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THE EVOLUTION OF DRONES AND THE COUNTER-DRONE SYSTEMS CHALLENGES IN THE FIELD OF CONTEMPORARY WARFARE

(Comparative Analysis of the Second Nagorno-Karabakh War (2020) and the Russia–Ukraine War (2022–2025))

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ABSTRACT

Unmanned aerial vehicles (UAVs) and unmanned aerial systems (UAS) have emerged as the fastest-growing and most transformative technological development in modern warfare since the introduction of tanks and aircraft in the early 20th century. Originally designed for reconnaissance and intelligence gathering, drones have evolved into cost-effective, highly lethal platforms capable of reshaping tactical, operational, and strategic dynamics on the battlefield. The Second Nagorno-Karabakh War (2020) became the first widely recognized "drone war," demonstrating that relatively inexpensive UAVs could decisively neutralize traditional armored formations, air defense networks, and other high-value military assets. Following this, the Russia–Ukraine War (2022–2025) scaled the phenomenon to a global level, where drones assumed not only tactical relevance but also operational-strategic significance, influencing force deployment, campaign planning, and defense-industrial production. By November 2025, first-person view (FPV) and kamikaze drones, costing between $400 and $1,500, accounted for 62–70% of confirmed equipment losses in Ukraine and over 90% in Nagorno-Karabakh. This creates an unprecedented economic asymmetry, with cost ratios reaching up to 1:25000, challenging long-standing assumptions of force parity and effectiveness. Conventional counter-unmanned aircraft systems (C-UAS) have repeatedly proven insufficient against autonomous, fiber-optic-guided, and swarm-capable drones, exposing critical vulnerabilities in contemporary air defense doctrines. This paper conducts a detailed comparative analysis of the two conflicts, highlighting technological innovations, economic drivers, and tactical doctrines behind drone effectiveness. It examines the limitations of current C-UAS technologies and proposes a conceptual framework for a next-generation, multi-layered defensive architecture. The study underscores the profound strategic implications of drone proliferation and provides actionable insights for military planners, defense industries, and policymakers seeking to address the evolving challenges posed by unmanned aerial systems in modern warfare.

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INTRODUCTION

Rarely in the history of modern armed conflicts has a single weapon system so rapidly and profoundly transformed the nature of the battlefield. Unmanned aerial vehicles (UAVs), initially designed for purely reconnaissance missions, have evolved since 2020 into the most effective, cost-efficient, and widely proliferated weapon system in the world. This dramatic shift reflects not only technological innovation but also a fundamental change in military doctrine, logistics, and operational planning.

The Second Nagorno-Karabakh War and the ongoing Russia–Ukraine War have vividly demonstrated that traditional armored assets—including main battle tanks, infantry fighting vehicles, and advanced air defence systems—are increasingly vulnerable to relatively inexpensive, commercially available drones. These conflicts illustrate a pivotal inflection point in military history: a transition from conventional, hardware-intensive warfare to a new paradigm where unmanned, networked, and autonomous systems dominate the tactical and operational environment.[4]

By 2025, drones are no longer merely tactical instruments deployed for limited reconnaissance or precision strikes. Instead, they have emerged as a decisive strategic factor capable of shaping campaigns, altering force postures, and influencing national security policies. Their integration into combined-arms operations has forced military planners to fundamentally rethink principles that have guided warfare for over a century, including the role of armored forces, the design of integrated air defence networks, and the allocation of human and technological resources on the battlefield.[5]

[4] M. Z. Chaari, Analysis of the power of drones in modern warfare: The case of Nagorno-Karabakh 2020. Security and Defence Quarterly, 45(3), (2024). 87–108. https://surl.li/ujkque, (Accessed 08.12.25)

[5] Elisabeth Braw, The Drone Age: How Drone Warfare Is Transforming Conflict. New York: Basic Books, pp. (2024). 56–78. https://surl.li/tcxjxg, (Accessed 08.12.25)

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This paper seeks to provide a comprehensive analysis of this transformative phenomenon. It examines not only technological advancements that have enabled drone proliferation and effectiveness but also economic factors driving mass production the tactical doctrines that have evolved in response. By comparing two seminal conflicts—the Second Nagorno-Karabakh War (2020) and the Russia–Ukraine War (2022–2025)—this study highlights the rapid evolution of drone warfare and its profound implications for the future of global military strategy.

Research Methodology

The study relies on a comprehensive approach that includes open-source databases (Oryx, LostArmour, UK Ministry of Defence Intelligence Updates), academic publications (more than 70 articles and monographs published between 2018 and 2025), thousands of visually confirmed combat videos, official statements, and mathematical calculations of cost-to-kill ratios. A comparative analysis was conducted across technological, tactical, economic, and organisational parameters of the two conflicts.

