

## Nove perspektive u pogledu borbene upotrebe komercijalnih dronova u kontekstu rusko-ukrajinskog sukoba

Damir Ilić<sup>1\*</sup>, Tatjana Ilić-Kosanović<sup>2</sup>

<sup>1</sup>School of Engineering Management, damir.ilic@fim.rs

<sup>2</sup>Unversity "Union - Nikola Tesla", tilickosanovic@unionnikolatesla.edu.rs

**Apstrakt:** Upotreba borbenih dronova dobija na svom značaju. Poslednjih godina je sve više prisutan fenomen upotrebe komercijalnih dronova za realizaciju vojnih zadataka. Cilj ovog rada je da kroz analiziranje aktuelnog vojnog sukoba u Ukrajini ukaže na moguće pravce dalje upotrebe ove tehnologije, kao i na efekte i dimenzije postojeće primene od značaja za odbrambeni sistem Republike Srbije. Moguće dimenzije primene komercijalnih dronova u lokalnim konfliktima su analizirane putem situacione SWOT analize. Izvedeni zaključak pruža realnu sliku stava do koga se došlo putem analize i daje pogled na dimenzije njihove upotrebe iz dva oprečna ugla.

**Keywords:** komercijalni dronovi, borbena primena, Ukrajina, SWOT

## New Perspectives Regarding the Combat Use of Commercial Drones in the Context of the Russian-Ukrainian Conflict

**Abstract:** The use of combat drones is gaining momentum. In recent years, the phenomenon of the use of commercial drones for the realization of military tasks increased significance. The aim of this paper is to provide an answer to the possible directions of further use of this technology, as well as to the effects and dimensions of the existing application, by analyzing the current military conflict in Ukraine as a lesson for the defence system of the Republic of Serbia. Possible dimensions of the application of commercial drones in local conflicts are analyzed through a situational SWOT analysis. The derived conclusion provides a realistic picture of the position reached through the analysis and gives a view of dimension of its use from two opposite angles.

**Keywords:** commercial drones, combat application, Ukraina, SWOT

### 1. Introduction

During the last decade, the number of conflicts in the world in which drones play a significant role is continuously increasing in importance. War in Iraq (2013–2017), the civil war in Syria (2011 - ), Yemen (2014 - ), Libya (2014 - ) and the conflict between Armenia and Azerbaijan over the disputed region of Nagorno-Karabakh (2020) are some of the glaring examples of training grounds for the use of drone technology for military purposes. The use of drones in these conflicts differs both in terms of scope, strategy, and the degree of sophistication of the aircraft used. There is also a big difference in the measures taken to combat drone attacks and to minimize the consequences of their use. What sets the conflict in Ukraine apart from all the aforementioned conflicts is the use of drones, which is unprecedented in scope and breadth of missions that are carried out with their help. It should also be emphasized that the war is characterized by a massive, never-before-seen application of Commercial off-the-shelf (COTS) solutions for the execution of various missions. In this article, after introduction, in the second chapter, a brief history of the application of commercial drones to achieve military goals will be presented. In the third chapter, a concise account of the genesis of the Ukrainian-Russian conflict is given. In the fourth chapter, a view of new perspectives regarding the combat use of commercial drones in the context of the Russian-Ukrainian conflict is given. In the fifth chapter, a SWOT Analysis of the applicability of commercial drones in local conflicts was made, based on the lessons learned from the Ukrainian-Russian conflict. The sixth chapter presents the conclusion of the work with the possible direction of future research.

## **2. A brief history of commercial drones application for military purposes by state and non-state actors**

During the last decade, there are numerous testimonies about the misuse of commercial drones both for military purposes and for the purpose of carrying out terrorist attacks. Use of commercial and hobbyist drones for military purposes is carried out by both states and non-state actors.

During the fighting for the Iraqi city of Mosul in 2014, the terrorist organization ISIS used commercial drones that had the ability to use improvised grenades in order to strike the positions of the Iraqi security forces (Conditt, 2016).

