INNOVATIVE ECOSYSTEM OF UAV AND C-UAV TECHNOLOGIES FOR URBAN DEFENSE: ANTHROPOLOGICAL STUDY AND SYSTEM MODELLING (EXPERIENCE OF UKRAINE AND SOLUTIONS FOR SOUTH KOREA)

by

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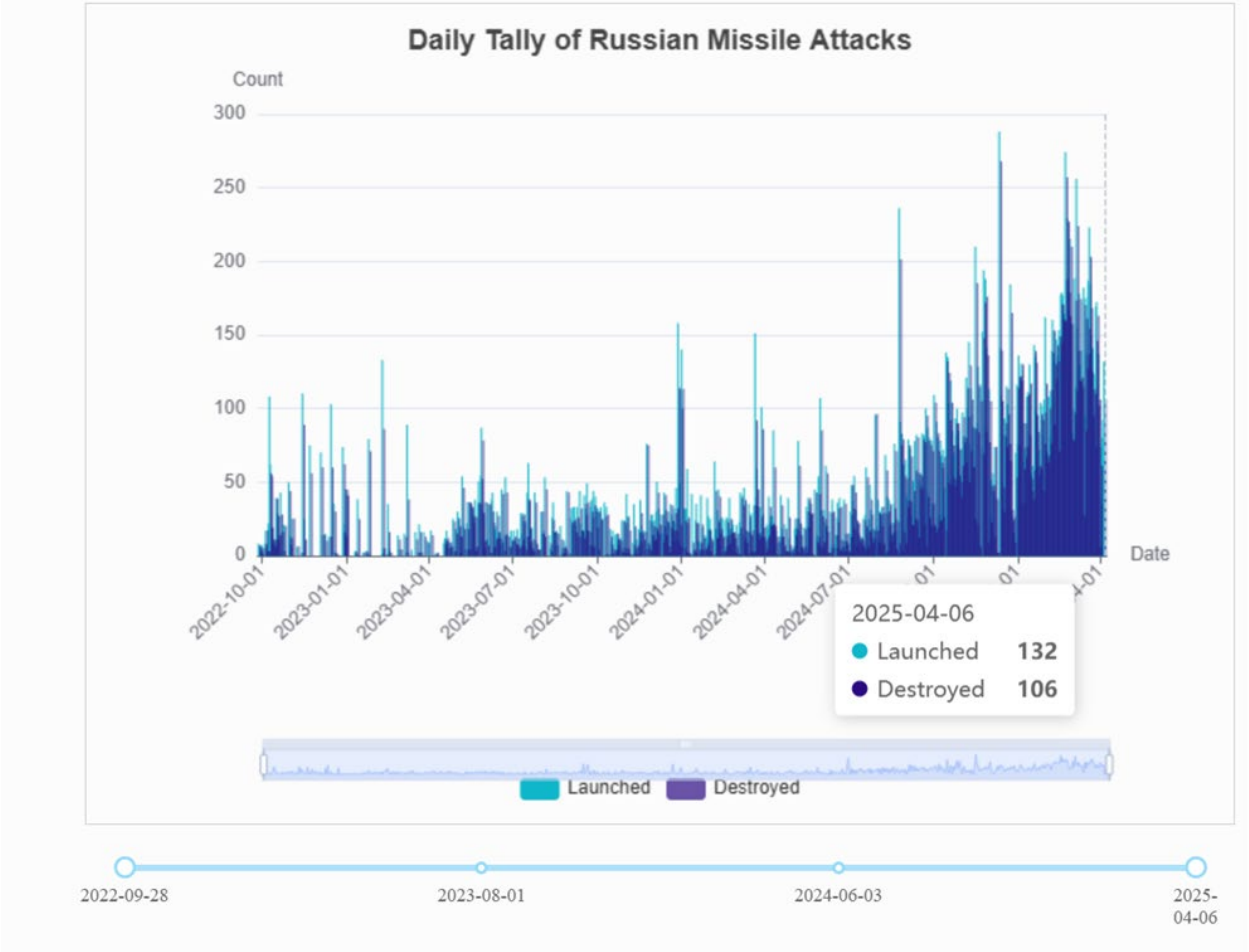
ABSTRACT

During the recent armed conflicts in Ukraine and the Middle East, people have become afraid of drones and are striving for counter-drone protection for their settlements. From September 28, 2022, through December 28, 2024, Russia launched more than 19,000 missiles, including over 14,700 one-way attack drones, at targets in Ukraine. Daily aggregated data on various missile types includes ballistic missiles, cruise missiles, various UAVs, and surface-to-air defense missiles such as X-101/X-555, X-22, Shahed-136/131 and Iskander-M [88].

Fig. 1. Ukrainian Air Force statistical data on daily Russian air attacks (bar chart)



On average, 23.2 Russian missiles were launched daily. Every night, these systems force millions of Ukrainians to flee underground. Mostly, in urban bomb shelters, because the targets of Russian air strikes are concentrated in cities. But along with military, administrative, industrial, and energy facilities, these attacks destroy residential neighborhoods and other urban infrastructure [89].

The largest item of damage caused by the military aggression of the Russian Federation is the loss of housing caused by the shelling of Ukrainian cities by Russian missiles, drones and artillery. It reaches over a third of the total amount, which is almost $60 billion. Over 50% of the housing stock in cities and towns located near the front line, as well as a significant portion in Ukraine's largest cities (Kharkiv, Dnipro, Odesa and Kyiv), has been damaged or destroyed [91].

Table 1. KSE report of infrastructure damages (as of November 2024)

Property type	Assessment of damages, $ billion	Share of damages by property type, % of total sum	Previous assessment of damages, $ billion	Dynamics
Residential buildings	60,0	35,3%	58,9	1,9%
Infrastructure	38,5	22,7%	36,8	4,6%
Energy sector*	14,6	8,6%	10,0	46,0%
Assets of enterprises, industry	14,4	8,5%	13,1	9,9%
Agriculture and land resources	10,3	6,1%	10,3	0,0%
Education	7,3	4,3%	6,8	8,8%
Forest fund	4,5	2,7%	4,5	0,0%
Healthcare	4,3	2,5%	3,1	32,3%
Culture, tourism, sports	4,0	2,3%	3,1	29,0%
Municipal services and utilities*	3,5	2,0%	3,5	0,0%
Transport vehicles	3,5	2,0%	3,1	12,9%
Trade	2,8	1,7%	2,6	7,7%
Digital infrastructure	1,2	0,7%	0,5	140,0%
Administrative buildings	0,8	0,4%	0,5	60,0%
Social sector	0,2	0,1%	0,2	0,0%
Financial sector	0,04	0,01%	0,04	0,0%
Total	**169,8**	**100%**	**157,2**	**8,0%**

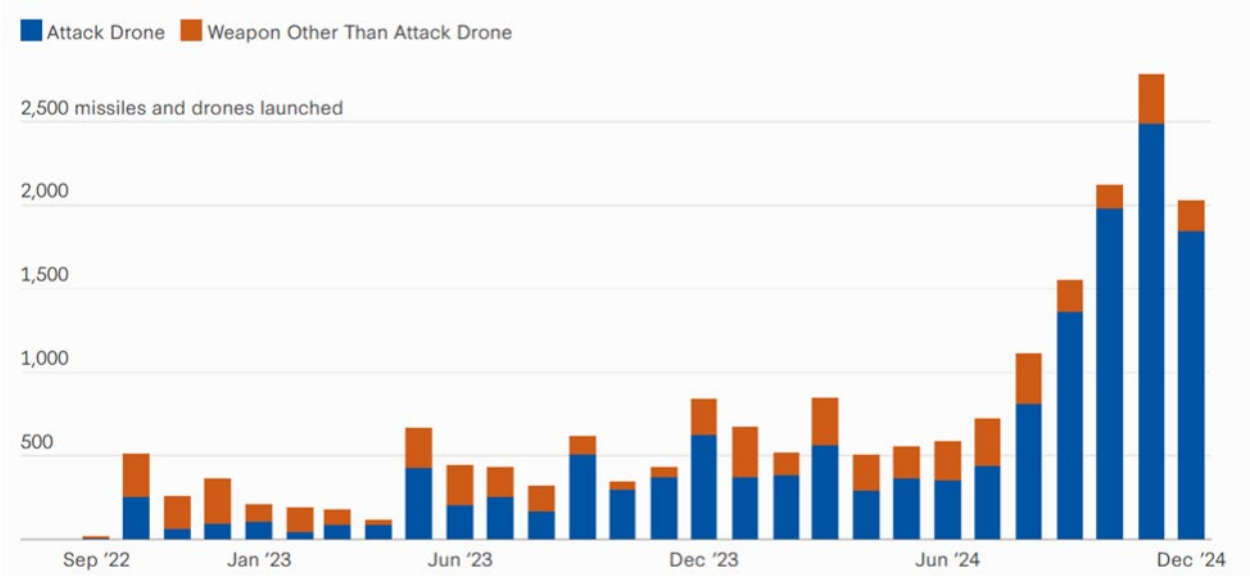
So how to protect cities from air attacks? Mostly with drones, which are over ten times cheaper than missiles. As the tables below show, to intercept the Russian X-22 or X-59 missiles with a Patriot (over $3 mln) or NASAM (just over $1 mln) interceptor is cost-effective. Using it against the SHAHED drone ($35,000) results in a significant loss of value [88].

Table 2. Costs and effectiveness of aerial Russian weapons

Weapon	Cost per unit (USD)	Hit percentage	Cost per target struck (USD)	Payload (lbs)	lbs of payload (USD)
Shahed drone	$35,000	10	$353,535	110	$3,213,958
Kh-22	$1,000,000	95	$1,057,082	2,200	$480,492
S-300/S-400	$1,500,000	100	$1,507,538	300	$5,025,126
Kh-59	$500,000	29	$1,748,252	700	$2,497,502
Iskander-M	$2,000,000	90	$2,224,694	1,000	$2,224,694
Iskander-K	$1,000,000	36	$2,747,253	1,000	$2,747,253
Kalibr	$1,000,000	20	$4,926,108	1,000	$4,926,108
Kh-47 Kinzhal	$15,000,000	74	$20,161,290	1,050	$19,201,229

Note: Selected weapons are those the data specifically identify by type and show were used in at least 10 separate attack events between September 28, 2022, and December 28, 2024, excluding the Kh-31P anti-radiation missile and weapons the data show reaching their targets less than 1 percent of the time [88].

Fig 2. Ukrainian Air Force statistical data on monthly attacks by Russian missiles and drones (bar chart)



A universal solution is a defense counter-drone urban complex with AI detection and response systems, including a cluster of existing air defense systems. This thesis focuses on the impact of UAV and C-UAV technologies on city life and the threats and challenges faced by urban space in the context of war and the prospect of post-war reconstruction. The relevant recommendations are based on the content analysis of the industry development, and technological, social, managerial, and administrative solutions tested during martial law in Ukraine, as well as results of thematic sociological studies (questionnaires, focus groups, in-depth interviews).

Thus, the paper takes into account the ambiguous public attitude to the relevant technologies and initiatives for their implementation in urban space, as well as the development of relevant local, national, and international policies. Examples of the practical implementation of Ukrainian experience are presented in the RSTUDIO radial-vector projection of a defense counter-drone city protection and in the QGIS case study for similar urban areas in strategic port cities of Ukraine and South Korea, which also suffers from constant aerial attacks by the neighboring aggressor country.

The strategy of post-war integration into the global specialized ecosystem was developed on the basis of the MIRO project's multi-level model of international cooperation and collaboration between government, academic, corporate, and business stakeholders and civil society sub-stakeholders and crowdfunding platforms of UxS/C-UxS industries in Ukraine and its allies.

CONTENTS:

LIST OF ABBREVIATIONS

PAC-3 - Patriot interceptor
NASAM - AIM-9X Block II variant of the Sidewinder missile
UAV - Unmanned Aerial Vehicles
Kh-22/Kh-59/Kh-31P – types of Russian missiles
ASX - Australian Securities Exchange
DRO - DroneShield Limited
MDTF - Multi-Domain Task Force
CRS - Congressional Research Service
KSE – Kyiv School of Economics
MIT – Massachusetts Institute of Technology
AGH – Kraków University of Science and Technology
DARPA - Defense Advanced Research Projects Agency
DIANA - Defense Innovation Accelerator for the North Atlantic
NATO - North Atlantic Treaty Organization
NIF - NATO Innovation Fund
UAS - Unmanned Aerial System
UGV Unmanned Ground Vehicles (Land)
USV - Unmanned Surface Vehicles (Naval)
C-UAV – Counter-Drone Technologies
UxS - Unmanned Systems
C-UxS – Counter-Unmanned Systems
AI - Artificial Intelligence
AGI - The Second Level of Artificial Intelligence.
ANI - The First Level of Artificial Intelligence.
ASI - The Third Level of Artificial Intelligence.
IE - Innovation Ecosystems
C2 - Command/Control
SHORAD - Short-Range Air Defense Systems
THAAD - Terminal High Altitude Area Defense Systems
ISR - Intelligence, Surveillance and Reconnaissance Missions
EW - Electronic Warfare
HPM - High-Power Microwave
HEL - High Energy Laser
MOSA - Modular Open Systems Approach
CMOSS - Modular Open Suite of Standards
TRL - Technical Readiness Level
DOD – Department of Defense
NSA - National Security Agency
RF - Radio Frequency
IFPC - Indirect Fire Protection Capability
CM - Cruise Missiles
RAM - Rocket, Artillery, and Mortar Attacks
DB - Database
LC - Life Cycle
IT - Information Technology

NR - Non-Functional Requirements
CAGR - Compound Annual Growth Rate
NM - Neural Networks
SW - Software
SP - Software Product
SS - Software System
SA - System Analysis
DBMS - Database Management System
DDBMS - Distributed Database Management System
Iot - Internet of Things
Tor - Terms of Reference
FR - Functional Requirements
FS - Formal Specification
SFE - Functional Efficiency Standard
AEG - Automatic Operation Generation.
AT&T - American Transnational Telecommunications Conglomerate.
BSI - British Standards Institute.
FN - Future Network.
GPS - Global Positioning System.
IA - Intelligent Agent.
IC - Intelligent Systems.
IIS - Intelligent Information Systems
IEC - International Electrotechnical Commission.
IMS - IP- of the Multimedia Subsystem.
ISO - International Organization for Standardization.
ITU - International Telecommunication Union.
IT - Informational Technologies.
IVR - Interactive Voice Response System.
LBD - Local Database.
ML - Machine Learning.
NBDRA - NIST Big Data Reference Architecture.
NFV - Network Functions Virtualization.
NGN - Next Generation Networks.
NIST - National Institute of Standards and Technology.
NLP - Natural Language Processing
RPA - Robotic Process Automation.
CCS - Common Channel Signaling.
SDN - Software-Defined Network.

INTRODUCTION

Relevance of the Topic in the Context of Urban Issues and Technological Trends

In the more than three years since the full-scale invasion of Ukraine, the drone technology market has changed rapidly, both quantitatively and qualitatively. Obviously, post-war requirements for the use of airspace in Ukraine should include mandatory registration and marking of drones, flight altitude restrictions and use permits, digital certification of drones and their operators to ensure safety, as well as new airspace control practices (monitoring, identification and neutralization of hostile drones) and new liability rules for the use of drones, especially in the context of their usage in C-UxS complexes, etc. Such restrictions on the use of drones may cause discontent among drone users, however they are particularly essential for Ukraine as it aims to rapidly reestablish commercial air services..

The deployment of technological complexes as part of counter-drone domes over Ukrainian cities will require the introduction of new airspace rules and bringing the current Regulation on the Use of Ukrainian Airspace, approved by the Cabinet of Ministers of Ukraine by Resolution No. 954 of December 6, 2017 [26], up to date. Scheduled for October 1, 2025, the amendments to this document, in accordance with Resolution No. 346 of March 28, 2025[27], do not provide for any regulatory innovations regarding the use of airspace for drone flights.

C-UxS technologies track not only enemy unmanned vehicles, but also drones used for legal purposes (e.g., photography, delivery, emergency). Therefore, counter-drone systems should be designed to minimize interference with legal purposes. Their neutralization should be carried out with minimal risk to people and in compliance with the 2 principles of International humanitarian law “Necessity” and Proportionality”[25]: the use of C-UxS should be justified solely by security needs, and the measures taken with the help of C-UxS should be proportionate to the threat. Decision-making processes on the use of counter-drone technologies should be transparent and accountable, and developers and users should be responsible for the consequences of using the C-UxS technology, including unintended outcomes, and take measures to minimize the risk that the technology will fall into the hands of criminals or terrorists.

Effective counteraction to UAV threats requires the development and implementation of comprehensive anti-drone systems that combine technical detection, identification, and neutralization capabilities with consideration of socio-ethical aspects and public perception, which is especially important for ensuring the safety of the Ukrainian population, which is exposed to long-term traumatic effects of unmanned technologies.

The effectiveness of any security system depends on cooperation with the public. Understanding their views and concerns is key to building trust and engaging them in the security process, as a constant sense of surveillance and threat from the sky can negatively affect people's psychological state, especially in areas with high urban concentration. It can even cause paranoid attacks in some citizens. Therefore, C-UxS systems should be designed to minimize people's fears of privacy violations and

interference with their private lives, and the data collected by the C-UxS systems should be protected from unauthorized access and not used to directly harm people.

The key to this process is to engage governments, companies, civil society organizations, and individuals in discussing and developing policies related to the use of counter-drone techs; to adopt laws that clearly define the limits of the use of C-UxS and establish liability for their violation, based on international standards and norms governing their use; and to establish independent regulatory institutions to oversee the use of C-UxS and ensure law enforcement.

These systems should impose hard restrictions on the gathering, saving and processing of data obtained by C-UxS techs, as well as apply the data-anonymizing technologies for preventing the illegal identification of individuals. Also, C-UxS developers should ensure transparency of the controlling algorithms to avoid bias and discrimination. And to identify and eliminate potential vulnerabilities, the systems should be regularly audited.

In this context, it is particularly important to develop an innovative ecosystem of drone and C-UxS technologies. Such an ecosystem should become a platform for combining the efforts of scientific institutions, private companies, government agencies, investors, and volunteer initiatives to stimulate innovation, develop production, and implement effective solutions in the field of unmanned systems and countermeasures.

Study Focus (Sub-Stakeholders' Phenomenon in the Uxs Ecosystem)

The study also focuses on the phenomenon of Ukrainian sub-stakeholders and their role in shaping and rapid development of the UxS industry during the war: volunteer organizations and charitable foundations (Come Back Alive, Prytula Foundation, Maria Berlinska Association, and other specialized initiatives)[33], technology companies and startups (Abris Design Group, DEF-C, Spartacus), as well as individual drone innovators and private entrepreneurs.

The research also pays special attention to the phenomenon of cottage industries and garage laboratories that meet the operational needs of the Ukrainian front. Given the growing level of threats and the continuous development of drone technologies in the world, they actually serve as technological incubators and accelerators, providing innovative developments in the field of UxS due to crowdfunding.

The study also analyses the effectiveness of their cooperation with the government's Brave1 platform[53], the state initiative "Army of Drones" [54] and the Unmanned Systems Forces [55] created within the Armed Forces of Ukraine.

Research Methodology (Anthropological Research and Comparative Analysis)

However, what is more important for researching the perspectives of innovative ecosystems and designing strategies for their development is not the gap with the identification of stakeholders or their subcategories, but the neglect of the basic approach - the anthropological one. People's attitudes towards specific innovations should be the basis for shaping the strategy of the respective innovation ecosystem. This is doubly important for "dual-use" innovations such as UAVs and counter-drone

technologies, and especially for their use in urban environments. So, the study includes the analysis of the world scientific literature on public perception of UAV and counter-drone technologies, as well as their impact on the urban environment, like supporting the safe and efficient usage of and preventing illegal activities, as well as mitigating noise pollution, especially in residential areas and at night hours.

Anthropological research was also used to extensively study the social and cultural aspects related to the development, implementation and perception of drones and counter-drone systems. This approach analyzed public attitudes (including the urban population of Kyiv and visitors to the capital), the opinions of various expert groups (veterans, scientists, developers and manufacturers of UxS and C-UxS technologies, representatives of local authorities and state institutions) to the use of unmanned systems in the city environment and the organization of counteraction to them in urban space. The data was analyzed using qualitative content analysis (for interviews and focus groups) and statistical methods (for quantitative data), in particular, the report ' Ukrainian Urban Public Perception...' [32]. This study allowed us to identify and analyze the values, norms, fears and expectations of different categories of respondents regarding the development and application of the technologies under study. The following methods were used to collect empirical data:

- semi-structured in-depth interview sessions [28] with key industry experts, government officials, technology developers and volunteers; focus group conferences [29] and discussions with representatives of different social groups.

- a broad anthropological survey of the attitudes of Kyiv residents and visitors to drone and counter-drone technologies [32] through a combination of online and offline surveys, as well as statistical analysis of public opinion polls, official documents, analytical reports, media and social media materials, statistics on drone production and investment in the UAV market, and observations [30].

The comparative analysis was conducted to identify common and distinctive features in the processes of formation and development of drone and counter-drone technology ecosystems by analysis of the global open data set The main object of comparison in this study is the Ukrainian context in the development of UxS/C-UxS technologies and Ukraine's potential in the formation of a global innovative ecosystem. The comparative analysis covered such aspects as the background of the UxS and C-UxS industry, the level of technological development, innovation and government support policies, public opinion, and international cooperation mechanisms

The study also provides the comparative analysis of state regulation in the field of UAVs in Ukraine and other world leaders in the global market of drone and C-UxS technologies. The trends were discovered in the reports "Global State of Drones 2024" [49], 'Role of the Bridge Maker in Innovation Ecosystems', as well as materials of the conferences'2025 "Counter UAS Technology Europe" in London, UK [50], and "Reimagine the Future of Urban Fright" in Los Angeles, USA [51]. Ukrainian experience, reflected in the report of the House of Lords Foreign Affairs and Defense Committee 'Ukraine: a wake-up call' [47] and the article 'Ukraine's Drone Evolution, From Mavic Scouts to Long-Range Strike Weapons' [9] was also studied.

This integrated and comprehensive methodological approach combining qualitative and quantitative methods of analysis ensured the validity, reliability, and representativeness of the research results.

The Purpose of the Study (C-UxS defense systems for urban spaces in Ukraine and South Korea)

Ukraine, as a country that has directly faced the intensive use of drones in military conflict, represents a unique case study for rapid innovation and adaptation of technologies in war. South Korea, for its part, is constantly facing the threat of military drone use by North Korea and has special needs to organize effective defense of urban areas and other types of settlements that have repeatedly been the target of aerial attacks by the neighboring aggressor country.

So, the main purpose of this study is to determine the need for counter-drone technologies to protect human settlements and model C-UxS urban defense systems for megacities in Ukraine and South Korea as countries facing a constant threat of enemy drone attacks, as well as to strategize a multi-level innovation ecosystem for the global implementation of leading counter-drone experience and. In particular, in a similar context of the need to reduce dependence on components from China [43], as a satellite of aggressor countries (e.g. Northern Korea and Russian Federation).

The current supply chain constraints weaken Ukraine's military resilience and its ability to deter full-scale Russian aggression. It also carries risks for associated with quality control the UAV industries in Ukraine and South Korea. The need to develop and implement domestic technological solutions, or those developed in concordance with steadfast allies for key components, is urgent to ensure the sustainability and independence of the Ukrainian and South Korean drone industry.

Object and Subject of Research (Critical Gaps in the Current Uxs Ecosystem and Potential of "Technical Debts and Personnel")

The object of this study is the current system of unmanned aerial systems (UAS) and counter-UAS technologies that is actively being formed in Ukraine in the context of the war in Ukraine. This ecosystem encompasses a wide range of stakeholders, including government agencies, private enterprises, academic institutions, volunteer organizations, investors, and the very innovators, designers, and users of unmanned systems.

The rapid development of technologies to counter enemy drones and electronic warfare requires Ukrainian developers to rapidly adapt to changing conditions on the battlefield and constantly implement their own drone and anti-drone solutions [47]. On average, it takes about three months from the appearance of a certain drone innovation on the front line to the development of a technology to counter it, but the Russian Armed Forces drone development, on average, moves at a much faster pace [48]. Such a long time usually occurs due to insufficient coordination between various stakeholders in the drone ecosystem, including government agencies, the private sector, and academic institutions.

So, the subject of the study is the critical gaps in the existing UxS&C-UxS ecosystem in Ukraine that impede its effective development and ability to provide comprehensive protection against hostile drones, in particular, Ukrainian cities and settlements, as well as the potential for the formation of a global innovative ecosystem based on the Ukrainian UxS&C-UxS industry for the further development of this area. Despite the significant progress made by Ukraine in the production and use of drones,

the existing UxS&C-UxS system still faces a number of significant challenges that require detailed analysis, close cooperation of all stakeholders and sub-stakeholders, and the establishment of joint resolutions on scientific and technical cooperation and financial support for the sector's development.

One of the key gaps is the limited capacity of the public sector to purchase the number of drones that the Ukrainian industry is capable of producing [44]. This leads to the idling of production capacity, a corresponding reduction in staff, and limited opportunities for innovation and business scaling, especially for startups. Inefficient use of resources and useless duplication of efforts usually arise from the lack of coordination between stakeholders and the absence of a common vision and a clear strategy for the development of the industry, so investments are needed in research and development of not only new technologies that can effectively counter modern threats, but also a new innovative ecosystem capable of autonomous development and independent solution of the challenges faced by humanity as a result of the development of drone and anti-drone technologies all over the world. Effective mechanisms for attracting private international investment and access to global markets are critical for the industry's further growth.

Along with the ban on exports of dual-use technologies and forced relocation of weapons manufacturers abroad[45], the innovation process is slowed down by bureaucratic obstacles and complex product certification and codification procedures [46], which also hinder the entry of new developments. These processes need to be simplified and optimized to encourage rapid innovation. In addition to bureaucratic obstacles in the drone certification process and lack of transparency in public procurement in the UAV industry, the study highlights the problem of “technical debts” inherent in the UxS&C-UxS techs ecosystem and focuses on the possibilities of “hidden” potential(<20% of its efficiency and performance) [56]. Today, entire landfills of crashed combat UAVs can be observed on the Ukrainian front line, which testifies not only to the obsolescence of the technologies themselves but also to the increasing effectiveness of counter-drone technologies. As a consequence, there is an overflow of investments from the UAV industry into the counter-drone sector, which is accompanied by a rapid growth in the capitalization of counter-drone companies and their stock exchange quotations, some of which exceeded 600% [7] in 2024.

The prospects for innovative development of the global UxS ecosystem require utilizing the available potential in “technical debts” and technical personnel, including the high level of qualification of specialists, their flexibility, and ability to quickly adapt in war and post-war conditions. Also a distinct problem of a sustainable entrepreneurial drone urban ecosystem(to job creation, economic growth and prosperity) based on rotor and other lethal technologies, which is at risk of being replaced by new ones[3], as identified by the Sustainability and Social Enterprise Program[4] at Bard College (both nonprofit and mission-driven for-profit organizations) and described in numerous scientific papers by the leading Ukrainian National Aviation University and other relevant higher education institutions[5] and R&D centers [6]. The development of a domestic component base, attraction of private investment, simplification of regulatory procedures, government programs of industrial and social support, international cooperation and active financial support of the innovation ecosystem by global institutions are key to ensuring sustainable and

effective development of the Ukrainian innovative UxS&C-UxS ecosystem capable of providing reliable protection to Ukrainian cities and being scalable to other countries.

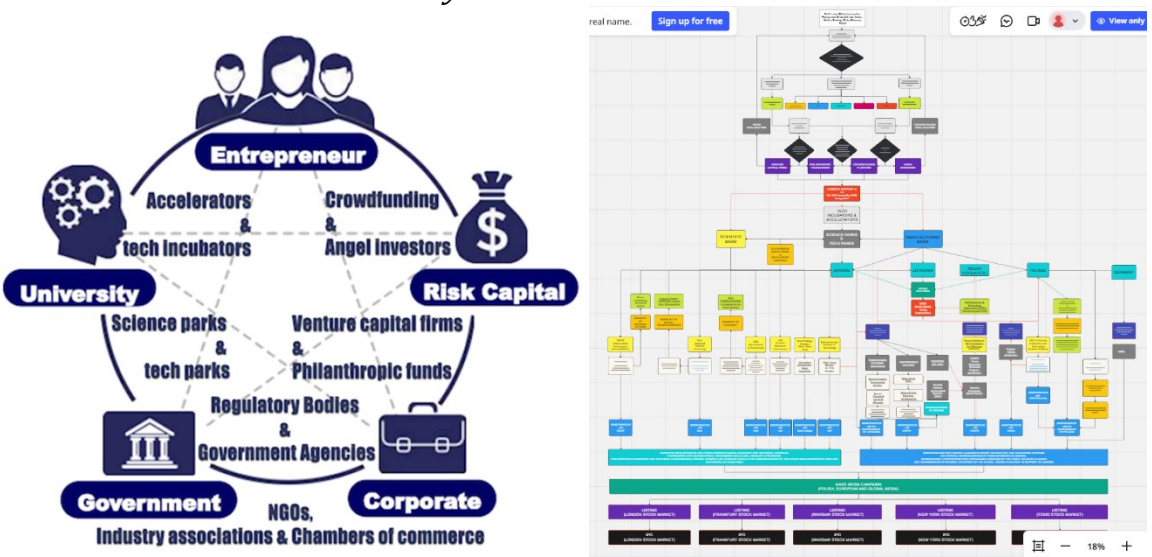
Research Objectives (Role of "Bridge Makers" for Innovation Ecosystem and Its System Modeling)

It was established in practice how gaps in the interaction between stakeholders and sub-stakeholders of the UAV industry lead to a conflict of algorithms of the entire UxS&C-UxS innovative ecosystem due to inefficient use of resources, excessive duplication of functions, and a slowdown in the pace and possibilities of its development. This made it possible to obtain a comprehensive understanding of the Ukrainian phenomenon of "sub-stakeholders" in the formation of the UxS and C-UxS innovative ecosystem in Ukraine and to model its perspective development, taking into account regional and global challenges.

To assess the role of different stakeholders and sub-stakeholders in the functioning of the drone industry, the author examines their motivation, mechanisms of interaction with other elements of the UxS&C-UxS ecosystem, and opportunities for direct cooperation (no mediation by military institutions and large defense enterprises). A partnership with one of the world's leading universities, the Massachusetts Institute of Technology (MIT), was used personally. The author also conducted relevant analytical work [31] as a member of the joint group of the Kyiv School of Economics and the Massachusetts Institute of Technology to study the drone industry and a participant in Gene Keselman's MIT specialty course [66].

The author has explored the gaps in the innovation ecosystem examined in a 2014 study [1] by an elected member of the UK Prime Minister's Science and Technology Council that year, MIT Professor Fiona Murray, who is the current Vice-Chair of the NATO Innovation Fund (NIF). In contrast to the model of the innovation ecosystem used in the world economic theory based on the Massachusetts Institute of Technology framework, which includes an exhaustive list of 5 stakeholders (government, scientific base, entrepreneurship, corporate and risk capital), non-traditional sub-stakeholders play a key role in the context of the war in Ukraine.

Fig. 3,4. The updated MIT framework and the MIRO-generated multi-level model of the UxS and C-Uxs innovative ecosystem



Then, the author supplemented the current MIT framework of the main stakeholders of the innovation ecosystem[2], developed under Prof. Murray's supervision, by adding sub-stakeholders, that have emerged and assumed the major role in the formation of the innovation ecosystem of the Ukrainian drone industry since the beginning of the full-scale Russian invasion. Further, the author has combined the concept of "bridge maker" [35] with key key theories of innovative development[36] and involved the Ukrainian and international scientific institutions and manufacturing enterprises, regional and global specialized associations such as the Drone Coalition [37], the NATO Innovation Fund [38], and its mil-tech agencies such as DARPA [39], DIANA [40], and South Korean Defense Development Agency [42] into a multi-level model of the innovation UxS/C-UxS ecosystem [57] with over 300 elements.

The proposed model has the potential to be used in designing effective urban defense against hostile, terrorist, and criminal drones not only for cities in Ukraine and South Korea [41], which are similar to the drone threat context, but also for Poland, the Baltic States(under threat from Russian aggression), and other countries facing similar challenges, including Taiwan, the United Kingdom, the United States of America, etc.

The system modelling was carried out using the Miro board platform to categorize the main stakeholders of the innovation ecosystem, define their roles and relationships in order to increase the efficiency of interaction and minimize the gap between scientific developments, their practical realization, and various sources of funding for the rapid deployment of innovative solutions in the field of UAVs and anti-drone technologies to protect Ukraine, the EU and the entire civilized world from threats. The modeling reflects a clear structuring and a deep understanding of the interrelationships between the various elements. It is characterized by a comprehensive vision of the development of the innovative ecosystem of drone and anti-drone technologies at the global level, which was achieved by objective, identification of elements, linkages, designing the architecture, consideration of the external environment:

- *Identification* of all key stakeholders and resources required for the system to function (including artisanal production and garage laboratories as a unique element of the Ukrainian ecosystem).

- *Defining* the interactions and flows between the elements (information, finance, technology, support).

- *Analyzing* the current and potential funding (from state financial sources and crowdfunding - to attracting investments through IPOs on global exchanges)

- *Projecting* a globally scalable innovation ecosystem for UxS urban defense.

- *Developing* the structure of the ecosystem, including its levels (local, national, global) and functional blocks (media, science, production and finance).

- *Modeling* the impact of global trends on the ecosystem (technology development, growth potential of C-UxS companies' shares and the use of the World Stock Exchange Networks, geopolitical integration of the Ukrainian ecosystem into global associations such as the Drone Coalition and NATO).

A multi-level global innovation ecosystem of UxS&C-UxS techs [57] the author modeled at MIRO Board takes into account the critical needs of Ukrainian sub-

stakeholders and their connecting with independent investors. Based on further refinement of the project as part of the month-long MIT Building for Ukraine hackathon in January 2025, the author presented a prototype of accelerator platform[58] for overcoming the identified "technical debts" and barriers to the development of the drone industry, including the changes in regulatory policy in the field of UAVs (from simplifying the regulation of the drone market to total codification of all UAV manufacturers and their products).

Structure of the Paper

This master's thesis is structured into five main sections, a conclusion, and a list of abbreviations and references. The sections include the theoretical framework of the study and the empirical research. The methods of personal observation and anthropological research, secondary data collection and comparative analysis, as well as program-vector designing and system modeling, were used in the work. The total volume of the paper is 141 pages, including 3 pages of the list of abbreviations and 6 pages of the list of references, as well as 30 pages of appendices.

The Introduction substantiates the relevance of the study, formulates the purpose, defines the object and subject, and outlines the main tasks and methodological approaches.

The First Chapter "Anthropological Research" is concerned with the theoretical concepts that form the basis for analyzing the public attitude towards drone and counter-drone technologies. The section substantiates an anthropological approach to the study of global public attitudes towards UAV technologies and counter-drone systems, as well as social and ethical dimensions around UAV and C-UAV technologies. The chapter describes the methodology and main methods of collecting and analyzing empirical data: quantitative (observations and overview of the thematical studies) and qualitative (surveys, focus-groups, in-depth interviews) methods. The section also includes relevant RStudio graphics too. The chapter is focused on the emergence of new social identity categories, in particular in the urban drone defense sector, and garage-based UAV labs and artisanal UAV productions, with their enormous public support through crowdfunding platforms, which have emerged as the leading actors in the Ukrainian national UAV sector during the war period.

The Second Chapter "Analyzing the Ukrainian Context" is devoted to the analysis of historical background and current state of development of UxS and C-UxS technologies in Ukraine and in the world. The section also contains a comparative analysis of regulatory legislation, as well as identification of existing barriers to the potential integration of the Ukrainian drone industry into the global market.

The Third Chapter "Overview of Existing Solutions" describes the latest Ukrainian and world experience in the field of UxS and C-UxS innovations: technologies, systems and complexes. The chapter also includes the design of a universal model of the C-UAV urban defense complex with a relevant RStudio chart.

The Fourth Chapter "Ukrainian UxS/C-UxS Solutions for the Protection of South Korean Cities and the Odessa-Incheon Case Study" is devoted to the analysis of South Korea's needs and the possibility of implementing Ukrainian experience for the C-UAV protection of urban environment. The section includes QGIS modeling of C-UAV

complexes for both Ukrainian and South Korean strategic port cities: Odessa and Inchon.

The Fifth Chapter "Designing an Innovative Ecosystem" focuses on the development of the concept of an innovative ecosystem of drone and anti-drone technologies for integrated UxS urban defense. The chapter identifies the needs of various stakeholders, proposes an ecosystem model, and develops policy recommendations for its effective evolution.

The Conclusions summarize the main results of the study, identify the scientific novelty and practical significance of the results, and provide recommendations for further research in this area.

The paper concludes with *a List of References,* which includes scientific papers, analytical reports, Internet resources, and other sources used in the research process.

CHAPTER 1. ANTHROPOLOGICAL RESEARCH

This section is dedicated to the disclosure of key theoretical concepts that serve as a basis for analyzing the formation and development of the innovative ecosystem of drone and anti-drone technologies, especially in the context of urban protection and on the example of Ukraine. The chapter takes an interdisciplinary approach, combining anthropological, technical, economic, and social aspects of the research.

The use of UAVs for military purposes and the deployment of counter-drone systems, in particular for the protection of urban settlements, raise important ethical issues related not only to the responsibility for the use of these technologies but also to the right to privacy and freedom of movement in urban environments. Understanding these social impacts is important for developing technologies that minimize the negative impact on citizens' privacy and help build trust between society and the authorities.

1.1. Global and Ukrainian societal impact as a reason for an anthropological approach in studying UAV technology

In the modern world, technology has become an integral part of human existence, deeply penetrating social, cultural, and political processes. Unmanned aerial systems and counter-drone technologies are no exception. The perception of these technologies varies depending on many factors, including the context of use, level of awareness, historical and cultural background, and personal experience. Innovations in the field of drone and anti-drone technologies have a significant social impact. On the one hand, they contribute to increasing the country's defense capability and ensuring the safety of citizens. On the other hand, they can lead to changes in the labor market, requiring new skills and competencies. Studying how society perceives new technologies is critical to understanding the processes of their adoption and diffusion.

The worldwide spread of Unmanned Aerial Systems (UAS), both geographically and in areas of application, is leading to significant life changes that require careful study and analysis. These effects are manifested in all corners of the planet where UAVs can reach, as well as in all sorts of aspects of life, including the formation of public opinion and ethical norms, privacy and security issues, and the labor market. The anthropological approach to UAS technology allows us to study not only its technical characteristics but also its perception by society and its impact on social norms, values, behavior, and interaction.

Emergence of new social identities in the Ukrainian urban UAV/C-UAV sector and its national public attitude

Since its spread, UAV technology has had a profound impact on the evolution of society, social behavior, and the ways in which people interact around the world, but in Ukraine this influence has been particularly pronounced. Following the full-scale Russian invasion, this effect materialized into colossal community support with donations through crowdfunding platforms of garage-based UAV labs and artisanal UAV productions, which together have become the dominant stakeholders in the national UAV industry during the war in Ukraine.

A study of public attitudes in Ukraine regarding drones and counter-drone systems, the results of which are presented in the report “Ukrainian urban public

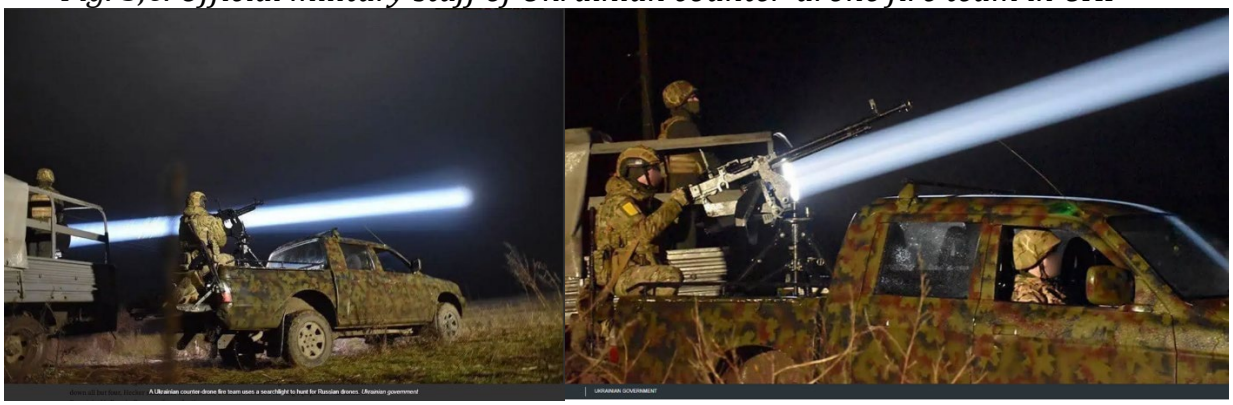
perception of UAVs and counter-drone domains over cities" [32] shows a complex and ambiguous picture. Analyzing the perception of technology by different social groups, such as internally displaced persons (IDPs), youth, and pensioners, allows us to identify key trends and form an understanding of social needs and concerns.

On the one hand, there is an understanding of the need to protect against potential threats associated with the use of drones, especially in the context of military conflict. On the other hand, there are concerns about privacy issues, the possibility of misuse of technology, and its impact on the citizens' daily lives.

Also, the deployment of counter-drone domes over Ukrainian cities may provoke negative social consequences among other broader categories of the public. The uneven provision of C-UxS techs may increase social inequality and create a sense of insecurity in some areas, as is already the case with the unequal provision of air defense over the capital of Ukraine and other cities. For instance, the constant feeling of surveillance and threat from the sky can have a negative impact on the psychological well-being of citizens, especially in areas with a high concentration of counter-drone units. At the same time, the deployment of counter-drone domes over cities inevitably leads to the formation of new social identities, such as:

- the identity of *C-UxS protected citizens* with new sense of safety and security, but also a fear of excessive surveillance and restrictions on their actions,
- the identity of *C-UxS "Guardian Heroes"* - official military staff of counter-drone complexes and volunteers who protect cities from enemy drone attacks [32].

Fig. 5,6. Official military staff of Ukrainian counter-drone fire team in UAF



In the Ukrainian context, the role of crowdfunding and media as non-traditional but effective tools to support the innovative ecosystem of drone and anti-drone technologies is also important. As experience in Ukraine shows, raising funds from the general public through media coverage by crowdfunding platforms ensures innovation not only for new projects and startups but also supports the innovative development of an entire industry of advanced technologies that are key to maintaining the state's defense capability in the face of existential challenges. This is especially true in the context of limited public funding and the need to respond quickly to the urgent needs of the frontline.

The formation of an innovation ecosystem should take into account these social aspects and be aimed at creating not only technological but also socio-economic benefits. So, this section describes the methodology and process of the empirical

research conducted to analyze the social grounds for the formation of the innovative UAV ecosystem in Ukraine and its phenomenon.

1.2 Secondary data analysis on public perceptions of drones

Existing scientific papers, analytical reports, statistics, media materials, and other relevant sources were analyzed to obtain an ambiguous public attitude to the use of drone and counter-drone technologies, which is largely determined by the context of their use. Public attitudes towards the dangers of drone use have been studied on the basis of the following research papers:

- Advanced Technologies in the War in Ukraine: Risks for Democracy and Human Rights [59] The report highlights the potential risks associated with the uncontrolled use of advanced technologies in military conflicts, including threats to democracy and human rights. Particular attention should be paid to the collection and processing of data obtained through drones and anti-drone systems, as well as the potential use of such data for mass surveillance. Establishing clear ethical principles and legal norms governing the development and use of these technologies is a key task to ensure their responsible and humane use.
- *Drone delivery: Factors affecting the public's attitude and intention to adopt (Wonsang Yoo, Eun Yu, Jaemin Jung)* [60]*:* The results of this study show that despite the potential benefits of drone delivery (speed, environmental friendliness), there are concerns about privacy, security and performance risks (malfunctions, cargo damage).
- *Public perceptions: Improving the world through mechanical engineering (SURVEY RESULTS 2019)* [61]*:* The survey found that three-quarters of adults support the use of drones for emergency response. However, support for the use of drones for recreation (24%) and online grocery delivery (23%) is much lower. This may indicate a higher level of risk perception in civilian drone use compared to emergency use.
- *Public Attitudes about Aerial Drone Activities: Results of a National Survey (Terance D. Miethe, Ph.D., et al.)* [62]*:* This national survey found that the majority of respondents oppose the use of drones to monitor people in their private lives (83%), at work (59%), and in public places (48%). This highlights the significant public concern about the privacy risks associated with the use of drones for surveillance.
- *The Current Opportunities and Challenges in Drone Technology (Mohamed Emimi et al.)* [63]*:* The article discusses current developments in various applications of drones. Among the challenges mentioned is the possibility of extremist elements hijacking drones to further their goals. This points to the risk of drones being used for criminal or terrorist purposes.
- *Societal acceptance of urban drones: A scoping literature review (Ning Wang et al.)* [64]*:* This literature review highlights various aspects of public acceptance of urban drones. Concerns about visual and noise pollution are highlighted, as well as the evolution of the debate from the safety of the drone technology itself to cargo security and data protection.

- *Attitude towards Drone Food Delivery Services-Role of Innovativeness, Perceived Risk, and Green Image (Asish Oommen Mathew et al.)* [65]*:* A study of attitudes towards drone food delivery found that perceived privacy risk has a significant negative impact on consumer attitudes. Other components of perceived risk, such as performance and delivery risk, are also mentioned, although they did not show a significant impact in this study.

