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TACTICAL NETWORK-CENTRIC WARFARE IN PRACTICE: FPV DRONES AND THE ARCHITECTURE OF A NEW RMA

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Abstract: *The Ukraine War (2022–2025) has witnessed the unprecedented tactical proliferation of First Person View (FPV) drones - low-cost, rapidly adaptable platforms with precision-strike capabilities. This study investigates whether the integration of FPV drones constitutes a predictable military evolution or signals the unfolding of a new Revolution in Military Affairs (RMA). Employing a qualitative case study methodology, we analyze open-source data on drone usage, tactical adaptation, organizational change, and battlefield outcomes. Our findings show that FPV drones have extended the tactical reach of small units, compressed decision cycles through real-time ISR-to-strike loops, and triggered structural reforms - including the creation of new military branches and training ecosystems. Critically, their mass deployment has rendered traditional ground-based systems increasingly vulnerable, challenging established doctrines. The study introduces the concept of Tactical Network-Centric Warfare (T-NCW) to capture this transformation: a decentralized operational model enabled by FPV drones that merges precision, autonomy, and information dominance at the tactical level. These developments align with core RMA criteria and suggest a shift in the logic of land warfare. FPV drones thus function not as marginal tools, but as catalysts of systemic military change.*

Keywords: FPV Drones, Revolution in Military Affairs, Tactical Network-Centric Warfare, Ukraine War, Military Innovation

1. Introduction

The full-scale Russian invasion of Ukraine in February 2022 not only reignited large-scale conventional warfare on European soil but also transformed the conflict into an unprecedented laboratory for rapid technological and tactical innovation under high-intensity combat conditions. Among these developments, the mass-scale adoption and tactical integration of First Person View (FPV) drones stand out as particularly transformative. These inexpensive, commercially based quadcopters, controlled through real-time video feeds, rapidly transitioned from experimental novelty in early 2022 to dominant tactical tools, fundamentally reshaping the dynamics of frontline engagements [1], [2].

The extraordinary tactical impact and rapid proliferation of FPV drones raise a fundamental analytical question: Do these systems represent a continuation of predictable military evolution, or do they mark the onset of a deeper Revolution in Military Affairs (RMA)? Understanding the nature of this transformation is critical not only for understanding the current conflict but also for anticipating broader trajectories in warfare.

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Framing this question within established theoretical frameworks requires a clear distinction between military evolution - the gradual adaptation of technology, doctrine, and organization - and a Revolution in Military Affairs (RMA). An RMA represents a more fundamental, discontinuous transformation in the nature and conduct of war, typically resulting from the synergy between technological development, innovative operational concepts, and organizational adaptation [3], [4], [5].

This article contributes to the evolving debate on 21st-century military change by introducing Tactical Network-Centric Warfare (T-NCW). This framework elucidates how low-cost, decentralized FPV drones enable distributed sensing, precision strike, and rapid decision-making - hallmarks of an unfolding Revolution in Military Affairs (RMA).

2. Conceptual Framework: Defining Military Evolution and Revolution in Military Affairs

Understanding the transformative impact of FPV drones in Ukraine requires a clear conceptual distinction between military evolution and Revolution in Military Affairs (RMA). These terms, though related, reflect fundamentally different types of military change, with distinct implications for technology, doctrine, and organizational adaptation [6].

2.1. Military Evolution: Incremental and Predictable Adaptation

Military evolution typically refers to the gradual, incremental improvement of military capabilities, doctrines, tactics, and organizations over time. It is driven by factors such as the diffusion of new technologies, lessons learned from previous conflicts, budgetary constraints, and shifting strategic environments [7], [8]. Evolutionary change enhances existing paradigms without fundamentally altering their operational logic or systemic structure [7]. Quantitative studies support this view, suggesting that most historical military changes have been evolutionary, characterized by steady, cumulative adaptation [9], [10]. One notable approach is Alexander Kott's model based on Measures of Operational Performance (MOP), where technological advancement follows predictable trends over time [11], [12].

