

Development of Air Battle in the Russia-Ukraine War (February 2022 to September 2024)

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Introduction

This paper examines how air battle evolved in the period from February 24, 2022 to September 30, 2024 in the Russia-Ukraine war. When conducting this research, this author took care to mainly take into account the views of air force officials and experts from the United States (U.S.), the United Kingdom and China, and to ascertain the evolution of all aspects of the war situation by carefully reading materials from the National Defence University of Ukraine. Furthermore, this author incorporated various media reports in the discussion as necessary.

As we will see in specific detail below, we can conclude that the struggle between the Russian military and the Ukrainian military for “air superiority”¹ is an extremely important perspective for understanding this war. This paper discusses the development of air battle from that perspective.

Dispersal of military power immediately before the outbreak of the war

In February 2022, the Russian Aerospace Forces (VKS) deployed air power of approximately 350 aircraft, including Su-30 fighters and the Su-34 and Su-35S state-of-the-art aircraft, to areas around Ukraine. The VKS not only had a numerical advantage, but was qualitatively superior to the Ukrainian Air Force (UkAF), due to the radars installed on its combat aircraft and its ability to launch long-range missiles.² The VKS also possessed outstanding Electronic Warfare (EW) equipment and Airborne Warning and Control Systems (AWACS), etc. The AWACS radar, which can see over long ranges, can communicate the situation of enemy aircraft to other Russian aircraft, so it was always in an advantageous position in air battle.

Most of the VKS fighter pilots participated on rotation in the air strikes on Syria in 2015, but their experience of complex operations and dropping Precision Guided Munitions (PGMs) was limited.³ However, the air defense units of the Russian military were capable of forming a large-scale and high-performance air

defense network including the SA-21 Surface to Air Missile (SAM) known as the S-400 which, when combined with the latest tracking and targeting radars, boasted a firing range three times that of the long-range SAMs of the UkAF.⁴

The opposing air defense units of the Ukrainian military consisted of a wide range of air defense radars, long-range SAMs (SA-10s), medium-range SAMs (SA-11s and SA-8s), anti-aircraft guns, and thousands of Man-Portable Air-Defense Systems (MANPADS).⁵

As tensions between the two militaries gradually increased, the UkAF, sensing that the Russian military was shifting into an attack posture, tried to limit the damage caused by Russian military attacks by dispersing and rotating its fighters and other air assets from its main air bases to auxiliary airfields to prevent concentrated deployment. The air defense units also set up dummy batteries and radar sites, augmented by signals deception, to draw missile attacks. Then, a few hours before Russia began its attack, the air defense units were deployed in a fanned-out manner, which also served as a form of dispersed protection.⁶

The start of the war and the Russian VKS air invasion

Before dawn on February 24, the military invasion by the Russian military began. Russia's concept of operations was to employ special forces to eliminate Ukraine's political leadership in Kyiv while ground forces sought to trap Ukraine's army units in the east and southeast. The VKS were tasked to degrade Ukraine's air defense capabilities and gain control of the air.⁷ However, the VKS did not actively use EW attacks to confuse the UkAF radars or deploy drones as decoys in order to identify the positions of the UkAF's SAM batteries;⁸ instead it used fighter-bombers and long-range cruise missiles to attack approximately 100 facilities related to the air defense of the UkAF (air force bases, radar, SAM batteries, anti-aircraft batteries, and the command and control systems) from a variety of directions.⁹

The Ukrainian battle formation that intercepted these attacks was much smaller and less capable, with the UkAF having approximately 50 MiG-29 and 32 Su27 fighters, and approximately 40 ground attack aircraft such as Su-24s and Su-25s.¹⁰ Despite that, the UkAF fighters promptly responded and intercepted the VKS aircraft invading at high altitudes. At the same time, however, Ukraine's air defense units hastily dispersed, preventing the UkAF from mounting a coordinated defense in the opening phase of the conflict.¹¹ The UkAF dispersed immediately before the start of the war, so most of its flying units and air defense units were able to survive the attacks from the VKS in the opening phase of the conflict.¹² Moreover, the invading VKS could not identify the positions of the dispersed Ukrainian air defense units promptly, which reveals the poor Battle Damage Assessment (BDA) capabilities on the Russian side. Nevertheless, the air defense units of the Ukrainian military were also in disarray, so for a while only the UkAF fighters intercepted the attacks.

