Building & leveraging Ukraine's drone capabilities in conflict & beyond:

Assessing the defense/security innovation ecosystem

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MIT MANAGEMENT SLOAN SCHOOL

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Executive Summary

Ukraine has earned a well-deserved reputation for rapid innovation in drone technology, building up its capabilities - to invent, innovate and scale - during conflict. Many western partners have talked about the need to "learn the lessons from Ukraine": that is important, so long as those lessons are understood in the complex context in which they arose. Even for Ukraine, the lessons (for innovation) of the last three years, will need to be adapted to its emerging geopolitical and economic context.

We believe there are insights for Ukraine, its partners, and other nations from using MIT's work on innovation ecosystems, specifically, the MIT innovation ecosystem approach to building a defense and security ecosystem and associated industrial base that can support and be support by a country's wider innovation ecosystems. This Working Paper sets out that approach, and then explores how (and when) the Ukrainian drone innovation ecosystem emerged: the current state of the drone innovation ecosystem provides an important foundation for Ukrainian recovery, potentially providing an industrial base to serve wider partners and contributing to long-term prosperity and national security i.e. economic security. The policy options for Ukraine to achieve this long-term goal which will be the focus of our next paper.

Technological innovation (especially that based on deep technologies at the frontiers of science and exploration, or technologies closely linked to proximate end users) tends to cluster in geographical regions referred to as 'ecosystems' for a wide range of reasons. Research into such a place-based innovation stands in contrast to a "world is flat" thesis that suggests that innovation should be happening anywhere and everywhere. Ukraine is a great example of a newly emerged 'innovation ecosystem' specialized on building advanced defense and security capabilities under unique, and geographically specific, circumstances. That said, without adaptation and support, especially from partners and Allies, the ecosystem may be fragile and fail to flourish to provide wider economic benefits.

As most observers of the Ukrainian response to the Russian invasion will recognize, drones - a term covering a range of uncrewed and autonomous craft, including 'unmanned aerial vehicles' (UAVs) in the air domain, but also sea and ground drones - have played a central role in the nature of contemporary warfare. They are also at the center of Ukraine's growing defense and security innovation ecosystem. While using drones as a core capability in its offensive and defensive approach to conflict, Ukraine has also worked to establish a strong defense and security innovation ecosystem with the capacity to design, build, field and adapt drone technologies at increasing pace and scale. Indeed, the media has been full of stories of rapid experimentation with drone technology at the frontline, as well as efforts to rapidly scale-up production in bedrooms, basements and, later, factories.

This White Paper provides insights from the Ukrainian perspective using an innovation ecosystem approach. In other words, we examine the ways in which five key stakeholders – start-ups, risk capital, universities as well as military/government and large defense corporations – came together to build and scale Ukraine's innovative defense/security industrial base at a time of conflict, and how this might be maintained to serve as source of peace and prosperity in the long term. This deeper understanding of Ukraine's experiences in innovation is intended to inform those seeking 'lessons from Ukraine', including the Ukrainian government, partners and others.

MIT's Innovation Ecosystem framework - an approach to analyzing key the stakeholders engaged in ecosystem development - allows for more systematic evaluation of Ukraine's success in drone innovation - from idea to warfare - beyond the headlines since 2022. Our emphasis on analyzing the role (large and small) of all relevant stakeholders for innovation provides more complete insights for Ukraine and for other nations seeking to build innovation ecosystems build on solving problems of defense and security, or indeed other missions that matter. And it allows observers to understand the role of innovation ecosystems in spurring and amplifying a resilient (military) industrial base - an element of growing importance for most nations during this time of increasing geopolitical tensions and a move to national sovereignty.

Our analysis highlights the unique aspects of the Ukrainian situation (i.e. a nation being on a war footing) that make it hard to precisely replicate elsewhere. However, it also reveals initial lessons for key stakeholders in how to build a whole-of-nation defense and security innovation ecosystem that could be leveraged for Ukraine's ongoing national security but also its long-term prosperity (with further commitments from stakeholders in Ukraine and beyond).

MIT's Innovation Ecosystem framework builds on a decade of research understanding innovation and the ways in which Ecosystems are developed to leverage and provide important comparative advantage.[1] Several elements characterize our approach. First, the emphasis on 'innovation driven enterprises' (IDEs): start-up ventures with high growth potential that are generating and adapting novel ideas. Second, the role of five (rather than three) key ecosystem stakeholders who enable innovation through their contributions to resources people, capital and infrastructure as well as demand signals and regulatory/policy rules that allow experimentation to happen at pace. Third, the recognition that innovation ecosystems are highly geographically concentrated, with a culture of experimentation and interaction that drives speed and iteration.

Rather than doing a full analysis of the entire Ukrainian innovation ecosystem(s) that rallied in support of the nation's war effort, we emphasize the nation's emerging Defense/Security innovation ecosystem (DSIE) with its focus on drone technologies. That said, the narrative on the ground suggested that Ukraine's drone DSIE was rapidly established through a 'whole of nation effort, with many stakeholders playing a systemic role in building drone capability in Ukraine. Beyond Ukrainians, it seems that outside individuals and organizations from each stakeholder group played a (greater or lesser role) in strengthening each of the internal stakeholder groups. Against this backdrop, we more systematically examine the first two of three key questions:

i) How (and when) did the Ukrainian drone defense/security innovation ecosystem emerge and what was the historical context against which key stakeholders responded to an extraordinary period of national need?

ii) What key changes in behaviors/policies enabled the growing strength of Ukraine's drone DSIE and among those changes which provide lessons for other nations, and which are, perhaps, unique to the Ukrainian context?

iii) What options might strengthen contributions of Ukraine's defense/security innovation ecosystem to its future security and economic prosperity?

Our Working Paper addresses the first two questions and provides the foundations for the third question about options for a new phase of economic security relevant to policy makers in Ukraine and among its partners wishing to learn from and support Ukraine's DSIE, to ensure the continued creation, growth and scaling of new businesses (especially IDEs) based on drone technologies in Ukraine, and with the potential to drive long-term benefits for its economic security. It also holds lessons for all those nations wishing to build or strengthen their own domestic defense/security innovation ecosystems.

[1] MIT Innovation and Ecosystem Framework: https://reap.mit.edu/assets/An-MIT-Approach-to-Innovation.pdf

Key insights

If necessity is the mother of invention, then war is the mother of Ukraine's defense and security innovation ecosystem. As with other origin stories of innovation ecosystems in times of conflict including e.g. the Greater Boston ecosystem which to a large extent was forged in the Rad-Lab at MIT during World War II, or Silicon Valley's early origins in the radio communications needs of the Pacific fleet in the post-World War I era, it is only by analyzing the extent of stakeholder engagement that we can learn lessons for the future.

From this initial research, we have several key insights:

- Ukraine's wartime innovation in the production and use of drones (especially UAVs in the air domain) has rightly captured international attention, but learning the right lessons for others requires some close analysis about how that happened;
- Prior to February 2022, like many other nations, Ukraine's post-Soviet 'military-industrial complex' had not appreciated the nature of war changing, even though development of many drones had started after the 2014 invasion, with the Russian occupation of Crimea and the war in the 'Donbas' region;
- Since the full-scale Russian invasion in February 2022, however, a Ukrainian 'whole of nation' response underpinned the rise of a multi-stakeholder innovation ecosystem which we refer to as a defense/security innovation ecosystem (DSIE), with an emphasis on the development, production and delivery of drones of increasing scale and sophistication;
- From close study of this period, it is clear that a key source of the success of this innovation ecosystem involved a network of individuals and organizations drawing from all five stakeholder categories – start-up entrepreneurs, risk capital, government and (but to a lesser extent) large corporations and universities;
- Domestic actors in each stakeholder category were supported - to a greater or lesser degree and in different ways - by foreign stakeholders from a range of countries. In addition to a few nations' special forces, there was also support through informal networks of preexisting relationships or through the agency of individuals as much as formal government to government activities;
- Especially interesting for those learning from Ukraine is that it took a nation moving to a wartime footing to mobilize the full range of mostly non-state actors to achieve the progress that has been observed, and that few state systems - even those with an effective military-industrial complex, and with effective government and corporate actors - have delivered such comparable innovation;
- With February 2025 marking the third anniversary of the Russian invasion, now is a moment to reflect with Ukraine and its Allies, and to inform options for:
    - Ukraine to continue to capitalize on its hard-won, conflict-driven defense/security innovation ecosystem;
    - Ukraine to ensure its security through sustainable production of the drones it needs (with productive uses of its additional manufacturing capability 'surplus');
    - Ukraine to benefit more broadly from the prosperity that can arise from its tech breakthroughs including from the scale of its domestic production that may allow for export opportunities.
- These considerations, if well developed and implemented, should provide Ukraine with more resilient paths to prosperity in a post-conflict (even if not fully peaceful) future, linking its defense and security innovation ecosystem and wider civilian ecosystems to those across Europe, and integrating with the rest of Europe to build a more prosperous future.

