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Russian Combat Air Strengths and Limitations: Lessons from Ukraine

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Abstract

This study provides an in-depth examination of the performance of the Russian Aerospace Forces (VKS) over Ukraine, and an analysis of where and why this performance differed from Western civilian and military pre-war expectations. It draws on fieldwork in Ukraine by the author, including interviews with senior Ukrainian Air Force commanders, military scientists, and inspection of captured and recovered Russian weapons and aircraft systems. The primary purpose of the study is to provide an open-source assessment of the enduring threat posed by the VKS to Ukraine in the short term, and to NATO nations in the medium and long term. To that end, the final section of the study looks specifically at the nature of that threat; particularly in the context of Russia's highly effective ground-based air defence network and long-range precision fires capabilities.

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Lessons from Ukraine about Russian Combat Air Strengths and Limitations

One of the defining features of the February 2022 Russian invasion of Ukraine and subsequent full-scale war has been the inability of the much larger and more technologically advanced Russian Aerospace Forces (VKS) to establish and exploit air superiority over its Ukrainian opponents. This came as a surprise to most Western and Ukrainian military and civilian analysts and has prompted a widespread reappraisal of the current capabilities of the VKS and, perhaps more importantly, the potential threat that it can pose in the medium term.[1] However, these efforts have been hindered by the lack of granular information about the actual tactics and operational tempo of VKS operations over Ukraine.

For external analysts, areas of VKS weakness have generally been possible to infer from the absence of visible operations and destructive effects. Examples of visible weakness include the VKS's inability to effectively conduct suppression and destruction of enemy air defense (SEAD/DEAD) operations, or to project fixed-wing or rotary strike sorties over most of Ukraine. However, the sorties that Russia's combat aircraft *have* been flying and the effects they have been achieving are much harder for outside observers to see and. In the land domain, ubiquitous small unmanned aerial vehicles (UAVs) and handheld cameras have provided a rich, albeit fragmentary, source of information on the tactics and nature of operations being undertaken by both sides at each stage in the conflict.[2] In contrast, footage available for air operations has been limited to cockpit footage that is carefully collated and released

[1] For example, see Samuel Charap and Scott Boston, "The West's Weapons Won't Make Any Difference to Ukraine," *Foreign Policy*, Jan. 21, 2022, https://foreignpolicy.com/2022/01/21/weapons-ukraine-russia-invasion-military/, accessed Dec. 16, 2022; Thomas Newdick, "How the Russian and Ukrainian Air Forces Stack Up Against Each Other," *The War Zone*, Dec. 23, 2021, https://www.thedrive.com/the-war-zone/43603/face-off-over-donbas-how-russian-and-ukrainian-air-forces-stack-up, accessed Dec. 16, 2022. For this author's pre-war estimation of Ukraine's options against the VKS, see Justin Bronk, "Ukrainian Air Defence Options in the Event of a Russian Attack," *RUSI Commentary*, Feb. 8, 2022, https://rusi.org/explore-our-research/publications/commentary/ukrainian-air-defence-options-event-russian-attack, accessed Dec. 16, 2022.

[2] See, for example, WarLeaks—Military Blog, "Watch How This Single Ukrainian Tank Takes on an Entire Russian Column in Extraordinary Combat Footage," YouTube, Apr. 6, 2022, https://youtu.be/BfTrQiFkWyk, accessed Dec. 16, 2022 and The Sun, "Ukrainian Troops Destroy Russian Infantry Fighting Vehicles in Donetsk," YouTube, Dec. 7, 2022, https://youtu.be/UtmcsdjTXD8, accessed Dec. 16, 2022.

periodically by both sides and clips filmed from the ground of aircraft either flying past or sometimes being engaged by surface-to-air missiles (SAMs).[3]

To help bring greater granularity to the Western picture of Russian combat air operations in Ukraine, the British think tank the Royal United Services Institute (RUSI) produced a special report based on face-to-face interviews conducted in Ukraine in August and October 2022 with senior Ukrainian Air Force (UkrAF) aviation, ground-based air defense (GBAD), intelligence, maintenance, and capability development commanders.[4] In compiling this report, the authors also inspected and disassembled significant numbers of Russian missiles, UAVs, and other weaponry, and conducted numerous secondary interviews with external intelligence professionals to cross-reference the material gathered. This paper builds on that work to assess the strengths and weaknesses of the Russian VKS as the war in Ukraine moves towards its second year.

The paper begins with an analysis of the major successes and failures of the VKS in operational and tactical terms during 2022. Next, it provides an analysis of the likely core reasons for the significant differences between the observed combat performance of the VKS over Ukraine and pre-war assessments. The paper then concludes with a section that examines the potential medium-term threat posed by the VKS to both Ukraine and, potentially, European NATO countries.

VKS Performance in the Russia-Ukraine War

It is important to begin by acknowledging the most influential failure of the VKS fixed-wing forces over Ukraine: the failure to find, fix, and destroy the bulk of Ukraine's GBAD assets. As 2022 came to a close, the UkrAF continued to operate a significant number of its 9M38M1 (SA-11) "Buk," S-300PS/PT (SA-10) "Grumble," and S-300V1 (SA-12) "Gladiator" SAMs, and the Ukrainian Army continues to operate numerous 9K33 (SA-8) "Osa" SAMs.[5] The effective

[3] For example, The Sun, "Dramatic Moment Ukrainian Troops Shoot Down Russian Helicopter Using British 'Starstreak' Missiles," YouTube, Apr. 2, 2022, https://youtu.be/rXnjQmoV2D8, accessed Dec. 16, 2022; The War Zone, "Ukrainian Mig-29 Fulcrum Firing US AGM-88 High Speed Anti-Radiation Missile," YouTube, Aug. 30, 2022, https://youtu.be/BuOkZc2I8cw, accessed Dec. 16, 2022; WarLeaks—Military Blog, "Russian Su-30 Shot Down in Southern Ukraine," YouTube, Sep. 24, 2022, https://youtu.be/BuOkZc2I8cw, accessed Dec. 16, 2022; The Sun, "Russian Fighter Planes Launch Air Strikes at Ukrainian Military Facilities," YouTube, Nov. 11, 2022, https://youtu.be/d-L2oVet_a4, accessed Dec. 16, 2022.

[4] Justin Bronk, Nick Reynolds, and Jack Watling, "The Russian Air War and Ukrainian Requirements for Air Defence," *RUSI Special Report*, Nov. 7, 2022, https://static.rusi.org/SR-Russian-Air-War-Ukraine-web-final.pdf, accessed Dec. 16, 2022.

[5] Author interviews with UkrAF GBAD commanders and military intelligence officers, Ukraine, Oct. 2022. Cross-referenced in ongoing discussions with Western military intelligence officers in the United Kingdom and United States, Nov. and Dec. 2022.

employment of these systems by Ukrainian forces has denied Russia air superiority over Ukraine and continues to force the VKS to operate very cautiously near the front lines.

Despite the overall mismatch in force ratios in favor of the VKS in the air domain and the Russian ground forces on land, the scale of the SEAD/DEAD challenge for the VKS is significant. Ukraine began the war with an impressive air defense inventory, the core of which was three brigades and two regiments of S-300PS/PT systems (SA-10), comprising an estimated 25 fire units with up to 12 launchers and a radar and command vehicle in each.[6] In addition, the UkrAF fielded one brigade of S-300V1s (SA-12) with at least two fire units and two brigades of SA-11 Buk with at least 11 fire units, and the Army fielded over 100 SA-8 Osa vehicles.[7] The Ukrainian air defense forces also fielded several units of largely immobile but deeply modernized S-125 (SA-3) Goa and reconditioned mobile 9K330 (SA-15) "Tor" systems. However, unlike in the land domain, where the Ukrainian Army has been reinforced by large quantities of Western-made equipment since the start of the invasion, in the air defense realm, Ukraine largely defended its skies with its own systems until October 2022.