The VKS air invasion was at the pace of an average of approximately 140 sorties per day, with its combat aircraft penetrating Ukrainian territory at medium altitudes for approximately 150 nautical miles (NM). However, the VKS aircraft only penetrated in formations of one to six aircraft each time, so the invasion was not as large-scale and did not involve as many aircraft as the invasion by the U.S. military in the 1991 Gulf War. Furthermore, ground attacks were mainly carried out by Su-25s with unguided bombs and rockets.¹³ Russian fighters such as Su-35s and Su-30s conducted combat air patrols (CAPs) at medium altitudes to provide cover for the attack aircraft for the first three days, shooting down MiG-29s, Su-27s, Su-24s, and Su-25s and other UkAF aircraft. The threat of Russia's high-performance SAMs and Su-35s gradually became greater, so the UkAF fighters were forced to shift to low altitudes for combat little by little in order to avoid these threats.¹⁴

In the opening phase of the conflict, the Russian military also attempted to seize Antonov Airport, located north of the capital Kyiv. However, several VKS transport aircraft carrying Russian paratrooper units were shot down, and although some of the paratroopers landed at the airport, the Ukrainian ground forces had destroyed the runway beforehand, so the following VKS transport aircraft could not land. The VKS did not provide air cover for the paratrooper units which landed at the airport, and the Russian military units isolated at the airport occupied it with only helicopter air support. However, they were mopped up by the Ukrainian military and were destined to be annihilated a few days later.¹⁵ In addition, the Russian military advancing from Belarus to the capital Kyiv was forced to detour from its route due to the sabotage of a dam by the Ukrainian military.¹⁶ As a result, many ground forces' vehicles were concentrated on limited routes, leading to traffic congestion, and they were attacked one after another by the Ukrainian military's Turkish-made drone, the Bayraktar TB-2.¹⁷ The Russian military, on the other hand, did not make extensive use of drones in the early stages, but gradually introduced the Orion reconnaissance and attack drone to the front lines, destroying the M777 howitzers provided to the Ukrainian military by the U.S.¹⁸

The fact that the drones of the Ukrainian military and the Russian military produced these surprising battle successes indicated that it will not be possible to talk about future warfare without drones going forward.

Russian VKS unable to gain air superiority

At the beginning of the war it was expected that the VKS, with its overwhelming air power, would promptly gain air superiority, but even after three days of the war, the VKS had not been able to gain air superiority.¹⁹ The organized air invasion by the VKS gradually decreased and as the Russian military advanced toward the capital Kyiv the VKS continued its isolated air operations. The background to the VKS stopping the organized air invasion was that the decapitation operation had failed. Subsequently, the Russian military's ground battle became a quagmire and the VKS was required to provide air cover immediately, so it was forced to change its policy from a focus on control of the air to close air support (CAS).²⁰

Even in such a situation, the VKS repeatedly launched missile attacks on UkAF radars, bases, infrastructure, etc. in an attempt to break through Ukraine's Integrated Air Defence System (IADS) capabilities.²¹ If the VKS had continued its Offensive Counter Air (OCA) operations in the same way, Russia might have gained air superiority, but the VKS's Suppression Enemy Air Defense (SEAD) operations were not effective in the first place. Moreover, the Russian military's BDA was also in a state where it could not be carried out quickly. And above all, due to the lack of flight training of VKS pilots, they had practiced hardly any drills on air invasions using multiple aircraft formations, so they did not have the ability to carry out SEAD operations using large-scale air invasions.²²

All of Russia's military services combined launched missiles at the pace of an average of approximately 24 missiles per day for the first three months of the war, consuming approximately 2,000 cruise missiles and approximately 240 ballistic missiles.²³ Despite that, the VKS, unable to adapt to the rapid changes in the combat space, was unable to degrade Ukraine's IADS capabilities or provide momentum to the Russian military's ground invasion. As a result, VKS aircraft and Russian military helicopters were forced to operate at low altitudes to avoid the Ukrainian military's air defense network, and days went by in which they did nothing but continue to launch unguided rockets. However, these aerial attacks were carried out daily on flight routes that were easy to predict,²⁴ making them easy prey for the Ukrainian military's huge number of MANPADS.²⁵

Formation of high-density air defense networks and the difficulty of gaining air superiority