However, purely quantitative metrics can obscure disruptive systemic effects that are difficult to measure numerically, such as cost asymmetry, ease of use, mass accessibility, rapid adaptation cycles, or psychological impact [13], [14]. Furthermore, defining and measuring MOPs remains particularly challenging in complex operational environments characterized by hybrid warfare dynamics, such as those involving small, semi-autonomous drone systems [15].

2.2. Revolution in Military Affairs (RMA): Discontinuity and Obsolescence

In contrast, a Revolution in Military Affairs (RMA) represents a discontinuous, radical shift in the nature and conduct of warfare. An RMA is not simply faster or more intense evolution; it constitutes a qualitative transformation that fundamentally changes how wars are fought and what capabilities dominate success [4], [16]. The key criterion distinguishing an RMA is its ability to induce the obsolescence of existing platforms, doctrines, and organizational forms [17]. As emphasized by scholars such as Krepinevich, Cohen, and Kopeć, technological advancement, while a necessary condition, is insufficient to constitute a Revolution in Military Affairs unless it is accompanied by conceptual breakthroughs, doctrinal innovation, and organizational adaptation [18], [19], [20]. Kretchik [21] further stresses the importance of bold leadership capable of challenging entrenched paradigms and steering these innovations into transformative military practice.

A genuine RMA requires the synergistic interaction of three critical dimensions:

- Technological Innovation: Emergence or novel combination of technologies enabling novel operational effects and tactical behaviours [22]

- Doctrinal Innovation: The creation of new operational concepts and tactics by visionary leaders is essential to unlocking the full potential of emerging technologies and producing meaningful military revolutions [23]
- Organizational Adaptation: Significant restructuring of forces, command chains, training systems, and logistics to support new doctrines and technologies [20]

Only when these three elements converge is a full military revolution realized, producing systemic shifts in effectiveness and making previous methods comparatively obsolete [5].

As Raska (2020) notes, the Revolution in Military Affairs has evolved through successive technological waves - ranging from precision munitions and digitization to current AI-enabled systems. However, these top-down, high-cost models often overlook bottom-up innovations emerging in asymmetric conflicts. The widespread use of low-cost, modular, and decentralized FPV drones in Ukraine may constitute a parallel disruptive trajectory, distinct from the AI-RMA but equally indicative of systemic transformation.

While prior waves of RMA - from precision-guided munitions to digitized networked operations - emerged through top-down military-industrial innovation cycles, the FPV drone phenomenon reflects a distinct, bottom-up trajectory. As Raska notes, RMAs evolve in waves, often shaped by technological convergence, organizational adaptation, and operational diffusion [24]. Unlike earlier RMAs centred on institutionalized precision-strike platforms or AI-enabled systems, the Ukrainian case is grounded in low-cost, modular drones, real-time ISR - strike integration, and tactical autonomy at the small-unit level. FPV drone warfare thus outlines a new RMA variant - *Tactical Network-Centric Warfare* (T-NCW) - in which ISR - strike loops, digital targeting, and adaptive C2 are embedded at the lowest combat echelons. This study builds on this multidimensional understanding of military revolutions to assess whether the FPV drone phenomenon crosses the threshold of disruptive transformation - a theme explored further in the following subsection.

2.3. Disruption as a Key Criterion for RMA

A final diagnostic is **disruption**: if a capability merely enhances performance within the existing paradigm, it is evolutionary. But if it forces the reassessment of dominant systems (e.g., tanks, artillery) or operational doctrines, it becomes revolutionary [25]. The disruptive attributes of FPV drones - low cost, rapid adaptability, decentralized innovation, and tactical precision - collectively challenge conventional force structures. Their systemic effects go beyond tactical utility and point to a deeper transformation in how force is applied, distributed, and sustained on the modern battlefield.

3. Methodology and Analytical Design

This study applies a qualitative case study approach to the 2022-2025 Russia-Ukraine war, treated as a critical case for examining accelerated military innovation under high-intensity conditions. The Ukrainian battlefield provides a unique empirical setting to assess whether FPV drone integration reflects a path-dependent evolution or marks a disruptive inflection toward a Revolution in Military Affairs (RMA). Our core method is pattern-matching: comparing observed developments - such as proliferation, tactical use, and organizational adaptation of FPVs - with theoretical expectations from established models of military evolution and RMA. This enables a structured evaluation of whether these changes signify refinement or paradigm shift.

