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Issue Brief

First Person View (FPV) Drones: When Quantity Equals Quality

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Summary

First Person View (FPV) drones have been used by both the antagonists in the Russia–Ukraine conflict. Despite their limited payload capacity and reduced flight time due to their focus on speed and maneuverability, FPV drones are ideal for close quarter battle (CQB) situations. FPV drones combine personalised target selection, accuracy, autonomy, EW resistance and guidance into a single platform, at the fraction of the cost of bigger and more sophisticated platforms.

Introduction

The ongoing Russia–Ukraine conflict has featured use of a host of critical and emerging technologies (CETs).[1] Artificial intelligence (AI), drones, unmanned underwater vessels (USVs), facial recognition technology (FRT) are some of the niche technologies that have been leveraged by both sides in an attempt to gain tactical advantages over the other. However, what remains under-appreciated in the strategic literature—at least outside of posts on social media platforms saturated with war footage of the conflict—is the innovative use of certain platforms and technologies.

Optimising the use of such technologies requires a combination of scale, training and innovation since the platform is generally a mix of collaboration, convergence and cost-savings. One such platform is the first person view (FPV) drone, whose initial usage by the Ukrainian Armed Forces (UAF) led to a reciprocal response by the Russian forces,[2] with a result that the conflict in the region has quite literally become a 'game of drones'.[3] This Brief analyses the FPV drone in detail, documents some of its uses in the ongoing Russia–Ukraine conflict and comments on the future of this technology and platform.

FPV Drones

FPV drones are aerial drones with an onboard camera whose live feed is streamed directly into the FPV user's goggles, headset, smartphone device or any other device deemed compatible.[4] FPV is a viewing angle where the pilot sees only what the drone sees. There are multiple types of FPV flying such as FPV freestyle (for beginners), cinematic and drone racing (going through a series of obstacles, flags and gates).[5] The first amateur drone racing was held in 2011 in Karlsruhe, Germany,[6] followed by Australia in 2013.[7] The event is now handled by professional racing agencies Drone Racing League (DRL), Airspeeder and MultiGP, among others.

FPV racers also use certain exclusive terms within their clique such as bando (abandoned buildings) and orbit (flying in a circular path).[8] These drones offer three major advantages: immersive experience for the user/pilot who can see in real-time what the drone is seeing, more precise flying and better accuracy due to low latency

[1] Ulrike Frank and Jenny Soderstrom, **"Star Tech Enterprise: Emerging Technologies in Russia's War on Ukraine"**, European Council on Foreign Relations, 5 September 2023.

[2] **"Ukraine to Produce a Million FPV Drones Next Year -Minister"**, *Reuters*, 21 December 2023.

[3] Can Kasapoğlu, **"A Game of Drones in the Russia-Ukraine War"**, Hudson Institute, 9 August 2023.

[4] Grace Dean, **"What are FPV Drones?"**, *Space.com*, 20 October 2021.

[5] **"The Best FPV Drones"**, UAV Coach, 2024.

[6] Grace Dean, **"Drone Racing: Everything You Need to Know"**, *Space.com*, 7 December 2021.

[7] **"What is Drone Racing ?"**, Drone Racing Australia Inc, 2024. "

[8] **"Glossary of Terms"**, FPV Freedom Coalition, 9 November 2018.

transmission. All three characteristics are a boon for the warfighter. Real-time communication, precision flying and accuracy are important attributes of modern warfare. This third dimension flying capability has been leveraged by soldiers in Russia and Ukraine to gain tactical advantages over each other.