In late March 2022, the Russian military's attempt to capture the capital Kyiv ended in failure, and the Ukrainian military recaptured the territory of northern Kyiv and Kharkiv. However, the Russian military began to concentrate its military power in eastern and southeastern Ukraine, and subsequently it launched a major offensive in these regions. The VKS continued its aerial attacks, using drones as decoys to weaken Ukraine's IADS capabilities. The VKS finally began to see coordination in their SEAD operations, in which, when the UkAF responded to the drones and activated their radars, Su-30 and Su-35 fighters launched Anti-Radiation Missiles (ARMs). As a result, the air defense units of the Ukrainian military gradually lost combat strength, and were forced to withdraw from the front lines, while the Russian aircraft gradually improved their ability to execute air operations at high altitudes.²⁶ Although the VKS faced challenges in SEAD operations, it was gradually producing results, while the UkAF's defensive counterair (DCA) operations were gradually falling into a situation in which they were at a disadvantage.

The Ukrainian military was attacking the southeastern front line using the U.S.-made High Mobility Artillery Rocket Systems (HIMARS) provided in June. Then the Russian ground forces, which were being attacked with precision, began to face an increasingly tough situation. In response to this situation, the VKS began

to provide cover to the Russian military from the air with CAS. In this way the VKS's mission was influenced by the circumstances of the Russian military's ground forces, so it developed air operations which lacked consistency. Then, in July, the VKS generally stopped sending fighter-bombers to penetrate deep into Ukrainian airspace, instead switching to attacks using stand-off weapons and long-range missiles. In the autumn of 2022, as the ground fighting intensified, the powerful air defense networks of both sides became densely concentrated on the ground. As a result, it became difficult for VKS and UCAF aircraft to easily enter the enemy's airspace. In addition, the large number of MANPADS possessed by both Russia and Ukraine posed a lethal threat to penetrating aircraft, even at low altitudes where radar detection was difficult.²⁷

Originally, the "air defense mission" was considered to be an extremely important role for the military of the former Soviet Union. For this reason, both the Russian military and the Ukrainian military have traditionally maintained large-scale air defense units. If the two were to engage in air battle, they would inevitably form a thicket of high-density air defense networks.²⁸ Therefore, in such a situation of parity, the result would be that they would deny each other's kill zones,²⁹ and neither side would be able to gain air superiority.³⁰

For that reason, the Russian military began to attack Ukraine using Iranian-made suicide drones, the Shahed 131 and 136.³¹ The Shahed flies at low altitudes at a slow speed of about 115 knots (kt) and carries 30 to 50 pounds (lbs) of explosives. Although it is relatively inexpensive at approximately \$30,000, it has a long range of 700 to 800 NM, meaning that it is not easy for Ukraine to identify the launch site and intercept it.³² The Russian military's tactics for using the Shahed have changed over time. At times they have used the tactic of openly flying the Shahed drones in groups to attract the attention of the Ukrainian military and then using that opportunity to secure an attack route for their long-range missiles,³³ and they have used other such tactics to turn the war situation in Russia's favor.³⁴ In October 2022, Ukraine, which was continuously being attacked by Russian suicide drones, also used a suicide drone to attack Tu-22M3 Backfires parked at Russia's Shaikivka Air Base, approximately 200 km from the border, damaging two aircraft.³⁵

Thus the air defense systems of both sides were extremely strong, so it continued to be impossible to secure air superiority and as a result OCA operations were developed, in which each side carried out attacks using suicide drones in an attempt to eliminate the other side's air power.

Waves of long-range missiles attacks and their interception by air defense units

As of 2023, Ukraine had not only sent a total of more than 100,000 drones of different types to the front lines,³⁶ but had also begun using suicide drones to attack Moscow and air bases.³⁷

Meanwhile, the VKS has avoided as much as possible flying manned aerial vehicles in operations to penetrate deep into Ukrainian territory, and instead has begun to send in many drones, cruise missiles, and ballistic missiles.³⁸ As of May 2023, Ukraine had shot down approximately 90% of Russian cruise missiles and unmanned aerial vehicles nationwide, and nearly 80% of ballistic missiles launched from the air and ground. In regions defended by the U.S.-made long-range SAM Patriot III missiles, it had shot down almost 100% of ballistic missiles from Russia.³⁹ Precisely for this reason, the VKS has been reluctant to use manned aerial vehicles to break through this strong air defense network of the Ukrainian military.