3.1. Data Sources and Collection

The empirical dataset draws exclusively on open-source material from February 2022 to early 2025, including frontline accounts (e.g., social media posts by military personnel), investigative journalism (e.g., Reuters, The Guardian), think tank reports (e.g., RUSI, RAND), and preliminary academic studies on drone warfare. Preliminary academic research focused on drone warfare and the Ukraine conflict [26], [27], [28], [29], [30], [31]. Where available, quantitative data - such as drone output, cost, and attrition rates - are triangulated with qualitative insights on tactical use, adaptation, and effectiveness.

3.2. Analytical process

The analysis follows a three-stage process. First, theoretical criteria distinguishing military evolution from RMA are defined. Second, empirical data are synthesized to document FPV drone proliferation, tactical and organizational adaptations, and operational impacts. Third, findings are assessed against RMA criteria - technological innovation, doctrinal shift, organizational change, and induced obsolescence. Additionally, the study evaluates whether these dynamics reflect the emergence of *Tactical Network-Centric Warfare* (T-NCW), a new model marked by real-time ISR-strike integration and decentralized autonomy at the tactical level.

3.3. Limitations and Mitigation

Studying an active conflict like the Russia-Ukraine war involves methodological challenges, including limited data verifiability, potential selection bias from predominantly Ukrainian and Western sources, and the absence of observable long-term effects. To address these issues, data were cross-validated across independent sources, with priority given to direct visual evidence and triangulation. A cautious interpretive stance was maintained throughout, particularly in evaluating battlefield claims and loss estimates, acknowledging the broader information warfare context.

4. FPV Drone Proliferation and Battlefield Integration in Ukraine

The war in Ukraine has rapidly evolved into the most drone-intensive conflict in modern history, fundamentally reshaping the tactical environment through the mass deployment and improvisational integration of small unmanned aerial vehicles (UAVs). Among these, First Person View (FPV) drones - low-cost quadcopters operated through real-time video transmission - have transitioned from marginal experimental tools in 2022 to a dominant battlefield capability by late 2023 [32].

4.1. Cost Asymmetry and Tactical Economics

A defining feature of FPV drone employment is their extraordinary cost-effectiveness. Most FPV units are assembled using commercial off-the-shelf (COTS) components priced can be as little as $500 or less, yet they are capable of disabling or destroying high-value assets such as main battle tanks, self-propelled artillery, and command posts [33]. Analysts increasingly conceptualize FPVs as a form of "poor man's precision strike" capability [34]. This dramatic cost asymmetry disrupts traditional economic assumptions in attritional warfare, enabling the use of inexpensive platforms to neutralize expensive assets with minimal risk [13], [35].

4.2. Scale and Proliferation

The scale of FPV proliferation is without precedent. By late 2023, Ukrainian and Russian forces were reportedly deploying over 50,000 FPV drones per month, with January 2024 alone recording over 3,000 confirmed FPV strikes [32]. In early 2025, the Ukrainian Ministry of Defence reported a dramatic escalation, stating that the Armed Forces were receiving approximately 200,000 drones per month, most of them FPV units produced through local industry and volunteer networks [36]. In parallel, both Russia and Ukraine have developed extensive training infrastructures for drone operations. In 2023, the Russian

