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Usage, effectiveness and recent trends of FPV-drones in the Russian invasion of Ukraine based on published combat footage

1 Introduction

This memo analyses the usage of so called ”FPV-drones” (First Person View) in the Russian invasion of Ukraine, with a special focus on the later developments of their deployment. The data, which consists of mainly video and image content, used for this analysis has been gathered from open sources available to the public through various websites and forums. Conducting this sort of data analysis, involving open source intelligence (OSINT), brings several important aspects to take into account, which will be addressed further on in this introduction.

1.1 FPV-drones

FPV-drones, or FPV's as they are often called, are named from the method that is used by the operator controlling the drone, where the operator has a first-person-view from the camera mounted on the drone that feeds the on-board video to a set of goggles or a monitor. These drones have previously been used in private and commercial settings with applications such as recreational racing and professional cinematography. Their ability to perform extremely quick accelerations and general agility in the air, enabled by a lack of stabilisation performed by the on-board avionics, puts high demands on the operator. This sets FPV's apart from the more commercially available multi-rotor drones with their relatively simple control setup and stabilisation. An example of an FPV-drone can be seen in Figure 1.

Figure 1, an FPV-drone with an example of a warhead to the right of the FPV. Photo credit: Joakim Rydell (FOI).

1.2 Disclaimers

The data used for this analysis were gathered from open sources available to the public through various websites and forums. This means that much of the content used for data analysis were published for a number of reasons, including propaganda. The usage that haven't been published are probably a mixture of failures and successes. Failures might not be published since it can give an observer the perception of poor performance from the publisher's part in the war. Success stories, on the other hand, might not be published due to the publisher's intent to keep the method of usage undisclosed in order to prevent the opponent from adapting to the methods used.

One must also consider other factors, which will negatively affect the analysis of the data gathered through these means. Perhaps a certain type of target is often seen in these types of videos published online, but what is not seen is another type of target that successfully counters the FPV-threat. This form of survivorship bias is difficult to account for in this type of data gathering. It is important to keep in mind that targets that, for example, have EW (Electronic Warfare) or other C-UAS (Counter-Unmanned Aerial System) capabilities will have a lower probability of being represented in this data set.

It is important to note that the mere existence of footage of an FPV striking a target, as seen from the drone's video feed, does not mean that the strike was successful. However, the footage of an FPV reaching a target nevertheless still indicates its usage and can assist in forming an overall picture of its capabilities with regards to range, technical limitations and flight characteristics.

Throughout this memo, several statements regarding what have been observed in published video footage will be made. These claims will have source links where it is applicable, but some instances will not provide an appropriate source of a trend. In these instances, the statement reflects impressions from the OSINT work conducted throughout the war.

This memo aims to briefly inform on the usage of FPV's by using published content only. There are, however, wider aspects that should be taken into account during discussions of FPV's. In order to get the full picture of their usage, one should take into account economical aspects, safety aspects of their usage and many more that are not represented in the footage published.

2 Usage of FPV-drones in the Russo-Ukrainian war

In the Russo-Ukrainian war, FPV's have been used in various combat roles. The most prolific of these is where different types of warheads have been strapped to them making them a sort of improvised missile as seen in Figure 2. The targets seen in these clips throughout the war has typically been infantry, combat vehicles such as armoured personnel carriers, infantry fighting vehicles and main battle tanks, as well as logistical vehicles operating close to the frontline. These remain the significant portion of targets seen in the published video content to this day but several other target categories have emerged as the war has progressed.

Figure 2, an example of an FPV-drone used in Ukraine. Note the anti-tank grenade mounted underneath the drone and the battery in blue strapped on top. "Ukrainian FPV loitering munition with RPG-7 ammo" by АрміяІнформ is licensed under CC BY 4.0.

A very common type of published video of FPV-usage shows only the last few seconds before the drone strikes its target. There are also videos showing a patrolling behaviour where an area is searched and once a target is detected the drone proceeds to strike [1] [2]. There are also several examples where a target is being filmed by a separate reconnaissance UAV (Unmanned Aerial Vehicle) and is then struck by an FPV [3]-[5]. These examples indicate that FPV's are filling roles that conventional militaries would leave to loitering munitions, precision-guided munitions and indirect fire. This does not necessarily mean that FPV's are suitable replacements for these types of systems but perhaps, as they are being used, the reason might be a lack of these aforementioned weapons. The rest of this chapter will cover three distinct capability trends of FPV's that have emerged during the Russian invasion of Ukraine, as well as a summary of open source data on the effectiveness of FPV's against armoured targets.