Building & leveraging Ukraine's drone capabilities in conflict & beyond: Assessing the defense/security innovation ecosystem

We examine the emergence of Ukraine's drone Defense and Security Innovation Ecosystem (DSIE) in three phases. First, we outline the history of drone development in Ukraine prior to February 2022. We then shift a narrative of the post-February 2022 period outlining the key drivers and actors for the urgent and rapid innovation ecosystem development. In the next section, we outline the state of the ecosystem in early-2025 from the perspective of drone creation, growth and scaling. We then turn to a stakeholder-by-stakeholder analysis to determine the key role of the various actors, before ending with more detailed conclusions about the ecosystem today.

History of drone development in Ukraine

Pre-February 2022

The foundations of Ukraine's innovation ecosystem for drone development (and production) were set in 2014. At the time when the war in east Ukraine began, the Ukrainian Armed Forces were still a legacy of the Soviet army and lacked equipment to withstand the enemy. To solve its issues of lack of intelligence, volunteers started working on drone development to provide "eyes" for their Armed forces enabling them to improve artillery targeting and conduct reconnaissance operations[2]. Some of the first Ukrainian-built drone models - - mostly for the purposes of Intelligence, Surveillance, and Reconnaissance (ISR) - were released later in 2014 and were quite simple, made from materials on hand. At that time, multiple developments in ground and air drones were rapidly undertaken providing a strong foundation for the industry's further development in 2022[3].

The Ministry of Defense started procurement of these drones at a small scale in 2014. Beyond the ministry, there were two other major customers for the drones in this period –volunteers buying drones for the Ukrainian military and export customers. The government procurement helped producers connect with the military and work on continuous improvement of their product. However, while the state was a large customer, companies could not earn much from these contracts due to margin limitations. Export contracts had a much higher margin and allowed companies to reinvest profits into R&D and production capacity expansion. For example, the price for Leleka ISR drones by DeViRo was 4x greater for export compared to domestic sales [2].

An increasing number of companies were founded and started to build drones in 2014-2015. However, out of ~50 companies created in this period, less than 10% survived[2]. The remainder could not find a path to profitability. According to the co-founder of Athlon Avia, many companies produced and supplied drones without making any profit and worked almost as volunteer organizations, allowing them to supply drones to the frontline cheaply but hindering their product development.

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[2] Texty.org "Війна дронів. Як волонтери постачають українські війська безпілотниками і створюють власний апарат" (https://texty.org.ua/articles/57216/Vijna_droniv_Jak_volontery_postachajut_ukrajinski_vijska-57216/)

[3] Forbes Ukraine "Народжені літати. З 2014 року в Україні виросла ціла галузь безпілотників. Чи допоможе війна їй стати глобальним гравцем" (https://forbes.ua/innovations/narodzheni-litati-z-2014-roku-v-kraini-virosla-tsila-galuz-virobnitstva-bpla-chi-dopomozhe-viyna-ukrainskomu-military-tech-stati-globalnim-gravtsem-06092022-8150)

February 2022 - a turning point

In February 2022 Russia invaded Ukraine on a larger scale, and drone production was accelerated. The Ukrainian military understood that it needed an asymmetric response to Russia's scale i.e. the size of its army, availability of weapons, production capacity, and financial resources. Ukraine had to find creative solutions and one of them was the increasingly sophisticated and creative use of drones. To ensure that this approach could be maintained, the country needed to use drones to reduce the loss of human life on the battlefield but also had to ensure a domestic ability to develop and produce at approach scale.

At the time of the full-scale Russian invasion start, however, the Ukrainian government did not activate massive drone procurement. Instead, it mostly focused on conventional weapon purchases. Most of the drone procurement for the military units was undertaken by charitable foundations and volunteers, such as Come Back Alive (Povernys' Zhyvym), Prytula Foundation and others. The full-scale invasion increased the role of drones in the war effort and made it more obvious to many in society. Nonetheless, the government still held back from scaling central procurement. Absent a 'demand signal' from the government, drone production in Ukraine was initially done by the companies that were founded before 2022 i.e. those founded since 2014 (DeViro, Aviation systems of Ukraine, UkrSpecsystems, Skyeton, Athlon Avia etc.) (see Figure 1). Volunteers and public figures, such as Mariia Berlinska, promoted the need to scale drone supply[4] for the Armed Forces of Ukraine and berated the Minister of Defense at that time for disregarding the role of drones in the battlefield[5]. The disregard of drones for battle usage was in part due to their association with hobby uses, and with the occasional drone photographer, so the establishment was slow to see that more entrepreneurial uses might be possible[6].

Some of the publicly known UAV producers

Company	Notable drone models	Year first notable drone was introduced	Year company was created
Aerodrone	D80-Discovery, E-300 Enterprise	2022	2015
Aerorozvidka	R-18	2016	2014
Airlogix	Hammerhead	2021	2020
Antonov (Ukroboronprom)	Liutyi	2023	1946
Atlon Avia	Furia, Hrim	2014	2013
Aviation Systems of Ukraine	Valkiria	2015	2015
DeViro	Leleka	2015	2014
Luch	Sokil-2, Sokil-300	N/A	1965
Meridian (Ukroboronprom)	Spectator	2016	N/A
Skyeton	Raybird-3	N/A	2006
SkyFall	Vampire	2022	N/A
Spaitech	Sparrow	2016	2012
UA Dynamics (Armadron)	Punisher	2016	2016
UkrJet	Bober, Skyline, Airborne	2021	N/A
Ukrspecsystems	PD-1, PD-2, Shark, Ram II, Shark	2015	2014
Ukrtehno-Atom	Kazhan-1	N/A	2004
Virazh (NAU)	M-10-2 Oko	2014	N/A

Source: press search

It was only at the end of 2022 that the Ministry of Digital Transformation kicked off work building the legislative grounds for promoting the market for drones. It did so by developing Decree 256[7] that aimed to catalyze drone market development through simplification and acceleration of procurement process, simplification of rules for drones' specific qualification for armament, and also establishment of a 25% profit margin cap for the producers. Later Decree 256 was amended,

[4] Forbes "Матір дронів. Марія Берлінська створила найбільшу в Україні екосистему з навчання аеророзвідників. У чому секрет ефективності волонтерки" (https://forbes.ua/leadership/matir-droniv-istorikinya-iz-mogilyanki-mariya-berlinska-stvorila-naybilshu-v-ukraini-ekosistemu-z-navchannya-aerorozvidnikiv-v-chomu-sekret-efektivnosti-volonterki-21082023-15519)

[5] Ukrainska Pravda "Президенту та міністру оборони: Там, де немає дронів, розхідним матеріалом стають люди" (https://www.pravda.com.ua/columns/2023/02/23/7390685/)

[6] LB "Олексій Резніков: «Війна не закінчилась, є ще велика загроза для нашої держави і нам треба вижити» (https://lb.ua/news/2022/12/30/540944_oleksiy_reznikov_viyna.html)

[7] KMU, 256 Decree (https://www.kmu.gov.ua/npas/pro-realizatsiiu-eksperymentalnoho-proektu-shchodo-zdiisnennia-oboronnykh-zakupivel-bezpilotnykh-system-vitchyznianoho-vyrobnytstva-256-240323)

so it provided that, if the margin were to be above 25%, producers needed to provide detailed explanation of reasoning behind the higher margin[8].

Decree 256 was followed by the founding of the "Army of Drones" project that aimed to encourage more new ventures to enter the market and start supplying drones for the Ukrainian military, using funds from United24 global fundraiser. The work of the Army of Drones was not limited to drone procurement. The Army of Drones effort also invested significant time and energy into helping the new players in the drone market get qualified and codified by the Ministry of Defense (MoD). The Army of Drones simplified testing and quality certification documents, had staff that helped entrepreneurs go through the testing and documentation, and also supported the codification process. After some of the producers were codified, the Army of Drones paid for their production for the Armed Forces of Ukraine. These events triggered the start of the mass production of drones and development of scale.

Early 2024 - Scaling at speed

The speed and scale of Ukraine's drone capacity expansion was unprecedented. In the beginning of 2024, the industry could produce ~300 thousand drones[9]. Overall, the nation planned in that year to expand capacity to 1 million first person viewer (FPV) drones, 10 thousand 'strike' drones, and 1 thousand 'deep strike' drones with a flight range of more than 1000 km[10]. But the actual capacity by Dec 2024 reached more than 4 million drones per year, significantly exceeding expectations[11] and defence budgets.

As of 2024, the government became a lead buyer of drones, supplying the vast majority of drones to the frontline (~80% of total supply, according to rough estimations of a charity leader)[12]. Nonetheless, the sector continued to suffer from complex demand issues: lack of financing, only 1.5 million drones were contracted,[11] and the plan for future procurement unclear. According to a survey of the defense tech company association TechForce (in December 2024), 55% companies stated that their capacity was only 30% occupied with state orders[13].

The Ukrainian government is actively establishing institutions to coordinate the industry and enhance procurement processes to overcome the various challenges faced by its burgeoning drone industry. Notably, Ukraine has created the Unmanned Systems Force; a separate branch within the Armed Forces to specialize in drone warfare and the use of unmanned military robots across land, sea, and air domains. The core purpose of this initiative is to centralize management, integrate UAVs into military doctrine, and ensure technological superiority in the war. One of its tasks has been to delineate the specific needs for drones, distinguishing them from those of traditional military equipment, and to clarify the technical specifications needed for unmanned systems[14].