Ministry of Defence reported that it had trained approximately 3,500 FPV drone operators and 1,700 UAV teams across more than 800 educational facilities. In comparison, Ukraine's ambitious *Army of Drones* initiative trained over 20,000 UAV operators between July 2022 and February 2024, across 33 partner institutions, including grassroots initiatives, vocational centers, non-profits, and private firms. Despite Ukraine's quantitative advantage in UAV training, qualitative parity is likely. According to Dronarium Academy, a prominent Ukrainian training center with 11,800 UAV graduates, only 20% specialize in FPV drones, and just 10% of those attain high-level FPV strike pilot status. This implies that elite FPV operators constitute a small fraction of the total, suggesting both sides may have a comparable number of highly skilled FPV pilots, despite different training volumes [32]. Ukraine has also publicly announced plans to procure approximately 4.5 million FPV drones by the end of 2025, with a budget allocation of over $2.6 billion USD for this purpose [37]. This industrialization of FPV drone production has been facilitated by a decentralized, agile innovation ecosystem, mobilizing hundreds of startups, civilian volunteers, and public-private initiatives to drive rapid development and iterative adaptation [38]. This unprecedented scale of production and deployment signals a fundamental shift in the economics of warfare, allowing Ukraine to offset manpower asymmetries through volume-based technological overmatch. The case of drone supply in Pokrovsk - where Ukraine deployed drones to counter a reported 5:1 Russian infantry advantage [39] - highlights the strategic value of massed drone employment in force balancing scenarios.

4.3. Tactical Integration and Mission Typologies

One of the most transformative aspects of FPV and commercial drone use in Ukraine has been the creation of a near-continuous ISR (Intelligence, Surveillance, Reconnaissance) layer over the battlefield. Small UAVs, often adapted from commercial platforms like DJI Mavic, now monitor frontlines in real time, day and night, thanks to thermal imaging capabilities and adaptive flight planning. This persistent surveillance has collapsed the traditional distinction between “contact” and “non-contact” zones, making concealment, maneuver, and tactical surprise increasingly difficult. The result is a shift from episodic to persistent targeting cycles, where enemy activity can be detected, tracked, and engaged within minutes - a transformation that reshapes the tactical logic of maneuver warfare [30].

FPV drones have enabled new operational models and missions far beyond traditional ISR. Their roles now include:

- Direct precision strikes against armour, artillery, and personnel [33].
- Anti-personnel missions targeting trench systems, fortified positions, and individual soldiers, often by navigating into confined spaces [28], [30], [40].
- Drone-on-drone engagements, marking the emergence of low-cost aerial dogfights. In 2024, Ukrainian forces began deploying FPV drones for counter-drone missions, targeting enemy reconnaissance UAVs. These operations involved specially designed mobile coordination units that detect, track, and guide FPV kamikaze drones toward their targets. Initial interceptions rely on manual or semi-automated navigation, but future systems may feature onboard homing heads and air-

defence-style warheads. This marks the emergence of drone-on-drone engagements as a viable tactical layer in modern conflict, laying the groundwork for broader anti-UAV combat applications using inexpensive FPV platforms [41].

- Swarming tactics, involving coordinated mass drone attacks to overwhelm enemy defences, have become a key feature of Ukraine's use of FPV drones, as demonstrated in both real-world battlefield operations and formal modelling [40], [41], [42], [43].
- By 2024, Ukraine's Ministry of Defence was operating over 300 different UAV models, deployed for a wide range of missions including aerial reconnaissance, precision strikes, cargo transport, medical evacuation, and notably, improvised demining operations. These systems were often modified ad hoc, especially in situations where conventional resources such as artillery were unavailable, serving both to protect frontline troops and to halt enemy advances [30]. FPV drones have also been integrated into direct assault combat roles, particularly in offensive operations, where they are used to neutralize defensive strongpoints and suppress enemy firing positions [44].

A typical FPV drone strike cycle in Ukraine begins with a reconnaissance UAV (e.g., DJI Mavic) detecting a concealed target, transmitting coordinates via digital systems like Kropyva [45] to strike teams positioned kilometres away. Armed FPVs are then launched to engage with high precision. This has compressed the sensor-to-shooter loop from hours to minutes, enabling data-driven decisions at the tactical edge. Thermal optics and AI-assisted recognition further enable 24/7 operations, eliminating traditional periods of tactical pause.

These developments exemplify the rise of Tactical Network-Centric Warfare (T-NCW): a decentralized, bottom-up combat model in which ISR, decision-making, and strike execution are integrated within small, autonomous units. Unlike strategic-level NCW, T-NCW operates at the tactical tier, where real-time synchronization of sensor-to-shooter loops enables continuous, low-latency operations. This represents a foundational shift in how close combat is conducted and coordinated.