That May, ground fighting intensified in Bakhmut in eastern Ukraine, while in the skies above the capital Kyiv, a battle was taking place between UkAF Patriot missiles and Kinzhal (Kh-47M2) air-launched cruise missiles launched by VKS MiG-31s.

The UkAF's air defense units succeeded in intercepting the first wave of Kinzhal missiles, but in the subsequent second wave Kinzhal missiles launched from MiG-31s, Kalibr cruise missiles from the Black Sea Fleet, Iskander-M and S-400 missiles from the ground forces, and multiple Shahed drones all attacked from different directions at the same time.⁴⁰ As a result, the UkAF's air defense units were pressured by the interceptions, and their stock of SAMs gradually decreased.⁴¹ The operations of the Russian military involved using low-cost Shahed drones in the first stage to carry out widespread airstrikes to provoke the operation of the conventional air defense systems deployed in Kiev to intercept the drones. Then in the second stage, the Russians would target the positions of the air defense systems revealed by the diversion and destroy these air defense systems by attacking with Kalibr missiles from the sea and Iskander-M missiles from the ground. In the third and final stage, the moment the reserve Patriot missiles were activated, the MiG-31s on standby in the sky would launch multiple Kinzhal missiles in an attempt to eliminate the Patriot missiles.⁴²

Attempts to resolve the stalemate using drones

By August 2023, the struggle between the two militaries had begun to reach a stalemate. The Ukrainian military, struggling with ground resistance operations, changed its tactics to picking off high-value military targets in the Russian military, and began to utilize drones as a means to that end. The Ukrainian military, which was beginning to run out of the weapons and ammunition provided by Western countries, used long-range drones to destroy an Il-76 transport aircraft and other Russian assets parked at a Russian airbase approximately 350 km from the border⁴³ and also destroyed a Tu-22 supersonic bomber parked at Soltsy-2 Airbase about 400 NM from the border⁴⁴ in August during the same period. Furthermore, in September, it also began to attack SAMs (S-400s and S-300s) deployed in the Crimean Peninsula.⁴⁵

In this way, Ukraine had carried out a total of 190 long-range drone attacks by September 2023, aiming to destroy fuel facilities, airfields, and even the Kremlin in the capital Moscow,⁴⁶ and other important functions supporting the VKS.⁴⁷ Nonetheless, despite the spectacular battle successes of the long-range drones, the Ukrainian military on the front lines remained in a difficult position. Moreover, the counter-offensive carried out from summer to autumn 2023 ended in failure, and the arrival of military aid supplies from Western countries was delayed. These developments had an effect, so the Ukrainian military rapidly lost its spare capacity, including soldiers, ammunition, and SAMs for the air defense units.⁴⁸

Even in such a situation, on October 17 the Ukrainian military deployed the Army Tactical Missile System (ATACMS) provided by the U.S. for the first time in actual combat, attacking Russian military units stationed in Berdyansk and Luhansk in Ukraine, destroying helicopters, ammunition depots, air defense systems, and other equipment.⁴⁹ Meanwhile, the Russian military continued to use expensive Kinzhal and Kalibr missiles, and others, in an attempt to suppress the Ukrainian military's air defense network.⁵⁰ Nonetheless, as their stocks dwindled, they were forced to change tactics and began using cheaper Shahed drones and Russian-made loitering suicide drones called Lancets.⁵¹ The Russian military's tactic of using a large number of these suicide drones was aimed at attacking Ukrainian infrastructure facilities.⁵²

Even in November the ground fighting continued to resemble World War I-style trench warfare, but a new dimension began to be seen; namely, drones of the Russian military and the Ukrainian military loitering in the skies.⁵³ At the end of 2023, the Russian military launched 44 drones to carry out air strikes on Odesa and although 34 of them were intercepted the ten surviving drones hit Ukrainian power plants, taking away the electricity supply of approximately 1.5 million people.⁵⁴