FPV drones offer other advantages too. They may be assembled with disparate parts from other cannibalised platforms, 3D printed, fitted with bespoke explosives and made ready in a fraction of the time it takes to put together more sophisticated platforms like fighter jets and bigger unmanned aerial vehicles (UAVs) on industrial assembly lines. An FPV drone, if handled properly, can be visualised as an extremely fast and manoeuvrable, pin-point explosive that can neutralise hard-to-reach targets such as soldiers hiding inside bunkers. It combines the accuracy of a precision-guided munition (PGM) with the mortar round's ability to locate and hunt targets in defiladed positions (reverse slope of a hill or within a depression in level or rolling terrain). Some obvious limitations, such as limited endurance, payload capacity and range have adverse implications for the soldier, if these are viewed as solely flying platforms. But viewed as alternatives to expensive ammunition with added benefits of manoeuvrability, scalability and cost-effectiveness, these appear as lucrative acquisitions in modern warfighting.

FPV vs Regular Drones

There are five key attributes in which FPV drones differ from regular drones.

Control and Perspective

Regular drones operate on a line-of-sight principle when a pilot is in charge or through GPS/GNSS receivers, inertial navigation systems (INS), LiDAR scanners, ultrasonic sensors and visual cameras when in autonomous or semi-autonomous mode. The drone pilot can view the flying drone (for tactical drones) directly or look at its video feed on a console or screen. The camera of a regular drone is generally underslung and mounted on a gimbal which allows for rotation of the camera and in-flight stabilisation. FPV drones, on the other hand, provide the operator with a first person view, simulating the experience of flying from the drone's cockpit. This is achieved by streaming the feed directly into the goggles or headset of the operator.

Manoeuvrability and Speed

Regular drones have the capability to hover and maintain a stable path, making them ideal for intelligence, surveillance and reconnaissance (ISR) missions where steady footage and detailed environmental scan are required. FPV drones rely on speed, compactness and extreme maneuverability—ideal for close quarter battle (CQB) situations such as counterinsurgency/counter terrorism (CI/CT) scenarios.

Payload and Endurance

Regular drones, depending on their type, have a larger payload capacity and endurance which allows them to be used for complex missions involving multiple sensors and coordination with other entities and platforms. FPV drones have limited payload capacity and reduced flight time due to their focus on speed and maneuverability. Their payload is generally an onboard camera (or two) and bare minimum additional equipment. They are ideally suited for kamikaze or one-way missions.

Operational Use

There is partial overlap between regular and FPV drones in terms of operational use, in that both categories are used for ISR and kinetic missions. The difference is in the nature, complexity and size of the terrain or battleground. While the former is used over a wide geographical area for gathering intelligence or to monitor ongoing operations, the latter is used in complex, congested, or close quarter situations which may involve small-scale precise tactical strikes.

Technological Complexity and Cost

Regular drones can be more technologically sophisticated, incorporating advanced navigation systems, autonomous capabilities, and high-definition sensor suites. This complexity often results in a higher cost per unit. FPV drones place more emphasis on manual control and agility, relying less on autonomous navigation and complex sensor payloads.

Sub-systems of FPV Drone

FPV drones are made up of four major component groups which are frame, flight system, power system and the FPV system.

Frame

The frame is the base or foundation of the FPV drone and all modifications and attachments to the drone have to be done based on the design of the frame. The frame is made up of carbon fibre. There are three attributes that need to be kept in mind when designing a frame for an FPV: frame shape (True X, Wide X, Stretch X, Hybrid X, Dead Cat, H, HX, Z, Plus and Vertical Arms), wheelbase (varies between 65mm to 280mm) and mounting holes.[9]

Flight System

Flight system components include flight controllers (FCs), electronic speed controllers (ESCs), motors, propellers or props, radio and receiver. While the flight

[9] Oscar Liang, **"A Comprehensive Guide to FPV Drone Frames"**, *OscarLiang.com*, 29 April 2023.

controller is generally considered the brain of the FPV drone and has sensors like gyroscopes, accelerometers, barometers, global positioning system (GPS) and magnetometers, ESC takes command from the FC, draws power from the battery and controls the speed of the motors. ESC comes in two varieties: individual ones for each motor or the 4-in-1 ESC which is a single circuit board with four speed controllers built into it. FPV drones usually employ brushless motors for powering their flight, while propellers provide the thrust needed to lift the drone off the ground. FPV drones can have three, four and six propellers too. Finally, the radio and receiver takes the command from the user's radio controller and relays it to the FC through a specific set of transmission protocols.

