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Conclusions from the use of aviation in the first half of the first year of the Ukrainian-Russian war

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Abstract

The aim of the article is to suggest a desirable direction in which the Polish air force, and indeed the air forces of other NATO countries, should develop so that they are better prepared for the challenges identified in the conflict in Ukraine so far. In order to achieve the aim of the research and answer the formulated research question, the collection and qualitative analysis of texts and documents, observation and interviewing took place. In order to have the ability to deter and gain air superiority during a defensive operation, the Polish air force, and air forces of other NATO countries, should have a large resource of fighter, multi-role, and fighter-bomber aircraft. An object-oriented multi-layer air defence of every military airfield needs to be organised and certain roads reconstructed as runways in the event of war. In turn, helicopter aviation units should be able to organise forward arming and refuelling points for helicopters to effectively support land forces. Attack helicopters should also have integrated fire systems that allow them to attack from a distance beyond the range of man-portable air-defence systems. All warplanes should be equipped with proven and modern systems of active and passive self-defence to make them less susceptible to enemy influence. To sum up, in light of the war in Ukraine, the article explains what aviation equipment is necessary and what actions should be taken to increase both Polish air force's ability and other NATO air forces' ability to perform tasks during wartime.

Keywords:

aviation, air operations, war in Ukraine, air force, defence operation

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Introduction

Since the first decade of the 21st century, the countries on NATO's eastern flank have perceived Russia's unpredictable policy as the greatest threat to Eastern Europe (Zieliński, 2020, pp. 33–45). Only few specialists in the field of international security predicted that a full-scale war, in other words a high-intensity conflict, was likely to occur in Europe. Bartosiak (2017, pp. 7–9) pointed out that "the Polish armed forces must prepare, during 2020–2050, for a symmetrical, modern, intensive war, which cannot be—contrary to the hopes of the last 25 years—excluded, especially in Eastern Europe." The first clear symptoms in the political dimension (Bielicki, 2021; Roth, 2021)[1] and military dimension (Harris and Sonne, 2021) were Russia's preparations for the invasion of Ukraine that were evident at the end of 2021. Russia continued to escalate its rhetoric towards Ukraine, mobilising troops and carrying out exercises and moving large armoured and mechanised forces, artillery, and aviation along its border with Ukraine. The nightmare scenario of a military confrontation became reality on 24 February 2022 (Adler, 2022, pp. 68–78). During that Wednesday night, Russian forces attacked Ukrainian territory from both air and land. The aggressor also launched offensive actions in cyberspace, the electromagnetic spectrum, and in the marine and information environment. Russia failed to achieve its strategic goals and end the war quickly. As a consequence of fighting that lasted more than 6 months, Russia and Ukraine "revealed more cards," showing how they carry out their combat operations.

According to military theoreticians and practitioners, contemporary warfare ought to be dynamic, network-centric in nature—based on the extensive use of IT networks, the speed of troops, and the widespread use of precision-guided weapons (Polcikiewicz, 2012, pp. 94–111). The troops should fight to maintain freedom of manoeuvre and superiority across the air, cyberspace, land, maritime, and space domains and the electromagnetic spectrum (Perkins, 2017, pp. 7–12). According to Mets (1999, pp. 11–50), Douhet (pp. 11–18), Trenchard (pp. 21–29), and Mitchell (pp. 31–50) appeared to assume that the future war would be total and air power (aviation) would play a major role in achieving goals, such as gaining and maintaining air superiority. Theorists found that air superiority would significantly improve a country's probability of winning the decisive battle as well as the overall war (McKenzie, 2012, p. 70; Radomyski, 2018, p. 114; Saunders and Souva, 2020, pp. 1–8). Saunders and Souva (2020, pp. 1–8) also found that air superiority would be a better predictor of winning a war than other well-known factors, such as adoption of a modern system, regime type, civil–military relations, and a general measure of military power. Control of the sky over the battlefield will allow air and ground forces to act "without prohibitive interference" from the other side's aircraft or air defences. However, it was pointed out that winning air superiority might not be an easy and short process when both sides of the conflict have numerous means of Anti-Access Area-Denial (Smura, 2016). According to John Warden (Mets, 1999, pp. 55–69), once air superiority is achieved, aviation can and should occupy a supporting role amongst the remaining components.

The aim of the article is to show the desired directions for the development of the Polish air force, and even the air forces of other NATO countries, so that they are better prepared for the challenges identified in the conflict under study. An important factor determining the choice of research is the high probability that Russia's strategic aims are beyond the borders of Ukraine, as Moscow seeks to reestablish the greatness of the former Soviet Union. These are not only the presumptions of the author of the article, but above all the opinion of Admiral Rob Bauer, chairman of the NATO military committee, who emphasised that NATO must be more prepared to confront Russia and there is not much time

in this regard (Nexta, 2023). Among the eastern flank countries closest to Russia, Poland has the greatest potential to defend its own skies against air threats. According to the Global Firepower (GFP, 2023) ranking, Romania and Bulgaria have much lower capabilities in this area, and Lithuania, Latvia, and Estonia are practically defenceless. Moreover, Hungary and Slovakia, which border Ukraine, also have little ability to defend their airspace (GFP, 2023). The vulnerability of small states results from the lack of long-term integration and a clearly defined defence policy as well as limited opportunities to raise funds for the purchase of equipment (Česnakas, 2019, pp. 273–293). For this reason, the current capabilities of the Polish air force were used when formulating conclusions. It was assumed that achieving such a formulated aim would require an answer being found to the following research questions: What are the implications of the empirical results of the first 6 months of the Ukrainian-Russian war on the future of air war in general and how should the Polish air force, and perhaps even the air forces of other NATO countries, respond? This made it possible to formulate conclusions useful for improving the ability of the Polish air force and the air forces of other NATO states to perform tasks on the modern and prospective battlefield.

In order to achieve the aim of the research and obtain answers to the formulated research question, qualitative research included the collection and qualitative analysis of texts and documents, observation, and interviewing (Bryman, 2012, p. 383). The author analysed every publicly announced shooting down of a plane and a helicopter, and additionally analysed available materials, data from the public domain on the Internet using his own aviation experience,[2] and then discussed conclusions with experts during interviews. Due to the impossibility of observing the conflict from the inside, that is being a participant who co-creates it, the empirical research method of indirect observation (Sztumski, 1999, p. 126), consisting in observing the activities of aviation during war in video recordings, photos made by civilians and the military, was considered important. In the research process, efforts were made to ensure that the observation was carried out in an objective manner not contaminated by the observer's attitudes, and was faithful—as free from distortions as possible; therefore, the information was verified on the basis of data from various independent sources. Determining the method and type of the downed plane and helicopter was very approximate in many cases. It happened that the aircraft specified in the report turned out to be of a different type after the wreckage was found. Some of these reports were corroborated by published photos of machine wreckage, aircraft shot down on film, and by captured flight crews. The comparative literature and document analysis methods were used to formulate scientific opinions in the field of tactics and procedures for the use of aviation in combat operations. Structured interviews were conducted with participants of combat operations in Ukraine. The author's interview with Ukrainian army officers during a meeting at the War Studies University on 04 October 2022 was of key importance for the research process. To conduct the interview, a research tool was used in the interview questionnaire form. The questions concerned how Russian and Ukrainian planes and helicopters perform tasks on the battlefield; how Russia's means of electronic warfare (EW) affect the operations of Ukrainian troops; how Ukrainian and Russian anti-aircraft systems work on the battlefield and what losses they suffered; what actions the Ukrainian air force has taken to increase the survivability of its assets; and how both Ukrainians and Russians coordinate close air support (do they have forward air controllers)? Most of the obtained information confirmed the image of the battlefield situation

[2] *The author graduated from an air forces school in Dęblin. For the last 18 years, he has performed flights in combat helicopters, holding various positions at the air base, where he planned, organised, and performed combat tasks during military exercises and a 15-month stay in Afghanistan. He graduated after various studies and courses in aviation management profile at the National Defence University in Warsaw and the Deployable Air Command and Control Centre based in Poggio Renatico in Italy.*

presented in open sources and allowed for the formulation of further conclusions in the field of air operations in Ukraine. Structured interviews were conducted in a classic (oral) way, that is, through a conversation between the interviewer and Ukrainian army officers. The author also conducted unstructured oral and written interviews with officers of the Polish armed forces during numerous official meetings and during university classes. An officer of the Polish air component command was asked how Russian aviation, visible using radar, conducts air missions in operations. While two experts of ground-based air defence (GBAD) were asked what the capabilities and limitations of the anti-aircraft and anti-missile systems of the Polish air force are and what the technical modernisation plan (TMP) in this area is. An officer of armed forces general command was asked about the condition of the road runways, whereas the students of the battalion commanders' course and the course of postgraduate operational and tactical studies at the War Studies University were asked about the technical condition of air-raid shelters. Two officers of army aviation were asked about the imperfections in the aviation training programme on helicopters in the context of preparation for the execution of combat tasks. It should also be added that two of the interviews—one with an instructor pilot of a Mi-8 (pseudonym Yevgeny), and the second with two Mi-8 pilots about flights to Mariupol in support of the defenders of Azovstal—have been accessible on the Internet.

This article has been divided into three parts. The first part focuses on the strategy and tactics of the use of combat aircraft during the operation in Ukraine, with certain irregularities pointed out, which resulted in a failure to achieve the objectives of the operation and losses. The second part specifies the tactics and procedures of helicopter operation in the theatre of military operations in Ukraine, with some irregularities pointed out, which resulted in losses and a failure to perform tasks. The third part is a broad overview of the capabilities and limitations of the Polish air force in light of the war in Ukraine and guidelines for the development of the Polish air force, and even the air forces of other NATO states.

The inspiration for the research was the ongoing conflict in Ukraine, the feeling that changes in the Polish air force are imminent, and the desire to develop guidelines whose assumptions will ensure that the Polish air force has the ability to counter the future threats on the battlefield. These premises and a small body of literature on the topic in question combined to bring about the considerations of the article.

Combat aircraft in operations over Ukraine

According to a report by the US Department of Defense, from the very first day of the operation, Russian forces launched missile attacks on critical military and defence infrastructure in the interior of Ukraine using missiles and artillery from land, sea, and air platforms (Johnson, 2022). Civil and military airports, airstrips, fuel and weapons depots, and railway junctions along which civilian and military transports travelled, all came under attack. In addition, command posts, communication nodes, and radar posts of the integrated air defence system of Ukraine[3] were hit (Bakuła, 2022a; Gurgurewicz, 2022). The initial Russian missile strikes, cyber attacks, electromagnetic spectrum offensive actions, and psychological operations were of a much smaller scale and effectiveness than expected (Dalsjö *et al.*, 2022, p. 7). It is estimated that at least eleven airfields[4] were attacked on the

[3] *For example, on the first day of the operation, the 232nd radio engineering battalion in the Mariupol suburbs and the 14th Independent Radar Company from Podilsk were attacked.*

[4] *Airfields were attacked in: Łuck, Wasylków, Ozerny, Mirgorod, Ivano-Frankivsk, Starokonstantynów, Kulbakin near Mikołajów, Nowy Kalinów, Czuhujewo near Kharkiv, Borispol near Kiev, Melitpol, Krematorsk, Czarnobajewka*

first night (Gurgurewicz, 2022) and fifty other military installations, including eighteen early detection radars (Arkin, 2022). On the first day of the war, seventy-five Russian heavy and medium bombers struck ten airfields, air defence systems, weapons depots, and military unit barracks (Horton *et al.*, 2022; Live Universal Awareness Map [Liveuamap], 2022a). The objects of impact indicate that the strike assets carried out air raids as offensive *counter-air* (OCA) operations aimed at destroying Ukrainian aircraft on aprons and in shelters before they could engage in air combat or be moved to safe places, and to destroy airfield infrastructure and air defence reconnaissance systems.