Houthi rebel forces in Yemen civil war are actively using modified commercial drones against the Saudi-led coalition. The Houthis use commercially available unmanned aerial vehicles and equip them with cameras and arm them with improvised bombs made from explosives inserted into ball bearings. The mentioned commercial drones represent a very economical use of available resources although they do not pose a huge problem in terms of firepower. The purpose of their use is to generate media attention and to send a clear message to coalition forces regarding their vulnerability (Reinl, 2019). On several occasions, with the help of small drones, the Houthis have carried out attacks on oil pipelines and air fields, thanks to the fact that they represent a difficult target due to the low radar reflection, they fly extremely low and they are able to exploit the weak points of anti-aircraft defense (Brumfiel, 2019)

Non-state actors operating in the Middle East, Sahel and East Africa region they mostly use drones for reconnaissance purposes, but a slightly smaller number of drones are adapted for the purpose of carrying weapons. There are two primary types of armed drones used in the Middle East. The first one that has the ability to hover over the target and throw explosives at it and those that are armed with explosive and upon collision with the target they detonate. Both modifications of civilian drones pose a serious threat to both the civilian population and security forces (Haugstvedt, 2021). In Africa, the acquisition of drones intended for commercial use and for hobbyists, which are then subject to modifications, is gaining momentum (Allen, 2021).

From the very beginning of the conflict in Syria, commercial drones have become a key technology both for gathering intelligence and for carrying out attacks on enemy targets. The Islamic State went the farthest in weaponizing commercial drones, and that approach has since been copied by many others, including both regular military units and non state actors outside the Middle East. The commercial drones used during the war in Syria were not exclusively used for reconnaissance, surveillance, information gathering and propaganda purposes. At some point, a trend appeared to arm drones with small bombs, making them a serious threat to government forces. A little later, the world witness the use of larger home-made drones equipped with small bombs for attacks on Russian airbases Hmeimim in Latakia, which led to a greater engagement of Russian air defense units (Pol & Zwijnenburg, 2022).

Cartels and criminal organizations use drones for drug smuggling and law enforcement surveillance on the US southern border, and as of August 2021, over 8,000 illegal drone incursions into US territory have been registered. These criminal groups also have armed drones (Joyal, 2022).

## **3. A brief history of the Russian-Ukrainian conflict**

After the overthrow of Ukrainian President Viktor Yanukovich on February 22, 2014 by pro-Western forces in Ukraine, Russia tried with all its might to regain its influence on Ukraine and regain its presence on the Crimean peninsula. Russia then launched a large-scale covert operation using its military resources in Crimea, whose movements were masked by the military exercises of Russian troops along the border with Ukraine. Soon, Russian troops took full control of the peninsula (Kofman et al., 2017). Along with the events in Crimea, the first conflicts in the Donetsk and Luhansk regions in eastern Ukraine began at the beginning of March 2014. The self-proclaimed Donetsk and Luhansk People's Republics (DNR and LNR) declare their independence from Ukraine in a referendum held on May 11, 2014. After the declaration of independence, the conflicts between the separatists backed by Russia and the Ukrainian state gained more and more intensity until the signing of the second Minsk agreement on February 12, 2015, which turned the hostility into a kind of frozen conflict (Hauter, 2021). During 2021, the Russian Federation began concentrating military units along the border of Russia with Ukraine, which resulted in the Russian invasion of Ukraine, on February 24, 2022. The

Russian leadership and state media are treating the aforementioned conflict as a military operation based on several bases (Harris, 2022).

#### **4. New perspectives regarding the combat use of commercial drones in the context of the Russian-Ukrainian conflict**

The Russian military intervention in Ukraine is characterized by the extremely large use of drones for military purposes, which by its scope exceeded all the conflicts that had been fought up to that time. Not only are military drones used in the conflict, but it is a widespread phenomenon that commercial off-the-shelf (COTS) drones and hobbyist drones are being used in combat by both sides.