According to the analysis of this secondary data, the level of public concern may vary depending on the sociodemographic characteristics of the audience and the specific application of the drone. To understand these factors as deeply as possible and to develop strategies to minimize risks and increase public acceptance of drone technologies, further research is needed, but the existing literature most commonly highlights the following aspects:

- *Safety risks:* The use of drones for criminal or terrorist purposes, as well as the threat of their crashing or malfunctioning.
- *Performance risks:* Concerns about the reliability of drone delivery and the safety of cargo.
- *Threat to privacy:* A key concern raised by the ability of drones to conduct surveillance.
- *Noise and visual pollution:* Particularly relevant for urban environments.

1.3 General public opinion and ethical issues on UAV and counter-drone technologies

Public attitudes toward the use of drones are an important factor influencing their further adoption and regulation. The results of public opinion polls in different countries show that the perception of drones depends on the context of their use. In general, there is more support for the use of drones in cases related to public safety, such as search and rescue operations or disaster monitoring.

At the same time, the use of drones for military purposes, especially for strikes, raises significant ethical debate. Studies show that support for the use of drones for military strikes decreases when the ethical and moral aspects of their use are emphasized [67]. The issue of drone autonomy and the transfer of decision-making authority to drones to hit targets is also a subject of lively debate. There are concerns about the potential for error, lack of human control, and potential consequences for civilians. Understanding public opinion and taking into account ethical considerations is important for the development of responsible and socially acceptable policies on the use of unmanned aircraft systems.

Balance of privacy and security for the use of UAV/C-UAV technologies in urban environments

One of the key social impacts of the widespread use of drones is the growing concern over privacy and security issues. The ability of drones to conduct aerial surveillance, often invisibly, raises legitimate concerns about the possible violation of citizens' right to privacy.

Regulation of the use of drones in the field of surveillance varies considerably from country to country [68]. In some countries, there are legal provisions restricting

the use of drones to collect personal data and requiring consent to video recording of private areas. In other countries, legislation in this area is still under development, which creates legal uncertainty.

In addition to privacy issues, there are also concerns about the safety of drones, especially in urban environments. Risks include the possibility of collisions with manned aircraft, drones crashing due to technical malfunctions or adverse weather conditions, and the possibility of their use for illegal purposes, such as espionage, the delivery of illegal substances, or even terrorist attacks. Ensuring the safe use of drones requires the development and implementation of effective technological solutions (such as geofencing and drone identification systems) and clear regulatory frameworks.

Social and ethnic dimensions of C-UAV defense urban complex deployment

The use of UAVs in the military sector and C-UAV technologies in the civilian ones, especially for urban defense, raises a number of important social and ethical issues. The uncontrolled introduction of these new technologies has the potential to cause disproportionate harm to civilians, violations of international humanitarian law, and ethical dilemmas associated with weapon autonomy.

The problem of distinguishing between military and civilian targets, as well as between friendly and hostile drones, is one of the key issues. In addition, the use of drones for surveillance and data collection may have implications for the right to privacy of citizens.

The deployment of counter-drone systems in urban areas may also raise concerns about potential over-surveillance and restrictions on freedom of action [10]. Addressing these social and ethical issues requires a broad public dialogue, the development of clear legal norms and ethical principles that would regulate the development and use of UAVs and counter-drone technologies.

1.4 Research methodology and procedure

The study was based on a combination of several methodological approaches (qualitative and quantitative methods) to gain a comprehensive understanding of the views of various stakeholders and the current state of the industry, which allowed for an in-depth and comprehensive analysis of the problem under study.

The combination of qualitative and quantitative research methods is an extremely effective approach to obtaining a more complete and detailed understanding of the complex phenomenon that is the urban drone ecosystem. This approach allows not only to measure the scale of the phenomenon but also to understand its underlying causes and consequences.

The usage of qualitative methods is the best way to understand what people really care about the urban UxS and C-UxS ecosystem and what their main motivations are. Open-ended questions and a flexible interview format allow for unexpected answers and new ideas for further research. And the information obtained during qualitative research helps to formulate clear and relevant questions for questionnaires.

In general, the qualitative research allowed us to:

- understand the nuances of how different groups of people perceive drones, and identify implicit needs and problems.
- based on the data obtained, formulate hypotheses that can be tested using quantitative methods.
- based on open-ended questions asked during focus groups, develop tools for quantitative research, such as closed-ended questions for a questionnaire.

The empirical research process included the following steps:

Preparatory stage:

- Detailed definition of the research goal, objectives and hypotheses.
- Development and piloting of research tools: questionnaires, guides for interviews and focus groups, observation protocols.
- Formation of the research sample for each method.
- Obtaining necessary permits (if necessary).

Data collection:

- Distribution of online questionnaires through social networks, e-mail and specialized platforms.
- Conducting in-depth interviews, focus group data, and face-to-face surveys of metro users (Kyiv residents, IDPs, and visitors) near underground stations in the capital of Ukraine on their perception of drones in the urban space.

1.5 Study sample

The study sample was formed taking into account the purpose and objectives of the work and included representatives of various stakeholder groups involved in the drone and anti-drone technology ecosystem in Ukraine. The following approaches were applied for each of the methods used:

- *In-depth interviews:* The sample for the in-depth interviews was purposive and included key informants with significant experience and expertise in the field of drone and anti-drone technologies. The number of interviews conducted was 14, which ensured a sufficient depth of understanding of the issues under study. The list of respondents was formed on the basis of recommendations from industry experts and the results of preliminary analysis of secondary data.
- *Focus group research:* To conduct the focus groups, 3 groups were formed, each of which included 6-8 participants selected based on the criteria of belonging to different social and professional groups with different levels of involvement in the field of drone technologies and different experiences of interaction with them.
- *Street survey:* Face-to-face surveys were conducted during the working week [23-27.12.2024] in different locations of Kyiv near the metro stations, which allowed us to analyze the different perceptions of its 64 users (Kyiv residents, IDPs, and visitors) of drone technologies in the urban space.
- *Online survey:* In addition to the street survey, an online survey format was used and a Summary Table of Priority Public Requirements for the Development of Drone Systems and the Implementation of Anti-Drone Protection Systems for Urban Areas in Ukraine was formed.

The sample included representatives of different age groups, professions, and levels of education, which allowed us to obtain comprehensive information about the perception of drones and anti-drone systems. So, potential stakeholders of the UAV and counter-drone technology innovation ecosystem are divided into the following categories:

- the largest segment is the civilian population, which needs protection from potential attacks by military and criminal actors or accidental dangerous drones,
- the public sector, which is responsible for the security of strategic networks of state infrastructure, enterprises and facilities, and, of course, ensuring the safety of the population,
- intelligence services and law enforcement agencies that fight and prevent the activities of organized terrorist and criminal groups,
- corporate capital and the business sector, which needs to protect its investments and preserve fixed and operating capital,
- angel investors, venture capitalists, and developers of advanced technologies in the field of UAVs and counter-drone operations.

1.6 In-depth interview research with RStudio chart results

In-depth interviews are an indispensable research method for understanding complex, multifaceted phenomena such as the innovative ecosystem of urban drone systems and anti-drone complexes. The following authoritative sources describe the in-depth interview method and its application in various fields of research in detail:

- "*Fundamentals of Qualitative Research*" by A. Cowin, K. Christensen. This textbook is a classic guide for researchers who want to master a variety of qualitative methods, including in-depth interviews. The authors describe in detail the process of conducting interviews, analyzing data, and interpreting results.
- "*Qualitative Research Methods in Psychology*" by S. M. Golovin. This textbook pays considerable attention to in-depth interviews as a method of data collection in psychological research. The author provides examples of the application of this method in various fields of psychology and social sciences.
- "*Interpreting Qualitative Data*" by A. Strauss, J. Corbin. This book is one of the most famous manuals on qualitative data analysis. The authors offer a detailed overview of various methods of coding and thematization of data obtained from in-depth interviews.

This method allows to gain a deep understanding of the public perception of drones by different groups, identify key challenges, and formulate recommendations for the development of this industry. The ***advantages of the method*** are:

- *Deep understanding of the context:* In-depth interviews allow the researcher to delve into the personal experiences, views, and motivations of the respondents. This helps to understand how people perceive drones and anti-drone systems in the context of their work, life, and social environment.
- *Identifying nuances and ambiguities:* Because of the open-ended format of the interview, respondents can express their thoughts, feelings, and associations that

may not be apparent using other methods. This helps to reveal nuances and ambiguities that may be important for understanding the problem under study.

- *Generation of new ideas and hypotheses:* In-depth interviews often lead to the emergence of new ideas and hypotheses that may not have been anticipated by the researcher in advance. This allows you to expand the scope of the study and get a more complete picture of the situation.
- *Collecting qualitative data:* In-depth interviews allow you to collect rich and detailed material that can be used for further analysis and interpretation. This material may include descriptions of specific situations, examples, and emotional reactions of respondents.

In-depth interview question guide blocks

The structure of the interviews was based on a developed guide that covered key aspects of the study, including experience with drones, technological, regulatory, social and ethical aspects of their use. An interview guide is a structured document that contains a list of questions and topics to be discussed during the interview. To explore the nexus between drone technology and urban planning, the guide may include the thematic blocks of relevant questions.

Table 3. Thematic framework for in-depth interviews

Thematic blocks	**Types of questions**
Experience with drones	What is your experience with drones? What are the main advantages and disadvantages of using drones in the city?
Technological aspects	What are the most interesting recent developments in the field of drones and AI? What are the technological barriers to wider use of drones?
Regulatory aspects	What are the regulatory requirements for the use of drones in your city? How do you assess the effectiveness of these requirements?
Social and ethical aspects	What are the social and ethical issues related to the use of drones? How can the risks associated with the use of drones be minimized?
The future of drones	How do you see drone technology evolving in the coming years? What new opportunities are opening up through the use of drones in the city?

A series of in-depth interviews were conducted to gain a deeper understanding of the nexus between drone technology and urban planning from the key informants, including representatives of government agencies, private companies developing and manufacturing UAVs and anti-drone systems, security and urban planning experts, and volunteers. The interview guide should be structured, but at the same time allow the respondent to freely express their experience with drones or anti-drone systems, expectations for technology development, regulatory aspects, social and ethical issues, and perceptions of the benefits and risks associated with drones.

Table 4. An example of a questionnaire for drone industry experts

Section 1: Demographics
• Age • Gender • Marital status • Place of residence (city, region) • Level of education

• Occupation
Section 2: General perception • What is the public's attitude towards the use of drones in urban areas? • What fears do people have about drones? • What are the main benefits and challenges of using drones in the city? • How do people see the ideal model of drone regulation?
Section 3: Technological development of the drone industry • What are the trends in the development of the drone industry? • How are AI technologies changing the capabilities and applications of drones? • What are the regulatory barriers to the development of the drone industry? • What are the potential use cases for anti-drone systems? • What are the most promising technological solutions?
Section 4: Challenges of anti-drone systems • What are the advantages and disadvantages of anti-drone systems? • What are the privacy, security, and freedom concerns of anti-drone systems? • How to balance security needs with privacy protection? • How far can the surveillance systems used in counter-drone domes go to protect the privacy of citizens? • How to prevent the use of counter-drone systems for mass surveillance purposes? • What ethical principles should guide the development and use of counter-drone systems? • How to ensure transparency of the algorithms that control anti-drone systems? How to ensure accountability in the use of anti-drone systems? • What accountability mechanisms can be introduced for developers and users of anti-drone systems? • What measures can be taken to reduce the negative impact of anti-drone systems on citizens? • How to ensure that the benefits of new technologies are available to all members of society? • How to reconcile national interests with international security standards

In-depth interviews research

To carefully select respondents with different experience and expertise in the use of drones is critical to conduct in-depth interviews. Thus, the search for participants was organized in the relevant communities and traditionally took 1-2 weeks:

- Social networks (groups of drone pilots, local communities)
- Specialized forums
- Contacts with local authorities
- Snowballing (recommendations from previous respondents)

Most of the participants were represented by both technical specialists and representatives of city administrations, NGOs, etc.:

- aerospace scientists and experts in various fields (UxS, AI, urban planning, security).
- Ukrainian and international drone manufacturers and developers of counter-drone systems.
- potential users of drones (delivery, monitoring, etc.).
- representatives of city administrations and law enforcement agencies.

In-depth interviews with 14 scientists for aerospace study of the Earth and researchers of geological sciences, UAV manufacturers and vendors, drone technology designers and developers were conducted in person or via video. Generally, in-depth interviews lasted from 45 minutes to 1.5 hours and were recorded on a dictaphone, smartphone or video camera. It traditionally took about 2 hours per interview to organize and conduct them (depending on the respondents).

Table 5. List of key informants for in-depth interviews conducted

№	NAME	POSITION	ORGANIZATION
1	Mykhailo Popov	Director	Center for Aerospace Research of the Earth, Institute of Geological Sciences of the National Academy of Science
2	Oleg Loshko	CEO	Unmanned solutions company DEF-C
3	Olexander Shutun	UAV designer	Abris Design Group
4	Andriy Melnykov	Commercial Director	SpartaqS Defense
5	Cameron Chell	President	Canadian-USA-German Drone Concern "DRAGANFLY"
6	Sergiy Grechka	UAV vendor	Kyiv drone production unit
7	Oleksandr Butkalyuk	UAV engineer	Drone StartUp “FOWLER”
8	Yurij Gazhyenko	UAV vendor	Poltava drone production unit
9	Igor Kovba	UAV engineer	Kyiv Drone Dome Project
10	Yaroslav K,	military drone operator	Ukrainian Armed Forces (UAV’s squadron)
11	Ruslan P'yatkovskiy	senior sergeant, commander of the squadron	Ukrainian Armed Forces (deminer's squadron)
12	Yuriy Zozulja	advisor to the mayor of Kyiv on digitalization	Kyiv State City Administration
13	Andriy Zaikin	Founder and CEO	YEP Accelerator
14	Sergiy Skydanov	CEO	Ukrainian-Polish UAV Holding "Abris Design Group"

In-depth interview data analysis (with comparative tab and RSTUDIO graph)

The key informants emphasize the rapid development of technologies, such as artificial intelligence and batteries, which is expanding the capabilities of drones. Also, the experts predict a bright future for drones with potential applications such as urban air mobility, delivery, and environmental monitoring.

Table 6. Comparison of the key informants’ assessment (based on deep interviews quotes and professional experience)

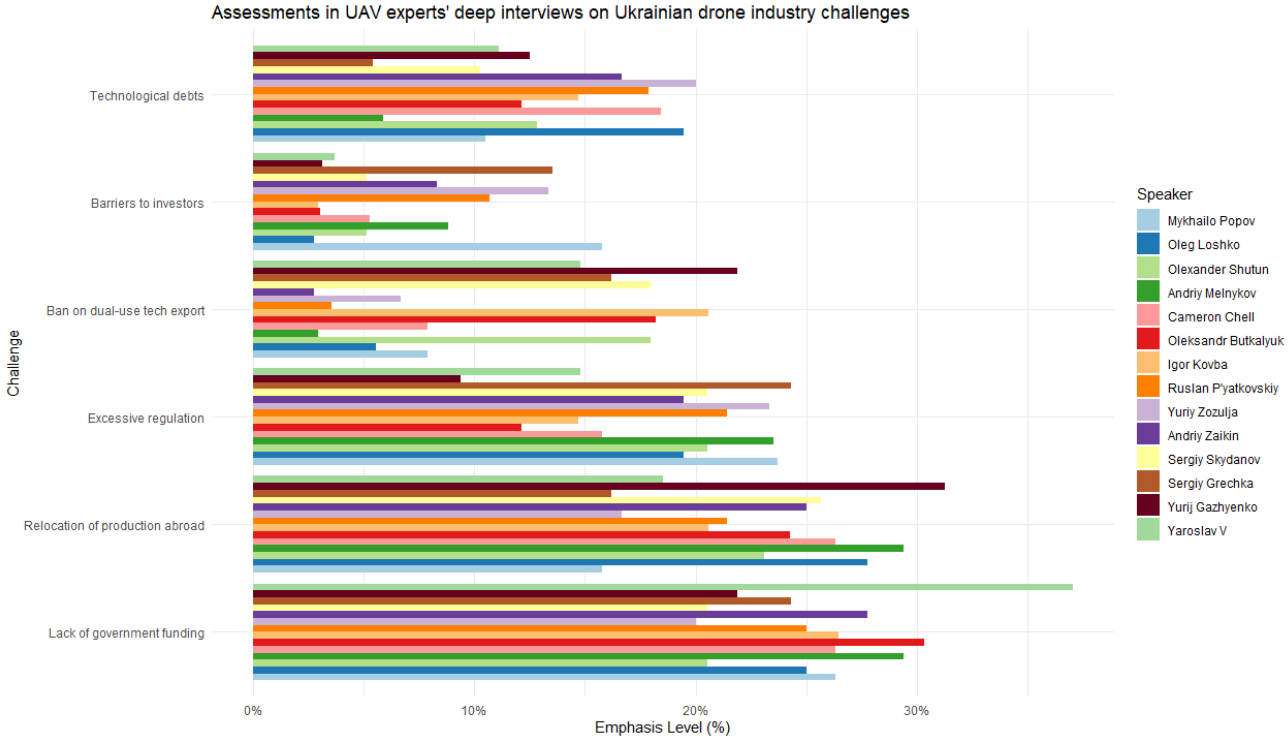
Mykhailo Popov, Director of the Center for Aerospace Research of the Earth:	**Oleg Loshko, CEO of unmanned solutions company DEF-C:**
Experience with drones and regulatory aspects: "As the director of the scientific center for aerospace research of the Earth at the National Academy of Sciences of Ukraine, I work at the main drone industry’s problem right now. It lies, firstly, in the large number of legal gaps that exist in the adopted law, in the process of creating various bodies that are	Experience with drones: “Our company specializes in developing unmanned solutions for various industries. We see great potential in using drones for infrastructure inspection, agriculture, and delivery.” Technological aspects:

currently being formed or have already been formed. The mandatory nature and functionality that this law should carry contain many things that require either revision or even reformatting. And the very concept of 'drones' needs to be introduced into the law, because it is not there. This applies to terminology as well, and how all this will help with algorithmic data transmission. We previously started creating our own Ukrainian standards, and now we have realized that it is much better to harmonize the frequencies that exist in the world with ours. It is impossible to do this one-to-one due to the specifics. Therefore, it is necessary to take European laws and standards and adapt them. Regarding the question of which laws define drone, copter, or UAV, I know that they have dozens of these standards that we use, and they can very significantly help in the formation of our Ukrainian regulatory framework. This is what we are doing, in particular, regarding remote sensing. We are ready to participate in this work."	"One of the most important advances is the development of data transmission systems that allow drones to be controlled over long distances. This opens up new opportunities for using drones in remote areas." Regulatory aspects: "Regulatory requirements for the commercial use of drones need to be balanced. On the one hand, they should ensure safety, and on the other hand, they should not hinder the development of the industry." Social and ethical aspects: "It is important to develop technologies that will be used for the benefit of society. We need to ensure that drones do not threaten people's privacy or create dangerous situations." The future of drones: "The future of military drones is associated with the development of swarm technologies, integration with other weapons, and the creation of autonomous systems. In the civilian sector, drones will become an integral part of our infrastructure. They will deliver parcels, monitor the environment, and assist in rescue operations."
Olexander Shutun, UAV designer at Abris Design Group: Experience with drones: "Our experience with drones and collaboration with G-sector spans over 10 years. We started with small amateur projects and now develop industrial drones for various industries, from agriculture to security. During this time, we have accumulated a large knowledge base about drone construction, software, and applications." Technological and regulatory aspects**:** "Now we are looking for opportunities to develop in the so-called hidden or technological debts that are inherent not only in the drone system but in any ecosystem, such as an underdeveloped technology for transmitting data or energy between drone nodes, its "underdeveloped" software, a weak battery, an incomplete prototype, or financing schemes with interruptions or delays in the supply of components. Typically, an additional 20% capacity can be found by closing these gaps. These hidden debts are even in the legislation. The same VAT makes the production of our drone 20% more expensive than the exact same Chinese or other foreign drone." Social and ethical aspects: The main issues are the potential violation of privacy, the risk of unauthorized surveillance, and the possibility of using drones for criminal purposes." Future of drones: "In the near future, we expect significant development of drone technology. More autonomous, quiet, and long-lasting devices will appear. Drones will be widely used for delivering goods, monitoring infrastructure, and conducting rescue operations. The most interesting achievements are the development of artificial intelligence systems for autonomous drone control, as well as the emergence of new materials	**Andriy Melnykov, Commercial Director of SpartaqS Defense:** Experience with drones: "We are focused on the development of military drones. We have seen how drone technology is developing rapidly and how it is changing the rules of the game on the battlefield." Advantages and disadvantages: "The main advantages of drones in the city are the speed of data collection, accessibility in hard-to-reach places, and the ability to automate routine tasks. However, there are also disadvantages: noise, limited flight duration, and potential safety risks for people. In addition, there is a risk of drones colliding with aircraft or people. Technological aspects: "Artificial intelligence allows drones to make independent decisions in difficult situations. This opens up new possibilities for reconnaissance, targeting, and even independent targeting." Regulatory aspects: "Regulatory requirements for military drones are different from civilian drones. We work in close cooperation with the military to ensure that all necessary standards are met. However, drone development in Ukraine is hampered by a lack of funding, with the budget covering only about a third of the industry's needs, leaving two-thirds of the market simply idle, which means production, salaries, and R&D costs. At the same time, along with simplifying regulatory procedures, the government is introducing mandatory codification of everything related to drones. As a result, Ukrainian manufacturers are moving their production bases abroad" Social and ethical aspects:

that allow creating lighter and stronger drones. These technologies open up new possibilities for using drones in complex conditions."	"The use of drones for military purposes raises serious ethical issues. We are committed to developing technologies that minimize the risk to civilians."

Each of the in-depth interviewed persons presented their point of view on the main UAV industry challenges. All experts were asked to distribute their importance in terms of 100% of this topic. As a result, the top spot in the issues of the Ukrainian drone industry was shared by the limited government funding and relocation of Ukrainian manufacturers abroad. Nearly the same priority problem is considered by the participants of in-depth interviews to be excessive regulation of the drone industry. The ban on the export of drone technology and barriers to investors are of the least concern to the interviewees, while drone industry experts consider the problem of technical debts to be quite urgent.

Fig. 7. UAV experts' point of view on the main industry challenges (bar chart)



Specifics of data-analysis, limitations and time-consuming of the in-depth interview method

The method of in-depth interviews is quite labor-intensive and time-consuming. Its results may be too subjective, as they directly depend on the personal views of the interviewer and the respondent. At the same time, a small number of respondents may limit the ability to generalize the results, which will jeopardize the representativeness of the study itself.

The analysis of the data obtained from transcribing the in-depth interviews required thematization and careful coding (highlighting key themes and categories in the text). On average, it took 3-4 hours to transcribe 1 hour of audio or video into text format (depending on the length of the interview and the speed of transcription). Thus, the timeframe for completion is from a few weeks to a month. This allowed for the

identification of key themes, patterns, and contradictions, while interpretation allowed for the analysis of the data and the formulation of conclusions.

Conclusions:

- Drones have a wide range of applications, from commercial (delivery, inspection) to military.
- The regulatory environment for drones is complex, and experts note the need for clear and consistent rules for safe use.
- Privacy and security are also important considerations, especially with regard to the use of drones for surveillance.

1.7 Focus group research with RStudio chart results

A focus group is a qualitative research method that involves a moderated group discussion to gather information about a particular issue or topic. This method and its application in various fields of research are described in detail in such authoritative sources as:

- "*Focus Groups. A Practical Guide*" by Mary Ann Casey, Richard Krueger: This practical guide contains many examples and tips for conducting focus groups, from developing a discussion guide to analyzing data.
- "*Qualitative Research Design: Choosing Among Five Traditions*" by W.K. Wong. Although this book covers a broader range of qualitative methods, it contains valuable sections on focus groups, including how to compare focus groups with other methods and how to choose the appropriate research design.
- "*Doing Narrative Research*" by Katherine Reeves. Although this book is devoted to narrative research, it contains many useful ideas on how to analyze the stories of focus group participants and build narratives.
- "*The SAGE Handbook of Qualitative Research*" (edited by Norman C. Denzin and Jürgen Lincoln). This multi-volume publication is a comprehensive overview of modern qualitative methods, including focus groups. It contains chapters written by leading experts in the field of qualitative research.

The focus group method allows to identify the common thoughts, feelings and attitudes of a group of people about the phenomenon under study. The ***advantages of the focus group method*** are***:***

- *Idea generation:* Focus group participants can generate new ideas that may be unforeseen by the researcher. This is especially useful for identifying previously unknown aspects of a problem.
- *Deeper understanding:* By observing the group discussion, the researcher can gain a deeper understanding of how people think about drones, what their fears and expectations are.
- *Identify commonalities and differences:* Focus groups can reveal common opinions and differences between different groups of people, which helps to understand how different social groups perceive drones.

- *Study group dynamics:* By observing the interactions of participants, you can understand how social norms and group pressures influence people's opinions about drones.

Limitations of the focus group method

The results may be subjective, depending on the personality of the moderator and participants and group pressure, which may have made some participants afraid to express their opinions different from the majority. Therefore, the results of focus groups cannot be directly generalized to the entire population. To mitigate these risks, we ensured the diversity of participants by demographic and social characteristics, combined the focus group method with other research methods (e.g., questionnaires), conducted training for the moderator and pilot testing with a trial focus group, and adapted, supplemented and improved the initially developed focus group guide.

Focus group question guide blocks and its example

A focus group guide is a structured document that contains a list of topics and questions for discussion. The topics of discussion included the perception of drones as a threat or protection, the need to use technology to counteract, regulation of drone use, ethical aspects, and the impact on privacy. Thus, the guide has to include the questions in the following sections:

- Demographic data with social-demographic characteristics
- Experience and knowledge of drones
- Specialization and responsibility
- Certification and registration

Table 7. An example of a questionnaire for the focus group paticipants

Section 1: Demographic data • Age • Gender • Marital status • Place of residence (city, region) • Level of education • Occupation
Section 2: Experience and knowledge of drones • How often have you used/do you have a drone? • What are the main purposes of using a drone? • Have you encountered any problems while using a drone (e.g., from other people)?
Section 3: Specialization • Have you received appropriate training as a drone operator? • Are you familiar with the liability for illegal drone use?
Section 4: Certification and registration • Has your UAV been certified by the regulatory authorities? • Is it necessary to introduce a drone identification system “friend or foe”? • Do you support the idea of mandatory registration of drones? • Do you support the idea of mandatory flight registration? • Do you support the idea of mandatory registration of crews and routes?

Specifics of conducting focus groups on drones and urban planning, data analysis and combination

To discuss the perception of drones and counter-drone systems, as well as to study their impact on the city and its residents, the participants for the research were selected according to key criteria predetermined by the individuals (e.g., experience in using drones, knowledge of regulation, etc.). So, the focus groups were formed with various participants: city residents, representatives of city authorities, drone experts, business representatives, etc.

The period of focus groups depended on the number of groups and participants, but usually 2-3 weeks were allocated for preparation (development of a guide and search for participants, organization of the venue). The discussions in specially equipped rooms with audio and video recording included 3 focus groups lasting 1-1.5 hours with 6-8 participants.

The same time period was spent on transcription (converting audio recordings into text format), coding (highlighting key themes and categories in the text), and interpretation (analyzing the data and drawing conclusions). The total time required is from one and a half to two months.

The discussions were formed by a professional moderator according to the relevant topics for each target audience: perception of drones as a threat or protection, regulation of drone use, ethical aspects of drone use, impact of drones on privacy, etc.

Focus group data analysis (with comparative tab and RSTUDIO graphs)

To identify the collective opinions, feelings and attitudes of different groups of people about drones and anti-drone systems, the data from the focus groups were analyzed by transcribing the recordings, coding the data and identifying key themes.

Fig. 8. Focus groups' attitude towards the main industry challenges (bar chart)

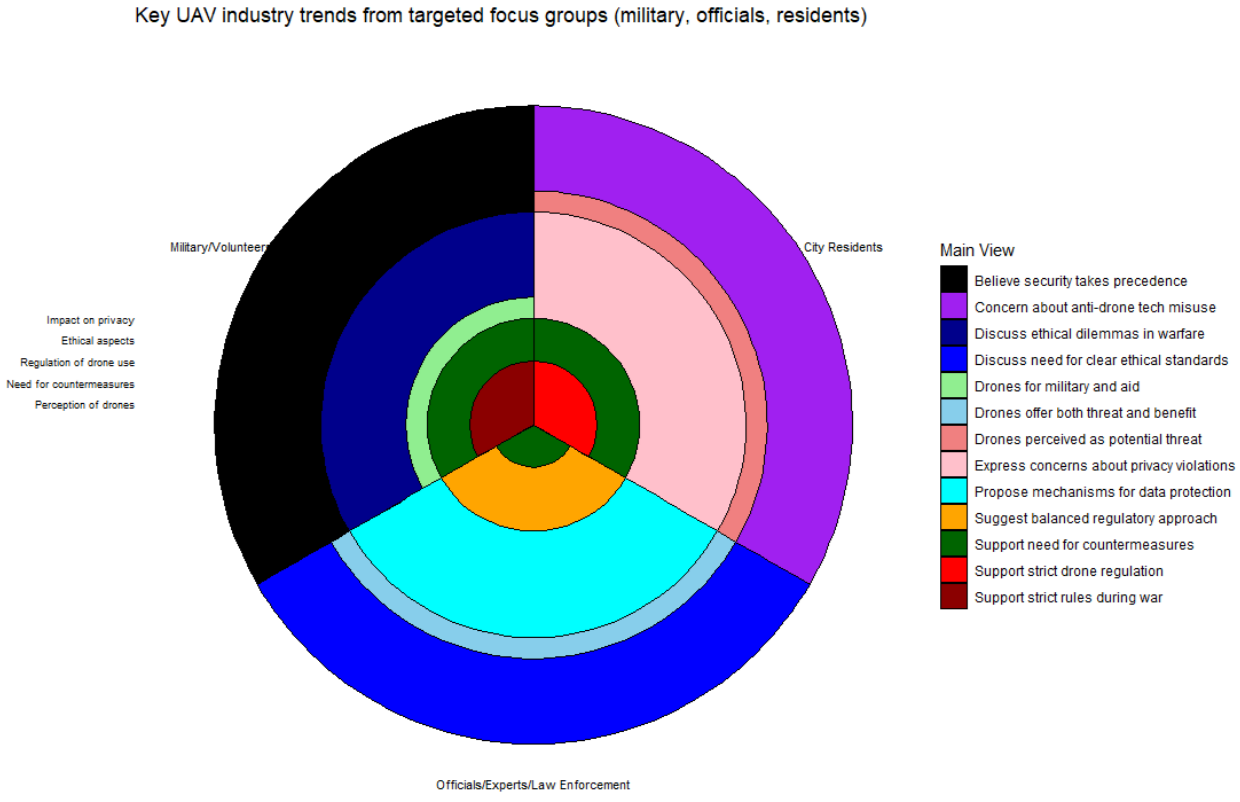


Table 8. Comparison of key trends and assessments from focus group studies

№	FOCUS GROUP 1	FOCUS GROUP 2	FOCUS GROUP 3
Group members ***Topics***	***City residents***	***City officials, UAV experts and law enforcement representatives***	***Military, volunteers and philanthropists***
Perception of drones	The majority of participants perceive drones as a potential threat, especially in times of war. They express concerns about the use of drones for attacks, eavesdropping, and surveillance.	Government and law enforcement representatives emphasize both the potential threat and the benefits of drones (e.g., for situation monitoring, search operations). Experts and businesses emphasize the potential of drones for the development of various areas (logistics, inspection, etc.).	The military emphasizes both the military necessity of drones and the risks of their use by the enemy. Volunteers and charity organizations focus on the humanitarian aspects of drone use (humanitarian aid delivery, evacuation).
Ethical aspects	Concerns have been raised about the possible misuse of anti-drone technology to restrict freedom of speech and surveillance of citizens.	Discusses the need to develop clear ethical standards for the use of drones and countermeasures.	Discusses the ethical dilemmas associated with the use of drones in warfare.
Impact on privacy	Many participants expressed concerns about privacy violations resulting from the use of drones and countermeasures.	Recognizes the problem of privacy violations and proposes the development of mechanisms to protect personal data.	Recognizes the problem of privacy violations, but believe that security takes precedence in times of war.
Need for counter-measures	There is unanimous support for the need to implement countermeasures against hostile drones to ensure city safety.	All participants support the need to implement technologies to counter hostile drones.	There is unanimous support for the need to introduce countermeasures against hostile drones to protect civilians and the military.
Regulation of the use of drones	They support strict regulation of the use of drones, especially in urban areas. They propose to introduce drone registration, restrictions on where drones can be launched, and establish liability for violating the rules.	Support the idea of regulation, but suggest more balanced approaches that would allow for the development of commercial drone use.	They support strict regulation of the use of drones under martial law.

1.8 The questionnaire research with RStudio chart results

The survey method is one of the most common methods of collecting quantitative and qualitative data in the social sciences. It is described in detail in classic scientific works:

- "*Survey Research Methods*" by Floyd J. Fowler: This textbook is one of the most popular English-language textbooks on survey methods. The author examines in detail all aspects of surveys, from questionnaire development to data analysis.

- "*Methods of Sociological Research*" by Y. A. Sherkovin: This textbook is one of the most famous in the Ukrainian language environment. The author discusses in detail various methods of sociological research, including questionnaires.
- "*Fundamentals of Sociological Research*" by R. Holosov: This textbook contains a detailed description of all stages of sociological research, including the development of questionnaires and conducting surveys.
- "*Survey Methods*" by V. Paniotto: This book is devoted to survey methods and is a relevant guide for students and researchers. The author discusses different types of questionnaires, methods of data collection and analysis of results.
- "*Sociological Research*" by V. I. Dotsenko: This book is also a classic of Ukrainian sociology. It contains chapters on questionnaire design, sampling, and sociological data analysis.

The questionnaire method allows to obtain quantitative and qualitative data on the opinions, attitudes, and behavior of different groups of the population regarding the use of drones, and therefore the survey method is indispensable for studying the ecosystem of urban drone and anti-drone complexes, and it has a number of advantages and features. The ***advantages of the method*** are:

- *Standardization* allows to obtain data that can be easily compared and generalized due to the same questions for all respondents.
- *Speed of data collection* with a possibility to interview a large number of people in a relatively short time.
- Respondents often feel more comfortable answering questions *anonymously*, which can lead to more candid responses.
- *Accessibility* due to distributing of questionnaires in a variety of ways: online, offline, by mail, etc.
- *Flexibility* is reaching by using different types of questions and collecting a variety of information.

Specificity of the survey method for the topic

It is important to clearly define the target audience: who to interview (drone pilots, local residents, security experts, etc.). The questions in the questionnaire should be clear, understandable, and relate to specific aspects of the study. The choice of how to distribute the questionnaire depends on the target audience and available resources. Statistical methods can be used to analyze the data obtained. In particular, an indispensable tool for researching people's attitudes and opinions on various aspects of drone use is Likert scales, which provide quantitative data that can be analyzed using statistical methods.

Likert scales

Likert scales are used to compare the attitudes of different groups of people toward drones, such as drone pilots, local residents, and security experts. Likert scales can help identify whether there are relationships between different factors, such as the level of anxiety about drones and the level of knowledge about their use.

A 5- or 7-point scale is commonly used, but Likert scales can be used to measure a wider range of variables.

Table 9. Examples of Likert scales used in surveys on attitudes toward drones:

ASSESSMENT	STATEMENT	LIKERT SCALE
Perceived usefulness	"Drones can be useful for rescue operations"	from 1 to 5, where 1 - strongly disagree, 5 - strongly agree
Anxiety	"I feel anxious when I see a drone flying low over my head"	from 1 to 7, where 1 is strongly disagree and 7 is strongly agree
Attitudes towards regulation	"The government should introduce stricter regulations on the use of drones"	from 1 to 6, where 1 is strongly disagree and 6 is strongly agree

It is easy for respondents to understand how to answer a Likert scale question, but statements should be clear, unambiguous, and free of double negation. The combination of questionnaires with open and closed questions and the use of Likert scales and other research methods (observation, interviews) is an important tool for studying the ecosystem of urban drone and anti-drone complexes and allows for a more detailed picture:

- *Closed-ended question:* On a scale of 1 to 7, how concerned are you about the privacy impact of drone countermeasures?
- *Open question:* What do you think are the most important factors to consider when developing drone regulation policies?

The example of questionnaire structure

Likert scales allow respondents to express their opinions on various statements related to drones, and allow researchers to assess the general mood toward drones in society and how strongly people feel positive or negative about drones. The presence of a neutral item allows respondents to express their uncertainty. Visual aids such as maps and diagrams should be included in the questionnaire design to help respondents understand complex concepts.

Table 10. An example of a questionnaire for local residents

Section 1: Demographic data • Age • Gender • Marital status • Place of residence (city, region) • Financial security level • Occupation
Section 2: Experience and knowledge of drones • Have you ever seen a drone in the sky? • Have you seen drones in your neighborhood? • How do you feel about the use of drones in the city? • Have you or someone you know used drones? If so, for what purposes? • How aware are you of the ban on the use of drones in Ukraine?
Section 3: Attitudes towards counter-drone systems • What risks associated with the use of drones do you consider to be the most pressing? • What measures do you think should be taken to ensure the safe use of drones? • What, in your opinion, are the most effective means of counteracting the illegal use of drones? • How do you feel about the idea of creating counter-drone systems in your city? What advantages and disadvantages do you see in such systems?
Section 4: Attitudes towards privacy threats • Do you think that such systems can threaten your privacy?

- Do you think counter-drone systems can affect your sense of security?
- In your opinion, how can the need for security and the protection of privacy be balanced when using counter-drone systems?
- What legislation is needed to regulate the use of drones in the city?
- What other issues related to drones and counter-drone systems do you consider important?

Empirical survey of Kyiv residents, IDPs, and visitors (with RSTUDIO graphs)

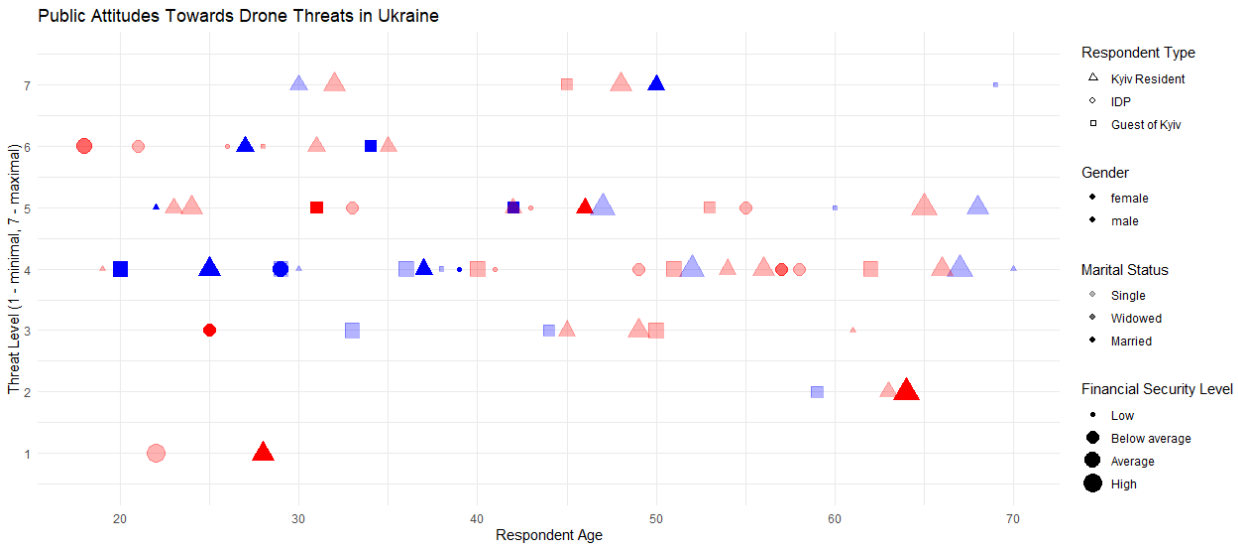
An 8-stages survey, conducted near Kyiv subway stations among respondents from various social backgrounds, revealed a number of general trends and nuances in attitudes toward drones and systems to counter them.

The online version of the survey allowed us to study attitudes not only in the capital of Ukraine, but also in other regions, which ensured a more representative sample of the population. At the same time, the online survey was targeted at certain categories of audience by demographic and social characteristics and included more detailed questions, including open-ended questions, rating scales, etc. Thus, as a result of the combined survey of public opinion, 64 fully completed questionnaires from residents of different cities of Ukraine were selected from the total volume of all received questionnaires for the specified period.

Key findings:

- *Security is a priority:* For the majority of Kyiv residents, security is a top priority, and they are ready to support any measures aimed at ensuring it.
- *The need for information:* It is important to conduct information campaigns to explain how anti-drone systems work and dispel myths.
- *Balance between security and privacy:* When designing and implementing anti-drone systems, it is necessary to take into account the need to maintain a balance between ensuring security and protecting the privacy of citizens.

Fig. 10. The level of public support for the development of C-UxS technologies (bar chart)



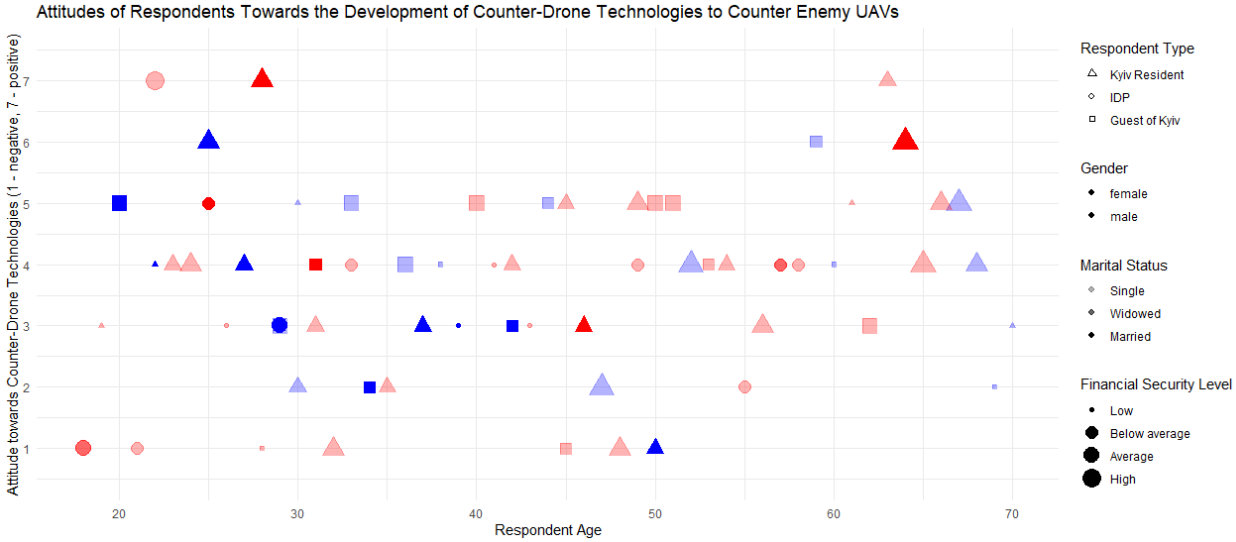
The graphs plotted in the RStudio application display the attitude of respondents of different ages and various sociodemographic characteristics towards the drone threats in Ukraine and the development of C-UxS technologies to counter enemy UAVs. The age of the respondents is placed on the horizontal axis (x-axis), and their attitude towards counter-drone technologies (from 1 - negative to 7 - positive) is on the vertical axis (y-axis).

The type of respondent is displayed by the shape of the points: triangles denote Kyiv residents, circles - internally displaced persons (IDPs), and squares - guests of Kyiv. The gender of the respondents is encoded by the color of the points: blue corresponds to males, and red corresponds to females. The marital status of the respondents is encoded by the transparency of the points: fully colored - "married", semi-transparent - widowed, and faintly - single individuals. The financial security level of the respondents is shown by the size of the points.

In general, the graph № 1 clearly demonstrates the absence of representatives among the Ukrainian public who are absolutely unafraid of drones or indifferent to this threat. All interviewed persons indicated a threat level equal to or higher than 1. At the same time, the majority of respondents' opinions were concentrated in the upper part of the graph between levels 4 and 6—in the area of high anxiety.

Simultaneously, the same survey participants who fear drone threats responded affirmatively to the question about their support for the development of C-UxS technologies. Most of their opinions were also concentrated in the upper area of the graph № 2, but one level lower (between levels 3-5). Also, the graph № 2 clearly demonstrates that there are no representatives among the Ukrainian public who absolutely do not support the development of C-UxS technologies to deter drone threats. The distribution of respondents by place of residence and sociodemographic characteristics is uniform.

Fig. 10. The level of public support for the development of C-UxS technologies (bar chart)



General trends

- *Perception of drones as a threat:* The majority of respondents perceive drones mainly as a threat associated with war and potential attacks. This view is especially typical for internally displaced persons, mothers of schoolchildren, and pensioners who are directly affected by the consequences of hostilities.
- *Support for anti-drone systems:* The vast majority of respondents support the idea of creating anti-drone systems in Kyiv. This position is driven by the desire to ensure security and protect the city from possible attacks.
- *Concern for safety:* The main motive for supporting anti-drone systems is the desire to ensure the safety of themselves and their loved ones. This issue is especially acute for mothers of schoolchildren and pensioners.
- *Distrust of technology:* Some respondents expressed concerns about possible malfunctions of anti-drone systems or their use for surveillance. These fears are more common among young people and people with higher incomes who are more aware of modern technology.
- *Financial support:* Civic funding of drone manufacturers through support of government programs and donations through crowdfunding platforms such as:
  - Come Back Alive,
  - Serhiy Prytula's foundation,
  - Serhiy Sternenko's RUSORIZ project and
  - Marija Berlinska's initiative AeroRozvidka

  are crucial for the functioning and development of C-UxS technologies to counter Russian hostile drones, as well as personal donations from concerned Ukrainian citizens for artisanal drone production and innovative UxS-design laboratories.