Power System

This consists of the battery and the power distribution board (PDB). FPV drones mostly use lithium polymer batteries and these define the amount of time the drone can remain airborne. PDB is a traditional circuit board which powers the motors but these days many flight controls come equipped with an integrated PDB.

FPV System

The FPV system contains a camera (or two if the user also wants to record a video), VTX module and goggles. One of the most unique things about the FPV cameras is that the main camera being used to 'sense' the surroundings is kept still and mounted at an elevation so that the user can see ahead. Unlike regular drones, there is no gimbal for horizontally or vertically panning the camera. The VTX module converts the captured image/video by the camera into a compatible signal for transmission.

Russian Use of FPV Drones

Russian design and deployment of FPV drones has followed two near parallel paths: private entrepreneurship and state-supported initiatives. The Russian forces have used FPV drones in both manual and AI-enabled modes and have continuously tested these platforms directly on the battlefield. Drone development efforts are spearheaded by volunteer communities in the country that have a significant academic and hi-tech background.

Initially ceding territory to the Ukrainians at the start of the conflict in 2022, Russia has clawed back its advantage on the back of rapid prototyping and scaling in late 2023 and 2024, focusing on two platforms: AI-enabled and manual FPV drones[10] and light weight quadcopters[11], the former for kinetic one-way missions and the

[10] **"How are 'Kamikaze' Drones Being Used by Russia and Ukraine?"**, *BBC News*, 29 December 2023.

[11] Samuel Bendett and Jane Pinelis, **"How the West Can Match Russia in Drone Innovation"**, *War on the Rocks*, 25 January 2024.

latter for ISR. The former's development is an outgrowth of the proliferation of commercially available off-the-shelf (COTS) equipment available in the open market. Another reason is the relative ease of bypassing sanctions on non-military commercial products.[12] AI-enabled FPV drones are the next step in the evolution of these platforms. The additional advantage of having a human 'on the loop' always remains.

The success of these AI-enabled drones was witnessed in a racing competition held at the University of Zurich between 5 and 13 June 2022 when Swift, an AI-enabled FPV drone designed by researchers at the university, went head on against three drone racing world champions and beat all of them.[13] The drone used reinforcement learning to train itself from real-time data collected by an onboard camera and an inertial measurement unit measuring acceleration and speed. This process had limitations of the drone not being able to replicate the same performance with changed ambience settings such as change in weather or light patterns.

A similar technique seems to have been used by Russian volunteers in August 2023 when they unveiled the Ovod (Gadfly) FPV drone whose onboard AI allowed for attacking static and dynamic targets with up to 90 per cent accuracy.[14] Some Russian media outlets have hinted that these drones have already been deployed in battle, mostly by irregulars of the Donetsk People's Republic (DPR) and the Luhansk People's Republic (LPR), in addition to the Wagner group.[15] A critical reason for the use of AI-enabled drones is to remove the drone pilot from harm's way since use of FPV drones requires the pilot to be in close vicinity of the target. These drones rely on line of sight communication with either the ground station or the radio controller with the soldier. Use of AI-enabled drones aims to preserve the lives of the pilots.

FPV drones are being increasingly adopted by Russian forces. An unofficial norm is to use Lancet for long range, kamikaze drones for operational depth and FPV drones for tactical strikes. One of the major advantages (or disadvantages depending on perspective) is that a majority of FPV drones are being procured by and innovated by volunteers and private groups, enabling much better adoption and innovative material scrounging.[16]

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[12] Nikolay Staykov, **"Catching Spiders: Russia's Drone Companies and Sanctions Evasion"**, *The Insider*, 19 February 2024.

[13] **"Challenge Accepted: High-Speed AI Drone Overtakes World-Champion Drone Racers"**, University of Zurich Press Release, 30 August 2023.