Western partners supplied thousands of shoulder-fired man-portable air defense systems (MANPADS), such as Stinger, especially during the initial months of the invasion.[8] They proved an important threat to Russian jets and helicopters at low altitudes, alongside Ukraine's extensive existing stockpiles of Igla and Strela MANPADS. However, it was thanks to Ukraine's own ground-based SA-11, SA-8, and S-300 SAMs that Russian aircraft were forced to fly low, inside the MANPADS threat envelope, in the first place. Since late October, IRIS-T SLM air defense systems, German-donated Gepard self-propelled anti-aircraft guns (SPAAGs), and United States–donated NASAMS batteries have been introduced and become increasingly important for cruise missile and counter-loitering munition defense around Ukrainian cities and key civilian infrastructure sites.[9]

To neutralise this extensive Ukrainian air defense network, Russia began the invasion with a significant SEAD campaign that also included DEAD efforts. The former was far more successful than the latter. On the morning of February 24, 2022, Russian Tu-95MS and Tu-160 strategic bomber aircraft from the VKS long-range aviation (LRA) force conducted a series of massed

[6] Alexander Mladenov, "Inside Ukraine's Extensive but Ageing Air Defence System," *Key Aero,* Jan. 17, 2022, https://www.key.aero/article/inside-ukraines-extensive-ageing-air-defence-system, accessed Dec. 16, 2022. Numbers quoted by Mladenov were broadly verified in author interviews with UkrAF GBAD commanders in Ukraine, Oct. 2022.
[7] Ibid.
[8] Alexandria Chastenet de Gery, "The West Needs to Keep Supporting Ukraine with MANPADS," *The German Marshall Fund*, Apr. 20, 2022, https://www.gmfus.org/news/west-needs-keep-supporting-ukraine-manpads, accessed Mar. 19, 2023.
[9] For an outline of Western air defense supplies sent, see Michael Peck, "Ukraine Is Scrambling to Shoot Down Russian Missiles and Drones. Here Are the Weapons Other Countries Are Sending in to Help," *Business Insider*, Nov. 14, 2022, https://www.businessinsider.com/countries-are-giving-ukraine-air-defenses-for-russian-missiles-drones-2022-11?r=US&IR=T, accessed Dec. 16, 2022.

sorties to launch waves of Kh-101 and Kh-555 air-launched cruise missiles (ALCMs) against Ukrainian air defense sites.[10] These were coordinated with salvos of 3M-54 Kalibr naval cruise missiles from surface ships and submarines in the Black Sea, and 9M720/9M723 ballistic missiles and 9M728 cruise missiles fired from Iskander systems on land.[11] In other words, Russia employed synchronized long-range precision fires effects from multiple domains as part of a unified fires plan. It is important to note, however, that although several hundred missiles were fired, the strike plan fell far short of the weight of fire that Russia could have employed given its missile stocks and available launch platforms.

The standoff missile strikes were accompanied by effective electronic warfare attacks to degrade and damage Ukrainian early warning, target acquisition, and fire control radars. Many Ukrainian air defense systems and radars were effectively blinded. Some cases required the replacement of components and multiple full system resets to bring the systems back online.[12] Russia was able to leverage its detailed understanding of the base SA-10, SA-12, SA-11, and SA-8 systems operated by Ukrainian air defense forces, since all of these systems had been made originally in the Soviet Union and have since been operated by the Russian Armed Forces. However, Ukraine had independently upgraded many of the key hardware components and the software controlling these systems in successive modernization programs since gaining independence, meaning that Russian electronic attacks caused less permanent damage than Russian planners anticipated.[13]

The Russian missile strikes and electronic attack efforts showed a strong understanding of the Ukrainian air defense network laydown, with more than 75 percent of sites accurately engaged in the first days of the invasion.[14] Crucially, however, Ukrainian forces received high-fidelity intelligence from foreign partners about the impending attack in the hours leading up to the invasion and so most of the air defense sites that were hit by the Russian strikes had already been vacated by mobile systems.[15] However, in the Kherson and Zaporizhzhia regions, multiple

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[10] Author interviews with UkrAF aviation and GBAD commanders and military intelligence officers, Ukraine, Oct. 2022.

[11] Ibid. See also Sam LaGrone and Heather Mongilio, "Russian Navy Has Limited Role in Initial Invasion of Ukraine," *USNI News*, Feb. 24, 2022, https://news.usni.org/2022/02/24/russian-navy-has-limited-role-in-initial-invasion-of-ukraine, accessed Dec. 16, 2022.

[12] Author interviews interviews with UkrAF aviation and GBAD commanders and military intelligence officers, Ukraine, Oct. 2022.

[13] Ibid.

[14] Ibid. See also Mykhaylo Zabrodskyi, Jack Watling, Oleksandr V. Danylyuk, and Nick Reynolds, "Preliminary Lessons in Conventional Warfighting from Russia's Invasion of Ukraine: February–July 2022," *RUSI Special Report*, Nov. 30, 2022, p. 24-25, https://static.rusi.org/359-SR-Ukraine-Preliminary-Lessons-Feb-July-2022-web-final.pdf, accessed Dec. 16, 2022.

[15] Ibid. See also Ministry of Defence of the Russian Federation, "Footage of the Destroyed Position of the S-300 Air Defence System Division of the Armed Forces of Ukraine," Mar. 30, 2022, https://eng.mil.ru/en/special_operation/multimedia/video/watch.htm?id=17688@morfVideoAudioFile, accessed Dec. 16, 2022.

SA-10 and SA-3 air defense sites that were immobile or could not be moved in time were badly hit.[16]

Immediately after the standoff missile strikes on Ukrainian air defenses, VKS Su-34 "Fullback" frontal bombers flew dozens of sorties up to 300 kilometers inside Ukrainian airspace to perform additional attacks on SAM sites, especially along the routes being used by massed helicopter formations to insert VDV and Spetznaz forces at Hostomel and elsewhere. Around 75 percent of these sorties were carried out by single aircraft against each target, with most of the remaining 25 percent being pairs rather than larger formations.[17] The most common weapons used were stacks of unguided bombs, and most strikes were carried out from around 4,000 meters. As with the cruise missile strikes, most of these fixed-wing airstrikes were conducted with reasonable accuracy against air defense positions that had, until only a few hours previously, been occupied by Ukrainian SAM systems, mobile radars, and command posts. However, for both the missile and fixed-wing aircraft strikes, Russian battle damage assessment was poor and follow-up strikes were seldom conducted, even though most of the strikes did not produce the intended physical effects.[18]

In assessing the initial VKS SEAD/DEAD performance, the physical damage was limited and did not create the DEAD effect that had been built into Russian overall campaign planning assumptions. However, the strikes forced Ukrainian SAM units to repeatedly reposition. This, alongside the electronic warfare effects, created a sufficient SEAD effect to allow two waves of Russian airborne forces (VDV) to be inserted by large-scale helicopter assaults into Hostomel airport (and other locations elsewhere in Ukraine) via routes that should have been defended by multiple Ukrainian air defense positions.[19] Collectively, the Russian SEAD effort was successful in itself, since it forced the Ukrainian fighter force to conduct the vast bulk of air defense tasks on its own during the first two days of the war, exposing it to serious losses from Russian GBAD and fighter patrols.[20]

The most significant limiting factor in terms of the initial VKS strike campaign was that dynamic battle damage assessment and retargeting processes were not granular enough or fast enough to account for Ukraine's successful repositioning of most of its mobile air defenses in the hours leading up to the attack to achieve large-scale DEAD results. However, it should be