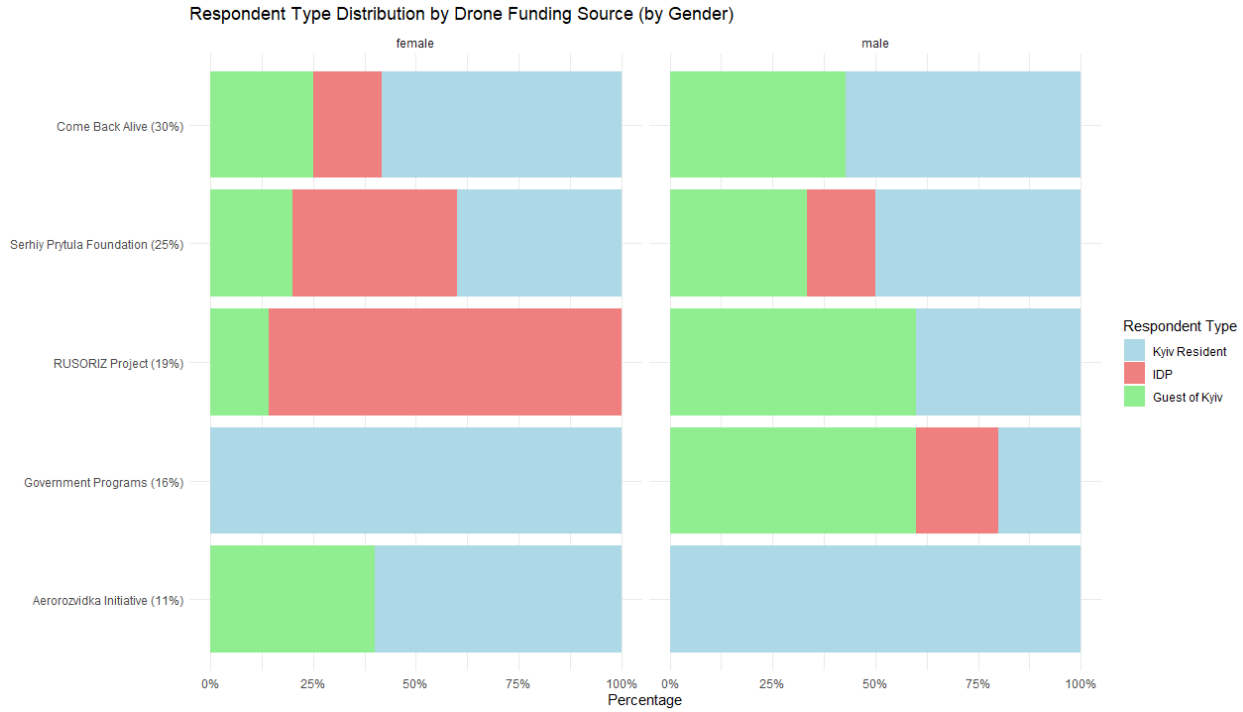
Fig. 11. The level of public support for drone production through donations via government programs and crowdfunding platforms (bar chart)

The overall level of support for drone production by donors through crowdfunding platforms (up to 85%) is 6 times higher than the level of support for government programs (up to 15%). The results of street surveys on funding support for government programs are indicative of Kyiv female residents, while Maria Berlinska's "Air Intelligence" initiative is funded exclusively by male citizens of the capital. This can be clearly seen in the graph №4, which is a horizontal bar graph visualization of the distribution of respondent types by residence and gender across the various drone funding platforms.

The diagram is divided into two columns by gender, and each horizontal row on the graph corresponds to a separate donation platform (with the name of the platform and the total percentage of donor support) and consists of colored segments that reflect the share of different types of respondents (Kyiv residents - blue, IDPs - pink, guests of Kyiv - green).

The total length of each row is 100%, and the length of each segment is proportional to the percentage of donor respondents of a particular gender and place of residence.

Fig. 12. Distribution of donor respondent types by residence and gender across different drone funding platforms (bar chart)



In general, the survey results show a high level of support for initiatives to develop counter-drone systems. However, it is important to take into account the different views and concerns of different social groups.

Attitudinal differences towards drones by social group in the survey:

- *Kyiv Residents and Internally Displaced Persons (IDPs):* They feel the threat of drones most acutely, as many of them have experienced shelling in their homeland. They are the most grateful for any measures aimed at ensuring security.

- *Women and married people:* They are concerned about the safety of their children and are ready to support any initiatives aimed at protecting the city.
- *Men and pensioners:* Both express being more critical of new technologies and express concern about safety.
- *Young people and people with high incomes:* They support the idea of creating counter-drone systems but are concerned about possible privacy violations.

Table 11. Comparison of motives in support of C-UxS development (by respondents' quotes, age, geographic and socio-demographics)

Respondent from the 1st stage of the survey: • Age: 33 years old • Gender: Female • Marital Status: Single • Place of residence [City where you moved to]: Kyiv [IDP from Kherson] • Financial Security Level: Below average • Occupation: Marketer *Q:* ***What risks associated with the use of drones do you consider to be the most relevant?*** *A: I know they can be used to correct artillery fire, but my biggest fear is that they can drop munitions on residential buildings or people, as I have seen repeatedly in Kherson. I frankly consider all our air defense personnel to be our saints and every time there is enough budget, I support our drone makers through the Prytula crowdfunding platform.*	**Respondent from the 2nd stage of the survey:** • Age: 59 years old • Gender: Male • Marital Status: Single • Place of residence: Dnipro • Financial Security Level: Below average • Profession: Truck driver *Q:* ***Have you ever seen a drone in the sky?*** *A: Yes, I have seen it more than once(laugh). Especially when I'm sitting in my car under the bridge during air raid alerts. But I saw them not only in the sky. Some guys I know have a small drone lab in our garage. There they disassemble enemy UAVs and make our Ukrainian ones. The state does not help them, so I give the guys 1000-2000 hryvnias whenever I can earn them. But I give it directly to them, because I don't trust any foundations or government officials.*
Respondent from the 3d stage of the survey: • Age: 40 years old • Gender: Female • Marital Status: Married • Place of residence: Irpin • Financial Security Level: Average • Occupation: Police officer *Q:* ***How do you feel about the idea of creating systems to counter drones in your city?*** *A: Very positively. Our unit has drones that we use for patrolling and reconnaissance. This is very necessary for security. It is protection from air attacks, from subversive groups and terrorist acts, and it helps in search operations. But it is also very expensive and has a risk of errors. We are now saving our family money to invest in the government's project to build an counter-drone wall along the entire 1,500-kilometer front line. I personally attended one of the hackathons where this project was presented by our ministers and the Kvertus UAV company.*	**Respondent from the 4th stage of the survey:** • Age: 47 years old • Gender: Male • Marital Status: Single • Place of residence: Kyiv • Financial Security Level: High • Profession: Programmer at a startup *Q:* ***What measures do you think should be taken to ensure the safe use of drones?*** *A: I myself have launched a small drone several times, which I bought for a hobby. And with a full-scale one, I often see these drones, especially near the airport. Therefore, after the war, it is necessary to maintain a strict license for the use of drones, establish geo-zones where it is forbidden to fly, develop a drone identification system and develop technologies that will allow us to distinguish enemy drones from civilian ones.*
Respondent from the 5th stage of the survey: • Age: 52 years old • Gender: Male • Marital Status: Single • Place of residence: Kyiv • Financial Security Level: High • Profession: Accountant	**Respondent from the 6th stage of the survey:** • Age: 61 years old • Gender: Female • Marital Status: Single • Place of residence: Kyiv • Financial Security Level: Low • Occupation: Pensioner, used to work as a teacher

Q: **How do you think it is possible to balance the need for security and privacy protection when using anti-drone systems?** A: *It is important to ensure that the technologies used for protection do not restrict people's rights and freedoms. It is also necessary to develop international cooperation in the field of drone regulation. It is necessary to hold broad public discussions, involve experts from various fields, develop clear rules for the use of anti-drone systems, and ensure transparency of their work.*	*Q: **Do you think anti-drone systems can affect your sense of security?*** *A: On the one hand, yes, because I will know that the city is protected. But how much does it cost? It's expensive. These drones make a lot of noise - I was scared several times when I saw them walking in the park. And I will be constantly worried that someone is watching me, and someone can simply make a mistake and harm an innocent person. And in general, it's not from God to create such systems with robots or drones*
Respondent from the 7th stage of the survey: • Age: 19 years old • Gender: Female • Marital Status: Single • Place of residence: Kyiv • Financial Security Level: Low • Occupation: Student Q: **What risks associated with the use of drones do you consider to be the most relevant?** *A: They can just fall on someone and kill them. They could be shot down by birds. And they can also be used for illegal surveillance or spying, which is not cool and not safe. I saw a video on social networks with the RUSORIZ logo on it, showing how Russian drones are being destroyed by our UAVs. It's very exciting, and that's why my colleagues and I are donating to the Sternenko Foundation.*	**Respondent from the 8th stage of the survey:** • Age: 31 years old • Gender: Female • Marital Status: Married • Place of residence: Kyiv • Financial Security Level: Average • Occupation: On maternity leave *Q: **How do you feel about the idea of creating anti-drone systems in your city?*** *A: Very positive! This is an additional protection for us. I am most concerned about the safety of my children. I want them to be able to study and play in peace, and not hide in the subway or in shelters every day. That's why we donate to the Come Back Alive Foundation every month, because we know Taras Chmut and trust him since the beginning of the full-scale invasion, as well as Maria Berlinska Foundation AeroRozvidka*

1.9 Integration of research methods and their main differences

Qualitative methods (in-depth interviews and expert focus groups conducted during numerous international thematic web sessions on the topic of drones as part of the “Money Wars” media project) allowed to delve into the minds of respondents, understand their views, feelings, and motivations, and get a more complete picture of the phenomenon under study, taking into account both individual characteristics and general trends. Thus, qualitative methods help to formulate hypotheses that can then be tested using quantitative methods to confirm or refute the results of qualitative research.

It is important to integrate the results of in-depth interviews, focus groups, and questionnaires to get a single picture, and therefore, to conduct such a study, skills in both qualitative and quantitative methods are required. However, these methods are quite different and their combining has some risks. To minimize the effect of a “broken phone” and reduce time costs, it is necessary to standardize the data collection procedure, conduct trainings for interviewers, as well as a pilot study. So, the use of triangulation - the verification of the results obtained through several methods of data collection with testing interviews to refine the guide and identifying possible problems - helps reduce these risks.

Table 12. №6 Advantages and disadvantages of various research methods

FEATURES	Questionnaire	Observation	In-depth interview	Focus group
Format	Structured questionnaire	Direct observation of actions	Unstructured or semi-structured conversation	Group discussion
Purpose	Obtain quantitative and qualitative data on opinions, attitudes	Capture real behavior	Deep understanding of one person's views	Identify commonalities and differences in the group
Advantages	Speed, scalability, standardization	Immediacy, contextuality	Depth, detail	Promotes new ideas through participant interaction
Disadvantages	Possible desired answers, limited open-ended questions	Observer subjectivity, limited data	Dependence on respondents' answers	Possible influence of dominant participants on the discussion

In addition, a combined study requires more time and resources, but this approach will provide more complete and reliable information about the ecosystem of urban UxS and C-UxS complexes, which is necessary to develop effective strategies for managing this modern phenomenon and its challenges.

Also, the use of quantitative and qualitative methods is required for a deeper understanding of key actors' perceptions and interests (developers, urban planners, authorities, politicians) and their interactions with other stakeholders and interested parties. In general, deep interviews with key stakeholders, focus groups with different segments of the population, and observation methods allowed to develop the recommendations for minimizing negative social consequences, overcoming barriers, and finding development opportunities for improving urban space safety.

General conclusions:

- The need for balance: Participants in all focus groups emphasized the need to strike a balance between ensuring security and protecting the rights and freedoms of citizens.
- Comprehensive approach: Effective regulation of the use of drones requires a comprehensive approach that includes both technical solutions and legal provisions.
- Importance of public awareness: There is a need to educate the public about counter-drone technologies and their impact on people's lives.
- International cooperation: Close international cooperation is needed to effectively counter the threats posed by the use of drones.

It is important to understand that people's attitudes towards technologies, including UAVs and C-UAVs, are shaped by their memory of events and processes in the sector, as well as their personal experience with drones. Therefore, to find the real roots of public perception, it is necessary to investigate the historical background of the industry and analyze secondary data, as well as relevant personal observations.

Thus, *Chapter 1, "Anthropological Research,"* lays the foundation for in-depth research on the basis of public perceptions of drone and anti-drone technologies and the industry in general. It reveals the key anthropological aspects of the study and

focuses on the social needs of the community, creating the necessary basis for further analyzing the historical background in *Chapter 2, "Analysis of the Ukrainian context"* and reviewing existing solutions with a comparison of their technical and economic characteristics in *Chapter 3 "Overview of existing UxS/C-UxS solutions"* , as well as designing comprehensive counter-drone urban defense in *Chapter 4 "Ukrainian UxS/C-UxS solutions for South Korea urban defense and case study "Odessa-Inchon""* and modeling an effective innovation ecosystem of drone and anti-drone technologies in *Chapter 5 "Key economic theories, models of markets and UxS and C-UxS innovative ecosystems".*

CHAPTER 2. ANALYSIS OF THE UKRAINIAN CONTEXT

Ukraine today is a unique case in the development of UxS and C-UxS technologies. The war has become a powerful catalyst for innovation and rapid growth in this industry. An analysis of the Ukrainian context allows us to identify not only current trends in this process, its achievements and key features, challenges, and potential for further development, but also the historical background and role of Ukrainian UAV developers at the beginning of the last century in the establishment of a global system of UxS and C-UxS technologies.

2.1 Ukrainian forebears of the global UAV and C-UAV industry: inventors of the world's first unmanned helicopter and optical radar with anti-reflective lens coating

The modern drone industry owes its start to a Ukrainian by birth Georgy Botezat, who graduated from two institutes, in Kharkov and Belge (Belgium) and was a professor at the Petrograd Technological Institute in the Soviet Union. He first designed, built and successfully tested in 1922 an unmanned helicopter with four propellers (quadcopter), equipped with only one engine transmitting rotation to four propellers [71].

It was an aerodynamically symmetrical, able to move equally well either side forward, flying machine with vertical takeoff and landing. However, due to instability in the air, low speed and difficulty in control, multirotors were superseded by simpler and faster carrier-wing airplanes. After Botezat's project, the idea of the quadcopter was forgotten almost until the end of the century.

In 1935, another prominent Ukrainian scientist, Oleksandr Smakula, [72] invented a way to improve optical devices, the so-called “optical enlightenment” (German patent number 6885767), thanks to the discovery of a unique compound, thallium bromide, which reduces light reflection from the lens surface and increases image contrast. In 1951, Smakula was invited to become a professor at the best technical research institution in America, the Massachusetts Institute of Technology, where he later founded and headed the Laboratory of Crystal Physics.

After the publication in 1962 of his 500-page monograph "Single Crystals: Growth, Fabrication, and Application, Alexander Smakula was elected a full professor at the world's most prominent institute of technology. He is still the only Ukrainian with such a distinguished status and whose invention has been used to date in cameras, microscopes, telescopes, night vision devices, and military radars, including for air defense.

2.2 Russian military invasions of Ukraine and Georgia as a catalyst for the formation of a drone ecosystem

The current global “era of drones” in military conflicts began with the so-called War of the Three Eights (“08.08.2008”), which itself was the culmination of the Russian-Georgian drone confrontation, both in the air over Georgia and on the world arms market [77].

By the start of hostilities on August 8th, 2008, Israel had sold Georgia 40 drones from the private defense contractor Elbit Systems [73]. The breakaway authorities of

unrecognized Abkhazia recorded several times the flight of Georgian Hermes-450 drones over the separatist territory. One of them was attacked by the Russian fighter jet, shooting it down with a missile on April 20, 2008. Two days before the war began, the Georgian Minister for Reintegration and later Georgia's Ambassador to the United States, Temur Yakobashvili, said that Israel had terminated arms deals with Georgia and publicly made it clear that it would consider selling modern equipment to Russia.

As a special correspondent of Ukraine's "5th TV Channel" on the war in Georgia in August 2008, I personally recorded these facts during interviews with Georgian officials in Tbilisi, as well as Chechen, Dagestani, and South Ossetian servicemen of the 58th Combined Arms Army of the North Caucasus Military District of the Armed Forces of the Russian Federation, stationed in the city of Gori (80 km from Tbilisi) for the upcoming attempt to blockade the capital of Georgia.

These facts were also made public in the Russian and Georgian news reports РИА Новини, ТАСС, Georgian National Television (GNT) and the World media outlets Defense News, Jane's Defence Weekly, Reuters, Agence France-Presse, Global Post.

Particularly, the foreign media outlets published statements by Vladimir Popovkin, then Deputy Minister of Defense of the Russian Federation and head of the procurement department of the Russian Armed Forces, who held senior positions in the space forces of the Russian Armed Forces. He claimed that the drones used by the Russian armed forces during the war in Georgia were outdated domestic models Pchela, Shmel and Strizh developed in the 70s and 80s [76], and several of them had been lost. "*Moreover, even the most modern Russian-designed drone in the air at the time "demonstrated many problems, among them a pronounced acoustic signature audible at a great distance, which, combined with its low flight ceiling, made it highly vulnerable to ground fire*," Vladimir Popovkin admitted.

In turn, according to Georgian and foreign media, the failure of Russian drone technology in the war with Georgia was caused not only by its technological obsolescence, but also by systemic problems in the management of specialized subdivisions of the Russian Armed Forces.

"*To begin with, Russia's drones were late to the battlefield as Russian Defense Minister Anatoly Serdyukov initially forgot to sign an order authorizing their use. Unable to gain real-time intelligence on the ground, the Russian top brass sent fighter jets and long-range bombers on reconnaissance and close air support missions before Georgia's air defenses were neutralized, leaving them vulnerable to being shot down*" – GlobalPost's South Caucasus reporter Nicholas Alan Clayton, senior editor of TV Channel PIK English in the Tbilisi, Georgia [77].

After the failure of drone testing and using in the war in Georgia, Russia was actively catching up with the development of the drone industry and had a well-established UAV production system by the time it invaded Ukrainian Crimea after the Revolution of Dignity in 2013. As soon as the fighting started in eastern Ukraine in 2014, the Kremlin began using drones: Russian-controlled militants used mostly homemade copters to adjust artillery fire on Ukrainian positions, and to ensure the effectiveness of Russian rocket and cannon artillery strikes, as well as Russian military personnel used entire UAV systems developed at defense enterprises with trained army crews.

At the same period, the formation of the space for UAV air traffic over the territory of Ukraine, its organization and management began when drones became available not so much for the military as for mass sale. With the development of the Air Code of Ukraine of 2013, Ukrainian state, corporate, and private actors in the UAV industry are working systematically to implement legislative norms for aircraft certification, flight route registration, and the Rules for the Use of Airspace. And from 2019 to 2022, the European Union funded a €2.5 million joint project, SAFER-U, to implement the European Aviation Safety Agency (EASA) standards into Ukraine's aviation legislation to bring its norms closer to EU law.

However, these systemic events were not the triggers for the formation of the Ukrainian innovation ecosystem of drone and anti-drone technologies in its current form. Also, it was not formed as a result of an organized state strategy to engage key stakeholders: from the private sector (agriculture, geodesy, land management) and the corporate segment (gas and oil pipelines, power grid, infrastructure) to the state authorities (State Aviation Service of Ukraine, State Enterprise UkSATSE, etc). This system began to form as a result of a war, one that preceded the full-scale invasion of Ukraine.

During the first phase of the full-scale war in Ukraine, by 2022, almost every unit of the Russian Armed Forces was equipped with them, and regular UAV units were created in the formations and units of the Russian Ministry of Defense, which are armed with both reconnaissance and attack drones.

In February-March 2022, the air defense systems and electronic warfare assets of both sides were not yet fully deployed, and long-range kamikaze drones demonstrated high efficiency in hitting military and civilian targets. However, neither side was able to achieve air dominance through the use of more technologically sophisticated UAVs, such as the Bayraktar TB2 or Orion.

Small and maneuverable drones, such as FVP drones, are also effective at hitting mobile targets, personnel, and fortifications, but they cannot completely replace artillery with its range and ability to cover entire sectors. In addition, small drones are difficult to use in bad weather. They are also sensitive to both their own and the enemy's electronic warfare systems, especially when it comes to the multi-frequency systems that are in service with the two armies.

Despite the huge amount of video showing the destruction of enemy forces and assets by drones, the most effective function of the massive use of drones remains reconnaissance. It is the reconnaissance functions that UAVs are capable of performing that have multiplied the time from target detection to target destruction and prevent the concentration of a significant amount of forces and assets in one area of the front. And the relatively low cost of drones and the ability to remotely control a whole range of drones that can conduct reconnaissance behind enemy lines allow for the effect of surprise and offensive operations.

To ensure development in the production and use of unmanned systems and robotic systems, the Ukrainian Ministry of Defense has been separating them into a separate branch of the military since the beginning of this year. On June 25, 2024, the Decree of the National Security and Defense Council of Ukraine on the establishment of the Unmanned Systems Forces came into force to accelerate and institutionalize the development of the use of such a high-tech arsenal, as well as to train qualified

personnel, create special positions, and organize units in the field of production and use of unmanned vehicles and the development of unmanned systems.

In addition, the Unmanned Systems Forces of the Armed Forces of Ukraine perform individual combat missions of various levels, which take into account the specifics of these forces to maximize the effectiveness of the use of drones and robotic systems in combat operations.

Also, the Unmanned Systems Forces are establishing comprehensive training for drone operators, introducing innovations and sharing international experience. For this purpose, special training centers and training grounds are being set up to test new developments in this area.

The Commander of the Unmanned Systems Forces, Vadym Sukharevskyi, notes the critical importance of creating a full-fledged doctrine of unmanned systems to accelerate the development of unmanned and robotic systems as a promising type of weapon within the Armed Forces of Ukraine. If properly developed, the Unmanned Systems Forces will qualitatively improve the combat capability of the Ukrainian army in the area of using and countering drones, unlike in Russia, where the use of unmanned systems is not so well institutionalized.

2.3 Development features and potential of the Ukrainian UAV market

The UAV market in Ukraine has come a long way, especially since the Revolution of Dignity, which was followed by the Russian invasion of Ukraine in 2014, and the full-scale war since 2022, which has led to a qualitative and quantitative continuous evolution of Ukrainian drones over three years, from simple reconnaissance Mavic to long-range strike systems [9].

Types of UxS-manufacturers and their product lines

The Ukrainian UAV market is characterized by a large number of active manufacturers at various stages of development. Among them are well-known private companies (TAF drones, DeViRo, WarBirds, BlueBird LLC), newly created startups, and even volunteer initiatives that mass-produce FPV drones [9], [75], [85]. Initiatives are also emerging to produce ground (Shablya M2, Lyut, MOROZ) and maritime drones (MAGURA V5, Sea Baby) [9].

Main areas of application

Currently, the military sector is the main driver of the UAV market in Ukraine. Drones are used for a wide range of tasks: reconnaissance and surveillance, artillery fire adjustment, destruction of enemy manpower and equipment (FPV drones, kamikaze drones, long-range strike drones, maritime drones), logistics and mine clearance. At the same time, the use of drones in civilian sectors of the economy is also growing, in particular in agriculture, infrastructure monitoring and mapping, which indicates the potential of dual-use technologies [79].

Potential for further growth

The potential of the Ukrainian UAV market remains significant. Growing demand from the military, government support through initiatives such as the UAV Army and Brave1, and continued and strong funding from crowdfunding platforms have made existing production capacity in Ukraine sufficient to meet President Zelensky's announced plan to produce 4 million drones for the Ukrainian Armed Forces in 2025 [55].

According to manufacturers' forecasts, up to 3 million UAVs can be produced by more than a dozen large manufacturers with a monthly production volume of 20,000 units, which is a condition for cooperation with the government's BRAVE 1 platform. The remaining one million UAVs can be equivalently produced by about fifty medium-sized manufacturing companies and almost 300 small production facilities. These figures are confirmed by the Minister of Digital Transformation of Ukraine, Deputy Prime Minister Mykhailo Fedorov: currently, more than 500 companies are working on drone production in Ukraine, and more than 240 developments have been codified [78].

2.4 Ukrainian state activity and private initiatives in stimulating the drone industry development

The Ukrainian defense technology market, with a significant share of the UAV segment, is showing rapid growth. According to the Ukrainian Defense tech market report, the UAV market volume in 2023 was about USD 0.4 billion [75]. The projected growth of the military drone market to USD 46.2 billion by 2025 indicates the enormous financial potential of this industry [74].

The development of the drone market is accompanied by significant economic aspects related to the international support, private investments, and government regulation of these technologies. The Ukrainian state plays an important role in creating a favorable environment for UAV innovation. In Ukraine, starting in 2022, the government began to regulate the drone and counter-drone industry much more actively. A number of diverse measures have been taken to both tighten and simplify regulatory procedures, as well as to support R&D in the field of UxS and C-UxS technologies and provide funding through the Drone Coalition and the Ukrainian government programs, such as the "Army of Drones".

Another state initiative “Brave1” and British defense companies, supported by the Kyiv School of Economics, have launched a large-scale public project in the creating a 1300 km long ‘anti-drone wall’ Atlas, which is estimated to cost UAH 5.2 billion. This project illustrates the significant investment required to ensure effective protection against aerial threats [80].

The risk capital of Ukrainian angel investors and international philanthropic foundations played an important role in financing drone innovations in the early stages of development. The activity of these actors in Ukraine has formed a network of investment funds specializing in defense and dual-use technologies, including the UAV and anti-drone systems sector [84].

Thus, the UAV sector is the most dynamic, accounting for a significant portion of private investment and donations for artisanal production and garage tech incubators and accelerators [85]. Thanks to the combination of resources from crowdfunding platforms and production bases of small and medium-sized enterprises (SMEs) the UxS and C-UxS industry has a rapid increase in the number of startups developing and implementing advanced solutions in this area. The association's direct connection to the Ukrainian front line allows it to respond quickly to the current needs of the military and develop effective innovations to counter enemy drone technologies,

keeping the civilian sector and private initiatives as key stakeholders in the Ukrainian drone industry [32].

The contrast between bureaucratized military technology development cycles and Ukraine's agile, results-oriented approach is a vivid illustration of the rapid adaptation, pragmatism, and necessity-driven innovation in the Ukrainian drone sector, as well as the social significance of technological innovation in times of war and the direct impact of developments on human survival and security.

2.5 Technical, economic and red tape barriers to the development of dual-use technologies in Ukraine

The analysis of the Ukrainian context shows a unique combination of rapid development and significant challenges in the field of drone and anti-drone technologies. The pragmatic approach of Ukrainians, where the main criterion is efficiency and speed of implementation rather than excessive engineering, which is often the result of bureaucracy and a desire to avoid responsibility ("cover your ass mindset"), is very important. At the same time, the existing scientific and technical potential and experience offer significant opportunities for the development of dual-use technologies that can benefit both the military and civilian sectors all over the world.

Obviously, the war has become a powerful incentive for innovation, but the development of the Ukrainian UAV sector is also hampered by a number of additional economic challenges, including the limited domestic market due to export restrictions, the insufficient capacity of the Ministry of Defense of Ukraine to fully absorb production volumes, and the risk of a shortage of qualified personnel [75].

To ensure the sustainable and efficient development of the industry, it is also necessary not just to attract investment, and actively cooperate internationally, taking into account the best international practices, but also to further simplify regulatory procedures.

Bureaucratic obstacles

Regulation of the UAV market is an important tool for ensuring the safety of their use and stimulating innovation. Ukraine has adopted a number of regulations aimed at regulating the use of airspace, certification of manufacturers, and registration of drones [26], as well as the abolition of VAT on the import of UAV components. [27]. Also, by Resolution No. 256 of March 24, 2023, the Ukrainian government simplified the rules for qualifying drones for weapons and set a 25% margin for manufacturers. However, less than a year later, on December 20, 2024, the same membership of the Cabinet of Ministers of Ukraine adopted Resolution No. 1450, which introduced mandatory codification of new domestic models of unmanned systems and tactical-level electronic warfare equipment [46]. Since then, no military unit can officially adopt a UAV that has not been codified.

So, despite significant efforts to simplify regulatory procedures for the production and supply of UAVs for military use after the start of the full-scale invasion, national market participants and international partners [86] continue to point to bureaucratic obstacles and an excessive number of approvals, long processing times,

and complexity of permitting procedures that can inhibit innovation and delay the market entry of new and effective solutions. [32].

Insufficient state funding

Although the amount of public and private funding for the drone industry in Ukraine is growing [75], the need for funds for basic and applied research aimed at creating qualitatively new technologies and breakthrough solutions remains significant. A significant portion of financial resources is currently directed to the purchase of off-the-shelf products, which, while important for meeting the immediate needs of the front line, may not contribute enough to the long-term innovative development of the industry. However, in practice, massive cottage industry production of drones is still the main supply channel for the Armed Forces of Ukraine, as government orders cover only a third of the Armed Forces' drone needs.

According to estimates by the Technological Forces of Ukraine [44], which includes more than 30 codified arms manufacturers for the Armed Forces, due to the lack of government contracts, despite the available production capacity, Ukrainian arms manufacturers did not produce above a billion and a half FPV drones, more than 70000 attack drones, above 15 hundreds of long-range drones, and more than 8000 electronic warfare systems. The total unused production capacity of companies in 2024 was approximately 63%. Thus, according to the NBU exchange rate, the amount of foreign exchange earnings that could have come to Ukraine if manufacturers could have used the state's unused capacities to fulfill foreign contracts for allied countries amounted to almost 2 billion UAH.

Attracting foreign investment in R&D, developing mechanisms for public-private and international partnerships in this area, supporting scientific start-ups and creating favorable conditions for the commercialization of scientific developments, along with opening up opportunities for exporting dual-use technologies are key factors in ensuring Ukraine's technological advantage in the long term [85].

"Technical debts"

The rapid growth of Ukraine's unmanned aerial systems (UAS) industry during the active phase of the Russian-Ukrainian war, while demonstrating impressive development and innovative potential, is inevitably accompanied by the accumulation of so-called "technological debts." In the context of this study, this term covers technical solutions adopted under conditions of limited time and resources, which, although effective in responding to the urgent needs of the front, may contain shortcomings that create barriers to further sustainable and high-quality development of the industry. The war has become a catalyst for a technological leap in Ukraine, driven by urgent need, not just the commercial interest of shareholders. This is a significant contrast to traditional military technology development cycles. In times of war, the priority is to deploy solutions quickly, even if it temporarily accumulates technical problems, but ignoring the "technical debt" can only last until a critical moment during the war or end up with the realization of a huge hidden potential, sometimes 20% of the entire ecosystem's capabilities [87].

Ongoing research and practical cooperation with the Massachusetts Institute of Technology, the US Department of Defense, and Silicon Valley investors to identify "technology debts" emphasize the importance of sharing experiences and recognizing innovations born in Ukraine. And the need for Ukraine to develop and produce its own

integrated chips for drones is strategically important to reduce dependence on foreign suppliers and increase not only regional but also global security.

Dependence on foreign components

The rapid scaling up of UAV production during the war often occurred through the use of imported components available on the market without deep localization of production. This dependence creates a number of strategic risks.

Quality and reliability issues

Imported components, especially those purchased in large volumes for rapid production, do not always meet the high quality and reliability standards. This can lead to higher reject rates, reduced efficiency, and shorter UAV service life.

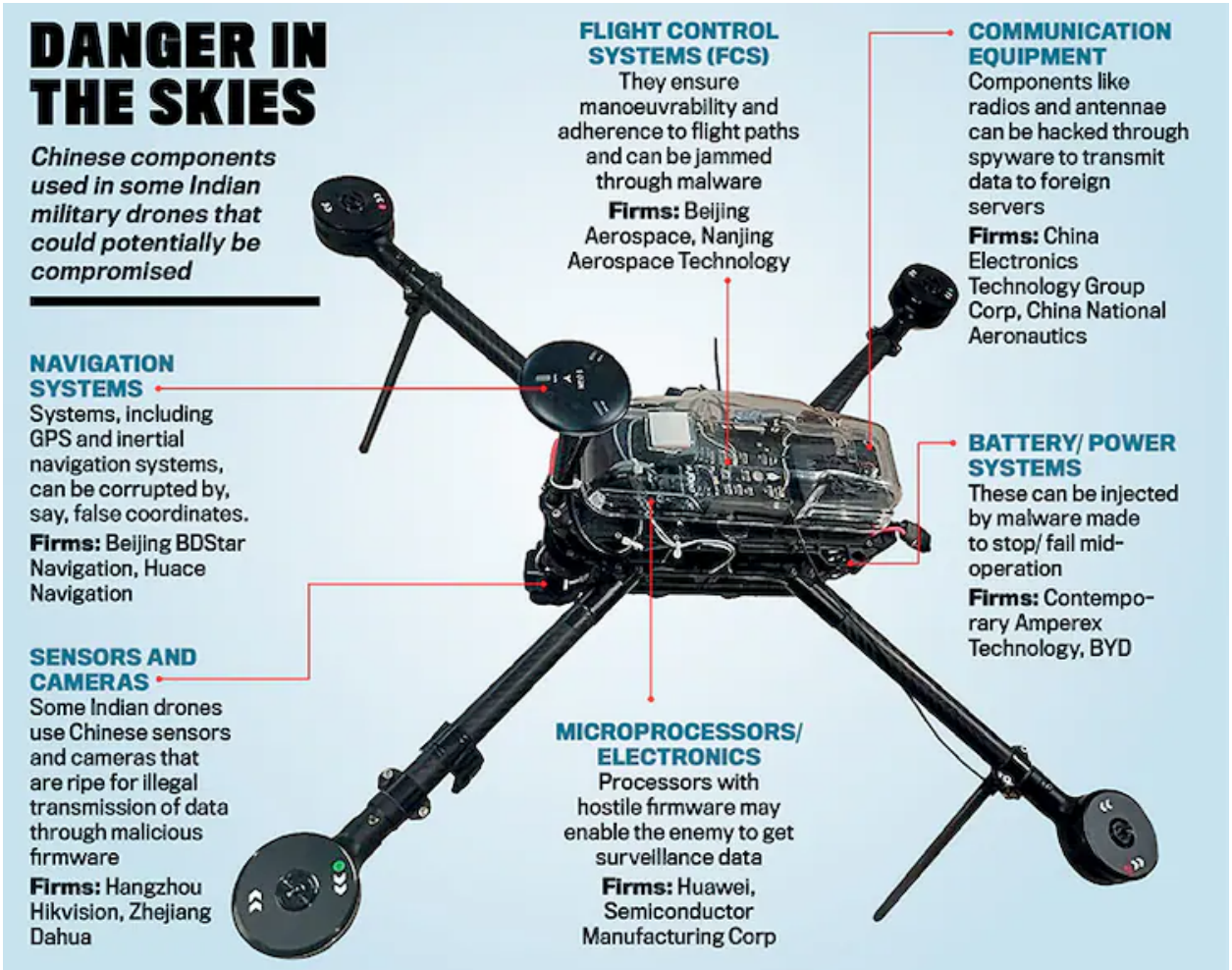
Safety risks

The use of components of unknown origin or from suppliers that may be under the influence of hostile states creates potential threats to the information security and operation of UAVs.

Supply disruptions

Changes in the geopolitical situation, trade wars, or internal decisions by exporting countries (as evidenced by an article about Taiwan's desire to reduce its dependence on Chinese components and information about restrictions on component exports from China) could lead to supply disruptions and production halts.

Fig. 12. Chinese UAV components and their suppliers for Indian market and worldwide



According to the manufacturers, if China's already disloyal stance toward Ukraine worsens and it closes supplies, the Chinese components available in Ukraine (engines, cameras, and control boards) will be enough for about 1.5-2 months or, in quantitative terms, for the production of half a million units.

There is no confirmation of information on the existence of at least one full-cycle UAV production facility in Ukraine using purely Ukrainian components. Currently, Ukrainian manufacturers can produce frames, propellers, and receivers separately on a Chinese basis, but with Ukrainian firmware. As the manufacturers note, Ukraine has the ability to organize the production of 100% of its own components but dependence on the supply of electronic components and other critical materials from abroad, primarily from China (according to the analysis of the Ukrainian Defense tech market report) is the most critical for the Ukrainian drone industry [75].

2.6 Military UAV personnel: total number, salary and assembly skills of the cheapest drones

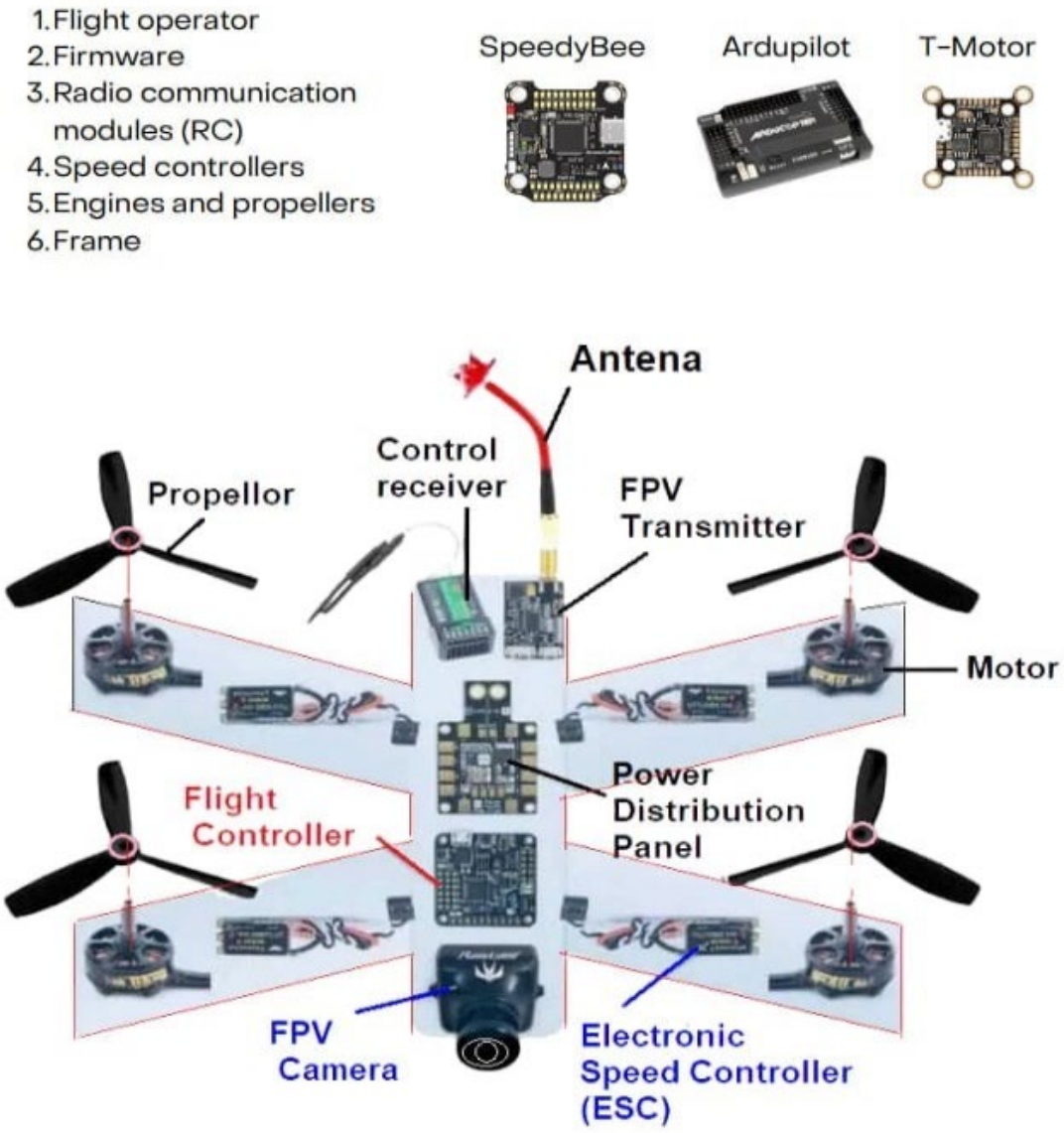
According to the official data of the Ministry of Digital Transformation of Ukraine [11], the number of military personnel serving as drone operators in the Armed Forces of Ukraine is currently around 20,000. The workload of servicemen of the relevant specialization on the front line can reach up to 50 sorties per day per squadron, which traditionally occurs during Russian assault attacks. Also, Ukrainian UAV engineers and developers demonstrate a high level of ingenuity and the ability to quickly adapt existing technologies to solve new problems:

- Non-GPS navigation systems developed for military drones to counter jamming can be used in civilian unmanned vehicles (delivery, agriculture).
- Pattern recognition and data analysis technologies used in reconnaissance drones can be applied to monitor urban infrastructure, agricultural land, or public safety.
- Materials and structural solutions developed to increase the strength and stability of military drones can be used in the production of civilian drones for extreme operating conditions.

The UAV operator's duties include assembling UAVs from components, as there are numerous cases when military units received from the state not ready-made drones, but paralon-wrapped boxes with components: boards, screws, axles, and engines:

- Typical components that make up an FPV drone: 5-inch frame, 4 motors, 4 propellers, 4 in 1 ESC (electronic speed controller), remote control, lithium polymer (LiPo) battery, FPV transmitter (vTx) and receiver (vRx), on-board camera for FPV channel, transmitter (Tx) and receiver (Rx) for radio control, antennas, 2 battery straps, action camera, FPV VR glasses, radio.
- Additional items: Battery charger, battery voltage indicator, soldering iron + solder with rosin, 4-in-1 hex screwdriver, wire cutters, pliers, rubber seating pads, 3rd hand tool, battery stand.

Fig. 13. Typical components of an FPV drone



According to information from UAV assemblers, 5-inch frames are too small to carry a load with a sufficient combat charge, so 7- and 10-inch frames are the most common. Among the batteries, there are high-current LiPo batteries that allow you to fly faster, but their capacity is smaller and the price is too high, so most drones fly on Li-Ion batteries. The most common assembly is 24 volts with a capacity of about 8-9 thousand mAh (6s2p or 6s3p assemblies) with Molycel and Samsung components.

In any way, the minimum cost of a typical set of components for one UAV (excluding the cost of the battery and assembly work) is up to UAH 7,000, which is just over $170. Taking into account the cost of the battery and the work of a volunteer assembler, the cost is 11,300 UAH, a little over $250.

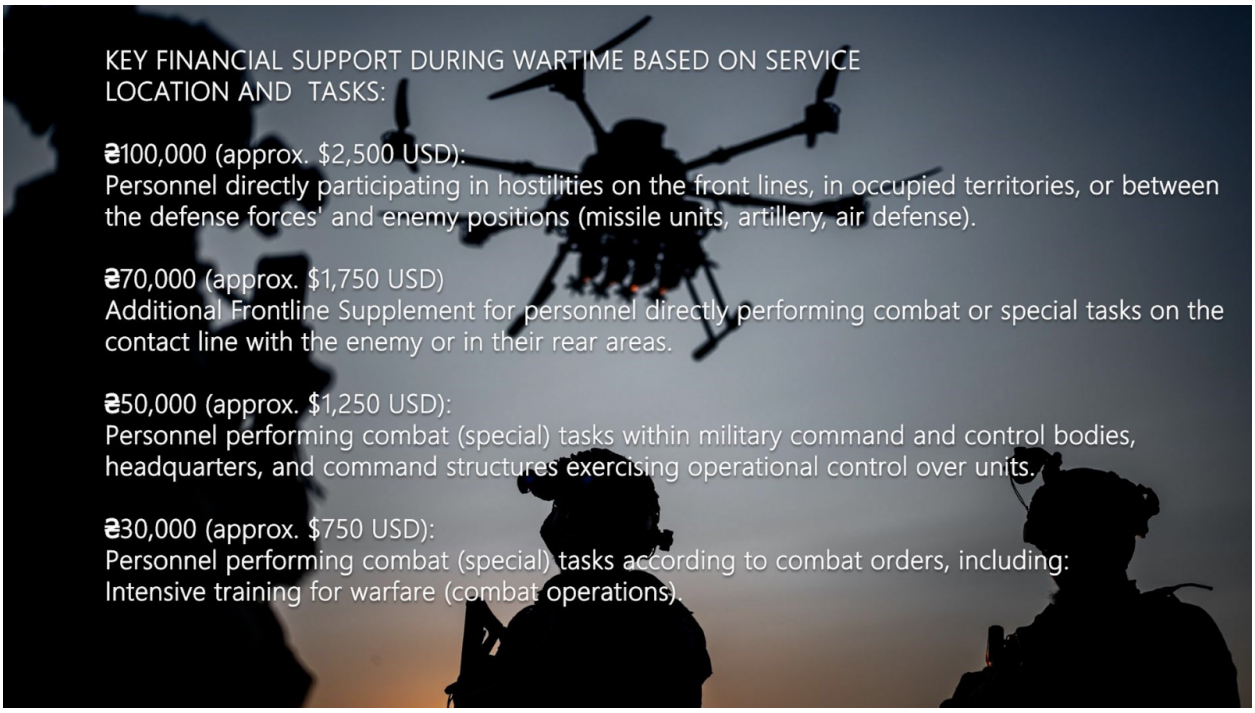
The combat-proven knowledge and skills of the 20,000 UAV operators in the Ukrainian Armed Forces in assembling and operating drones will be needed by the state and private sector to perform a variety of tasks in the military, security and civilian sectors. But this process will require support in the form of financial programs and retraining and job placement assistance, as the average civilian salary is currently

almost six times lower than the working conditions for military drone operators in the Ukrainian Armed Forces.