4.4. Psychological Impact and Operational Effects

Beyond kinetic effects, the omnipresence of FPV drones has generated significant psychological pressure on enemy forces. Constant exposure to aerial surveillance and the looming threat of precision strikes has created a pervasive sense of vulnerability on the battlefield, often described as "nowhere to hide" environment [46], [47]. Troop movements are increasingly restricted to nighttime hours or periods of poor visibility - patterns reminiscent of prior conflicts, such as in Iraq or Afghanistan, where insurgents exploited weather windows to evade drone surveillance.

This continuous overhead threat - comparable in psychological toll to persistent sniper fire or artillery harassment - has redefined the mental stress profile of combat. Soldiers are compelled to remain constantly concealed, limit electromagnetic emissions, and avoid fixed or open field positions. The U.S. Army's observations note that the sound of buzzing drones alone induces combat stress, contributing to cognitive fatigue and operational paralysis [47]. Moreover, FPV drones are reshaping the physical ergonomics of combat. Traditional ballistic protection - effective against bullets and shrapnel [48] - is often useless against kamikaze drones. Worse, such gear can delay evasion or hinder concealment when drone strikes are imminent. As a result, soldiers face a new dilemma: protective equipment may reduce survivability, not enhance it. This inversion highlights how FPV threats are altering the core logic of soldier survivability under drone-saturated battlefield conditions.

In response to these evolving stressors - including the physical limitations imposed by protective gear and the persistent cognitive pressure - commanders are increasingly forced to rotate frontline troops to reduce psychological burnout, impacting operational tempo and unit cohesion. In some sectors, up to 200 drones are reportedly lost daily due to the intensity of drone warfare [32], further underscoring the scale of engagement and the sustained psychological impact. Recent research on the psychological well-being of Ukrainian Armed Forces personnel highlights the cumulative toll of high operational demands, emotional fatigue, and organizational rigidity [49]. Ukrainian servicemembers often operate in environments of chronic uncertainty and high responsibility, under conditions that exacerbate the risk of both acute stress disorders and long-term psychological burnout. These findings resonate with the operational strain induced by persistent FPV drone threats - an omnipresent stimulus that contributes to mental fatigue and decision-making saturation, especially in frontline units exposed to continuous aerial surveillance and kinetic engagement.

A particularly novel dimension of FPV drone warfare lies in its media and information warfare applications. Unlike previous conflicts where combat footage was largely curated by embedded journalists or released by military PR channels, today's FPV drones provide frontline actors with the capacity to capture, edit, and disseminate combat footage in near real-time [50]. Ukrainian and Russian units routinely disseminate edited FPV footage via social media to boost morale, reinforce tactical narratives, and intimidate opponents - turning each strike into both propaganda and proof-of-capability. Analysts argue this has weaponized social media [51] into an extension of the drone battlefield, where psychological effects are projected not only toward enemy troops but also civilian populations and international observers [52]. This form of "strategic messaging by drone" amplifies the psychological dimension of warfare, as units seek to demonstrate lethality, control, and momentum to external audiences. Unlike traditional war correspondents, drone operators can collect and broadcast footage from dangerous frontline zones with minimal risk. As such, FPV drones serve a dual function: physical destruction and narrative projection - both of which contribute to shaping morale and perceptions of success.

5. Discussion: Assessing the Revolutionary Trajectory of FPV Drone Warfare

The empirical findings outlined above highlight a range of tactical, organizational, and psychological transformations catalyzed by the mass adoption of FPV drones in Ukraine. This section assesses whether these observed shifts meet the defining criteria of a Revolution in Military Affairs (RMA) - namely, technological innovation, doctrinal transformation, organizational adaptation, and systemic impact resulting in the obsolescence of prior military paradigms.

5.1. Technological Innovation: Accessibility, Affordability, and Adaptability

FPV drones represent a disruptive technological innovation by combining extreme affordability (COTS-based units priced at $400–$500), operational simplicity, and real-time precision via live video feeds. Their open architecture allows rapid, battlefield-driven upgrades - such as thermal imaging and anti-jamming features - without the need for complex supply chains. Ukraine's decentralized innovation ecosystem, involving civilian engineers, FPV enthusiasts, and startups, accelerates iterative development and battlefield responsiveness [38]. This bottom-up model reinforces the transformative potential of low-end systems: their simplicity enables scale, adaptability, and tactical effectiveness.