During the initial phase of the conflict, Russian aviation was not engaged intensively to gain and maintain air superiority. It is estimated that during the first 24 days of the conflict, Russian aviation executed 1,400 sorties, dropping about 1,000 missiles mostly (about 80%) on ground targets as part of close air support land forces and the remaining 20% on airfields, barracks, and logistic warehouses (Arkin, 2022). For comparison, the American fighter and strike aviation made up of 706 aircraft executed 18,695 sorties during the 30-day operation "Iraqi Freedom" from 19 March 2003 to 18 April 2003, which means 623 sorties per day on average (Moseley, 2022, pp. 1–16). Taking into account the Russian involvement in Ukraine, during the first phase of the conflict, the fighter and strike aviation statistically executed only about sixty sorties per day, with the proviso that in the first few days of the war, multi-role fighter aircraft flew around 140 sorties per day, conducting fighter sweeps and strike sorties, after which the number gradually decreased (Bronk *et al.*, 2022, p. 7). So, we cannot speak of a massive air force strike. Moreover, the Russians spent less than 20% of this apportionment on OCA. It should be emphasised that OCA does not include attacks on targets and logistic devices from outside the air force component, which should be perceived in terms of air interdiction carried out with the support of land component. Therefore, it should be considered that aviation performed tasks with an apportionment of less than 20% per OCA (DD–3.3.2(A), 2022, p. 13). Hence, taking into account the great potential of the combat air assets of the Russian Federation,[5] its headquarters of the armed forces has apportioned a surprisingly low number of aviation sorties to achieve superiority, especially air supremacy. This appears incomprehensible, as the Russians deployed an impressive air force in the region prior to the invasion, including hundreds of advanced fighters, bombers and attack aircraft, and special-purpose aircraft designed to provide command and control (C2) and intelligence, surveillance, and reconnaissance (ISR) (Wetzel, 2022). Gathering overwhelming forces and means to fight the Ukrainians should enable them to focus their potential on a priority area of action, ignoring auxiliary areas and secondary tasks. Therefore, Russia broke the principles of the operational art—unity of effort and concentration of force at a time and place designed to generate air superiority (NATO Standards, 2019; Szpyra *et. al.*, 2007; Warden, 2014). It was only in mid-March, when the forward line of their own troops (FLOT) was relatively stabilised, and the attackers significantly increased the use of aviation to about 200 sorties per day (Wilk, 2022). Also, in the opinion of experts in the Ukrainian army, the effort of the Russian air force warplanes at that time amounted to 100–200 sorties per day.[6]

The Russians failed to incapacitate, reduce the effectiveness, or fully disrupt the operations of Ukraine's aircraft, missile, and radar systems. During the first days of the conflict, Russian Su-35S and Su-30SM fighters flew numerous high-altitude CAPs at around 30,000 ft in support of the medium-altitude Russian strike aircraft carrying out tasks deep in the territory of Ukraine (Bronk *et al.*, 2022, p. 8). As a result, they managed

near Kherson, and Kornicz near Kołobrzeg.
[5]In 2020, the Russian Federation had 1,616 combat aircraft (1,183 fighters and strike aircraft) (Kulik, 2020, p. 137).
[6]The conclusion was drawn after an interview with Ukrainian army officers on 04 October 2022 at the War Studies University.

to shoot down several Ukrainian MiG-29 fighters in the air (Table 1). Ukrainian pilots confirm that Russia's Su-30SM and Su-35S completely outclass Ukrainian fighter aircraft on a technical level, especially as they have much longer reach and the R-77-1 air-to-air missile has an active-radar guidance capability compared with the semi-active R-27R/ER available to Ukrainian fighters (Bronk *et al.*, 2022, pp. 8–10). However, a few days after the start of the war due to the numerous losses in equipment caused by the active multi-layer anti-aircraft defence of Ukraine created with the use of medium-range S-300PT/PS systems, short-range 9K37M Buk, 9K330 Tor, and Igła-, Stinger-, and Piorun-manned anti-aircraft missile systems, many of these combat missions were operated from outside Ukrainian airspace, while the Ukrainian air force, with only about fifty-six combat aircraft, executed five to ten combat flights a day (Atlantic Council, 2022). As for the Ukrainian radar systems, it should be noted that in the first 2 days of the war, they were heavily jammed by Russian use of electronic warfare, and some of them were destroyed by missile strikes.[7] Those that survived were quickly moved to other positions, and some of the damaged ones were gradually repaired, which consequently allowed continued support for Ukrainian aviation.[8] The evidence from this study suggests that a fighter aircraft's long-range reconnaissance and engagement capabilities, as well as its self-protection systems, are critical for ensuring success in dogfights. Radar systems should also be highly mobile on the modern battlefield, so that they can quickly change positions to avoid an attack, and moreover, and they should have radar decoys that are able to mislead the enemy about the location of the essential elements of the radar system. Taken together, the above solutions should increase the life of air force assets on the battlefield.

Changes in the tactics of performing strikes against Ukrainian positions over Russian and Belarusian troops significantly increased the safety of the crews and drastically reduced the losses of tactical aviation in the following months of combat (Table 1). It should be emphasised that the Russian strategic bombers Tu-95MS and Tu-160 fired missiles while manoeuvring repeatedly from the Caspian Sea over 800 km from the front line (Hmelnicka, 2022; Ukrainian MOD, 2022b). The attack on the facilities of the International Centre for Peacekeeping and Security Operations at the Jaworów training ground was also carried out using rockets launched from bombers in the Black Sea and Azov Sea (Gurgurewicz, 2022; Regan *et al.*, 2022). On the other hand, Russian fighter-bombers and attack planes performed their tasks in small formations of either one or two aircraft and none was observed that involved more than six aircraft in a strike package that attacked the first echelons of ground units of the Ukrainian forces (Bronk *et al.*, 2022, p. 8). A different opinion is held by the EW/reconnaissance officer of of the Polish air component command, who claims that organised activities of larger formations, up to twelve/fourteen aircraft, were detected several times.[9] For example, on 9 March 2022, six Su-34 flew from the Lida airport towards the holding area in front of the Ukrainian border, joined by six Su-35S/Su-30SM from the Baranavichy airfield.[10] The formation of twelve aircraft flying deep into the territory of Ukraine was supported by A-50 and Il-22M aircraft operating in their zones over the territory of Belarus.[11] Taking into account various sources of information, it should be assumed that during the initial phase of the

[7] *The conclusion was drawn after an interview with Ukrainian army officers on 4 October 2022 at the War Studies University.*

[8] *The conclusion was drawn after an interview with Ukrainian army officers on 4 October 2022 at the War Studies University.*

[9] *The conclusion was drawn after an interview with electronic warfare/reconnaissance officer on 27 January 2023 at the Air Component Command.*

[10] *The conclusion was drawn after an interview with electronic warfare/reconnaissance officer on 27 January 2023 at the Air Component Command.*

[11] *The conclusion was drawn after an interview with electronic warfare/reconnaissance officer on 27 January 2023 at the Air Component Command.*

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Table 1. Scope of Russian and Ukrainian aviation losses in specific periods during the first 6 months of the conflict.
TBM: tactical balistic missile; SAM: surface-to-air missile; AAA: anti-aircraft artillery; MANPADS: man-portable air-defence systems. The author's work is based on the following: Fandom (2022); Live Universal Awareness Map (Liveuamap) (2022g); Wikipedia (2022); and other websites (e.g. Twitter) presenting information confirmed by photos and films from the Russian-Ukrainian conflict.

War day	Aircraft losses									
	Armed forces of Russia					Armed forces of Ukraine				
	Cause of losses					Cause of losses				
	TBM/ artillery	SAM/AAA	A/A	MANPADS	Cause unknown	TBM/ artillery	SAM/AAA	A/A	MANPADS	Cause unknown
The first 10 days of the conflict										
Feb 24	-	-	-	Mi-24, 2 x Ka-52	Su-25, An-26	Su-27 An-225	-	L-39 Albatros 4 x Mig-29	-	An-26 Su-24
Feb 25	Su-30SM	Mi-35	-	-	-	-	Su-27	-	-	-
Feb 26	-	2 x Ił-76	-	-	-	-	-	-	-	3 x Su-25
Feb 27	-	-	-	-	2x aircraft	6x Mi-29	Su-25	-	-	3 x Su-24
Feb 28	-	Su-34	-	-	Mi-35	-	-	-	Su-27	Mi-8
Mar 1	-	Samolot bombowy	-	Mi-35	-	-	-	-	-	-
Mar 2	-	Su-25	-	-	Ka-52	-	-	Mig-29	-	Su-25 Su-24
Mar 3	-	Su-30 Su-34		-	-	-	-	-	-	Su-25
Mar 4	-	-	-	-	2 x Su-25 2 x Mi-8	-	-	-	-	-
Mar 5	-	Su-30 SM 2 x Su-34 UAV	-	Mi-24 Mi-35	-	-	-	-	-	-
After 1 month from start of the conflict (10 days of the conflict)										
Mar 24	-	Su-35	-	-	-	-	-	-	-	-
Mar 26	-	UAV	-	-	-	-	Su-24	-	-	-

(*continues*)

Table 1. Continued

Mar 28	-	UAV	-	-	-	-	Mi-8	-	-	-
Mar 29	-	-	-	-	-	-	2 x UAV	-	-	-
Mar 30	Mi-8	-	-	-	-	-	UAV	-	-	Su-24
Mar 31	-	-	-	-	-	-	Mi-8	-	-	-
Apr 1	-	Ka-52	-	Mi-28	-	-	-	-	-	-
Apr 2	-	UAV	-	-	-	-	-	-	-	UAV
After 3 months from start of the conflict (10 days of the conflict)										
May 24	-	-	-	-	-	-	-	-	-	-
May 27	-	-	-	Ka-52	-	-	-	-	-	-
May 30							UAV			
Jun 2	-	-	-	-	UAV	-	-	-	-	Su-25
Jun 4	-	-	-	Ka-52	-	-	UAV	-	-	-
After 6 months from start of the conflict (10 days of the conflict)										
Aug 24	-	-	-	-	3 x UAV	-	-	-	-	-
Aug 25	-	-	-	-	2 x UAV	-	-	-	-	-
Aug 30							UAV			
Sep 2.	-	UAV	-	-	-	-	-	-	-	-
Beginning of the Ukrainian offensive (10 days of the conflict)										
Sep 6	-	Ka-52, UAV	-	-	-	-	-	-	-	-
Sep 7	-	Su-25, 5 x UAV	-	Su-25 Mi-24	-	-	-	-	-	Su-25
Sep 8	-	-	-	Ka-52	-	-	-	-	-	-
Sep 9	-	-	-	-	Su-34	-	-	-	-	-
Sep 10	-	-	-	-	-	-	-	-	-	-
Sep 11	-	Su-34	-	-		-	UAV	-	-	-
Sep 12	-	Su-30	-	-	Su-25	-	-	-	-	-
Sep 13	-	Su-24, Su-25, UAV	-	-	Mi-8	-	-	-	-	-
Sep 14	-	Su-30	-	-	-	-	-	-	-	-
Sep 15	-	-	-	-	-	-	-	-	-	-

war, the Russians were able to organise a small composite air operations (COMAO) for air attacks on Ukraine.