Thus, the maximum monthly salary of military personnel [51] with the relevant specialization on the front line is currently $1,000 higher than the highest monthly income of an infantryman, who receives 130,000 hryvnias per month (the average is 70,000-100,000 hryvnias). The maximum monthly salary of a drone operator in the Armed Forces of Ukraine is 170,000 hryvnias (the average level is 100,000-130,000 hryvnias). These data were provided by a platoon commander of the Armed Forces of Ukraine (Yaroslav K.), who transports UAV pilots to their place of service.

At the same time, the average length of a working day, or rather a working night, for such an operator is the same eight hours as before. Typically, a night shift starts around 8 p.m. and lasts until about 3 a.m. Transportation takes another hour. In fact, for 21 days of work in the format of an 8-hour work shift, an operator of an Armed Forces drone receives 100,000 hryvnias with an additional combat bonus of 70,000 hryvnias (usually 50% of this amount), which is $1,000 more than an infantryman's monthly salary.

Fig. 14. Salary overview of military UAV operators in the Armed Forces of Ukraine



After the war, the number of available jobs in the civilian sector will be influenced by the overall state of the country's economy and the regulation of the use of drones in the civilian sector. In particular, operators may need additional certification and licensing to work in the civilian sector.

2.7 Potential of Ukrainian military UAV labor force inside the country and abroad

The impact of UAV technology on the labor market is multifaceted. On the one hand, the automation and robotization of certain processes with the help of drones

may lead to a reduction in employment in traditional industries. For example, in agriculture, the use of drones to monitor crops and apply fertilizers can reduce the need for agronomists in the field. In the construction industry, drones help to track assets and construction progress without the need for a large number of workers to be physically present at the site. In the energy sector, drones are used for faster and safer inspections, reducing the risk to workers in hazardous areas [69].

On the other hand, the growing demand for drone technology is also creating new jobs in related industries. There is a need for qualified specialists in the development, production, maintenance, and operation of drones [70]. New professions are emerging related to the analysis of data obtained with the help of drones, the development of software for their management, and the integration of drones into existing business processes. Thus, the impact of drones on the labor market is ambiguous and requires careful analysis to predict future changes and develop retraining and training programs. Realizing the potential of this workforce in Ukraine requires targeted efforts by the state, business, and the scientific community to support dual-use developments for their commercialization, but undoubtedly, this category of dual-use sector personnel will have a wide range of potential opportunities in **the military sector:**

- Continued service in the Armed Forces and a separate branch of the Armed Forces of Ukraine - the Unmanned Systems Forces:

- *Instructors and training staff:* Operators with combat experience can become instructors to train new generations of drone operators, passing on their knowledge and skills.
- *Specialized units:* Maintain and develop unmanned aerial vehicle (UAV) units within the various branches of the military (Army, Air Force, Navy, Special Operations Forces). Operators will be able to hold positions related to reconnaissance, surveillance, fire control, logistics, demining and other applications of drones.
- *UAV repair and maintenance:* Operators with technical skills can be retrained as specialists in drone maintenance, repair and upgrades.
- *Research and development:* Participate in research institutes and design bureaus that develop new types of UAVs and improve existing ones.
- *Anti-drone operators:* Given the importance of defending against hostile UAVs, operators with drone control experience can be deployed to units that use anti-drone systems to detect, identify and neutralize hostile UAVs.

- Other military and law enforcement agencies:

- *National Guard of Ukraine:* The use of drones for public order, border control, and search and rescue operations.
- *State Border Guard Service of Ukraine:* Monitoring of the state border, detection of illegal activities.
- *Security Service of Ukraine (SSU):* Use of drones in counter-intelligence activities, fight against terrorism and organized crime.
- *State Emergency Service (SES):* Search and rescue operations, monitoring of fires and other emergencies, and damage assessment.

as well as favorable conditions for its employment **in the civilian sector:**

- Production and maintenance of drones, educational and scientific activities:

- *Testing and debugging of UAVs:* Work in companies that develop and manufacture drones.
- *Maintenance and repair:* Work in service centers that maintain and repair civilian drones.
- *Teachers and instructors:* Work in training centers, universities, vocational schools to train civilian drone operators.
- *Research:* Participation in projects related to the use of drones in various fields of science.
- *Entertainment:* Film and TV industry, organization of events and activities (sporting events, concerts, festivals).

- Commercial use of drones:

- *Safety and security:* Patrolling large areas, infrastructure facilities, access control.
- *Search and rescue operations (civilian):* Assistance to the SES and other organizations in the search for missing people.
- *Energy:* Inspection of power lines, wind turbines, solar panels, oil and gas pipelines.
- *Construction and infrastructure:* Inspection of bridges, pipelines, construction quality control, photo and video recording of work progress.
- *Environmental monitoring:* Monitoring the state of forests, water bodies, detecting pollution.
- *Agriculture:* Monitoring crops, applying fertilizers and plant protection products, assessing yields.
- *Geodesy and cartography:* Creation of high-precision maps and 3D terrain models, cadastral work.
- *Logistics and delivery:* Delivery of small-sized cargo, medicines, documents to hard-to-reach areas.

Although neither the Ministry of Transport nor the Ministry of Social Policy, as specialized government agencies, provides any information regarding the postwar employment of drone operators in the logistics, delivery and freight sectors, the organization of this process, according to Deputy Minister of Transport Sergey Derkach (off-records), will be entrusted primarily to the Ukrainian state postal operator UKRPOCHTA.

However, the main basic figure in such state support programs will undoubtedly be the largest postal operator Nova Posta, which provided the first domestic flights of cargo drones and launched an extensive network of branches in Ukraine and 17 European countries (under the brand Nova Post). On April 8, both postal operators also launched Ukraine's first inclusive financial banks [83], which will support the employment process for drone operators and veterans inside the country and abroad.

Thus, the rapid technological development taking place in Ukraine during the war opens up significant opportunities for the post-war involvement of the Ukrainian labor forces in the world market for the implementation of their experience of dual-use technologies around the world that can be effective for both military and civilian needs of humanity.

2.8 UAV regulation systems of the leading countries and the need to adapt Ukrainian industry legislation

The development of the world market for unmanned aerial systems (UAS) is accompanied by the active formation of a regulatory framework aimed at ensuring airspace safety, integrating drones into the existing aviation system, and regulating their use in various sectors of the economy and public life. An analysis of the regulatory systems of leading countries in the field of drones is important for identifying best practices, approaches to solving common problems, and determining possible directions for the development of legislation in Ukraine.

Particularly, Israel's experience in countering air threats, stimulating innovation, ensuring security, and integrating drones into the airspace is particularly valuable for Ukraine. The US approaches to supporting the commercialization of military technologies (through DARPA programs) and regulating the civilian use of drones (FAA) may also be interesting to study. European initiatives to create a common regulatory space and develop U-space may provide Ukraine with insights into future trends in this area. China's experience with mass production and export control of drones is also important to consider. South Korea has shown significant interest in developing unmanned systems for various purposes, including defense and urban security.

- ***In the United States,*** the Federal Aviation Administration (FAA) regulates civil and commercial drone operations. The main regulatory document is Part 107 of the Code of Federal Regulations (Part 107), which sets forth the rules for the commercial use of drones weighing less than 55 pounds (about 25 kg). These rules include requirements for drone registration, pilot certification (obtaining a remote pilot certificate), restrictions on flying over people, at night, and beyond the operator's line of sight (under certain conditions and with the appropriate permits). The FAA also regulates the use of drones for recreational purposes by imposing altitude restrictions (no higher than 400 feet in uncontrolled airspace and subject to FAA authorization in controlled airspace), visual line-of-sight requirements, and prohibiting flights in restricted areas (e.g., near airports without authorization). Recently, the FAA has been actively working on the implementation of Remote ID rules for drones, which aims to improve safety and provide the ability to track aircraft in the airspace. Rules are also being developed for more complex operations, such as beyond line-of-sight (BVLOS) flights and drone cargo delivery.
- ***The European Union*** has a unified regulatory framework for civilian drones, established by the European Aviation Safety Agency (EASA) on the basis of EU Regulations 2019/947 and 2020/1058. These regulations introduced the classification of drones according to the level of risk of operations in three categories: Open, Specific and Certified. EASA also develops standards for the integration of drones into urban airspace and for the development of drone services (U-space).
    - *Open category:* Covers low-risk operations that do not require prior approval, but are subject to certain restrictions, such as a maximum flight altitude of 120 meters, flying within the operator's line of sight, and a ban

on flying over crowds (depending on the subcategory). Starting January 1, 2024, operations in the open category must be performed using drones that are marked as C0, C1, C2, C3 or C4, or drones built by yourself (weighing up to 25 kg) or purchased before December 31, 2023 without class markings.

- *Special category:* Includes operations with a medium level of risk that require a preliminary risk assessment and authorization from the national aviation authority.
- *Certified category:* Applies to high-risk operations, such as the transportation of passengers or dangerous goods, and requires certification of the drone and operator to standards comparable to manned aviation.

- ***Israel,*** with its extensive experience in the security sector, pays great attention to regulating the use of drones in both the civilian and military sectors. The general rules for civilian operations include a ban on flying over people and crowds, mandatory line-of-sight, a 50-meter altitude limit, and a ban on flying within 2 kilometers of airports and 250 meters of people or structures. Commercial drone operations in Israel require a license. Since March 2024, drone operators have been allowed to use drones in Israeli airspace, subject to the relevant rules, including keeping a distance of at least 3 kilometers from military bases, airports and strategic facilities, as well as a buffer zone of 30 kilometers from all Israeli borders. The regulation of military use of drones is more closed and is determined by the relevant agencies.
- ***China*** is the world leader in the production of commercial drones, and regulation of this area is important for the government. According to reports, China's Ministry of Industry and Informatization will lift temporary controls on certain consumer-grade drones and prohibit the export of civilian drones not on the export control list for use in proliferation, terrorist activities, or military purposes. It has also been reported that Chinese manufacturers have recently begun to restrict the sale of key drone components to the United States and Europe, and it is expected that in early 2025, Beijing will impose broader export restrictions on drone parts. These measures could have a significant impact on the global supply chain of UAV components, which is an important aspect for Ukraine given its dependence on Chinese components.
- ***Canada*** has a fairly clear drone regulation system established by Transport Canada. All drones weighing between 250 grams and 25 kilograms are subject to mandatory registration. To operate drones, depending on the type of operations (basic or advanced), pilots must obtain a license. A written exam is required to obtain a license, and a practical flight test is required for an extended license. Canadian regulations impose restrictions on flying in controlled airspace, near airports, over people, and at a distance of less than 30 meters from them (for a basic license). An extended license provides more options, subject to additional requirements. In general, the Canadian system emphasizes a clear distinction between the types of operations and the corresponding level of pilot qualifications.

In comparison with the regulatory systems of the US, EU and Canada, ***Ukrainian drone regulation legislation***, especially after the start of the full-scale invasion, has undergone significant changes, but is still in its infancy, and its regulation is subject to completely opposite directions. In order to bring the Ukrainian legislation in line with international standards and stimulate the development of the UAV industry in Ukraine by simplifying and optimizing domestic processes, introducing electronic document management, and increasing the transparency of regulatory requirements, it is important to analyze regulatory systems of different countries. There are different approaches to regulating the UAV sector, each with its own advantages and disadvantages:

- *Classification of drones and operations:* In the EU and Canada, there is a clearer classification of drones by weight, technical characteristics, and risk of operations (open, special, certified in the EU; basic and advanced in Canada). In Ukraine, this classification can be further detailed for different areas of use (military, commercial, recreational).
- *Requirements for pilots:* In international practice, considerable attention is paid to the certification and licensing of drone pilots, including theoretical and practical training. Ukraine is also developing a system of training for UAV operators, but the experience of other countries may be useful for its improvement and standardization.
- *Airspace management:* Integrating drones into existing airspace and ensuring flight safety, especially in urban areas and near critical infrastructure, requires clear rules and procedures. The experience of the US, EU, and Israel in this regard is particularly useful for Ukraine.
- *Countering unauthorized flights:* The development and implementation of effective anti-drone measures based on Israeli practice is an important aspect of regulation.
- *Dependence on foreign components:* Unlike countries with a developed domestic component manufacturing base (e.g. China), Ukraine faces the problem of dependence on imported components. Regulatory policy can be aimed at stimulating the development of domestic component production and reducing dependence on foreign suppliers, as Taiwan is trying to do.
- *Bureaucratic procedures:* Simplification and digitalization of regulatory procedures, as is being implemented in many developed countries, could facilitate faster development and innovation in the drone sector in Ukraine.

As Ukraine actively develops this sector in the context of war, it is important to take into account international experience, adapting best practices to its own needs and context in order to create a favorable and safe environment for further innovative development. Studying their experience in developing counter-drone solutions to protect urban infrastructure, approaches to government regulation, and support for UAV industry labor force, could be useful for Ukraine. Especially in the prospect of social adaptation of tens of thousands of Ukrainian military UAV operators to work in the civilian sector.

2.9 Recommendations for Ukrainian public policy in the UAV sector

To create a favorable environment for the development of an innovation ecosystem of drone and anti-drone technologies in Ukraine, including comprehensive UxS urban defense, a number of policy measures should be taken, including amendments to existing legislation and the adoption of new regulations, such as:

Amend the Air Code of Ukraine:

- *Classification of drones and operations:* Develop and legislate a detailed classification of unmanned aerial vehicles (UAVs) by weight, technical characteristics, purpose (military, commercial, recreational) and risk level of operations, similar to the regulatory framework of the EU (open, special, certified categories) and Canada (basic and extended licenses). This will allow establishing clear requirements for operators and aircraft depending on the type of use.
- *Flight rules in urban areas:* Develop special rules for UAV flights in urban areas, taking into account the high population density and critical infrastructure. The restrictions in force in Israel (prohibition of flights over people, crowds, near airports at a certain distance, height restrictions) can be used as a basis, adapting them to Ukrainian realities. The possibility of defining special flight zones (e.g., for infrastructure monitoring or delivery) should be envisaged, subject to obtaining the appropriate permits.
- *Certification of operators:* Introduce mandatory certification of UAV operators depending on the category of drone and type of operation, including theoretical and practical training, similar to the requirements of the FAA in the US and EASA in the EU. This will increase the level of flight safety and operator responsibility.

Development and adoption of bylaws (resolutions of the Cabinet of Ministers of Ukraine, orders of ministries and agencies):

- *Regulation of the use of anti-drone systems:* Determine the legal status, procedure for the acquisition, registration and use of anti-drone systems of various types (electronic warfare, kinetic means) for different categories of users (government agencies, critical infrastructure enterprises, private individuals). Consider international experience in this area, including Israeli practices.
- *Standardization and certification of domestic UAVs:* Introduce technical standards and certification procedures for Ukrainian-made UAVs, which will improve the quality and reliability of products and facilitate access to international markets. The development of standards should take into account the requirements of EASA and NATO.
- *Regulation of data exchange and privacy protection:* Establish clear rules for the collection, processing, and storage of data obtained by UAVs to protect the right to privacy of citizens, taking into account the European GDPR standards.

Stimulating innovation and investment

- *Introduce targeted state grant programs:* Establish and administer special grant programs through the Ministry of Digital Transformation or the newly created Unmanned Systems Forces to support research and development and innovative projects in the field of drone and anti-drone technologies, similar to the Brave1 program.

Providing tax incentives

- *Consider introducing tax incentives* for enterprises engaged in the development, production and operation of UAVs and anti-drone systems, as well as for investors investing in these areas.
- *Create a State Fund to support the development of drone technologies:* Initiate the creation of a state fund that would accumulate funds from the state budget, as well as from international donors and private investors to finance priority UAV projects. The experience of countries with advanced defense technologies can be used as an analogy.

Development of human resources

- *Support and expand the network of specialized educational programs:* Provide state support to universities and vocational schools that offer UAV educational programs (including the list provided earlier). Encourage the development of new courses and programs that meet market needs.
- *Stimulate cooperation between universities and businesses: Encourage* the conclusion of cooperation agreements between educational institutions and private companies to organize internships, practices, and joint research projects.
- *Introduce state retraining programs for veterans:* Expand initiatives to retrain military personnel with UAV experience for further work in the civilian sector (taking into account relevant news).

Ensuring safety and ethical use

- *Develop and implement a national strategy to counter the unauthorized use of drones:* The strategy should include a set of measures aimed at detecting, identifying and neutralizing hostile or dangerous UAVs, especially in urban areas and near critical infrastructure. Take into account Israel's experience in this area.
- *Define ethical principles for the use of UAVs:* Establish an interagency working group with the participation of ethics, law, and technology experts to develop ethical principles that will govern the use of UAVs in various areas, including privacy and liability for autonomous solutions.
- *Conducting a public awareness campaign:* Organize a broad information campaign to raise public awareness of the risks and benefits of using UAVs, as well as the rules of conduct when detecting drones.

The implementation of these policy recommendations will help create a favorable and effective environment for the development of an innovative ecosystem of drone and anti-drone technologies in Ukraine, which in turn will strengthen national security and promote economic growth.

In addition, effective interaction between the state, private initiative, the non-governmental sector, philanthropic platforms, and angel investors is a key condition for the development of a successful innovative drone technology ecosystem and its integration into the regional economic environment with the prospect of global scaling. It is also important to implement a strategy at the state level to develop Ukraine's own drone manufacturing sector, as well as to create standardized means of countering drones by the following activities:

- *Develop unified standards and guidelines for both the manufacture and use of drones and their countermeasures.* This will help unify the approach to the manufacture of unmanned vehicles, reduce the likelihood of low-quality products reaching the frontline, and establish an effective mechanism for their use.
- *Provide comprehensive support to private initiatives* that are engaged in both the search for new technological solutions for further effective use of drones and the search for new ways to counter Russian drones: development of personal anti-drone weapons, development and modification of ground-based unmanned systems, etc.

The priority is to communicate with Ukraine's partners on the supply of modern air defense and electronic warfare equipment and to implement international projects involving global research institutions and specialized international and global associations to support the Ukrainian unmanned aerial vehicle industry and the sector of countering unmanned threats. It is also necessary to find ways to limit Russia's ability to develop industrial production of unmanned aerial vehicles and obtain components for them through imports. As soon as possible, Ukraine's Western partners, for whom the development of the Russian drone sector also poses potential threats, should focus on actions that will help deprive Russia of access to critical components and strengthen Ukraine's defense capabilities:

- *Establish cooperation with Ukrainian and international research institutions and ensure scientific and technical developments in the field of drone production.* Access to advanced technologies for the production of drones and their means of operation will allow the Ukrainian military-industrial complex to produce high-quality unmanned vehicles and gain a technological advantage over the enemy. This will also result in a mutual exchange of practical information on the success of certain innovations, which can improve further research in this area.
- *Increase the supply of Western components to Ukraine and reduce Ukraine's dependence on Chinese components* and minimize the risks associated with the possibility of low-quality products or delays in delivery.
- It is necessary to conduct ongoing information campaigns to explain to Western politicians that Russia's superiority in the development of unmanned systems will pose more serious threats not only to Ukraine but also to European countries. For example, threats in the Black Sea, especially to Romania and Bulgaria, could potentially increase, and Russia would have inexpensive tools for provocations and reconnaissance in NATO member states. The following steps should be taken:
- *Scale up cooperation with Ukraine within the framework of the Drone Coalition.* This process should be based not only on increasing the supply of Western drones, but also on opening joint ventures for the manufacture, repair, and maintenance of unmanned systems.
- *Increase the supply of fire and electronic warfare equipment against drones.* Given the massive use of drones by the Russian Federation on the contact line and to damage Ukraine's critical infrastructure, additional fire and electronic warfare equipment will significantly increase the Armed Forces' ability to neutralize threats from Russian UAVs.

CHAPTER 3. OVERVIEW OF EXISTING UXS/C-UXS SOLUTIONS

This section is devoted to a comprehensive analysis of existing solutions in the field of drone and anti-drone technologies, covering both the global context and the specifics of the Ukrainian experience. The purpose of this analysis is to identify best practices, existing problems, technological trends, and potential for innovation. Understanding all the aspects of UAVs and counter-drone technologies is a prerequisite for analyzing the innovation ecosystem in this area.

3.1 Advanced Ukrainian and global UAVs specifications and capabilities

The rapid development of technology has led to the emergence of various types of unmanned aerial systems, each with its own unique characteristics, capabilities, and applications. Today, there is a wide range of UAVs that are classified according to various criteria, including size, range, payload, engine type and functional purpose. In the context of the war, the following ***types of advanced Ukrainian drones*** have been particularly recognized in the world [9], [81]:

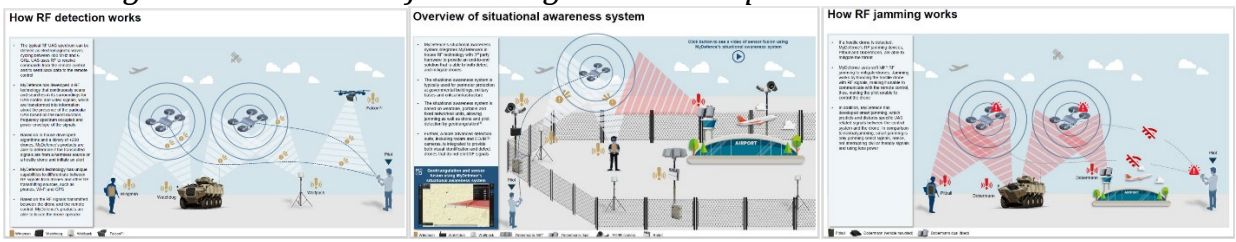
- *Quadcopters (Mavic): Lightweight and maneuverable commercial-grade drones that have become indispensable for tactical reconnaissance and surveillance due to their affordability and high-quality cameras*
- *FPV drones: Fast and highly maneuverable drones with a first-person view, used as strike vehicles to engage enemy manpower and lightly armored vehicles*
- *Bayraktar-type drones: Larger reconnaissance and strike drones such as the TB2 capable of carrying payloads for precision strikes against important enemy targets*
- *Reconnaissance UAVs (Leleka-100): More sophisticated and specialized drones with improved range, airborne time and electronic warfare (EW) protection. The use of Kevlar, glass and carbon fiber ensures their durability and lightness*
- *Long-range strike UAVs (Bober): Loitering, e.g. "kamikaze" drones designed to destroy enemy military targets and infrastructure at a considerable depth of the enemy's territory*
- *Mother drones: The concept of drones capable of transporting and launching smaller FPV drones at a considerable distance from the operator, which increases pilot safety and the range of strike assets*
- *Unmanned Ground Vehicles (UGVs): Unmanned ground vehicles used to perform a variety of tasks, including mine clearance, medical evacuation, and logistical support for troops. Examples include the Shablya M2, Lyut, MOROZ, D-11, ARK-1, and PD15 FOXY*
- *Unmanned Surface Vehicles (USVs): Unmanned surface vehicles, such as MAGURA V5 and Sea Baby, which have demonstrated their effectiveness in the Black Sea for reconnaissance, patrolling, mining, and engaging enemy ships.*

3.2 Principles of C-UAV Technologies and Components of Drone Dome Protective Systems

Counter-drone protective systems are a concept that is being actively developed and implemented around the world. These systems are designed to counter the

growing threat of unmanned aerial vehicles (UAVs) through multi-level protection against unauthorized or hostile drones.

Fig.15-17. Overview of C-UxS algorithms and processes



Typically, an anti-drone dome is an integrated system that includes the following key components [92]:

Detection systems:

- *Radar systems* are among the most popular technologies for the initial detection of aerial objects, including drones, within a certain radius. Short-range radars can provide early detection of drones approaching protected objects. Modern radars can be optimized to detect small and low-flying targets.
- *Radio Frequency (RF) Analyzers* can help identify the type of drone and determine the location of the operator.
- *Optical and infrared (EO/IR) cameras* are used for visual confirmation, target identification, and tracking, especially in difficult weather conditions or at night. These high-resolution cameras are especially effective when combined with thermal imaging technologies (EO/IR systems). Particularly useful in urban environments where direct visibility may be limited by buildings.
- *Acoustic Sensors (Microphones)* can detect the sound of approaching drone engines at close range. Although the effectiveness of this technology may be limited by urban noise, it can be used as an additional means of detection.

Neutralization systems:

- *Radio frequency analysis systems* cannot just identify the drone's model and manufacturer, but *RF Jammers* also can generate powerful radio interference on the frequencies used to control drones, leading to the loss of communication between the operator and the drone and its immobilization.
- *Electronic countermeasures (ECM):* Jamming control channels and navigation signals (e.g. GPS) of drones, which can cause them to hover, return to their launch point or land.
- *Directed energy systems (laser or microwave systems):* Can physically disable drone electronics.
- *Directed Energy Systems (High-Power Electromagnetic - HPEM)* use powerful electromagnetic pulses to disable the electronic components of drones. Its application in urban environments may be limited due to the potential impact on other electronics.
- The use of physical nets fired from special guns(*Net Guns)* or launched by other drones (*Skyhooks)* allows for the safe neutralization of drones by tangling their propellers and immobilizing them. This method can be particularly useful in urban environments where it is necessary to minimize the risk of a drone falling on buildings or people.

- *Interceptor drones* are specially designed and equipped with nets or other means for capturing or physically destroying enemy drones.

Command and control system:

- *Centralized software* that combines data from all sensors, analyses it to classify an object as a drone and determine its threat level, displays information to the operator, and allows decisions to be made about countermeasures.

3.3 Counter-UAV Systems Overview in the World and in Ukraine

Ukrainian and global experience demonstrates the effectiveness of echeloned air defense (AD) systems and specialized counter-drone complexes in ensuring such protection. Protecting military bases, airfields, weapons depots, and other military infrastructure from drone attacks is a priority for Ukraine:

- *US PATRIOT Air Defense System:* This system is capable of intercepting ballistic and cruise missiles, as well as unmanned aerial vehicles, at long ranges.
- *Israeli "Iron Dome" Air Defense System:* Developed to intercept short-range rockets, but can also be used against drones. Israel also has other systems such as "David's Sling" and "Arrow" that provide multi-layered protection against various air threats.
- *Elbit ReDrone™ complexes* with short-range radar systems and *Elbit SupervisIR™* (EO/IR systems) for visual detection and identification of drones at any time of the day and in various weather conditions, especially in complex urban environments with high building density and noise pollution.
- *Lockheed Martin Developments:* The company has presented a scalable, multi-layered counter-unmanned aerial systems (C-UAS) system designed to detect, track, and neutralize both single drones and swarms.

Ukraine, being under constant missile and drone attacks, uses a multi-layered air defense system that includes engagement assets at various ranges, as well as radars for early detection, optical and acoustic sensors for identification, and electronic warfare equipment or net guns for neutralizing detected threats. Although a significant part of these systems is focused on countering missiles, they are also effectively used against drones:

- *Echeloned Air Defense System:* Ukraine employs an echeloned air defense system that includes engagement assets at various ranges, as well as detection and EW systems.
- *Medium- and Long-Range Systems:* Anti-aircraft missile systems such as NASAMS, provided to Ukraine by Western partners, have demonstrated high effectiveness in intercepting both missiles and drones.
- *Short-Range Systems:* Man-Portable Air-Defense Systems (MANPADS) and self-propelled anti-aircraft guns, as well as autonomous AI turret are used for the direct protection of objects [95].
- *RF Jammers:* Ukraine actively uses a commercially available solution of Dedrone Portable CUAS that generates powerful radio interference on the frequencies

used to control drones, leading to the loss of communication between the operator and the drone and its immobilization.

- *Electronic Warfare (EW) Systems:* Portable EW complexes, such as Kvertus, are widely used in Ukraine to jam enemy drones. Larger-scale projects, such as the £103 million 1,500-kilometer counter-drone wall using EW and electronic intelligence technologies, are being developed.
- *Ukrainian Counter-Drone Complexes:* Ukrainian companies are developing their own counter-drone systems, such as "Sky Hunter," designed to protect strategic objects from various types of enemy UAVs [96]. The development of laser weapons capable of physically destroying drones is also known [102].
- *Application of Counter-Drone Rifles and Other Kinetic Means:* In the context of the massive use of drones, especially at low altitudes, Ukrainian military personnel use C-UAV rifles and counter-aircraft installations during territorial defense operations for destroying enemy UAVs.
- *Laser Weapons:* Ukraine demonstrates the development of its own laser weapons capable of destroying drones, cruise missiles, and ballistic missiles at distances up to 3 kilometers [102].
- *UAV vs. UAV:* KrattWorks developed high-performance UAVs, that used in Ukraine for reconnaissance and as target drones for counter-UAV exercises, as well as drones with EW-resistant radios with a frequency hopping capability and the ability to fly without using GNSS [97].
- *Camouflage and Dispersion of Military Equipment:* Ukraine actively uses camouflage and dispersion methods for military equipment to reduce its vulnerability to drone attacks. South Korea should take this experience into account.

3.4 World List of C-UxS Complexes for the Urban Space Protection

It is important to note that information on the use of counter-drone systems in urban infrastructure is mostly confidential for security reasons, but the latest innovative projects in this area are as follows:

- Founded in 1993 in Scottsdale, Arizona, the American defense technology corporation Axon Enterprise, Inc. has gained worldwide fame for its Taser line of stun guns. The company is currently developing technologies and weapons for the military, law enforcement, and civilians, including the eponymous stun gun drones. In October 2024, Axon Enterprise completed the acquisition of Dedrone Holdings, an American company that develops anti-drone and unmanned aerial vehicle technology and contributes to Ukraine's efforts to counter Russian UAVs, as well as protects South Korean airspace and the Korea Power Exchange (KPX) national power grid from drones from North Korea. Dedrone's software and hardware can detect radio frequencies, video channels, and other electronic signatures of drones. In addition, according to the company, its specialized counter-drone defense system for urban areas, *Dedrone City-Wide*, is used in major US cities (40 in total): Washington, D.C., New York, Los Angeles, Chicago, and Las Vegas. The American city of Houston, Texas, uses Airsight's AirGuard software platform to detect drones. Dedrone City-Wide is also used to protect

against unwanted drones in several European regions, including the UK and Germany.

- In turn, at Enforce Tac 2025, the German company Diehl Defense presented its *Sky Sphere defense system*, which includes the CICADA eMissile anti-drone missile designed to neutralize Class 1 and Class 2 drones. (Live from Nuernberg: Diehl Defense is showing two drone defenses as part of their integrated Skysphere system at Enforce Tac 2025, the trade fair of security tasks and the armed forces.
- At the end of January 2025, the German company Rheinmetall, which has been supplying the Ukrainian Armed Forces with Skynex stationary air defense systems with four 35 mm guns optically connected to a control post and a radar station to capture and neutralize small air targets since August 2024, handed over a prototype of the new *Skyranger 30 mobile air defense system* to the Bundeswehr. The Boxer armored personnel carrier is equipped with a KCE gun (30 x 173) with a range of about 3000 meters and a rate of fire of 1200 rounds/minute with specially designed remote-fuzed shells, which will allow for effective counter-drone operations. To detect small aerial targets, the Skyranger 30 uses an AMMR multi-target radar operating in the S-band. In total, the vehicle has five antennas that provide 360-degree coverage. In addition to this prototype, as part of a €595 million contract signed with the German government in February 2024, the Bundeswehr placed an order for the production of 18 more production models of the Skyranger 30 anti-aircraft system. Additionally, the contract has an option to order 30 more of these additional air defense systems, if the appropriate budget is allocated by the Ministry of Defense. The new Skyranger 30 mobile air defense system is also being contracted by Denmark, Germany, Austria and Hungary. And the Dutch Ministry of Defense ordered the same mobile air defense systems from Rheinmetall 22 with the installation of the Oerlikon KCA rapid-fire cannon and Mistral/Stinger anti-aircraft missiles on the ACSV (Armored Combat Support Vehicles) tracked chassis from Flensburger Fahrzeugbau, which was presented at the Eurosatory 2024 exhibition in the Norwegian air defense systems NOMADS. The Ministry of Defense of the Netherlands cited the critical role of drones on the battlefield in Ukraine and the Middle East and announced its intention to increase its capabilities to counter threats from unmanned systems by purchasing 18 more NOMADS air defense systems from Norway.
- *Spain's Cervus III system* is an example of an integrated system that includes various sensors and electronic warfare capabilities to protect against drones. Its use in Mali and Latvia, although not necessarily over entire cities, demonstrates the principle of deploying protective systems over certain areas.
- On April 21, 2025, as part of the deepening strategic industrial cooperation between the United States and the UAE to strengthen regional defense capabilities, the American defense giant Raytheon (RTX) signed a landmark agreement with the United Arab Emirates' Tawazun Council to establish local production of the *Coyote counter-drone system* in the UAE, including Abu Dhabi and the newest innovation city of Mazdar. Also, the Coyote system currently in use by the U.S. military includes multiple launch effects known as LE variants,

which are designed to support a range of missions, including surveillance, precision strike, electronic warfare, and communications. These variants provide the tools necessary to accurately detect and engage airborne threats from a variety of platforms. There are several variants of Coyote drones: Coyote Block 1, Block 2, Block 3 and the new Coyote LE SR. The first two variants, Block 1 and Block 2, are equipped with high-explosive warheads designed to physically destroy targets, while Block 3 and Coyote LE SR are reusable. In addition to CUS operations, the Coyote system supports beyond line-of-sight operations and customized effects in challenging environments.

- In early 2025, Epirus delivered a completed *ExDECS HPM system* to the U.S. Marine Corps Warfighting Laboratory under a $5.5 million contract with the U.S. Navy's Office of Naval Research (ONR), enhancing the U.S. Marine Corps' ground air defense capabilities. The compact, scalable HPM system, designed for expeditionary operations, uses long-pulse microwave technology and is capable of disabling multiple drones in seconds. On March 5, 2025, Epirus announced that it had successfully raised an additional $250 million to fund its program to help the military transition from the traditional 1-to-1 model of counter-drone defense to a more scalable 1-to-many approach, emphasizing that modern battlefields - especially in Ukraine and the Middle East - are “filled with thousands of low-cost, highly networked, and highly distributed threats.” To provide a realistic training environment for preparing users of the Leonidas counter-drone microwave system for modern threats, EPIRUS is launching a simulation center in Oklahoma in the third quarter of 2025, where the US Army's Fort Sill garrison and the Joint University for Countering Small Unmanned Aircraft Systems are located. Also, available sources of information indicate the use of the EPIRUS Leonidas counter-drone microwave system in the Middle East, which was deployed in 2023 after its effective testing by the US Department of Defense and the signing of a $66 million contract for its use.
- In the Asia-Pacific region and Latin America, anti-drone protection of cities is provided by the Australian company DroneShield, which in January 2025 received a Latin American contract for $9.7 million and in April closed four contracts in the Asia-Pacific region for a total of $44 million, having previously launched a 3D planning tool for designing multi-level UAV protection and a global UAV incident information platform to increase customer situational awareness.

3.5 AI-Based Defense Systems against Hybrid Threats, including UAVs

Nowadays, all over the world, most of dual-use companies, government defense agencies, and international security organizations are increasingly using artificial intelligence to detect, analyze, and respond to threats, enabling them to effectively protect their interests and ensure the safety of citizens in various areas such as cybersecurity, drone defense, law enforcement, and humanitarian missions:

- *The Squad X program*, which developed by the Defense Research and Projects Agency of the US Department of Defense (DARPA), uses artificial intelligence to support soldiers on the battlefield. This program involves the use of autonomous

drones equipped with sensors and pattern recognition systems that can detect hidden threats and provide recommendations for soldiers' actions.

- *The IBM Watson for Cybersecurity platform* uses artificial intelligence to analyze large amounts of data and identify potential cyber threats. It uses neural networks and machine learning algorithms to find anomalous patterns in large data streams. Coming from a "computing in the cloud" approach, Watson analyzes data from a variety of sources, including event logs, network traffic, and threat reports, to identify unusual activity that could indicate a cyberattack or other threat. The platform then makes recommendations on measures that can be taken to protect against threats.
- *Darktrace AI systems* for cyber threat detection use neural network technology to train a computer to recognize normal network behavior and detect unusual or suspicious activity. Darktrace's systems can detect even the most sophisticated attacks that other systems may miss and provide real-time recommendations for protecting the network.
- *Lockheed Martin AI-Powered Defense,* one of the world's largest military equipment manufacturers, develops defense systems that use artificial intelligence to predict and respond to various threats. For example, their AI technology can analyze large amounts of data collected from sensors, detect unusual activity that could indicate the presence of enemy forces, and provide military system operators with recommendations for further action.
- *The PredPol law enforcement system* uses artificial intelligence to predict the locations of possible crimes. It analyzes crime statistics, geographic data, and other factors to identify trends and patterns that may indicate places and times when crimes are most likely to occur. Once analyzed, PredPol provides police officers with areas where crimes are most likely to occur so they can pay special attention to those areas.
- *Project Greenlight Detroit,* a project of the city of Detroit and the city police, uses video surveillance and artificial intelligence to detect and respond to crimes. The system analyzes video streams from surveillance cameras and detects suspicious behavior, such as running or rapid movement, and automatically sends alerts to police officers who can arrive at the scene and take appropriate action.
- *UNICEF's Magic Box* initiative uses artificial intelligence to support humanitarian action. This system analyzes large amounts of data from various sources, including population, resource, and need data, to provide recommendations on how to distribute humanitarian aid and ensure efficient use of resources.

Particularly, In the field of counter-drone countermeasures, the following examples of artificial intelligence software that is designed for use in counter-drone systems to protect drone settlements are known worldwide:

- *Dedrone DroneTracker* uses a variety of sensors, including radar, cameras, and acoustic sensors, to detect and identify drones based on their characteristics and behavior.
- *DJI AeroScope* is a specially designed software to detect and identify DJI drones based on their transmitter signal.

- *DroneShield Sentinel* is a software for tracking drone movement and classifying drones by type and threat based on the analysis of sensor and video camera data.
- *Airbus Defenders* uses artificial intelligence to analyze the movement and behavior of drones in real time and classify them by type and intent.

Situation analysis and decision-making:

- *Sensofusion AIRFENCE* is software that assesses potential threats posed by drones and provides recommendations for further action to operators.
- *Citadel Defense Titan* uses machine learning to analyze incoming data and make decisions to neutralize threats.
- *DroneShield DroneSentry* is a software for managing and coordinating a variety of support assets such as radio jammers and electromagnetic devices.
- *MyDefence PITBULL* provides integration with various security and defense systems to coordinate threat control and neutralization activities.

Interface for operators:

- *CerbAir Cerberus* provides an intuitive interface for operators to monitor and analyze drone data.

CHAPTER 4. UKRAINIAN UXS/C-UXS SOLUTIONS FOR THE PROTECTION OF SOUTH KOREAN CITIES AND THE ODESSA-INCHEON CASE STUDY

This chapter focuses on a comparative analysis of the experiences of Ukraine and South Korea in the development and implementation of solutions for countering unmanned threats in the urban environment (UxS urban defense). The selected countries have different geopolitical contexts and levels of technological development, but both face growing challenges related to the potential use of drones for dangerous purposes.

4.1. Background of drone incidents and analysis of potential UAV threats to South Korea's national security

South Korea, located in one of the most geopolitically tense regions of the world, directly bordering North Korea, acutely feels the growing need for effective solutions to counter unmanned threats. A series of incidents and underscore the relevance of this issue for the country's national security:

- *North Korean drone incursions in 2023*: In January 2023, the South Korean military acknowledged that one of five North Korean drones that entered the country's airspace on December 26, 2022, reached the no-fly zone above the presidential office in central Seoul [100]. This incident served as a wake-up call about the vulnerability of even the most protected government facilities to the intrusion of unmanned aerial vehicles and triggered sharp criticism of the military command for its slow response.
- *Collision of a military drone with a helicopter in 2025:* In March 2025, at a military airbase in Gyeonggi Province, a South Korean military drone collided with a parked helicopter during landing, resulting in a fire and the complete destruction of the aircraft, valued at $14 million [2]. Although this incident involved military infrastructure, it clearly demonstrates the potential risks associated with the intensive use of drones, even in a controlled environment.
- *Increase in unauthorized flights near the presidential office:* Since the relocation of the presidential office to Yongsan in 2022, there has been a sharp increase in the number of unauthorized drone flights in the area. Since the move, over 230 such incidents have been recorded, with the number rising to 141 in 2023 compared to 89 in 2022 [98]. This indicates a systemic problem in ensuring security in a highly sensitive area and raises concerns about the possibility of espionage or other malicious activities.
- *Airport disruptions:* Illegal drone activity has also led to significant disruptions at major South Korean airports, posing a threat to flight safety and causing inconvenience to passengers. Incheon International Airport recorded over 80 flight disruptions due to illegal drone flights between 2020 and 2023. On September 13, 2024, a similar incident occurred at Jeju International Airport, highlighting the seriousness of this threat to critical transportation infrastructure.

South Korea, with its developed economy and powerful military force, critical infrastructure, and densely populated urban areas, is an attractive target for potential aggressors. The analysis of potential risks shows that enemy or unsanctioned drones can be used by the North Korean regime for:

- *Reconnaissance:* Gathering information about the location and activities of military facilities, air defense systems, ports, airports, and other strategically important objects.
- *Attacks:* Launching strikes against military bases, energy infrastructure (as simulated during exercises in Taebaek, where a drone caused an explosion at a substation), transportation hubs, communication facilities, and other critical elements of urban infrastructure. Even small drones can carry explosive devices or be used as kamikaze drones.
- *Creating interference:* Disrupting the operation of communication, navigation, and control systems using electronic warfare (EW) equipment that can be mounted on drones.
- *Proliferation of weapons of mass destruction* (although this threat is less likely, it cannot be completely ruled out). The South Korean government and military experts are increasingly aware of these risks and see an urgent need to develop and implement effective counter-drone solutions.

4.2 Overview of UAV and C-UAV defense for South Korea's key state sectors and prospects for Ukrainian defense-tech innovations

Despite significant efforts, South Korea still needs further development and improvement of its counter-drone capabilities to ensure reliable protection of urban infrastructure and national security from the growing threat of unmanned aerial vehicles. South Korea actively invests in the development of its own drone technologies, but also pays significant attention to building up its counter-UAV capabilities:

- *Electronic Warfare (EW) Systems:* An intelligent EW system has been developed to detect, jam, and neutralize enemy drones, including both conventional and kamikaze drones. This system is installed on main battle tanks (MBTs) and is capable of countering drones attacking at high speed with vertical dives.
- *Radar Systems***:** South Korea has successfully tested a photonic radar using artificial intelligence, capable of detecting small and stealthy drones at a distance of several kilometers. The country is also developing other new-generation radars to enhance the effectiveness of UAV detection, which can be difficult to detect by traditional optical or electromagnetic sensors.
- *Other Countermeasures:* During territorial defense exercises, anti-drone rifles were used to attempt to neutralize enemy drones using EW methods, as well as K263 self-propelled anti-aircraft guns to destroy them.
- *Deployment of Advanced Counter-Drone Systems:* Following the North Korean drone incident in 2022, South Korea accelerated the process of procuring and deploying advanced counter-drone systems developed by the domestic defense conglomerate Hanhwa Systems for rapid response to future UAV incursions.

- *Establishment of the Drone Operations Command:* To improve coordination and response to drone-related threats, the Drone Operations Command has been established in South Korea.

Counter-drone protection systems are also being actively developed and implemented worldwide, which may be relevant for protecting power plants, substations, power lines, and other energy sector facilities of South Korea from UAV attacks:

- *Leading Protection Systems (Advanced Protection Systems), AIM Defence, Anduril Industries, AP-FLYER, ASELSAN, BAE Systems, Bharat Electronics Limited (BEL), Blighter Surveillance Systems Limited:* These companies offer a wide range of solutions for detecting, identifying, and neutralizing drones, including radar systems, optoelectronic complexes, EW capabilities, and kinetic neutralization means [98]. www.businesswire.com
- *Directed Energy Systems:* Laser and microwave systems are being developed to disable drone electronics. The Indian Defence Research and Development Organization (DRDO) has developed a vehicle-mounted laser complex for dazzling and engaging drones [99].
- *Middle Eastern countries (Saudi Arabia, UAE, Israel*) have already integrated advanced anti-drone technologies into their defense strategies, particularly for the protection of critical infrastructure such as oil refineries [98].

Engaging leading global developers of counter-drone systems (Advanced Protection Systems, Anduril, Elbit, Dedrone, and others) is critically important for national security and protection of energy infrastructure. The energy infrastructure of South Korea, like that of Ukraine, is an object of particular attention from a security perspective. Ukraine, being at the epicenter of a large-scale military conflict with the active use of unmanned aerial vehicles (UAVs) by the adversary, has accumulated valuable and unique experience in the field of counter-drone protection. So, South Korea can utilize it to enhance the protection of own energy sector. In the context of war, Ukraine has accumulated significant experience in protecting its energy sector from drone attacks by:

- *Physical Fortification of Facilities:* Ukraine employs physical barriers to complicate the striking of critical equipment.
- *Mobile Response Teams with EW Capabilities:* Rapid deployments of mobile teams to counter drone attacks have become standard practice.
- *Use of Interceptor Drones:* The development and application of proprietary interceptor drones is an important element of the layered defense.
- Combining these measures, taking into account the specifics of South Korea, will allow for the creation of a reliable counter-drone protection system for the country's energy sector:
- *Combining Technologies:* Deployment of a layered defense system that includes radars for early detection, optoelectronic and acoustic sensors for identification, EW capabilities for jamming, and physical neutralization methods (e.g., net guns or interceptor drones).