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[8] Ministry of digital transformation, press release (https://thedigital.gov.ua/news/zakupivlya-droniv-bez-pereplat-ta-deregulyatsiya-virobnitstva-boepripasiv-uryad-vnis-zmini-do-postanov?utm_source=chatgpt.com)

[9] Mind.ua "Україна у 10 разів збільшила виробництво дронів – Мінцифри" (https://mind.ua/news/20280331-ukrayina-u-10-raziv-zbilshila-virobnictvo-droniv-mincifri)

[10] RBC.ua "Скільки дронів виготовила Україна в 2024 році: що кажуть у Міноборони" (https://www.rbc.ua/rus/news/skilki-droniv-vigotovila-ukrayina-2024-rotsi-1729685527.html)

[11] President's press release (https://www.president.gov.ua/en/news/ukrayina-mozhe-j-bude-stvoryuvati-najkrashi-zrazki-zbroyi-vi-93613)

[12] Kyivpost "Марія Берлінська: математика війни - наука збереження людей" (https://www.kyivpost.com/uk/post/41558)

[13] Techforce survey (https://techforce.in.ua/news/article/z-75-privatnih-virobnikiv-opk-ne-vedutsya-peremovini-pro-derzhavni-kontrakti-na-2025-rik-opituvannya-tsu)

[14] Radio Svoboda "Зеленський підписав закон про створення Сил безпілотних систем як окремого роду військ ЗСУ" (https://www.radiosvoboda.org/a/news-zakon-syly-bezpilotnykh-system/33122138.html)

Stakeholders in the drone innovation ecosystem

Figure 2: The MIT model has identified a range of five essential stakeholders who come together to support effective innovation ecosystems. For an understanding of defense/security, this includes, especially, Ministries related to defense, established (defense) corporations as well as educational institutions, start-up entrepreneurs and investors (risk capital).

Following the MIT innovation ecosystem stakeholder model, we have interviewed and sought input from all give of the key stakeholders in the Ukrainian innovation ecosystem for drones.

Corporations

Ukraine had few private corporations engaged in defense prior to 2022, with no large corporations exclusively focused on drones. Most of the defense sector was concentrated in a single state-owned conglomerate enterprise – Ukroboronprom - that combined multiple smaller companies (e.g. Antonov which became the basis of the Aircraft Corporation). As a reform to the post-Soviet defense sector, the creation of Ukroboronprom a consolidate 'prime' contractor was a rational re-organization at that time in support of the nation's 'military-industrial complex'.

In many nations, the 'prime' defense contractors play a key role in the state's 'military-industrial complex', but they are not often advocates for the types of tech innovation that could be found in other stakeholders in innovation ecosystems. The latter include defense tech start-ups, and other new, digital-first 'dual-use' enterprises, that have come to play an important role: in the US, such companies include Palantir, Anduril and ShieldAI (with the latter focusing on drones, which were not always a focus for incumbent primes). As such, Ukraine was quite typical of the mainstream of defense establishment in the 2010s.

As this Paper highlights, much of the innovation in drone warfare came from non-traditional actors, such as entrepreneur and their start-ups, after the full Russian invasion of Ukraine in early-2022. While some Ukroboronprom subsidiary companies were engaged in drone production prior to 2022, this only increased dramatically in 2022, alongside many other actors that swiftly moved into this space. These Ukroboronprom subsidiaries doubled down on development and production of innovative drones. Some of these subsidiaries collaborated with international companies to create joint development and production of defense technology (e.g. a notable example is the collaboration with Milrem Robotics on ground platforms).

An important role in ecosystem development was also played by non-defense corporations. Ajax - a major security hardware and software company is a notable example- partnered with the Kiev School of Economics (KSE) to open an engineering school that would help with talent for defense tech (incl. drones). Importantly, Uklon (a ride-sharing service much like Uber) has built its own Venture Capital fund to invest in defense tech companies. Some companies work directly with producers as customers, ensuring companies' stable demand.

Entrepreneurs

At the heart of Ukraine's drone ecosystem are more than 500 ventures able to produce more than 4 million drones[15]. While a variety of drone types are used in the battlefield, the production and the concentration of producers vary significantly category-to-category, for instance FPV drones account for the majority of production volume and are a core product of the majority of producers. For the purposes of our analysis, we focus our attention on entrepreneurs in three broad categories: Air, Sea and Land.

Air drones (i.e. Unmanned Autonomous Vehicles)

Functionally there are two major types of air drones - ISR drones and strike/combat - noting that some are mixed as “ISR/Strike”. Ukraine produces all three of these types. The NATO STANAG classification provides three categories by weight, altitude, and flight radius but all of these drones have different specifications, design and production complexity. Again, Ukraine has the capacity to produce all three, based on publicly known sources.

Innovation, Development and Production process: Overall, many of the Ukrainian UAV drone companies have pursued similar paths for innovation. The rate and nature of experimentation of UAVs after full-scale invasion was strongly “demand-driven”. It took place in several phases:

- First, the developer collects technical requirements from the battlefield and starts working, adjusting or developing the drone to have necessary technical characteristics.
- Second, prototypes are constructed. There are two major drone formats: fixed-wing and multi-rotor drones. Simple tactical kamikaze multi-rotor prototypes are often built from the ready-made components (many of the components now start to be produced in Ukraine), while fixed-wing drones need more thorough design of aerodynamics[16] and sophisticated parts. As a result, **there are many more companies producing simple copter drones and just a few producing fixed-wing drones**.
- Third, after the prototype is built, it needs to be tested. During wartime, unauthorized usage of drones was prohibited, and so the developer needs access to an official testing ground or to get special testing permits. After initial testing, developers often send free samples to the military asking them for feedback.
- Fourth, after the testing phase the drone needs to go through official certification by the MoD, which requires paperwork and quality tests. Achieving certification enables the developer to have contracts with MoD.
- After securing the order for the Armed Forces (either from the state, volunteers, or other customers), the companies scale production of their drones.

Supply chain: Ukrainian drone producers have used both local and imported components. For different types of drones, different components are required, however there are some common themes that can help describe supply chain structure qualitatively. In the early days of drone production and scaling, most of the components were Chinese. However, with time, Ukrainian companies have developed some local production[17] for many components - up to 40-70% of local content for some drone types (e.g. FPV - attack copters)[18].

There are, however, challenges in competing with Chinese suppliers: even though the cost of production might be similar or even cheaper in Ukraine, imported goods are still sometimes

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[15] ArmyInform (https://docs.google.com/document/d/1gjgm2Lc-K2kdP_1TE8PsIS8FDgn6_ckB/edit)

[16] Mezha media “Українські ударні дрони: хто і як розробляє БПЛА Punisher, R-18, Кажан та інші” (https://mezha.media/articles/ukrainski-udarni-drony/)

[17] Freedom portal “Україні вдалося налагодити виробництво власних компонентів для дронів” (https://uatv.ua/uk/ukrayini-vdalosya-nalagodyty-vyrobnytstvo-vlasnyh-komplektuyuchyh-dlya-droniv-ekspert/)

[18] Texty.org ““У Китаї дешевше, але ми виробляємо в Україні”. Як у нас починають випускати компоненти для FPV-дронів” (https://texty.org.ua/articles/113254/v-kytayi-deshevshe-ale-my-vyroblyayemo-v-ukrayini-yak-u-nas-pochynayut-vyroblyaty-komponenty-dlya-fpv-droniv/)

cheaper, as Ukraine has canceled value-added tax (VAT) for imported defense-related goods, but did not cancel this tax for Ukrainian-produced components[19]. Besides that, the quality and availability of some of the critical materials from China also make importing from China attractive (e.g. magnetic ore, lithium). Nonetheless there is still an appetite for localization, as it allows for faster customization of components (especially important in the context of changing electronic warfare technology), quality control (25% of Chinese components have some deficiencies[21]), delivery speed, and independence from China that can cut supplies.

Starting September 2024, China imposed export restrictions for some drone components (e.g. carbon frames, motors, propellers, cameras, flight controllers, landing gear, signal amplifiers for remote control, communication systems, and video signal transmitters). However, this did not create as significant a market shock as might be expected, as many components had already been localized (e.g. frames, propellers, antennas, connection systems, detonation boards). Besides that, Ukraine has come up with creative solutions on how to facilitate and accelerate localization. For example, the Ministry of Strategic Industries announced the development of a digital catalog of Ukrainian suppliers to speed up partnership development and spread information about local suppliers[20]. Another interesting solution is a decentralized 3D printing factory, organized by volunteers to coordinate and mass-produced components and final goods for the military[21].

Competitive advantage: The combination of rapid iteration near the battlefield, an increasingly localized supply chain and growing sophistication mean that Ukrainian air drone producers have a significant advantage over the drones produced abroad. Indeed, the time it takes to send a drone to the frontline, receive operator's feedback, update the model, and send an updated version back to the frontline is counted in days for Ukrainian producers, compared to weeks in case of producers abroad (who are not working locally). Additionally, Ukrainian producers typically are well connected to drone operators who can provide them feedback almost instantly.