2.1 Long-range capability

The initial video footage of FPV's in an improvised missile role showed them targeting unarmoured vehicles such as logistic trucks, as well as armoured fighting vehicles in the form of main battle tanks, infantry fighting vehicles and armoured personnel carriers. Later in the war in 2023, the selection of targets increased to sensor and weapon systems that, according to common military doctrine, should be situated further from the front. This may represent an increase in effective range, assuming that targets such as anti-aircraft-systems and radar systems are situated further from the front compared to the previously mentioned targets [6]-[13]. This is of course difficult to verify without knowing the location of the strike, however the pattern of struck vehicles could be an indication of an increased range capability. It could also be the result of long-range capabilities being deployed closer to the front due to various reasons such as degraded gun barrels in artillery, or an especially strong need to reach further into the opponent's rear thus forcing the long-range systems to deploy closer. Nonetheless, footage of these presumed long-range strikes have continued as of the writing of this memo.

The method of the aforementioned usage indicates a reconnaissance part of the operation since the location of a target has to be known if it is in the further rear of the enemy in order for an FPV to acquire the target. This can be seen in one of the examples previously mentioned where a separate reconnaissance UAV is tracking the target before the FPV strikes [9]. Two technical aspects that limit the effective range of the FPV's are the battery capacity and the communication link between the drone operator and the drone itself. The question of which is the limiting factor depends on factors such as the EW environment and what payload the FPV carries. Communication, for example, can be improved through the usage of UAV's equipped with communication relays. The issue of battery capacity could be resolved by deploying the FPV closer to the target by releasing it from another UAV in a setup not all too dissimilar to conventional UCAV systems, such as the American MQ-9 Reaper or the Russian Orion. It has been mentioned that this has occurred and it is by no means unfeasible [14] [15], but it is rather difficult to verify this kind of usage through publicly available combat footage, where often the intent is to display success and perhaps not all the technical and operational aspects that led to the said success.

2.2 C-UAS using FPV-drones

Two new types of video footage started appearing in the latter half of 2024. The first shows FPV's targeting primarily fixed-wing reconnaissance drones at significantly higher altitudes compared to previously seen videos of FPV usage [16]-[21]. Most of the published videos showing this phenomenon depict Russian UAV's being targeted, but there is also usage from the Russian side where Ukrainian fixed-wing drones are being targeted [22] [23]. In some of the footage there are more than one FPV chasing the fixed-wing UAV [24] [25]. Similar footage, where the FPV instead targets loitering munitions was also noted in the late summer of 2024 [26]-[29]. Earlier in the war, footage of quadcopter UAV's engaging other multirotor UAV's was observed [30]-[33], but this new usage against fixed-wing UAV's using FPV's, became a clear trend in the second half of 2024 where an increased amount of footage was published consistently.

Compared to the FPV-strikes on ground targets, this new capability raises several more questions regarding the method of usage. One aspect that certainly sets this method of usage of FPV's aside, from earlier ones, is how the FPV is guided to the right location and correct altitude. It essentially turns the problem of target acquisition from 2D into a 3D-problem since instead of looking for targets on the ground, it has to scan the airspace. In addition, the fixed-wing UAV's targeted are often flying at various altitudes and at considerably higher speeds compared to ground targets. Getting to the high altitude where the fixed-wing UAV's operate will drain much of the FPV's battery. This is a key issue for the quadcopter-style FPV's which might be weighed down by some sort of warhead, as mentioned in the previous section regarding the long-range capability. Utilising another UAV to carry the FPV closer to the target could work as a solution in this use case, similar to the long-range capability case. Compared to the ground strike capability, this new method of operation cannot be accomplished unsupported. It seems improbable that the EO/IR sensors on these FPV's is enough by itself in finding fixed-wing UAV's and therefore it could be theorised that other sensor systems work in tandem with the FPV's, such as radar, or more capable EO/IR sensor systems.