[14] David Hambling, **"Russians Are Developing an Arsenal of Deadlier FPV Drones — But Bureaucracy is Holding Them Back"**, *Forbes*, 1 September 2023.

[15] Ria Novosti, **"It is Planned to Create Their Own UAVs for the Troops of the DPR and LPR, Rogozin Said"**, *Ria.ru*, 12 November 2022.

[16] David Hambling, **"Russian Volunteer Group Claims to Make 1,000 FPV Kamikaze Drones A Day"**, *Forbes*, 5 December 2023.

A typical example is that of the Sudoplatov 'Judgment Day' group which has created an FPV drone worth US$ 440 and which can carry a payload of seven pounds over almost eight kilometres.[17] Other groups include Archangel[18] and models like Ghoul.[19] Training for FPV pilots has been reduced from four to two weeks while drone racing may be included as an official Russian sport, part of the Games of the Future event this year.[20] However, slow procurement efforts by the Russian Ministry of Defence (MoD), as of date, may dampen these efforts in the medium to long term since production scaling will require capital investment in terms of machinery and money.

Ukrainian Use of FPV Drones

Ukraine has been a pioneer of drone warfare in this conflict from the start. Ukraine initially relied on larger drones, but shifted to smaller technology to adapt to Russian advances. This was a progressive step based on Russia's increasing control of the airspace. In the initial days of the conflict, when Russia's air defense and electronic warfare (EW) capabilities were less pronounced, Ukraine relied on larger drones such as the Turkish TB2 Bayraktar to great effect.[21] Ukrainians have also gained from US transfers of tactical micro drones and loitering munitions such as Switchblade, Puma and Phoenix Ghost.[22]

FPV drones were first introduced by the Ukrainians in end of July 2022 when a video uploaded on X (previously Twitter) by Ukraine's 93rd Brigade showed an FPV drone taking out Russian soldiers by precisely striking through an open doorway.[23] Today, companies like Escadrone have developed Pegasus FPV drones which take five minutes to be assembled and deployed.[24] The drone has gone through multiple iterations in design optimisation (improvements in motors, radio antennas and control electronics) since the different variants can be sent to the same target in case

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[17] Samuel Bendett, **"From Russia's Sudoplatov 'Judgment Day' volunteer effort [...]"**, *Twitter*, 21 July 2023.

[18] David Hambling, **"Russia Prepares An 'Avalanche 'Of FPV Kamikaze Drones"**, *Forbes*, 26 July 2023.

[19] **"Meet 3D-printed Ghoul Drone Used by Russian Special Forces in Ukraine"**, *Armyrecognition.com*, 9 October 2023.

[20] David Hambling, **"Russia Prepares An 'Avalanche 'Of FPV Kamikaze Drones"**, no. 18.

[21] Agnes Halou, **"With Turkish Drones in the Headlines, What Happened to Ukraine's Bayraktar TB2s?"**, *Breaking Defense*, 6 October 2023.

[22] Jon Harper, **"US Commits to Procuring a Variety of Additional Drones for Ukraine on Anniversary of Russian Invasion"**, *Defense Scoop*, 24 February 2023.

[23] **"Angry Drones of Ukraine Armed Forces. What Types of Kamikaze Drones Are Most Publicly Mentioned: Statistics and Examples"**, Molfar.

[24] David Hambling, **"The Key is Pilots, Not Drones: Ukraine's Escadrone on the Skill of Flying FPV Kamikazes"**, *Forbes*, 5 May 2023.

of failure, being produced at the rate of 1,000 per month currently. Other groups include Vyriy Drone (Molfar FPV), Aerorozvidka and Drones for Ukraine.[25]

Ukraine has also attempted using AI-enabled FPV drones to target Russian trenches and troop positions.[26] One of the main challenges for Ukrainian drone pilots has been the deployment of extensive electronic warfare (EW) suites and air defence (AD) systems by Russia, as a result of which they were losing close to 10,000 unmanned systems a month. In previous attempts, while a significant number of their FPV drones did get close enough to trenches and Russian armour to inflict damage, there have been ample sightings and reports that suggest that electronic interference has prevented the pilot from observing and therefore precisely homing in on their target as a consequence of the link between the drone and pilot rupturing.