[16] Author interviews with UkrAF aviation and GBAD commanders and military intelligence officers, Ukraine, Oct. 2022.
[17] Ibid.
[18] Ibid. See also Zabrodskyi et al., "Preliminary Lessons."
[19] Zabrodskyi et al., "Preliminary Lessons." See also Sebastien Roblin, "Pictures: In Battle for Hostomel, Ukraine Drove Back Russia's Attack Helicopters and Elite Paratroopers," *19FortyFive*, Feb. 25, 2022, https://www.19fortyfive.com/2022/02/pictures-in-battle-for-hostomel-ukraine-drove-back-russias-attack-helicopters-and-elite-paratroopers/, accessed Dec. 16, 2022.
[20] Justin Bronk with Nick Reynolds and Jack Watling, "The Russian Air War and Ukrainian Requirements for Air Defence," *RUSI Special Report,* Nov. 7, 2022, p. 6-12, https://static.rusi.org/SR-Russian-Air-War-Ukraine-web-final.pdf, accessed Dec. 16, 2022.

acknowledged that the VKS succeeded in producing an extensive and generally accurate target list for LRA and fighter-bomber regiments, and the strike plan was well coordinated with ground forces' long-range strike assets, electronic warfare systems, and naval fires. This targeting process was largely informed by an extensive network of human intelligence (HUMINT) assets, including multiple long-term penetrations of the Ukrainian state and military hierarchy, as well as teams from the Main Directorate of the General Staff of the Armed Forces of the Russian Federation (GRU) and other Russian special services agencies.[21] The VKS had also conducted regular Su-24MR "Fencer-E" and Il-20M "Coot" electronics intelligence gathering reconnaissance sorties from January 2022 onward along Ukraine's borders to help detect and map changes in the Ukrainian air defense laydown.[22]

Fighter patrols were another area of comparative VKS success in the initial days of the invasion. While the ground strike sorties flew into Ukrainian airspace, Russian Su-35S and Su-30SM multirole fighters conducted independent combat air patrols at higher altitudes of around 8,000 meters. Several Russian fighters engaged UkrAF strike sorties and fighter patrols in uneven combat, while others fired numerous Kh-31P and older Kh-58 anti-radiation missiles (ARMs) against any illuminated Ukrainian radars.[23] Both the ARMs and the R-77-1 (NATO designation: AA-12B) air-to-air missiles were generally launched at long ranges and with cumbersome command and control procedures that together greatly reduced the probability of kill for each shot.[24] Disciplined use of short illumination times and regular relocation tactics by Ukrainian SAM operators further reduced the hard-kill effectiveness of Russian ARM launches. Attempts to coordinate the ARM launches for SEAD with Su-25s flying alone or in pairs at low altitudes to find and conduct DEAD strikes were made throughout March and April, but were not successful.[25] However, Ukraine lost a significant number of fighter and ground-attack jet sorties from its Su-27, Mig-29, Su-24, and Su-25 fleets as well as a light trainer jet to a mix of VKS fighters and long-range SAM engagements during the first week of the invasion.[26]

The radar and missile performance of the primary Russian Su-35S and Su-30SM fighters has been impressive throughout the conflict. The N035 Irbis-E and N110M Bars-M radars on the

[21] Author interviews with senior Ukrainian intelligence officers from multiple intelligence agencies, Ukraine, Oct. 2022.
[22] Ibid.
[23] Author interviews with UkrAF aviation and GBAD commanders and military intelligence officers, Ukraine, Oct. 2022.
[24] Ibid. See also HUD footage in film from VKS sorties such those in as Kirill Kunetsky and Nikolay Baranov, "В МО РФ показали кадры применения Су-35 в ходе спецоперации на Украине" ["The Ministry of Defence of the Russian Federation Showed Footage of the Use of Su-35 During a Special Operation in Ukraine"], *Zvezda*, Mar. 7, 2022, https://tvzvezda.ru/news/202237820-suPZe.html, accessed Dec. 16, 2022.
[25] Author interviews with UkrAF aviation and GBAD commanders and military intelligence officers, Ukraine, Oct. 2022.
[26] Ibid. See also some of the confirmed losses geolocated in Stijn Mitzer and Joost Oliemans, "List of Aircraft Losses During the 2022 Russian Invasion of Ukraine," *Oryx*, Mar. 20, 2022, https://www.oryxspioenkop.com/2022/03/list-of-aircraft-losses-during-2022.html, accessed Oct. 18, 2022.

two respective fighters give them a major advantage over Ukrainian fighters in a meeting engagement with up to five times the effective range, greater tactical flexibility with track-while-scan (TWS) capabilities, and significantly better ability to burn through electronic interference compared to the radars carried on Ukrainian Su-27P and MiG-29 fighters.[27] Both radars have also performed well in look-down, shoot-down engagements against very low-flying jets, helicopters, and UAVs trying to hide in ground clutter.[28] Su-34 fighter bombers and also Su-30SM and Su-35S fighters have also generally carried L-175 "Khibiny" electronic warfare pods throughout the war, although during the first week many did not have them fitted.[29] The Khibiny pods have proven effective at degrading Ukrainian in-flight communications and radar performance, although they also interfere with Russian radar performance when in use.[30]

Meanwhile, the use of the AA-12B medium range air-to-air missile has consistently allowed Russian pilots to fire at much greater ranges than their Ukrainian opponents, who have been limited to shorter ranged R-27R/ER (AA-10A/C) missiles for beyond-visual-range combat.[31] The combination of an active-radar seeker head on the AA-12B and the TWS capabilities of the N035 and N110M radars has also allowed Russian fighters to engage Ukrainian fighters and ground-attack jets without sacrificing situational awareness or giving a tracking lock or missile launch warning to their opponents. TWS also allows Russian pilots to guide multiple missiles simultaneously against multiple targets, and the active seeker on the AA-12B allows the launching fighter to turn away and break radar lock to maintain positional advantage or defend against any incoming shots once the missile has "gone active" and acquired the target for itself.[32] By contrast, Ukrainian pilots have had to get much closer and illuminate Russian aircraft in a single-target-track (STT) lock before firing. An STT provides reflected radar energy to guide the semi-active seeker on the AA-10A/C missile, but the lock must be maintained until missile impact. Furthermore, the amount of concentrated radar energy involved in an STT lock also generally ensures that Russian pilots receive warnings about locks and missile launches from their radar-warning receivers.

Given the much stronger technical capabilities of Russian fighters, the threat from long-range Russian SAM systems, and the fact that Ukrainian pilots have been consistently outnumbered in the air, Ukrainian fighters have been consistently forced to fly at very low altitudes using

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[27] Author interviews with UkrAF aviation commanders and military scientists, as well as inspection and disassembly of Russian R-77-1 (AA-12B) and R-37M (AA-13) air-to-air missiles, Ukraine, Oct. 2022. For more detail, see Bronk, Reynolds, and Watling, "The Russian Air War."
[28] Ibid.
[29] Zabrodskyi et al., "Preliminary Lessons."
[30] Author interviews with UkrAF aviation commanders and military scientists, as well as inspection and disassembly of Russian R-77-1 (AA-12B) and R-37M (AA-13) air-to-air missiles, Ukraine, Oct. 2022. For more detail, see Bronk, Reynolds, and Watling, "The Russian Air War.".
[31] Ibid.
[32] Ibid.