Counteracting this new threat to fixed-wing UAV's has also been observed. It is important to keep in mind the inherent bias in the footage being shown. If a method for countering these FPV's works well, there is a high chance that footage of the counteraction seen from the FPV's point of view is not published due to the inherent propaganda value of only publishing combat footage displaying successes. Nonetheless, a method of trying to manoeuvre out of harm's way can be seen in those videos where fixed-wing UAV’s manufactured by Russian Zala Aero Group seem to detect the incoming threat and turn sharply in a distinct movement in order to avoid contact, this occurs similarly in all these examples [34]-[36]. The first of these videos was uploaded within a couple of months of the first published footage of FPV’s being used for this C-UAS purpose, which indicates a very active development of these fixed-wing UAV’s.

An interesting note regarding this type of footage emerging when it did, was that the number of published videos, showing Russian ‘Lancet’ loitering munition strikes, decreased significantly after the C-UAS capability of FPV’s emerged [37]. This reduction could stem not only from Lancet loitering munitions being targeted, but also because other UAV’s, conducting relay communication between a Lancet and the operator were struck, thus affecting the Lancet’s communication system [38]. This could potentially mean that other long-range weapon systems, such as artillery, relying on reconnaissance from these fixed-wing UAV’s, have had their combat effectiveness reduced as well. However, this is very difficult to investigate using open published footage.

2.3 Fibre-optic communication

The second new type of footage emerging from the war in late 2024 was that of FPV’s utilising fibre-optic cables for communication with the operator. This replaces the “conventional” radio-communication typically seen on FPV’s, which is susceptible to EW and can struggle to perform at longer distances and in more covered environments such as vegetation, between buildings and close to the ground. This same development has occurred previously with conventional military equipment where many anti-tank guided missiles today utilise fibre-optic communication for communication between the operator of the missile and the missile itself.

Important to note here is that the fibre-optic cables seen used in the conflict cannot supply an FPV with electricity and therefore the range limitation from an energy perspective is shortened due to the added weight of the spool of fibre. However, the range limitation for FPV’s with wireless communication could be caused by communication issues and in that aspect fibre-optic communication may increase the effective strike range.

The first published usage of fibre-optic equipped FPV’s is dated back to late summer 2024 [39]. Notably some of the published videos of FPV’s equipped with fibre-optics are of strikes against targets seemingly equipped with EW-capabilities. This has not been as commonly seen in videos of conventional FPV’s using radio-communication [40]-[46].

Similar to the usage of conventional FPV’s, footage of fibre-optic FPV’s striking targets which, according to common military doctrine, should be stationed further to the rear areas of the front, is also present. Similarly, this type of footage started appearing nearly at the same time as footage of fibre-optic FPV’s were emerging, dating back to October 2024 [47]. As previously mentioned, conventional FPV’s were seen to be only attacking assets close to the front until much later in the timeline of their published usage.

Fibre-optic FPV’s also enable strikes on targets in enshrouded areas such as forests with dense tree canopies [48]-[51], inside buildings [52]-[56], through or below protective netting [57] [58] and into underground trenches [59]. A conventional FPV could perhaps manage this, but it requires significant signal strength and possibly repeater drones, within line-of-sight of the FPV, supporting it.

2.4 Efficiency of FPV drones

There are many reports describing the capabilities and efficiency of FPV’s based on their usage by Ukraine and Russia. The format of the reports varies and are therefore difficult to compare. The following is an attempt to summarise the data presented in available reports and articles and make reasonable assumptions in order to present an estimation of the efficiency of FPV’s targeting armoured vehicles.

The following assumptions are made to translate statements from reports and articles to percentages which are then used in Table 1:

- "A majority fail" is assumed to indicate an effect of 25-50 %.
- "Less than 50 %" is assumed to be 25-50 %.
- "You usually don't kill a tank the first few times, […]. It can take ten or more [FPV drones] to kill a tank." is assumed to be 10-25 %.
- "Successfully reaches its target, delivers the strike, and the impact is duly recorded" is assumed to mean that the target is successfully destroyed.
- "It now takes five or even more to destroy one unit of armoured vehicles" is assumed to be 15-20 %.

Table 1: Summary of data from reports and articles. Effect is defined as the probability of hitting the target multiplied by the probability of destroying the target. In the cases where an interval is presented, the lower end of the interval is based on the lower values and the higher end of the interval is based on the higher values.