The widespread use of drones is characterized by the use of three basic types of aircraft: rotary wing drones, fixed wing drones and loitering ammunition:

- The rotary wing drones used in the conflict in Ukraine include the following types of aircraft: KBLA-IVT (Russia), Autel Evo II (China), DJI Mavic Series (China), Golden Eagle (USA), Skydio X2 (USA), Aerorozvidka R18 (Ukraine) and Kvazimachta (Russia).
- Fixed wing drones used in the conflict in Ukraine include the following types of aircraft: Kronshtadt Orion (Russia), Bayraktar TB2 (Turkey), UJ-22 Airborne (Ukraine), Forpost (Russia), Zala 421 (Russia), PD-1 People's Drone (Ukraine), Tupolev Tu-141 Strizh (Former Soviet Union), WB FlyEye (Poland), Granat-4 (Russia), Orlan-10 (Russia), Orlan-30 (Russia), Quantum Systems Vector (Germany), RQ-20 Puma (USA), E95 (Russia), Tupolev Tu-143 Reis (Former Soviet Union), Zastava (Russia and Israel), Punisher (Ukraine), Mini-Bayraktar (Turkey), Takion (Russia), Leleka-100 "Stork" (Ukraine), Athlon Avia A1-CM Furia (Ukraine), Eleron-3 (Russia), and AeroVironment Quantix (USA).
- Loitering munitions used in the conflict in Ukraine include the following types of aircraft: Switchblade 300 (USA), Switchblade 600 (USA), Phoenix Ghost (USA), WB Group Warmate (Poland and Ukraine), Geran-2 / Shahed-136 (Iran) and Zala KYB (Russia) (Hambling, 2022; Chapple, 2022; Lowther & Siddiki, 2022).

Some of these aircraft, and we are primarily referring to the Autel Evo II and the DJI Mavic Series, are civilian commercial aircraft.

Professor Peter Lee, an expert on unmanned aerial vehicles at the University of Portsmouth, believes that in a situation where no side has absolute control over the airspace, the use of drones to gather information gains importance (Sabbagh, 2022).

What largely characterizes the war in Ukraine is the extensive use of small commercial drones, piloted by civilian volunteers. Civilian drones are used primarily to collect various intelligence data (Wolf & Dunn, 2022). According to Valerii Iakovenko, the founder of the Ukrainian company DroneUA, which provides advisory services regarding the use of drones, Ukraine has more than 6,000 commercial drones, most of which are of Chinese origin and they are used for military purposes (Galey, 2022). Even before the outbreak of hostilities in 2022, Aerorozvidka, Ukraine's drone unit, put armed COTS drones into operational use. The mentioned unit has developed two types of drones: quadcopters with smaller payloads capable of carrying anti-personnel hand grenades, and octocopters capable of carrying anti-tank or mortar shells. Numerous videos of commercial DJI drones equipped to carry hand grenades used by Russian units can also be seen on social media (Fogel & Mathewson, 2022).

According to Mark Cancian advisor at the Center for Strategic and International Studies, the essence of the use of commercial drones and drones intended for hobbyists by Ukraine is that with an investment of several thousand euros you get the opportunity to destroy Russian equipment worth several hundred thousand euros. An ordinary hand or mortar grenade can cause serious damage to a tank or an armored personnel carrier, and the damage is incomparably larger when the target is light fortified enemy position or unarmoured vehicle (Ayad & Brody, 2022).

Russian and Ukrainian forces are coming up with innovative new ways to incorporate commercial drones into their war efforts. Applications of commercial drones for military purposes include a wide range of missions such as: intelligence, surveillance, target acquisition, and reconnaissance, electronic warfare, psychological operations and cyber operations and with various modifications for attacking ground targets. Russia, like Ukraine, also uses Chinese commercial drones produced by the company

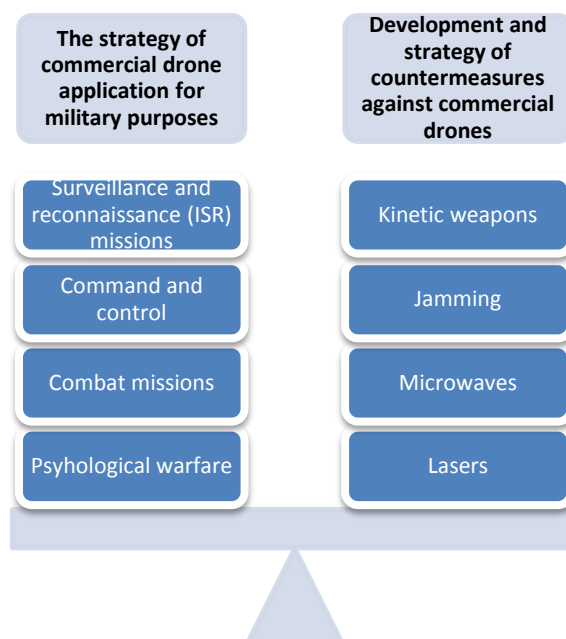
DJI for the implementation of various missions. The Ukrainian side appealed to the DJI company to find a way to disable the drones used by the Russian army in Ukraine. Russian forces have made certain modifications to the DJI firmware to eliminate the possibility of using the DJI technology in order to detect drones. The Ukrainians claim that in certain situations Russian troops used the DJI-produced AeroScope drone tracking system to pinpoint the location of a Ukrainian drone operator. After the location was completed, artillery attacks would follow with the aim of eliminating the operator (Joyal, 2022).