terrain masking and clutter to try to evade early detection. However, missiles fired from low altitudes and at correspondingly slower speeds against faster, higher-flying targets must overcome additional aerodynamic drag in the dense air at low altitude and also work against gravity to reach their targets with enough kinetic energy left to complete a successful intercept. In other words, the Russian fighter force radar and missile capabilities forced Ukraine to adopt tactics in aerial clashes that further increased the effective range disparity between their missiles. During the first few days of the war, Ukrainian fighter pilots used very low-level terrain masking and clutter to, in some cases, get close enough to higher flying Russian aircraft to fire missiles without being locked onto and engaged.[33] However, they lost significantly more aircraft to the combination of Russian fighters and SAMs than they were able to claim as high-confidence kills.[34]

The lack of success conducting DEAD operations against the Ukrainian mobile SAM systems, which began to take a significant toll of Russian fighters and helicopters from the third day of the invasion, meant that VKS fighter patrols were rapidly forced back to high altitudes on their own side of the frontlines. However, they have continued to pose a serious threat to Ukrainian fighter, ground-attack, helicopter, and TB-2 Bayraktar UAV sorties near the front lines, even at very low levels.[35] The range at which Russian combat air patrols (CAPs) can take valid missile shots against Ukrainian aircraft has also significantly increased since September 2022. The key change has been the use of large numbers of the long-range R-37M (AA-13) air-to-air missiles by both Mig-31BM interceptors and modified Su-35S fighters.[36] Better coordination has also been observed between Russian fighters on CAP and supporting A-50U and Il-20 command and control and surveillance aircraft as the war has progressed.[37] Therefore, one area where the VKS can be assessed as having been reasonably successful is in its use of fighter CAPs to provide an enduring threat and deterrent against Ukrainian sorties close to the front lines.

One area where the VKS has almost completely failed to be effective throughout the war, however, is in providing dynamic close air support to Russian units on the battlefield. Once it became clear that the initial Russian plan to decapitate the Ukrainian political, military, and security leadership and compel a rapid capitulation by surrounding key cities had failed, its ground forces were forced to rapidly adapt while under fire from the unexpectedly formidable

[33] Author interviews with UkrAF aviation commanders and military scientists, Ukraine, Oct. 2022.
[34] Ibid.
[35] Ibid.
[36] Ibid. Verified by author inspection and disassembly of two R-37Ms recently fired into Ukraine by the VKS, Ukraine, Oct. 2022. Also referred to specifically as threat in Thomas Newdick, "A MiG-29 Pilot's Inside Account of the Changing Air War over Ukraine," *The War Zone*, Dec. 15, 2022, https://www.thedrive.com/the-war-zone/a-mig-29-pilots-inside-account-of-the-changing-air-war-over-ukraine, accessed Dec. 18, 2022.
[37] Ibid.

Ukrainian resistance.[38] Consequently, the various VKS fast jet and rotary regiments assigned to each military district on the various axes were tasked with close air support to assist the Russian ground forces in breaking through Ukrainian defensive positions from the beginning of March. However, by this time, Ukrainian SAM systems had been repositioned and brought back online throughout most of the country, making Russian penetrating sorties across the frontlines above very low altitude extremely hazardous. The VKS accordingly switched to low-level daylight attacks, primarily using unguided bombs and rockets, until the end of the first week of March 2022.[39] These strikes, however, produced almost no significant results because it is extremely difficult to find, identify, and accurately hit dug in troops and vehicle positions in dense terrain at very low altitudes. At very low altitude, pilots are only likely to have a few seconds of clear line of sight to a given target, and can only make a single pass unless they are willing to brave concentrated anti-aircraft fire from fully alerted defenders. Outside the Su-25SM(3) Frogfoot fleet, moreover, very few Russian fixed-wing pilots had significant training or currency for very low-altitude close air support in contested airspace, since this never formed part of their core training tasks before the invasion.[40]

In exchange for causing very limited damage to Ukrainian frontline positions, Russian fixed-wing aircraft and helicopters suffered serious losses with this switch to daylight, low-level close air support operations, with around 10 jets and a similar number of helicopters shot down during the first week of March.[41] Flying below 3,000 meters, and especially orbiting or making multiple passes looking for targets, left them highly vulnerable to the large number of shoulder-fired MANPADS, such as Igla-S and Stinger, carried by Ukrainian troops and mobile air defense teams. After a week of such unproductive operations, the VKS rapidly ceased daylight penetrations across the frontlines with both fixed-wing and rotary aircraft. Instead, close air support efforts switched to standoff bombardments with unguided S-13 and S-8 rockets from gunships and Su-25s, and standoff precision guided missile attacks with Kh-29

[38] For more detail, see Jack Watling and Nick Reynolds, "Operation Z: The Death Throes of an Imperial Delusion," *RUSI Special Report*, Apr. 22, 2022, p. 2-6, https://static.rusi.org/special-report-202204-operation-z-web.pdf, accessed Dec. 18, 2022.

[39] Author interviews with UkrAF aviation and GBAD commanders, Ukraine, Oct. 2022. See also contemporary footage, such as OP Info, "Russian Su-34 Bombers Operate in the Kharkiv Region," YouTube, Feb. 28, 2022, https://youtu.be/hneCGWKAuKw, accessed Dec. 18, 2022.

[40] For more information, see Justin Bronk, "Developments in Russian Combat Air Spending and Likely Operational Implications," in Pentti Forsström (ed.), *Russian Concept of War, Management and Use of Military Power* (Helsinki: Finnish National Defence University, 2022), 100-101, https://doria.fi/bitstream/handle/10024/185874/Russia%20Seminar%20publication%202022_web.pdf, accessed Dec. 19, 2022.

[41] Author interviews with UkrAF aviation and GBAD commanders, Ukraine, Oct. 2022. Confirmed losses have been geolocated; see Mitzer and Oliemans, "List of Aircraft Losses." See also Joseph Trevithick, "The Russian Air Force Just Had a Terrible Day over Ukraine," *The War Zone*, Mar. 7, 2022, https://www.thedrive.com/the-war-zone/44602/the-russian-air-force-just-had-a-terrible-day-over-ukraine, accessed Dec. 18, 2022.

and Kh-59 missiles by the Su-30 and Su-34 fleets.[42] In addition, the Su-34 "Fullback" fighter-bomber and Ka-52 "Alligator" attack helicopter fleets continued to conduct low-level penetration missions at night, with the Ka-52s attempting traditional hunter killer operations and the Su-34s almost exclusively dropping sticks of unguided bombs on large targets such as the besieged cities of Chernihiv, Sumy, Kharkiv and Mariupol.[43] However, once Ukrainian mobile MANPADS teams began to be equipped with effective night vision goggles, even these nighttime penetrating sorties trailed off, so that by April 2022, almost no penetrations were being flown across Ukrainian lines by either fixed-wing or rotary-wing aircraft.[44]

VKS close air support tactics and patterns have remained similar following the Russian retreat from the Kyiv axis, during the subsequent battles in Donbas from late April to mid-July and then over Kherson and Kharkiv. The bulk of strikes have been standoff rocket lobbing attacks conducted by Su-25 Frogfoot, Ka-52 Alligator, Mi-28 Havoc, and Mi-24/35 Hind, while the latter gunships have also conducted antitank guided missile (ATGM) strikes on visible vehicle and fighting position targets from limited standoff ranges across the frontlines. The rocket lobbing attacks produce an effect similar to 122 millimeter "Grad" rocket artillery—able to hit rough grid squares and cause a suppressive effect against troops and vehicles moving in the open, or keep troops under cover in defensive positions, but insufficiently accurate to hit individual vehicles of positions with any regularity.[45]

Airstrikes on known static targets such as Ukrainian command and control positions and logistics concentrations have been carried out primarily by Su-34s, sometimes Su-30SMs using Kh-29, and occasionally satellite-guided KAB-series bombs from medium altitudes and several kilometers behind the frontlines. These strikes are more akin to standoff battlefield interdiction than close air support in most cases, but these tactics have also been used to hit established Ukrainian frontline positions.[46] One more recent change during October and November 2022 is that Su-34s have been observed conducting low-level unguided bombing runs against frontline positions by day.[47] This suggests an increasingly acute shortage of