- *Implementation of Mobile EW Complexes:* Creation of mobile groups equipped with powerful EW systems for rapid response to threats near energy facilities. Ukraine's experience with portable systems like Kvertus may be useful.
- *Investment in the Development and Acquisition of Directed Energy Systems:* Consideration of the possibility of using laser technologies, which Ukraine is actively developing, for the cost-effective destruction of drones.
- *Strengthening the Physical Security of Facilities:* Reinforcing perimeters, installing protective nets, and using other physical barriers to complicate the striking of critical equipment.

4.3 Potential analysis of Ukrainian UAV technologies for the South Korean defense sector

Ukrainian UAV innovations, particularly in the sphere of combined drone detection and engagement systems, as well as the active participation of non-state actors in the development and implementation of counter-drone solutions, can be valuable for South Korea in this endeavor.

- *Strike and Reconnaissance UAVs:* Ukraine has developed a range of specialized drones, such as the long-range kamikaze drone "Bober" and the high-precision strike drone "Bulava" [9]. South Korea could study the technical specifications and capabilities of these developments to assess their potential application in its own armed forces.
- *Maritime Drones:* Ukraine's successful deployment of MAGURA V5 and Sea Baby maritime drones to strike enemy warships in the Black Sea indicates a high level of development in Ukrainian unmanned technologies in the maritime domain [9]. South Korea, with its significant coastline, might be interested in this experience to strengthen the security of its maritime borders and ports.
- *"Elf-P" Drone:* A drone developed in Ukraine that is currently being optimized to counter enemy kamikaze drones of the "Shahed" type [97]. South Korea could study the approaches of Ukrainian engineers to the development of specialized software for intercepting and neutralizing such threats.

Under the conditions of intense combat operations, Ukraine demonstrates significant progress not only in the mass production of UAVs but also in the development of specialized technologies and innovative software that could be utilized by South Korea to enhance its own counter-drone defense, especially in densely populated urban environments. Ukrainian specialists are actively developing innovative software for drone control, data analysis, and countering enemy UAVs:

- *Situational Awareness System "DELTA":* This system serves as a platform for planning operations and displaying the location of both own and enemy drones in real-time. It ensures secure data exchange between drones and combat systems. South Korea could study this development for integration into its own troop management systems.

- *Software "Sky Hunter":* Developed by the Ukrainian defense-tech cluster Brave1, this software analyzes data from Ukrainian radar systems in real-time, tracks the coordinates of aerial targets, and visualizes them on a control panel. The system is designed to protect strategic objects from various Russian reconnaissance and strike drones, including "Shahed" [96]. Similar software solutions could significantly enhance South Korea's capabilities in detecting and tracking enemy UAVs.
- *Visual Positioning System Vermeer:* This technology, successfully applied in Ukraine to ensure drone navigation in the absence of GPS, could be particularly valuable for South Korea, considering potential threats of satellite signal jamming.
- Also, the domestically produced unmanned aerial system "Ptashka" ("Bird of Prey") was recently adopted into service.

4.4 Ukrainian C-UAV systems and complexes for the protection of South Korean urban spaces, housing and communal facilities

South Korea, like Ukraine, faces the need to protect infrastructure and densely populated urban areas from potential threats posed by unmanned aerial vehicles (UAVs). Considering Ukraine's experience in countering enemy drones in cities, South Korea may consider implementing the following counter-drone technologies and anti-drone complexes to provide multi-layered protection for the housing and communal services sector. Studying Ukrainian and global experience in creating echeloned air defense systems and implementing specific counter-drone complexes will allow South Korea to significantly increase the level of protection from the growing threat of unmanned aerial vehicles. South Korea may consider integrating the following counter-drone systems and complexes into its air defense system:

- *Mobile EW Complexes Based on Armored Vehicles:* Deployment of mobile EW complexes on the chassis of armored fighting vehicles (Sky Sentinel, a new air defense system created by Ukrainian engineers, operates completely autonomously thanks to AI. The system is equipped with a heavy machine gun, an air defense turret that can rotate 360° For the turret to work, no human intervention is required: it only needs to be deployed and radar data transmitted to it, and then, using artificial intelligence, it calculates the shot and fires. The fully autonomous Sky Sentinel shoots down shahids and other targets moving at 200, 400, and even 800 kilometers per hour, even those five times smaller than a shahid, and can also shoot down a cruise missile within its range. The system has already proven itself in air combat by shooting down Russian drones. It is being prepared for mass production [95].
- *Portable EW Complexes:* Procurement or development of its own portable EW systems, similar to the Ukrainian Kvertus, to protect individual military facilities from drone attacks.
- *Integrated Detection and Neutralization Systems:* Combining of radars, optoelectronic detection means, and EW or kinetic engagement assets into a single network (analogous to Lockheed Martin's developments or Israeli complexes).

- *Interceptor Drones:* Ukrainian experience for South Korea development of its own programs for the design and production of interceptor drones capable of effectively shooting down enemy UAVs.
- *Directed Energy Systems:* Investment in research and development of laser weapons for countering drones, taking into account Ukrainian developments in this field.

However, the selection of specific technologies and complexes should be carried out taking into account the specifics of South Korea's urban environment, building density, the level of electromagnetic radiation, and other factors.

4.5 Framework for projecting South Korean C-UAV defense complexes based on Ukrainian experience

Applying Ukrainian experience, adapted to the specific needs of South Korea to enhance the security of the urban environment against drone attacks, can significantly improve the effectiveness of protecting its urban environment from the growing threats associated with the use of unmanned aerial vehicles. In particular, Ukrainian experience has proven that effective protection against drone threats requires a multi-layered approach, where various countermeasures are applied at different stages of UAV detection and neutralization. South Korea can create similar units and structures, based on the following framework:

Table 13. Ukrainian experience of using C-UxS with prospects for South Korea

Distance/Process	Ukrainian Experience	Recommendation for South Korea
Long Range/ Early Detection	Use of long-range radar stations (RLS) capable of detecting aerial objects at a significant distance. In Ukraine, such radars are often integrated into the general air defense system.	Deploy a network of modern radars optimized for detecting small, low-flying targets such as drones. Possible integration with existing air defense systems to provide broader coverage of airspace.
Medium Range/ Precise Detection and Identification	Application of electro-optical and infrared (EO/IR) systems for visual confirmation of the target and its identification. In Ukraine, such systems are often mounted on mobile platforms.	Implement a network of EO/IR cameras, especially in urban areas and near critical infrastructure, for accurate tracking and recognition of drones. Possible use of thermal imaging cameras for detecting drones at night or in adverse weather conditions.
Short Range / Neutralization	Widespread use of electronic warfare (EW) for jamming drone control and navigation channels. In Ukraine, both stationary and portable EW systems, such as the Ukrainian Kvertus systems, are successfully used.	Deploy a network of stationary and mobile EW complexes in urban agglomerations and around important facilities. Mobile complexes can be placed on specialized vehicles for rapid response.
	Use of anti-drone rifles for the physical destruction of drones at short distances.	Provide rapid response units with anti-drone rifles for engaging drones in close proximity to protected objects.
	Development and use of interceptor drones.	Invest in the development and production of its own interceptor drones capable of intercepting and neutralizing hostile UAVs.

Despite differences in the geopolitical context and the level of technological development, the Ukrainian experience can be extremely useful for South Korea in developing its own strategies for ensuring the security of the urban environment

from drone threats. It has also demonstrated the effectiveness of mobile teams capable of responding promptly to threats arising in various parts of the city. In addition, it is necessary to develop clear protocols for responding to drone threats and ensure proper training of personnel responsible for the operation of anti-drone systems*:*

- *Team Composition:* The team should include specialists in drone detection and identification (radar and electro-optical systems operators), electronic warfare specialists (EW complex operators), and combat personnel armed with anti-drone rifles or other means of physical destruction.
- *Equipment:* Mobile teams should be equipped with high-speed vehicles, portable short-range radars, electro-optical systems, EW complexes (e.g., similar to the Ukrainian Kvertus), anti-drone rifles, communication equipment, and personal protective gear.
- *Response Protocols:* Clear response protocols should be developed for various drone attack scenarios, including procedures for detection, identification, localization, and neutralization of drones. Establishing effective interaction between mobile teams and stationary command centers is crucial.
- *Deployment:* Mobile teams should be deployed in a way that ensures the fastest possible arrival at any point in the city in the event of a threat. It is possible to create several such teams responsible for different districts of the city.
- *Interaction with City Authorities and Utility Services:* Establishing close cooperation between mobile rapid response teams and city authorities, as well as utility services, is important for obtaining information about potential threats and coordinating actions in the event of incidents.

4.6 Radial-vector projecting of urban C-UAV defense AI-complex (RStudio histogram)

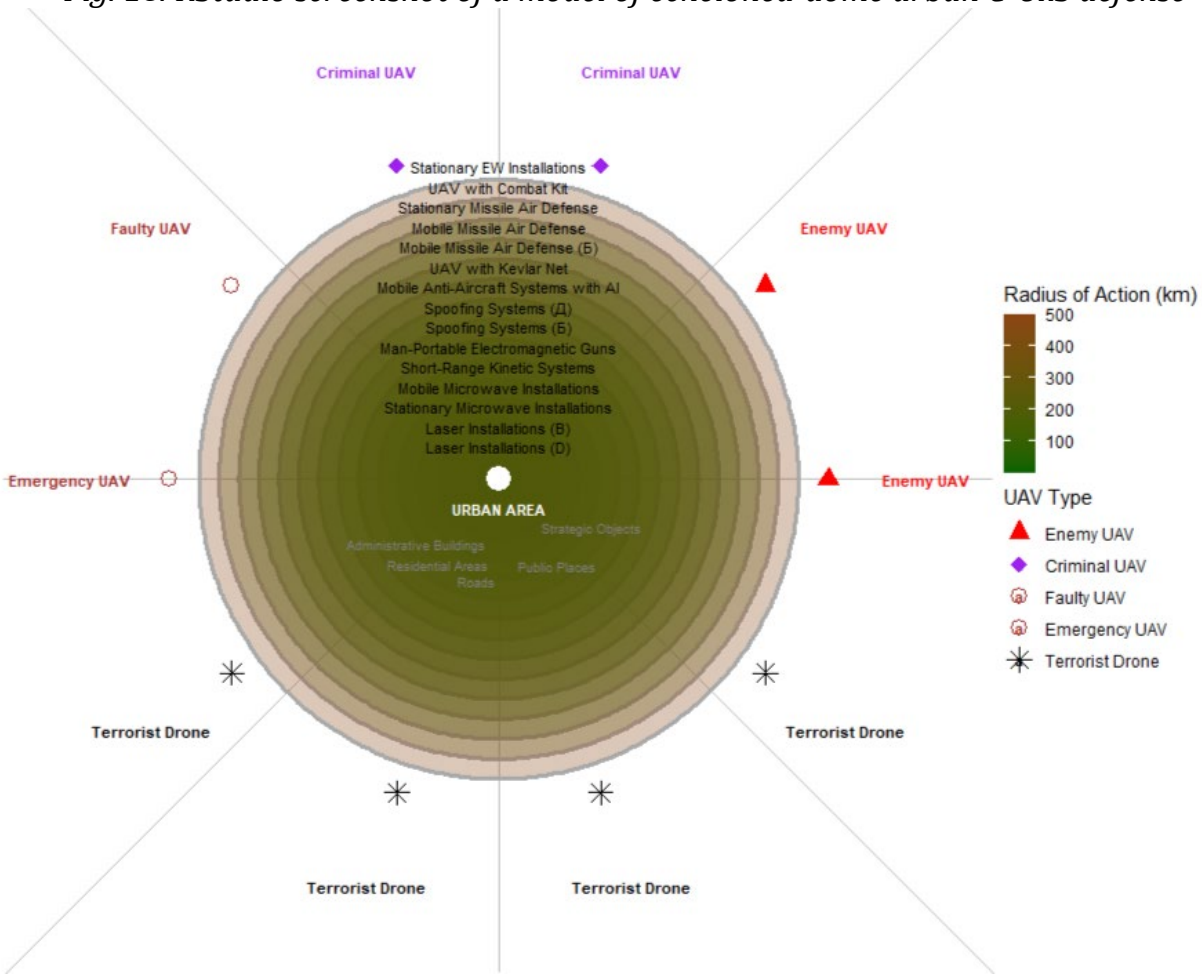
By analyzing the spatial and technical characteristics of the existing systems of countering drone threats in the world and the application of advanced Ukrainian technologies, the author of the work modeled a universal model of counter-drone defense for urban environments in a specialized application, RStudio.

Counter-drone protection of strategic facilities and urban life support enterprises, including international airports, seaports, power plants, oil depots, and water utilities, should be provided by short-range kinetic systems with a range of about a kilometer and supported by security teams capable of neutralizing the drone threat with electromagnetic weapons with twice the range. Spoofing systems are used to de-orient dangerous UAVs, so they should be deployed on the seafront approach to city centers - stationary ones with a 5-km range and mobile ones with a 3-km range - on the approaches to the city center from the main roads - supported by mobile AI-controlled air defense systems with a range of more than 20 km. At even twice the distance from cities, enemy drones can be safely intercepted by systems with twice as fast drones (up to 300 km/h) and Kevlar mesh. The use of a warhead instead of a mesh

in the same “own” UAVs is allowed at an even five times longer distance from the city. In between these rings of drone defense with a radius of 50 km and 200 km are stationary and mobile missile defense systems. The widest counter-drone protection around cities is provided by electronic warfare systems with a radius of up to 500 km.

The histogram generated from the dataset of C-UAV tech efficiency [94] illustrates a universal complex for counter-drone protection around an urban area. The defense systems are arranged in concentric circles, with the radius of each circle representing the approximate range of the technology. The labels for these technologies are curved along their respective circular ranges. Within the 'URBAN AREA', labels indicate key infrastructure and zones: Residential Areas, Public Places, Administrative Buildings, Strategic Objects, and Roads, located in the lower portion of the diagram. The diagram also depicts various threats approaching the urban area: Enemy UAVs (red), Criminal UAVs (purple), Faulty UAVs and Emergency UAVs (brown), and Terrorist Drones (black), positioned around the outer perimeter of the defense system.

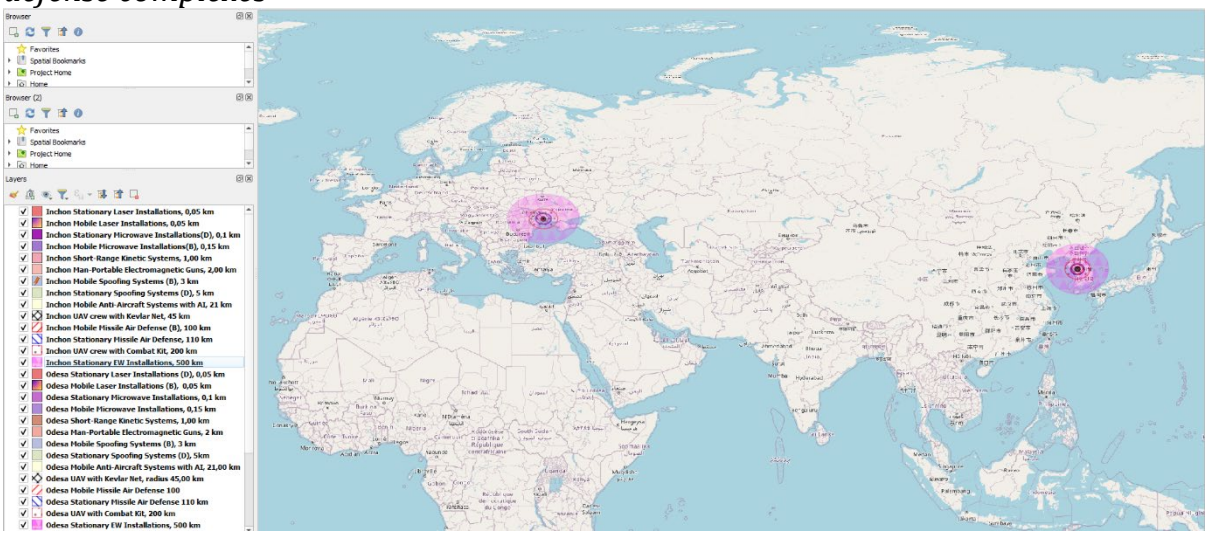
Fig. 18. RStudio screenshot of a model of echeloned-dome urban C-UxS defense



4.7 QGIS modeling drone defense domes for strategic port cities of Ukraine and South Korea (Odessa and Incheon)

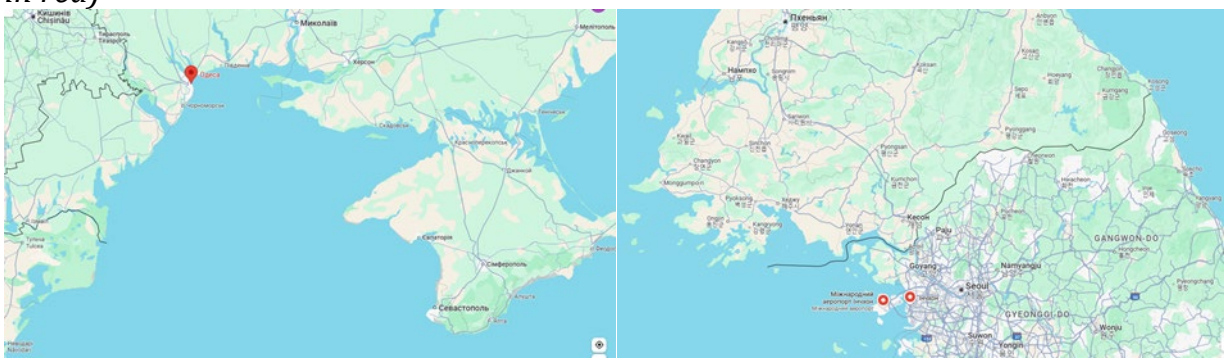
A comprehensive solution for South Korea should include all of the above means of detecting UAV threats, preventing them and directly countering drone attacks, and most importantly, focus on counter-drone defense of urban space, because military, industrial, energy, municipal and residential facilities are concentrated in city areas. To conduct a spatial analysis, the author of this article analyzed the natural, geographical, and socio-demographic characteristics of South Korean and Ukrainian cities. A pair of port cities was chosen for the study based on the similarity of certain parameters such as their location, landscape, access to the sea, strategic status, industrial specialization, building density, and population: Ukrainian Odesa and South Korean Incheon.

Fig. 19. Screenshot of QGIS modeling for Odesa and Incheon urban C-UAV defense complexes



Both cities are close in population to each other, with a predominantly flat landscape and building density. But the main similarity between these port cities is their location on the seashore, which makes both Odesa and Incheon easy targets for drone attacks by aggressor countries from the seaside.

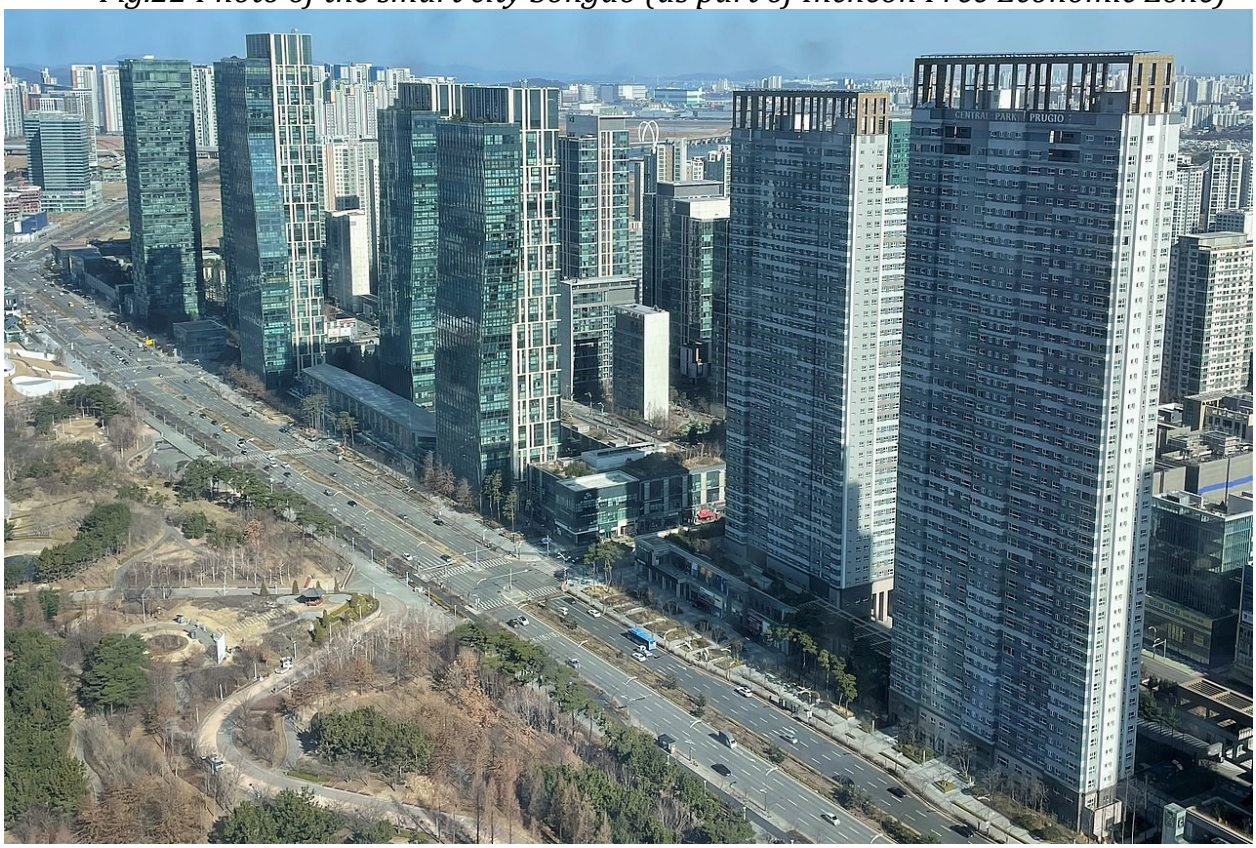
Fig. 20,21. Google Maps screenshot of Odesa and Incheon (the cities are marked in red)



Also, Incheon is called the “gateway to the Korean capital” and is considered part of Greater Seoul, as the Incheon subway is connected to the Seoul subway by a 30-km line.

The most important attraction of Incheon is the newest smart city Songdo, built in the format of a 15-hundred-mile city 15 years ago, which is recognized as one of the most expensive in the world with a cost of more than $ 40 billion.

Fig.22 Photo of the smart city Songdo (as part of Incheon Free Economic Zone)

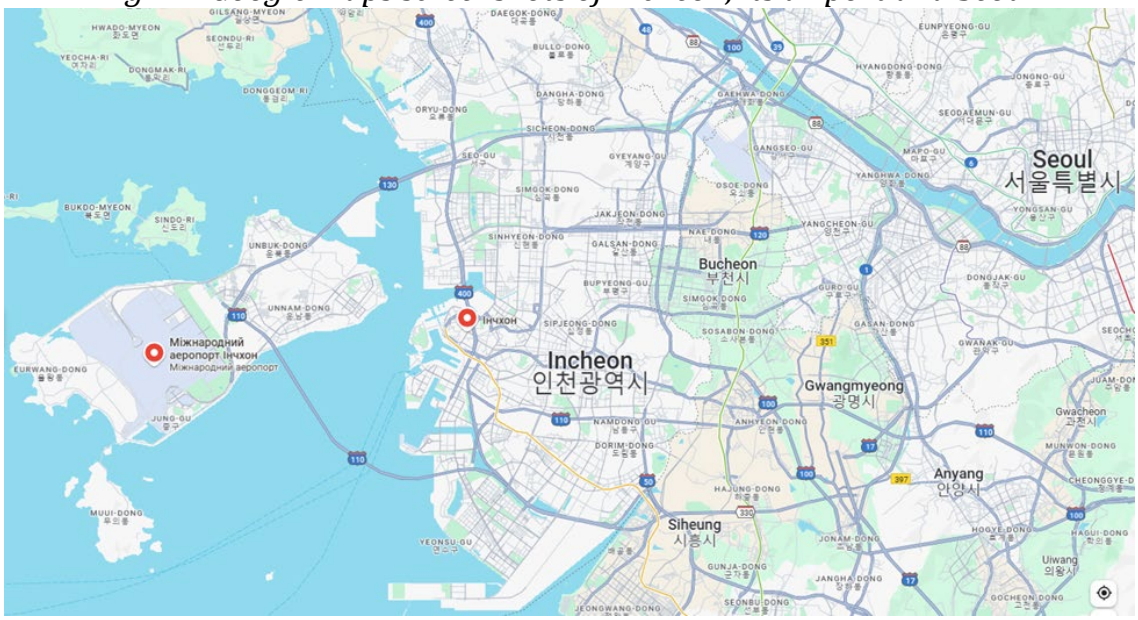


Therefore, the model of the counter-drone dome developed for Odesa, with electronic warfare complexes to jam enemy drone control signals, acoustic and radar systems for early detection, cameras for visual surveillance, cyber defense against hacker attacks, and, of course, mobile rapid response teams, could serve Incheon well.

Especially given its proximity to Seoul, where the presidential administration has recently been located.

South Korea plans to establish another administrative center in Sejong with a focus on electronic security and radar monitoring of the airspace, which is occasionally bombarded by North Korean airborne “gifts” in the form of debris balls.

Fig. 23. Google Maps screenshots of Incheon, its airport and Seoul



Obviously, Incheon's counter-drone dome will need to be adapted: adjusting electronic warfare frequencies to possible signals from North Korean drones, integrating with existing security systems, and training personnel. The basic idea of developing comprehensive protection for Odesa can become a reliable basis for Incheon's security in the current environment, especially given the strategic importance of the country's largest airport and its location near the country's capital, which is constantly under a drone threat from the aggressor neighbor.

Fig. 24-26 QGIS modeling of urban C-UAV defense complex for Odesa city

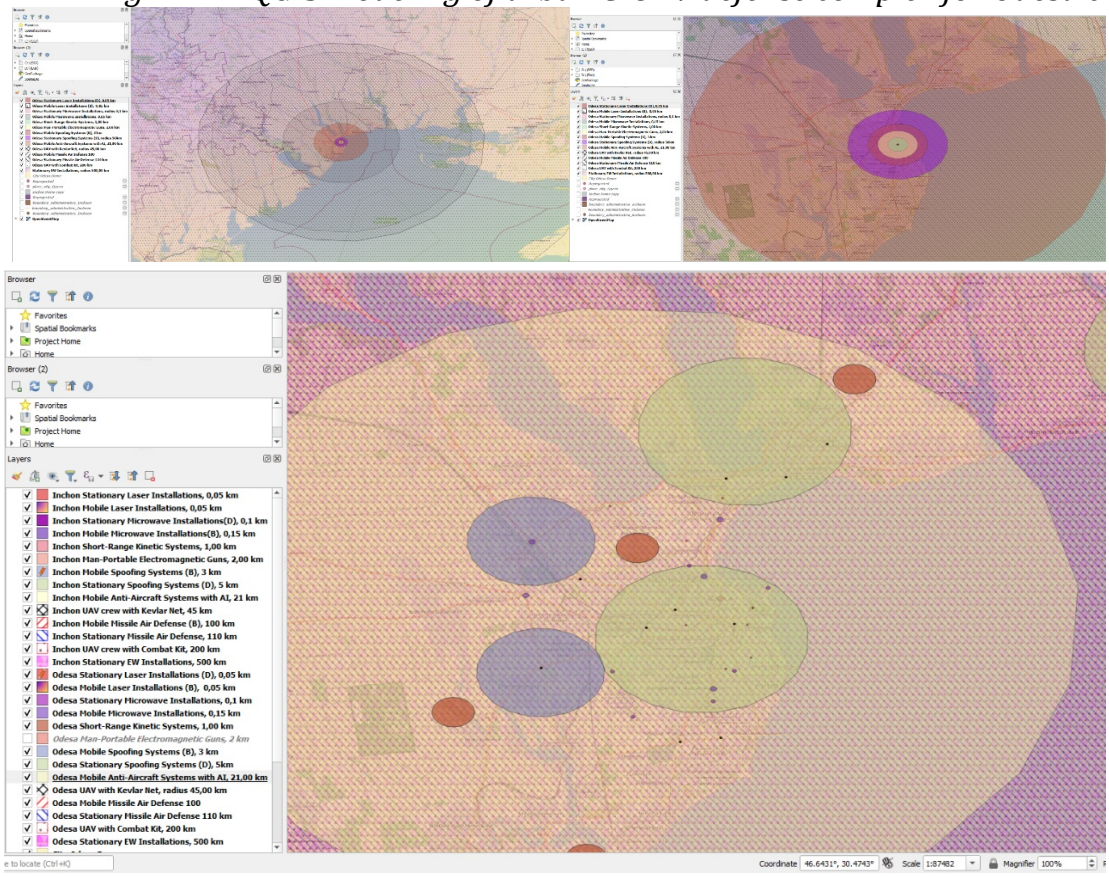
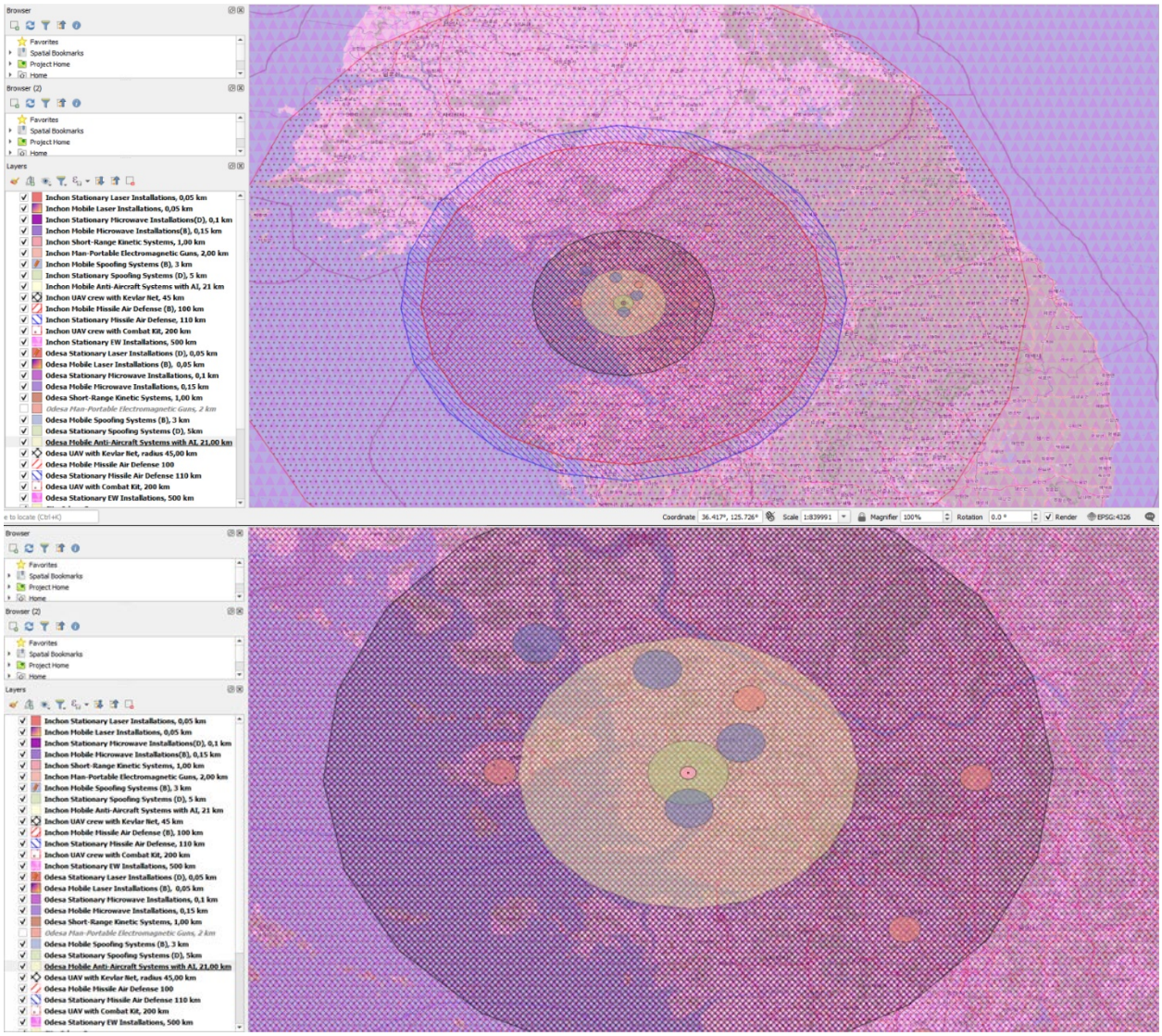


Fig. 27,28. QGIS modeling of urban C-UAV defense complex for Inchon city



4.8 General recommendations for South Korean public policy in the sector

Considering the Ukrainian experience in countering drone threats and the analysis of existing counter-drone technologies, South Korea can significantly enhance the protection of its urban environment by implementing the following recommendations:

- Develop and implement a comprehensive, multi-layered counter-drone system encompassing detection, identification, jamming, and physical destruction of unmanned aerial vehicles.
- Establish mobile rapid response teams equipped with the necessary resources to counter drone threats in urban areas.
- Develop and implement a public awareness campaign regarding actions to take upon detecting hostile drones.
- Actively collaborate with international partners, including Ukraine, to exchange experiences and best practices in the field of counter-drone defense.

Drawing upon the analysis of Ukrainian experience, the following recommendations can be proposed for South Korea:

- ***Deployment of multi-layered detection and neutralization systems:*** South Korea should invest in the deployment of integrated systems that combine radars for early detection, optoelectronic and acoustic sensors for accurate identification, as well as EW (Electronic Warfare) and kinetic means (e.g., net guns) to neutralize drones at various distances. An example could be the use of a combination of Elbit ReDrone™ radar systems for detection and portable EW systems, similar to the Ukrainian Kvertus, for the direct protection of critical infrastructure objects in the housing and communal services and energy sectors.
- ***Active use of electronic warfare (EW):*** Given the effectiveness of the Ukrainian experience in using EW against enemy drones, South Korea should expand the development and implementation of its own EW systems, including both stationary complexes for the protection of large urban areas and infrastructure facilities, as well as mobile EW groups for rapid response to threats. An example could be the adaptation of the Ukrainian "Sky Hunter" development for integration with South Korean radar systems.
- ***Development of military-civilian cooperation:*** Engaging private companies and volunteer organizations in the development and implementation of counter-drone solutions, which has been successfully implemented in Ukraine, could also be beneficial for South Korea. Creating favorable conditions for cooperation between the military, research institutions, and the private sector will facilitate the rapid introduction of innovations in the field of anti-drone protection.
- ***Investment in innovative technologies:*** South Korea should support research and development of the latest counter-drone technologies, such as directed energy systems (laser and microwave weapons), as well as drone interception technologies using other interceptor drones, taking into account Ukrainian developments in this area.
- ***Involving crowdfunding platforms to finance counter-drone projects:*** Popular South Korean platforms such as Wadiz, K-Funding, or Baidu Fund could be used to raise funding for projects aimed at protecting urban infrastructure. An example could be a fundraising project for the purchase and installation of acoustic sensors for the early detection of drones in residential areas, as well as Ukrainian cases in raising funds from the public through crowdfunding platforms to support the development and implementation of innovative solutions in the field of anti-drone protection.
- ***Cooperation with K-Water and other municipal enterprises:*** Given K-Water's interest in Ukraine's reconstruction projects, including water supply and renewable energy, South Korea could involve K-Water in co-financing and implementing counter-drone protection projects for critical infrastructure facilities, including water utilities, hydroelectric power stations, and other energy sector facilities. K-Water could invest in the development and installation of drone detection and neutralization systems around its facilities, considering this as part of a comprehensive approach to ensuring their security and stable operation. In addition, given K-Water's interest in renewable energy, projects could be considered for the development and implementation of drones for

monitoring the condition of solar and wind power plants, as well as anti-drone systems for their protection, using crowdfunding platforms to attract additional funding from citizens interested in the development of "green" energy and infrastructure security.

- ***Training and preparation of specialists:*** Developing specialized training programs for the preparation of specialists in the operation and maintenance of counter-drone systems, as well as for training critical infrastructure personnel on actions in the event of drone attacks. Sharing experience with Ukrainian specialists who have practical experience in countering drones in real conflict conditions can be invaluable.
- ***Cooperation between South Korean research institutions and Ukrainian colleagues in the field of counter-drone protection:***
    - *National Aerospace University – Kharkiv Aviation Institute (KhAI):* This university has a powerful research base in the field of aviation and rocket-space technology, including the development of unmanned aerial vehicles and related technologies.
    - *National Aviation University (NAU):* NAU also has significant experience in training specialists and conducting research in the field of aviation and unmanned systems.
    - *National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" (KPI):* KPI is known for its strong engineering schools, including departments of aviation and rocket-space technology, as well as radio engineering, which is important for the development of both drones and counter-drone means (EW).
    - *Research institutes of the National Academy of Sciences of Ukraine (NAS of Ukraine):* A number of institutes of the NAS of Ukraine conduct research in related fields such as materials science, radiophysics, cybernetics, and informatics, which may be useful for the development of components and software for counter-drone systems.
    - *Kyiv School of Economics (KSE),* as a think tank, can serve as a platform for organizing professional discussions involving representatives of city authorities from both Ukrainian megacities (Kyiv, Lviv, Dnipro, Odesa), who have practical experience in countering drone attacks, and South Korean municipalities interested in implementing effective urban defense systems. In addition, KSE can leverage its existing expertise and activities in cooperation with South Korea in the field of counter-drone protection:
        - Drone industry analytics: KSE has expertise in analyzing the drone industry, which can be used to provide consulting services to South Korean government and private entities on the development of their own UAV market and counter-drone means. Joint analytical research could help identify key trends, challenges, and opportunities for cooperation between the countries in this field.
        - Cooperation in the "anti-drone wall" project with Kvertus EW backpack systems: Since KSE is already involved in this project, its representatives can share experience and knowledge on the specifics of developing, implementing, and operating long-range counter-drone

systems, which may be valuable for South Korea in creating similar systems for protecting urban perimeters or critical infrastructure.

- Holding hackathons: KSE's experience in conducting hackathons focused on the use of drones in demining may be relevant to South Korea, which may also face challenges in clearing territories from explosive ordnance. Joint hackathons could promote the exchange of ideas and the development of innovative solutions in this area.
- Training drone operators: The opening of the Faculty of Drone Operator Training indicates KSE's educational potential in the field of unmanned systems. KSE could develop joint educational programs with South Korean universities or training centers to train specialists in the operation of not only drones but also anti-drone systems.

CHAPTER 5. KEY ECONOMIC THEORIES, MODELS OF MARKETS AND UXS AND C-UXS INNOVATIVE ECOSYSTEMS

Innovation ecosystems are complex and dynamic environments in which various actors interact to stimulate innovation, accelerate the pace and scale of its implementation, and increase economic growth and competitiveness. The successful development and implementation of innovations in the field of UxS and C-UxS technologies requires the formation of an effective innovation ecosystem.

Awareness of the historical and current "balance of power" is crucial to obtain a more accurate and nuanced assessment of all stakeholders and the systemic role of the stakeholders involved, as the dynamics of stakeholder engagement are still important and serve as a source of useful "lessons learned" from historical and landmark events to build a roadmap to support the creation and growth of new businesses (especially IDEs) with social and economic benefits.

In the context of the development of the innovation ecosystem of drone and anti-drone technologies, understanding the historical background and these three theories helps to identify key success factors:

- the continuous introduction of new technologies and approaches (the theory of "creative destruction"),
- active cooperation between science, business and government (the theory of "triple helix"),
- leveraging the impact of critical, unexpected events that have played a crucial role in the development of the drone and counter-drone innovation ecosystem and continue to shape its future (the theory of "victories and defeats").

Based on these theories and the historical background, the analysis of Ukraine's unique experience in building the UxS and C-UxS innovation ecosystem emphasizes the importance of flexibility and adaptability of innovation ecosystems, especially in crisis conditions, and shows how informal initiatives can play a crucial role in technological development and national security.

5.1 Joseph Schumpeter's theory of "creative destruction"

The essence of "creative destruction" is that new innovations (new products, services, techs, markets, organizations) are not just added to the existing economy, but also destroy the old, less efficient ones. This process is continuous and necessary for economic progress. Joseph Schumpeter (1883-1950) believed that the capitalist economy does not develop evolutionarily, but through revolutionary changes caused by innovations.

As an example of Schumpeter's concept, the introduction of online food ordering services led to the closure of many traditional restaurants that could not adapt. Another instant of "creative destruction" is the emergence of self-driving taxicabs which disrupt the traditional cab market. The same trend is evident in the drone field, where the development of cheaper and more effective UAV countermeasures is leading to a decrease in the production of certain types of expensive drones that are easily shot down.

The ***five main types of innovation*** identified by Joseph Schumpeter almost a century ago are relevant to the current development of the UxS industry as well:

- *Introduction of a new product* or a new quality of an existing product: For example, the emergence of FPV drones with better flight characteristics and destruction capabilities than previous models.
- *Introduction of a new production method*: The use of 3D printing to rapidly prototype and produce drone components, which is faster and cheaper than traditional methods.
- *Opening a new market:* For instant, using drones to deliver medicines to remote or hard-to-reach areas, thus creating a new market for services.
- *Gaining a new source of raw materials or semi-finished products*: Although less relevant to drones, an example is the development of new, lighter and stronger materials for drone body parts that replace traditional ones.
- *The introduction of a new organization* of any industry, such as the creation or elimination of a monopoly: For example, the emergence of large platforms that bring together drone manufacturers, component suppliers, and end users, changing the market structure.

5.2 Henry Itzkowitz's and Loic Leidesdorff's theory of "triple helix"

The triple helix theory, developed by Henry Itzkowitz and Loic Leidesdorff, argues that innovation arises from the intense interaction between ***three key institutional forces:***

- *Universities (academic science):* Generate new knowledge, conduct basic and applied research, and train qualified personnel.
- *Business (Industry):* Implements scientific developments in production, commercializes innovations, creates new products and services.
- *Government (Public Authority):* Creates an enabling environment for innovation through legislation, funding, infrastructure support, and fostering collaboration between universities and businesses.

This theory emphasizes that an innovation ecosystem is most effective when these three constituent elements actively exchange information, resources, and experience, and the boundaries between them become more blurred, facilitating hybrid forms of cooperation.

However, in the case of Ukraine, precisely since the beginning of the full-scale Russian military aggression, the government function of providing financing for the drone industry from the state budget and financing from corporate capital has been taken over by crowdfunding platforms and philanthropic associations, the market share of industrial manufacturers and the business sector has been filled by mass artisanal drone production, instead of productive-technical laboratories and research universities, drone innovations are delivered to UAV operators of the Ukrainian Armed Forces from hand-made labs in the basements of residential buildings and mini-accelerators in household utility rooms and car garages.

As a result, in Ukraine, there is a massive emergence of small groups assembling FPV drones from available components and sending them to the frontline. Volunteer

groups are modernizing commercial drones for military use. Garage laboratories are developing their own drone control software or tools to counter enemy UAVs. Universities are creating their own start-ups based on their UAV developments (e.g., new sensors for drones), attracting investment from the private sector to produce them and integrate them into commercial products. Businesses are turning to universities to solve complex technical problems in the field of drone countermeasures, and the government is facilitating this partnership through tax incentives, as well as early development support and further funding through grant programs.

Thus, due to the unique Ukrainian experience, the generally accepted theory of the "triple helix" has been upgraded and expanded by including these three dominant layers of "sub-stakeholders" as critical elements for the existence of a domestic drone innovation ecosystem. They closely interact with both the military (in fact, as a direct customer) and universities (involving students and graduates, using their knowledge), and receive further support from an extremely wide range of Ukrainian citizens and small and medium-sized private businesses in the form of not only money, but also the supply of components and software.

Distinctive features of the "triple helix" theory in the Ukrainian context:

- *Responsiveness and flexibility:* Unlike large corporations and sometimes bureaucratic state institutions, these informal associations and individual enthusiasts demonstrate an extraordinary speed of response to the needs of the frontline. They are able to quickly prototype, test, and implement new UAV and counter-drone solutions.
- *Low entry threshold and high motivation:* The creation of such projects often does not require significant financial investments at the initial stage. The main driving force is patriotism, the desire to help the military, and engineering enthusiasm.
- *Direct connection with needs:* Most of the newly emerging sub-stakeholders of the drone ecosystem in Ukraine are in direct contact with the military on the front line, receiving instant feedback, bypassing the bureaucracy of the Ministry of Defense and quickly adapting their developments to the realities of combat operations.
- *Utilization of available resources:* Due to financial and time constraints, these sub-stakeholders focus on using the lowest possible cost components and minimal time for their production and assembly of drones, and constantly find additional potential in the already established drone ecosystem through innovative solutions and identifying hidden technical debts to maximize the use of available resources.
- *Incubator and gas pedal function:* Although formally these sub-stakeholders are mostly not even legally registered as incubators or accelerators, in fact they fulfill their role by providing a platform for the rapid development of ideas and technologies that can then be picked up and scaled up by larger companies or government agencies in Ukraine and abroad.

5.3 Andre Sorenson's theory of "victories and defeats"

For an understanding of the dynamics of the formation and development of the innovative ecosystem of drone and anti-drone technologies in Ukraine, it is important to take into account the historical balance of past and current challenges, as well as their common dependence.