The two militaries are using not only military drones, but also commercial drones of various sizes for diverse applications.⁵⁵ The Ukrainian military's use of these drones is particularly notable, and in February 2024 they even established "the Unmanned Systems Forces" while accelerating innovation in the development of drones for land, sea, and air.⁵⁶ There are actually abundant ideas for utilizing these drones, while anti-drone electromagnetic pulse guns have also evolved more and more.⁵⁷ In addition, the forms of combat involving drones have rapidly evolved beyond battlefield surveillance and direct attacks, with drones equipped with small explosives and operators equipped with first-person view (FPV) cameras directly flying drones into Russian armored vehicles, bunkers, and trenches.⁵⁸

Increasing dependence on stand-off weapons

In contrast to the Ukrainian military, which failed in its counteroffensive and is running out of ammunition, the Russian military has seized the opportunity to launch a series of offensive operations in eastern Ukraine since early 2024, and has been securing key positions.⁵⁹ In February, the VKS's latest stealth fighter, the Su-

57 Felon, was deployed in actual combat for the first time,⁶⁰ and it has also been operated as a launch aircraft for the new air-launched cruise missile (ALCM) Kh-69.⁶¹

Even after two years of hostilities, neither of the militaries has been able to break through the other's air defense systems or gain air superiority. Looking at the war overall, there has been a tendency for the two sides to gradually become more dependent on stand-off weapons such as long-range artillery, missiles, and drones. In March, the VKS began to drop glide bombs in large numbers from aircraft⁶² while taking the new approach of attempting to establish superiority on the battlefield.⁶³ Furthermore, Russia combined upgraded Shahed drones with long-range missiles to launch air strikes against Ukraine,⁶⁴ as it tried to get the Ukrainian people to lose the will to fight by destroying infrastructure such as power plants.⁶⁵

Meanwhile, the Ukrainian military has begun attempting to break through the anti-drone air defense network built by the Russian military's ground forces, using crowdsourcing, a method that has been actively adopted for commercial drones, to provide real-time feedback on areas for improvement while endeavoring to remodel and repair the drones.⁶⁶ In April, the UCAF's long-range drones began attacking Russia's Shahed manufacturing plant and oil refining facilities,⁶⁷ and an estimated 50 long-range drones were launched against Russia's Morozovsk, Kursk, and Yeysk airbases, destroying six fighters.⁶⁸

Nonetheless, the Russian military's superiority based on their amount of material remained strong. In May, a new front line was developed at Kharkiv, where the Russian military began to close in on Kharkiv, Ukraine's second largest city.⁶⁹ However, the Russian military began to rapidly lose personnel and equipment and in May it suffered record losses in personnel, artillery systems, and transport vehicles. Its losses of tanks and armored vehicles were the second highest since the start of the war,⁷⁰ and in this period it also lost one Ka-52 helicopter and seven Su-25 fighters all at once.⁷¹

Around June, military aid supplies finally began to arrive in Ukraine from Western countries. The 340 AEW&C (airborne early warning and control) aircraft provided by Sweden,⁷² the Mirage 2000 fighters⁷³ and ALCMs such as SCALP-EG/Storm Shadow⁷⁴ provided by France, the F-16 fighters provided by various European countries,⁷⁵ and others entered the preparation stage as the UCAF's new air power in the upcoming air battle. The European countries supplying these weapons approved their use against military targets in Russia, but with regards to the use of the ATACMS⁷⁶ ballistic missiles with a range of 300 km provided by the U.S., the restrictions on their use imposed by the U.S. remained.⁷⁷

The U.S. took the stance that the weapons it provided would only be allowed to be used against the Russian military "attacking or preparing to attack Ukraine in the border areas," so the Ukrainian military was unable to use the weapons that would be decisive.⁷⁸ Despite these problems, the Ukrainian military continued to attack military targets in Russian territory and to fight within Ukrainian territory, using also the weapons it had been supplied to date.⁷⁹ However, Ukraine found itself in a situation where it was forced to fight using a combination of weapons provided by Western countries and outdated weapons from the Soviet era. Many conventional weapons were still weapons made by the Soviet Union, and although they could be produced and procured domestically in Ukraine, it was unclear how long they would last. The Ukrainian

military began to use the weapons from the Western countries extensively, and naturally they were also forced to rely heavily on the Western countries for the supply of ammunition for those weapons.⁸⁰

The problem of having to change the weapons used during the war also arose in the field of IADS. The air defense units of the Ukrainian military were already running out of stocks of anti-aircraft shells and SAMs. This problem of a shortage of ammunition affected many systems, from MANPADS like the Stinger to long-range SAMs like the Patriot.⁸¹