Use of AI on board these drones may enable them to continue on an autonomous mode even after communication between the pilot and the drone breaks down. A Ukrainian company, Twist Robotics, is at the helm of creating these drones, which have been termed the 'poor man's Javelin'.[27] Ukrainian President Volodymyr Zelensky has announced the creation of an Unmanned Systems Forces that will bring all drones operated by the country's armed forces under a single centralised command. Ukraine aims to produce one million First Person View (FPV) drones in 2024 and the BRAVE1 defence technology cluster is at the forefront of this effort.[28] Pilot training has also been expedited at the Boryviter Military School whose primary goal is to enhance the qualifications of Ukrainian service members, focusing on intensive training in eight crucial areas, including UAVs and military communications.[29]

Quantity as Quality: A Shift in Warfighting Perspective

Five attributes need to be kept in mind when analysing FPV drones from a quality versus quantity perspective.

Cost Benefit Analysis

One of the major aims within any conflict is to attain a desired military end state with minimal damage and expenditure of own platforms and ammunition. The ongoing conflict in Ukraine, American expenditure of Tomahawk missiles against the

[25] Ibid.

[26] Alex Wickham, Ellen Milligan and Alberto Nardelli, **"UK, Allies Look to Arm Ukraine With AI-Enabled Swarm Drones"**, Bloomberg, 17 February 2024.

[27] Evgen Pilipenko, **"Ukraine Creates FPV Drones with Artificial Intelligence: They Pursue a Target Without an Operator – WP"**, *Liga.net*, 26 July 2023.

[28] Natalia Drozdiak, Ellen Milligan and Aaron Eglitis, **"Ukraine is Promised 1 Million Drones Within a Year by Allies"**, Bloomberg, 16 February 2024.

[29] Dominique Sogel, **"War on a Budget: Ukraine Becomes Hotbed for Drone Tech"**, *The Christian Science Monitor*, 20 December 2023.

Houthis in the Red Sea[30] and Israeli strikes in Gaza have renewed urgency across countries on the need for massive quantities of ammunition. The requirement of different calibres along with requirements of precision, combined with limited production capabilities of industrial complexes and exorbitant costs of the ammunition themselves mean that cheaper, faster and scalable alternatives need to be found.

FPV drones offer one such alternative. Capable of being produced in their thousands, these drones offer a cheaper and scalable alternative to precision weapons since they combine personalised target selection, accuracy, autonomy, EW resistance and guidance into a single platform, at the fraction of the cost of bigger and more sophisticated platforms. One of the major challenges faced by both countries' forces has been the syncing between volunteer efforts innovating effective and new designs and the capital expenditure of the governments.

Once these are in place, these drones offer far better alternatives to their costlier counterparts and can be seen to offset certain shortfalls in various forms of ammunition including artillery shells, short range tactical missiles and PGMs. Even the US Department of Defense (DoD) has realised the advantages of having thousands of autonomous systems across multiple domains, and announced the Replicator Initiative in August 2023. The aim is to produce 'attritable' platforms which are unmanned and are built affordably by August 2025.[31] However, though cost is a significant factor in this programme, the aim of the Pentagon is to reduce the cost per piece of an unmanned system from tens of millions of dollars to tens or hundreds of thousands of dollars per piece. Currently, the Switchblade 600 kamikaze drone is likely to be the first platform to be selected under the initiative.[32]

Collaboration

FPV drones are currently used in standalone modes for tactical level actions. But they may be required to act in coordination with other platforms such as other bigger UAVs, artillery batteries and as part of a combined arms assault. FPV drones may also be used in CI/CT areas as part of what this author terms a 'disaggregated mothership mode' (DMM) where a larger UAV/ quadcopter can hover over a particular area in a mountainous, forested or built up terrain, register the coordinates and then send them to an FPV operator who can then use the FPV drone for taking out hostile individuals without causing any collateral damage.