[42] Author interviews with UkrAF aviation and GBAD commanders, Ukraine, Oct. 2022. See also footage such as AirForceTube, "Russian Mi-28N Havoc and Ka-52 Alligator firing Rockets," YouTube, Mar. 17, 2022, https://youtu.be/RM30BNUYOe8, accessed Dec. 18, 2022; Defence Simplified, "Russian MoD releases video showing Su-34 Bomber launching Kh-29 Air-to-ground missile on Ukraine," YouTube, Apr. 24, 2022, https://youtu.be/yPOBfHtGPu0, accessed Dec. 18, 2022; WarLeaks—Military Blog, "Russian Su-25 Combat Sortie Over Ukraine POV," YouTube, June 14, 2022, https://youtu.be/ATwkpH9mSqI, accessed Dec. 18, 2022; and RedIntelPanda, "Russian SU-25 Fires Rockets on Zaporizhzhia Front—Located," YouTube, Oct. 16, 2022, https://youtu.be/rAZR70XaobU, accessed Dec. 18, 2022.
[43] Author interviews with UkrAF aviation and GBAD commanders and military scientists, Ukraine, Oct. 2022.
[44] Ibid.
[45] Author interviews with Ukrainian operations analysis specialists and military scientists, Ukraine, Oct. 2022.
[46] Ibid.
[47] For example, see Rum Raisin, "Russian Su-34 Low-Altitude FAB-250 Bomb Run in Ukraine," YouTube, Nov. 4, 2022, https://youtu.be/7zteCjC8vcc, accessed Dec. 20, 2022; Rum Raisin, "Russian Su-34 FAB-500 Bomb Run on Ukrainian Trenches Near Berestovoe," YouTube, Nov. 19, 2022, https://youtu.be/97jYPrBYILM, accessed Dec. 20, 2022.

standoff precision-guided munitions (PGMs), since the danger from MANPADS and even anti-aircraft artillery is high for low-level daylight bombing runs, and both VKS planners and pilots would undoubtedly prefer to avoid running the risk if possible.[48] In terms of losses during close air support attempts, the confirmed VKS fixed-wing ground-attack aircraft losses as of late March 2023 include 20 Su-34s from a fleet of approximately 130 at the start of the war and 30 Su-25SM(3)s from a fleet of around 120.[49] For the helicopter gunships, the confirmed losses at time of writing include 33 Ka-52 Alligators out of a fleet of around 120, and 11 Mi-28 Havocs out of a fleet of similar size.[50] In other words, the VKS has taken serious losses without significant results across both its fixed-wing and rotary tactical ground-attack fleets.

In conclusion, over Ukraine, the VKS has performed reasonably well in the defensive and at times offensive counter-air mission using Su-35S and Su-30SM fighters, and in long-range standoff strike operations against a range of strategic and operational targets using cruise missiles fired by bombers from the LRA force, and sometimes Kh-59 cruise missiles fired from Su-34 fighter bombers, Su-30SM, and Su-35S fighters. The LRA strikes in particular, in combination with naval- and ground-launched fires and electronic warfare effects, were successful in producing effective SEAD effects against Ukrainian air defenses during the first three days of the invasion. They have also continued to reliably cause damage to infrastructure and logistics targets across Ukraine throughout the war. However, the VKS has proven incapable of effectively conducting DEAD against Ukrainian mobile SAMs or performing effectively in the close air support role on the battlefield. Both of these deficiencies essentially boil down to an inability to reliably find, fix, identify, and accurately strike dynamic mobile targets in a contested air environment. Together, the failures to prosecute a successful DEAD campaign or be effective as a close air support force have prevented the VKS from exerting a decisive effect against Ukraine in 2022.

[48] For example, see Factor War, “Ukrainian Air Defense Systems Shoot Down a Russian Su-34 During a Counteroffensive,” YouTube, Oct. 8, 2022, https://youtu.be/4IdUlrARjqI, accessed Dec. 20, 2022.
[49] For confirmed losses, see Mitzer and Joost Oliemans, “List of Aircraft Losses.” For early 2022 VKS fleet acquisition and modernisation totals according to Russian sources, see Bronk, “Developments in Russian Combat Air Spending,” 89-95.
[50] Mitzer and Oliemans, “List of Aircraft Losses.” For Ka-52 fleet size estimates, see Dan Parsons, “Ukraine Situation Report: Russia’s Ka-52 Attack Helicopter Fleet Has Been Massacred,” *The War Zone*, Oct. 25, 2022, https://www.thedrive.com/the-war-zone/ukraine-situation-report-russias-ka-52-attack-helicopter-fleet-has-been-massacred, accessed Dec. 20, 2022; for Mi-28 fleet size estimates, see Alexander Mladenov, “Mean Havoc Rising,” *Key Aero*, Dec. 24, 2022, https://www.key.aero/article/mean-havoc-rising, accessed Dec. 20, 2022.

Explaining VKS Performance Compared to Pre-war Expectations

The most significant aspect of the VKS performance over Ukraine that had been overlooked or at least not explicitly predicted by VKS experts before the invasion is the fact that Russian pilots and planning staff lack the ability to plan, organize, and execute composite air operations (COMAOs). COMAO is a NATO term used to describe missions where "dissimilar types of aircraft interact in coordinated actions, to achieve defined military objectives within a given time and geographical area…normally involving between 20–100 aircraft."[51]

The Russian VKS began the invasion with an inventory of around 400 genuinely modern multirole fighter and fighter-bomber aircraft like the Su-35S, Su-30SM, and Su-34, and another 300 or so heavily modernized legacy types like the Mig-31BM, Su-25SM(3), and Mig-29SMT.[52] Therefore most external analysts simply assumed that these technically impressive fleets would be employed in COMAOs to leverage the combined strengths and compensate for the weaknesses of each type against Ukraine. This assumption was held despite that fact that the VKS had never really demonstrated such a capability in practice. For example, over Syria, the vast majority of Russian sorties were flown by single aircraft or pairs, involving largely fighter patrols and unguided weapon drops from medium altitude.[53] VKS training sorties have also almost always been flown in small formations or by single aircraft, and largely involve simple navigation sorties, unguided weapon deliveries on open ranges, ground-controlled interception tasks, and SAM-target simulation serials.[54] Furthermore, the typical Russian fast jet pilot flew only around 80–100 hours per year before the invasion, and VKS regiments do not have access to the sort of modern simulator facilities that Western air forces increasingly rely on for complex synthetic training.[55] Together, this lack of exposure to large formation tactics in training and previous operations, limited live flying training hours for frontline pilots,

[51] Pål Kristian Fredriksen, "Interaction in Aerial Warfare: The Role of the Mission Commander in Composite Air Operations (COMAO)," in G.-E. Torgersen (Ed.), *Interaction: 'Samhandling' Under Risk. A Step Ahead of the Unforeseen*, (Oslo: Cappelen Damm Akademisk, 2018), 481–500, https://press.nordicopenaccess.no/index.php/noasp/catalog/view/36/175/1742, accessed Dec. 20, 2022.
[52] Bronk, "Developments in Russian Combat Air Spending," 89-101.
[53] Author interview with senior NATO air force officer with experience monitoring Russian air operations over Syria, London, Mar. 16, 2022.
[54] Author interview with senior NATO fighter force commander, Helsinki, Feb. 9, 2022.
[55] "В командовании Военно-воздушных сил ВКС подвели итоги за 2018 год" [The Command of the Air Force of the Aerospace Forces Summed up the Results for 2018], Department of Information and Mass Communications of the Ministry of Defense of the Russian Federation, Dec. 4, 2018, https://function.mil.ru/news_page/country/more.htm?id=12206756@egNews, accessed Feb. 11, 2022. See also Piotr Butowski, *Flashpoint Russia: Russia's Air Power: Capabilities and Structure* (Czech Republic: Harpia Publishing, 2019), 33.

and a focus on relatively simple tasks during those training hours explains why the VKS was not able to fly COMAOs in Ukraine.