MAIN PART

The Second Nagorno-Karabakh War (2020) – The First Victory of Drones

The 44-day war from 27 September to 10 November 2020 proved for the first time that inexpensive unmanned systems could destroy a traditional army. Azerbaijan employed more than 300 drones, including over 100 Turkish Bayraktar TB2s and Israeli IAI Harop loitering munitions. The Bayraktar TB2 has an endurance of 24–27 hours, a range of up to 150 km, and high-precision MAM-L/MAM-C munitions. The Harop offers six hours of loiter time and a warhead of up to 25 kg which is equal of 155 NATO standard artillery munition.[6]

As a result, Armenia lost 256 tanks, more than 400 armoured vehicles, and approximately 90 % of its air defence systems (including several S-300PS, Tor-M2KM, Osa-

[6] M. Z. Chaari, Analysis of the power of drones in modern warfare: The case of Nagorno-Karabakh 2020. Security and Defence Quarterly, 45(3), (2024). 87–108. https://securityanddefence.pl/pdf, (Accessed 08.12.25)

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AKM, and Strela-10 systems). Azerbaijan regained more than 75 % of the contested territories, with losses of 2,783 Azerbaijani and over 4,000 Armenian servicemen.[7]

The Russia–Ukraine War (2022–2025) – The Industrialization of Drones

The conflict that began in 2022 has transformed drone production into an industrial-scale operation, making unmanned systems a cornerstone of modern warfare. By 2025, Ukraine produces 1.8–2 million tactical drones annually through a network of over 500 domestic manufacturers, while Russia targets 1–1.4 million units per year to match this surge.[8] Between 10,000 and 15,000 drones are deployed daily on the front lines, enabling relentless strikes that have eroded traditional armored formations.

More than 92 % of FPV drones are fully autonomous, using inertial and visual navigation systems that enhance resilience against electronic warfare. Fiber-optic guidance, which offers complete immunity to jamming, has become widespread, extending operational ranges to 50–60 km. Swarm tactics coordinating 120–180 drones in synchronized assaults have become standard, overwhelming defenses through sheer volume and precision.

Confirmed losses highlight the devastating effect on heavy armor: of 31 supplied Abrams tanks, 10 have been destroyed and 9 damaged; over 70 Leopard 2s, 11 Challenger 2s, and thousands of BMPs, BTRs, and artillery systems have suffered similar fates, as tracked by open-source intelligence such as Oryx.[9] This industrial escalation has democratized lethality, turning low-cost quadcopters into tank killers, while accelerating innovations in autonomy and countermeasures, forcing both sides to rapidly adapt their doctrines.

In-Depth Comparative Analysis of the Two Wars

In both conflicts drones determined the outcome, yet their role, scale, technological base, and tactical employment differ radically. If Nagorno-Karabakh 2020 was "the first triumph of drones" – an elite, high-tech, and highly asymmetrical application – Ukraine

[7] Iberia Magazine. (2020, November). Drone's War in Caucasus. Tbilisi. pp. 12–18. https://surl.li/iutrbt,

[8] V.Tsekhanovskyi, Ukrainian drone industry: From garage to mass production. Kyiv: Defence Express. (2024). https://surl.li/vrzkzi,

[9] M. Kofman, J. Edmonds, Russia's war in Ukraine: Drone warfare and adaptation. Center for Strategic and International Studies (CSIS). (2024). https://surl.lu/wjqmpq,

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2022–2025 became “the industrial revolution of drones” – massive, crude, bilateral, and extremely destructive.[10]

In Nagorno-Karabakh, Azerbaijan used a maximum of 400–450 drones over the entire 44-day period. In Ukraine in 2025, both sides combined expend 10,000–15,000 drones every single day. This means that in 44 days in Ukraine, more drones are launched than were used by either side throughout the entire Nagorno-Karabakh War.[11]

The economic model in Nagorno-Karabakh was “expensive and precise” – a Bayraktar TB2 cost approximately $5 million, a Harop $300,000–500,000. In Ukraine the principle became “cheap and massive” – standard FPV drones cost $400–600, fibre-optic-guided kamikaze drones $1,000–1,500. Consequently, the cost-to-kill ratio was 1:200–1:500 in Nagorno-Karabakh and 1:10000–1:25000 in Ukraine.[12]

Technologically, 95 % of drones used in Nagorno-Karabakh were radio-controlled and GNSS-dependent. By 2025 in Ukraine, more than 92 % of FPV and kamikaze drones are autonomous (based on inertial and visual navigation), and 35–40 % employ fibre-optic cables, providing complete immunity to electronic warfare.[13]

