts, C.A, Ambrosia, G.V & Hinkley, A.E.(2012). Unmanned Aircraft Systems in Remote Sensing and Scientific Research:Classification and Considerations of Use. *Remote Sensing,* 4(6),1671-1692.

29 Nohel, J., Pavlačka, M. &Stodola, P.(2022). Future Tactical Unmanned Aircraft Systems of the Czech Armed Forces.*Vojenské rozhledy, 31(63),51-70, DOI:10.3849/2336-2995.31.2022.01.051-070*

30 Mitrović, M. & Bojanić, D.(2021). Bataljonske taktičke grupe oružanih snaga ruske federacije u izmenjenoj fizionomiji savremenih sukoba.*Vojno delo*, 73(2),44-62.

31 Terzić, M., Dobrić, D., Bulatović, N. (2018). Obaveštajna priprema bojišta i modelovanje upotrebe snaga za operacije u urbanim sredinama.*Vojno delo,* 70(6), 217-236.

32 Ilić, M., Živković, M. & Djurić, Z. (2022). Offensive Operation Force Modeling – Analysis of an Example of Batallion Tactical Group of Russian Federation in Ukraine. In: 8th International Scientific Professional Conference Security and Crisis Management – Theory and Practice (SeCMan) -Safety for the Future. 373-379: Sremska Kamenica: RASEC and EDUCONS.

33 Radanović, T., Slavković, R. &Mačak, Z. (2018). Koncept finansijskog obezbeđenja operacija Vojske Srbije. *Vojno delo,*70(3), 343-360.

34 Hlavizna, P., Vasicek, R. & Oulehlova, A. (2022). Approaches to the Conduct of Electronic Warfare in Support of Joint Operations. In: 3rd INTERNATIONAL CONFERENCE Challenges to National Defence in Contemporary Geopolitical Situation (CNDCGS'2022). 43-45: Vilnius, Lithuania

35 Slavković, R., Šipka, B. & Jukić, J. (2018). Manevar u napadnoj operaciji snaga kopnene vojske.*Vojno delo,*70(2), 277-297.

36 Marinković, Ž., Slavković, R. &Cmiljanović, B. (2017). Vazduhoplovna vatrena podrška snagama kopnene vojske u napadnoj operaciji.*Vojno delo,* 69(6), 262-276.

Treaty Organization and the United States Armed Forces towards Electronic Warfare, the military activity in the Electromagnetic Environment.[37]

2 DEFINITION AND CLASSIFICATION OF UNMANNED AIRCRAFT

Unmanned aerial systems (UAS - Unmanned Aerial Systems) have several different systems such as “unmanned aircraft” (UAV- Unmanned Aerial Vehicles), aerial robot or drone, but unmanned aircraft and drone are the two most common terms. Unmanned aerial system is a term adopted by the US Department of Defense and usually includes three components: an unmanned aircraft, a ground control station, and a communication and data transmission component.

Petrovski and Radovanović[38] defined the term drone and unmanned aerial vehicles and their classification (Figure 2).[39] The term drone has a broad meaning, it represents means with a motor that are remotely controlled by an operator or means that have a certain level of autonomy (control is carried out using communication software, and artificial intelligence and various types of sensors are often used), which can be used once or repeatedly and can carry lethal or non-lethal payloads, transmit data in real time, be used as Wi-Fi stations, etc. It represents a synthesis of means and devices necessary for communication and its management. They differ in their purpose, construction characteristics (shape, dimensions, mass, payload, maximum flight height, maximum range, flight time, speed, etc.), the environment in which they are used, and the source of energy they are powered by. Depending on the purpose, they can be used in different environments such as land, water, air and space, and a wide range of possibilities has created the conditions for application in defense and security (for the needs of the army and the police - the original purpose), and they are also used in agriculture, construction, traffic, trade, communication, science, medicine, research, architecture, video and photography, geology, forestry, mining, oceanography, environmental management, sports, mapping, etc. A drone or unmanned aerial vehicle (UAV) is an aircraft without a pilot. The term drone is more general than the term unmanned aerial vehicle, as all unmanned aerial vehicles can be called drones, while a drone does not necessarily have to be an unmanned aerial vehicle.

Until now, there is no generally accepted definition of unmanned aerial vehicles as well as their classification, so the European Association of Unmanned Vehicles Systems - EUROUVS defined the classification of unmanned aerial vehicles in relation to purpose,

37 Hlavizna, P. (2018). Komparace přístupů k elektronickému boji. *Vojenské rozhledy*, 27 (4), 078-104.

38 Petrovski, A. & Radovanović, M. (2021). Application of detection reconnaissance technologies use by drones in collaboration with C4IRS for military interested.*Contemporary Macedonian Defence*, 21(40),117-126.