That said, as the enemy's counter-UAV electronic warfare technology develops, Ukrainians aim to increase the efficiency of attacks and outcompete the enemy through technological enhancements, such as electronic warfare equipment, machine vision[22], swarm technology, automation, etc. Ukraine is also developing new capabilities, for example using drones as a means of air defense (e.g. shooting down the ISR drones of an enemy with interceptor-drones), developing a new type of weapon - known in the media as "Dragon" drones[23] or using drones as long-range missiles (e.g. rocket-drone introduced in August 2024). Some of these newer types of drones are local versions of drones such as the DJI Mavic or drones that would satisfy new needs of the Armed Forces (e.g. solutions to reach operational-tactical depth of up to 70 km). This technological development is largely driven by Brave1 (see the government stakeholder analysis below) who signal needs and coordinate priorities by awarding grants and implementing development programs. Other development is driven directly by producers that get technical needs from the frontline and work on building technology to satisfy this need.

It is important to emphasize that entirely new categories of drones are also under consideration in Ukraine. For example, the development (and first successful tests) of rocket-drones was announced by the President of Ukraine in August 2024 and, as of December 2024,

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[19] Ukrainska pravda "Zelenskyy signs laws exempting drone component imports from VAT and customs duty" (https://www.pravda.com.ua/eng/news/2023/06/20/7407676/)

[20] Ekonomichna pravda "Побороти залежність від Китаю. Мінстратегпром створить майданчик для торгівлі українськими компонентами" (https://epravda.com.ua/news/2024/10/7/720246/)

[21] Ekonomichna pravda "Тіньовий ОПК. Як тисячі українців з 3D-принтерами побудували великий збройовий завод" (https://epravda.com.ua/publications/2024/10/31/721234/)

[22] Forbes "Наступний game-changer. Україна і Росія ведуть перегони за FPV-дрони з машинним зором. Що це за технологія та як може вплинути на війну? Розбір Forbes" (https://forbes.ua/war-in-ukraine/nastupniy-game-changer-ukraina-i-rosiya-vedut-peregoni-za-fpv-droni-z-mashinnim-zorom-shcho-tse-za-tekhnologiya-ta-yak-mozhe-vplinuti-na-viynu-rozbir-forbes-05032024-19640)

[23] BBC Ukraine "Дрони-дракони і перехоплювачі. Чи справді українці здійснили революцію в БПЛА" (https://www.bbc.com/ukrainian/articles/cy9e90rv280o)

rocket drones were serially produced and deployed by the Ukraine Armed Forces. While most of the details are classified, weapons like “Palianytsia” and “Peklo” are described as a "rocket-drone," indicating a hybrid system that combines characteristics of drones and missiles: it is faster than a regular kamikaze drone, but it is smaller than a standard missile and carries a smaller warhead[24]. This design likely offers advantages such as extended range, precision targeting, and the ability to evade enemy defenses. The system is reported to be cost-effective, with ongoing domestic Ukrainian efforts to further reduce production costs and increase manufacturing scale.

Below, we outline in more detail, the production of different categories of air drones in Ukraine: Kamikaze drones and ISR drones.

Kamikaze drones (loitering munition)

Copter kamikaze drones (e.g. FPV): FPV drones are the most numerous on the Ukrainian battlefield, with ~200 companies producing one version or another of FPV drones[25]. **More than 100 different drone models are operational at the frontline as of October 2024**. Their presence on the battlefield started by soldiers attaching a shell to the civilian drone. There was even a high-scale social initiative called “People’s drone” organized by the Ministry of Digital Transformation and “Victory drones” charitable foundation teaching civilians how to assemble FPV copters at home[26]. With time the technology started to develop and became more and more sophisticated –- enhanced with AI, advanced shells, and enhanced control systems[27].

The military has managed to replace defense equipment shortages (e.g. artillery ammunition) with tactical FPV drones and achieved impressive successes – e.g. it managed to shoot down equipment that costs hundreds of thousands of dollars by drones that cost ~US$1k. Over time, Russian forces learned to defend themselves against Ukrainian drones using electronic warfare. The response of Ukrainian engineers has been to advance FPV drones and design them to use different frequencies. The Russians in response improved and increased coverage of their electronic warfare. As of February 2025, this competition is ongoing with proximity to the frontline continuing to enable quick FPV iteration cycles is crucial for the relevance of drones on the battlefield. One of the biggest challenges of engineers is to overcome this competition through technology such as the ability to change frequency while flying, computer vision technology that can automatically lead the drone to the target without connection to the operator or mass production of fiber-optic drones. Computer vision enabled drones have already been developed and produced in Ukraine.

Fixed-wing Kamikaze drones: Fixed-wing drones are more advanced than copter drones and typically have a higher flight range and more advanced technical characteristics. Some of the drones have a range of more than 1000 km and practically act as missiles for Ukraine to target objects farther into Russia. Such deep-strike drones are critical for Ukraine especially in the context of not being able to use western weapons in Russian territory. Availability of such drones allows Ukraine to prevent Russian future strikes by targeting military warehouses, factories, and oil refineries to minimize attack potential. In 2024, Ukraine's Ministry of Defense allocated ~ UAH 20 billion (around US$482 million) for deep-strike drones, contracting five Ukrainian companies for

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[24] Ekonomichna pravda “"Пекло" для росіян. Як Україна робила супер-дрон, а вийшла крилата ракета” (https://epravda.com.ua/oborona/peklo-dlya-rosiyan-yak-ukrajina-robila-super-dron-a-viyshla-krilata-raketa-800910/)

[25] Forbes “Безпілотна суперсила України. Як влаштована українська індустрія дронів? Розбір Wired” (https://forbes.ua/war-in-ukraine/armiya-droniv-ukraini-poglyad-wired-na-ukrainsku-industriyu-bezpilotnikiv-03052024-20980)

[26] Forbes “Народний FPV» від Федорова і Берлінської.” (https://forbes.ua/innovations/narodniy-fpv-vid-fedorova-i-berlinskoi-proekt-zbirki-droniv-na-kukhni-ne-planue-zaminyati-seriyne-virobnitstvo-ale-khoche-vikhovati-pleyadu-novikh-inzheneriv-skilki-koshtue-kvitok-v-tsyu-industriyu-19012024-18592)

[27] Ekonomichna pravda “Рій дронів та божевільні покупці. Як інженери перетворюють виробництво FPV на велику індустрію” (https://epravda.com.ua/publications/2024/07/25/717109/)

production[28]. As of 2024 the government announced plans to achieve a capacity of 1000 deep-strike drones per year. Some of the companies and products in this segment include ST-35 Hrim (Althon Avia), Lyutyi (Antonov (Ukroboronprom)), UJ-22 Airborne (UkrJet).

Multi-use copter drones: Multi-use copter drones can carry a load up to 20-30 km. Their main use is carrying and dropping munition on a target, but they can also be used for humanitarian tasks (e.g. dropping food/water supplies to people that cannot be reached). Such drones appeared in Ukraine before 2022 (e.g. R18), however after the full-scale invasion the diversity of models has expanded, and development speed accelerated. Some drone developers started by adapting large copter drones used for agriculture[29] - initially with a shorter range of 3-5 km just enough to get the drone on the other side of the front line, and with time expanding to ~20 km. The biggest problem that developers have tried to solve is the problem of the connection with the pilot. Eventually two solutions were developed: connecting the drone with Starlink, that practically made the distance between the pilot and drone irrelevant (as the drone could be flown from virtually anywhere in the world) and powering the drone with an automated control system, - making the drone independent from the pilot after it is launched.

The effects of this type of drone on the battlefield is that enemies' armored vehicles and other military equipment must be hidden further away from the frontline, expanding the buffer zone. Moreover, these drones enable the destruction of enemy equipment without putting the pilot's life at risk. Prior to their introduction, the military often relied on technologies like anti-tank guided missiles (ATGMs) to neutralize enemy armored vehicles. While effective, the use of ATGMs frequently exposed the operators' location, allowing the enemy to retaliate swiftly. In contrast, drones can be operated from a safe distance, minimizing risk to personnel and making it significantly harder for the enemy to pinpoint the location of Ukrainian forces. Moreover, the drone costs roughly the same as an ATGM missile but can be used multiple times, creating economic advantage. The producer of the Nemesis drone calculated that $1 spent on each Nemesis drone helped to destroy $50 worth of the enemy's military equipment[32]. Key development goals for these drones are increase of flight range and improvement of resistance to jamming. Key Ukrainian companies and products include Nemesis, Vampire (Skyfall), HeavyShot, R18 (Aerorozvidka).

Multi-use fixed-wing drones: These drones operate similarly to conventional aircraft, generating lift through wings rather than relying solely on rotors, which offers several distinct advantages: extended flight times (some reaching >20 hours), longer distances (some reach more than 1000 km) and greater altitudes. Many of these drones have a mix of reconnaissance and attack functions. Multi-use fixed wing drones often use functionally similarly to multi-use copter drones to target enemy equipment ~20 km away from the frontline. Longer range multi-use fixed wings drones are typically the ones that are designed as ISR drones but can also attack if necessary. **Ukrainian companies/products include Punisher (UA dynamics), Backfire, Sokil 300 (Luch)**.