Source text	Assumption	Reference
40 % pkill against armoured vehicles	P(hit and destroyed): 40 % P(effect): 40 %	[60]
"Between 60 and 80 % of Ukrainian FPV's fail to reach their target, depending on the part of the front and the skill of the operator. Of those that do strike their targets, a majority fail to destroy the target system when striking armoured vehicles."	P(hit): 20-40 % P(destroyed): 25-50 % P(effect): 5-20 %	[61]
20 % of FPV's reach their target.	P(hit): 20 % P(destroyed): - P(effect): -	[62]
"the overall accuracy of FPV drones is less than 50 %" "You usually don't kill a tank the first few times, […] It can take ten or more [FPV drones] to kill a tank."	P(hit): 25-50 % P(destroyed): 10-25 P(effect): 2.5-12.5 %	[63]
"The efficiency of FPV drones in the Ukrainian Armed Forces and among Russians is 20 to 40 %, […]. Madiar clarified that this figure specifically refers to instances when a drone successfully reaches its target, delivers the strike and the impact is duly recorded."	P(hit and destroyed): 20-40 % P(effect): 20-40 %	[64]
"hit and kill rates for FPV's, ranging from 50 % or more for elite units to a low of 10 % for ordinary operators."	P(hit and destroyed): 10-50 % P(effect): 10-50 %	[65]
"it now takes five or even more to destroy one unit of armoured vehicles"	P(hit and destroyed): 15-20 % P(effect): 15-20 %	[66]

Based on these assumptions, the efficiency of FPV's varies between a lower interval of 2.5-25 % and a higher interval of 10-50 %. According to some sources, the effect may be as high as 80-85 % for individual units. It is stated that the effect varies greatly depending on the experience of the operator and it is hard to draw definitive conclusions due to the limited amount of available data. The efficiency also depends on the type of target and whether the drone is controlled through radio or fibre-optics. Multiple references state that main battle tanks are difficult to defeat. Even if a majority of the values presented in the references are mostly based on armoured vehicles it is not unlikely that the higher values of efficiency also include other types of targets that are easier to defeat using FPV's.

Based on the available data and assumptions made, the efficiency of FPV's are assumed to be approximately 20-25 % against armoured vehicles. The true efficiency might, however, be either lower or higher based on the experience of the operator, type of target and whether the drone is controlled by radio or through fibre-optics.

3 Response to FPV-threat

Throughout the war, both sides have been adapting to the opponent's methods of warfare. FPV's are no exception to this as several countermeasures have been used to combat their usage. Some of these measures are probably added to fight other weapon systems of the opponent, such as conventional loitering munitions, having the added effect of providing some sort of countermeasure against FPV's. A few of examples of these measures are; electronic warfare [45] [67] [68], several forms of netting or cages mounted on top of and around vehicles, deployed both at the frontlines and further to the rear [69]-[74], along roads [75] [76] and small arms fire [77]-[80]. Some of these may or may not prove to be effective, but all come with the added strain on the military organisation whether it is on the level of individual platoons or higher levels of command, as it pulls resources and manpower from other key functions of the armed forces. The most efficient way to counter the usage of small UAS will continue to be a hot topic in most military organisations and looking at the usage of drones in Ukraine could be a key part in answering this question in the future.

4 Conclusions and summary

Since the outset of the war, the role of drones have evolved throughout the conflict. Combat footage of FPV's used as improvised missiles started to emerge in late summer 2022 and remains in prominent use as of the writing of this memo. The efficiency of FPV's used in Ukraine is difficult to estimate but an attempt to summarise statements from reports and articles has been conducted in this memo where the efficiency of FPV's seems to hover around 20-25 % when used against armoured vehicles. From the combat footage gathered it is hypothesised that their effective operating range has been increased, enabling strikes on targets deeper into the opponent's territory and also enabling strikes against fixed-wing UAV's operating at higher altitudes compared to most multirotor drones. Utilising fibre-optic communications instead of radio link has also given FPV's added capabilities, enabling strikes in areas affected by EW, and striking targets hidden in covered terrain and vegetation, as well as inside structures while maintaining low latency and high-quality communication with the drone operator.

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