Considering the way Russian aviation works, a tricky question arises: Why do the Russians not organise large COMAO to attack high-value and highly profitable objects? It is estimated that in the modern highly dynamic battlefield, in order to ensure proper protection and flexibility in the operation of attack aircraft and to increase the probability of destroying objects, large groups of airplanes of up to fifty machines and more should be organised for various purposes (James, 2007, p. 99). Such missions were commonly performed during the 1991 Gulf War. Depending on the conditions and the purpose of the mission, such a grouping may be composed of strike planes (STRIKE), escort planes (ESCORT), planes for sweeping enemy air fighters jets (SWEEP), EW planes, planes for the suppression of enemy air defence (SEAD), planes for intelligence, surveillance, target acquisition, and reconnaissance (ISTAR), airborne warning and control system (AWACS) aircraft, and air-to-air refuelling tanker aircraft (AAR). It is not known whether the tactics of aviation, the training of the crews, or even the availability of equipment allow the Russians to organise COMAO. According to Ukrainian military experts, the Russians have no experience in organising and executing COMAO.[12] It is known that during military operations in Chechnya, Georgia, and Syria, the Russian air force only performed sorties in small formations. Modern propulsion systems, avionics, communication systems, and aircraft weapon systems are saturated with electronics that are susceptible to malfunction. Therefore, it is difficult to estimate the state of combat readiness and availability of aircraft, in particular SEAD aircraft and their anti-radiation missiles, which are crucial for breaking enemy air defence and providing cover to other combat aircraft in an environment saturated with air defence systems. It should be emphasised that most aviation powers in the world, including Russia, have very limited resources in this regard. It may be a practice of some kind to cancel a COMAO mission if certain elements of the group (machines or personnel) are missing. On the other hand, Russian strategic bombers, in turn, strike at targets in the interior of Ukraine with the Raduga Ch-555 and Raduga Ch-101 cruise missiles while being out of range of Ukrainian air defence systems during the attack. On the other hand, the A-50U AWACS aircraft orbit in zones beyond the range of Ukrainian air defence and are used by Russians to increase the ability to detect air targets, especially low-flying ones.[13]

The airspace over Ukraine has remained disputed since the beginning of the conflict. Since the Second World War, air superiority is considered as an absolutely necessary condition for victory (Skibiński, 1977, p. 89). Without gaining air superiority, without preparing cover and air support, there could have been no landing of allied troops on the beaches of Normandy that were fortified and defended by German troops (Skibiński, 1977, p. 89). The Allies would also not have been able to land in Sicily, Salerno, or Anzio, and thousands of British and American bombers would not have been able to drop bombs on Germany (Van Creveld, 2011, p. 50). In turn, the defeat of the Israeli air force in gaining air superiority during the Yom Kippur war caused the military command not only to lose faith in the ability of its forces to provide direct air support but also revealed serious weaknesses in the operational doctrine of the air force (Chisnall, 2012, p. 73). The First Persian Gulf War clearly demonstrated the importance of the air force and air superiority for the land forces (McKenzie, 2012, p. 70). Air superiority is currently treated as a

[12] *The conclusion was drawn after an interview with Ukrainian army officers on 4 October 2022 at the War Studies University.*
[13] *Signals intelligence (SIGINT) means repeatedly intercepted communication between AWACS and other airplanes. The conclusion was drawn after an interview with Ukrainian army officers on 4 October 2022 at War Studies University.*

necessary condition to initiate a land or sea operation (Radomyski *et al.*, 2018, p. 114). Hence, air superiority should be considered as the primary goal, and all activities necessary to achieve it should be subordinated to it. The implementation of this concept by the Russian armed forces in the war with Georgia in 2008 meant that Russian aviation quickly gained air superiority, at the same time creating favourable conditions for the operations of the ground forces (Radomyski *et al.*, 2018, p. 114). Gaining air superiority makes it possible to eliminate important subsystems of the state's defence, and as a result, reduce its vitality and ability to conduct war. It appears that the Russian command, while preparing the plan of operations in Ukraine, underestimated the will of the defenders to fight and their equipment, somehow sent by European countries and the United States. The operational assumptions were incorrectly defined that with a small aviation effort, the importance of greater artillery and tactical ballistic missile forces, while using armoured, mechanised, and air-assault forces within a few days, they would neutralise the Ukrainian's main lines of defence and resistance. In a war lasting for more than 6 months, neither side can achieve such a degree of air dominance that would allow it to conduct operations through all components of the armed forces in the entire area of operation, without the significant influence of the enemy's air force (DD-3.3(B), 2014, p. 9). Contrary to pre-invasion expectations that Russia would quickly gain air supremacy,[14] Ukrainian jets and air defence systems are still active and fight against enemy air attack assets, and support their own ground forces from the air (BlueSauron, 2022). It should be emphasised that the Ukrainian air force showed great flexibility and ingenuity in arming MiG-29 fighters with AGM-88 high-speed anti-radiation missiles (HARM) (Kadam, 2022). These are still ad hoc solutions that do not turn the MiG-29 into a true EW aircraft specialised for suppressing enemy air defence but will allow them to provide a temporary protective umbrella for their own attack aircraft against the threat of Russian air defence systems. Ukrainian anti-aircraft defence, both stationary and mobile systems, proved to be resilient and lethal for the fix wing aircraft and helicopters of the aggressor.[15]

The ability to survive and the effectiveness of air defence surprised the adversary. According to estimates, Ukrainian air defence had downed at least 63 Russian aircraft and 57 helicopters by late October (Jonsson and Norberg, 2022, pp. 91–122). Because of active Ukrainian mobile surface-to-air missile (SAM) systems, Russian strike aircraft cannot provide effective close air support to ground forces as it is forced to operate at stand-off ranges, high altitudes, or at night, which made their targeting weak and their overall performance underwhelming (Jonsson and Norberg, 2022, pp. 91–122). It is estimated that most of the Russian aircraft losses came from SAM systems, including the long-range mobile S-300 and man-portable air-defence systems (MANPADS) (Atlantic Council, 2022). The latter are especially effective against low-flying attack aircraft.[16] Ukrainian troops, using the Stinger and Igla-S MANPADS, organise air defence ambushes against low-flying air attack systems. Russia, despite the overwhelming quantitative and qualitative advantage of all types of aviation, is not able to comprehensively attack Ukraine with airplanes (Jonsson and Norberg, 2022, pp. 91–122). Both Russian and Ukrainian fighter and strike aircraft have continued to operate, but cautiously and at great risk. With this in mind, it should be emphasised that Ukraine's success in the fight to maintain a favourable airspace situation is to a greater extent due to GBAD measures, rather than to fighter planes, of which Ukraine has trace amounts in relation to the aggressor (Table 1).

[14] *Air supremacy is that degree of air superiority wherein the opposing air force is incapable of effective interference. (DD–3.3(B), 2014, p. 10; NATO Standard, 2016a (AJP–3.3), p. 18).*

[15] *The conclusion was drawn after an interview with Ukrainian army officers on 4 October 2022 at the War Studies University.*

[16] *Video recorded on 26 February 2022, showing the shooting down of a Su-25 attack aircraft with a portable anti-aircraft missile system in the Kherson region (Liveuamap, 2022c).*

So, it's hard to completely agree with Yurdatapan and Süngü (2022, pp. 29–44) that the Ukrainian army does not have an effective air and missile defence system, except for portable air defence weapons supplied by the West. One must certainly agree that Ukraine does not have enough air defence systems to ensure the security of all military facilities and critical infrastructure.

Many civil and military airports in Ukraine were bombed during the first days of the war, including those located in western Ukraine (in Lutsk, Lviv, and Ivano-Frankivsk). The Russians suspected that they would become the most likely destinations for donated combat aircraft from Eastern European countries (Arkin, 2022). However, even if the Russians made attacks on military airfields, they were largely ineffective because the runways and taxiways were barely damaged, and not enough combat aircraft were destroyed on the ground to prevent an effective defence of Ukraine (Wetzel, 2022). On the one hand, it can be assumed that the Russians, by implementing their plan of lightning war, did not intend to destroy all planes and elements of airport infrastructure but only aimed at disrupting their functioning, mainly by damaging their navigation systems, communications, and fuel depots. On the other hand, it should be assumed that Ukrainian aviation using western intelligence data largely avoided attack from the Kalibr cruise missiles, Iskander ballistic missiles (NATO SS-26 Stone), and Tochka (NATO SS-21 Scarab) as well as from missiles and bombs dropped from bombers. Before the outbreak of the war, some airplanes were disassembled and concealed at smaller (backup) airfields and moved to road runways, which measurably increased their viability on the battlefield.[17] It should be emphasised that the Ukrainian Soviet-made planes, the Su-25 and the Mi-29, are less sensitive than the F-16 planes to the cleanliness of the surface on which they take off and land. The Su-25 has high-located air intakes, while the MiG-29 twin-engine planes have air intakes directly under the wings, on both sides of the fuselage. However, they are at a higher altitude than in F-16 airplanes and, moreover, they are not in the track of the landing gear wheels. In order to prevent the engines from being sucked in by foreign objects, the air inlets are blocked during the run-up. The air is then sucked into the inlet channel through special diffusers located on the upper surface of the wings, thanks to which the planes can operate even from ground-surfaced airfields (Uchman, 2019, p. 60).

In the activities of the armed forces of the Russian Federation, there is no methodical campaign for destroying key objects. Air and missile strikes have been and continue to be carried out at targets spread across the country, making it impossible to concentrate the effects, and these effects are hardly aimed at critical command nodes (Wetzel, 2022). According to the report of the General Staff of the Armed Forces of Ukraine of 05 September 2022, the Russian army carried out twenty-five missile attacks using ground systems and twenty-two air strikes throughout Ukraine: in Kharkiv, Dmytrivka, Konstantynówka, Zelenopilla, Zaitsev, Kodem, Soledara, Mykolaiv, Wozniesieńsko, Oczakowo, Suchy Stawok, and Bezimenn (Liveuamap, 2022g). These attacks directly support ground forces and destroy civilian infrastructure instead of consistently targeting the objects related to the Centres of Gravities (CoGs).[18] In light of the theoretical assumptions for conducting an air operation, it appears that these attacks should be focused on leadership, the state's defence command and control system, including the integrated air defence system, and the state's vital sources (Chun, 2006, pp. 361–371). Already in 1988, the outstanding American air campaign theorist Warden (1988) had pointed out that the

[17] *The conclusion was drawn after an interview with Ukrainian army officers on 4 October 2022 at the War Studies University.*

[18] *COGs exist at the strategic, operational and tactical level of war and multiple COGs can exist at each level. A COG is always linked to an objective and if the objective changes, the COG could change (Allied Powers Europe, 2021, pp. 3–31; NATO Command, 2015, p. 17).*

most important responsibility of a commander is to correctly identify the enemy centres of gravity and strike appropriately. In line with the new trends, victory is possible, even without destroying the enemy's armed forces, by hitting the strategic cyber structures central to the state—its knowledge, information, and communication systems (Zilincik, 2022, pp. 5–32). It is certainly not easy to identify the centres of gravity and even more difficult to strike them effectively (James, 2007, p. 99). Even the use of planes invisible to radars does not guarantee the destruction of critical elements of the defender (Gotowała, 2008, p. 50). According to military experts, "the Ukrainian army has not lost control over the troops at any stage of the defence operation."[19] The Russians also did not carry out a systematic attack on transport routes or bridges, or logistic devices to hinder the transport of supplies to the front line. In light of the above, it should be concluded that not only the effectors have failed but also the reconnaissance systems that do not provide reliable and accurate information on an ongoing basis to effectively hit high-value and highly profitable targets. The ineffective operation of Russia's aviation also results from incorrectly defined targets for destruction, their order of destruction, and the selection of means that were created at the stage of planning the operation. It can be assumed that after the first dozen days of the war and many failures, the Russians decided to attack the civilian population, public, and industrial facilities in order to provoke a political rebellion and disintegrate the Ukrainian community, and to put pressure on the government in Kiev to surrender or to enter into negotiations on their terms. Like conventional bombing during the Second World War and the Vietnam War, these actions backfired (Gurantz, 2022, p. 126). The morale of the defenders has not been broken and the government elite is still willing to endure extensive destruction, rather than forgoing war goals. Moreover, the Russian rhetoric that it is very difficult to create a safe zone for civilians in the middle of military operations is hardly credible (Yurdatapan and Süngü, 2022, pp. 29–44).

Russia's ineffective air operation partly explains the failure of its land forces—the transition to defence, and even the loss of part of the territory at the turn of September and October in the Mykolaiv–Kherson, Kryvyi Rih–Kherson, and Kharkiv–Luhansk areas. The inability to obtain air control not only limits the Russian air force in conducting air interdiction of the battlefield but also hinders close air support, including increasing the fire of organic means of the Russian battalion tactical group (BTG) in the close area. Therefore, the Russian air force operation was not sufficient to effectively disrupt, delay, degrade, or destroy Ukrainian armoured, mechanised, and artillery units advancing from deep into Ukrainian territory to the front line before they could take effective action. In addition, the air force was less and less engaged in destroying logistic support nodes of the Ukrainian troops and elements of their command system (command posts and means of communication). A significant drawback is the poor coordination of air–ground operations in close air support, which was de facto identified after Russia's attack on Georgia in 2008 and has not been resolved since (Dalsjö *et al.*, 2022, p. 10). The radio correspondence of the attack crews of the aircraft with the land forces, intercepted many times by the Ukrainian forces, shows that their first-line subunits include fire coordinators, indicating the objects to attack and the positions of their own troops.[20] It is estimated that the exchange of information between the supported air force and the enemy ground forces has not brought the intended effects in the form of manoeuvres and precise hits on defenders' positions. Moreover, the operation of the Russian EW systems appears to be ineffective, as the Ukrainian command authorities have permanent communication with the farthest sub-units. On the other hand, Russian troops struggle to maintain secure,

[19] *The conclusion was drawn after an interview with Ukrainian army officers on 4 October 2022 at the War Studies University.*

[20] *The conclusion was drawn after an interview with Ukrainian army officers on 4 October 2022 at the War Studies University.*

covert communication, as evidenced by the interception of correspondence by the defenders (Dalsjö *et al.*, 2022, p. 20).