39 Petrovski, A., Bogatinov, D., Radovanovic, M. & Ackoska S. (2023). Application of Drones in Crises Management Supported Mobile Applications and C4IRS Systems. In: Dobrinkova, N., Nikolov, O. (eds) Environmental Protection and Disaster Risks. EnviroRISKs 2022. *Lecture Notes in Networks and Systems*, 638, 321-334: Springer: Cham.

flight height, flight duration, speed, maximum take-off weight, dimensions of the aircraft, signal range, etc.[40] When classifying drones and unmanned aircraft, it is necessary to thoroughly review all aspects that can have an impact on different understandings of drones and unmanned aircraft, in order to make their classification as accurate and precise as possible with the application of methods of analysis, synthesis and classification. Today, there are several different divisions of drones depending on the institution that classified them into different categories. According to the control and management model, unmanned aerial vehicles are divided into autonomous systems, self-driving systems, radar or radio beam control systems, remote control systems and combined systems. The US Department of Defense has classified UAVs into five categories as shown in Table 1[41]:

Table 1: Classification of unmanned aerial vehicles according to the US Department of Defense[42]

UAS Groups	Maximum Weight (lbs) (MGTOW)	Normal Operating Altitude (ft)	Speed (kts)	Representative UAS	
Group 1	0 – 20	<1200 AGL	100	Raven (RQ-11), WASP	
Group 2	21 – 55	<3500 AGL	< 250	ScanEagle	
Group 3	< 1320	< FL 180		Shadow (RQ-7B), Tier II / STUAS	
Group 4	>1320		Any Airspeed	Fire Scout (MQ-8B, RQ-8B), Predator (MQ-1A/B), Sky Warrior ERMP (MQ-1C)	
Group 5		> FL 180		Reaper (MQ-9A), Global Hawk (RQ-4), BAMS (RQ-4N)	

40 Arjomandi, M. (2006). Classification of Unmanned Aerial Vehicles.*Mechanical Engineering,* 3016, 1-48.

41 Agbeyangi, A., Odiete, J. &Olorunlomerue, A. (2016). Review on UAVs used for Aerial Surveillance.*Journal of Multidisciplinary Engineering Science and Technology (JMEST),* 3(10),5713-5719.

42 *Unmanned Aircraft System Airspace Integration Plan*. (2011). Department of Defense, Editor.

A detailed classification of drones according to several different parameters was carried out by Hassanalian and Abdekelfi.[43] The NATO classification of unmanned aerial vehicles[44] is shown in Table 2.[45]

Table 2: Classification of unmanned aerial vehicles according to the NATO classification[46]

Class	*Category*	*Normal Employment*	*Normal Operating Altitude*	*Normal Mission Radius*	*Primary Supported Commander*	*Example platform*
Class III (>600kg)	Strike/ combat	Strategic/ Nacional	up to 19812 m	Unlimited (BLOS)	Theatre	Reaper
	High Altitude Long Endurance (HALE)	Strategic/ Nacional	up to 19812 m	Unlimited (BLOS)	Theatre	Global Hawk
	Medium Altitude Long Endurance (MALE)	Operational/ Theatre	up to 13716 m MSL	Unlimited (BLOS)	JTF	Heron
Class II (150– 600 kg)	Tactical	Tactical formation	up to 5486 m AGL	200 km (LOS)	Brigade	Hermes 450
Class I (<150kg)	Small (>15 kg)	Tactical unit	up to 1524 m AGL	50 km (LOS)	Battalion/ regiment	Scan Eagle
	Mini (< 15 kg)	Tactical subunit (manual or hand launch)	up to 914 m AGL	up to 25 km (LOS)	Company/ Platton/ Squad	Skaylark
	Micro (< 6 kg)	Tactical subunit (manual or hand launch	up to 60 m AGL	up to 5 km	Platton/ Squad	Black Widow

Yet another classification system based in Europe appears below in Table 3. This system actually seems to alternate its criteria between size (Nano, Micro, Mini) then range (Close, Short, Medium) and then altitude and endurance. An important distinction in the European system currently occurs at 150kg (approx. 330 lbs.). The European agency responsible for certifying aircraft actually exempts UAS below this weight from their

43 Hassanalian, M. &Abdelkefi, A. (2017). Classifications, applications, and design challenges of drones: A review. *Progress in Aerospace Sciences,* 91(May), 99–131.

44 Castrillo, V., Manco, A., Pascarella, D. &Gigante, G. (2022). A Review of Counter-UAS Technologies for Cooperative Defensive Teams of Drones.*Drones, 6(*65),1 - 36.