Russia's conversion to attrition warfare and Ukraine's resistance

Russia, which received large amounts of weapons and ammunition from Iran and North Korea, had a large stockpile of anti-aircraft shells and SAMs.⁸² Russia continued to have an overwhelming advantage as, for every shell fired by the Ukrainian military, the Russian military would fire back ten shells, and the Russian military even used its SAMs as substitutes for ground attacks of the kind which usually use surface-to-surface missiles (SSMs).⁸³ Furthermore, they regularly attacked Ukraine using Shahed drone attacks in combination with various types of long-range missiles.⁸⁴ The tactic of simultaneously launching these stand-off weapons from air, land, and sea platforms produced the results of not only frightening the Ukrainian people,⁸⁵ but also steadily depleting the Ukrainian military's SAM stocks.⁸⁶

Therefore, the Ukrainian military began to lack all of the resources needed to continue the combat, so they tried to hold the current front lines while reducing their use of ammunition.⁸⁷ For that reason, there were cases in which the Ukrainian military on the ground was forced to immediately retreat from Russian military positions they had managed to occupy.⁸⁸ Needless to say, all this had an impact on air battle.⁸⁹

Having skillfully transformed the war into a war of attrition, Russia also began dropping UMPB D-30SN glide bombs on Ukrainian positions from VKS Su-34 Fullback aircraft.⁹⁰ As the air defense units of the Ukrainian military have weakened, the Russian military has stepped up its intelligence, surveillance, and reconnaissance (ISR) activities and started sending drones to loiter around the front lines. Moreover, it has been destroying the Ukrainian military's howitzers, drones, and anti-aircraft missiles as soon as it identifies their positions.⁹¹ As of September 2024, the VKS is gaining more freedom of action. The Su-25s can now openly attack targets directly, and attack helicopters such as the Mi-28 Havoc and Ka-52 Hokum can now launch the cutting-edge Kh-39/LMUR helicopter-launched air-to-surface missiles.⁹²

Meanwhile, the UCAF, which was extremely short of SAMs, had to send fighters from the CAPs to intercept drones flying from Russia. Nonetheless, it was far too inefficient to have fighters flying at high speed engage drones flying at low speeds. For that reason, a tactic was adopted in which a sniper rode on a propeller training aircraft in order to fly parallel to the drone and shoot it down. In addition, the tactic of ramming Russian military drones with FPV drones was also tried.⁹³ Nonetheless, no matter which tactic was

used, it was difficult to effectively intercept the large number of drones launched from Russia, and the damage to Ukraine caused by drones continued to increase.

Conclusion

This paper discusses how air battle in the Russia-Ukraine war has evolved in the period from February 24, 2022 to September 30, 2024. Two and a half years have passed since the start of the war, and the air power of the two militaries has not been able to break through the other's air defense systems or gain air superiority. On the other hand, it is necessary to note that in the war overall, even in situations where air superiority cannot be secured, there has been an increasing reliance on stand-off weapons such as missiles, drones, and glide bombs. Attempts to use these weapons to break through the enemy's air defense systems and degrade the capabilities of their IADS (Integrated Air Defence System) are being seen.

Just from looking at the air battle so far, the side attempting to break through air defense systems is increasingly using stand-off weapons. We can conclude that in order to counter this, it will be essential for the side that wants to maintain air defense systems to have a stable supply of SAM munitions. One of the important lessons obtained from the Ukraine war is that gaining air superiority will probably be an extremely important element in the overall war situation. There is a high likelihood that if air superiority cannot be gained, the ground fighting will remain at a stalemate, and the situation will continue to resemble the trench warfare of World War I.

In any case, in the current situation where neither of the two militaries has gained the freedom to operate in an environment of air superiority, it can be concluded that as long as the two militaries continue their war of attrition, the ultimate winner will be the side that can deploy more military power and soldiers.

¹ The latest U.S. Air Force doctrine explains that "air superiority" is "that degree of control of the air by one force that permits the conduct of its operations at a given time and place without prohibitive interference from air and missile threats" (U.S. Air Force, Counter Operation, *Air Force Doctrine Publication 3-01*, June 15, 2023); Yanagida, Osamu [柳田修], "Control of the Air and Air Superiority in the U.S. Military [米軍における『制空権』と『航空優勢』]," *Briefing Memo* [ブリーフィングメモ], *National Institute for Defense Studies* [防衛研究所], June 2020.