When analysing the use of aviation in the war in Ukraine, particular attention should be paid to situational awareness (SA) of the operational environment of the defending troops. Tzu (1996, p. 26) holds the view that in a fight, it is crucial to know one's own abilities and those of the opponent as well as their intent. It has commonly been assumed that from an air force perspective, situational awareness refers to the capability to conceive the current and future disposition of the enemy and one's own aircraft and surface threats within a volume of space (Munir *et al.*, 2022). In this regard, NATO's reconnaissance and command systems using the space segment and the air environment play a key role. These systems provide Ukraine with up-to-date information on the situation on land and in the air. Projects initiated in September 2014 by NATO to support Ukraine in the area of secure tactical communications, knowledge-sharing, and situational awareness are yielding good results in times of war (Piotrowski, 2021, p. 21). The headquarters of various organisational levels of the Ukrainian armed forces are familiarised with the direction, quantity, and characteristics of the advancing enemy's air attack assets, and the civil authorities are familiarised with the threat. Quick acquisition of reliable and precise information during combat operations allows Ukrainians to take precautionary and remedial steps in relation to the enemy's actions. The military and civilians are being alerted to the threat. Hence, a significant part of the civilian population has the opportunity to take refuge, while the air defence systems can increase the level of combat readiness and preparation to detect and shoot down the enemy. Ground troops up to the platoon level carrying out tasks in the FLOT also have current information about the location of their own and enemy aircraft.[21] The crews of fighter planes stationed on airfield aprons or road runways receive commands to take off in order to destroy the enemy's flying assets or rockets. Moreover, fighter planes if they are executing combat air patrol (CAP) in Fighter Area of Responsibilities (FAORs) are directed to the danger zone.

The Russian air force is very active in reconnaissance of the airspace over Ukraine. Russian S-band 48Ya6 "Podlet-K1" all-altitude radar in Belarus covering the Kyiv axis, and another in the south near Nova Kakovkha, has allowed Russian forces to track Ukrainian fixed-wing and rotary sorties at low altitudes at a distance of over 150 km (Bronk *et al.*, 2022, p. 12). These systems effectively provided information for long-range S-400 "Triumph" SAM systems based in Belarus and Crimea and forced Ukrainian aircraft to fly at extremely low altitude—below 100 ft—for most of their sorties on the northern and southern axes (Bronk *et al.*, 2022, p. 12). IL-20 M "Coot-A" and IL-20 M "Coot-B" notoriously (day after day) conducted electronic signals intelligence and communication intelligence (ELINT/COMINT) flights in the territory of Belarus along the border with Ukraine.[22] Captured signals served the attacking side better for understanding and neutralising the Ukrainian defence network. In addition, these aircraft were used as airborne command post and relay aircraft passing information from ground networks to patrolling Russian fighters. On the other hand, from the territory of Russia along the southern border with Ukraine, surveillance of the Donbas front was carried out by A-50M/U mainstay AWACS aircraft, which flew an average of two–three sorties per day. These kinds of aircraft were also heavily used in Belarus along the Ukrainian border for detection of air

[21] *The conclusion was drawn after an interview with Ukrainian army officers on 4 October 2022 at the War Studies University.*
[22] *The conclusion was drawn after an interview with Polish Air Component Command officer on 10 November 2022 at the War Studies University.*

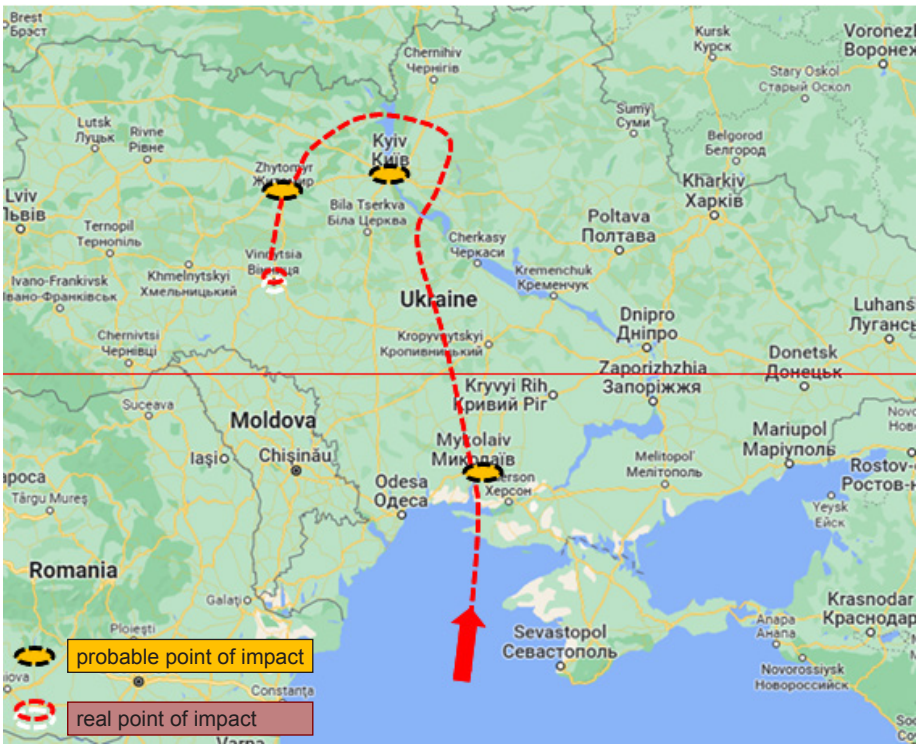


Figure 1. Flight path of the Kalibr missile during one of the air attacks (author's own work based on an interview with Ukrainian army officers on 4 October 2022 at the War Studies University).

targets and ground targets as well as control fighter aircraft for either air-to-air intercept or air-to-ground attack missions.[23]

The Russians are trying to outsmart Ukraine's air defence systems, including recognition systems. Most often, they use long-range cruise missiles for this purpose. From 24 February 2022 to the end of May 2022, more than 2,000 cruise missiles were fired into Ukraine, usually in salvos of 4–12 at once (Bronk *et al.*, 2022, p. 25). The Kalibrs were fired from naval ships and submarines in the Black Sea, while the Kh-101, Kh-55, and Kh-555 were typically launched from Tu-95 strategic bombers from inside Russian airspace (Bronk *et al.*, 2022, p. 25). For example, the Kalibr manoeuvring missile, which was launched from the Black Sea, performed a low-profile flight, making it difficult to detect and track through the Mykolaiv Oblast towards Kiev, bypassed Kyiv from the north and flew towards Zhytomyr, and then towards Vinnitsa, where it had just hit the target (Figure 1). The flight characteristics and range of the Kalibr missiles make them difficult to shoot down when detected, and it is even more difficult to pinpoint their target. The Kh-101 (a newer-generation than the Kh-55) is used in a similar way, which has a low-altitude flight profile, travels at 30–70 m above the ground and moves along planned flight path checkpoints, and it is thus hard for SAM to detect them.[24] The data reported here suggest that to protect critical infrastructure facilities and one's own troops, the air force should have anti-missile systems to destroy fast manoeuvring targets day and night.

To sum up, even though the Russians did not manage to gain air supremacy during the first half of the conflict, their combat aviation proved that it could strike targets throughout Ukraine beyond the range of Ukrainian anti-aircraft systems. In addition, the Russian

[23] *The conclusion was drawn after an interview with Polish Air Component Command officer on 10 November 2022 at the War Studies University.*

[24] *The conclusion was drawn after an interview with Ukrainian army officers on 4 October 2022 at the War Studies University.*

air force is able to use small formations and COMAO in strength of up to a dozen aircraft with which it can harass the Ukrainian air force, land forces, and other ground facilities. However, it is not able to fly freely into the territory of Ukraine without incurring losses, which is mainly the result of the operation of mobile GBAD systems of the defending country. Air battles in Ukrainian airspace have proved that the Mi-29 aircraft are incapable of countering the Russian Su-30SM and Su-35S due to the lower capabilities of their reconnaissance and fire systems. The Russians intensively use IL-20 M "Coot-A," IL-20 M "Coot-B" reconnaissance, and A-50M/U mainstay AWACS aircraft over their own terrain in order to increase the situational awareness of their troops with regard to aviation, ground anti-aircraft systems, and Ukrainian land forces. Russia's failure in the fight for air supremacy is largely due to the lack of unity of effort and concentration of force at a time and place designed to generate air superiority. In this respect, the passive air defence of Ukraine in the form of dispersal of aircraft—moving them to different airfields and road runways—did not help the offensive forces, which measurably increased the survivability of Ukrainian aviation on the battlefield.

Helicopters in combat operations over Ukraine

During the first half of the conflict, the Russians and Ukrainians also used combat helicopters in the air campaign, apart from planes. On the Russian side, these were Ka-52 "Alligator," Mi-28 "Havok," and Mi-24/35 "Hind" attack helicopters and Mi-8 transport helicopters. The Ukrainians, on the other hand, used Mi-8 and Mi-24 "Hind." Helicopters mainly performed attack and airlift (transport) tasks. Attack missions were generally flown in pairs, and used a combination of unguided rockets and artillery weapons against troop concentrations and lightly armoured vehicles, and less frequently anti-tank guided missiles (ATGMs) against armoured vehicles and other hardened targets. Transport tasks mainly included the transport of units, personnel, supplies, equipment, and materiel. In addition, transport tasks concerned the movement of airborne forces and their equipment and logistical support into an objective area by helicopters. The use of helicopters for casualty evacuation was also identified—transporting patients without medical supervision from the area of operations to hospitals, and for combat search and rescue.

The manner in which Russian helicopters performed combat tasks during the first half of the first year of the war in Ukraine raises many issues regarding their ineffective tactics, helicopter equipment, crew training, and planning combat missions. We already know that the Russians made mistakes when carrying out their tasks with large helicopter formations. On the first day of the war, Ka-52 attack helicopters escorting Mi-8AMTSz transport helicopters carried out air-assault operations at the Kyiv–Hostomel airport. About twenty Mi-8AMTSz and a dozen Ka-52 helicopters made up a movement of assault forces from an airport in Belarus almost 100 km into Ukraine to engage and to seize the Hostomel airport. Russian rotary-wing aircraft flew low over the buildings at high speeds, manoeuvring (periodically changing course and altitude) and using the masking properties of the terrain (Bakuła, 2022b). This tactic used by Russian pilots was to avoid detection by Ukrainian air defence radar and to prevent detection and destruction by operators of MANPADs, thanks to the effect of surprise. However, during the mission, three machines, including one above the water, were shot down. Probably the losses of helicopters on the Russian side could have been smaller if the crews had not made a cardinal error—flying in a large formation, although dispersed over a vast reservoir of water. During this time, they lost their masking effect and became easy targets to detect and engage from a long distance.

The situation was similar on 01 March 2022, during the flight of Mi-24 attack helicopters escorting a large group of Mi-8 transport helicopters over the Dnieper reservoir towards Kiev (Liveuamap, 2022d; YouTube, 2022). Fortunately for the Russians, only one Mi-24 was shot down over the water from MANPADS. Russian helicopter defensive aids that combine a radar warning receiver and a countermeasures dispensing system have functioned reasonably well throughout the mission, succeeding in repelling many incoming missiles (Bronk *et al.*, 2022, p. 22). Despite the use of passive helicopter defence systems, that is the firing of thermal cartridges (flares), hot helicopter engines against a background of cold water made it possible to effectively destroy rotary-wing aircraft with infrared-guided missiles. The Russian crews made the thermal warheads of homing missiles towards targets emitting infrared radiation easier to reach the hot helicopter engines. Moreover, the missions were carried out during the day, and not under the cover of night with the use of night-vision goggles (NVG), which would have reduced the risk of fire from small arms and anti-aircraft artillery (AAA) and missile sets. Helicopters flying at night with the marker lights turned off become invisible to soldiers who are not equipped with night-vision devices (thermal or NVG). With this equipment, due to the narrow range of vision through the goggles, they still have little ability to detect, fix, and track helicopters moving quickly between terrain obstacles at low altitudes. The reasons for carrying out a mission by day can be found in the insufficient number of trained and experienced crews for night flights in NVG, in not adapting all helicopters to flights in NVG, or in the mission-planning stage of improper threat assessment for the air-assault group. It is worth emphasising here that the Mi-24 and Mi-28 crews are less well trained in low-level night operations than the Ka-52 crews, which are assigned to support Russian special forces in adverse conditions and at night (Bronk *et al.*, 2022, pp. 20–22). Mi-24 and Mi-28 crews also probably have worse night-vision equipment than Ka-52 crews (Bronk *et al.*, 2022, pp. 20–22). Each of these factors, or all of them together, may have contributed to errors in the implementation of tasks, and, consequently, to losses of aviation personnel and machines.