Intelligence, Surveillance, and Reconnaissance (ISR) Drones

ISR fixed wing drones are used to collect intelligence and correct the targets for artillery. Many of the **key companies that are supplying the most popular ISR drone models were founded in 2014-2015** after the start of the war in the east of Ukraine in 2014 (e.g. DeViRo, Ukrspecsystems). These ISR drones have significantly changed the battlefield, allowing the military to have much higher efficiency for the artillery and other types of weapons due to availability of "eyes" observing the target. Some drones were simplified to lower the price, achieve higher scale and, thus higher battlefield coverage. Other drones were improved with more advanced features (e.g. anti-jamming,

[28] Ukrainska pravda "Ukrainian Ministry of Defence signs contract for purchase of long-range drones worth roughly US$482 mln" (https://www.pravda.com.ua/eng/news/2024/11/9/7483693/)
[29] Ukrainska pravda ""Баба Яга" жжот. Як Україна вигадала новий вид зброї" (https://www.pravda.com.ua/articles/2024/06/3/7458837/)

multi-functionality, interceptor drones). **Key Ukrainian companies and products include Leleka-100 (DeViro), Valkiria (Aviation system of Ukraine), Shark (Ukrspecsystem).**

ISR copters are mostly used for tactical reconnaissance and typically are imported. DJI and Autel are some of the most widely used brands in the frontline, noting the importance of foreign produced drones. **There were multiple attempts to replicate the Mavic-like drones in Ukraine, however Ukrainian industry struggled to achieve quality and cost comparable to foreign drones**. In 2024, the Ministry of Strategic Industries conducted a hackathon to develop local versions of DJI-like drones, as a result finding >5 producers with 2 of them already codified and planned to be contracted in 2025.

Sea drones

Ukrainian sea drones have proved to be a major pivotal force in the war, allowing Ukraine - with no real naval fleet - to defeat the massive Russian fleet in Black Sea. Development and usage of sea drones is another example of Ukraine finding an asymmetric response to Russian threats. Not only are the drones efficient in achieving their military targets, but also fighting the enemy economically e.g. the Magura naval drone costing ~$400k has destroyed a Russian ship of ~$110M.

In 2022, Ukraine was one of the first countries to create a fleet of naval drones. Ukraine uses its naval drones for a variety of applications: strike drones (both reusable and kamikaze) and ISR drones; moreover, most of these drones have become “platforms” - able to carry air defense, electronic warfare equipment, etc. While sea drones are some of the most secretive weapons, we still can observe their influence on the course of the war[30]. Some drones, like Sea Baby, developed by Security Service of Ukraine (SBU), managed to attack multiple frigates of the Russian sea fleet and blow up the Crimean bridge[31]. Another visible factor is the reduced presence of Russian vessels in Black Sea, which has decreased from 40-50 vessels per day in 2022 to <4 vessels in 2024. **Key companies and products include Magura, Sea Baby, and Mamai.**

Ground drones

Ground drones are a complicated technology with multiple development challenges: they must be effective on uneven surfaces, across different weather conditions, and short- as well as long-distances. Typically, these drones have different functional elements: attack (e.g. “Lyut’”), delivery, rescue (e.g. “Volya-E”), mining/demining[32] or reconnaissance (e.g. robot-dog). **Ukrainian producers have developed more than 200 models of various robotized platforms,** and the field is growing increasingly fast[33]. **These ground platforms are projected to be a critical element of 2025 state procurement.**

The development of autonomous ground robotic platforms started before the full-scale invasion in 2022. In 2016, the General Staff of Ukraine approved the concept of the ground platforms[34] and one of the famous robotic platforms by Roboneers was observed on the battlefield

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[30] Molfar (https://molfar.com/blog/navaldrones)

[31] Forbes “United24, monobank та волонтери розпочали перший збір на 35 морських дронів Sea Baby” (https://forbes.ua/news/united24-monobank-ta-volonteri-rozpochali-pershiy-zbir-na-35-morskikh-droniv-sea-baby-22022024-19383)

[32] Focus “В "Азові" показали бойового робота "Лють 2.0": як він допоможе знищувати ЗС РФ (фото)” (https://focus.ua/uk/digital/663829-v-azovi-pokazali-boyovogo-robota-lyut-2-0-yak-vin-dopomozhe-znishchuvati-zs-rf-foto)

[33] Radio Svoboda “Замість бійців – роботи. Як Wolly, «Лють», «Тарган» і робот-собака виконують завдання на передовій” (https://www.radiosvoboda.org/a/zamist%CA%B9-biytsiv---roboty-yaki-zadachi-nazemni-roboty-uzhe-vykonuyut%CA%B9-na-peredoviy-/33156202.html)

[34] Defense Express “Роботизовані платформи для ЗС України: включають в ДОЗ-2021 і готують до параду” (https://defence-ua.com/weapon_and_tech/bezdusha_sila_jak_vojujut_striljajut_jizdjat_nimetski_korejski_kitajski_ta_ukrajisnki-2572.html)

back in 2015[35]. After 2022 it was clear that development of robotic platforms was a priority for the military and there was a clear signal from the government to push the development further.

Brave1 issued $1 million in grants for robotic platform development spurring many of the ground drones found today[36]. In contrast to air and sea, some of these platforms have been developed between traditional defense primes in Ukraine and international companies e.g. Ukrainian defense conglomerate Ukroboronprom and European company Milrem Robotics. This collaboration kicked off during 2023 DFNC1 Defense Industries Forum organized by the Ministry of Strategic Industries and aims to build a platform for Ukrainian and international company collaboration[37]. That said, Ukraine-produced ground drones ~ 40-70% local content and supply chain can be localized. Currently the industry can produce hundreds of robotic platforms per month but is limited by government procurement capacity. Developers are currently working on the improvement of key technological characteristics of robotic platforms: range, time of work, connection protection. At the same time, producers are developing more advanced features, e.g. automation of target identification and attack. **Companies and products: Myslyvets (Robotiks), Roboneers, Piranha (Kuznya na rybalskomu), Tencore, Ratel, Trident Technologies**.

In the context of a fragmented producer base, with over 500 defense tech companies, industry associations act as a consolidated voice for policy advocacy (e.g. on sector deregulation, export facilitation), ecosystem-building through networking and partnerships, and for industry-relevant research. These associations work in close collaboration with the Ministry of Defense (e.g. Ukraine Tech Force association has signed a Memorandum of Understanding for further collaboration with the Ukrainian MoD), Ministry of Strategic Industries, and Ministry of Digital Transformation.

Risk capital

Entrepreneurs do not operate in a vacuum. Even with significant demand signals coming from the frontlines and from Ministries, the start-ups rely on funding. **That said, the risk capital used to develop, produce and sell drones has taken a different path compared to traditional western innovation ecosystems.**

Initial development of many drone models did not use any institutional investment: typically, the founders invested their own money or money from friends and family to start the company and developed further from small profit margins from sales. However, with time the government and institutional investors became more engaged and focused on supporting technology development. As important, funding has come from contracts **provided specifically for the purchase of finished products and to support manufacturers.** Such capital is used only to purchase finished products and does not support investment in development, but it has nevertheless been essential in the ecosystem. Unusually, it comes from three sources:

1. **Government funding**. From 2014 and more extensively from 2022 and onwards, the government started funding drone procurement through traditional channels. Money was fundraised through **United24 platform** and was provided directly through state budget allocation and legal enablement of regional governments to procure drones.

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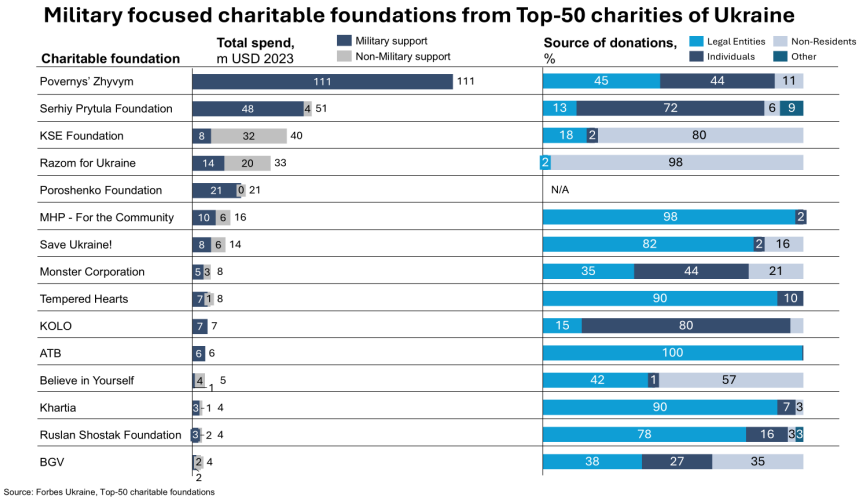
[35] Ukrainska pravda “Україна збирає армію роботів. Коли вони вступлять у бій?” (https://epravda.com.ua/publications/2024/04/17/712501/)

[36] Texty. org “В Україні масово вироблятимуть наземні дрони. Випробували уже понад 50 різного призначення” (https://texty.org.ua/fragments/111986/v-ukrayini-masovo-vyroblyatymut-nazemni-drony-vyprobuvaly-uzhe-ponad-50-riznoho-pryznachennya-foto/)

[37] Texty.org “Україна розроблятиме роботизовані системи разом з лідером галузі Milrem Robotics” (https://texty.org.ua/fragments/111294/ukrayina-rozroblyatyme-robotyzovani-systemy-razom-z-liderom-haluzi-milrem-robotics/)

2. **Volunteer initiatives.** Charitable foundations such as Come Back Alive Foundation (Povernys' Zhyvym) and Prytula Foundation are among the key non-government off-takers of UAVs, communications and other light military solutions. Personal volunteerism of such opinion leaders as Mariia Berlinska (Victory Drones, Dignitas), Serhii Sternenko, Oleh Horokhovskyi (Monobank), Vasyl Baydak (stand-up comedian) and others, in cooperation with business, used crowdfunding for purchases for individual military units and periodically transferred hundreds of UAVs, defense or communication systems to the front line[38]. **Indeed these donations represent 2-2.5% GDP of Ukraine in 2023** according to Forbes.[39] Of this about 1,5% is represented by the biggest charitable foundations (see Figure 3), an amount comparable to the share of construction or export of black metals[40].