There are two basic elements within the Aeroscope system. The first element of the system is the Signal, which is automatically emitted by each DJI drone and through which information is provided about the position of the drone in space, its height, speed, direction of movement, as well as the serial number and location of the drone pilot. The second element consists of receivers that are able to detect the mentioned signals at a distance of up to 50 kilometers (Hollister, 2022). In April 2022, the Chinese drone manufacturer DJI announced that it was temporarily suspending its operations in Russia and Ukraine. The company vehemently opposed the use of their drones for military purposes, as well as modifications in order to use drones for military purposes (Burgess, 2022).

What greatly favours the use of drones and therefore commercial solutions used for military purposes is the length of the front line. Ukraine is working intensively on a so-called "drone army program" a large fleet of drones consisting mostly of commercial drones and drones donated by enthusiasts. Col. Oleksii Noskov, assistant commander-in-chief of Ukraine's armed forces, stated that with the help of the army of drones, monitoring of the 2,470 km long front line will be facilitated (Vallance, 2022).

Both sides in the conflict, in parallel with the intensive use of drones to achieve war goals, are trying to disable the drones belonging to the opposing side. During the conflict, Russia used some of the modern electronic warfare systems such as Krasukha-2/4, R-330Zh Zhitel, and RB-301B Borisoglebsk-2, whose original purpose is not to implement measures against drones (Lowther & Siddiki, 2022). On the front line in the fight against militarized COTS solutions, the Ukrainian side uses both fire from small-calibre infantry weapons and directed jammers. Cannons for jamming drones can be seen more and more often, namely the American "Drone Defender" and the Lithuanian "Sky Viper" EDM4S (Fogel & Mathewson, 2022).

Figure 1. Seesaw of strategies from new perspective - Authors based upon (ZenaDrone, n.d.; Thompson, 2022; Fogel & Mathewson, 2022)



How difficult the fight against drones is is not only evidenced by the experiences from the current Russian-Ukrainian conflict. It is enough to look back at the experience from Syria, Libya, as well as the one in Nagorno-Karabakh, or let's say the attacks on the territory of the UAE and Saudi Arabia. These examples clearly show how much modern state of the art anti-aircraft defense struggle in the fight

against small low-flying targets (Millburn, 2022).

## 5. SWOT Analysis of the applicability of commercial drones in local conflicts

This chapter will analyze the internal and external factors regarding the possibility of using commercial drones for military purposes. The immediate focus will be on the current conflict in Ukraine and the impact that mentioned conflict has on the implementation of commercial (COTS) solutions.

### Strengths

Samuel Bendet, a military analyst at Virginia-based research group CNA, believes that the future availability of combat drones for sophisticated long-duration operations coupled with the need to have low-cost tactical drones for close support operations will significantly affect the battlefield of tomorrow (Khurshudyan, Ilyushina & Khudov, 2022). According to Roger Bohn, professor emeritus of technology management at the University of California San Diego, the use of commercial drones in conflicts is attractive for several reasons. The necessary knowledge as well as the parts necessary to assemble drones are readily available online, so even self-taught enthusiasts can assemble them. No special training is required to operate the aircraft, and thanks to their small size, they can be transported on the ground in an ordinary backpack (Moumen, 2022). Commercial unmanned aerial vehicles of small size and low cost make the war in Ukraine completely unique, providing hitherto unimagined possibilities of surveillance over the battlefield with the enviable possibility of correction of usually imprecise artillery fire (Khurshudyan, Ilyushina & Khudov, 2022).