Helicopters used during the conflict in Ukraine are not able to support their own land forces with impunity. The data reported here appear to support the assumption that non-compliance with the rules of tactics by helicopter crews increases their vulnerability to anti-aircraft systems and significantly reduces their survivability on the battlefield. This has been discussed with a few given examples. On 31 March 2022, a pair of Ka-52 (leading) and Mi-28 (wingman) helicopters flew at a low altitude above the ground (about 20–30 m) over an area occupied by their own troops. In the vicinity of the village of Zolote, helicopters carried out missions at intervals of 10–15 seconds between the leading and wingman and quickly climbed up to 70–100 m above the ground prior to weapons engagement, then flares fired during the combat turned towards the return route and returned to lower-level flight. After about half a minute of flight on the return route, the Mi-28 was hit in the tail beam by a MANPADS missile, causing the helicopter to crash to the ground (Liveuamap, 2022f). The above case confirmed the old rule that the wingman or the aircraft whose closing group protects the formation is more exposed to engagement with the opponent.[25] This is due to the longer exposure of the wingman or the aircraft whose closing group is being fixed, tracked, and struck by the enemy during the manoeuvre, thus the loss of the surprise effect as well as the awareness of the MANPADS operator that hitting the helicopter that closes the group will not result in another aircraft attacking it. For this reason, it is advisable that the wingman and helicopters closing the group

[25] *At the end of the Soviet intervention in Afghanistan, the Afghan rebels drew conclusions from the activities carried out against helicopters and introduced a principle to the tactics that the helicopter closing the group should be fired at from the rear hemisphere, which deprives the leader of protection, and manoeuvres, it allows the rebels to hide (Zieliński, 2012, p. 86).*

(formation) should manoeuvre continuously and vary separation and angle anywhere in the manoeuvre area behind the leader from approximately 3 o'clock to 9 o'clock. At this point, it should be noted that during the initial phase of the conflict, the crews of Russian helicopters were sometimes quite nonchalantly flying without manoeuvring at a constant height of approx. 50 m above the ground (Liveuamap, 2022b), which increased their exposure to small arms, shoulder-fired missiles, such as rocket-propelled grenades (RPG) and AAA, MANPADS as well as air-to-ground missiles (DU–3.3.49(G), 2017, p. 23 [use of helicopters in land operations]; NATO Standards, 2016b (ATP-49), pp. 1–13). This was probably due to the sense of safety of the crews and their confidence in the low risk of being shot down, ignorance of the tactics for minimising the possibility of being detected and reducing the time for staying within the threat range, and possibly even improper training and qualification of helicopter crews. Certainly, flying as close to the earth's surface as vegetation and obstacles permit (Nap of the Earth [NOE] flying), by using the available terrain (masking features) effectively reduces helicopters' exposure to threat, minimises exposure time, and increases their unpredictability, thus increasing their survivability and effectiveness on the battlefield.

Russian helicopters also incidentally became easy prey for Stugna-P anti-tank-guided missiles (ATGMs). On 05 April 2022, Ukrainian soldiers from the 95th Airborne Brigade detected and shot down a Ka-52 helicopter with a Stugna-P missile (Juraszek, 2022a). It is estimated that the rotary-wing aircraft was struck from a distance of about 5 km when hovering, while the crew prepared to attack armoured vehicles of the ground forces. Keeping the helicopter hovering well above the treetops of the forest massif made it visible from a long way away and easy to detect, track, and target. Such an action by the crew is unquestionably unacceptable on the modern battlefield. AH-64 helicopter pilots prepare to attack targets during hover but from behind cover, using millimetre fire control radar located above the helicopter rotor. The skill of the operator Stugna-P, who set the firesight on the helicopter only a moment before the impact, should be emphasised. Being too hasty to keep the helicopter in firesight would cause the defence systems of the helicopter, including the laser beam warning system, to give warning signals, and could even determine the positions of the beam emitter, which would involve the helicopter crew starting to manoeuvre or launch missiles at the launcher. A similar shooting down of the Ka-52 took place a month later on 01 May 2022. The helicopter was also high above the terrain in a hover, with the difference that the ATGM shooter was located about 2 km from the target and kept the firesight on the target the whole time of the recording and not—as before—aimed at the target just before the hit (Juraszek, 2022b). In this case, the error should be seen to be the crew's as well as the unreliability of the Ka-52 warning system.

In a conflict of high intensity, the situation on the battlefield can change very dynamically. The troops are constantly manoeuvring in order to create favourable conditions for them to disturb the enemy more effectively. Radio communication between ground and air forces is often disrupted and sometimes misinformation is introduced. In such conditions, it is difficult for supported and supporting units to maintain situational awareness about the position of their own forces and the enemy in three-dimensional space. Maintaining high efficiency of task execution while maintaining safety conditions is a great challenge for all participants of combat operations. Fratricidal fire was also not avoided. In July 2022, the Russian military shot down its own Ka-52 attack helicopter, which mistakenly attacked Russian positions in the occupied Kherson region in southern Ukraine (*Ukrinform*, 2022). At noon, near the village of Olhine, three Ka-52s, which were going to attack Ukrainian units, mistakenly attacked the positions of their own troops. As a result, they were attacked by their own anti-aircraft defence systems and one of the helicopters was shot down. The evidence from this study suggests that the cause of the Russian losses may have been errors committed in the exchange of data on cooperation between

helicopter crews and supported subunits, regarding the marking of their own troops, indicating impact targets for aviation, incorrect target coordinates, or a lack of communication between helicopter crews and commanders of supported land subunits. According to Bronk *et al.* (2022, p. 13), Russia had many problems with radio communication caused by its own EW capabilities, which often introduced severe interference in communication between its own land forces. Moreover, they had no coherent communication plans. Many units had not exchanged encryption keys and had a shortage of trained radio operators. It should be assumed that in the formation of the supported ground sub-unit, there were no specialists who could coordinate the operation of Ka-52 helicopters in the vicinity of their own troops. It is estimated that unguided missiles, which can be unreliable and imprecise in terms of impact, may also have been used during the attack by helicopters. It is worth emphasising that they should not be used to destroy objects in close proximity to one's own troops. In addition, friendly fire from helicopters could also be caused by a mistake made by crews during targeting, including a premature decision to use weapons dictated by the reluctance to enter the enemy's firing zone. It could be a human error of the crews, resulting from the fact that the helicopter formation commander, at a speed of over 250 km per hour, had only a few seconds to make a decision to shoot or not. In turn, fire at helicopters from organic and assigned air defence systems to ground troops and sub-units was apparently a self-defence response, especially since the helicopters probably had Identification Friend-or-Foe (IFF) systems turned off in order to avoid detection by the Ukrainian air defence systems. On the one hand, it increased their survivability on the battlefield, but on the other, limited the possibility of identification by their own air defence sensors. It is least likely that IFF was jammed effectively by the Ukrainians, denying use of the equipment for identification of friendly contact. In this one-off case, the methods of airspace control and coordination of joint operations that would eliminate communication constraints and ensure security for their own air and ground forces failed. It is almost certain that jamming resistance will become a critical issue on the future battlefield. Communication systems must provide troops with timely, reliable, and encrypted communication with superiors, subordinates, and support assets (e.g. strike aircraft and attack helicopters).

Personnel recovery (PR) from an enemy area of highly saturated air defence systems usually results in a high risk of losses for recovering forces, especially those not properly prepared for these missions. This thesis is confirmed by two search and rescue missions carried out in the first half of the first year of the conflict. The first incident occurred on 04 March 2022 when a Russian Mi-8 helicopter was shot down near the village of Volnovacha in the Donetsk Oblast. The crew of the helicopter was probably shot down during a mission to recover an isolated pilot who ejected from a Su-25 plane forced to crash by the air defence systems of Ukraine (Liveuamap, 2022e; Military Wiki, 2022; *Ukrinform*, 2022; Ukrainian MOD, 2022b). PR missions are typically of high risk and difficult to undertake, especially during the day in area occupied by the enemy. In this case, it should be presumed that the Russians, having received the report on the isolation event, launched the emergency procedure of rescuing the pilot using the helicopter on duty dedicated to PR mission, or re-tasked the helicopter from another mission. The method of carrying out a rescue mission and its effect allow for the formulation of several conclusions. Firstly, the threat and risk of carrying out a PR mission were incorrectly estimated. Since the warplane was shot down, it was absolutely necessary to assume the high threat of air defence systems, including AAA and MANPADS. Hence, taking into account the high risk of a PR mission, and the short time for its preparation and implementation, it was a mistake to send one unarmed recovery vehicle (RV) with an extraction forces (EF) team without a Rescue Escort (RESCORT) and aircraft dedicated to SEAD or electronic warfare. In terms of tactics of operation in an environment of high risk of enemy influence, it was advisable to send an fix wing rescue escort (FW RESCORT) and at least a rotary-wing

rescue escort (RW RESCORT) performing a flight behind the helicopter transporting the recovery team (Lubiejewski, 2019, p 138). In this case, the RW RESCORT would cover and observe the RV from the rear hemisphere, while the FW RESCORT would cover the entire group from above or from the transport helicopter's front hemisphere. This would allow the escorted element to be closely protected and to respond quickly to identified threats. In order to disrupt, destroy, or incapacitate enemy air defence systems, the most important thing was to send SEAD aircraft, which would allow the Russian aviation to safely operate in hostile airspace, and, consequently, to reach the pick-up point and extract the survivor (US Marine Corps, 2016, pp. 1–3). Nevertheless, the Russians, apart from a few EC Ił-22PP "Porubszczyk" EW aircraft, do not have typical SEAD aircraft that could break and degrade anti-aircraft defence systems, which measurably affects the fact that they cannot gain air superiority over Ukraine. As Bronk *et al.* (2022, p. 16) note, Su-35S and Su-30SM fighters were sometimes tasked to conduct SEAD operations using Kh-31P and older Kh-58 ARMs at long ranges to home in on radar emissions. To this end, their CAPs were used as bait to try to make Ukrainian SAM systems turn on their radars to fire at them.

At the end of March 2022, the Ukrainians also carried out one unsuccessful search and rescue mission to rescue the wounded from Mariupol (YouTube, 2023). In the final phase of the flight over an area occupied by the enemy, about 7 km from FLOT, one of the Ukrainian Mi-8 helicopters was shot down. A rescue helicopter was sent to the area, which unfortunately was also shot down (YouTube, 2023). The conclusions from the analysis of the incident indicate that the Ukrainians acted identically to the Russians during the organisation and implementation of the rescue mission. The findings of this study suggest that to have the ability to search and rescue isolated personnel (ISOP) in a high-intensity conflict, it is advisable to keep a PR task force on high alert (including recovery vehicles and extraction force) with the ability to SEAD and escort all packages during a mission (e.g. a readiness state of 15 minutes). Other types of response in the future could include the use of special unmanned aerial vehicles (UAVs) that would have the ability to covertly move to the ISOP area for pick up. However, much research is required to develop the design and construction of such an aircraft, because current UAVs are not adapted to carry out PR missions in this way.