COMAOs are absolutely critical to the way that the US and its NATO allies employ airpower in contested airspace. By combining the capabilities of many different types of combat aircraft and enablers such as aerial refuelling tankers and airborne warning and control system (AWACS) and electronic support aircraft, NATO has routinely deployed combat air packages that are far more capable in aggregate than the sum of their individual parts would suggest. For example, a typical NATO COMAO during the first week of a campaign against an enemy air force and air defense network might combine both offensive and defensive fighter sweeps, a core strike package to force defenses to illuminate and engage, ARM "shooters" such as F-16CM and electronic jamming and escort aircraft such as the EA-18G for SEAD, and DEAD elements such as F-35A to locate and physically destroy suppressed SAM systems.[56]

To enable all the different force elements to safely assemble at an initial point, fly the required mission, and recover safely with allowances for combat maneuvers, extensive aerial refuelling would be provided at a safe distance from enemy defenses, and AWACS aircraft would provide early warning and mission-command/deconfliction functions.[57] Because this way of operating is so central to the US Air Force and its main partner air forces, the extraordinary complexity of the planning, enabler support provision, and command and control arrangements required is often overlooked or forgotten by non-practitioners. Below the planning level, flying COMAOs in a complex and contested environment requires highly experienced weapons instructor pilots at the squadron level to plan, brief, lead, and then debrief each sortie. It also requires that regular pilots are trained from basic flying training onwards to execute complex sorties while adapting their route, fuel calculations, communications planning, and tactical decisions on the fly so that when enemy action, weather, or mechanical failures change things, they still hit their assigned rendezvous and weapon release points accurately to within several seconds.[58] This is simply not a skill set that can be quickly learned or backfilled if it is not a core part of an air force's training DNA.

Put simply, VKS has never trained its pilots to operate in the relatively independent, mission command-focused way that RAF, US Air Force, Armée de l'Air or other Western air forces have always done. Instead, Russian pilots are trained to perform narrower mission profiles under tighter command and control arrangements in smaller formations. Therefore, when the invasion of Ukraine began, neither the pilot capacity nor a sufficient understanding among VKS

[56] Author interviews with multiple NATO fast jet weapons instructor pilots at RAF Coningsby, July 6–7, 2021; AEE Orange-Caritat, Aug. 18, 2021; RAF Lakenheath, Sep. 23–24, 2021; RCAF Bagotville, May 24–27, 2022; GAF Laage, Aug. 16, 2022; RAF Marham, Sep. 20, 2022; RAF Lossiemouth, Nov. 2, 2022.
[57] Ibid.
[58] Author interviews with multiple NATO fast jet weapons instructor pilots at RAF Coningsby, July 6–7, 2021; AEE Orange-Caritat, Aug. 18, 2021; RAF Lakenheath, Sep. 23–24, 2021; RCAF Bagotville, May 24–27, 2022; GAF Laage, Aug. 16, 2022; RAF Marham, Sep. 20, 2022; and RAF Lossiemouth, Nov. 2, 2022.

commanders of the practical planning requirements were present to enable COMAOs at scale to facilitate effective offensive counter-air, SEAD/DEAD, and strike tasks. Instead, as detailed in the first section, Russian fighters flew CAPs and launched ARMs while individual or pairs of strike aircraft were sent to hit individual air defense targets.

It should be pointed out at this stage that the inability to conduct COMAOs and, consequently, the inability to sequence effective SEAD/DEAD operations with effective deep strike and offensive counter-air sweeps should not have come as a major surprise to Western analysts given the traditional doctrinal role of the VKS within the Russian military as a whole. Russia has long relied primarily on its extensive ground-based integrated air defense system (IADS) to control the air in any conflict with NATO forces. The US and NATO collectively have a fairly unassailable technology and experience lead in the air-to-air domain. The devastating lethality of NATO airpower against ground forces once air superiority had been attained has also been repeatedly demonstrated over Iraq, the Balkans, and Libya. Therefore, Russia has long doctrinally and financially prioritised denying NATO airpower the ability to operate effectively rather than the ability to project VKS sorties into defended airspace. By the same token, NATO has collectively under-invested in GBAD capabilities since the end the of Cold War. Where Russia has made investments, they have generally been in systems such as Patriot PAC-3 and THAAD that are optimised for anti-ballistic missile work rather than intercepting combat aircraft.[59] Consequently, the primary high-end threat that the VKS itself had to plan to face was from NATO fighter aircraft rather than NATO SAM systems. This was a further incentive to deprioritise investment in the specialist weapons and training required to conduct SEAD/DEAD effectively at scale.

The observed VKS limitations around close air support (CAS) and battlefield interdiction in Ukraine should also not have been surprising given the known deficiencies in Russian laser- and GPS/GLONASS-guided PGMs and targeting pods compared to Western multirole fighters.[60] Modern targeting pods such as the Litening III and Sniper are vital to Western CAS tactics as performed by fighter aircraft and bombers. They provide a sensor with well-stabilised multi-spectral optics that allow target acquisition, identification, tracking, and designation from a holding orbit at a sufficient distance and altitude to remain outside the reach of short-range air

[59] Paul van Hooft and Lotje Boswinkel, “Surviving the Deadly Skies Integrated Air and Missile Defence 2021–2035,” The Hague Centre for Strategic Studies, Nov. 2021, 1-2, https://hcss.nl/wp-content/uploads/2021/12/Integrated-Air-and-Missile-Defense-HCSS-Dec-2021.pdf, accessed Dec. 21, 2022.
[60] For more information, see Justin Bronk, “Russian and Chinese Combat Air Trends Current Capabilities and Future Threat Outlook,” RUSI Whitehall Report 3–20, Oct. 2020, 19-23, https://static.rusi.org/russian_and_chinese_combat_air_trends_whr_final_web_version.pdf, accessed Dec. 20, 2022.

defense systems and MANPADS.[61] However, despite producing several prototype targeting pods for potential export customers, the VKS has not bought them for its own fast jet fleets and so lacks this crucial capability.[62]

As a dedicated ground-attack aircraft, the Su-34 has a retractable electro-optical sensor with laser-designation capabilities called "Platan," but this only provides a limited field of view forward and downwards and does not include thermal sighting capability for night or bad weather operations.[63] The fixed SOLT-25 sensor on the Su-25SM3 or the Kaira 24 retractable system on the older Su-24M come with even worse field-of-view limitations, although the SOLT-25 at least includes an infrared capability.[64] In addition to the fixed forward field of view, Russian optical targeting systems provide significantly worse stabilisation and zoom performance compared to Western targeting pods, further limiting VKS pilots' ability to rapidly find and accurately identify battlefield targets from a safe distance. What this means in practice is that even dedicated Russian ground-attack aircraft have to fly toward a target area while trying to locate, identify, and then designate and drop/fire weapons at Ukrainian positions or vehicles, using sensors with limited bad weather performance, poor stabilisation, and limited resolution and zoom capabilities. This results in greatly increased time pressure and cockpit workload and a flight path that increases vulnerability while within effective sensor range of battlefield targets. For fighters such as the Su-35S and Su-30SM, the situation is even worse, since the only really viable way to conduct CAS with PGMs against targets that do not show up on radar or have a known fixed GPS/GLONASS position is to fly toward them while trying to use an electro-optical or IR sensor on the missile itself to locate, identify, and lock onto targets. The sensors on missiles are by nature more constrained by cost, space, weight, and power limitations than those fitted to aircraft or targeting pods, so they provide worse image resolution, zoom, resolution, and stabilisation. They also have much more limited fields of view than targeting pods or even systems like Platan or SOLT-25.