3. **Foreign donors.** Monetary donations from foreign countries have also financed the purchase of Ukrainian defense products through the "ZBROYARI - Manufacturing Freedom", project led by the Ministry of Strategic Industries which includes ~$1 billion in donations from the EU, Denmark, the Netherlands and Canada (with a final target of ~$10 billion)[41]. Many countries started to replicate the "Danish model" in which other countries finance the procurement of Ukrainian defense products for Ukraine. For example, Sweden has announced it will finance production of Ukrainian deep-strike drones for Ukraine's Armed Forces following the "Danish model"[42].

Beyond funding for procurement, the funding allocated for the development of drone innovation in Ukraine has three sources:

1. **State funds** remain the main driver of Ukrainian defense tech growth[43]. Various Ukrainian Ministries are investing in defense technology startups through different initiatives. **Brave1 is the biggest governmental platform** created in collaboration by the Ministry of Digital

[38] Molfar (https://molfar.com/blog/dalni-drony-rozbir-molfar-ta-vidpovid-blagodiinyh-fondiv)

[39] Forbes "Обсяг благодійності в Україні становить 2-2,5% ВВП – дослідження Forbes" (https://forbes.ua/news/obsyag-blagodiynosti-v-ukraini-stanovit-2-25-vvp-doslidzhennya-forbes-23082024-23213)

[40] Forbes "Двоє з трьох людей жертвують гроші. Україна – в першій десятці світового рейтингу благодійності Charities Aid Foundation" (https://forbes.ua/news/dvoe-z-trokh-lyudey-zhertvuyut-groshi-ukraina-v-pershiy-desyattsi-svitovogo-reytingu-blagodiynosti-charities-aid-foundation-22082024-23168)

[41] Zbroyari (https://www.zbroyari.gov.ua/)

[42] Militarnyi "Швеція профінансує виробництво українських далекобійних дронів" (https://mil.in.ua/uk/news/shvetsiya-profinansuye-vyrobnytstvo-ukrayinskyh-dalekobijnyh-droniv/)

[43] Forbes "к працює екосистема defence tech в Україні та які перспективи розвитку?(https://forbes.ua/war-in-ukraine/rinok-na-mayzhe-1-mlrd-ta-z-ponad-300-gravtsyami-yak-pratsyue-ekosistema-defence-tech-v-ukraini-ta-yaki-perspektivi-rozvitku-analitik-viktor-karvatskiy-dilitsya-visnovkami-z-doslidzhennya-vid-datadriv-10092024-23529

Transformation, the Ministry of Defense, the General Staff of the Armed Forces of Ukraine, the National Security and Defense Council, the Ministry of Economy, and the Ministry for Strategic Industries to accelerate defense innovation[44]. It is a coordination platform created for efficient communication between all stakeholders of the sphere, providing organizational, informational, and financial support for defense tech projects in Ukraine. The strategic goal of Brave1 is for Ukraine to become a leader in the global defense technology market. In its ~1.5 years of operations, Brave1 has gathered >1400 teams run >3200 developments and in total provided ~400 grants totaling more than $10.5m. The **Innovation Development Fund** is a state institution whose mission is to drive the Ukrainian innovation ecosystem and to promote Ukraine's tech industry. The IDF has been managed by the Ministry of Digital Transformation as of 2024. Within the framework of IDF, the "Fast Track to Victory" program is devoted to simplifying the process of manufacturers' UAV approval by the Ministry of Defense. During its implementation, 50 samples of Ukrainian-made UAVs were approved, 43 of which received approval through the IDF's Fast Track program[45].

Largest private investors in Ukrainian DefenseTech

Country	Name	Investment, USD '000	# of companies in portfolio	Type
	Brave1	12-50	211	Gov. defense cluster
	MITS	200	N/A	Accelerator
	Defence Builder	350-500	N/A	Accelerator
	Darkstar / Extreme Bootcamp	500	N/A	Acceler. program
	Innovation Hub	1000	N/A	Tech cluster
	United Angels Network	N/A	3	Angel investors club
	Dare to Defend Democracy (D3)	125	9	VC
	Freedom Fund VC	N/A	1	VC
	Koryos	N/A	N/A	VC
	Green Flag Ventures	100-1200	N/A	VC
	Double Tap Investments	N/A	1	VC
	Resist.UA	500	1	VC
	Fund of co-founders of Uklon	200-500	1	VC

Source: Forbes Ukraine

2. **Individual private investors (angel investors and high-net-worth individuals) have been a significant capital source.** Many start-ups have received funding from like-minded entrepreneurs turned investors. UAN (United Angels Network) for example offers flexible investment terms into its recommended startups to its members[46].

3. **Institutional private investors (funds)** are a key source of investment - more typically as equity investors into Ukrainian start-ups. D3, Uklon Nezlamni, Freedom Fund VC, Green ventures, RezistUA, MITS, Defense Builder, Double Tap Investments (DTI), Koryos, Slava and other specialized funds (with the support of their limited partners) have invested in startups and well-known companies in the field of defense technology[47]. These funds offer not only investment, but also expertise in business growth and development, as many of the founders have technical rather than business background[48] (see Figure 4 above).

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[44] Governmental portal "Ukraine launches BRAVE1 defence tech cluster to stimulate development of military innovations and defence technologies" (https://www.kmu.gov.ua/en/news/v-ukraini-zapustyly-defense-tech-cluster-brave1-iakyi-stymuliuvatyme-rozvytok-viiskovykh-innovatsii-ta-oboronnykh-tekhnolohii)

[45] USF (https://usf.com.ua/en/programs/fast-track-to-victory/)

[46] Interview of UAN founder (https://simeinyi-budzhet.ua/familybudget/investytsiyi-v-defense-tech/)

[47] Data driven research (https://datadriven.group/defence-and-demining)

[48] Forbes "«Щонайменше 10-річний тренд». Forbes зібрав найбільші приватні ініціативи, готові вкладатися в український miltech. Як це змінює обличчя оборонної індустрії" (https://forbes.ua/innovations/proponuvati-ekspertizu-z-pobudovi-biznesu-26072024-22387?utm_source=facebook&utm_medium=cpc&utm_campaign=AMS_Conv_Forbes+Digital_Article_subscribe&utm_content=subscribe_Article_malitari&utm_id=120204133154630111&utm_term=Article_malitari&fbclid=IwZXh0bgNh

In spite of widespread interest, many general (especially foreign) investment funds refrain from investments in defense tech for several reasons: 1) lack of market understanding, 2) LPs restrictions (e.g. ethical concerns), 3) export restrictions, and 4) unpredictable government procurement. Those funds that do invest are mostly motivated by accelerating victory and (to a lesser extent, profit).

Government

The government started playing an important role in the drone market at the end of 2022. Before that, as noted above, the government did not invest significantly in drone development and was mostly focused on conventional weapons (with a few notable exceptions including some air drones and ground platforms in 2016). Indeed, throughout 2022 the need for drones on the battlefield was fulfilled by the charitable foundations. While the Ministry of Defense, responsible for procurement of military equipment, was buying some drones (mostly for ISR), it underestimated the importance of drones on the battlefield (especially small drones with strike capabilities). From late 2022, however, the government became invested in development of drones. There are several key roles government bodies have played including in coordination and regulation, procurement:

With regards to coordination & regulation we observe:

- **Regulation to facilitate internal Ukrainian drone market development.** In March 2023 the Ministry of Digital Transformation and the Ministry of Strategic Industries passed Decree 256[7] to simplify procurement of unmanned vehicles, through simplification of the procurement criteria and by setting profitability requirements of 25% margin; this decree helped deregulate the market and drew more Ukrainian entrepreneurs into the sphere. **The result of this initiative was an increase in the number of drone producers: in 2022 only 8 types of drones were contracted by the state, by the beginning of 2024 this grew to 67**. The quantity of producers grew to >200[49]. In September 2024 the Ministry of Defense also passed the Decree 763 that deregulated the ammunition market (overall and for the UAVs specifically), allowing producers of the UAVs that do not have the operational approval order to expedite product delivery[50].

- **Creation of Unmanned System Forces** (as part of Ukraine Armed Forces). Development of specialized forces is expected to refine and separate the demand for drones from more expensive conventional weapons to emphasize drones' importance. It establishes drones as a standalone category, with dedicated experts for the definition of demand for procurement and to clarify technical requirements from the producers[51].

- **Coordinating relationships with international partners.** The Ministry of Strategic Industries has been actively involved in mediating partnerships of Ukrainian companies with international ones. Starting in 2023, they organized the annual DFNC forum that was held again in 2024, where >200 companies from Ukraine and abroad looked for ways to collaborate with one another and with the government[52].