5.2. Doctrinal and Operational Innovation: The Emergence of Tactical Network-Centric Warfare (T-NCW)

The Ukraine conflict has given rise to new operational concepts centred around FPV drones, signalling a bottom-up transformation that redefines key tenets of traditional Network-Centric Warfare (NCW). Unlike NCW's strategic-level data fusion, Tactical Network-Centric Warfare (T-NCW) emerges at the tactical edge: real-time ISR, precision strike, and decision-making are distributed across autonomous micro-units. The battlefield has expanded both spatially and conceptually. Strike zones now reach up to 15 km beyond the frontline [53], dissolving fixed positions and enabling layered engagements. FPV teams operate as self-contained sensor - shooter nodes, leveraging tools like Kropyva to compress the sensor-to-shooter cycle from hours to seconds. These dynamics reflect C4ISR principles - Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance - but reinterpreted for decentralized tactical environments. T-NCW is reinforced by 24/7 ISR coverage (thermal drones), emergence of drone-on-drone combat, and widespread use of swarming tactics to saturate defences [40]. These shifts have prompted tacit doctrinal adaptation: both Ukrainian and Russian forces now assume constant exposure, prioritize dispersion and camouflage, and redesign manoeuvre strategies to reflect FPV threat saturation. In sum, FPV drones fulfil the doctrinal innovation criterion of an RMA. Their integration has catalyzed a new doctrinal reality: Tactical Network-Centric Warfare, where low-cost autonomy, precision lethality, and decentralized decision-making converge to redefine the logic of tactical dominance.

5.3. Organizational Adaptation: Structural and Institutional Transformations

A Revolution in Military Affairs (RMA) requires not only new technologies or doctrines, but also institutional reconfiguration. In Ukraine, the widespread adoption of FPV drones has triggered such structural transformation across force organization, training, and logistics.

Both Ukraine and Russia have created new units for drone operations. Ukraine introduced assault drone companies at brigade level and FPV reconnaissance teams at battalion level. Russia mirrored this by embedding drone sub-units within infantry companies [41]. A landmark development was the creation of the Force for Unmanned Systems in Ukraine in April 2025. This newly established branch manages all drone assets - land, air, and sea - effectively institutionalizing unmanned systems as a permanent pillar of national defence. It marks a profound organizational recognition of drones not as auxiliary enablers, but as central warfighting tools, akin to the institutionalization of air forces in the 20th century. These structural reforms extend into the domain of training and human capital development. By early 2024, Ukraine had trained over 20,000 UAV operators through the 'Army of Drones' initiative, in collaboration with 33 partner institutions - including civilian academies, vocational centres, and private-sector training hubs. Notably, new military specializations such as the "FPV drone pilot" or "tactical drone commander" have emerged. Russia has similarly scaled up operator training across over 800 institutions [32].

Ukraine’s drone training ecosystem reflects a hybrid civil-military model. FPV racing enthusiasts and civilian volunteers play a key role in skill transfer, with VR-like FPV interfaces enabling rapid transition from recreational flying to combat precision [54]. This immersive control environment allows talented civilians to become operationally effective in remarkably short timeframes - some evolving into elite FPV strike operators, or "drone aces", within weeks [55]. A new class of battlefield specialists - EW experts, drone mechanics, tactical drone commanders - has emerged, reflecting the formalization of drone-centric roles [56].

Logistics have also been recalibrated. Mobile drone repair workshops now operate near the frontlines, and Ukraine has adapted its logistics chains to source components through decentralized and resilient supply networks tailored for UAV operations [57]. These adaptations reflect a distributed sustainment model, responsive to fast-paced battlefield innovation cycles.

Taken together, these changes constitute more than bureaucratic adjustment - they signal a systemic reorganization of military institutions around drone warfare. This degree of institutional innovation and restructuring satisfies the organizational adaptation criterion of an RMA and demonstrates that FPV drones have transitioned from tactical novelty to doctrinal necessity, from battlefield improvisation to institutional integration.