An analysis of the theory of "victories and defeats" outlined by University of Toronto professor Andre Sorenson in his research paper "Planning History and Theory" (2018) allows us to identify events that occurred outside the predicted models or plans, but had a significant impact on the formation of the ecosystem, its participants and key players (Dedehayir, Makinen & Ortt 2016).

The main principle of this theory is to identify not only patterns and planned steps, but also unexpected "victories" and "defeats" that arose outside the foreseen coordinate system but radically changed the trajectory of the innovation ecosystem.

Silicon Valley is an example of the theory of "victories and defeats", presented in the framework “MIT's Stakeholder Framework for Building & Accelerating Innovation Ecosystems” by Dr. Phil Budden (MIT Sloan School of Management) and Prof. Fiona Murray (MIT Sloan School of Management MIT Innovation Initiative).

The success of this innovation center is largely due not only to planned actions (government support, investment in universities) but also to random factors and unpredictable "wins" (e.g., key technological breakthroughs in certain universities) and "losses" (disappearance of certain technologies or companies).

It has emerged as a driver of the innovation economy with steadily increasing profits for many decades as a result of a combination of forecasted events, as well as “lucky and not so lucky” accidents.

Similarly, the *unexpected and unprovoked full-scale Russian military aggression of February 24, 2022*, played a key role in the rapid development and accelerated growth of the innovative ecosystem of drone and anti-drone technologies in Ukraine. This event became a powerful catalyst that, although tragic, led to the rapid mobilization of engineering and entrepreneurial potential, as well as to the reorientation of resources to the development and production of UAVs and countermeasures.

The immediate ban on civilian air traffic in Ukraine after the beginning of the full-scale Russian invasion invasion, as well as its first initial wave, which caused significant damage to Ukraine's limited air force, and essentially forced Ukraine to destroy its own airfields, such as the Hostomel airport, also created unique conditions for the development and use of unmanned systems.

These events are examples of unexpected "defeats" (war aggression and prohibition of air traffic) and "victories" (rapid adaptation and innovative response) that have dramatically affected the formation of the ecosystem.

Also, Nobel Laureate 2024 James Robinson emphasized that threat and uncertainty of war can be Ukraine’s advantage, while the South Korea and Taiwan have achieved economic breakthroughs not because of peace, but of the constant risk of a new invasion [93].

5.4 Key model of UAS market innovative development in the world

The global development of the unmanned aerial systems (UAS) market is a complex process that requires concerted efforts from the government, the private sector, research institutions, and investors. The economic efficiency of the chosen development model determines the growth rate of the industry, its international competitiveness, and the ability to meet the needs of society for safety and innovation. For Ukraine, which seeks to build an innovative ecosystem in the field of drone and anti-drone technologies, the best option may be to combine different models, taking into account its own strengths and weaknesses, as well as world best practices.

State support: Government support plays a key role in stimulating the development of the UAV market, especially at the initial stages. The cost-effectiveness of government initiatives can take many forms:

- *Direct funding for research and development (R&D):* Providing grants and subsidies to scientific institutions and private companies for basic and applied research in the field of UAVs can lead to the creation of breakthrough technologies and innovative products with high added value. For example, the US is considering the DRONE Act of 2025, which aims to expand federal grants to law enforcement agencies for the purchase of drones, indicating government support for the development of the market for non-military applications [1].
- *Creating a favorable regulatory environment:* Simplifying the procedures for certification, registration and use of drones, and developing clear and transparent flight rules help reduce administrative barriers and stimulate the growth of UAV operators and manufacturers. In Indonesia, for example, it is expected that with clear regulation, the use of drones in various sectors (logistics, agriculture, infrastructure) will be streamlined, supporting the growth of the digital economy [2].
- *Public procurement:* As the first major customer, the state can ensure a stable demand for the products of domestic UAV manufacturers, providing them with the opportunity to scale up production and attract investment.
- *Tax benefits and incentives:* Providing tax incentives for UAV companies can reduce their operating costs and increase the investment attractiveness of the industry.

Private investment: Attracting private investment, especially in the early stages of startup development, is critical for the commercialization of innovative ideas and the rapid growth of UAV companies. The economic efficiency of this model depends on many factors:

- *Availability of promising technologies and business models:* Investors are interested in financing companies that develop unique and competitive technologies and have a clear strategy for entering the market and generating profits. An example is the Indian drone startup Garuda Aerospace, which has raised $11 million in Series B investment, which indicates a significant interest of private investors in promising companies in this sector [3].

- *Favorable investment climate:* Stable economic situation in the country, protection of investors' rights, availability of developed infrastructure and skilled labor force contribute to attracting private capital to the UAV industry.
- *Opportunities for scaling up and entering international markets*: Investors are looking to invest in companies with the potential for rapid growth and global expansion, which provides a high return on investment. Tekever, a Portuguese UAV startup, has raised €70 million in investment from funds backed by SpaceX and NATO to further develop its products and expand globally [4].

Public-private partnership (PPP): The PPP model involves combining the resources and expertise of the public and private sectors to implement joint UAV projects. The cost-effectiveness of PPPs can be high due to:

- *Risk and cost sharing:* The partnership allows for the distribution of financial and operational risks between public and private partners, reducing the burden on each of them individually.
- *Attracting private capital and innovation:* PPPs allow to attract private investment and advanced technologies to solve important governmental tasks in the field of UAVs. An example of an effective PPP is the cooperation in South Africa, where private companies offer their systems to modernize military Rooivalk helicopters, demonstrating how joining forces can lead to the revitalization of existing weapons [5].
- *Increase the efficiency of project management:* Involving the private sector with its expertise in business process management can contribute to more efficient implementation of UAV projects.

International cooperation: International cooperation is an important factor in the development of the UAV market, especially for countries that do not have the full range of necessary technologies and resources. The cost-effectiveness of international cooperation can be manifested through:

- *Knowledge and technology sharing:* Participation in joint research projects, exchange of experts and technological solutions help accelerate the innovation process and reduce R&D costs. The European Drone Collaboration (EDC) is an example of an initiative aimed at promoting innovation and commercialization of drone technologies in Europe [6].
- *Attracting foreign investment:* Cooperation with foreign companies and investors can provide access to additional financial resources for the development of the UAV industry.
- *Access to international markets:* Partnerships with foreign companies and participation in international projects can open up new markets for domestic UAV manufacturers. RTI International, for example, is exploring the possibility of using commercial drones for various research projects, which shows the potential for international cooperation in this area [7].

The effectiveness of each of the UAV market development models under consideration depends on many factors, including the specifics of the national economy, the level of development of the technological base, political stability, and the availability of qualified personnel.

5.5 The needs and conflicts of interest among UAV/C-UAV industry stakeholders

In an innovation ecosystem, potential conflicts of interest inevitably arise between different stakeholders and sub-stakeholders, which requires the development of possible mechanisms to address them in order to offset their negative impact on the entire ecosystem. For example, between the desire of private companies to maximize profits and the need to ensure the availability of technologies for public needs. There may also be conflicts between the state's desire to control the market for security reasons and the desire of businesses to have more freedom to innovate, or the desire of media and crowdfunding platforms to engage the widest possible audience despite the risk of information leakage.

Table 14. Framework of stakeholder interests in the UAV/C-UAV industry

NEEDS **STAKEHOLDERS**	**ECONOMIC**	**SOCIAL**	**ENVIRONMENTAL**
The state (represented by the Ministry of Defense, the Ministry of Digital Transformation, the Ministry of Economy, the State Aviation Service of Ukraine and other agencies)	Ensuring the country's defense capability in a cost-effective manner, stimulating the development of high-tech industries, creating new jobs, and attracting investment.	Ensuring the safety of citizens and critical infrastructure, supporting war veterans through retraining and employment programs, minimizing the negative impact of military operations on the civilian population, taking into account public opinion on the use of drones.	Ensure environmental safety in the use and production of drones, support developments aimed at minimizing environmental impact.
Private companies developing and producing UAVs and counter-drone systems	Access to financing (investments, loans, government grants), support for entering domestic and international markets, protection of intellectual property, favorable regulatory environment and simplifying bureaucratic procedures.	Opportunity to realize innovative potential, contribution to strengthening the country's defense capabilities, creation of high-tech jobs, attraction of qualified personnel.	Support for developments aimed at reducing energy consumption and the use of environmentally harmful materials in the production of drones.
Investors (risk capital, angel investors)	High return on investment, minimization of risks, clear mechanisms for exiting investments, market predictability.	Participation in the development of promising technologies, support for innovative entrepreneurship, contribution to national security and the strategic importance of investments in the drone industry.	Support for investments in green technologies and projects that have a positive impact on the environment.
Research institutions and educational institutions	Financing of research (government grants, private investment), commercialization of research results, attraction of talented students and researchers.	Development of science and education in Ukraine, training of highly qualified personnel for the UAV industry, participation in solving important social and economic problems of the country.	Conducting research in the field of clean energy for drones, development of eco-friendly materials.

Volunteer organizations and public initiatives	Raising charitable funds to support the development and purchase of drones for the military.	Active participation in the defense of the country, support for innovation from below, prompt response to the needs of the frontline.	Ensuring environmental safety when using drones, raising public awareness of environmental aspects.
Media	Attracting an audience, generating revenue from advertising and affiliate programs.	Informing the public about the development of UAV technologies and anti-drone systems, shaping public opinion, supporting innovative entrepreneurship.	Coverage of environmental aspects of drone use and their impact on the environment.
End users of technologies (military, civilian population, critical infrastructure enterprises)	Access to efficient and cost-effective solutions for security and various tasks.	Ensuring personal and collective safety (especially in urban environments), protecting critical infrastructure, improving quality of life.	Use of environmentally friendly technologies, minimization of negative environmental impact.

5.6 Structure of the innovation ecosystem, algorithms of collaboration and coordination mechanisms

The successful functioning of the ecosystem requires identifying and developing mechanisms to resolve the conflicts of interests through dialogue, compromise, and clear rules of the game for all participants. The proposed model is a dynamic system of interconnected elements, each of which plays an important role in stimulating innovation and ensuring its successful functioning:

Coordination center: A key element of the ecosystem should be a Coordination Center (possibly integrated into the structure of the Unmanned Systems Force or established within the Ministry of Digital Transformation). Its main functions will be:

- Developing and updating a strategy for the development of drone and anti-drone technologies at the national level, taking into account the needs of both the military and civilian sectors.
- Formation and implementation of a regulatory policy aimed at stimulating innovation, ensuring the safety of drone use and supporting domestic producers.
- Coordination of efforts of all ecosystem stakeholders, including government agencies, private companies, research institutions, educational institutions and public organizations.
- Promoting international cooperation in the field of knowledge and technology exchange and investment attraction.
- Monitoring and evaluation of ecosystem performance.

Innovation support centers: A network of innovation support centers, including business incubators, accelerators and technology parks, will play a key role in supporting startups and innovative companies:

- Providing mentoring support and expert advice on technological development, business planning, investment attraction and market entry.

- Providing access to infrastructure (office space, equipment, software) on preferential terms.
- Organizing educational programs, trainings and seminars to improve the skills of developers and entrepreneurs.
- Facilitating contacts with investors, potential partners and clients.

Test sites and open laboratories: Creating a specialized infrastructure for testing and trialing new developments is a prerequisite for their rapid deployment:

- Organization of test sites with different terrain conditions and means of simulating real threats.
- Creation of open laboratories with access to modern equipment and software for developers.

Educational and research clusters: Cooperation between universities, research institutions, and businesses is the key to training highly qualified personnel and conducting cutting-edge research:

- Development and implementation of joint educational programs in the field of drone and anti-drone technologies (taking into account the list of specialized programs of Ukrainian universities).
- Establishment of joint research laboratories and centers.
- Involvement of undergraduate and graduate students in real innovative projects.

Funds for financing: An extensive system of funding funds is critical to support innovation at different stages of development:

- *Public funds:* Provide funding for basic and applied scientific research, as well as support for strategically important projects in the field of national security.
- *Private investment funds:* Raising venture capital and angel investments to finance startups and early-stage companies.
- *Charitable foundations and crowdfunding platforms:* Support projects aimed at solving socially significant problems and meeting urgent needs (especially in times of war).

Cooperation platforms: To ensure effective communication and interaction between ecosystem participants, it is necessary to create an extensive network of cooperation platforms:

- *Online platform:* A web portal that provides access to information about all ecosystem participants, their projects and needs, as well as tools for finding partners, sharing experiences and organizing online events.
- *Offline platforms:* Regular thematic forums, conferences, workshops, and roundtables to establish personal contacts, discuss current issues, and present new developments. Hackathons like the “Building for Ukraine” at MIT (where you participated) should become a regular tool for generating innovative ideas and forming new development teams.

“Bridge makers”

“Bridge makers” are organizations and individuals that play a role of a link between different elements of the ecosystem, ensuring their effective exchange of information, knowledge and resources (based on the concept from the study “The Role of Bridge in Innovation Ecosystems”). This category includes specialized consulting

companies, industry associations, and individual experts. These “bridge makers” are crucial for the evolution of the innovation ecosystem, as they support and develop the processes of internal and external interconnections by:

Regular meetings and dialogues: Introduce the practice of regular meetings and strategic sessions involving representatives of all elements of the ecosystem (government, business, academia, investors, and the public) to discuss key issues, identify problems, and find common solutions.

- *Establishment of joint working groups:* Formation of interagency and cross-sectoral working groups to develop specific projects, address regulatory issues, and coordinate actions.
- *Encouraging public-private partnerships:* Creating favorable conditions for the implementation of projects based on public-private partnerships with a clear distribution of responsibilities and risks.
- *Use of cooperation platforms:* Active involvement of all stakeholders in the use of online and offline platforms for communication, exchange of ideas, and search for partners.

5.7 Strategizing the UxS and C-UxS innovation ecosystem

Based on the provisions and requirements for building an innovation ecosystem model, the author of the paper has developed the strategy of innovative ecosystem of UAV and anti-drone technologies with the potential scaling of its functioning at the global level, launching from a media campaign and crowdfunding - through cooperation with the national and global scientific and political environment - to the formation of an international production network and its listing and quotation on European and global stock exchanges.

The rapid development of drone technology and the delay in establishing rules for its use lead to its uncontrolled use, including by criminal and terrorist groups. This should be counteracted by the advised development of anti-drone technologies, but the pace of their introduction and dissemination does not cover the challenges faced by mankind at all.

So, global organizations that support Ukraine in the war against Russia, particularly in the field of UAVs, are interested in financing this project. These are NATO and its defense innovation agencies DARPA and DIANA, as well as the Drone Coalition consisting of Great Britain, the United States of America and Latvia. In addition, Lithuania also supplies its unmanned systems to Ukraine. And the global university research environment is definitely most interested in the formation of a unified innovation ecosystem of drone and anti-drone technologies, as technology parks, hi-tech incubators and accelerators are the most profitable places to invest in for their further implementation at the global level.

This unified innovation ecosystem of drone and anti-drone technologies will be funded by both businesses and non-profit organizations. In particular, crowdfunding system, which collects donations from all people of the world, and global organizations that support Ukraine in the war against Russia, as well as various and specialized non-governmental organizations, philanthropic foundations, industrial associations and chambers of commerce and industry.

Turning to the business sector, it is clear that the same risk capital, venture capital funds and angel investors are interested in establishing a unified innovation ecosystem for drone and anti-drone technologies around the world, as well as corporate capital, which needs to protect its facilities, its fixed assets and working capital. Also, private business, which before the war used UAVs very extensively, now also has to use anti-drone technology to protect itself from possible attacks by random UAVs, criminal UAVs or terrorist UAVs or military. Traditional stock exchange investors will also invest in this project, taking into account last year's growth of anti-drone companies' share prices of more than 300%, and twice as much in the first half of this year alone - more than 600%.

The ultimate beneficiaries of the implementation of this innovative ecosystem of drone and anti-drone technologies will be the target categories:

- the largest category is the civilian population, which requires safety from possible attacks by military and criminal forces or accidental dangerous drones,
- the public sector, which is responsible for the security of strategic public infrastructure networks, enterprises, and facilities,
- special services and law enforcement agencies fighting and preventing the activities of organized terrorist and critical groups
- corporate capital and business sector that needs to protect its investments and preserve fixed and working capital
- angel investors, venture capital and developers of advanced technologies in the field of UAVs and anti-drone technologies.

Media, pushing, targeting, crowdfunding and data-analysis

Thus, at the initial stage, sustainable financing of the innovative ecosystem of drone and anti-drone technologies in Ukraine is ensured through the synthesis of the media and crowdfunding components: its media products are distributed in Ukraine, Europe and the world, each of which is accompanied by links to the crowdfunding platform and calls for donations to support the innovative ecosystem.

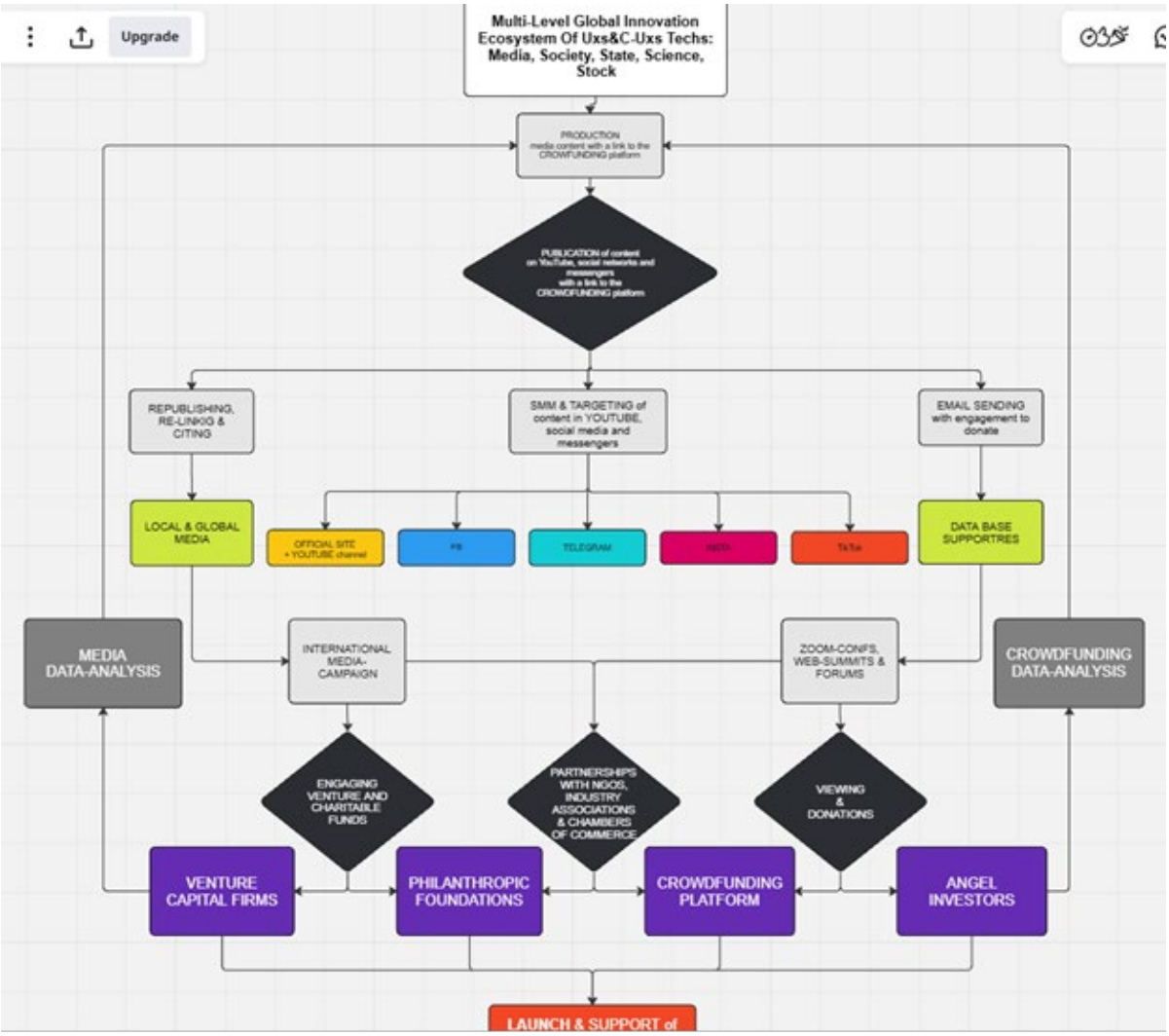
The initial publication of the produced content takes place on the official website of the innovation ecosystem project, the official YouTube channel, in groups in messengers and on social media profiles.

The next stage is SMM, which ensures the distribution of media products through various communication channels to a wide target audience: subscribers of messenger and social media groups, participants of pre-themed ZOOM conferences, web panels, forums and summits.

Personalized targeting of the potential donor audience is carried out by automatically sending emails (generated by AI) to the email addresses of the personalized database of Ukrainian supporters compiled by data analysts.

The distribution of media products to the global audience is carried out within the framework of memorandums of cooperation with international media (Poland, Lithuania, France, Canada, the United States, the United Kingdom) and global news agencies (Reuters, CNN, BBC News, Associated Press (AP), Agency France-Presse (AFP), Al Jazeera).

Fig. 29. MIRO project of multi-level model of UxS/C-UxS innovative ecosystem



Analytics of the distribution of media products and the effectiveness of their impact on target audiences, as well as the volume and sources of donations, donor characteristics, and their feedback are studied by in-house data analysts, whose findings are used to adjust the communication strategy and crowdfunding campaigns to support the innovative ecosystem of drone and anti-drone technologies in Ukraine.

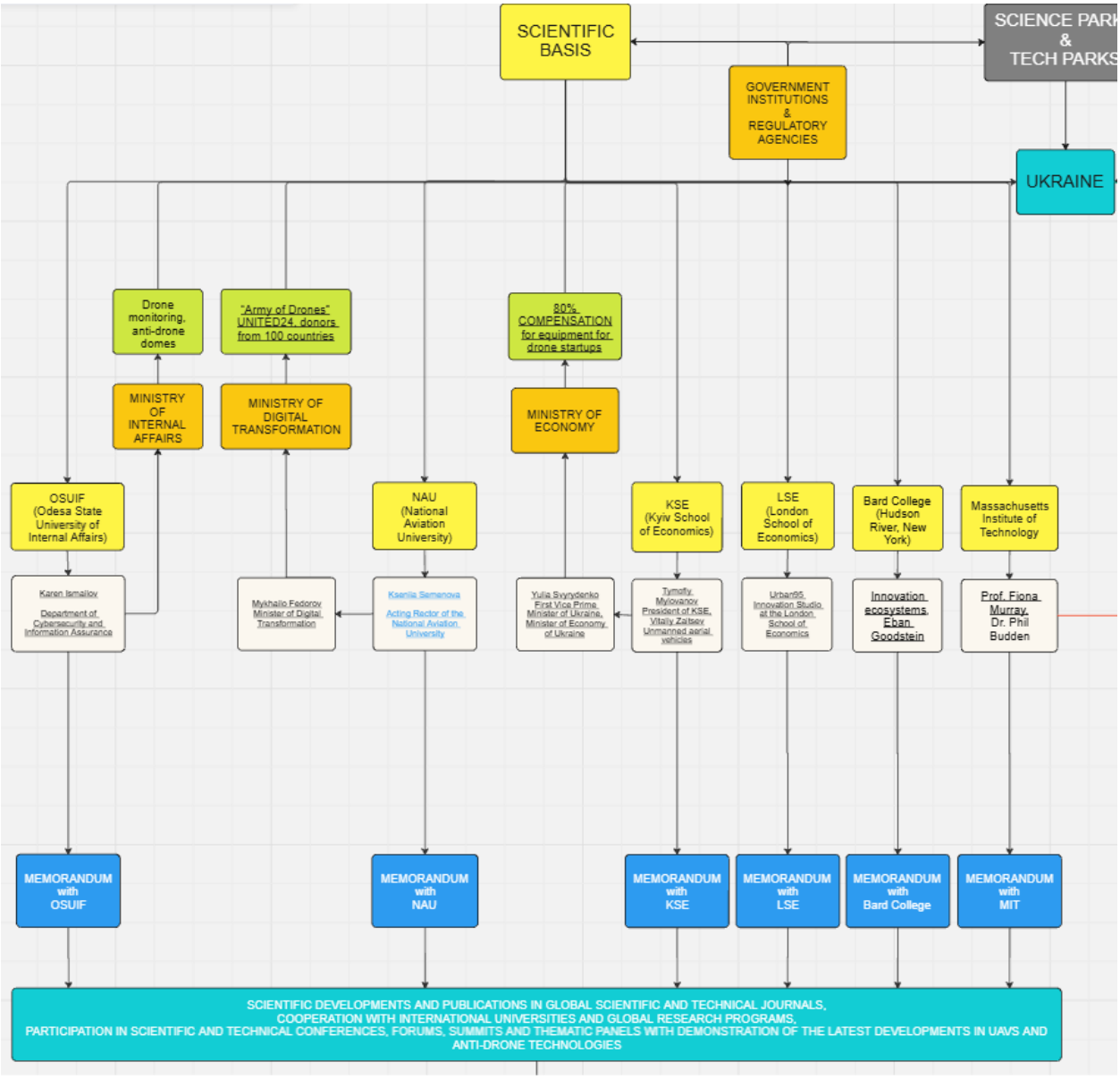
Tech incubators & accelerators, science parks & tech parks

The preliminary development of the production cycle is based on the practical experience of other market participants and scientific research and analysis of drone/anti-drone technologies from leading higher education institutions in Ukraine and the world:

- National Aviation University, namely the Lab418 engineering laboratory, which is engaged in the modernization and development of UAVs and related technologies;
- Odesa University of Internal Affairs, namely the Department of Cyber Security and research on the use of AI in anti-drone systems;

- Kyiv School of Economics, namely the master's program “Unmanned Aerial Vehicles” under the supervision of Vitalii Zaitsev;
- Massachusetts Institute of Technology, namely the joint study “Building & Accelerating Innovation Ecosystems” on the status-quo, challenges and prospects of the drone/anti-drone technology industry in Ukraine;
- Bard College (Hudson River, New York), namely the international study “Urban-based innovation ecosystems” curated by Eban Goodstein;
- London School of Economics (the Urban95 project and the postgraduate program),
- AGH University of Science and Technology (Kraków, Poland), namely the Cybersecurity Center & Kraków DIANA Accelerator;

Fig. 30. MIRO project of multi-level model of UxS/C-UxS innovative ecosystem



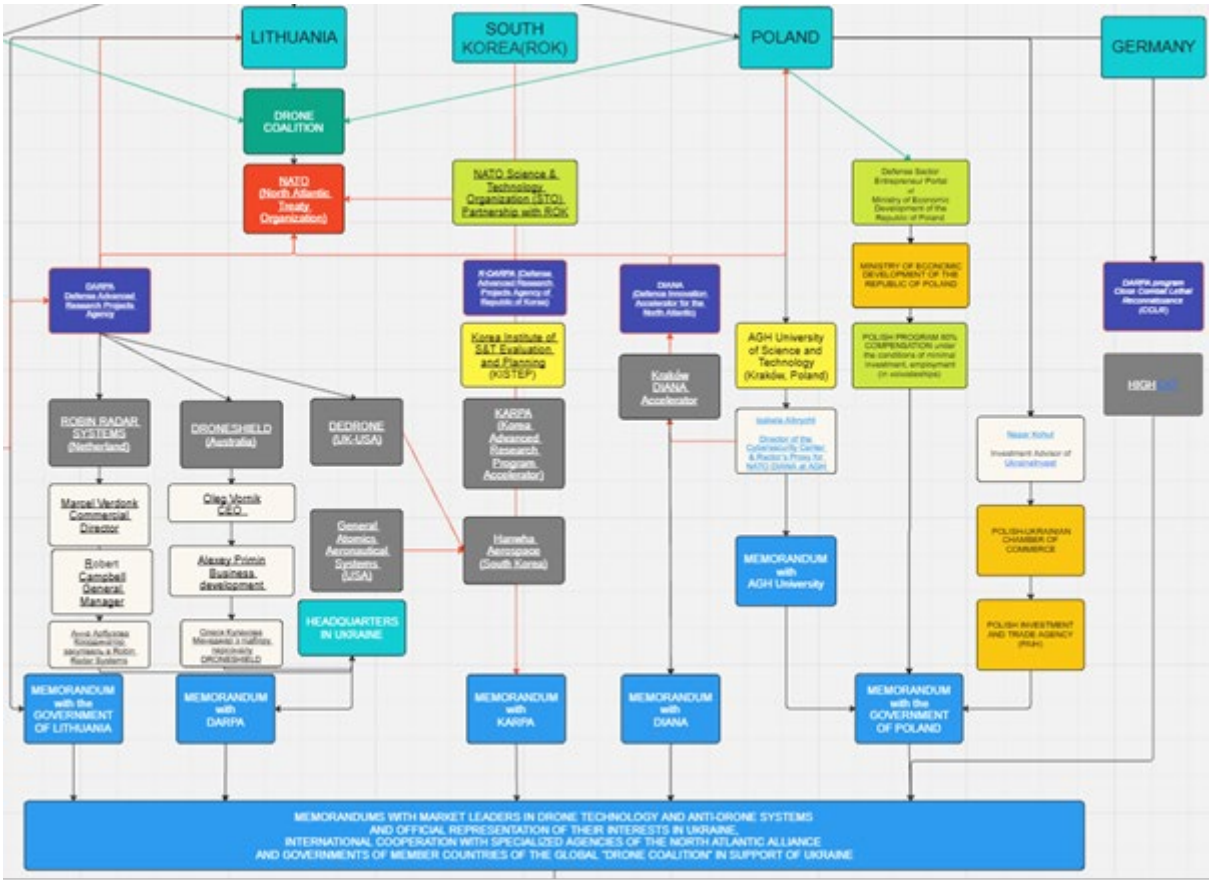
Scientific cooperation with the above-mentioned educational institutions, their faculty and management provide the founders of the innovative ecosystem of

drone and anti-drone technologies in Ukraine with a basis for concluding memorandums and framework agreements on cooperation with relevant state and international bodies and institutions:

- The Ministry of Internal Affairs of Ukraine (on ensuring drone surveillance of the crime situation in the Odesa region and the construction of anti-drone complexes over megacities);
- The Ministry of Economy of Ukraine (regarding the state program for compensation of 80% of the costs of purchasing equipment for drone startups);
- the Ministry of Digital Transformation (on joining the Army of Drones program and the UNITED24 crowdfunding platform with donors from more than 100 partner countries);
- Specialized and authorized agencies for defense innovation DARPA and DIANA (on cooperation with Lithuania within the global association of partner countries "DRONE COALITION" and participation in the NATO international program "One Million Drones for Ukraine").

Along with her representation in the DIANA Krakow Defense Innovation Accelerator, Izabela Albrycht is the director of the Center for Cybersecurity at the AGH University of Science and Technology in Krakow, whose scientific cooperation will further facilitate the conclusion of a memorandum with the Polish government and the involvement of 80% of the costs of establishing drone startups in certain voivodeships of the country (subject to the minimum required amount of investment and local employment).

Fig. 31. MIRO project of multi-level model of UxS/C-UxS innovative ecosystem



G-sector collaboration and international compensation policies

The developed strategy also includes an algorithm for the implementation of the Ukrainian innovation ecosystem of UAV/drone defense technologies into the global specialized association of states in support of Ukraine within the Drone Coalition and, through the specialized and authorized defense innovation agencies DARPA and DIANA, into the NATO North Atlantic Alliance.

The main communication strategy is based on the synthesis and parallel development of the production and research base with personalized contacts of decision-makers in both industries. In addition to promotion in the scientific, technical and political spheres, this strategy provides for specific corporate solutions for the innovative ecosystem of drone and anti-drone technologies in Ukraine: from compensatory mechanisms of co-financing (cost coverage) through government programs of partner countries (Ukraine, Poland and Lithuania) to industrial and financial cooperation with leaders of the drone/anti-drone industry and attraction of international investment through listing and subsequent IPO on global exchanges.

Expansion growth peak & headquarters in Ukraine

Given the staggering growth of stock prices of anti-drone companies (over 600% in the first half of this year and over 300% for the entire last year - DRONESHIELD), the innovation ecosystem development strategy includes profiles of contacts (natives of Ukraine) who work for the leaders of the anti-drone sector and are interested in officially representing their employers in Ukraine:

- Australian company “DRONESHIELD” (contact person - recruitment manager Olesya Kulakova, graduate of the National Aviation University);
- British company DEDRONE (contact person - Oleksiy Prymin, Business Development Manager, a graduate of the Kyiv Polytechnic Institute);
- Netherlands company “ROBIN RADAR SYSTEMS” (contact person - procurement coordinator, graduate of the Ukrainian State University of Science and Technology Anna Arbuzova).

From mass promo campaigns to listing and IPO on stock exchanges

Public coverage, media support in Ukrainian, Polish, Lithuanian, European and global media, as well as crowdfunding support as part of the strategy for building an innovative ecosystem of drone and anti-drone technologies in Ukraine is provided for each of its stages, the key ones being:

- scientific developments and publications in global scientific and technical journals,
- cooperation with international universities and global research programs,
- participation in scientific and technical conferences, forums, summits and thematic panels with demonstration of the latest developments in UAV and anti-drone technologies
- memoranda with market leaders in drone technology and anti-drone systems,
- official representation of their interests in Ukraine,

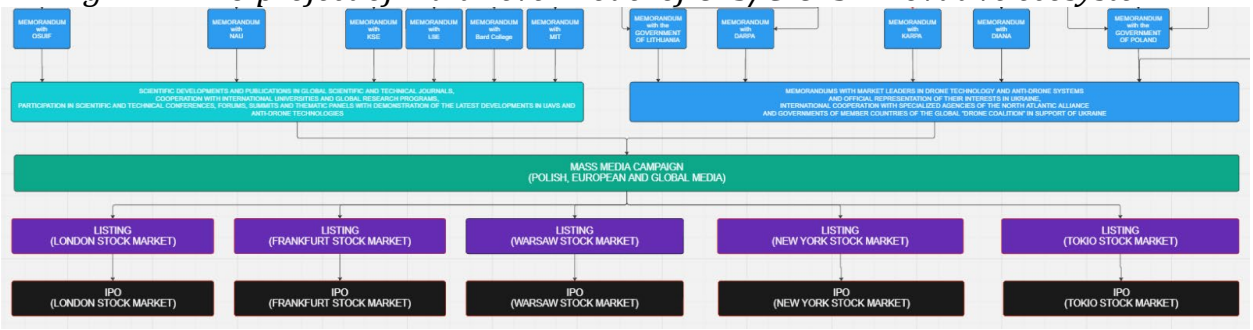
- international cooperation with specialized agencies of the North Atlantic Alliance and governments of countries that are members of the global “Drone Coalition” in support of Ukraine.

The above-described media and crowdfunding strategy in the EU, in cooperation with the Polish government (through collaboration with the AGH University of Science and Technology in Krakow and the Krakow Accelerator of the Defense Innovation Agency DIANA), allows us to use the potential of the Warsaw Stock Exchange for the innovative ecosystem of drone and anti-drone technologies in Ukraine, which over the past six months has become a global leader in gambling, displacing the New York Stock Exchange from the top position in this area.

The Warsaw Stock Exchange is of great interest to the gambling industry because of the Ukrainian computer games Cossacks and S.T.A.L.K.E.R. “ of the Ukrainian private company GSC Game World, as well as the Vital Engine and X-Ray Engine developed by it and the studios Deep Shadows, 4A Games, Vostok Games, Union Studio, West-Games, Flying Cafe for Semianimals, and the games Venom, Metro 2033, Survarium, Fear the Wolves, Cradle developed by its natives.

Know-how projects from other areas of the Ukrainian economy, such as the high-tech drone and anti-drone industries, also have a huge potential for attracting investment through stock trading on the Warsaw Stock Exchange. However, this option is currently used only by Ukrainian farmers, whose shares have experienced a drop in prices in the past year and the first half of 2024. At the same time, shares of anti-drone companies and drone holdings on the stock markets are showing growth. If the activity is related to the war in Ukraine, it is higher than the market average. For example, compared to the 15% growth in the shares of the world leader Amazon, the shares of Aero Environment rose by almost 100% (from $118 to $219) in the first six months.

Fig. 32. MIRO project of multi-level model of UxS/C-UxS innovative ecosystem



The international innovative ecosystem of drone and anti-drone technologies, in cooperation with Ukrainian, Polish and Lithuanian government agencies and global research institutions, as well as world leaders in the field of anti-drone technologies and defense innovation agencies of the North Atlantic Alliance and the global drone coalition of partner countries, has an unprecedented potential to enter the Warsaw Stock Exchange. Further prospects for attracting investment in the European Union include the listing of the above-mentioned innovative ecosystem of drone and anti-drone technologies on the Frankfurt Stock Exchange, in the Asian region - on the Tokyo Stock Exchange, and on the American continent - on the New York Stock Exchange.

Digital solution and AI software

As a technological solution for the implementation of the developed strategy, I see AI software that includes thousands of datasets and millions of individual insights, comprehensive data, research and insights covering the global public and private capital markets in the UAV sector. In particular, through the synthesis of two software applications adapted to the goals of the strategy: the first is an analogue of the PitchBook platform (since 2016, part of Morningstar) for startups and innovations in the field of UAS, and the second is an analogue of Muck Rack with a global database of contacts and the ability to thematically select by tags all possible categories of stakeholders of the supplemented MIT framework of the UAS innovation ecosystem.

Prospects

The proposed strategy for the development of the innovation ecosystem is comprehensive and covers all the key aspects necessary for the successful development of unmanned and anti-unmanned technologies in Ukraine. Its implementation will require concerted efforts by all stakeholders from different countries, as the innovative ecosystem of AI UAVs will become a full-fledged part of the noosphere, especially urban settlements and agglomerations, where, according to the World Bank, 70% of the world's population will live by 2050. That is why the development of unmanned and anti-unmanned technologies is now a priority for the governments of most advanced countries. Among them are the United States of America, Canada, and the United Kingdom. The entire post-Soviet space faces threats from the Russian Federation, as well as North Korea's drones for the Republic of Korea, as the largest and longest-lasting confrontation with UAVs in the Asian region.

CONCLUSIONS

The conducted research allowed for an in-depth analysis of the formation and development process of the innovative ecosystem of drone and counter-drone technologies for ensuring comprehensive UxS urban defense, with a particular focus on the experience of Ukraine and the possibility of its application in South Korea. Given the increasing threat of using unmanned aerial vehicles for military and terrorist purposes, as well as for illegal activities, the issue of effective protection of the urban environment is becoming extremely important for ensuring national security and sustainable city development.

The analysis of global experience showed that regulatory systems in the field of drone and counter-drone technology usage vary significantly across different countries, reflecting their specific needs and the level of industry development. However, a common aspiration is to ensure airspace security, protect the privacy of citizens, and stimulate innovation. The economic efficiency of different UAV market development models depends on a combination of government support, private investment, public-private partnerships, and international cooperation. The social consequences of drone use include the impact on the labor market, issues of privacy and security, as well as the formation of public opinion and ethical norms.

The study of the Ukrainian context revealed a rapid development of the UAV market, driven by military aggression. Ukraine has demonstrated a significant capacity for innovation and rapid technology adaptation, but faces challenges such as dependence on foreign components and bureaucratic obstacles. At the same time, a unique feature of the Ukrainian drone ecosystem is the extraordinary importance of crowdfunding platforms as a flexible and rapid source of funding. In the context of military aggression, when state procurement did not always keep pace with the urgent needs of the front, it was crowdfunding initiatives, such as Serhiy Sternenko's "RUSORIZ" project, that ensured the rapid flow of funds for the development, procurement, and modification of critical technologies, particularly means of countering enemy drones. This experience demonstrates the enormous potential of direct public involvement in supporting innovation in the field of national security and defense.

Another unique phenomenon of the Ukrainian innovation ecosystem was the massive emergence of artisanal UAV production and "garage drone cooperatives." These informal associations of enthusiasts, engineers, and technical specialists effectively played the role of drone tech incubators and accelerators. Operating with high speed and flexibility, they promptly responded to the needs of the front, developing and improving FPV drones, ammunition dropping devices, and other innovative solutions without complex bureaucratic procedures. These "garage drone cooperatives" became a kind of technology park in the initial stages, ensuring rapid iteration of developments and their practical application on the battlefield.

The uniqueness of these sub-stakeholders lies in their ability to effectively establish cooperation between different sectors. Crowdfunding platforms provide a financial bridge between society and developers, while artisanal production and "garage cooperatives" often become a link between the scientific sector (involving students and young scientists), the public sector (through direct requests from the

military), and the corporate sector (providing small and medium-sized businesses in the field of high technology).

It is this dynamic and flexible ecosystem, where volunteer initiatives and informal associations play a key role, that has significant potential for establishing closer cooperation between the scientific community, the state, and the corporate sectors. The speed and innovation inherent in these sub-stakeholders can become a catalyst for the commercialization of scientific developments and the implementation of advanced technologies in production.

Designing an innovative ecosystem for UxS urban defense requires taking into account the needs of all stakeholders and creating effective mechanisms for coordination and cooperation. The proposed model includes a Coordination Center, cooperation platforms, innovation support centers, funding funds, educational and scientific clusters, and test ranges. The implementation of policy recommendations aimed at improving the regulatory framework, stimulating innovation and investment, developing human resource potential, and ensuring the safe and ethical use of technologies is a key factor for success.

In the context of attracting investor funds on global exchanges, successful Ukrainian companies that have grown out of such artisanal productions or have been supported through crowdfunding platforms and have demonstrated high effectiveness of their technologies in real combat conditions have significant chances of attracting international investors. Their unique expertise, proven by combat experience, can become a significant advantage when entering global markets and attracting funding for further development and scaling of production, including the possibility of an initial public offering (IPO) on global stock exchanges.

Ukraine's experience is a unique example of how, in times of war, sub-stakeholders of the innovation ecosystem can play a decisive role in ensuring national security and stimulating technological development. This model, based on openness, collaboration, and rapid response to needs, can be valuable for study and adaptation by other countries, including South Korea, in their efforts to strengthen their own potential in the field of drone and counter-drone technologies.

A comparative analysis of the experience of Ukraine and South Korea in the field of counter-drone defense showed that both countries face a growing threat, but have different approaches to its solution. South Korea, with its powerful technological and economic potential, can borrow valuable Ukrainian experience, especially in the field of rapid innovation implementation, involvement of volunteer and private initiatives, and the use of flexible and effective solutions for countering drone threats.

Drawing upon Ukraine's experience in forming its current innovative drone ecosystem during the full-scale war, based on the interaction of sub-stakeholders, the creation of a multi-layered air defense system, and the organization of a network of mobile rapid air response teams, South Korea can significantly increase the effectiveness of its own air attack warning system from North Korea and counter hostile drones, as well as protect cities and settlements from the growing threats associated with the use of unmanned aerial vehicles.

However, official Seoul should also consider the experience of pre-war cooperation between official Kyiv, Tbilisi, and Tel Aviv in increasing the combat

capability of the Georgian Armed Forces through Ukrainian military equipment and Israeli drones. This particularly includes the Russian-Israeli exchange of electronic "codes" of drones supplied to the mountain republic, in exchange for "codes" to the Russian Tor-M1 anti-aircraft missile systems sold to Iran, as described in Wikileaks. It also includes Israel's refusal of military cooperation with Georgia on the eve of the Russian military annexation of South Ossetia and the initiated process in the British High Court in a lawsuit by the drone manufacturer (Elbit Systems), which, after the war, won $100 million from the Georgian state for 40 Hermes 450 UAVs supplied to it. [72]

The scientific novelty of the research lies in:

- A systematic analysis of the phenomenon of the formation of an innovative ecosystem of drone and counter-drone technologies in the context of a military conflict using the example of Ukraine.
- The development of a conceptual model of the UxS urban defense innovation ecosystem, taking into account technological, economic, social, and ethical aspects.
- A comparative analysis of the experience of Ukraine and South Korea in countering drone threats in the urban environment and the formulation of practical recommendations for South Korea based on Ukrainian experience.

The practical significance of the research lies in:

- Providing specific policy recommendations for the state authorities of Ukraine and South Korea to stimulate the development of the drone and counter-drone technology industry and ensure the security of the urban environment.
- Identifying promising areas of cooperation between Ukraine and South Korea in the exchange of experience and counter-drone defense technologies.
- Promoting investment in the development of innovative projects in the field of UxS urban defense.

Prospects for further research:

The conducted research opens new directions for further scientific exploration. In particular, promising areas include:

- Detailed study of the ethical and legal aspects of the use of autonomous drones and counter-drone systems in the urban environment.
- Research on the long-term socio-economic impact of the development of drone technologies on the labor market and urban infrastructure.
- Development of detailed models and scenarios for the application of integrated UxS urban defense systems for specific urban agglomerations of South Korea.
- Analysis of public opinion in South Korea regarding the perception of drones and counter-drone systems and its impact on the formation of relevant policies.
- Studying the possibilities of using artificial intelligence to increase the effectiveness of drone detection and neutralization systems in complex urban environments.

I hope that the results of this study will contribute to the development of an innovative ecosystem of drone and counter-drone technologies and to strengthening the security of the urban environment in both Ukraine and South Korea, as well as all over the world.