45 *Allied Joint Doctrine for Air and Space Operations*. (2016). Nato Standardization Office (NSO). NATO Standard AJP-3.3. Edition B Version 1. April 2016. Available online: https://www.japcc.org/wp-content/uploads/AJP-3.3-EDB-V1-E.pdf (accessed on 20 July 2022).

46 *Guidance for the Training of Unmanned AircraftSystems (UAS) Operators.* (2014).TP–3.3.7 – NATO STANAG 4670 (Edition 3). NATOStandardization Agency.

typical certification standards and allows any airworthiness standards to be handled by the individual nation[47].

UAS Categories	Acronym	Range (km)	Flight Altitude (m)	Endurance (hours)	MTOW (kg)	Currently Flying
Tactical						
Nano	η	< 1	100	< 1	< 0,025	yes
Micro	μ (Micro)	< 10	250	1	< 5	yes
Mini	Mini	< 10	150 b to 300 a	< 2	< 30 (150 b)	yes
Close Range	CR	10 to 30	3.000	2 to 4	150	yes
Short Range	SR	30 to 70	3.000	3 to 6	200	yes
Medium Range	MR	70 to 200	5.000	6 to 10	1.250	yes
Medium Range Endurance	MRE	> 500	8.000	10 to 18	1.250	yes
Low Altitude Deep Penetration	LADP	> 250	50 to 9.000	0,5 to 1	350	yes
Low Altitude Long Endurance	LALE	> 500	3.000	> 24	< 30	yes
Medium Altitude Long Endurance	MALE	> 500	14.000	24 to 48	1.500	yes
Strategic						
High Altitude Long Endurance	HALE	> 2000	20.000	24 to 48	(4.500 c)12.000	yes
Special Purpose						
Unmanned Combat Aerial Vehicle	UCAV	approx. 1500	10.000	approx. 2	10.000	yes
Lethal	LETH	300	4.000	3 to 4	250	yes
Decoy	DEC	0 to 500	5.000	< 4	250	yes
Stratospheric	STRATO	> 2000	>20.000 & <30.000	> 48	TBD	no
Exo-stratospheric	EXO	TBD	> 30.000	TBD	TBD	no
Space	SPACE	TBD	TBD	TBD	TBD	no

TBD = To Be Defined   a = according to national legislation   b = in Japan   c = Predator B

Table 3: European UAS Classification System

Based on the classification of unmanned aerial vehicles, the conclusion is reached that the characteristics of unmanned aerial vehicles mostly depend on their purpose. It is necessary to analyze the tactical and technical characteristics of unmanned aerial vehicles in order to see their possibility of use in modern large-scale combat operations.

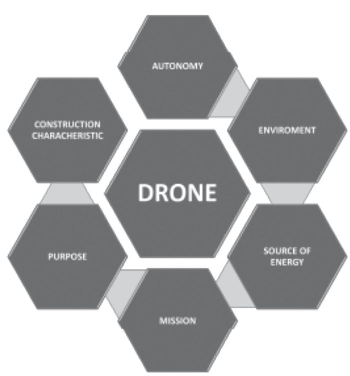

Figure 2: Drones' classification

47 *Regulation No 1592/2002 of the European Parliament and of the Council on Common Rules in the Field of Civil Aviation and Establishing a European Aviation Safety Agency*. 2002.

2 LARGE-SCALE COMBAT OPERATIONS

Planning and organizing any military operation cannot be done well without information about the enemy, which can be gathered by using drones.Military operations are a set of combat and/or non-combat activities, movements and other actions undertaken with a single idea, either independently or in cooperation with other defense forces, to achieve a general goal of varying importance.[48]

Any armed conflict tends to be characterized by major combat operations, often requiring intense combat activity and high logistic consumption. Major combat operations often involve large-scale maneuver by complex joint forces organized and commanded as functional components. Particular emphasis is placed on maintaining freedom of action and denying that freedom to an adversary.[49]Combat operations involve conventional force-on-force combat of varying scale, frequency and intensity between opposing armed forces where the armed forces of a state act principally to implement that state's national policy and dominate the other instruments of power. Combat operations characterized a series of battles and major engagements, and therefore involve intense activity and high logistic consumption. Particular emphasis is placed upon maintaining freedom of action and denying that freedom to an adversary, either directly or indirectly. The tempo of activities is usually high, with a need to prioritize resources and generate additional fighting power. Combat operations often involve large-scale maneuver by complex and multi-faceted Joint Task Forces, organized and commanded as functional components. [50]

Threats are countered by the ability of Armed forces to respond to a wide variety of challenges along a conflict continuum that spans from peace to war as shown in figure 1-1.[51]

48 Milić, A., Ranđelović, A. & Radovanović, M. (2019). Use of drones in operations in the urban environment. in: 5th International Scientific conference Safety and crisis management – Theory and practise Safety for the future – SecMan 2019, 124-130, Belgrade: Regional Association for Security.