In Syria, many of these limitations were mitigated by the fact that the VKS was able to operate fixed-wing bombing sorties at medium altitude outside the range of MANPADS so that it could take its time to find, designate, and hit targets. Even then, most of the munitions dropped were

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[61] Examples of Western targeting pods include the Litening III/V series, Sniper Pod series, and Damocles. See "LITENING Advanced Targeting Pod," Northrop Grumman, https://www.northropgrumman.com/what-we-do/air/litening-advanced-targeting-pod/, accessed Dec. 21, 2022; "Sniper ATP Superior Targeting Capability," Lockheed Martin, https://www.lockheedmartin.com/en-us/products/sniper.html, accessed Dec. 21, 2022; and "DAMOCLES Multi-function Targeting Pod," Thales, https://omnirole-rafale.com/wp-content/uploads/2018/05/Fiche-technique-DAMOCLES.pdf, accessed Dec. 21, 2022.
[62] Piotr Butowski, *Russia's Air-Launched Weapons: Russian-Made Aircraft Ordnance Today* (Czech Republic: Harpia Publishing, 2017), 40-41.
[63] Thomas Newdick, "All the Crazy Quirks and Features on Russia's Su-34 Fullback Strike Fighter," *The War Zone*, Jan. 23, 2022, https://www.thedrive.com/the-war-zone/43921/all-crazy-quirks-and-features-on-russias-su-34-fullback-strike-fighter, accessed Dec. 21, 2022.
[64] Alexander Mladenov, "Fighting Workhorse," Key Aero, Apr. 27, 2017, https://www.key.aero/article/fighting-workhorse, accessed Dec. 21, 2022.

unguided bombs, and the targets were primarily fixed fighting positions or besieged urban areas. The success of the Russian air campaign in Syria largely hinged on the fact that opposition groups had no way to contest control of the air and were struggling to hold ground under sustained bombardment with little capacity to maneuver unpredictably. In Ukraine, the VKS's inability to destroy Ukrainian mobile SAM systems has prevented them from operating at altitude beyond the frontlines, and the vulnerability of its jets and helicopters to MANPADS when flying very low has prevented repeat passes over targets within visual range. In this context, the VKS's technical limitations go a long way towards explaining why its relatively inexperienced crews have struggled to effectively conduct battlefield interdiction or CAS. Without targeting pods, they can only reliably hit fixed targets pre-identified by friendly troops, HUMINT sources, or UAVs using standoff weapons or conduct standoff barrages against area targets with rockets.

Many of these limitations stem not from inherent Russian technological limitations, but from the fact that the Russian military as a whole has long relied on massed artillery, armored vehicles, and land-based precision fires for the core of its tactical and operational level battlefield lethality rather than CAS. Therefore, Russia has not invested heavily in the sort of sensors, weapons, and pilot training that Western air forces have taken for granted after decades of counter-insurgency campaigns where airpower provided the majority of deployed joint force firepower. Consequently, it should not have been a surprise for Western observers that the VKS proved poor at conducting dynamic CAS and interdiction on the battlefield in Ukraine.[65]

VKS Medium- and Long-term Threat Outlook

In assessing the threat posed by the VKS to Ukrainian military fortunes in the ongoing war to retake territory still illegally occupied by Russian forces, it is crucial to understand why it has not had a major effect on the ground war so far. First and foremost, it is because of Russia's failure to establish control of the air over most of Ukraine, and even over most frontline areas. This is almost entirely due to the inability of the VKS to fly COMAOs and bring the required mix of SEAD/DEAD capabilities to bear to reliably suppress, fix, and destroy Ukrainian mobile SAMs. This is important because it follows that the threat that the VKS can pose to Ukraine in the ongoing war is almost entirely dependent on whether Ukraine can sustain its GBAD coverage near the frontlines. Ukraine has lost a significant number of SA-11 and SA-8 SAM

[65] Previously identified by this author as a VKS limitation pre-invasion in Justin Bronk, "Russian and Chinese Combat Air Trends," 19-23, and Justin Bronk, "Developments in Russian Combat Air Spending and Likely Operational Implications," in Pentti Forsström (ed.), *Russian Concept of War, Management and Use of Military Power* (Helsinki: Finnish National Defence University, 2022), 89-101, https://doria.fi/bitstream/handle/10024/185874/Russia%20Seminar%20publication%202022_web.pdf, accessed Dec. 21, 2022.

systems over the course of the war, primarily to artillery, missile, and loitering munition strikes after being located and designed by Orlan-10 UAVs operated by Russian ground forces.[66] Furthermore, Ukraine is increasingly reliant on external missile supplies to keep its Soviet-made SAM systems combat-effective because of the high rate of ammunition consumption required to continuously intercept Russian aircraft, UAVs, and cruise missiles throughout the country.[67]

Russia's fighter force has shown that it is more than capable of overmatching Ukrainian fighter aircraft due to the great disparities in radar and missile performance, as well as superior Russian numbers and electronic warfare equipment. Furthermore, the VKS attack aircraft fleets have proven in Syria that they can be brutally effective against fixed defensive positions, cities, and infrastructure targets if they are able to operate freely at medium altitude.[68] Therefore, if Ukraine's SAM systems cannot be kept resupplied, augmented, and ultimately replaced by Western partner nations, then the VKS could credibly threaten to overpower the UkrAF's remaining fighters and gain control of the airspace over the frontlines in key areas. This would pose a serious risk to the Ukrainian Army's ability to sustainably hold fixed defensive positions, assemble reinforcements and reserve units in rear areas, and safely marshal ammunition and logistics supplies. However, if Ukraine can maintain its current levels of tactical and strategic SAM coverage, then it is unlikely that the VKS will be able to significantly change its fortunes so far into the war.

In terms of a threat to NATO nations in a medium-term context, the Russian airpower picture remains largely unchanged. The two major Russian military capability areas that threaten the ability of NATO to establish and exploit air superiority, and thereby credibly defend its territory in the event of Russian aggression, have always been the IADS and long-range precision strike capabilities. Both of these capabilities have performed very effectively in Ukraine.

Russian SAM systems have proven extremely lethal against both Ukrainian aircraft and also, in many cases, munitions when emplaced and operating within the IADS as doctrinally intended. From very long-range S-400 launches against low-flying Ukrainian fighters and ground-attack aircraft guided by exotic radars like the 48Ya6-K1 to medium- and short-range engagements by SA-17s and SA-15s, Russian SAMs remain the primary killer of Ukrainian fast jets,

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[66] For details of the Orlan-10, see James Byrne et al., "The Orlan Complex: Tracking the Supply Chains of Russia's Most Successful UAV," *RUSI Special Report,* Dec. 15, 2022, p. 7-8, https://static.rusi.org/SR-Orlan-complex-web-final.pdf, accessed Dec. 21, 2022. For confirmed Ukrainian SAM losses, see Stijn Mitzer with Joost Oliemans, "Attack On Europe: Documenting Ukrainian Equipment Losses During The 2022 Russian Invasion Of Ukraine," *Oryx*, Mar. 20, 2022, https://www.oryxspioenkop.com/2022/02/attack-on-europe-documenting-ukrainian.html, accessed Dec. 18, 2022.
[67] Author interviews with UkrAF GBAD commanders, Ukraine, Oct. 2022.
[68] Michael Kofman, "Syria and the Russian Armed Forces," Foreign Policy Research Institute, Sep. 2020, 13-14, https://www.fpri.org/wp-content/uploads/2020/09/syria-and-the-russian-armed-forces-kofman.pdf, accessed Dec. 21, 2022.