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[49] KMU (https://www.kmu.gov.ua/news/vidkryttia-rynku-bpla-pershi-u-sviti-udarni-roty-ta-morski-drony-rezultaty-armii-droniv-za-2023-rik)

[50] KMU (https://www.kmu.gov.ua/news/uriad-sprostyv-protseduru-vyhotovlennia-ta-postachannia-boieprypasiv)

[51] Forbes "Мільйон безпілотників і бум у школах дронів." (https://forbes.ua/innovations/milyon-bezpilotnikiv-ta-bum-u-shkolakh-droniv-yak-stvorennya-sil-bezpilotnikh-sistem-u-skladi-zsu-vpline-na-industriyu-bpla-forbes-zapitav-virobnikiv-ta-instruktoriv-08022024-19060)

[52] DFNC (https://www.dfnc.gov.ua/)

- **Formulating industry development direction by defining requirements or predicting technology needs.** Although there are many entities for drone market coordination, they themselves are not well coordinated. As a result they often duplicate tasks and areas of responsibility. As of September 2024, plans are in flux as to who should own the coordination role for the drone market, but a few elements are key.

    - *Center of innovations and defense technologies* (Ministry of Defense) –aims to coordinate development of innovative technologies in the format of project management with sprints;
    - *Agency of Defense Procurement* – a procurement party that coordinates the market by signaling some demand;
    - *State Special Communications Service of Ukraine* – procurement party that coordinates market by signaling some demand;
    - *Brave1* – coordinates the market by deciding what start-ups would get financing, connecting private companies, startups, investors, and government bodies to speed up drone research and deployment.

- **Regulation of the market through export closure.** Ukrainian companies cannot export their products as of January 2025 due to the government regulation. This creates significant challenges for companies in a context where production capacity is much higher than the procurement budgets of the State.

- **Reserve Process**. The Ministry of Strategic Industries oversees the "reserve" process for employees of defense companies, recusing them from mobilization to ensure continuity in critical operations. Eligibility for this reservation is governed by a set of regulations, including criteria such as whether a company has received a grant from Brave1 or holds a government contract. Meeting these conditions qualifies company employees for reservation, ensuring that key personnel remain available to contribute to the development and production of essential defense capabilities[53].

- **Facilitation of Access to Funding**. In November 2024 the government introduced a subsidized financing program, enabling defense manufacturers to access loans at an interest rate of just 5%, with the remaining interest subsidized by the state. Under this program, defense companies can secure loans of up to UAH 100 million for working capital with a 3-year term or up to UAH 500 million for capital expenditures with a 5-year term[54].

With regards to procurement, there are several key government stakeholders driving activities in different periods.

- **Army of Drones for market facilitation.** Launched by the Ministry of Digital Transformation to enforce Decree 256, the goal was to scale public procurement of drones and create the market for drones. The team worked with entrepreneurs on testing their drones, had employees hired to help the entrepreneurs with their paperwork, and supported the entrepreneurs with codification of their products through the Ministry of Defense.
- **State Special Communications Service of Ukraine** / **Army of Drones.** A buyer of drones for the government, this institution has become a major government body to buy drones, from several thousand now reaching hundreds of thousands.
- **The Agency of Defense Procurement (Ministry of Defense) is** currently the central procurement unit that buys defense products (including drones); created in 2022 to follow

[53] Liga (https://biz.ligazakon.net/aktualno/14575_bronyuvannya-pratsvnikv-osnovn-pravila)

[54] Ekonomichna pravda "Оборонні підприємства тепер можуть отримати дешеві кредити: умови" (https://www.google.com/url?q=https://epravda.com.ua/news/2024/11/5/721428/&sa=D&source=docs&ust=1739917773475429&usg=AOvVaw33sehSQf8XU3cKROM-MCF2

NATO procurement procedures, kicked off mass drone procurement after in 2023 the State dedicated UAH 40 billion for drone procurement.

- **Regional government –** in 2024 regional governments were granted a right to use their local budget for drone procurement.
- **Procurement by military units** – in 2024 the government also allows brigades to buy drones directly from the producers.

R&D financing and testing is recognized as an essential element for the development of the drone innovation ecosystem with several government efforts:

- **Brave1 (Ministry of Digital Transformation)** – as noted above, Brave1 is forming a mature environment for developing defense tech and accelerating the development and delivery of ready-made equipment samples to the front.

- **Ukrainian Start-up Fund** – is a government initiative aimed at supporting early-stage startups in Ukraine[55].

- The **Ministry of Strategic Industries** - has developed a range of infrastructure elements to facilitate technology development and scaling: open range services to provide infrastructure for new defense products testing[56], and development of a digital marketplace-like platform for local components to help companies overcome limitations of export from China and deepen product localization.

University and other Educational Institutions

The education sector in Ukraine has played a relatively smaller role in the development of the drone innovation ecosystem compared to the role of universities in the innovation ecosystems of other countries. That said, its primary contribution has focused on rapidly creating UAV-specific degrees, conducting foundational research, and offering hands-on training. While programs like the Kyiv School of Economics' dual-use engineering school and research efforts from Kharkiv National University of Radio Electronics and the Institute of Artificial Intelligence Problems contribute to industry needs, the overall impact remains limited.

A significant challenge is the acute shortage of engineering talent—fields like microelectronics, UAV design, and other technical professions face a talent deficit, with many companies reporting dozens of unfilled vacancies. Universities mainly act as subcontractors for labor-intensive research or calculations, while the scientific community struggles to deliver impactful developments. Despite high demand for skilled engineers (students often receive job offers as early as their third year), the ecosystem suffers from a lack of cutting-edge innovation directly originating from academic institutions.

Nonetheless, informal/private and formal educational institutions have been ramping up efforts to support the defense and security innovation ecosystem with an emphasis on innovation and production in drones.

Informal / private educational institutions. Ukraine is witnessing a rapid proliferation of specialized training institutions to upskill civilians and military personnel using UAVs. While not traditional schools or universities, these institutions offer high-level, practical courses tailored for operational efficiency in war zones. This trend is a direct response to the increasing importance of drone warfare and civilian defense mechanisms amid the Russian invasion of Ukraine.

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[55] USF (https://usf.com.ua/4-roki-diyalnosti-usf/)

[56] MSI press release (https://mspu.gov.ua/news/zaliznyi-polihon-dlia-vyrobnykiv-ozbroiennia-ta-viiskovoi-tekhniky-zapustyly-posluhu-vidkrytoho-polihonu)

- **Operational training for UAV operators**: KillHouse Academy provides FPV drone operations courses for civilians and military personnel. Training is geared towards practical skills for operating drones in various environments, especially for combat or security purposes. ProFPV UA Drones offers courses for drone operators, covering essential topics like engineering basics and drone tactics using DJI Mavic and Autel EVO copters under combat conditions. The goal is to train operators who can handle advanced drones in high-pressure scenarios. Schools like Boryviter and Kruk became accredited to certify military personnel with military specialization of drone pilot for Unmanned System Forces.
- **Courses on UAV engineering: development, assembly, and maintenance**. The largest massive open online course (MOOC) provider in Ukraine, Prometheus, offers engineering-focused courses, including the People's FPV course and fundamental training in drone combat tactics, covering DJI and Autel copters. Kyiv Drone Pilot offers engineering courses on FPV drone control, enabling participants to master the technical aspects of piloting and maintaining FPV drones. Dronarnia specializes in the development, assembly, maintenance, and serial production of tactical-level attack UAVs. It provides hands-on training for military personnel on assembling, maintaining, and repairing UAVs to enhance field readiness. UA Drone School hosts a 4-day pilot training program focusing on UAVs, designed for quick skill acquisition for individuals or military personnel, making it shorter and more intensive.
- **Vehicle-specific upskilling programs**. Schools like Boryviter offer separate training on multi-rotor UAVs, fixed-wing UAVs, and FPV multi-rotor UAVs. The institution ensures that its participants are versatile in handling different UAV models, making them valuable assets in dual-use applications.

Formal education institutions offer similar services but also provide conceptual and technical foundations for other stakeholders through R&D. Universities and state-funded institutes share such responsibilities as:

- **Development of industry-responsive UAV engineering degrees and programs.** In 2024 Kyiv School of Economics partnered with Ajax Systems to create an engineering school centered on dual-use technologies, particularly UAVs, showing a clear link between academia and industry needs. In turn, Nobel Alfred University established a BSc in UAV Engineering as part of its Unmanned Systems Engineering program, ensuring a structured curriculum for UAV design and operation.
- **Foundational research for industry and government R&D initiatives**. The Kharkiv National University of Radio Electronics (KhNURE) conducts academic research in UAV development. These are formal studies published by university faculty and students, contributing directly to industry solutions, especially in defense. The Institute of Artificial Intelligence Problems (IAIP) at the National Academy of Sciences of Ukraine focuses on the development of AI systems for UAVs, specifically creating systems to predict cruise missile flight paths and enhance ground monitoring.
- **Classes for the UAV engineers and operators: drone assembly, navigation, and racing**. The National Aviation University (NAU), recently renamed to KAI, is involved in basic training in unmanned aerial systems and related technology, working on pilot projects for defense applications. Oles Honchar Dnipropetrovsk National University (DNU), the Kharkiv Aviation Institute (KhAI), the Institute of Aerospace Technologies (IAT) at Igor Sikorsky Kyiv Polytechnic Institute (KPI), and the European University provide courses and activities focused on UAV navigation and racing. The Lviv Polytechnic National University launched a course on manufacturing and controlling drones, providing technical expertise in drone assembly and operations. The Kyiv-based Brobots School offers similar drone manufacturing and navigation classes for Ukrainian high school students.