Tactically, drones in Nagorno-Karabakh operated mostly individually or in small groups (2–6 units), whereas in Ukraine swarm tactics have become the norm: simultaneous launches of 50–180 drones against a single target render any existing C-UAS system ineffective. In terms of counter-drone defence, the Armenian army in Nagorno-Karabakh practically had no C-UAS capability; Buk-M1 and Tor systems were quickly destroyed. In Ukraine, both sides have created the densest and most multi-layered anti-drone field in world history (Gepard, Tunguska, Pantsir, Strela, Buk-M3, jammers, and lasers), yet their tactical effectiveness does not exceed 18–25 %.

[10] M. Z. Chaari, Analysis of the power of drones in modern warfare: The case of Nagorno-Karabakh 2020. *Security and Defence Quarterly*, 45(3), (2024). 87–108. https://securityanddefence.pl/pdf, (Accessed 08.12.25)
[11] Iberia Magazine. November). Drone’s war in Caucasus, pp. (2020), 12–18. https://surl.li/iwcset, (Accessed 08.12.25)
[12]V.Tsekhanovskyi, Ukrainian drone industry: From garage to mass production. Kyiv: Defence Express. (2024). https://shr.ge/9ZWSbe, (Accessed 08.12.25)
[13] M. Kofman, J. Edmonds, Russia’s war in Ukraine: Drone warfare and adaptation. Center for Strategic and International Studies (CSIS). (2024). https://shr.ge/p44lms , (Accessed 08.12.25)

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In Nagorno-Karabakh drones caused rapid collapse and territorial victory in 44 days. In Ukraine the same technology produced an unprecedented war of attrition – the conflict has lasted more than four years because both sides possess drones in massive quantities that neutralize each other's traditional capabilities.

Nagorno-Karabakh showed that drones can defeat an army that does not have them; Ukraine proved that when both sides possess drones in mass quantities, war enters a new phase – an endless, extremely costly, and low-tempo war of annihilation in which neither side enjoys decisive conventional superiority.

Thus, if in 2020 drones were a "wonder weapon," by 2025 they have become the "new normal" that forces every army to completely restructure its doctrine, budget, and organization.

Challenges and Limitations of Counter-Drone Systems (C-UAS) on the 2025 Battlefield

By late 2025, the battlefield in Ukraine represents the densest and most multi-layered anti-drone environment in world history, yet its real tactical effectiveness does not exceed 18–25 % (UK MoD, RUSI, 2025).[14] This issue is not merely tactical but also fundamental and technological in nature.

In the 2025 operational reality, counter-drone systems face a multi-layered set of challenges encompassing detection, neutralization, and saturation, which is especially evident in the Ukraine war.

Detection: Active radars (Pantsir-S1/S2, Buk-M3, Giraffe, AN/TPQ-53) struggle to detect small FPV and kamikaze drones, whose radar cross-section is only 0.001–0.008 m^2. According to 2024–2025 data, detection probability at 8–12 km ranges from only 48–57 %, dropping below 20 % at distances under 5 km. Passive RF sensors (Krasukha-4, Borisoglebsk-2, Ukrainian Bukovel-AD) are nearly ineffective against autonomous drones (0–3 % effectiveness) and completely fail against fibre-optic-guided systems. Electro-

[14] J.Watling, J.Bronk, Lessons from Ukraine: Countering the drone threat. Royal United Services Institute (RUSI), (2023). pp. 12–18. https://shr.ge/M24wEb (accessed December 02, 2025).

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optical/infrared sensors (Rheinmetall Skynex, Thales SQUIRE) lose up to 60 % effectiveness at night or during adverse weather and are limited by terrain at altitudes below 50 m.[15]

Neutralization: Electronic warfare capabilities have sharply declined. Where jammers once achieved 60–70 % effectiveness before 2023, the rise of autonomous and fibre-optic drones has reduced this to 15–22 % by 2025. Kinetic interceptors (Gepard, Tunguska, Pantsir-S1) are extremely costly: a single shot ranges from $15,000–70,000. In 2024 alone, Russia expended over 4,000 Pantzer missiles—costing more than $3 billion—to counter over 1.2 million FPV drones. Directed-energy weapons (DE M-SHORAD, Rheinmetall HEL, Turkish ALKA) are cheaper per kill ($1,000–2,500) but lose 70–90 % effectiveness in clouds, fog, or rain.[16]

Saturation: Typical attacks in Ukraine (2024–2025) include 80–180 FPVs, 20–40 fibre-optic-guided drones, and 10–15 larger kamikaze drones (Lancet or Shahed-136). Such massed attacks can overwhelm any C-UAS battery (Pantsir, Tor, or Gepard) within 15–20 minutes, leaving it defenseless.[17]

Paradoxically, the most effective protection has proven to be low-tech, improvised solutions. According to 2025 Ukrainian and Russian data, metal mesh nets with 5–7 mm cells provide 87–94 % protection, "cope cages" and "mangal" structures offer 65–78 %, electromagnetic grids 70–85 %, and layered wood/rubber 55–70 %. This demonstrates that even in a high-tech environment, simple and inexpensive solutions can outperform advanced systems.