49 *NATO Standard AJP-01: ALLIED JOINT DOCTRINE*. 2017. NATO Standardization Office (NSO), point 2.20,2-12

50 *Allied Joint Publication (AJP)-3, Allied Joint Doctrine for the Conduct of Operations*. 2019. NATO Standardization Office (NSO), point 1.65.

51 *Operations, FM 3-0, Change No. 1.* (2017). Headquaters, Department of the US Army, Washington, DC, point 1-1.

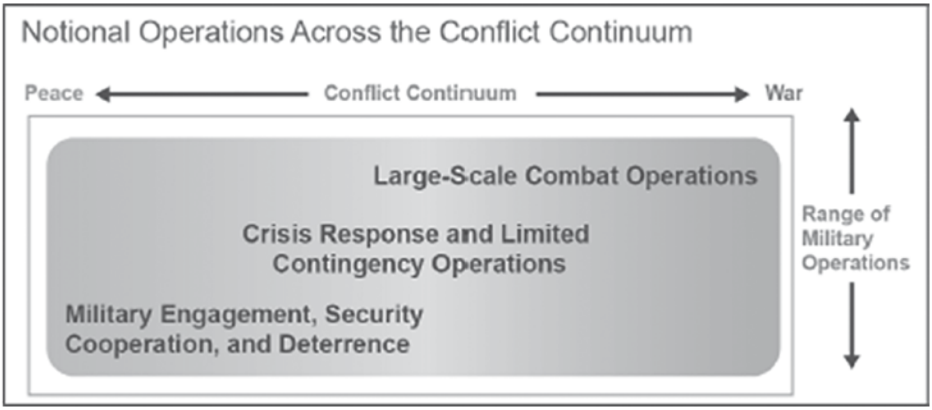

Figure 3: The conflict continuum and the range of military operations. [52]

Military conduct a range of military operations to respond to these challenges. The conflict continuum does not proceed smoothly from stable peace to general war and back.[53]Typically, crisis response and limited contingency operations are focused in scope and scale and conducted to achieve a specific strategic or operational-level objective in an operational area. Large-scale combat operations occur in the form of major operations and campaigns aimed at defeating an enemy's armed forces and military capabilities in support of national objectives.[54]

Large-scale combat operations are at the far right of the conflict continuum and associated with war.[55]Large-scale combat operations are intense, lethal, and brutal. Their conditions include complexity, chaos, fear, violence, fatigue, and uncertainty. Battlefields on the beginning of 21-st century include noncombatants, and they are crowded in and around large cities. Different armed forces employ conventional tactics, terror, criminal activity, and information warfare to complicate operations. To an ever-increasing degree, activities in theinformation environment are inseparable from ground operations. Large-scale combat operations present thegreatest challenge for Armed forces.[56]

In order to successfully analyze the use of unmanned aircraft in modern large-scale combat operations, it is necessary to look at the characteristics and factors of modern combat operations, which directly or indirectly affect the use of unmanned aircraft.

The more significant use of unmanned aircraft in combat operations began at the end of the 20th century, so different types of unmanned aircraft were used in the NATO aggression against the FRY, while their more significant use was in the conflicts in Libya

52 *Ibid.*

53 *Ibid*

54 *Ibid,* point 1-2.

55 *Ibid,* point 1-3.

56 Ibid, point 1-4.

and Syria. The armed conflict in Nagorno-Karabakh in 2020[57] represented one of the turning points regarding the application of this disruptive technology for combat purposes. Like never before, the mass use of combat drones decisively influenced the outcome of an armed conflict.[58] Unmanned aerial vehicles determined the strategy and tactics of the preparation and execution of the military operation. The following UAVs were used in the aforementioned conflict: Krunk-25-1, Aerostar, Hermes, kamikaze-drone Heron, Harop, Orbiter 2M and Bayraktar TB2. Turkey's Bajraktar TB2 combat drone has demonstrated exceptional versatility during the conflict. In addition to identifying, tracking and homing in on targets, TB2s were armed combat systems capable of autonomously destroying targets.[59]

The conflict in Nagorno-Karabakh clearly demonstrated the effectiveness of the use of drones, which once again indicates a change in the tactics of armed conflicts as such. The airspace is completely dominated by drones and we see that they are drawing a "line" up to which armored vehicles can be "safely" used. Armored vehicles are absolutely defenseless in front of them, even with built-in dynamic protection.When armored vehicles are fighting an almost equivalent battle with ATGMs, artillery and other anti-tank weapons, then they become powerless against BPL attacks. First, because BPL hits from above in the most vulnerable places of the tanks - in the thin upper armor of the turret and the engine compartment. Second, an unmanned aircraft, especially if it is controlled remotely, has to a certain extent "artificial intelligence", which enables target identification, the ability to maneuver and a high probability of destroying the target.