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APPENDICES

Fig. 1. Ukrainian Air Force statistical data on daily Russian air attacks (bar chart)

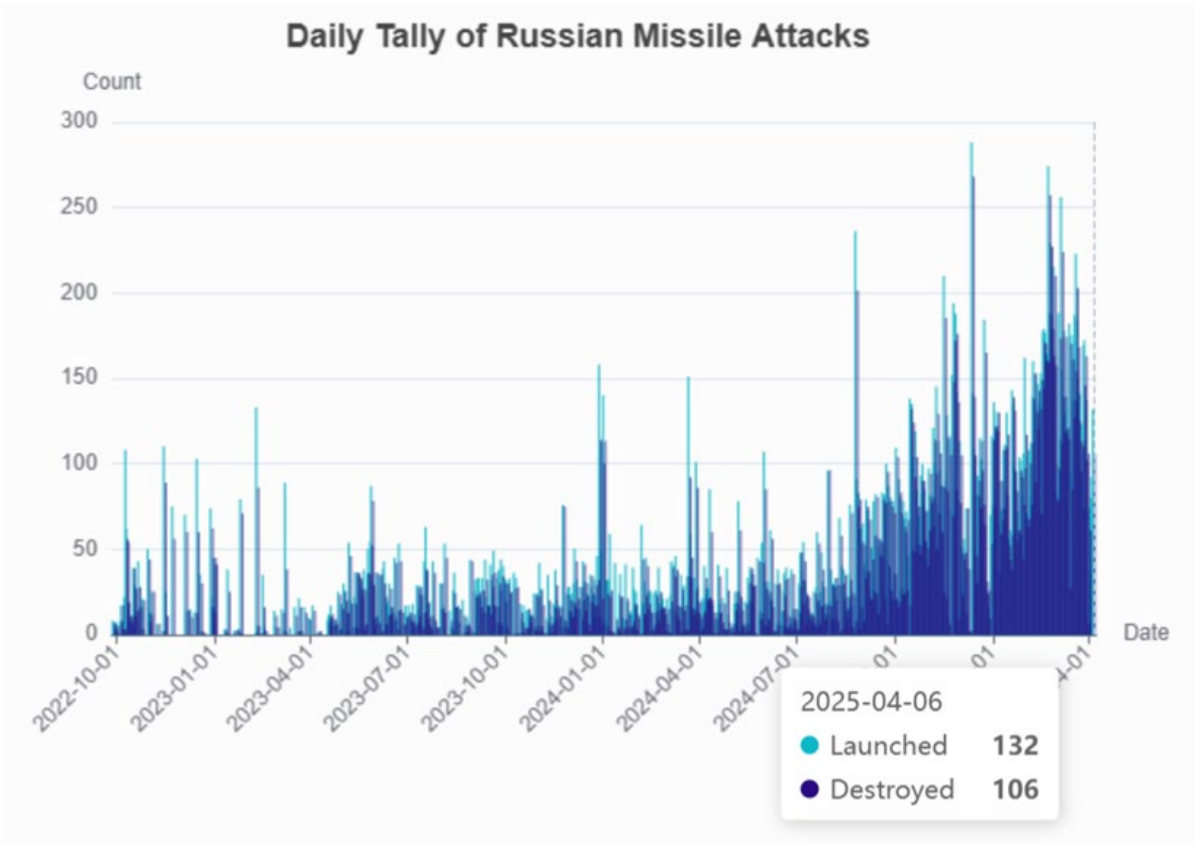


Table 1. KSE report of infrastructure damages (as of November 2024)

Property type	Assessment of damages, $ billion	Share of damages by property type, % of total sum	Previous assessment of damages, $ billion	Dynamics
Residential buildings	60,0	35,3%	58,9	1,9%
Infrastructure	38,5	22,7%	36,8	4,6%
Energy sector*	14,6	8,6%	10,0	46,0%
Assets of enterprises, industry	14,4	8,5%	13,1	9,9%
Agriculture and land resources	10,3	6,1%	10,3	0,0%
Education	7,3	4,3%	6,8	8,8%
Forest fund	4,5	2,7%	4,5	0,0%
Healthcare	4,3	2,5%	3,1	32,3%
Culture, tourism, sports	4,0	2,3%	3,1	29,0%
Municipal services and utilities*	3,5	2,0%	3,5	0,0%
Transport vehicles	3,5	2,0%	3,1	12,9%
Trade	2,8	1,7%	2,6	7,7%
Digital infrastructure	1,2	0,7%	0,5	140,0%
Administrative buildings	0,8	0,4%	0,5	60,0%
Social sector	0,2	0,1%	0,2	0,0%
Financial sector	0,04	0,01%	0,04	0,0%
Total	**169,8**	**100%**	**157,2**	**8,0%**

Table 2. Costs and effectiveness of aerial Russian weapons

Weapon	Cost per unit (USD)	Hit percentage	Cost per target struck (USD)	Payload (lbs)	lbs of payload (USD)
Shahed drone	$35,000	10	$353,535	110	$3,213,958
Kh-22	$1,000,000	95	$1,057,082	2,200	$480,492
S-300/S-400	$1,500,000	100	$1,507,538	300	$5,025,126
Kh-59	$500,000	29	$1,748,252	700	$2,497,502
Iskander-M	$2,000,000	90	$2,224,694	1,000	$2,224,694
Iskander-K	$1,000,000	36	$2,747,253	1,000	$2,747,253
Kalibr	$1,000,000	20	$4,926,108	1,000	$4,926,108
Kh-47 Kinzhal	$15,000,000	74	$20,161,290	1,050	$19,201,229

Fig 2. Ukrainian Air Force statistical data on monthly attacks by Russian missiles and drones (bar chart)

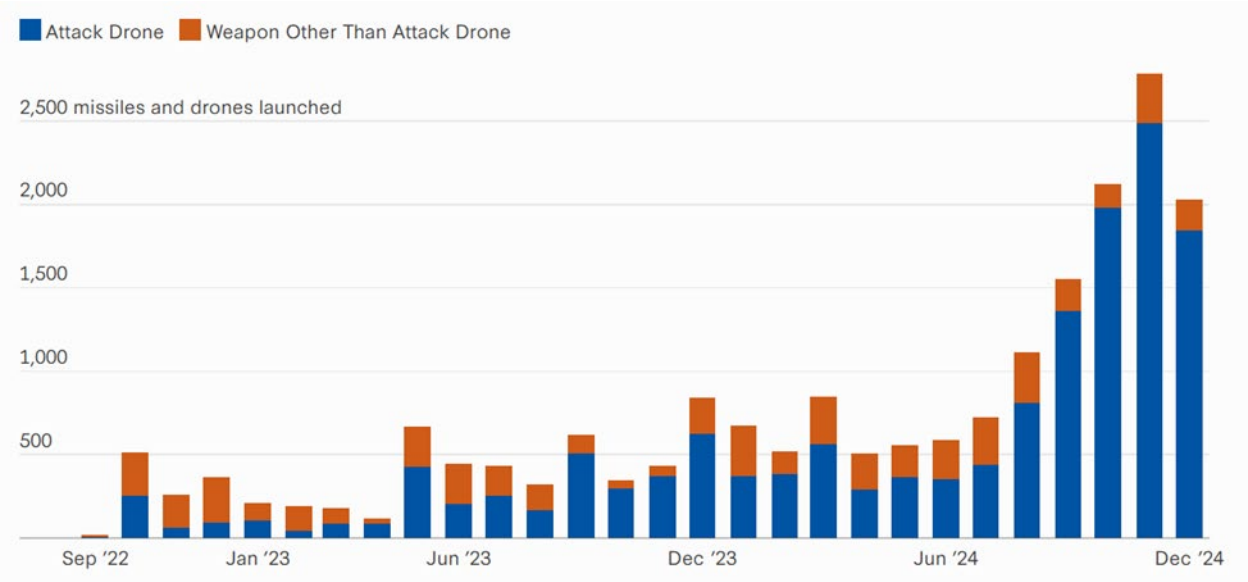


Fig. 3. The updated MIT framework


Entrepreneur
Accelerators & tech incubators
Crowdfunding & Angel Investors
University
Risk Capital
Science parks & tech parks
Venture capital firms & Philanthropic funds
Regulatory Bodies & Government Agencies
Government
Corporate
NGOs, Industry associations & Chambers of commerce

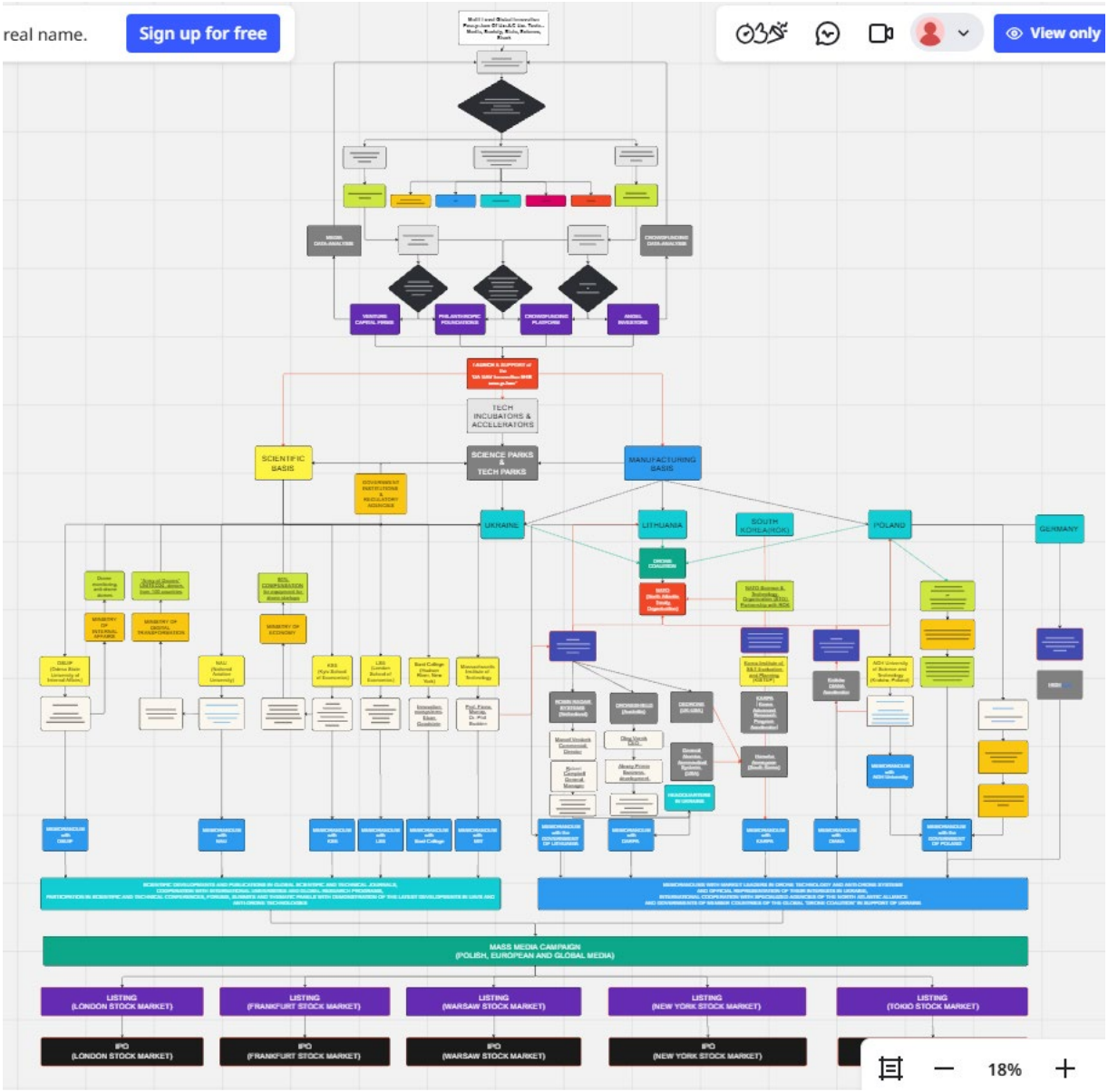

real name.
Sign up for free
View only
TECH INCUBATORS & ACCELERATORS
SCIENTIFIC BASIS
SCIENCE PARKS & TECH PARKS
MANUFACTURING BASIS
UKRAINE
LITHUANIA
POLAND
GERMANY
MASS MEDIA CAMPAIGN (POLISH, EUROPEAN AND GLOBAL MEDIA)
LISTING (LONDON STOCK MARKET)
LISTING (FRANKFURT STOCK MARKET)
LISTING (WARSAW STOCK MARKET)
LISTING (NEW YORK STOCK MARKET)
LISTING (TOKIO STOCK MARKET)
IPO (LONDON STOCK MARKET)
IPO (FRANKFURT STOCK MARKET)
IPO (WARSAW STOCK MARKET)
IPO (NEW YORK STOCK MARKET)
18%

Fig. 5,6. Official military staff of

Table 3. №4 Thematic framework for in-depth interviews

Thematic blocks	**Types of questions**
Experience with drones	What is your experience with drones? What are the main advantages and disadvantages of using drones in the city?
Technological aspects	What are the most interesting recent developments in the field of drones and AI? What are the technological barriers to wider use of drones?
Regulatory aspects	What are the regulatory requirements for the use of drones in your city? How do you assess the effectiveness of these requirements?
Social and ethical aspects	What are the social and ethical issues related to the use of drones? How can the risks associated with the use of drones be minimized?
The future of drones	How do you see drone technology evolving in the coming years? What new opportunities are opening up through the use of drones in the city?

Table 4. An example of a questionnaire for drone industry experts

Section 1: Demographics • Age • Gender • Marital status • Place of residence (city, region) • Level of education • Occupation
Section 2: General perception • What is the public's attitude towards the use of drones in urban areas? • What fears do people have about drones? • What are the main benefits and challenges of using drones in the city? • How do people see the ideal model of drone regulation?
Section 3: Technological development of the drone industry • What are the trends in the development of the drone industry? • How are AI technologies changing the capabilities and applications of drones? • What are the regulatory barriers to the development of the drone industry? • What are the potential use cases for anti-drone systems? • What are the most promising technological solutions?
Section 4: Challenges of anti-drone systems • What are the advantages and disadvantages of anti-drone systems? • What are the privacy, security, and freedom concerns of anti-drone systems? • How to balance security needs with privacy protection? • How far can the surveillance systems used in counter-drone domes go to protect the privacy of citizens? • How to prevent the use of counter-drone systems for mass surveillance purposes?

- What ethical principles should guide the development and use of counter-drone systems?
- How to ensure transparency of the algorithms that control anti-drone systems? How to ensure accountability in the use of anti-drone systems?
- What accountability mechanisms can be introduced for developers and users of anti-drone systems?
- What measures can be taken to reduce the negative impact of anti-drone systems on citizens?
- How to ensure that the benefits of new technologies are available to all members of society?
- How to reconcile national interests with international security standards

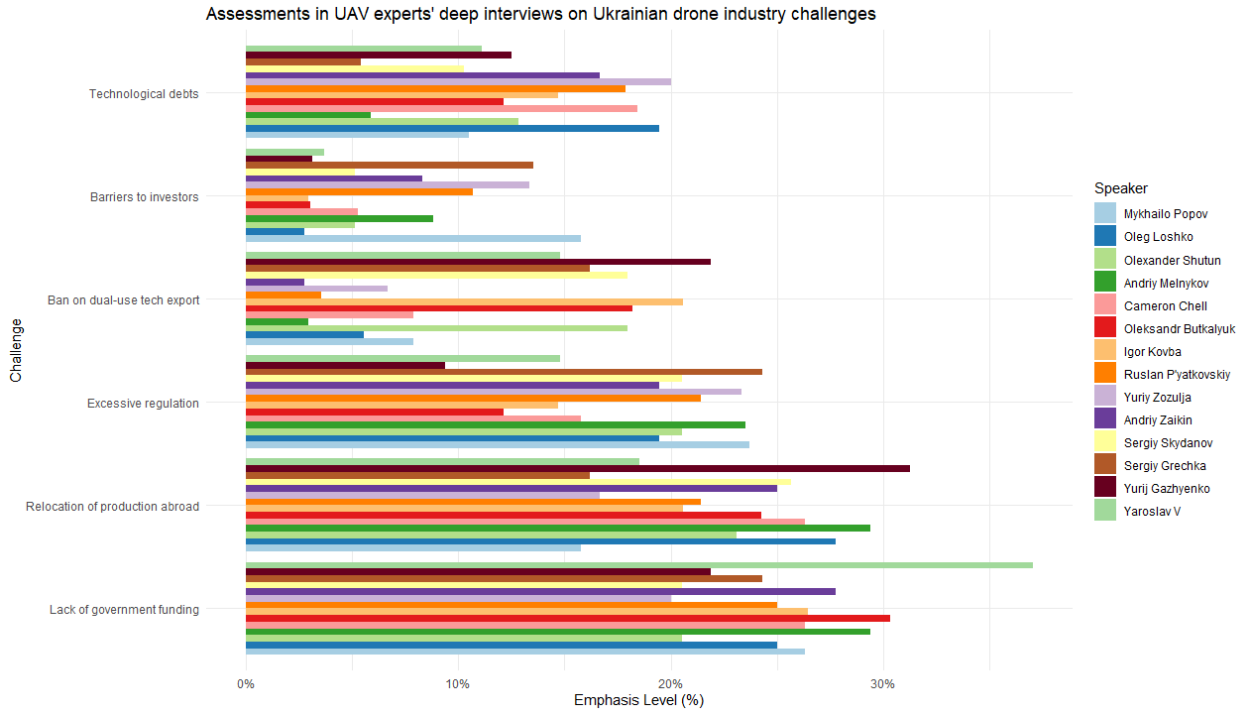
Table 5. List of key informants for in-depth interviews conducted

№	NAME	POSITION	ORGANIZATION
1	Mykhailo Popov	Director	Center for Aerospace Research of the Earth, Institute of Geological Sciences of the National Academy of Science
2	Oleg Loshko	CEO	Unmanned solutions company DEF-C
3	Olexander Shutun	UAV designer	Abris Design Group
4	Andriy Melnykov	Commercial Director	SpartaqS Defense
5	Cameron Chell	President	Canadian-USA-German Drone Concern "DRAGANFLY"
6	Sergiy Grechka	UAV vendor	Kyiv drone production unit
7	Oleksandr Butkalyuk	UAV engineer	Drone StartUp “FOWLER”
8	Yurij Gazhyenko	UAV vendor	Poltava drone production unit
9	Igor Kovba	UAV engineer	Kyiv Drone Dome Project
10	Yaroslav K,	military drone operator	Ukrainian Armed Forces (UAV’s squadron)
11	Ruslan P'yatkovskiy	senior sergeant, commander of the squadron	Ukrainian Armed Forces (deminer's squadron)
12	Yuriy Zozulja	advisor to the mayor of Kyiv on digitalization	Kyiv State City Administration
13	Andriy Zaikin	Founder and CEO	YEP Accelerator
14	Sergiy Skydanov	CEO	Ukrainian-Polish UAV Holding "Abris Design Group"

Table 6. Comparison of the key informants’ assessment (based on deep interviews quotes and professional experience)

Mykhailo Popov, Director of the Center for Aerospace Research of the Earth, Institute of Geological Sciences of the National Academy of Sciences of Ukraine: Experience with drones and regulatory aspects: "As the director of the scientific center for aerospace research of the Earth at the National Academy of Sciences of Ukraine, I work at the main drone industry’s problem right now. It lies, firstly, in the large number of legal gaps that exist in the adopted law, in the process of creating various bodies that are currently being formed or have already been formed. The mandatory nature and functionality that this law should carry contain many things that require either revision or even reformatting. And the very concept of 'drones' needs to be introduced into the law, because	**Oleg Loshko, CEO of unmanned solutions company DEF-C:** Experience with drones: “Our company specializes in developing unmanned solutions for various industries. We see great potential in using drones for infrastructure inspection, agriculture, and delivery.” Technological aspects: “One of the most important advances is the development of data transmission systems that allow drones to be controlled over long distances. This opens up new opportunities for using drones in remote areas.” Regulatory aspects: “Regulatory requirements for the commercial use of drones need to be balanced. On the one hand, they

it is not there. This applies to terminology as well, and how all this will help with algorithmic data transmission. We previously started creating our own Ukrainian standards, and now we have realized that it is much better to harmonize the frequencies that exist in the world with ours. It is impossible to do this one-to-one due to the specifics. Therefore, it is necessary to take European laws and standards and adapt them. Regarding the question of which laws define drone, copter, or UAV, I know that they have dozens of these standards that we use, and they can very significantly help in the formation of our Ukrainian regulatory framework. This is what we are doing, in particular, regarding remote sensing. We are ready to participate in this work."	should ensure safety, and on the other hand, they should not hinder the development of the industry." Social and ethical aspects: "It is important to develop technologies that will be used for the benefit of society. We need to ensure that drones do not threaten people's privacy or create dangerous situations." The future of drones: "The future of military drones is associated with the development of swarm technologies, integration with other weapons, and the creation of autonomous systems. In the civilian sector, drones will become an integral part of our infrastructure. They will deliver parcels, monitor the environment, and assist in rescue operations."
Olexander Shutun, UAV designer at Abris Design Group: Experience with drones: "Our experience with drones and collaboration with G-sector spans over 10 years. We started with small amateur projects and now develop industrial drones for various industries, from agriculture to security. During this time, we have accumulated a large knowledge base about drone construction, software, and applications." Technological and regulatory aspects**:** "Now we are looking for opportunities to develop in the so-called hidden or technological debts that are inherent not only in the drone system but in any ecosystem, such as an underdeveloped technology for transmitting data or energy between drone nodes, its "underdeveloped" software, a weak battery, an incomplete prototype, or financing schemes with interruptions or delays in the supply of components. Typically, an additional 20% capacity can be found by closing these gaps. These hidden debts are even in the legislation. The same VAT makes the production of our drone 20% more expensive than the exact same Chinese or other foreign drone." Social and ethical aspects: The main issues are the potential violation of privacy, the risk of unauthorized surveillance, and the possibility of using drones for criminal purposes." Future of drones: "In the near future, we expect significant development of drone technology. More autonomous, quiet, and long-lasting devices will appear. Drones will be widely used for delivering goods, monitoring infrastructure, and conducting rescue operations. The most interesting achievements are the development of artificial intelligence systems for autonomous drone control, as well as the emergence of new materials that allow creating lighter and stronger drones. These technologies open up new possibilities for using drones in complex conditions."	**Andriy Melnykov, Commercial Director of SpartaqS Defense:** Experience with drones: "We are focused on the development of military drones. We have seen how drone technology is developing rapidly and how it is changing the rules of the game on the battlefield." Advantages and disadvantages: "The main advantages of drones in the city are the speed of data collection, accessibility in hard-to-reach places, and the ability to automate routine tasks. However, there are also disadvantages: noise, limited flight duration, and potential safety risks for people. In addition, there is a risk of drones colliding with aircraft or people. Technological aspects: "Artificial intelligence allows drones to make independent decisions in difficult situations. This opens up new possibilities for reconnaissance, targeting, and even independent targeting." Regulatory aspects: "Regulatory requirements for military drones are different from civilian drones. We work in close cooperation with the military to ensure that all necessary standards are met. However, drone development in Ukraine is hampered by a lack of funding, with the budget covering only about a third of the industry's needs, leaving two-thirds of the market simply idle, which means production, salaries, and R&D costs. At the same time, along with simplifying regulatory procedures, the government is introducing mandatory codification of everything related to drones. As a result, Ukrainian manufacturers are moving their production bases abroad" Social and ethical aspects: "The use of drones for military purposes raises serious ethical issues. We are committed to developing technologies that minimize the risk to civilians."



5 code

```
library(ggplot2)
library(dplyr)

# Create the dataframe with 14 speakers and their modeled emphasis on the issues
speakers_data_en <- data.frame(
  Speaker = factor(rep(c("Mykhailo Popov", "Oleg Loshko", "Olexander Shutun", "Andriy Melnykov",
"Cameron Chell", "Oleksandr Butkalyuk", "Igor Kovba", "Ruslan P'yatkovskiy", "Yuriy Zozulja", "Andriy
Zaikin", "Sergiy Skydanov", "Sergiy Grechka", "Yurij Gazhyenko", "Yaroslav V"), each = 6),
           levels = c("Mykhailo Popov", "Oleg Loshko", "Olexander Shutun", "Andriy Melnykov",
"Cameron Chell", "Oleksandr Butkalyuk", "Igor Kovba", "Ruslan P'yatkovskiy", "Yuriy Zozulja", "Andriy
Zaikin", "Sergiy Skydanov", "Sergiy Grechka", "Yurij Gazhyenko", "Yaroslav V")),
  Challenge = factor(rep(c("Lack of government funding",
                           "Relocation of production abroad",
                           "Excessive regulation",
                           "Ban on dual-use tech export",
                           "Barriers to investors",
                           "Technological debts"), 14),
                     levels = c("Lack of government funding",
                                "Relocation of production abroad",
                                "Excessive regulation",
                                "Technological debts",
                                "Ban on dual-use tech export",
                                "Barriers to investors")),
  Emphasis = c(
    7, 3, 9, 8, 6, 5,  # Михайло Попов
    6, 8, 7, 3, 9, 4,  # Олег Лошко
    5, 6, 8, 4, 7, 9,  # Олександр Шутун
    9, 7, 8, 5, 4, 3,  # Андрій Мельников
    8, 7, 6, 4, 9, 5,  # Cameron Chell
    7, 5, 4, 3, 6, 8,  # Олександр Букалюк
```

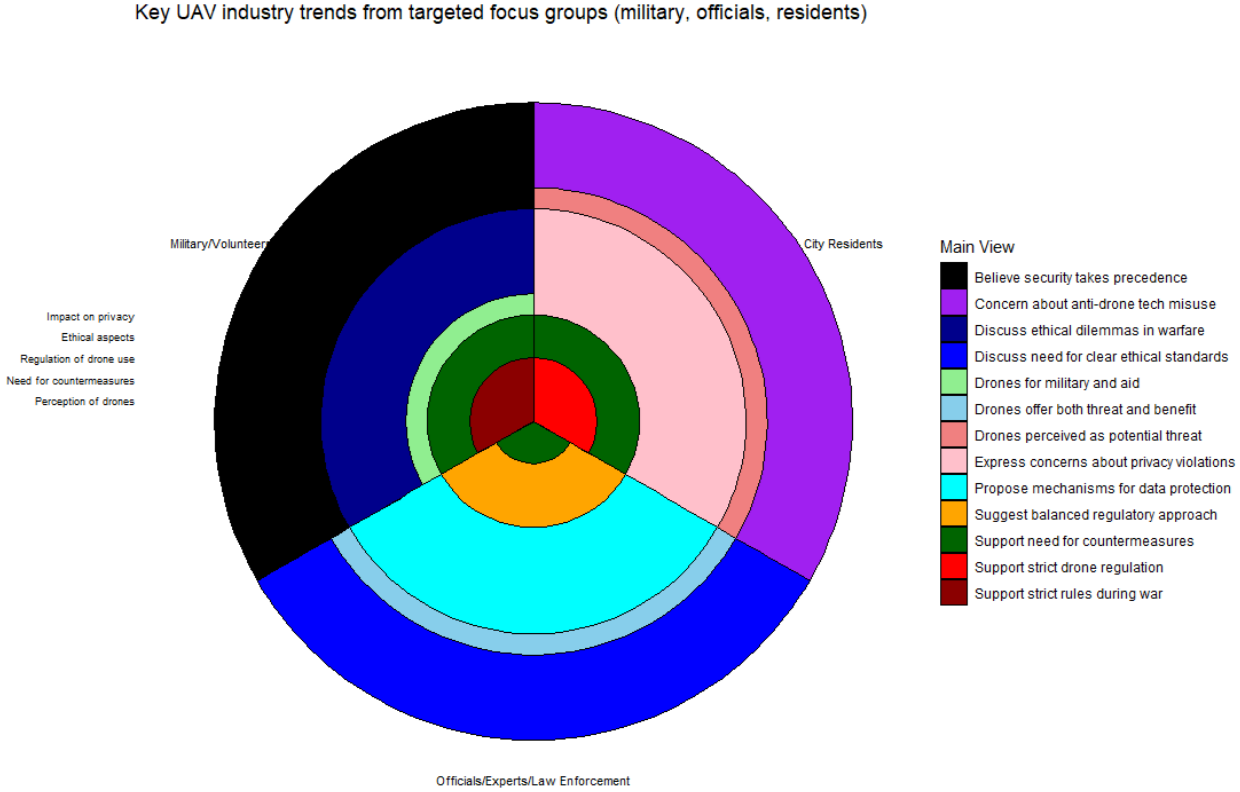
```
   6, 4, 5, 3, 7, 9,  # Ігор Ковба
   4, 3, 6, 5, 7, 2,  # Руслан П'ятковський (замість Ксенії Семенової)
   3, 2, 7, 6, 8, 4,  # Юрій Зозуля
   9, 6, 7, 5, 8, 3,  # Андрій Заікін
   5, 7, 8, 4, 6, 9,  # Сергій Скиданов
   6, 3, 9, 7, 4, 8,  # Сергій Гречка (замість Віталія Зайцева)
   4, 7, 3, 2, 6, 9,  # Юрій Гажиєнко
   10, 2, 4, 3, 5, 6   # Ярослав В
  )
)

# Decrease emphasis on "Technological debts" and "Ban on dual-use tech export"
speakers_data_en <- speakers_data_en %>%
  mutate(Emphasis = ifelse(Challenge == "Technological debts", pmax(1, Emphasis - 2), Emphasis),
         Emphasis = ifelse(Challenge == "Ban on dual-use tech export", pmax(1, Emphasis - 2), Emphasis),
         Emphasis = ifelse(Challenge == "Lack of government funding", pmin(10, Emphasis + 3),
Emphasis),
         Emphasis = ifelse(Challenge == "Relocation of production abroad", pmin(10, Emphasis + 3),
Emphasis),
         Emphasis = ifelse(Challenge == "Barriers to investors", pmax(1, Emphasis - 2), Emphasis))

# Normalize emphasis levels for each speaker to sum up to 100%
speakers_data_en <- speakers_data_en %>%
  group_by(Speaker) %>%
  mutate(SumEmphasis = sum(Emphasis),
         NormalizedEmphasis = (Emphasis / SumEmphasis) * 100) %>%
  ungroup()

# Reorder the factor levels for Challenge to swap "Technological debts" and "Ban on dual-use tech
export"
levels(speakers_data_en$Challenge) <- c("Lack of government funding",
                                        "Relocation of production abroad",
                                        "Excessive regulation",
                                        "Ban on dual-use tech export",
                                        "Barriers to investors",
                                        "Technological debts")

# Define a more differentiated color palette
distinct_palette <- c(
  "#a6cee3", "#1f78b4", "#b2df8a", "#33a02c", "#fb9a99", "#e31a1c",
  "#fdbf6f", "#ff7f00", "#cab2d6", "#6a3d9a", "#ffff99", "#b15928",
  "#67001f", "#a1d99b"
)

# Create the horizontal chart with a more differentiated color palette
ggplot(speakers_data_en, aes(y = Challenge, x = NormalizedEmphasis, fill = Speaker)) +
  geom_col(position = "dodge") + # Use dodge to display columns of each speaker side by side
  scale_x_continuous(breaks = seq(0, 100, by = 10), labels = paste0(seq(0, 100, by = 10), "%"), name =
"Emphasis Level (%)") +
  scale_fill_manual(name = "Speaker", values = distinct_palette) +
  labs(title = "Assessments in UAV experts' deep interviews on Ukrainian drone industry challenges",
       y = "Challenge") +
  theme_minimal() +
```

```
theme(legend.position = "right")
```

Table 7. An example of a questionnaire for the focus group participants

Section 1: Demographic data • Age • Gender • Marital status • Place of residence (city, region) • Level of education • Occupation
Section 2: Experience and knowledge of drones • How often have you used/do you have a drone? • What are the main purposes of using a drone? • Have you encountered any problems while using a drone (e.g., from other people)?
Section 3: Specialization • Have you received appropriate training as a drone operator? • Are you familiar with the liability for illegal drone use?
Section 4: Certification and registration • Has your UAV been certified by the regulatory authorities? • Is it necessary to introduce a drone identification system "friend or foe"? • Do you support the idea of mandatory registration of drones? • Do you support the idea of mandatory flight registration? • Do you support the idea of mandatory registration of crews and routes?

Fig. 8. Focus groups' attitude towards the main industry challenges (bar chart)



6 code

```
library(ggplot2)
library(dplyr)
```

```
library(gridExtra)

# Створюємо датафрейм з результатами фокус-груп та розширеними описами думок
focus_group_data_detailed <- focus_group_data %>%
  mutate(Percentage = 1) %>% # Використовуємо 1 як базову одиницю для кільця
  mutate(Detailed_View = case_when(
    View == "Threat" ~ "Drones perceived as potential threat",
    View == "Threat & Benefit" ~ "Drones offer both threat and benefit",
    View == "Military Necessity & Humanitarian" ~ "Drones for military and aid",
    View == "Support" ~ "Support need for countermeasures",
    View == "Strict" ~ "Support strict drone regulation",
    View == "Balanced" ~ "Suggest balanced regulatory approach",
    View == "Strict (Martial Law)" ~ "Support strict rules during war",
    View == "Misuse Concern" ~ "Concern about anti-drone tech misuse",
    View == "Ethical Standards" ~ "Discuss need for clear ethical standards",
    View == "Ethical Dilemmas" ~ "Discuss ethical dilemmas in warfare",
    View == "Privacy Concern" ~ "Express concerns about privacy violations",
    View == "Privacy Protection" ~ "Propose mechanisms for data protection",
    View == "Security Precedence" ~ "Believe security takes precedence"
  ))

# Кольорова схема (відповідно до попередньої)
color_values_detailed <- c("Drones perceived as potential threat" = "lightcoral",
                           "Drones offer both threat and benefit" = "skyblue",
                           "Drones for military and aid" = "lightgreen",
                           "Support need for countermeasures" = "darkgreen",
                           "Support strict drone regulation" = "red",
                           "Suggest balanced regulatory approach" = "orange",
                           "Support strict rules during war" = "darkred",
                           "Concern about anti-drone tech misuse" = "purple",
                           "Discuss need for clear ethical standards" = "blue",
                           "Discuss ethical dilemmas in warfare" = "darkblue",
                           "Express concerns about privacy violations" = "pink",
                           "Propose mechanisms for data protection" = "cyan",
                           "Believe security takes precedence" = "black")

# Оновлюємо назву рівня фактора "Military/Volunteers/Philanthropists"
levels(focus_group_data_detailed$FocusGroup)[levels(focus_group_data_detailed$FocusGroup) ==
"Military/Volunteers/Philanthropists"] <- "Military/Volunteers"

# Створення складної кругової діаграми з внутрішніми кільцями для думок
ggplot(focus_group_data_detailed, aes(x = FocusGroup, y = as.numeric(Topic), fill = Detailed_View)) +
  geom_col(position = "stack", color = "black", linewidth = 0.2, width = 1) + # Використовуємо stack
для створення кілець
  coord_polar(theta = "x") +
  scale_fill_manual(values = color_values_detailed, name = "Main View") +
  scale_x_discrete(labels = levels(focus_group_data_detailed$FocusGroup)) + # Відображаємо назви
фокус-груп по колу
  scale_y_continuous(breaks = 1:length(levels(focus_group_data_detailed$Topic)), labels =
levels(focus_group_data_detailed$Topic)) + # Відображаємо теми як внутрішні кільця
  labs(title = "Key UAV industry trends from targeted focus groups (military, officials, residents)") +
  theme_void() +
  theme(axis.text.x = element_text(size = 8), # Налаштування розміру тексту для назв фокус-груп
```

```
    axis.text.y = element_text(size = 7, vjust = 0.5, hjust = 1), # Налаштування розміру та положення тексту для тем
    legend.position = "right")
```

Table 8. Comparison of key trends and assessments from focus group studies

№	FOCUS GROUP 1	FOCUS GROUP 2	FOCUS GROUP 3
Group members ***Topics***	***City residents***	***City officials, UAV experts and law enforcement representatives***	***Military, volunteers and philanthropists***
Perception of drones	The majority of participants perceive drones as a potential threat, especially in times of war. They express concerns about the use of drones for attacks, eavesdropping, and surveillance.	Government and law enforcement representatives emphasize both the potential threat and the benefits of drones (e.g., for situation monitoring, search operations). Experts and businesses emphasize the potential of drones for the development of various areas (logistics, inspection, etc.).	The military emphasizes both the military necessity of drones and the risks of their use by the enemy. Volunteers and charity organizations focus on the humanitarian aspects of drone use (humanitarian aid delivery, evacuation).
Ethical aspects	Concerns have been raised about the possible misuse of anti-drone technology to restrict freedom of speech and surveillance of citizens.	Discusses the need to develop clear ethical standards for the use of drones and countermeasures.	Discusses the ethical dilemmas associated with the use of drones in warfare.
Impact on privacy	Many participants expressed concerns about privacy violations resulting from the use of drones and countermeasures.	Recognizes the problem of privacy violations and proposes the development of mechanisms to protect personal data.	Recognizes the problem of privacy violations, but believe that security takes precedence in times of war.
Need for counter-measures	There is unanimous support for the need to implement countermeasures against hostile drones to ensure city safety.	All participants support the need to implement technologies to counter hostile drones.	There is unanimous support for the need to introduce countermeasures against hostile drones to protect civilians and the military.
Regulation of the use of drones	They support strict regulation of the use of drones, especially in urban areas. They propose to introduce drone registration, restrictions on where drones can be launched, and establish liability for violating the rules.	Support the idea of regulation, but suggest more balanced approaches that would allow for the development of commercial drone use.	They support strict regulation of the use of drones under martial law.

Table 9. Examples of Likert scales used in surveys on attitudes toward drones:

ASSESSMENT	STATEMENT	LIKERT SCALE
Perceived usefulness	"Drones can be useful for rescue operations"	from 1 to 5, where 1 - strongly disagree, 5 - strongly agree

Anxiety	"I feel anxious when I see a drone flying low over my head"	from 1 to 7, where 1 is strongly disagree and 7 is strongly agree
Attitudes towards regulation	"The government should introduce stricter regulations on the use of drones"	from 1 to 6, where 1 is strongly disagree and 6 is strongly agree

Table 10. An example of a questionnaire for local residents

Section 1: Demographic data • Age • Gender • Marital status • Place of residence (city, region) • Financial security level • Occupation
Section 2: Experience and knowledge of drones • Have you ever seen a drone in the sky? • Have you seen drones in your neighborhood? • How do you feel about the use of drones in the city? • Have you or someone you know used drones? If so, for what purposes? • How aware are you of the ban on the use of drones in Ukraine?
Section 3: Attitudes towards counter-drone systems • What risks associated with the use of drones do you consider to be the most pressing? • What measures do you think should be taken to ensure the safe use of drones? • What, in your opinion, are the most effective means of counteracting the illegal use of drones? • How do you feel about the idea of creating counter-drone systems in your city? What advantages and disadvantages do you see in such systems?
Section 4: Attitudes towards privacy threats • Do you think that such systems can threaten your privacy? • Do you think counter-drone systems can affect your sense of security? • In your opinion, how can the need for security and the protection of privacy be balanced when using counter-drone systems? • What legislation is needed to regulate the use of drones in the city? • What other issues related to drones and counter-drone systems do you consider important?