Another example can be that of AI-enabled FPV drones acting in tandem with drone swarms for taking out adversary counter drone, AD systems while the swarm targets

[30] Elbridge Colby, **"The Tomahawk Land Attack Missile (TLAM) [...]"**, *Twitter*, 13 February 2024.

[31] Joseph Clark, **"Defense Officials Report Progress on Replicator Initiative"**, US Department of Defense, 1 December 2023.

[32] Brandi Vincent, **"Switchblade 600 Kamikaze Drones in the Running for Replicator Mass Production"**, *Defense Scoop*, 2 February 2024.

the bigger installation. The requirement of collaboration will require compatible communication systems, all mapped to a certain plug and play command and control architecture, where decentralised teams can cause extensive damage.

Scaling and Government Support

The effectiveness of FPV drones as a major attack platform took a significant amount of time to register in the higher echelons of the Russian military hierarchy as compared to the Ukrainians, because for the latter, innovation exists as a complement to aid. Bigger conventional militaries consider attritable platforms as a sideshow as compared to armour, fighter jets or artillery. However, once the Russian soldiers realised the efficacy and, more importantly, the constant availability and readiness of FPV drones, the Russian MoD has slowly started providing financial support to selected drone makers and help them to scale.[33]

State support is absolutely essential in scaling up the production line of FPV drones. Platforms like FPV drones will have to demonstrate their effectiveness as kinetic platforms in the battlefield before being considered worthy of being supported through the national treasury. One of the biggest reasons behind this is that the entire concept of an FPV drone is anathema to a conventional warfighter. Most consider 'rigged' drones to be worthy of being used only by non-state actors due to their cheap costs and COTS components.

Pilot training and Push for Innovation

The cheap cost of FPV drones is offset by the amount of training and hand-eye coordination required to operate them. Even when used in drone racing, the constraint of a look-ahead camera with a narrow field of view requires constant practice to overcome. It is for this reason that the Ukraine Army trains their FPV pilots for a month with a pass rate of only 60–70 per cent, as compared to the Russians' two weeks training.

A study conducted at the University of Zurich involving five drone racers each from the professional and novice categories respectively concluded that professional pilots consistently outperformed beginner pilots by achieving faster lap times, higher velocity and chose more optimal racing lines.[34] The training standards can also be improved using virtual reality (VR) simulations.[35] Also, the role of private funding and crowdsourcing also needs to be understood and put in context. In the case of

[33] David Hambling, **"Russians Are Developing an Arsenal of Deadlier FPV Drones — But Bureaucracy is Holding Them Back"**, *Forbes*, 1 September 2023.

[34] Christian Pfeiffer and Davide Scaramuzza, **"Expertise Affects Drone Racing Performance"**, Cornell University, 15 September 2021.

[35] Matteo Macchini, Manana Lortkipanidze, Fabrizio Schiano and Dario Floreano, **"The Impact of Virtual Reality and Viewpoints in Body Motion Based Drone Teleoperation"**, Cornell University, 30 January 2021.

Ukraine and Russia, the funding, innovation and push for deployment of these FPV drones has come from university students, academics and soldiers on the ground. Combining the experience of the soldier with the expertise of technical experts is one of the better ways to push a particularly effective, yet under-appreciated, technology on to the battlefield.

Iterative Deployment and Design

Deployment of FPV drones has preceded design in an iterative fashion. Stress testing of these platforms has not been done in a lab or firing range but directly on the battlefield which tests the equipment in the conditions it is meant to be used and not on idealised representations. In a number of cases, the design and structure of the FPV drones has undergone a major change based on inputs from users and battlefield footage.

Conclusion

FPV drones, combined with AI, are the next evolution in warfare. Cheap to design and develop, comparatively easy to scale, these drones have proven that quantity has a quality of its own, at least in future warfare where rates of ammunition expenditure, especially precision ones, may determine the outcome of a war.

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