The drone itself is quite vulnerable to anti-aircraft defense systems due to its low speed and limited maneuverability. It can easily be taken down by man-portable anti-aircraft missile systems or even a large-caliber tank machine gun. Unmanned aerial vehicles capable of carrying out long-range attacks, such as the Turkish Bajraktar TB2, have a certain degree of protection, but even then there is a possibility of counteraction in the form of electronic warfare systems or other systems against unmanned aerial vehicles (C-UAV).

Russian troops in Syria have thwarted attempts to attack the Khmeimim air base with the effective use of air defense systems and means specialized in combating BPL and electronic warfare systems. Specifically, the "Pantsir S1" and "Tor-M2" systems are mostly used to destroy drones, other tasks are performed with electronic anti-drone guns.

Among the most effective Russian electronic countermeasures against small BPL, the Repellent, Sapsan-Bekas, Kupol, Rubezh-Avtomatika, Luch and Pishchal systems can be mentioned. The anti-drone system Repellent-1 is able to suppress or destroy swarms of reconnaissance, unmanned aerial vehicles, of very small areas and dimensions. The

57 German, T. (2021). The Nagorno-Karabakh Conflict between Azerbaijan and Armenia: Security Issues in the Caucasus.*Journal of Muslim Minority Affairs*,32(2),216–229.

58 Ilić, D. & Toamašević, V. (2021). The impact of the Nagorno-Karabakh conflict in 2020 on the perception of combat drones. *Serbian Journal of Engineering Management,* 6(1),9-21.

59 Shaikh, S. & Rumbaugh, W. (2020). The Air and Missile War in Nagorno-Karabakh: Lessons for the Future of Strike and Defense. *CSIS*. Retrieved on November 30, 2020 from: https://www.csis.org/analysis/air-and-missile-war-nagorno-karabakh-lessons-future-strike-anddefense

system is able to automatically detect and neutralize enemy reconnaissance drones at distances of 30 km, performing powerful electronic jamming of their control sensors or satellite navigation links. The system is able to detect drones through their transmission control signals, in all weather conditions.

The armed conflict on the territory of Ukraine is also characterized by the massive use of drones by both the Russian armed forces and the Ukrainian army. The Ukrainian forces mostly use the "Bajraktar TB2" drone, while the Russian forces most often use the "Forpost", "Orlan-10" "Zala" drones and the "Shahed-136" Iranian kamikaze drone.

Unmanned aerial vehicles can be used to gather information through aerial reconnaissance and imaging and to attack by destroying assigned targets with guided or unguided missiles while integrating with the C5ISR system. The information obtained should be forwarded in a timely manner to the center for commanding forces in the operation. The use of unmanned aerial vehicles in combat operations provides a wide range of capabilities to the units that use them, by adding a wide range of additional equipment. Unmanned aerial vehicles provide an advantage during the execution of combat operations, as they provide support for quick decision-making to the commander on the ground and the possibility of controlling a larger area of combat operations in the operation zone.

The use of unmanned aerial vehicles equipped with modern technical devices (high-resolution cameras, infrared and thermal cameras, microphones, various types of sensors, guided and unguided missiles and other additional equipment) integrated into the C5ISR system significantly increases the efficiency of units engaged in combat operations. By using this sophisticated technology, it is possible to obtain timely and accurate information about the event in real time, as well as to destroy the target without risk to the personnel while transmitting the situation to the battlefield command center. Drones can still be used to deliver medical supplies and other necessary combat and non-combat equipment to units in the area of operation.

The use of unmanned aerial vehicles in large-scale combat operations, regardless of the limitations, increases the efficiency and effectiveness of the units engaged in the operation, and also increases the protection and reduces the risk to the engaged personnel. Based on the tactical and technical characteristics of unmanned aerial vehicles, it is possible to perform various tasks.

3 C5ISR SISTEMS IN LARGE-SCALE COMBAT OPERATIONS

Modern militaries have come to rely increasingly on information technology to support both mission planning and execution. In-line with growing investigation into Multi-Domain Operations (MDO) research[60], conventional mission operations are anticipated to involve numerous interactions between cyber and physical assets. In future battlespaces, these cyber-physical interactions are expected to be introduced both by features of

60 Russell, S., Abdelzaher,T., & Suri, N. (2019). Multi-domain effects and the internet of battlefield things. in 2019 IEEE Military Communications Conference (MILCOM),724-730.

the operating environment as well as the tools and techniques used to accomplish C5ISR (Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance and Reconnaissance) missions.[61]