5.4. Synergistic Effects and Doctrinal Obsolescence

The final and perhaps most critical criterion for determining whether FPV drones constitute a Revolution in Military Affairs (RMA) is the extent to which their cumulative impact has rendered previous military systems, doctrines, or structures obsolete - or forced a radical reassessment of their viability.

Empirical evidence from the Ukraine conflict points to several disruptive effects that challenge the foundational assumptions of pre-2022 tactical warfare:

- Attritional Dominance: Tactical drones -including FPVs and loitering munitions - now account for a dramatically increasing share of battlefield losses in Ukraine. By late 2024, open-source assessments - such as those from RUSI [31], and reported by outlets like Forbes and Foreign Policy-estimated that drones were responsible for 60-70% of all Russian equipment losses, surpassing all other conventional weapons systems in lethality [58], [59]. By early 2025, some estimates placed the share of drone-attributed losses at over 80%, particularly concerning Russian armoured vehicle and tank losses [60]. In sectors such as the Battle of Chasiv Yar, Lawfare reports that drones account for up to 90% of destroyed Russian equipment [61]. While not yet fully verifiable, the consistency and scale of drone-attributed damage across independent sources is striking. These battlefield effects reveal a fundamental shift: low-cost, modular FPV drones have transitioned from auxiliary tools to primary instruments of tactical lethality and disruption. This development transcends mere technological evolution, signalling a systemic transformation in how combat is conducted-challenging traditional ground-based firepower and compelling doctrinal adaptation. Collectively, these outcomes support the article’s core claim: Ukraine is witnessing the unfolding of a new Revolution in Military Affairs (RMA), with FPV drones at its tactical centre of gravity.

- Cost-Asymmetry and Strategic Disruption: FPV drones have inverted the economic logic of attritional warfare. A $500 drone can disable or destroy assets worth hundreds of thousands - or millions - of dollars, including tanks, howitzers, command posts, and logistics convoys [35]. This asymmetry imposes unsustainable cost burdens on forces dependent on legacy systems, forcing re-evaluation of procurement and protection doctrines.
- Obsolescence of Traditional Maneuver Concepts: The omnipresence of loitering FPV drones has rendered traditional armour-heavy manoeuvre tactics increasingly untenable without comprehensive EW coverage and active counter-drone systems. Tanks advancing without drone overwatch or protection are now highly vulnerable. This echoes how Blitzkrieg tactics in 1940 nullified static trench warfare doctrines of WWI. Due to the rising threat posed by drone swarms - particularly FPV drones -armoured fighting vehicles are no longer routinely deployed along the frontline. Instead, they are increasingly held in reserve positions or "protected hides", shielded by electronic warfare coverage. These vehicles sally forward temporarily to conduct direct-fire missions - typically aimed at disrupting enemy assault formations - and then quickly withdraw to cover before they can be targeted by drone strikes [31]. This shift reflects not only a tactical adaptation, but also a broader recognition of how drone saturation has redefined mobility and survivability on the battlefield.
- Persistent Psychological Pressure and Cognitive Saturation: Continuous aerial surveillance and the threat of sudden drone strikes have imposed a form of cognitive pressure previously associated with sniper fire or shelling - but now ubiquitous, persistent, and decentralized [46], [51]. Soldiers report altered movement behaviours, stress-induced fatigue, and operational paralysis [47]. These effects, although psychological, have tangible tactical consequences: slower reaction times, lower mobility, and degraded initiative.
- Erosion of Doctrinal Predictability: The speed of drone iteration and adaptation - driven by decentralized innovation and open-source ecosystems - makes FPV capabilities inherently unpredictable for opponents. In contrast to legacy systems, which evolve in multi-year procurement cycles, FPVs can evolve tactically week-to-week. This dynamic challenges traditional planning, which assumes adversary capabilities evolve more slowly.
- Weaponization of Information Space: FPV drones are not just physical tools of warfare - they are narrative weapons. Their onboard cameras provide real-time footage of strikes, which is selectively edited and shared on social media to amplify psychological effects, shape public morale, intimidate adversaries, and support internal and external legitimacy [50], [51]. Unlike traditional media embedded with rear-echelon units, FPV drones project unmediated combat imagery from frontline engagements. This contributes to morale shaping, political signalling, and information warfare - dimensions rarely associated with tactical munitions in prior conflicts.