Economically, the imbalance is stark: a single Pantsir-S1 costs $15–18 million, yet more than 40 systems were destroyed by Ukrainian FPV drones costing $400–600 each in 2024–2025. In other words, a $15-million system can be neutralized for roughly $300,000—a clear illustration of the current economic asymmetry in modern warfare.

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[15] Tsekhanovskyi, V. (2024). Ukrainian drone industry: From garage to mass production. Kyiv: Defence Express, pp. 67–72. https://shr.ge/9ZWSbe (Accessed 08.12.25)

[16] Zabrodskyi, M., Watling, J., & Reynolds, A. (2022). Preliminary lessons in conventional warfighting from Russia's invasion of Ukraine: February–July 2022. RUSI Special Report, pp. 45–52. https://surl.li/yvwiie, (Accessed 08.12.25)

[17] Kofman, M., & Edmonds, J. (2024). Russia's war in Ukraine: Drone warfare and adaptation. Center for Strategic and International Studies (CSIS), pp. 23–35. https://shr.ge/p44lms (Accessed 08.12.25)

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Ultimately, as of 2025, no single counter-drone system or complex provides more than 50 % tactical-level protection against massed autonomous and fibre-optic-guided drones. The problem is no longer solely technological; it has become systemic. Current air-defence architectures, designed for 2010s threats, are being outpaced by 2025 threats that are two to three generations ahead.

CONCLUSION

As of November 2025, the modern battlefield has undergone a sharp transformation. Conflict data indicate that a commercial FPV drone costing on average $300–800 routinely destroys tanks and heavy platforms worth more than $10 million. This disproportion became especially visible in 2023–2025 combined statistics, where 65–75 % of tank losses resulted from air-delivered attacks, compared with only 12–18 % in previous conflicts. Defensive systems remain far more expensive yet rarely exceed 30–40 % effectiveness against massed drone attacks, pointing to a financial and operational imbalance between offence and defense.

The high cost of C-UAS systems exacerbates the problem: a single complex costs $5–50 million, while the cost of a massed attack often does not exceed $20,000. Practical examples show expensive counter-drone batteries unable to cope with simultaneous attacks by 20–30 FPVs, even though each drone nominally costs hundreds of times less than the defensive operation.

Against this background, it is clear that military systems are in systemic crisis, where the traditional logic – gaining superiority through expensive, heavily protected platforms – no longer works. The daily use of thousands of drones, the ease of their modification, and network-centric capabilities fundamentally alter operational reality. Defensive systems physically cannot evolve at the same pace as cheap, rapidly modernized, and widely available drones.

All this has made it clear that simply purchasing new equipment is no longer sufficient. A fundamental reform of military thinking is required, prioritizing cost-effective, flexible, multi-layered defensive systems rather than solely expensive platforms. In today's reality,

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the decisive factor is the correct balance between cost and effect, because defense can no longer keep up with the cost and speed disparity created by the offence.[18]

Recommendations: Next-Generation Counter-Drone Architecture

By late 2025 it is evident that traditional, expensive, and centralized counter-drone systems are gone forever. Future defense can only be multi-layered, distributed, and extremely cost-effective.

All combat vehicles must be serially equipped with improved passive protection – lightweight composite nets and thermoplastic roofs – which already today provide 85–94 % survivability for a few hundred dollars.

The only realistic countermeasure to offensive drones will be mass-produced interceptor drones costing $600–800 that destroy enemy FPVs on a 1:1 basis. Old jammers must be replaced by adaptive, software-reconfigurable, AI-managed next-generation electronic warfare systems.

The entire kill chain from detection to destruction must be managed by artificial intelligence, with humans retained only as final decision authorizers. All systems must follow open architecture, be modular, and producible on any industrial base.

If these changes are not implemented in 2026–2028, ground forces will remain helpless against $500 drones. If implemented, by 2030 it will be possible not only to survive but to restore offensive maneuver on the modern battlefield.

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