US Army C5ISR Center Cyber Security Service Provider (CSSP) is a 24/7 Defensive Cyber Operations(DCO) organization that defends US Department of Defense and US Army networks from hostile cyber activity, aswell as develops technologies and capabilities for use by DCO operators within the DoD. In recent years, C5ISR CenterCSSP has been researching various advanced data visualization concepts and strategies to enhance the speed and efficiency of cybersecurity analyst's workflow. To achieve these goals Virtual and Mixed Reality (VR/MR) tools havebeen employed to investigate, whether these mediums would enable useful remote collaboration of DCO operators andwhether stereoscopically perceivable 3D data visualizations would enable DCO operators to gain improved hindsightinto their datasets.[62] Use the Joint Services C5I-ISR and C2 (Command & Control) integration enabling the new JointWarfighting Concept for All-Domain Operations.

An understanding of the information environment, which includes the spectrum, space, cyber domain, and the data that flows between them, is necessary to achieve success in the traditional domains of warfare. Warfare in the information age is defined by making decisions based on precise data that results in success. The ability to quickly analyze the environment and opponents in order to make faster decisions is key to success. The ability to communicate effectively is critical to the success of any modern military operation.

This applies to every branch, mission and training program. Combat power is now used in tandem with effective intelligence collection and dissemination across the defense spectrum to determine the outcome of any conflict. C5ISR technologies help identify and respond to events. Modern C5ISR systems, powered by AI and Cloud technologies, help provide critical data to frontline personnel.

Armed Forces want decision-making superiority over adversaries in complex, contested and dense urban environments as well as in conflicts in open environments without built-in civilian populations and infrastructure. Consequently, C5ISR systems have the tools to provide the necessary information to enable command and control operations in complex operational scenarios, both in the air, on land, at sea and in cyberspace.

61 Michaelis, J. (2020). Explanation systems for supporting IoBT-based C5ISR applications, in: *Proc. SPIE 11413, Artificial Intelligence and Machine Learning for Multi-Domain Operations Applications II*, 114131B https://doi.org/10.1117/12.2557549

62 Kullman, K. Ryan, M. &Trossbach, L. (2019). VR/MR Supporting the Future of Defensive Cyber Operations, *IFAC (International Federation of Automatic Control) by Elsevir*,52(19),181-186, https://doi.org/10.1016/j.ifacol.2019.12.093

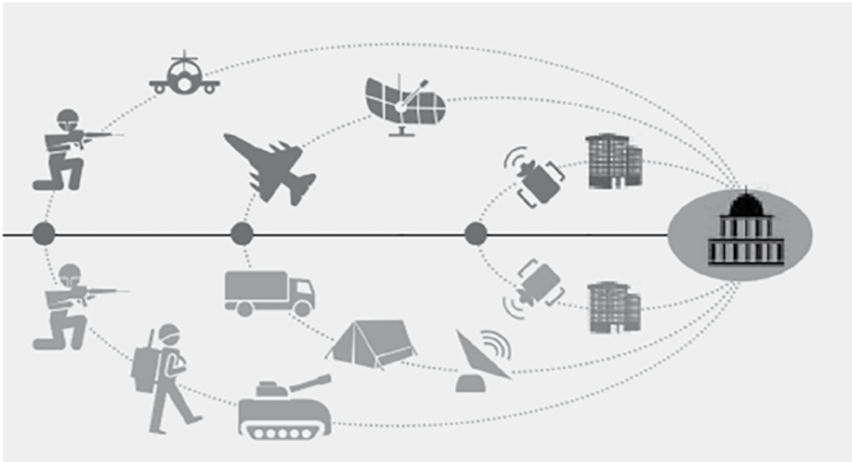

Figure 4: C5ISR in different environments including SEA, AIR, LAND, CYBER

The C5ISR system integrates information received at the operational level and generates the operational situation, manages plans, orders, reports and disseminates information among various levels of command. Combat situational awareness is the cornerstone of all modern large-scale combat operations. C5ISR systems seamlessly integrate large amounts of information from multiple sources and sensors and based on them generate a general overview of the situation on the battlefield, which enables timely and correct decision-making.[63]

Figure 5: Example of C5ISR Interface in various combat scenarios

63 indracompany.com–C5ISR Defense & SecurityAvailable 22. October 2022.: https://www.indracompany.com/sites/default/files/c5isr_v0916_en_baja.pdf

C5ISR provides various capabilities on the battlefield that can positively affect the very outcome of ongoing operations.