It should be pointed out that both sides (predominantly Ukrainian) use a large number of commercial drones, and among them the DJI Mavic 3 quadcopter model dominates for the Tactical Intelligence, Surveillance and Reconnaissance (ISR) Mission, which indirectly confirms the increasing importance of civil technology in warfare (Borsari, 2022). In the early days of the war, the Russian military relied on heavy weapons such as artillery and tanks, and was less prepared and open to adapting consumer technology to the battlefield. It is also more than noticeable the lack of small commercial drones that the Ukrainian forces have been receiving in the form of donations. The Ukrainian side has numerous workshops where commercial aircraft are adapted to carry different types of modified shells (Kramer, 2022). The ability of commercial drones used by Ukrainian forces to evade fairly powerful air defenses reveals numerous adversary vulnerabilities and plays a notable role as an important tactical victory that boosts the morale of troops on the ground. At the same time, it is a strong psychological blow for Russia, since Ukraine, using commercial drones, demonstrates its ability to retaliate against the enemy, regardless of the overestimated capabilities of Russia's anti-aircraft defense (Wolff, 2012).

### Weaknesses

There are numerous limiting factors regarding the use of commercial drones for military purposes. There is primarily a relatively small payload, which in most cases is limited to a gimbal, camera and battery, while there are commercial drones with slightly higher payloads. The next limiting factor is range in terms of range by signal transmission and image relay distance and battery power. Then commercial drones have a limited use in adverse weather conditions that cannot be compared to military drones capable of flying in all weather conditions. It should be noted that the quality of the sensor (camera resolution) is weaker compared to the military drones (Abbott et al., 2015). Commercial drones face certain obstacles when carrying out their missions. Those obstacles are embodied in the technologies that have been developed to combat drones (anti-aircraft systems, jamming the aircraft's telecommunications and GPS, and various approaches to computer hacking. The aforementioned vulnerability of aircraft to jamming, and the lack of robustness compared to drones for military use, make commercial drones a less reliable tool for the implementation of certain operations in the field. In addition, the operator of commercial drones may be exposed to risk if the adversary uses systems to determine the operator's position, such as the AeroScope system of the Chinese company DJI (Moumen, 2022). Many technology companies retain a certain degree of control over their product even after it has been sold to a customer. It should be mentioned that all DJI drones are delivered to the customer with geofencing technology, which means that the drone potentially will not be operational in a certain protected area (Greenwood, 2022).

## Opportunities

According to Strategic Market Research, there are expectations that the size of the commercial drone market is expected to reach a value of around \$47.38 billion by 2030 and to record a very strong growth at a CAGR of 28.58% from 2022 to 2030. (STRATEGIC MARKET RESEARCH LLP, 2022). Today on the market it is possible to acquire a large number of extremely high-quality drones intended for commercial use, and some of the prominent models are listed in Table 1.

Table 1. Commercial drones comparison table (Gross, 2023)

Model	Range (km)	Size (mm)	Flight time (min)	Weight (kg)	Max Speed (m/s)	Camera
<b>DJI Matrice 300 RTK</b>	15	810×670×430	55	3.6	23	960p, 30 fps
<b>Freefly Alta 8</b>	3,22	1346 diagonally	12-15	6.2	15,65	Not included
<b>DJI Mavic 2 Enterprise Advanced</b>	10	322×242×84	31	0,909	20	48 MP, 3840×2160@30fps
<b>DJI Phantom 4 Professional+</b>	7	350 diagonally	30	1,388	12,5	20M, 4096×2160 24/25/30p @100Mbps
<b>Yuneec H520E RTK</b>	7	551x482x309	30	1,860	20	Not included
<b>DJI Agras MG-1</b>	1	1471 x 1471 x 482	24	8,8	22	Not included
<b>Autel Evo Lite+</b>	12	427×384×95	40	0,835	18	50M, 3840x2160 p 60/50/48/30/25/24
<b>DJI Mavic Air 2</b>	10	183×253×77	34	0,570	19	48 MP, 3840×2160 24/25/30/48/50/60 fps
<b>Parrot Anafi</b>	4	175x240x65	25	0,320	15	16MP (4608x3456)
<b>DJI Inspire 2</b>	7	604 diagonally	27	3,440	26,11	Not included