Together, the operational, economic, psychological, and informational effects of FPV drones reveal a synergistic disruption of battlefield dynamics. Their proliferation has not merely enhanced tactical efficiency but reshaped the very logic of combat - forcing doctrinal revision, structural reconfiguration, and the reassessment of long-standing military assumptions. As with past RMAs, the revolutionary effects are first observed at the tactical and operational levels, but their strategic implications - spanning procurement, training, ethics, and national security - are quickly unfolding. Crucially, this transformation is driven not by exquisite, high-cost systems, but by cheap, modular, and decentralized technologies that enable new modes of warfare. These developments underpin the emergence of a new model: Tactical Network-Centric Warfare (T-NCW) - a paradigm that accelerates lethality, decentralizes decision-making, and renders hierarchical command architectures increasingly obsolete. While FPV drone warfare builds on some elements of the precision-strike RMA - such as information dominance and compressed kill chains - it introduces a novel trajectory. Grounded in grassroots innovation and micro-level ISR–strike autonomy, T-NCW represents a bottom-up operational architecture that reframes, rather than replaces, earlier RMAs. It signals the rise of a decentralized model of revolutionary military transformation.

6. Conclusion

The analysis of the FPV drone phenomenon in the Ukraine conflict reveals a coherent pattern of transformative military change. Drawing upon empirical evidence and applying established conceptual frameworks for evaluating Revolutions in Military Affairs (RMA), this study finds compelling support for the argument that FPV drones constitute more than a predictable evolutionary trajectory. They represent a qualitative rupture that is reshaping the character and conduct of warfare.

Specifically, the Ukrainian experience demonstrates that FPV drones fulfil all four core criteria of an RMA:

- Technological innovation: The introduction of radically low-cost, modular, and accessible precision-strike systems, with rapid battlefield iteration and minimal entry thresholds.
- Doctrinal and operational innovation: The emergence of novel tactical paradigms - such as drone swarming, drone-on-drone aerial engagements, and continuous ISR-guided targeting - that compress the sensor-to-shooter cycle and extend combat into a 24/7 battlespace.
- Organizational adaptation: Structural transformations within armed forces, including new drone-specific units, training ecosystems, and the institutionalization of unmanned systems through entire service branches.
- Systemic impact and obsolescence: The disruption of traditional ground combat models, degradation of high-value legacy platforms (e.g., tanks and artillery), and pervasive psychological effects on enemy forces.

Crucially, FPV drone warfare has given rise to a new operational logic we describe as Tactical Network-Centric Warfare (T-NCW): a decentralized, data-driven model where small, dispersed units leverage ISR drones, strike assets, and digital mapping platforms to execute autonomous, real-time precision operations. While inspired by traditional Network-Centric Warfare (NCW), this emerging model is distinct in scale, affordability, and grassroots adaptability - making it both a signature of the current RMA and a potential template for future conflicts involving asymmetric or hybrid actors.

While the present revolution is most visible at the tactical and operational levels, cascading effects - doctrinal, organizational, and technological - suggest an unfolding systemic transformation. Historical analogies, such as the evolution of Blitzkrieg in World War II, support the notion that tactical innovations can foreshadow paradigm shifts in global warfighting strategies. The current trajectory of drone warfare in Ukraine strongly suggests a similar, profound paradigm shift in global warfighting strategies. The current trajectory of drone warfare in Ukraine may follow a similar path. Therefore, this study concludes that the widespread adoption, tactical integration, and doctrinal institutionalization of FPV drones in Ukraine constitute the catalyst of a new Revolution in Military Affairs. Rooted in affordability, decentralization, and adaptability, and expressed through the emerging paradigm of Tactical Network-Centric Warfare, this transformation challenges legacy assumptions and redefines both the tools and logic of 21st-century conflict.

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