Table 4: Capabilities of C5ISR systems in support of combat operations

PERSONNEL	STAFF ORGANIZATION PERSONNEL MANAGEMENT STAFF TRAINING
INTELLIGENCE DATA	ANALYSIS OF THE ENEMY TERRAIN ANALYSIS
OPERATION	PLANNING OF OPERATIONS MONITORING THE OUTCOME OF OPERATIONS
LOGISTIC	SUPPLY PLANNING MOVEMENT PLANNING
CONNECTION	NETWORK ADMINISTRATION MANAGEMENT AND MONITORING OF COMMUNICATIONS DATA DISTRIBUTION
CYBER	INFORMATION SECURITY

C5ISR systems, in addition to their various capabilities, also have a number of functions that are useful on the battlefield. Through its tools, C5ISR constantly collects and classifies data for decision-making during the entire operation. It also contains tools for the process of strategic decision-making, in such a way that it generates "Order of Battle" (order of battle/operation) and generates orders that define the actions to be taken, the time for all taking them and the geographical area of the activities in which they are taken. In addition to these functions, it also has the functions of simulating and predicting the possible responses of enemy forces and providing tips on how to react to them.[64]

4 INTEGRATION OF C5ISR SYSTEM ON UNMANNED AIRCRAFT

Svendsen shows in his chapterincludes the referencing of further-ranging target acquisition and command, control, communications and computers, as well as cyber, considerations – extending its evaluation of ISR into ISTAR and C4ISR enterprises.[65] The domain of ISR is constantly expanding and being extended, particularly as there are greater innovative movements manifested both structurally and culturally away from merely TPED (tasking, processing, exploitation and dissemination) activities to more of 'a high-tech intelligence enterprise' enacted at computer speeds in real time.

64 Indracompany.com – C5ISR ProductsAvailable 22. October 2022: https://www.indracompany.com/sites/default/files/indra_c5isr_en_2020.pdf

65 Galbreath, D.J., & Deni, J.R. (Eds.). (2018). *Routledge Handbook of Defence Studies (1st ed.). Chapter Intelligence, Surveillance and Reconnaissance.by Svendsen, A.,*Routledge. https://doi.org/10.4324/9781315650463

As technological leaps are now increasingly based on the needs of the commercial market, military systems find themselves at two very different speeds of technology adaptation. However, military technologies require high-performance systems, therefore the latest high-end technology must be integrated into such technologies and systems used for military purposes. However, the costs of developing, implementing and maintaining such systems are high, but military operations in the modern world have become more and more widespread. This requires a more modern communication system with improved defensive capabilities, which the ISR system easily provides. In view of this, the high initial costs of designing, developing and implementing ISR systems are likely to affect the progress and development of these technologies. Therefore, the new generation of C5ISR systems that meet the above conditions are being developed exclusively, thanks to the most modern artificial intelligence (AI) and Cloud technologies. Advanced AI can endlessly filter through vast amounts of data and spot trendsthat human operators would miss.

C5ISR technology is undergoing a major overhaul that promises to improve detection rates and reduce response times. Command centers will be able to process much more information than ever before thanks to the power of AI. Accordingly, machine learning capabilities have also been developed that find patterns in large heterogeneous data sets and improve the speed and accuracy of data-driven decision-making tools used by commanders in operational environments. Additionally, operators will be able to focus on directing effective incident responses instead of identifying different trends, and field teams will be able to respond to incidents more easily and safely thanks to improved domain.[66]

Based on the above, data related to the physical world (eg terrain, weather, ammunition, strength of enemy forces, network availability, etc.) and which are necessary for the proper functioning of the C5ISR system can be obtained in the easiest way by using unmanned aerial vehicles. Also, the key elements of the C5ISR system related to the actual execution of combat operations are also carried out with the help of their integration with unmanned aerial vehicles, and in addition to the above-mentioned reconnaissance of the battlefield, it also includes the integration of firing and missile systems on unmanned aerial vehicles, communications and other sensors necessary for proper functioning C5ISR system.[67]

66 CSMI Technology Services – About C5ISR, Available 24. October 2022: https://csmi.com/what-is-c5isr/

67 SIGMA Defense C5ISR solutions, Available 22. October 2022: https://sigmadefense.com/solutions/c5isr/

Figure 6: C5ISR drones providing real-time feedback to on ground units

C5ISR systems integrate numerous unmanned aerial vehicles, ranging from small tactical unmanned aerial vehicles from Group I, to the largest unmanned aerial vehicles from Group V, depending on the system itself, the purpose, and the type of combat task being performed. However, most drones fly at relatively low speeds, but C5ISR systems require the long-term operation of drones, which enables greater efficiency and control over the battlefield and provides the system with the ability to fulfill all its tasks at the highest possible level. Therefore, the technical and tactical characteristics of unmanned aerial vehicles must be carefully selected depending on the system and the mission being performed.