When purchasing a commercial drone, you should focus on certain aspects that the system provides, such as: flight time, range, payload capacity, camera quality, speed, size and weight (Gross, 2023). There are four key military drone technologies in terms of sensors that are being exported to the Commercial Market: Hyperspatial Sensors, Wide Area Surveillance, Multi-spectral Targeting Systems and Light Detection and Ranging (LIDAR) (Miltech, n.d.). The essence of choosing the right energy source for commercial drones is reflected in the fact that an energy source that can last a long time is necessary, that it is based on a resource that is widely available and affordable, that it has a good energy-to-weight ratio, that it has as little negative impact as possible on the environment, that it creates little noise or vibration, and that it can be refilled quickly and easily (Sharewater Aerospace, n.d.).

Commercial drones have a bright future as they expand their presence into new industries, and more companies are becoming aware of the potential profits from their use. The future of autonomous commercial drones is particularly bright due to the FAA's move to simplify approvals for fully autonomous drone flights. With this roadblock removed, autonomous drones will be implemented on a much larger scale in both the consumer and commercial industries (Alkobi, 2019). During conflict, in addition to performing a surveillance role that can greatly contribute to the collection of valuable intelligence, video captured by commercial drones could help in determining responsibility for documented crimes after the war ends (Burgges, 2022).

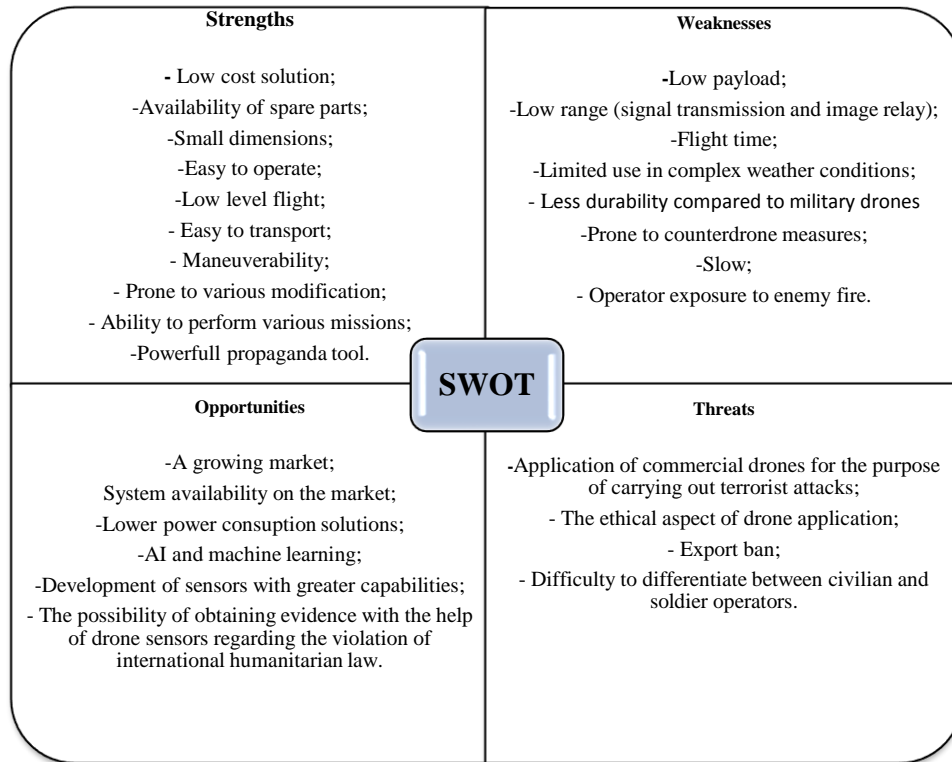
### **Threats**

The wide availability of cutting-edge technology embodied in civilian drones has provided violent non-state actors (VNSA) or terrorists with new possibilities. Due to their accessibility and variety of uses, drones have provided the VNSA with an advantage over the aerial component that they used until their appearance (balloons, missiles, rockets or the hijacking of commercial planes). One of the most important reasons why commercial drones are attractive to VNSA is the fact that they are affordable for procurement and that the matter is still quite unregulated, which greatly complicates the interruption of the supply chain. To make things even worse, the VNSA also has centers for the production and modifications (examples of terrorist groups that operated in Iraq and Syria). In other words, the use of civilian drones provides the VNSA with a completely innovative, extremely effective platform for the realization of their plans (Chavez & Swed, 2020). In April 2022, DJI, the world's largest drone manufacturer, issued a statement that it was temporarily suspending operations in Russia and Ukraine. Adam Lisberg, DJI's director of corporate communications for North America, said on that occasion that DJI abhors any use of their drones to cause harm, and that they are temporarily suspending sales in Russia and Ukraine to ensure that no one uses their drones for execution of combat missions (Al Jazeera, 2022).