Before the outbreak of the war, few military experts were convinced that helicopters were capable of carrying out tasks 100 km deep into enemy territory with multi-layer air defence. The defence of Mariupol and the attempt to help Ukrainian soldiers fighting in the besieged Azovstal plant confirmed that helicopters are still irreplaceable on the battlefield, even in an extremely dangerous environment. A total of sixteen helicopters participated in the special operation of delivering weapons, food, and medicines to the defenders of Mariupol (Jastrzębski, 2022). The supplies were delivered by multi-role Mi-8 helicopters, even four times a day. The most seriously injured were also evacuated in this way (Nexta, 2022; WP Wiadomości, 2022). The crews of the Mi-8 helicopters used the tactic of flying at maximum speed at a very low altitude, several metres above the ground, sometimes with the front wheel touching grass or tree tops in order to make it difficult for the Russian air defence systems to detect and track them and thus to shoot them down (Osinttechnical, 2022). In the opinion of experienced pilots, taking a helicopter up to 30 m dramatically increased the risk of detection and being hit by various anti-aircraft systems.[26] Flights to Mariupol were planned on different routes, along a curved line. About 100 km of the route out of the total of 160 km was within the range of Russian anti-aircraft systems. Hence, most flights took place at dawn, often under the cover of

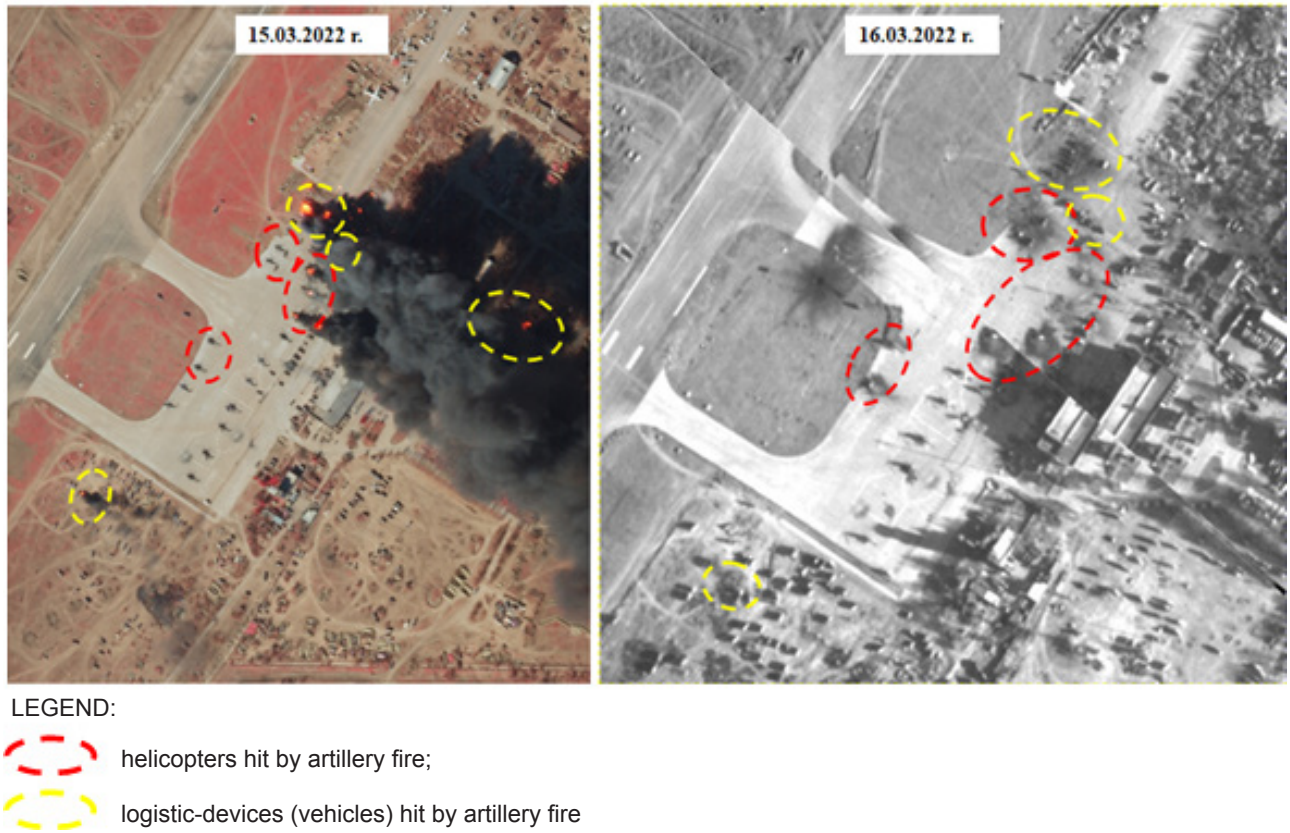
[26] *Interview with the Mi-8 instructor pilot (pseudonym Yevgeny), involved in the air transport missions to Mariupol (Venckunas, 2022).*

darkness and in bad weather conditions. The pilots for night flights used NVG, and they had a two men crew, excluding an on-board technician, to reduce the weight of the helicopter (Venckunas, 2022). All these factors had an impact on the effectiveness of air transport and medical evacuation. The tactics of flights using terrain masking properties made it difficult for the Russians to detect and engage helicopters using surface-to-surface missiles (SSM) and MANPADS. In addition, it allowed Ukrainian pilots to obtain the effect of surprise, which would appear impossible in these conditions. It should be noted that all the helicopters that flew there reached their destination with their cargo—not one of them was shot down along the way. Several helicopter landing pads were prepared at the Azovstal plant in Mariupol. These locations were changed between flights as the previous locations were immediately attacked by Russian artillery. The cargo was unloaded quickly and twenty wounded soldiers and one accompanying person were taken on board. The unloading and loading procedure was carried out in 10 minutes, as this was followed by artillery fire. Moreover, the landing sites were within range of at least two or three anti-aircraft missile systems. For this reason, helicopters were most susceptible to being hit right after take-off in the acceleration phase, when they had limited manoeuvrability and the approximate taking-off position was known. It must not be forgotten that the transport helicopters performed tasks without the cover of attack helicopters as there were too few of them in the armed forces of Ukraine. The exception was the task on 31 March 2023, when one Mi-24 escorted four Mi-8s (YouTube, 2023). In order to confuse the enemy, the take-off and flight from Mariupol took place in a direction other than straight to their own troops. On the way back (egress route), after losing the surprise effect, some of the helicopters were successfully attacked, which usually ended in a catastrophe. If a helicopter was hit, for example one of the engines was damaged as a result of shelling, few of the crews managed to return to their own base (Venckunas, 2022). It is now understood that Ukrainian pilots thoughtfully and skillfully selected the tactics of operation in relation to the enemy, the terrain, and the capabilities of their helicopters. Despite the threats, they showed their dedication and courage as well as good piloting skills in difficult weather conditions. It is still a mystery how effective the Mi-8 defence systems were, and whether there were any imperfections in the operation of the Russian anti-aircraft systems in the Mariupol area. However, it should be underlined that helicopter flights to Mariupol were for a short time—they were few, as the Russians had accumulated a large air defence force on the route to Mariupol and around the city, including anti-aircraft defence systems on navy ships that began operating at the waterfront (YouTube, 2023). Strong Russian anti-aircraft defences ultimately prevented the continuation of air transport using helicopters. After the fifteenth failed flight attempt, which ended in the section from FLOT to halfway to the besieged city, operations were abandoned (YouTube, 2023).

In the first half of the first year of the war in Ukraine, helicopters were also destroyed on the ground while restoring combat capability. Experience from the conflict shows that the use of helicopters and their logistic support elements on the battlefield without appropriate procedures makes it impossible to quickly and safely refuel and arm helicopters near the enemy. In order to identify errors in the tactics of helicopter aviation in this regard, an incident of 15 March 2022 was researched. On this day, Ukrainian rocket artillery launched an attack on the airbase in Kherson, which was occupied by the Russians. The attack resulted in damage and destruction of several helicopters, most likely the Ka-52 or Mi-35 assault helicopters, and several heavy-duty off-road vehicles (Vasylchenko, 2022) (Figure 2).

The loss of the Russians may have been greater due to the dispersion of missile fragments that could have damaged the fuselage of other helicopters. Additionally, tanks with petroleum, oil, and lubricant stored in this part of the airport were destroyed. It should be noted that FLOT at that time ran in the Mykolaiv region about 30–40 km from the

Figure 2. Kherson airbase after a rocket attack by Ukrainian troops on 15 March 2022 (author's work based on satellite images taken by Planet Labs and @Maxar satellites).



Kherson airbase. Hence, the Ukrainians had to use precise artillery means with a range of over 40 km for the attack. Losses of rotary-wing aircraft, vehicles, and fuel resulted from Russian underestimation of the enemy or a lack of knowledge of the elementary tactics for organising helicopter operations in combat conditions. When analysing the effective attack by Ukrainian artillery, it should be noted that Russian combat helicopters had been using the Kherson airbase for several days before the attack.[27] They were not masked or dispersed, and the numerous trucks and tankers were arranged in rows, without separation, concealment, and no anti-aircraft cover (Figure 2). The biggest mistake was primarily the decision to use the Kherson airbase, which was located close to the position of the Ukrainian troops, and moreover, it was notoriously used by a large group of helicopters. In addition to the fact that single-site take-off and landing operations exposed the helicopter's position, they were also within the range of the organic artillery means of the Ukrainian land forces. In this situation, the assembly area of the helicopter unit (forward operation base of helicopter aviation) should have been organised at least 120–150 km from the FLOT. In order to increase the tactical radius of operation of helicopters or significantly extend the play time on the target area (object area) or to intensify impacts by eliminating the need for the helicopters to return to the main base for refuelling and arming, the Russians should have used forward arming and refuelling points for helicopters (FARPs) developed on unprepared terrain, instead of permanently keeping the machines in a zone exposed to the detection and fire of first-line artillery units of armoured and mechanised troops. It is possible that the Russians felt very confident in this area. On the other hand, the lack of knowledge and experience in the FARP organisation is clearly

[27] *The conclusion drawn after analysing Maxar Technologies satellite images.*

visible among Russians, and maybe even laziness, because the logistic support for helicopters in the vicinity of FLOT requires effort from the headquarters in terms of planning, organising, and coordinating the FARP operation with ground forces, and also a big effort from the FARP staff. Depending on the operational needs, FARP should provide fuel and ammunition to helicopters for up to several days, moving during this time from one area to the next, 30–40 km from the FLOT (Lubiejewski, 2018, p. 119). Helicopter weaponry and refuelling points should be frequently relocated in high-risk areas. The essence of the operation of FARP is that helicopters stay on their pads only when their combat capability is restored and then depart. The position of the FARP should be changed when it fulfils its role in a given location, that is, after the helicopters have been restored (Headquarters, Department of the Army, 2007 (FM 3-04.126), pp. 4–15; 2012 (ATP 3-04.94), p. 3-3). The use of the Kherson airport was also a mistake due to the fact that the Ukrainians knew exact details about this facility and the Russians' tendency to use fixed infrastructure (airports and landing areas with a concrete strip, parking areas, and taxiways) conveniently located for combat operations. The schematic and predictable action, hence, also revealed the location of the aggressor's helicopter aviation. Research has revealed that Russia made several mistakes when planning, organising, and executing the restoration of helicopters' combat capability. It transpired that a significant number of helicopters nonchalantly used one completely unconcealed airfield for a long time, which was within the range of Ukrainian artillery. This allowed for the detection and effective destruction of helicopters and logistical support equipment. It was also a mistake not to disperse the equipment on the apron, and this increased the losses. There are still unanswered questions: did the crews of Russian helicopters in the airfield perform air operations in radio silence, or did they establish communication on encrypted frequencies? If not, the radio correspondence probably also unmasked them.

To sum up, in light of the ongoing conflict in Ukraine, helicopters are most desirable on the battlefield for attack missions, air transport, and combat search and rescue. During the research, it was identified that helicopter flights of more than 30 m above ground level, without the use of terrain masking properties, especially without anti-aircraft and artillery manoeuvres, make them very susceptible to enemy detection and impact. It is unacceptable to attack ground targets from helicopters hovering over terrain obstacles, or to fly over open water reservoirs. Carrying out flights as close to the earth's surface as vegetation and obstacles permit effectively reduces the helicopters exposure to threat, minimises the exposure time, and makes them more unpredictable. The passive and active defence systems of helicopters, as well as night flights, increase their survivability on the battlefield. To prevent losses incurred because of fratricide, it is necessary to use methods of airspace control and coordination of joint operations. High-intensity conflict experience confirms that the execution of combat search and rescue missions using a single helicopter is almost impossible. In addition, the notorious landing, refuelling, arming, and parking of helicopters at a place not far from FLOT for several days, all the more susceptible to reconnaissance, is a big mistake, and results in losses.