Unmanned aerial vehicles integrated with the C5ISR system use pusher propellers and have various configuration options including the integration of weapons and air-to-ground missiles intended for fire support or destruction of key communications. Also, they must support EO/IR cameras, SAR equipment and the like for successful reconnaissance and monitoring of the course of combat operations and the collection of necessary information for the possibility of the most efficient functioning of the C5ISR system. Although C5ISR systems rely on SATCOM and satellite support and communications support, most unmanned aerial vehicles integrated into C5ISR systems come with a communications relay package that facilitates control and communication over the field where combat operations are conducted in support of C5ISR systems.[68]

CONCLUSION

In modern combat operations, it is unthinkable to carry out combat operations without the use of drones, i.e. unmanned aerial vehicles. Their versatile use and wide range of capabilities provide a significant advantage and increase the combat capabilities of

[68] VICORPOWER C5ISR capabilites – tethered drone, Available 22. October 2022: https://www.vicorpower.com/industries-and-innovations/aerospace-and-defense-solutions/aerospace-defense-c5isr

the units that use them. With the use of unmanned aerial vehicles integrated into the C5ISR system, it is possible to have a picture of the battlefield in real time with cyber protection, which provides the decision maker with the possibility of timely and effective command of forces in modern large-scale combat operations. C5ISR technologies help identify and respond to events. Modern C5ISR systems, powered by AI and Cloud technologies, help provide critical data to frontline personnel. Through its tools, C5ISR constantly collects and classifies data that is meaningful to the decision maker throughout the entire combat operation.

It also contains tools for the process of strategic decision-making, in such a way that it generates "Order of Battle" (order of battle/operation) and generates orders that define the actions to be taken, the time for all taking them and the geographical area of the activities in which they are taken. The mentioned system has the ability to simulate and predict the possible responses of enemy units and has the ability to propose certain actions as a result of the response. The development of a new generation of C5ISR systems that meet the requirements imposed by modern large-scale combat operations using state-of-the-art artificial intelligence (AI) and Cloud technology is underway. By implementing modern C5ISR systems, command centers will be able to process much more information than before thanks to the power of AI.Based on the above, data related to the physical world (eg terrain, weather, ammunition, strength of enemy forces, network availability, etc.) and which are necessary for the proper functioning of the C5ISR system can be obtained in the easiest way by using unmanned aerial vehicles. Also, the key elements of the C5ISR system related to the actual execution of combat operations are also carried out with the help of their integration with unmanned aerial vehicles, and in addition to the above-mentioned reconnaissance of the battlefield, it also includes the integration of firing and missile systems on unmanned aerial vehicles, communications and other sensors necessary for proper functioning C5ISR system

Although C5ISR systems rely on SATCOM and satellite support and communications support, most unmanned aerial vehicles integrated into C5ISR systems come with a communications relay package that facilitates control and communication over the field where combat operations are conducted in support of C5ISR systems.

Further research should be focused on the selection of the most efficient unmanned aircraft for integration into the C5ISR system, as well as the development of the existing C5ISR system, which would significantly increase the combat capabilities of maneuver units on the ground.

UAVs becam not only efective sensors in reconnaissance but also and weapons to stike the enemy. In contemporary large scale combat operations C5ISR systems are alredy integrated with Unmanned Aircrafts and effectivenes of those integration means less waste of material and human resources. C5ISR systems integrated with UAVs change so many things. To be able to provide equipment for C5ISR systems in large-scale combat operations advanced tehnology is needed for production and for maitanance. It also requaire trained personell with adequate skills to work with sophisticated equipment. Artificial intelligence is excelnt resolution for decrease in trained officers but it is not jet complete supstitute for them. Because of that, C5ISR systems integrated with UAVs are not quick solutions, they need time to raise capabilities but they are ecelent solution for present situation on the Battlefield on the beginning of 21st century and they sertenly evolve.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
AI	Artificial Intelligence
ATGM	Anti-Tank Guided Missile
C2	Command & Control
C4IRS	Command, Control, Computers, Communications, Intelligence, Surveillance and Reconnaissance
C5ISR	Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance and Reconnaissance
CSSP	Cyber Security Service Provider
DCO	Defensive Cyber Operations
EUROUVS	European Association of Unmanned Vehicles Systems
GIS	Geographic Information System
IoT	Internet of Things
ISTAR	Intelligence, Surveillance, Target Acquisition, and Reconnaissance
LSCO	Large-Scale Combat Operations
MDO	Multi-Domain Operations
NATO	North Atlantic Treaty Organization
SATCOM	Satellite Communications
TPED	Tasking, Processing, Exploitation and Dissemination
UAS	Unmanned Aerial Systems
UAV	Unmanned Aerial Vehicles
UCAV	Unmanned Combat Aerial Vehicle
VIKOR	Viekriterijumsko KOmpromisno Rangiranje (eng. Multi-Criteria Optimization and Compromise Solution)
VR/MR	Virtual and Mixed Reality

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