US Air Force Maj. Gen. James Poss recently stated that commercial drones have proven so effective that they have created an entirely new way of warfare. In the following, the general apostrophizes and fears that if non-governmental organizations and commercial companies are able to have such an influence on the implementation of combat operations, what could be the influence that terrorists could potentially have (Zoldi, 2022). There is a great risk to people who fly small drones both on and near the battlefield. According to the International Committee of the Red Cross, it is clearly stipulated that parties to an armed conflict must make a clear distinction between the civilian population and combatants. It is also necessary to distinguish between civilian and military objectives. This is certainly the case when combat aircraft are used on the battlefield.

Small consumer or commercial drones are very difficult to distinguish visually in the air. Drones intended for civilian use have an unclear status under international humanitarian law. Civilian users of drones, such as journalists and curious citizens, who operate drones in or around a combat zone may not be aware of the implications of their actions and the extent to which they are putting themselves in danger (Greenwood, 2022). Numerous videos of commercial drones dropping improvised grenades on enemy personnel can be seen on media (The Telegraph, 2022; The Sun, 2022a; Express, 2022; The Sun, 2022b; The Sun, 2022c) and social networks.

Figure 2: SWOT analysis of the applicability of commercial drones in local conflicts



## 6. Conclusion

The conflict in Ukraine is accompanied by an unprecedented deployment of various commercial drones performing different tasks. Some carry out Intelligence, surveillance, and target acquisition missions, while others are modified into combat drones or suicide drones (loiterng munition). We can agree with many of the sources cited in the paper who expressed their view on the extent to which the use of commercial drones has changed the course of warfare, especially the current Russian-Ukrainian conflict. When we look at footage of commercial drones in action, our view of the brutal reality is divided.

On the one hand, the inventiveness of the users and the versatility of the use of aircraft give the impression that commercial drones, or rather their use in conflict, have largely changed the character of warfare. Let's clarify. A commercial drone that costs a few hundred or thousands of dollars is able to accurately direct artillery fire on enemy units. Commercial drones capable of carrying out combat missions are capable of knocking out expensive air defense systems worth several hundred thousand or even million dollars. You don't need to mount large amount of explosives to disable a sophisticated air defense system. Most armored vehicles and tanks have extremely weak armor protection on the top side of the vehicle, precisely on the side where they can suffer a drone attack. Additionally, commercial drones are extremely difficult to detect due to their flight profile, size and speed. And when they can be detected it raises the question of the justification of launching very expensive rockets at a target that costs incomparably less. Again, the same cheap commercial drone is capable to cause immeasurable damage to your troops, either by correcting the artillery fire, monitoring the movement of units and their direction in real time, or directly acting on the target with improvised devices. If the adversary is ready to act, it is simply necessary to saturate the airspace with drones. This is what awaits us in the near future with an increased level of AI (human-out-of-the-loop systems) and acting in swarm formations.

On the other hand, the application of commercial drones in some of its segments is in conflict with the existing conventions of international humanitarian law. What we observe today in Ukraine may one day return to the whole world like a boomerang (the methods of action of certain violent non-state actors have already been mentioned in the paper). What we see every day in Ukraine materialized with



the help of commercial drones has nothing to do with compliance with International Humanitarian Law. Commercial drone manufacturers are not at all to blame for this situation. That must be clear to everyone. They cannot be blamed because it was not by their decision that the tool was transformed into a weapon.

Commercial drones are here to help us in carrying out various business activities from a whole new perspective. Commercial drones should not be part of the military effort.

Which of these two realities we choose depends only on us. The authors of this paper still want to see commercial drones as a tool that will change the human future for the better.

Future research will address the use of loitering munition in this conflict and its implications for further development.

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