helicopters, and UAVs.[69] Furthermore, despite some success with the AGM-88 HARM missile since summer 2022, Russian SAM losses in Ukraine remain a small fraction of Russia's total inventory.[70] As such, the Russian IADS remains a serious threat to NATO's ability to rapidly establish control of the air over the battlespace in any medium-term clash. The extent that this remains the case will depend on whether or not European NATO air forces prioritise the regeneration the capability to conduct SEAD/DEAD against Russia's modern, mobile SAM systems at scale in the coming years.[71]

In terms of cruise and ballistic missiles, salvos from VKS LRA, ground-based Iskander systems, and naval platforms have consistently proven accurate enough hit their targets in quantity at great distances.[72] The threat to NATO from the VKS was always primarily cruise missiles and air-launched quasi-ballistic missiles fired from the LRA Tu-95 and Tu-160 bombers and Mig-31K modified interceptors, respectively. These assets allow the VKS to credibly threaten NATO air forces with large salvos of accurate precision-guided missiles against the main operating bases lacking air defenses that are largely the norm in Europe following decades of uncontested Western air operations. Against Ukraine, the LRA fleets have consistently maintained solid readiness and a reliable launch tempo from the first waves of the invasion to the winter bombardment of Ukrainian power and water infrastructure. These bombardments have depleted stockpiles, but Russia maintains the ability to produce at least 6 9M723 Iskander ballistic missiles and around 40 cruise missiles per month, so even a pause of a few years would allow the VKS to rebuild a sufficient arsenal to cause major damage to NATO bases not protected by layered GBAD.[73] If effective Western sanctions succeed in cutting the flow of key sub-components to Russian factories, then a key determinant of sustainable re-armament efforts in this area (and elsewhere) will be the degree to which China steps in to assist with key components or even whole systems once a ceasefire is reached in Ukraine.[74]

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[69] Author interviews with UkrAF aviation commanders and military scientists, Ukraine, Oct. 2022. For more information, see Justin Bronk with Nick Reynolds and Jack Watling, "The Russian Air War and Ukrainian Requirements for Air Defence," *RUSI Special Report,* Nov. 7, 2022, p. 12-13, https://static.rusi.org/SR-Russian-Air-War-Ukraine-web-final.pdf, accessed Dec. 16, 2022.

[70] For confirmed Russian SAM losses, see Mitzer and Oliemans, "Attack on Europe."

[71] Justin Bronk, "Getting Serious About SEAD: European Air Forces Must Learn from the Failure of the Russian Air Force over Ukraine," RUSI Defence Systems*,* Apr. 6, 2022, https://rusi.org/explore-our-research/publications/rusi-defence-systems/getting-serious-about-sead-european-air-forces-must-learn-failure-russian-air-force-over-ukraine, accessed Dec. 21, 2022.

[72] Author interviews with UkrAF aviation commanders and military scientists, Ukraine, Oct. 2022. For more information, see Bronk, Reynolds, and Watling, "The Russian Air War," 23-34.

[73] Ibid. See also General Vadym Skibitsky's comments in Marc Santora, "Russia Is Using Old Ukrainian Missiles Against Ukraine, General Says," *The New York Times*, Dec. 12, 2022, https://www.nytimes.com/2022/12/12/world/europe/russia-ukraine-missiles.html, accessed Dec. 21, 2022.

[74] For detailed analysis of the Western components in Russian cruise missiles, see James Byrne et al., "Silicon Lifeline: Western Electronics at the Heart of Russia's War Machine," *RUSI Special Report*, Aug. 8, 2022, https://static.rusi.org/RUSI-Silicon-Lifeline-final-updated-web_1.pdf, accessed Dec. 21, 2022.

The medium-term threat to European NATO from the VKS fighter, fighter-bomber/ground-attack, and helicopter gunship fleets should be understood in this context. Ukrainian experience has confirmed that the VKS is not capable of effective SEAD/DEAD, is not good at organic CAS or battlefield interdiction, and almost certainly cannot meet the best Western air superiority types head-on. However, civilian analysts and military intelligence agencies were likely aware of these facts before the invasion.[75] It is unlikely that Russia will be able to fix many of these deficiencies for the foreseeable future, especially since the skills required to routinely employ combinations of air assets in COMAOs would require total reform of basic pilot training and sufficient time for the resulting skills to be promoted up to operational commander level. The primary threats to European NATO airpower were always Russia's long-range precision strike and IADS, and those capabilities have been largely verified as effective in Ukraine.

Despite poor tactical employment and an unworkable strategic plan, the Russian ground forces have also proven resilient in the face of terrible losses and able to concentrate vicious massed artillery and electronic warfare effects when on the attack. In a future frontal, single-axis clash over disputed territory with NATO forces, the Russian military would not fundamentally need air superiority to threaten NATO. Instead, it requires the ability to deny NATO air superiority until ground can be taken with massed artillery firepower, and then nuclear threats can be made to try to secure those gains. Therefore, the dangerous but not first-class combat air patrol and strike capabilities against fixed targets that the VKS might bring to any future NATO confrontation should be seen for what they are: a situationally potent second echelon behind the primary IADS, long-range precision strike, and massed artillery threats.

In terms of the VKS's long-term equipment plans, the primary question is whether or not China ultimately chooses to supply its more modern sensors, targeting pods, PGMs, and air-to-air missiles to help Russia re-arm after the war. This would require a significant policy change on both sides, but it is unarguable that Russia will depend on Chinese economic and component supply support anyway, and that China has a strong geopolitical interest in Russia remaining a military threat to European security to tie down US and European NATO capabilities away from the Indo-Pacific. Either way, with a faltering economy likely to remain fragile and under extensive sanctions, Russia's own military-industrial complex is likely to fall back on producing and attempting to modernize existing types. Therefore, the VKS threat is likely to remain concentrated around its existing bomber, Foxhound, Flanker, and Fullback fleets and the missiles they carry, rather than vanity programs like the Su-57 Felon, Su-70 Okhotnik-B, or PAK DA bomber, which are unlikely to see production in large quantities.[76]

[75] For example, see Kofman, "Syria and the Russian Armed Forces," 13-14, and Bronk, "Russian and Chinese Combat Air Trends."
[76] For more detailed analysis, see Bronk, "Developments in Russian Combat Air Spending," 96-100.

Abbreviations

ALCMs	Air-launched cruise missiles
ATGM	Antitank guided missile
AWACs	Airborne warning and control system
CAPs	Combat Air Patrols
CAS	Close air support
COMAO	Composite air operations
GBAD	ground-based air defense
GLONASS	Globalnaya Navigatsionnaya Sputnikovaya Sistem (Russian GPS)
HUMINT	Human Intelligence
IADS	Integrated air defense system
LRA	Long Range Aviation
MANPADS	Man-portable air defense systems
PGM	Precision-guided munitions
RUSI	Royal United Services Institute
SAMS	Surface-to-Air Missiles
SEAD/DEAD	suppression and destruction of enemy air defenses
SPAAGs	self-propelled anti-aircraft guns
STT	single-track-target
TWS	Track-while-scan
UkrAF	Ukrainian Air Force
VKS	Russian Aerospace Forces

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SP3 provides strategic and political-military analysis informed by regional expertise to support operational and policy-level decision-makers across the Department of the Navy, the Office of the Secretary of Defense, the unified combatant commands, the intelligence community, and domestic agencies. The division leverages social science research methods, field research, regional expertise, primary language skills, Track 1.5 partnerships, and policy and operational experience to support senior decision-makers.

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