Notably, this trend of educational innovation remains exclusive to UAVs at the moment. There is no equivalent proliferation of training or educational initiatives in other domains, such as water drones or robotic platforms.

Today's drone innovation ecosystem insights and challenges

Through our narrative history of the drone-focused defense and security innovation ecosystem that emerged in Ukraine since 2014 and our detailed stakeholder evaluation, we have identified several key lessons. Together, these capture the factors driving the rapid development and scaling of the urgently needed drone industrial base and the defense and security innovation ecosystem that supports it.

- *Existential threat requiring asymmetric solutions.* The full-scale invasion of Ukraine by Russia created an urgent, existential threat to national sovereignty and security. It was only in this context that Ukraine was able to galvanize all key stakeholders. Moreover, the nature of the conflict required asymmetric solutions to counterbalance the enemy's numerical and technological superiority. Drones, as cost-effective and versatile tools could be deployed to decrease human losses and emerged as a critical component of Ukraine's defense strategy. **Drones could also be designed, developed and scaled by start-up ventures**. The combination of urgency and technological accessibility fostered novelty in a widening array of drone technologies by startup IDEs supported by an innovation ecosystem.
- *Streamlined communication and access to decision makers and end-users.* The war's high stakes minimized bureaucratic barriers among stakeholders, enabling direct communication between innovators, military leadership, and end-users (on the front lines). This direct feedback loop accelerated iterative development of drone systems, ensuring they met operational needs and performed effectively under battlefield conditions building up a culture of experimentation.
- *Decentralized procurement.* A decentralized approach to procurement empowered individual military units and volunteer organizations to acquire drones and related technologies directly. This agility enabled rapid scaling of deployment and fostered competition among developers, leading to better and faster innovation but as noted above, was stifled by limited resources.
- *Developed network of volunteers to provide resources.* Ukraine's robust network of volunteers played a critical role in the ecosystem’s early success. These networks were well-organized and had accumulated experience since the 2014 war started in Donbas. Volunteers sourced components, assembled drones, and provided logistical support to frontline units, filling gaps where state resources were insufficient. Most importantly, volunteers often acted as a link between the military and producers: collecting the needs from the military, fundraising, and then buying necessary technology from producers.
- *Crowdfunding resources.* Crowdfunding was a vital source of financing for early drone acquisition, with campaigns reaching domestic and international donors. Platforms like United24 generated financial support, enabling the rapid procurement. Crowdfunding was enhanced by relatively stable banking, fundraising infrastructure (e.g. “jars” for donations that anyone can open and share), and a ban of taking money out of the country.

Despite its extraordinary success over the past few years, Ukraine faces multiple challenges in building a resilient drone-based innovation ecosystem through this next phase and for the long-term. The challenges include the ways in which the government (especially the defense department) interacts with the newly-emerged drone sector and the various stakeholders, especially the start-ups. In an initial assessment of the issues which Ukraine faces, the research reveals that the following eight areas are of particular concern.

To explore these findings further, MIT and KSE will be conducting survey research so as to help clarify the issues for the Ukrainian leadership as it considers the options to safeguard the country’s interests in national security, and future prosperity, in these fast-changing circumstances.

1. *Lack of financing for government procurement.* If previously Ukraine struggled to get enough capacity to produce sufficient numbers of drones for the battlefield, now it faces lack of financing to procure the millions of drones that Ukrainian industry can produce.

2. *Export block.* After the full-scale invasion in 2022, the government (understandably) blocked the export of defense products including drones. This adds to the difficulties of lack of domestic sales by preventing producers from tapping international markets when Ukraine does not have sufficient budget to make use of the capacity its domestic companies have developed. This block might have a longer-term impact, as it disincentivizes companies to correspond to requirements of potential international buyers.
3. *Lack of long-term demand planning.* Constantly changing battlefield conditions, budget issues and regulatory limitations makes it hard for Ukrainian General Staff and Ministry of Defense to build long-term plans, which in turn complicates operations for producers, as they have very limited understanding of future demand and do not have the resources to invest in more flexible production, inventory etc.
4. *Russian attack threat.* The physical location of manufacturing sites in Ukraine poses significant risks due to potential Russian attacks. Despite efforts to keep these locations confidential, information leaks can endanger personnel and disrupt operations.
5. *Threat of worker conscription.* Ongoing mobilization efforts in Ukraine present challenges for defense companies as employees may be conscripted into military service. While regulations exist to reserve personnel in critically important enterprises, including those with government defense contracts, instances of worker mobilization still occur (e.g. not all drone companies are instantly defined as “strategically critical").
6. *Supply chain risks.* Usage of Chinese components poses a significant challenge, as their export has been limited by China since September 2024[57], and their inconsistent quality often requires military units to rely on engineers to repair flawed drones. This dual issue of supply limitations and reliability complicates the deployment and maintenance of drone technologies. While Ukraine has started to localize component production and is launching initiatives to facilitate the components market (e.g. digital catalog of locally produced components)[58] localization remains an issue.
7. *Shortage of technical talent.* Ukraine faces a shortage of engineers and technicians. This is compounded by low enrollment in engineering and technical programs at universities.
8. *Reverse-engineering of Ukrainian innovation by Russia*. Russia has reverse-engineered Ukrainian innovations rapidly, undermining Ukraine's hard-won technological progress and adding additional R&D costs and IP protection to sustain Ukraine's competitive edge.

The combination of national issues (government funding, export bans, worker conscription and lack of demand planning) together with international ones from adversaries (including threats to facilities, and supply chain risks) make today's industrial base for drones quite fragile. These challenges also pose a significant problem for drone producers themselves; they have idle capacity and cash flow issues. Overall, the defense and security innovation ecosystem that has come to characterize the Ukrainian economy has potential but remains at a point of emergence. It has not yet reached its full potential and in the medium term the key entrepreneurial ventures will struggle to fund and maintain rapid cycles of future innovation given limited resources to invest in R&D and the hopeful (but challenging) slowing of the pace of innovation that should accompany the end of the conflict. Lastly, in the long term, funding limitations (from government and investors) mean that many companies might consider partial or full relocation abroad to be able to sell internationally to raise funds for technology development and operations[59]. This would severely weaken Ukraine’s burgeoning drone-based innovation ecosystem and a potential source of the nation's long-term peace and prosperity.

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[57] Ekonomichna pravda “Китайські санкції. Чи залишиться Україна без дронів та РЕБу?” (https://epravda.com.ua/publications/2024/09/4/718868/)

[58] Ekonomichna pravda “Побороти залежність від Китаю. Мінстратегпром створить майданчик для торгівлі українськими компонентами” (https://epravda.com.ua/news/2024/10/7/720246/)

[59] Techforce survey (https://techforce.in.ua/news/article/relocation-analytics-by-TFUA)

Summary and Conclusions

- Ukraine's wartime innovation in the production and use of 'drones' (especially UAVs in the air domain, and naval drones that managed to push back the Russian Black Sea fleet) has rightly captured international attention, but learning the right lessons for others requires some close analysis about what actually took place, and how that happened;

- Prior to February 2022, Ukraine's post-Soviet 'military-industrial complex' had started to respond to the nature of war changing to the UAV drone dimension with development of air drones but did not scale the production capacity and usage, despite the Russian occupation of Crimea and the war in the 'Donbas' region;

- Since the full Russian invasion in February 2022, however, a Ukrainian 'whole of nation' response underpinned the rise of a multi-stakeholder 'innovation ecosystem' effort to develop, produce and deliver UAV 'drones' of increasing sophistication;

- Especially interesting for those trying to 'learn the lessons' from Ukraine is that it took this nation moving to a wartime footing to mobilize the full range of mostly non-state actors to achieve the progress that the state system had not delivered;

- As February 2025 marked the third anniversary of the Russian invasion, this is a time to help Ukraine and its Allies consider options for:

    - Ukraine to capitalize on its hard-won, conflict-driven innovation in drones;

    - Ukraine to ensure its security through sustainable production of the drones it needs (with productive uses of its additional manufacturing capability 'surplus');

    - Ukraine's partners and allies to learn the right lessons, support Ukraine into this next phase, and adapt their own military establishments.

Together, insights into these will provide a roadmap for those wishing to support Ukraine's ecosystems and ensure the continued creation, growth and scaling of new businesses (especially IDEs) especially in those with drone technologies in Ukraine with the potential to drive long-term social and economic benefits.

This Working Paper sets out these insights, and seeks comments. Based on the findings from its next phase of research, and responses to this Paper,, it will be easier to outline the right policy and programmatic interventions that Ukraine might wish to make (and with which its partners may wish to reckon for themselves), so as to provide insights for others wishing to build or strengthen their own domestic defense/security innovation ecosystems.

Looking further into 2025, these considerations may be necessary, even as paths towards Ukraine's prosperity in a 'post-conflict' (but perhaps not a fully peaceful) future, integrating with the rest of Europe (especially the EU) and engaging with Allies in NATO.