The Polish air force in light of military operations in Ukraine

The Polish armed forces, together with the armed forces of other NATO countries, have been carrying out exercises for several years, in which the scenarios of the enemy's offensive actions do not differ significantly from the way the Russian armed forces conduct their offensive in Ukraine. They assume that a potential adversary may attack NATO's eastern flank countries from several directions (as is currently the case in Ukraine) as part of a multi-domain offensive operation conducted in the following environments: sea, space,

information, electromagnetic and cyberspace, going beyond land, and airspace (Česnakas, 2019, pp. 273–293; Government of Republic of Poland, 2017; Karber, 2015).

The Polish air force is preparing to carry out tasks during peacetime in accordance with war purposes and develop its capabilities to meet the threats of the modern battlefield. It also participates in the NATO Baltic Air Policing mission to patrol and prevent violation of the airspace of Estonia, Lithuania, and Latvia (Zieliński, 2020, pp. 33–45). For the purposes of securing the key military and critical infrastructure against air attack, the Polish air force still has quite limited anti-missile and anti-aircraft defence capabilities, in terms of both quality and quantity of GBAD systems as well as fighter and multi-role aircraft.

The Polish air force currently has one ground tactical unit designed to counter air attack—the 3rd Air Defence Missile Brigade. The Brigade has limited capabilities to counter air threats (Smura and Oleksiejuk, 2022, pp. 35–36). The restrictions apply to neutralising (countering) ballistic missiles, cruise missiles, RAM, and UAV threats (Milewski, 2021, pp. 50–52). The basic armaments of the Brigade are seventeen short-range anti-aircraft systems S-125 S.C. (SA-3) and one long-range anti-aircraft S-200 WEGA S.C. (SA-5) system. These are single-channel sets from the times of the Warsaw Pact, which significantly reduces their effectiveness on the modern battlefield (Smura and Olesiejuk, 2022, pp. 35–36). In 2022, the Brigade was equipped with three very short-range air defence Pilica systems. The combat means of the systems are 23-mm anti-aircraft guns and very short-range Grom (Piorun) anti-aircraft missiles. The advantage of these armaments is that they are six-channel and, together with the previously mentioned sets, form a substitute for a multi-layer fire system (Radomyski, 2014, pp. 231–260). Full integration of the multi-layer defence system against air threats will be achieved by the Brigade upon completion of the implementation of the armaments in accordance with the TMP of the Polish armed forces—implementation of the Wisła and Narew programmes (Milewski, 2021, pp. 52–59; Serwis Rzeczypospolitej Polskiej, 2019).[28]

When analysing the needs in the field of defence of the state (military facilities AND critical infrastructure) against air strikes, it should be stated that the available forces and means of GBAD are insufficient. The events in Ukraine indicate that important military infrastructure facilities, such as command posts, airfields, vital sources of the state, and critical infrastructure facilities, should be protected in the first place. Hence, among other things, individual Patriot systems from NATO resources are currently participating in securing the eastern border of the country. Conclusions from the war beyond the eastern border of NATO clearly show the importance of a fully integrated and multi-layered air defence system. Therefore, intensifying the modernisation of the Polish air force in GBAD is completely understandable. The first air defence systems acquired under the Wisła and Narew programmes are being introduced in the Polish armed forces. With the completion of TMP projects, the Polish air force will have at its disposal multi-channel medium-range (up to 100 km) Patriot systems (in accordance with the implementation of the Wisła programme), short-range (up to 25 km) systems consisting of British launchers and British CAAM missiles, Polish Soła radiolocation stations with a fire control system (in accordance with the implementation of the Narew programme), and very short-range (up to 5 km) Pilica and Grom (Piorun) systems.[29] The listed armaments will allow for building

[28] *The conclusion was drawn after an interview with two experts of ground-based air defence (GBAD) on 11 January 2023 at the War Studies University.*
[29] *The armament was delivered to the units in 2022, while their certification and operational readiness is planned to be achieved in 2023. The conclusion was drawn after an interview with two experts of ground-based air defence (GBAD) on 11 January 2023 at the War Studies University.*

a multi-layered air defence to counter such air assets as ballistic missiles, cruise missiles, and UAVs—which has so far been difficult to achieve (Milewski, 2021 pp. 52–59; Serwis Rzeczypospolitej Polskiej, 2019). The implementation of the systems will increase the defence capabilities of the country and the NATO Integrated Air and Missile Defence System (NIAMD) (Radomyski, 2019, pp. 110–126). According to experts, these still will not meet all the needs of the Polish armed forces in the field of protection of the key military and critical infrastructure of the state.[30] Therefore, further modernisation plans of the Polish armed forces should include the acquisition of further short- and medium-range anti-aircraft and anti-missile systems calculated to ensure that the above-mentioned facilities are fully protected.

The Polish air force has too little potential in relation to the needs of gaining and maintaining air superiority over its territory in conflict conditions. Taking into account the conclusions from the conflict in Ukraine, as well as the analysis of the forecasted threat scenarios, it is estimated that the Polish air force needs about forty fighter or multi-role aircraft at the same time to perform CAP as part of defensive counter-air (DCA) over Poland itself (Cieszan *et al.*, 2015, p. 18; Smura and Oleksiejuk, 2022, p. 38). This would allow the creation of five fighter areas of responsibility (FAOR) with eight aircraft on air duty each. To this should be added multi-role or fighter aircraft in reserve or at ground alert to counter air (CA), multi-role aircraft at ground alert to air power contribution to counter-land operations (APCLO), and air power contribution to counter-maritime operations (APCMO). In addition, it is reasonable to have AWACS aircraft and an AAR ESCORT. Aircraft repairs and maintenance, as well as losses during combat, should also be considered (during the first 10 days of combat, the Ukrainians lost twenty-five aircraft, while the Russians lost fourteen) (Table 1). It follows that the analyses of aviation experts are not exaggerated and the Polish air force should have at least 150–200 combat machines (fighters and multi-role) (Ciastoń *et al.*, 2015, p. 18), the more considering that the modernisation plan of the Polish armed forces for 1998–2012 assumes the acquisition of 160 modern multi-role aircraft. This would ensure an increase in the attack capability of the Polish air force and the NATO Integrated Air Defence System (NATINADS), which is primarily a guarantor of security in the airspace of the European alliance countries.

The Polish air force currently has ninety-four combat aircraft, with only forty-eight multi-role F-16s, most of which can be operated in a perspective of several years. Considering their reconnaissance, attack, aerodynamic, and self-protection capabilities, they are fully fledged means of combat that can be effectively used to attack air and ground targets. For example, Romania has only thirty fighters, twenty of which are ready for use, and Bulgaria has only eleven fighters, with seven ready for use, and six attack aircraft (GFP, 2023). Unfortunately, the remaining combat aircraft of the Polish air force—post-Soviet MiG-29 fighters and Su-22 fighter-bombers—can be used in a very limited way on the modern battlefield (Lipka, 2014, pp. 1–6; Zieliński, 2020, pp. 33–45). Old and heavily exploited aircraft have very limited capabilities for recognising and engaging air and ground targets and operate at a long distance from their home bases due to high fuel consumption and lack of aerial refuelling capabilities. Considering the capabilities of GBAD systems and fighter aircraft used by the Russians in Ukraine, it should be assumed that the viability of the MiG-29 (in the Polish air force version) and the Su-22 on the battlefield will be low. In addition, their number decreases every year, as because of their service life coming to an end, they are gradually withdrawn from aviation units. With the above in mind, Zieliński (2020, pp. 33–45) notes that it is necessary to replace and acquire four additional squadrons with multi-purpose combat aircraft, including fifth-generation aircraft.

[30] *Basically, the conclusion was drawn after an interview with two experts of ground-based air defence (GBAD) on 11 January 2023 at the War Studies University.*

At the beginning of 2020, a contract was signed for the purchase of thirty-two fifth-generation F-35 multi-role aircraft for the Polish air force (Serwis Rzeczypospolitej Polskiej, 2020), which, in addition to attacking air and ground targets, can be used for SEAD. The increased threat to Poland caused by the conflict in Ukraine meant that on 16 September 2022, the Minister of National Defence approved a contract for the supply of forty-eight FA-50 light combat aircraft with capabilities and a purpose comparable to F-16. The first twelve aircraft from the Republic of Korea are to be delivered to Poland as early as 2023 (Serwis Rzeczypospolitej Polskiej, 2022a). In light of the needs of the Polish air force to have a total of over 150 fighter and multi-role aircraft, their potential of forty-eight F-16s, forty-eight FA-50s, and thirty-two F-35s should be increased by at least another twenty-five machines soon.

Bearing in mind that the air force will have to operate under the strong influence of Russian air defence, including anti-access/area denial (A2AD) measures, which may effectively prevent air operations, it is advisable to increase the arsenal of JASSM cruise missiles and deliver JASSM-ER with a range of 1,000 km (Lipka, 2018, pp. 1–11). This will not only deter the enemy but also carry out precise air strikes outside the range of A2AD.

When analysing the current state of the Polish air force in the context of the conclusions of the war in Ukraine, it should be noted that, similar to the other countries of NATO's eastern flank, it does not have ISR, AWACS, and AAR aircraft, which would create favourable conditions for the combat aviation operations discussed earlier (GFP, 2023). There is no doubt that the inclusion of AWACS and ISR aircraft in the air defence system would ensure recognition of air targets flying at very low altitudes, thus increasing the reconnaissance capabilities of NATINADS (Radomyski, 2019, pp. 110–126). However, taking into account the costs of obtaining F-35A and FA-50 aircraft being USD7.6 billion (*Forsal.pl.*, 2022; Serwis Rzeczypospolitej Polskiej, 2020a) and the additional investments necessary to adapt air bases to accommodate aircraft, and also the simultaneous implementation of many technical modernisation programmes of the Polish armed forces (e.g.: HOMAR, KRUK, GRYF, MIECZNIK, and BORSUK), it must be said that ISR, AWACS, and AAR aircraft will remain on a wish list for many years, if not decades.

The experience of the conflict in Ukraine shows that masking and distributing the air potential on many airfields and other hidden take-off and landing sites can disperse the effort and eliminate the effects of massive missile attacks by the enemy. It should be emphasised that GBAD systems, especially in scarce numbers, will not be fully effective during a massive saturation missile attack by the enemy (Wang *et al.*, 2022, pp. 1177–1189). To increase the survivability of combat aviation when stationary on the ground or to increase its operational tactical radius, it is advisable to maintain and use road runways. This would make it possible to mislead the enemy as to the deployment of one's own forces and to hide some combat capabilities. Unfortunately, in the current situation in Poland, it is not possible to use road runways for training or combat purposes. Over the past 20 years, the Polish air force has not conducted flight training using road runways. It appears that there were many reasons for this, including: high requirements in terms of surface cleanliness for F-16 aircraft, difficulties related to the organisation of such training (especially in terms of logistics, communication, and flight insurance), additional costs resulting from maintaining road runway infrastructure, and, probably, a feeling that they might not be needed on the battlefield. In the 1990s, there were several road runways in Poland, which gradually fell out of use. High-voltage power lines have been built near some of them, the condition of the surface has deteriorated on some of them, there are no embankments to arm aircraft around the parking planes, and there are no safety belts for air operations due to pits and ditches on the side of the road. On the other hand, on new road sections (highways) suitable for use as road runways, culverts for animals and energy-intensive

barriers were built near them, and concrete barriers were placed in the middle of the road to separate lanes of traffic going in the opposite direction. The surface tests carried out after removing the slabs indicate that it often crumbles and is not suitable for use by aircraft.[31] For this reason, in 2022, the construction of a new road runway in north-eastern Poland was completed, which is to be tested and used for training purposes by all types of aviation belonging to the Polish armed forces this year. Nevertheless, Poland should have many road runways for training purposes, ready for use in combat conditions.

The use of high-tech mock-ups of aircraft would enable the protection of real machines, misleading the enemy with disinformation as to the number and quality of the weaponry and reducing the potential of the enemy because of weapons being deployed on fake targets (Pettersson, 2018, pp. 181–195; Wiśnicki, 2014, pp. 56–60). According to available sources, the Polish air force does not have mock-up aircraft, which indicates that military decision-makers are not interested in this type of camouflage. One should not expect this issue to be solved during an armed conflict alone, and big purchases need to be made and training in the tactics of their use carried out in a short time.