² David A. Deptula and Christopher J. Bowie, "The Significance of Air Superiority: The Ukraine-Russia War," *Mitchell Institute Policy Paper*, Vol. 50, July 2024, p. 4.

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⁴ Charlie Gao, "Russia's S-300 Provided Capable Air Defense, but the S-400 System is World-Class," *The National Interest*, February 20, 2021, <https://nationalinterest.org/blog/reboot/russias-s-300-provided-capable-air-defense-s-400-system-world-class-178563>.

⁵ National Defence University of Ukraine, *Lessons Learned of Russian-Ukrainian War*, Ministry of Defence of Ukraine, 2023, pp. 9-13.

⁶ Deptula and Bowie, "The Significance of Air Superiority," p. 4.

⁷ Deptula and Bowie, "The Significance of Air Superiority," p. 4.

⁸ Mykhailo Zabrodskyi, Jack Watling, Oleksandr Danylyuk, and Nick Reynolds, *Preliminary Lessons in Conventional Warfighting from Russia's Invasion of Ukraine*, London: RUSI, February-July 2022.

- ⁹ National Defence University of Ukraine, *Lessons Learned of Russian-Ukrainian War*, p. 99.
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- ¹¹ Deptula and Bowie, “The Significance of Air Superiority,” p. 4.
- ¹² Zabrodskiy et al., *Preliminary Lessons in Conventional Warfighting from Russia’s Invasion of Ukraine*, p. 21.
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- ¹⁴ Liu [刘], “Seen from Russia’s Invasion of Ukraine: Ukrainian Air Power [从俄乌冲突看：乌空军战力],” pp. 53-54.
- ¹⁵ “One Year After Russia’s Invasion of Ukraine, What Problems Have Been Exposed? Interpretation by Jin Yinan [俄乌冲突一周年，暴露了哪些问题？金一南解读],” *Shanghai Observer* [上观新闻], February 24, 2023, <https://www.jfdaily.com/wx/detail.do?id=586010>.
- ¹⁶ National Defence University of Ukraine, *Lessons Learned of Russian-Ukrainian War*, pp. 117-118.
- ¹⁷ Xiao, Mei [骁媚], “Flying Around the Battlefields of Russia and Ukraine: How Big is Turkey’s Unmanned Aerial Vehicle Force? [驰骋俄乌战场：土耳其无人机战力几何?],” *Aerospace Knowledge* [航空知识], No. 621 (January 2023), pp. 42-43; National Defence University of Ukraine, *Lessons Learned of Russian-Ukrainian War*, p. 119.
- ¹⁸ Chinese experts point out that the performances of the Bayraktar TB2 and Orion are far inferior to those of advanced drones such as the U.S. military’s Predator and Reaper drones or People’s Liberation Army drones, such as the Wing Loong made by the Aviation Industry Corporation of China’s ChengDu Aircraft Design & Research Institute and the Rainbow made by the China Academy of Aerospace Aerodynamics. (“Current Affairs in Depth: Unmanned Aerial Vehicles Participate in the War; How will Future Wars be Fought? [「环时深度」无人机参战，‘未来战争’怎么打?],” *Huanqiu.com* [环球网], May 28, 2022).
- ¹⁹ Aita, Moriki [相田守輝], “Digital Transformation of the Chinese Air Force: Initiatives Observed in the PLAAF’s Introduction of a New Maintenance Management System [中国空军をめぐるデジタルトランスフォーメーション——新しい整備管理システム導入から見える取り組み——],” *Security & Strategy* [安全保障戦略研究], vol. 3, no. 2 (March 2022), pp. 85-86.
- ²⁰ There were several factors behind this. The fact that many UkAF fighters had been shot down by VKS aircraft and it took time to reconstitute the air defense units was relevant, but the fundamental factor was the failure of Russia’s decapitation operation against the political leadership of Ukraine (Deptula and Bowie, “The Significance of Air Superiority,” p. 5).
- ²¹ In particular in the northern areas around Kyiv, Anti-Radiation Missile attacks were carried out by Su-35s and limited attacks were carried out by Su-24s using PGMs.
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