The experience of the war in Ukraine shows how important air raid shelters and slit trenches are for civilians and military personnel. The sense of security caused by Poland's accession to NATO and the European Union (EU), among other things, has meant that over the last three decades, the threat of air attack on the country was not taken very seriously.[32] This feeling was also caused by a sceptical approach to shelters, especially light ones, and air raid slit trenches in the context of protection against high-powered precise means of destruction. Observations of civil and military infrastructure and unstructured interviews conducted with air force officers indicated that there is a deficit in the army of well-camouflaged reinforced concrete air-raid shelters deeply embedded in the ground, in particular shelters in remote and hidden places. Moreover, many of the shelters are neglected.[33] Almost all those who were interviewed suggested that shelters should be expanded and the technical condition of many existing ones, including their equipment, should be improved. The people surveyed added that the situation with shelters for civilians is even worse, because new buildings mostly have shallow basements and underground garages with relatively light ceilings. These buildings were not built to protect the civilian population from air threats, so it is difficult to require such capability from them. There are also few public places, such as subways or train stations, that can be used as shelters. Filipowicz, based on the conducted research, stated that there are shelters in Poland for only a few proportion of civilian population (Witek, 2022). Therefore, it should be recognised that the current conditions and number of shelters against air attacks are not satisfactory for soldiers and civilians. For this reason, it is necessary to build new shelters for the army and civilians, and to improve the existing ones. Central state institutions, in cooperation with the military, should define the technical requirements for shelters, which should be included, for example, in the regulations on the construction of multi-apartment buildings.

Helicopter units of the Polish armed forces participate in exercises at least once every 2 years, in which planning, organising, and executing redeployment of their forces to the new assembly area are carried out. In most cases, this is a movement to other airfields.[34] Few of the units every year train their subunits as part of their own exercises (e.g. 56th Aviation Base) in the organisation and functioning of FARP in combat conditions. The approximate forces and resources necessary to organise the FARP into four pads for arming and refuelling helicopters and for two-shift operation amount to about seventy soldiers and twenty vehicles for various purposes (Lubiejewski, 2018, p. 119). When analysing the equipment and organisational structure of the army aviation, it should be emphasised that they are able to organise and maintain a maximum of one FARP in operation. Taking into

account the current staff and equipment of the army aviation units and the fact that the logistic support of these units in the main assembly areas is a priority, it is not difficult to see that the commanders of the helicopter units have difficulties in directing specialists and resources to perform tasks at FARP (Lubiejewski, 2018, p. 119). This is because helicopter units were created or reorganised at a time when real needs in the organisation and operation of FARP on the modern battlefield were not realised. Therefore, efforts should be made to create a sub-unit in helicopter aviation units dedicated to FARP with personnel trained in the tactics and procedures of FARP operation in combat conditions and equipped for efficient arming and refuelling of helicopters in field conditions.

The conducted analyses of the helicopter training process (Program szkolenia lotniczego na śmigłowcach w lotnictwie Sił Zbrojnych Rzeczypospolitej Polskiej (PSzL, or Polish Aviation (Helicopters) Training Program), 2012) in light of threats and missions for helicopters during the war in Ukraine made it possible to identify that it includes several exercises for preparing crews for flights in combat conditions. During the day training, the crews are obliged to perform terrain flights, including low level, contour, and NOE and flights in difficult weather conditions. In addition, they carry out flight training at night in difficult weather conditions and training at night with the use of NVG (PSzL, 2012). Because flights at night using NVG are notable for a high degree of difficulty, maximum time is devoted to them. Nevertheless, in the opinion of some instructor pilots, formation flying training is too limited in terms of the number of exercises and time.[35] Crews are also trained in flights with simulated SAM, MANPADS during the day, but there is no such training at night (PSzL, 2012). It should be emphasised that a small amount of aerial munitions are allocated for training pilots in attacking ground targets during the day and at night, but, what is worse, the training is carried out without anti-tank-guided missiles due to shortages in warehouses. Shortage in armaments has meant that most of the crews have never fired air-to-surface anti-tank-guided missiles, and the older staff has lost the habit of performing this type of shooting (Lubiejewski, 2020, pp. 90–93). The use of only 57-mm S-5 and 80-mm S-8 unguided rockets and artillery armaments is not very effective against tanks and armoured fighting vehicles, because they are designed to destroy unarmoured, lightly armoured targets and manpower. To sum up, the training of helicopter crews for the execution of tasks during wartime is most adversely affected by the identified limitations in training for attacking ground targets. Improving imperfections in this area is a challenge, as they primarily result from the lack of armaments and the limitations of combat helicopters of the Polish armed forces.

Unfortunately, all combat helicopters of the Polish armed forces (Mi-2, Mi-24, W-3, W-3PL, Mi-8, and Mi-17) designed to support land component are unable to engage tanks and armoured fighting vehicles due to the lack of anti-tank-guided missiles. What's more, they do not have fire control systems that enable detection, reconnaissance, and tracking of targets and effective fire at targets during the day and at night from a safe distance of 6–9 km (beyond the range of MANPADS). In addition, their self-defence systems are not adapted to the threats identified on the battlefield during the Ukrainian-Russian war. For this reason, the Minister of National Defence approved a contract for the supply of thirty-two multi-role AW149 helicopters from 2023–2029 for the army's aviation, and the Polish side submitted a request for proposals to Washington regarding ninety-six AH-64E Apache attack helicopters, which are to be acquired as part of the KRUK programme (Serwis Rzeczypospolitej Polskiej, 2022b, 2022c). Taken together, these results suggest that it is necessary to acquire new helicopter platforms as soon as possible, together with elements of logistical support, and to start flight training related

[35] *The conclusion was drawn after an interview with two officer of the Army Aviation on 11 January 2023.*

to attacking armoured targets during the day and at night from a distance of more than 6 km in an air defence threat environment.

Recent research has suggested that Polish air force has much to do in terms of adjusting their capabilities to ensure the inviolability of Poland's territory. Moreover, their combat potential is currently modernised towards building capabilities necessary for NATO's collective defence (Zieliński, 2020, pp. 33–45). Although small states, despite their technological innovations, are not able to produce and gain from allies technologically advanced weapons in high numbers, should develop their defence capabilities at least in a limited manner (Česnakas, 2019, pp. 273–293). Identified directions of development of the Polish air force to face threats in the conflict under study appear to be largely universal—also possible to be used by NATO's eastern flank countries and even other European NATO countries, especially in terms of increasing the potential of ground-based anti-aircraft and anti-missile defence systems, which are never too many, improving procedures and methods of airspace control during war, and construction of shelters.

Conclusions

The aim of the article was to show the desired directions of development for the Polish air force, and even the air forces of other NATO countries, so that they are better prepared for the challenges identified in the conflict under study.

This article argued that the Polish air force should, in the first place, have at its disposal large resources of fighter planes equipped with advanced medium-range air-to-air missiles in order to destroy enemy's air attack assets or reduce their effectiveness. The ideal solution would be to reduce the combat capability of enemy aircraft on the ground or as close to their point of take off as possible as well as enemy's missile systems. It is therefore advisable for the Polish armed forces to have multi-purpose and fighter-bomber aircraft equipped with a joint standoff weapon, enabling them to hit targets beyond the range of enemy's anti-aircraft systems. The above airplanes could also be used for the tasks of air interdiction and close air support of land component as well as for missions flown in support of friendly naval forces. The above solution is reflected in Poland's defence policy comprising the replacement of Su-22 and MiG-29 aircraft with F-35 and FA-50. However, the analyses show that this potential should soon be increased by at least another twenty-five machines with similar characteristics. To provide support for the above-mentioned aircraft, the Polish air force should have a wider variety of aircraft at its disposal, for instance, intelligence, surveillance, and reconnaissance aircraft (ISR), SEAD assets, AWACS assets, and many others. Unfortunately, the Polish state, like the countries of NATO's eastern flank, cannot afford such a rich aviation arsenal in the foreseeable future; therefore, it should count on the support of NATO alliance countries in this area.

This study has identified that to protect aviation, it is necessary to organise multi-layer object-based air defence of each military airfield. For this reason, with the potential enemy in mind, short- and medium-range air defence systems should be organised in the direction of the approach to each significant military airfield–base defence zone (BDZ). The current plans to modernise air defence systems of the Polish air force must be re-examined with a view to ensuring anti-aircraft and anti-missile protection for the above-mentioned facilities.

This study has shown that passive air defence is an important factor in increasing the survivability of air forces on the modern battlefield. The Polish air force and that of other NATO states must focus on masking issues, prepare shelters for aviation equipment, and

hiding places for staff. In addition, the network of road runways located throughout the country needs to be rebuilt. Creation of a new road runway in the north-eastern Poland and plan to start aviation training using it suggest that Polish decision-makers are slowly beginning to see the need to recreate or build more road runways.

During cyclical exercises of air force units, their ability to disperse aircraft and means of logistical support should be improved. Take-offs and landings using road runways should be included in the aviation training programmes for every area of aviation. Helicopter aviation units should also be regularly moved away from airfields to other assembly areas on grass terrain during exercises. For the purposes of using helicopters in an operation, it is advisable to organise subunits with specialist knowledge of organising FARPs in army aviation units.

The research has also shown that all helicopter pilots should be trained in low-level, contour flights and NOE with the use of night-vision devices as well as have the skills to use anti-artillery air defence and anti-aircraft manoeuvres. Combat helicopters should definitely be active along with passive defence systems in order to increase their survivability on the battlefield. In addition, attack helicopters should have integrated fire systems that enable them to attack enemy ground forces from a distance of more than 7–8 km, beyond the range of MANPADs. Requirement to purchase new attack helicopters for Polish armed forces is not new and resulted, for example, from the KRUK programme, which assumed the acquisition of first machines in 2016. In the current situation, there is no time to postpone the implementation of the programme for the future. However, it is reasonable that the acquired helicopters meet the requirements formulated based on the conclusions based on the use of aviation in the war in Ukraine as articulated above.

This study found that during exercises, the command authorities of all organisational levels of armed forces should be trained in the field of airspace control during crisis and war time. Airspace users must be familiarised with the principles of its use, including the use of procedural and positive control methods to maximise the effectiveness of combat operations without unduly restricting the capabilities of any service or functional component and to reduce the risk of fratricide.

The next major finding was that the fight to achieve air superiority is part of a joint operation in which, apart from the key activities of the air force, other components of the armed forces play an important role. In the course of the ongoing war, various air defence systems of the Ukrainian land forces have effectively reduced the potential of the enemy's means to attack from the air and discouraged it from operating in the airspace. These systems complement multi-layer air and missile defence based on long-range systems.

This study confirmed that flying deep into enemy's territory, even during such missions as air-assault operations and the recovery of personnel, carries a high risk of losses. The results of this study indicated that the use of vertical landing and take-off (VTOL) of UAVs for PR missions should be considered in the future. Their task would be to act as recovery vehicles. UAVs should be able to perform tasks in an environment threatened by anti-aircraft systems, electronic warfare, and offensive cyber capabilities. Such platforms should be required to transport and move stealthily and quickly, which means that they should be as small as possible (they should have a small effective radar reflection area) so that they can move undetected as flying platforms in an enemy-occupied territory, but large enough to carry an aircrew (one or two soldiers). Building platforms that meet the above requirements would force changes in NATO tactics and procedures of joint PR on the modern battlefield.

The study was limited by the lack of scientific studies of the Ukrainian-Russian air war, because it started several months ago and is still on-going. Some of the information used for the research was obtained from the media. The author is aware that most of the Ukrainian and Russian media are biased because they are dependent on the state authorities. For this reason, great emphasis was placed on the verification of the research material using subsequent sources of information to confirm or falsify the same. Thirdly, the research covered the use of UAVs in the conflict in Ukraine to a very limited extent, hence this is an area that should be thoroughly explored in the future study.

The results of the presented research can and should become the basis for further in-depth research on the issue of the Polish air force, and perhaps even the air force and air defence of other NATO states, so that they are better prepared for the challenges identified in the Ukrainian-Russian conflict. The results of scientific research can be used in practice by representatives of headquarters and military institutions involved in the reorganisation of air force, necessitated by war challenges and the need to replace and modernise military equipment.

A key priority should, therefore, be to plan for a long-term reorganisation of air force, which can consume a lot of money, and increasing the capabilities of armed forces on the modern battlefield, *ipso facto,* the security of Poland and other NATO member nations.

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The data presented in this study is available on request from the corresponding author.

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