Fig. 9. The level of public perception of drone threats

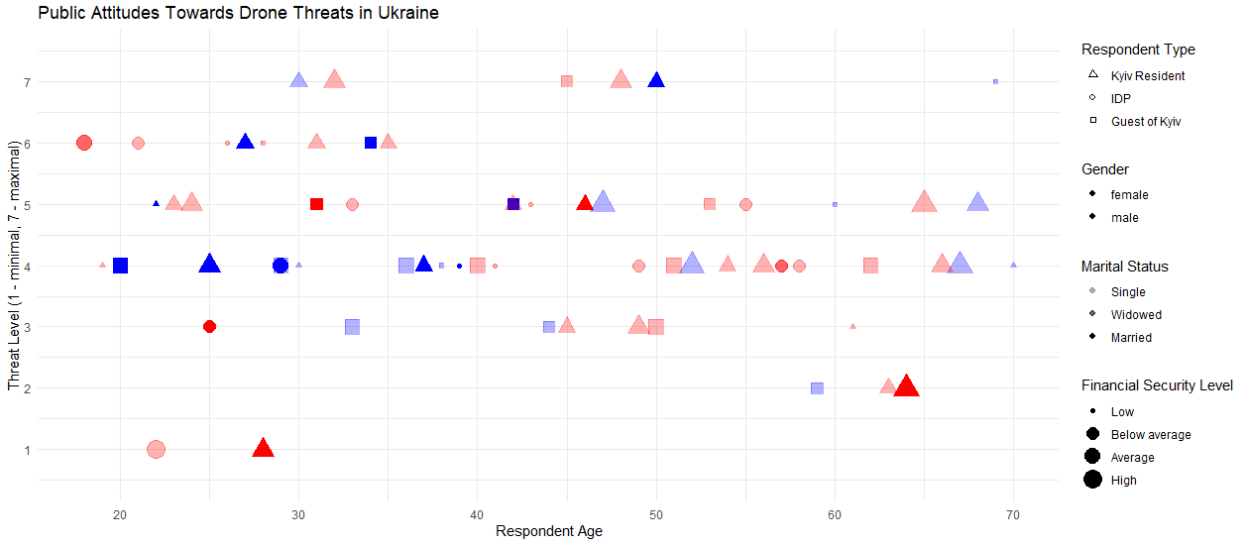
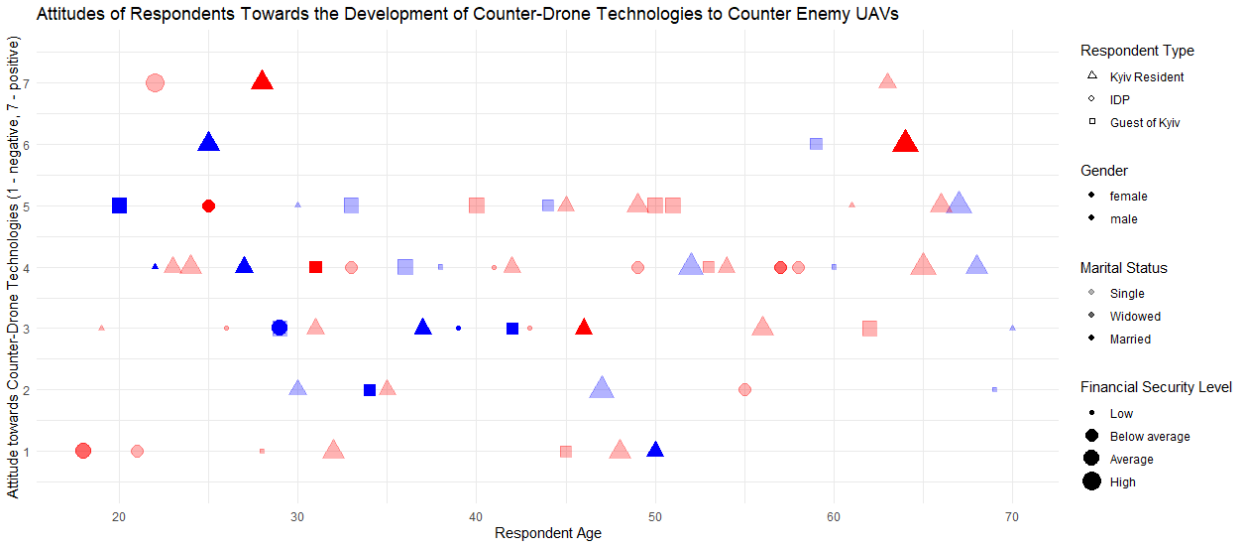


Fig. 10. The level of public support for the development of C-UxS technologies



Survey chart 2 code

```
library(ggplot2)
library(dplyr)

# Використовуємо той самий датафрейм respondent_data з попереднього коду

# Генеруємо гіпотетичні рівні ставлення до контр-дронних технологій (від 1 до 7)
# Припустимо, що ті, хто більше боїться дронів (вищий ThreatLevel), більш позитивно ставляться до контр-дронів
set.seed(404) # Для відтворюваності результатів
respondent_data <- respondent_data %>%
  mutate(AttitudeCounterDrone = round(8 - ThreatLevel + rnorm(n(), mean = 0, sd = 1))) %>%
  # Обмежуємо значення від 1 до 7
  mutate(AttitudeCounterDrone = pmax(1, pmin(7, AttitudeCounterDrone)))

# Будуємо графік
ggplot(respondent_data, aes(x = Age, y = AttitudeCounterDrone, color = Gender, size = FinancialSize,
alpha = MaritalFill, fill = Gender, shape = RespondentType)) +
  geom_point(stroke = 1) +
  scale_y_continuous(breaks = 1:7, limits = c(0.5, 7.5)) +
  scale_shape_manual(values = c("Kyiv Resident" = 24, "IDP" = 21, "Guest of Kyiv" = 22),
                     labels = c("Kyiv Resident", "IDP", "Guest of Kyiv"),
                     name = "Respondent Type") +
  scale_color_manual(values = c("male" = "blue", "female" = "red"), name = "Gender") +
  scale_size_continuous(name = "Financial Security Level", breaks = 2:6, labels = c("Extremely low",
"Low", "Below average", "Average", "High")) +
  scale_fill_manual(values = c("male" = "blue", "female" = "red"), name = "Gender") +
  scale_alpha_identity(name = "Marital Status", labels = c("Single", "Widowed", "Married"), breaks =
c(0.3, 0.6, 1), guide = "legend") +
  labs(
    title = "Attitudes of Respondents Towards the Development of Counter-Drone Technologies to
Counter Enemy UAVs",
    x = "Respondent Age",
    y = "Attitude towards Counter-Drone Technologies (1 - negative, 7 - positive)"
```

```
) +
theme_minimal() +
guides(alpha = guide_legend(order = 3, title = "Marital Status"),
       shape = guide_legend(order = 1),
       size = guide_legend(order = 4, title = "Financial Security Level"),
       fill = guide_legend(order = 2),
       color = "none")
```

Fig. 11. The level of public support for drone production through donations via government programs and crowdfunding platforms

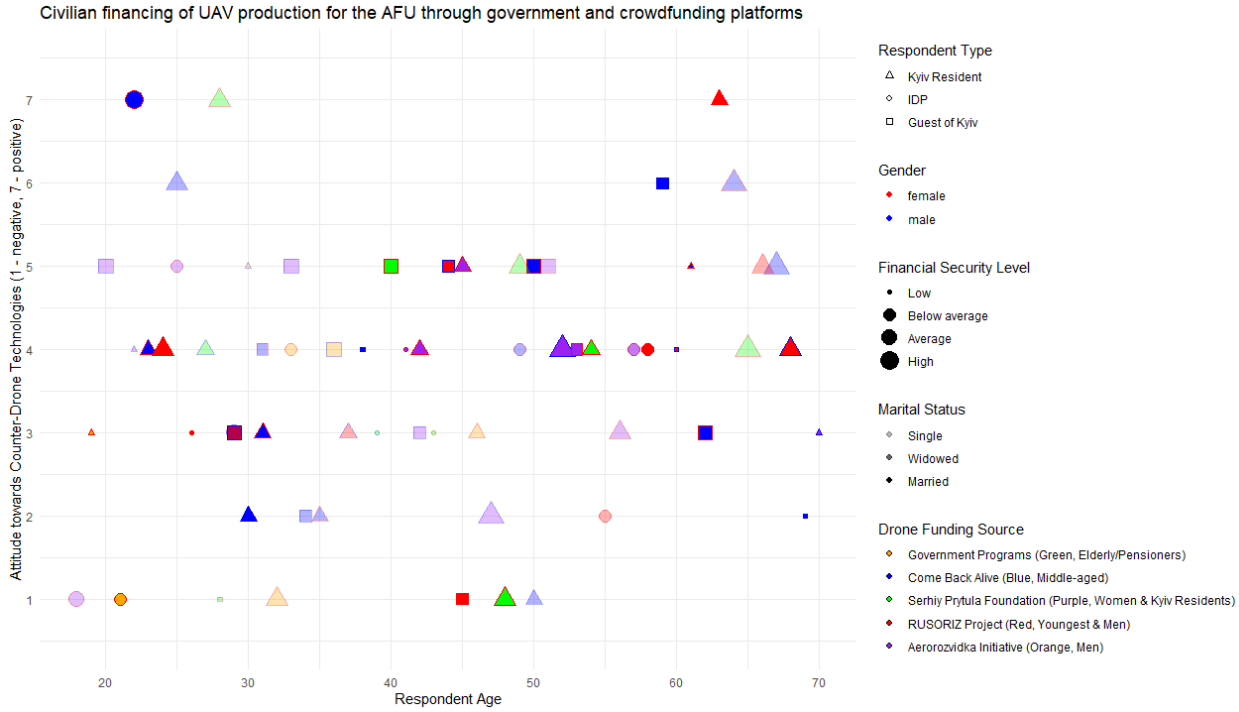
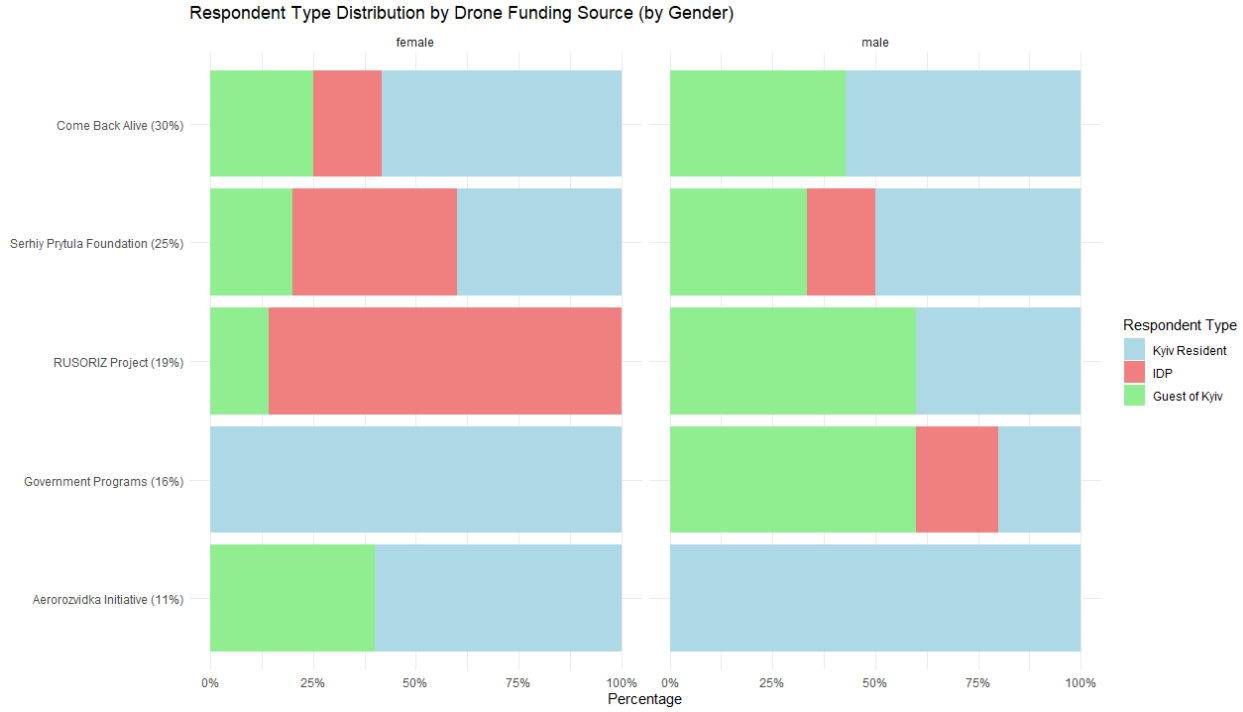


Fig. 12. Distribution of donor respondent types by residence and gender across different drone funding platforms



Survey chart 4 code

```
library(ggplot2)
library(dplyr)

# Використовуємо той самий датафрейм respondent_data з попереднього коду

# Генеруємо гіпотетичні рівні ставлення до контр-дронних технологій (від 1 до 7)
# Припустимо, що ті, хто більше боїться дронів (вищий ThreatLevel), більш позитивно ставляться до контр-дронів
set.seed(404) # Для відтворюваності результатів
respondent_data <- respondent_data %>%
  mutate(AttitudeCounterDrone = round(8 - ThreatLevel + rnorm(n(), mean = 0, sd = 1))) %>%
  # Обмежуємо значення від 1 до 7
  mutate(AttitudeCounterDrone = pmax(1, pmin(7, AttitudeCounterDrone)))

# Визначаємо вікові групи
respondent_data <- respondent_data %>%
  mutate(AgeGroup = case_when(
    Age >= 50 ~ "Elderly/Pensioner",
    Age >= 30 ~ "Middle-aged",
    TRUE ~ "Young"
  ))

# Генеруємо випадкові дані про сімейний стан
set.seed(2022)
```

```
marital_statuses <- sample(c("одружений/заміжня", "вдова/вдівець",
"незаміжня/неодружений"),
                    64, replace = TRUE, prob = c(0.47, 0.01, 0.42))

respondent_data$MaritalStatus <- marital_statuses

# Визначаємо рівень заповненості для сімейного стану
respondent_data <- respondent_data %>%
  mutate(MaritalFill = ifelse(MaritalStatus == "одружений/заміжня", 1,
                       ifelse(MaritalStatus == "вдова/вдівець", 0.6, 0.3)))

# Створюємо вектор джерел фінансування з потрібними пропорціями
n_respondents <- nrow(respondent_data)
set.seed(808)
funding_sources <- c(
  rep("Government Programs", round(n_respondents * 0.15)),
  rep("Come Back Alive", round(n_respondents * 0.30)),
  rep("Serhiy Prytula Foundation", round(n_respondents * 0.25)),
  rep("RUSORIZ Project", round(n_respondents * 0.18)),
  rep("Aerorozvidka Initiative", round(n_respondents * 0.12))
)

# Забезпечуємо правильну кількість елементів (може бути нерівно через округлення)
if (length(funding_sources) > n_respondents) {
  funding_sources <- funding_sources[1:n_respondents]
} else if (length(funding_sources) < n_respondents) {
  remaining <- n_respondents - length(funding_sources)
  funding_sources <- c(funding_sources, rep("Other", remaining))
}

# Перемішуємо джерела фінансування для випадкового призначення респондентам
set.seed(909) # Added a seed for reproducibility
funding_sources <- sample(funding_sources)

# Призначаємо джерела фінансування до датафрейму
respondent_data$DroneFundingSource <- funding_sources

# Перетворюємо FinancialStatus у фактор з потрібним порядком рівнів
respondent_data <- respondent_data %>%
  mutate(FinancialStatus = factor(FinancialStatus, levels = c("нижче середнього", "середній", "вище
середнього", "високий", "низький", "вкрай низький"))) # Включаємо всі рівні для повноти

# Обчислюємо відсоток респондентів для кожного джерела фінансування та типу
респондента
funding_respondent_percentage <- respondent_data %>%
  group_by(DroneFundingSource, RespondentType, Gender) %>%
  summarise(n = n(), .groups = 'drop') %>%
  group_by(DroneFundingSource, Gender) %>%
  mutate(percentage = n / sum(n) * 100)

# Обчислюємо загальний відсоток респондентів для кожного джерела фінансування
total_funding_percentage <- respondent_data %>%
  group_by(DroneFundingSource) %>%
```

```
  summarise(total_percentage = n() / nrow(respondent_data) * 100, .groups = 'drop')

# Об'єднуємо відсотки з назвами платформ
funding_respondent_percentage <- funding_respondent_percentage %>%
  left_join(total_funding_percentage, by = "DroneFundingSource") %>%
  mutate(PlatformWithPercentage = paste0(DroneFundingSource, " (", round(total_percentage), "%)"))

# Визначаємо порядок платформ за загальним відсотком донатів (за зростанням)
ordered_platforms <- total_funding_percentage %>%
  arrange(total_percentage) %>% # Змінено на зростання
  pull(DroneFundingSource)

# Перетворюємо PlatformWithPercentage у фактор з визначеним порядком рівнів
funding_respondent_percentage <- funding_respondent_percentage %>%
  mutate(PlatformWithPercentage = factor(PlatformWithPercentage, levels =
paste0(ordered_platforms, " (",
round(total_funding_percentage$total_percentage[match(ordered_platforms,
total_funding_percentage$DroneFundingSource)]), "%")))

# Будуємо стовпчасту діаграму з розбивкою за типом респондента (горизонтальну) з
окремими колонками для статі
ggplot(funding_respondent_percentage, aes(y = PlatformWithPercentage, x = percentage, fill =
RespondentType)) +
  geom_col(position = "stack") +
  scale_x_continuous(labels = function(x) paste0(x, "%"), name = "Percentage") +
  scale_fill_manual(name = "Respondent Type",
                    values = c("Kyiv Resident" = "lightblue",
                               "IDP" = "lightcoral",
                               "Guest of Kyiv" = "lightgreen"),
                    labels = c("Kyiv Resident", "IDP", "Guest of Kyiv")) + # Легенда англійською
  labs(title = "Respondent Type Distribution by Drone Funding Source (by Gender)",
       y = "Drone Funding Source") +
  theme_minimal() +
  facet_grid(. ~ Gender, switch = "y") + # Додаємо розбивку по статі
  theme(strip.text.y.left = element_text(angle = 0, hjust = 1), # Робимо текст назв рядків
горизонтальним
        axis.title.y = element_blank(), # Прибираємо назву вертикальної осі, бо вона продубльована
в назвах рядків
        legend.position = "right")
```

Table 11. Comparison of motives in support of C-UxS development (by respondents' quotes, age, geographic and socio-demographics)

Respondent from the 1st stage of the survey:	**Respondent from the 2nd stage of the survey:**
• Age: 33 years old • Gender: Female • Marital Status: Single • Place of residence [City where you moved to]: Kyiv [IDP from Kherson] • Financial Security Level: Below average • Occupation: Marketer	• Age: 59 years old • Gender: Male • Marital Status: Single • Place of residence: Dnipro • Financial Security Level: Below average • Profession: Truck driver
Q: ***What risks associated with the use of drones do you consider to be the most relevant?***	*Q:* ***Have you ever seen a drone in the sky?*** *A: Yes, I have seen it more than once(laugh). Especially when I'm sitting in my car under the bridge during air raid alerts. But I saw them not only in the sky. Some*

A: I know they can be used to correct artillery fire, but my biggest fear is that they can drop munitions on residential buildings or people, as I have seen repeatedly in Kherson. I frankly consider all our air defense personnel to be our saints and every time there is enough budget, I support our drone makers through the Prytula crowdfunding platform.	*guys I know have a small drone lab in our garage. There they disassemble enemy UAVs and make our Ukrainian ones. The state does not help them, so I give the guys 1000-2000 hryvnias whenever I can earn them. But I give it directly to them, because I don't trust any foundations or government officials.*
Respondent from the 3d stage of the survey: • Age: 40 years old • Gender: Female • Marital Status: Married • Place of residence: Irpin • Financial Security Level: Average • Occupation: Police officer *Q: **How do you feel about the idea of creating systems to counter drones in your city?*** *A: Very positively. Our unit has drones that we use for patrolling and reconnaissance. This is very necessary for security. It is protection from air attacks, from subversive groups and terrorist acts, and it helps in search operations. But it is also very expensive and has a risk of errors. We are now saving our family money to invest in the government's project to build an counter-drone wall along the entire 1,500-kilometer front line. I personally attended one of the hackathons where this project was presented by our ministers and the Kvertus UAV company.*	**Respondent from the 4th stage of the survey:** • Age: 47 years old • Gender: Male • Marital Status: Single • Place of residence: Kyiv • Financial Security Level: High • Profession: Programmer at a startup *Q: **What measures do you think should be taken to ensure the safe use of drones?*** *A: I myself have launched a small drone several times, which I bought for a hobby. And with a full-scale one, I often see these drones, especially near the airport. Therefore, after the war, it is necessary to maintain a strict license for the use of drones, establish geo-zones where it is forbidden to fly, develop a drone identification system and develop technologies that will allow us to distinguish enemy drones from civilian ones.*
Respondent from the 5th stage of the survey: • Age: 52 years old • Gender: Male • Marital Status: Single • Place of residence: Kyiv • Financial Security Level: High • Profession: Accountant Q: **How do you think it is possible to balance the need for security and privacy protection when using anti-drone systems?** A: *It is important to ensure that the technologies used for protection do not restrict people's rights and freedoms. It is also necessary to develop international cooperation in the field of drone regulation. It is necessary to hold broad public discussions, involve experts from various fields, develop clear rules for the use of anti-drone systems, and ensure transparency of their work.*	**Respondent from the 6th stage of the survey:** • Age: 61 years old • Gender: Female • Marital Status: Single • Place of residence: Kyiv • Financial Security Level: Low • Occupation: Pensioner, used to work as a teacher *Q: **Do you think anti-drone systems can affect your sense of security?*** *A: On the one hand, yes, because I will know that the city is protected. But how much does it cost? It's expensive. These drones make a lot of noise - I was scared several times when I saw them walking in the park. And I will be constantly worried that someone is watching me, and someone can simply make a mistake and harm an innocent person. And in general, it's not from God to create such systems with robots or drones*
Respondent from the 7th stage of the survey: • Age: 19 years old • Gender: Female • Marital Status: Single • Place of residence: Kyiv • Financial Security Level: Low • Occupation: Student Q: **What risks associated with the use of drones do you consider to be the most relevant?** *A: They can just fall on someone and kill them. They could be shot down by birds. And they can also be used for illegal surveillance or spying, which is not cool and not safe. I saw a video on social networks with the RUSORIZ logo on it, showing how Russian drones are*	**Respondent from the 8th stage of the survey:** • Age: 31 years old • Gender: Female • Marital Status: Married • Place of residence: Kyiv • Financial Security Level: Average • Occupation: On maternity leave *Q: **How do you feel about the idea of creating anti-drone systems in your city?*** *A: Very positive! This is an additional protection for us. I am most concerned about the safety of my children. I want them to be able to study and play in peace, and not hide in the subway or in shelters every day. That's why we donate to the Come Back Alive Foundation*

being destroyed by our UAVs. It's very exciting, and that's why my colleagues and I are donating to the Sternenko Foundation.	*every month, because we know Taras Chmut and trust him since the beginning of the full-scale invasion, as well as Maria Berlinska Foundation AeroRozvidka*

Table 12. №6 Advantages and disadvantages of various research methods

FEATURES	Questionnaire	Observation	In-depth interview	Focus group
Format	Structured questionnaire	Direct observation of actions	Unstructured or semi-structured conversation	Group discussion
Purpose	Obtain quantitative and qualitative data on opinions, attitudes	Capture real behavior	Deep understanding of one person's views	Identify commonalities and differences in the group
Advantages	Speed, scalability, standardization	Immediacy, contextuality	Depth, detail	Promotes new ideas through participant interaction
Disadvantages	Possible desired answers, limited open-ended questions	Observer subjectivity, limited data	Dependence on respondents' answers	Possible influence of dominant participants on the discussion

Fig. 12. Chinese UAV components and their suppliers for Indian market and worldwide

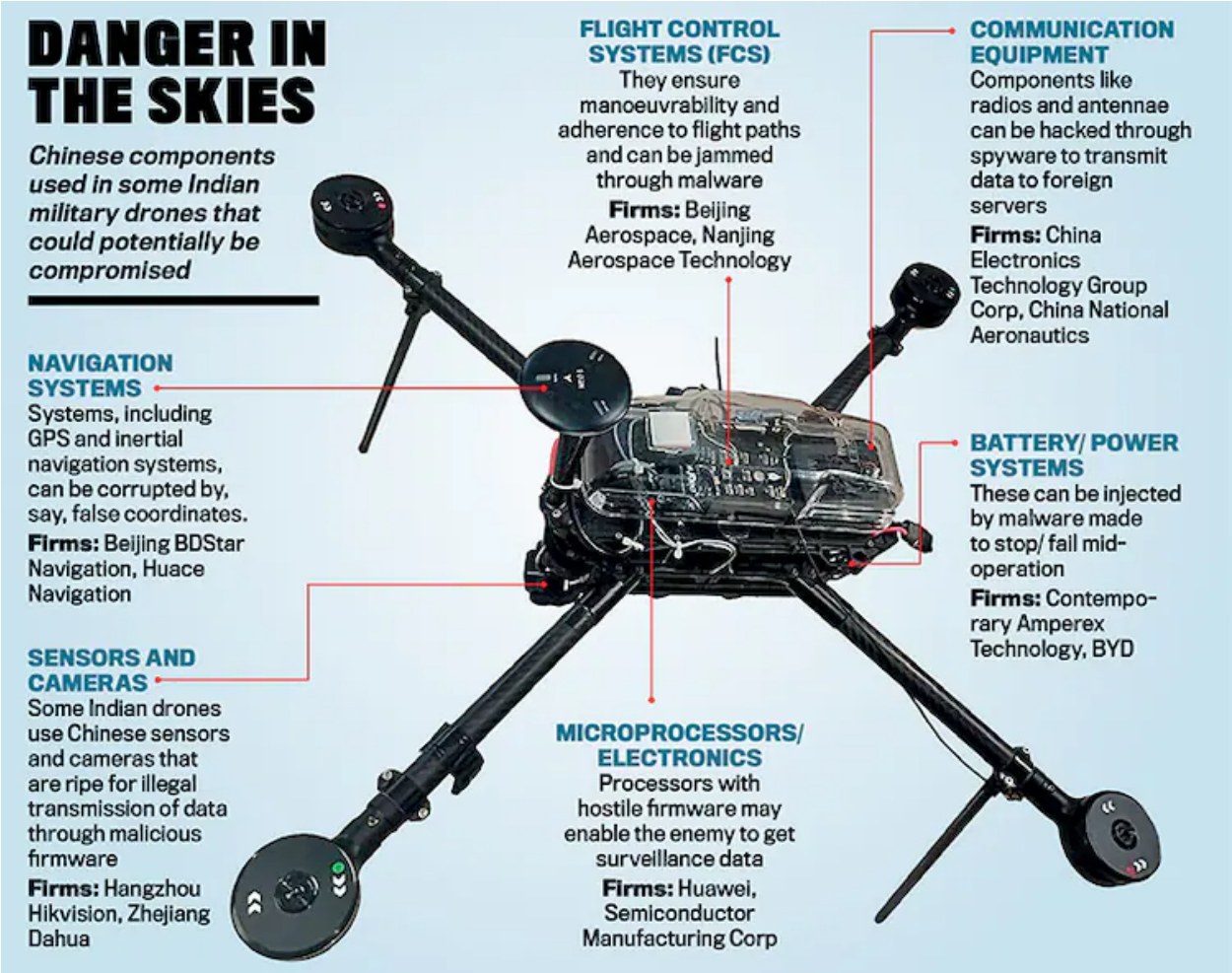
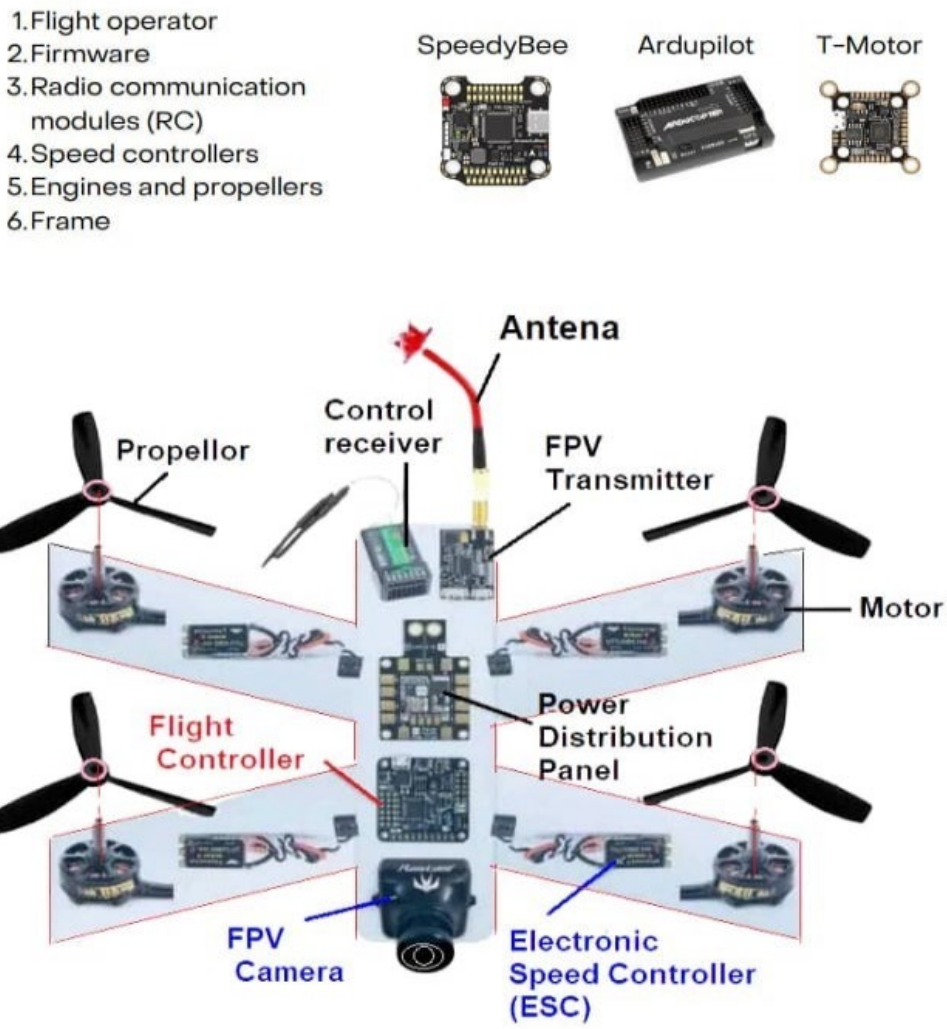


Fig. 13 Typical components of an FPV drone



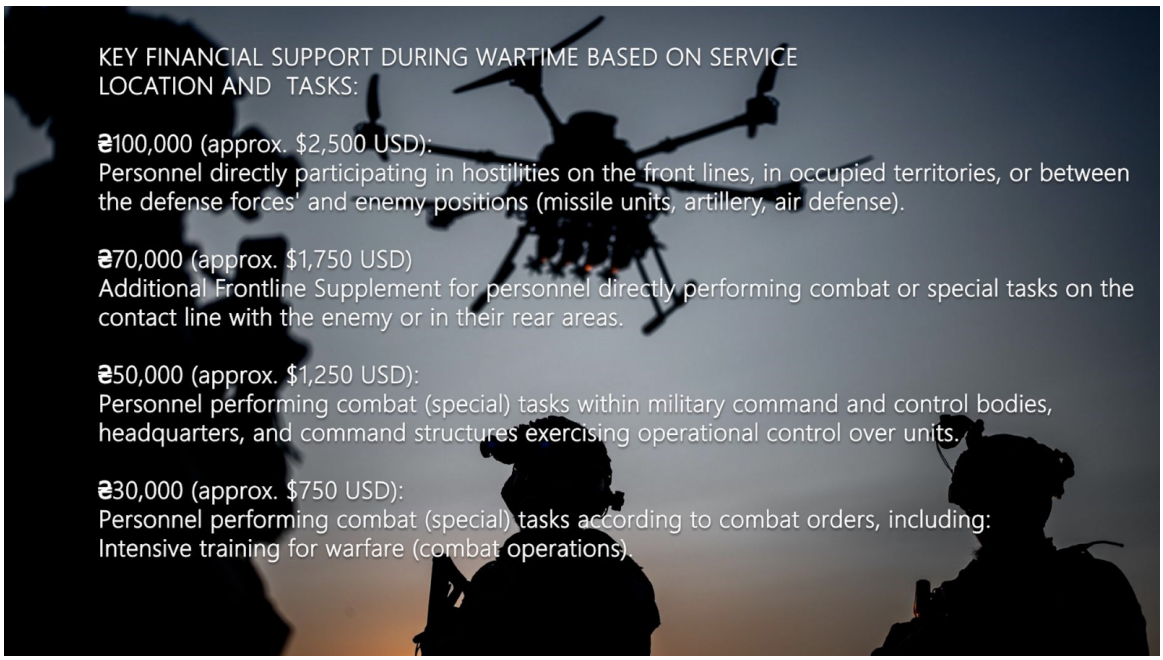
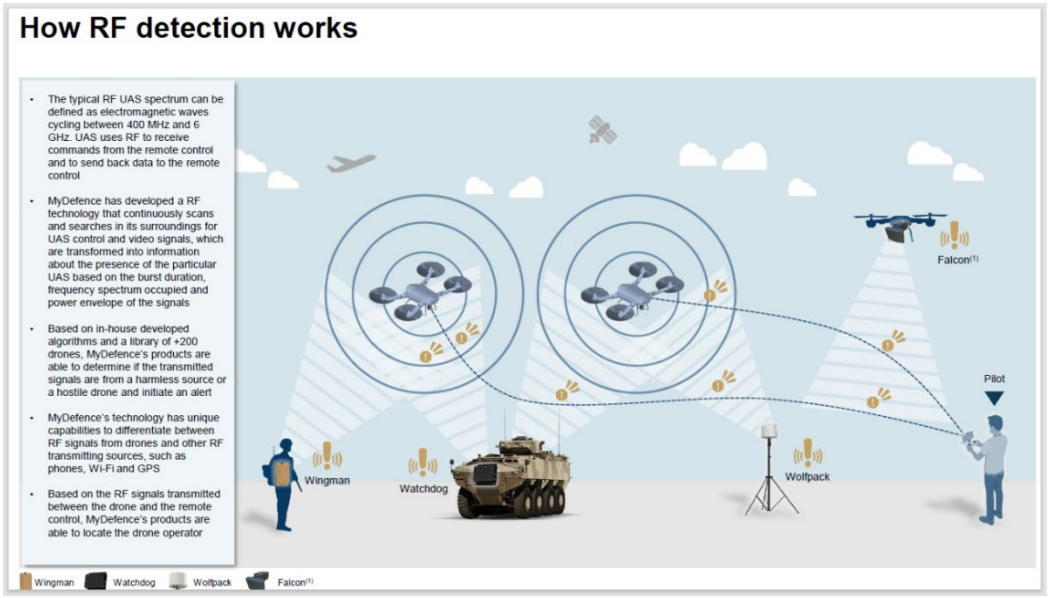
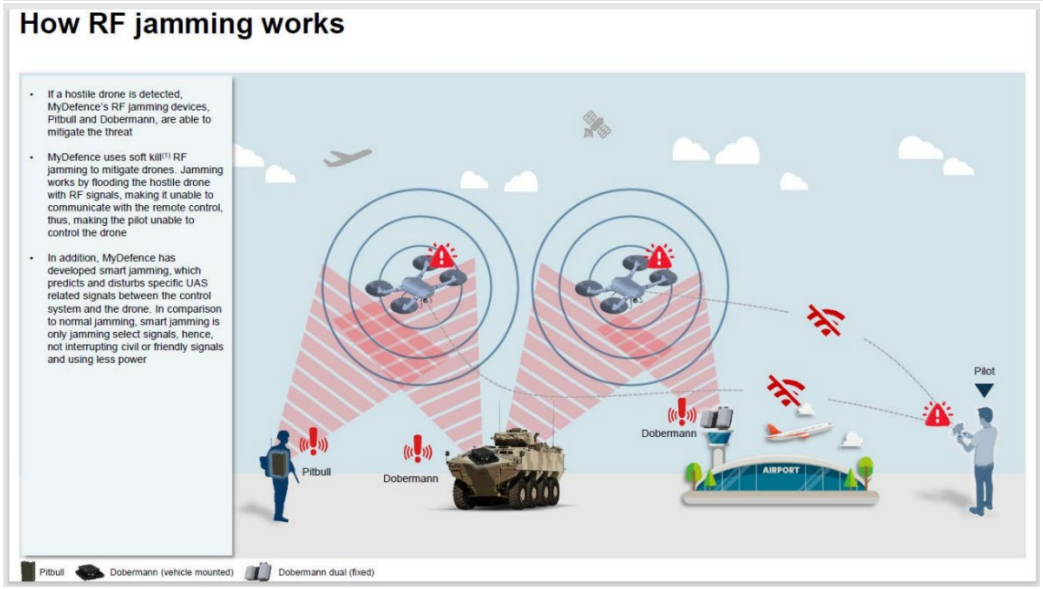


Fig.15-17. Overview of C-UxS algorithms and processes





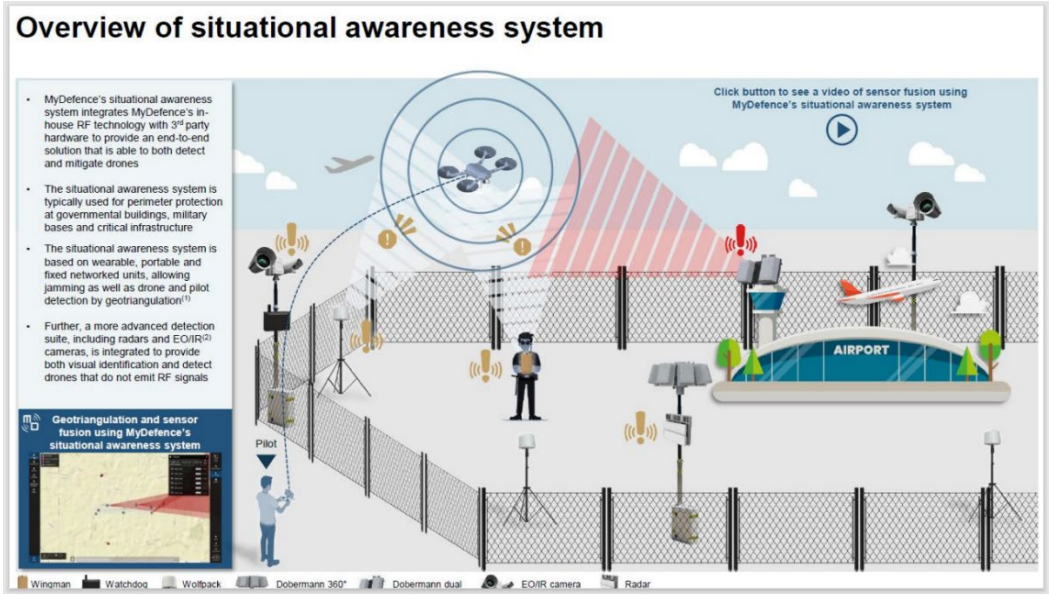
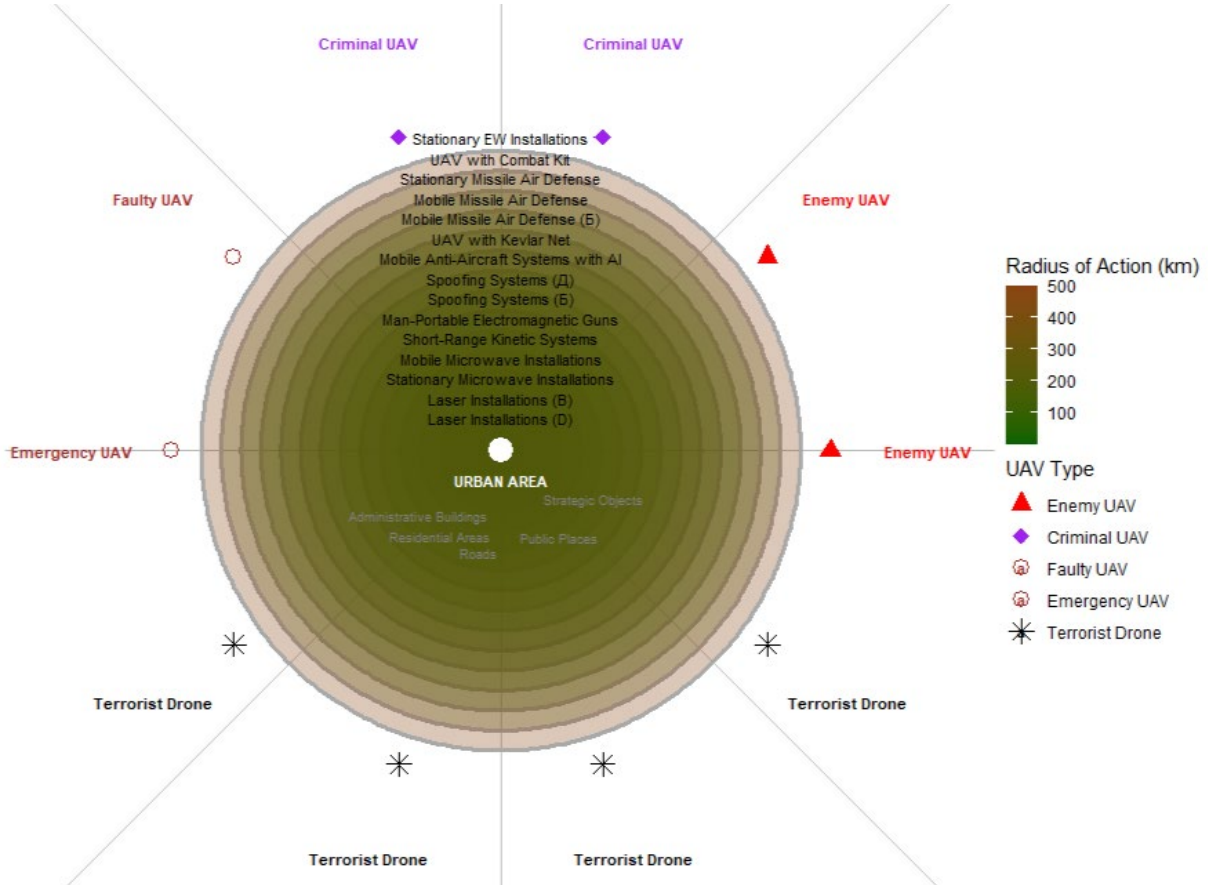


Table 13. Ukrainian experience of using C-UxS with prospects for South Korea

Distance/Process	Ukrainian Experience	Recommendation for South Korea
Long Range/ Early Detection	Use of long-range radar stations (RLS) capable of detecting aerial objects at a significant distance. In Ukraine, such radars are often integrated into the general air defense system.	Deploy a network of modern radars optimized for detecting small, low-flying targets such as drones. Possible integration with existing air defense systems to provide broader coverage of airspace.
Medium Range/ Precise Detection and Identification	Application of electro-optical and infrared (EO/IR) systems for visual confirmation of the target and its identification. In Ukraine, such systems are often mounted on mobile platforms.	Implement a network of EO/IR cameras, especially in urban areas and near critical infrastructure, for accurate tracking and recognition of drones. Possible use of thermal imaging cameras for detecting drones at night or in adverse weather conditions.
Short Range / Neutralization	Widespread use of electronic warfare (EW) for jamming drone control and navigation channels. In Ukraine, both stationary and portable EW systems, such as the Ukrainian Kvertus systems, are successfully used.	Deploy a network of stationary and mobile EW complexes in urban agglomerations and around important facilities. Mobile complexes can be placed on specialized vehicles for rapid response.
	Use of anti-drone rifles for the physical destruction of drones at short distances.	Provide rapid response units with anti-drone rifles for engaging drones in close proximity to protected objects.
	Development and use of interceptor drones.	Invest in the development and production of its own interceptor drones capable of intercepting and neutralizing hostile UAVs.

Fig. 18 RStudio screenshot of a model of echeloned-dome urban C-UxS defense



Urban C-UxS defense complex histogram code

```
library(ggplot2)
library(dplyr)
library(geomtextpath)

# Дані з таблиці (Переклад назв технологій на англійську)
data <- data.frame(
  technology = c(
    "Laser Installations (D)", "Laser Installations (B)", "Stationary Microwave Installations",
    "Mobile Microwave Installations", "Short-Range Kinetic Systems", "Man-Portable Electromagnetic
Guns",
    "Spoofing Systems (Б)", "Spoofing Systems (Д)", "Mobile Anti-Aircraft Systems with AI",
    "UAV with Kevlar Net", "Mobile Missile Air Defense (Б)", "Mobile Missile Air Defense",
    "Stationary Missile Air Defense", "UAV with Combat Kit", "Stationary EW Installations"
  ),
  radius_km = c(0.05, 0.05, 0.1, 0.15, 1, 2, 3.5, 3.5, 21, 45, 100, 100, 110, 200, 500)
)

# Сортування даних за радіусом дії
data <- data %>% arrange(radius_km)
data$order_num <- 1:nrow(data) # Use a different name to avoid confusion with order()

# Визначення фіксованих радіусів для відображення всіх технологій
base_radius <- 1
data$display_radius <- base_radius + (data$order_num - 1) * base_radius
max_radius <- max(data$display_radius)

# Параметри для розміщення БПЛА по колу
uav_radius <- max_radius * 1.1
n_enemy <- 2
n_criminal <- 2
n_faulty <- 2
n_terrorist <- 4
n_total_threats <- n_enemy + n_criminal + n_faulty + n_terrorist

# Визначення кутів для БПЛА (намагаємося чергувати типи)
angles <- seq(0, 2 * pi, length.out = n_total_threats + 1)[1:n_total_threats]

uav_data <- data.frame(
  type = factor(c(rep("Enemy UAV", n_enemy), rep("Criminal UAV", n_criminal), "Faulty UAV",
"Emergency UAV", rep("Terrorist Drone", n_terrorist)),
                levels = c("Enemy UAV", "Criminal UAV", "Faulty UAV", "Emergency UAV", "Terrorist
Drone")),
  angle = angles[1:length(c(rep("Enemy UAV", n_enemy), rep("Criminal UAV", n_criminal), "Faulty
UAV", "Emergency UAV", rep("Terrorist Drone", n_terrorist)))]
)

color_mapping <- c("Enemy UAV" = "red", "Criminal UAV" = "purple", "Faulty UAV" = "brown",
"Emergency UAV" = "brown", "Terrorist Drone" = "black")
shape_mapping <- c("Enemy UAV" = 17, "Criminal UAV" = 18, "Faulty UAV" = 1, "Emergency UAV" = 1,
"Terrorist Drone" = 8)
```

```
# Кути для позначень міських об'єктів
city_object_angles <- data.frame(
  label = c("Residential Areas", "Public Places", "Administrative Buildings", "Strategic Objects",
"Roads"),
  angle = c(4.1, 5.3, 3.5, 5.8, 4.5)
)

# Змінюємо кут для "Administrative Buildings" щоб розмістити нижче
city_object_angles$angle[city_object_angles$label == "Administrative Buildings"] <-
city_object_angles$angle[city_object_angles$label == "Administrative Buildings"] + 0.3

ggplot(data) +
  # Вертикальна вісь
  geom_vline(xintercept = 0, color = "gray", linewidth = 0.4) +
  # Горизонтальна вісь
  geom_hline(yintercept = 0, color = "gray", linewidth = 0.4) +
  # Діагональна вісь (з лівого нижнього в правий верхній)
  geom_abline(intercept = 0, slope = 1, color = "gray", linewidth = 0.4) +
  # Діагональна вісь (з лівого верхнього в правий нижній)
  geom_abline(intercept = 0, slope = -1, color = "gray", linewidth = 0.4) +
  # Різнорадіусні кола технологій (фіксовані для відображення всіх)
  geom_circle(aes(x0 = 0, y0 = 0, r = display_radius, fill = radius_km), alpha = 0.3, linewidth = 1.2, color
= "darkgrey") +
  scale_fill_gradient(low = "darkgreen", high = "saddlebrown", name = "Radius of Action (km)") +
  # Підписи технологій (вигнутий текст)
  geom_textpath(aes(y = display_radius, # Розміщуємо текст на радіусі кола
                x = (order(radius_km) - 1) * (2 * pi / nrow(data)), label = technology),
            hjust = 0.5, vjust = 0.5, size = 2.8, color = "black",
            linewidth = 0.3) +
  coord_polar() + # Перехід до полярних координат
  # Центральна чорна крапка "URBAN AREA"
  annotate("point", x = 0, y = 0, color = "white", size = 6) +
  annotate("text", x = 0, y = -max(data$display_radius) * 0.1, label = "URBAN AREA", size = 3, color =
"white", fontface = "bold") +
  # БПЛА
  geom_point(data = uav_data, aes(x = uav_radius * cos(angle), y = uav_radius * sin(angle), color =
type, shape = type), size = 4) +
  geom_text(data = uav_data, aes(x = uav_radius * 1.3 * cos(angle), y = uav_radius * 1.3 * sin(angle),
label = type, color = type), size = 3, fontface = "bold") +
  scale_color_manual(name = "UAV Type", values = color_mapping) +
  scale_shape_manual(name = "UAV Type", values = shape_mapping) +
  # Позначення міських об'єктів
  geom_text(data = city_object_angles, aes(x = (max_radius * 0.35) * cos(angle), y = (max_radius *
0.35) * sin(angle), label = label, color = c("steelblue", "lightcoral", "gold", "forestgreen", "skyblue")),
          size = 2.5) +
  coord_fixed(ratio = 1, xlim = c(-max_radius * 1.5, max_radius * 1.5), ylim = c(-max_radius * 1.5,
max_radius * 1.5)) +
  theme_void() +
  labs(title = "Model of Echeloned-Dome Counter-Drone Protection of Urban Space") +
  theme(plot.title = element_text(hjust = 0.5),
      legend.position = "right")
```

Fig.19 Screenshot of QGIS modeling for Odesa and Incheon urban C-UAV defense complexes

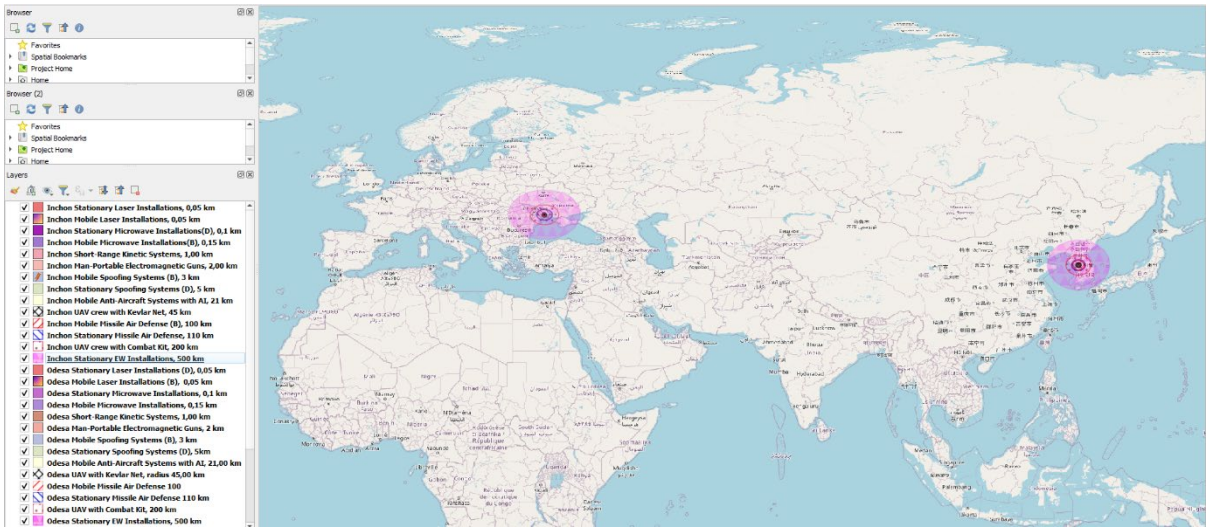


Fig. 20,21. Google Maps screenshots of Odesa and Incheon (the cities are marked in red)

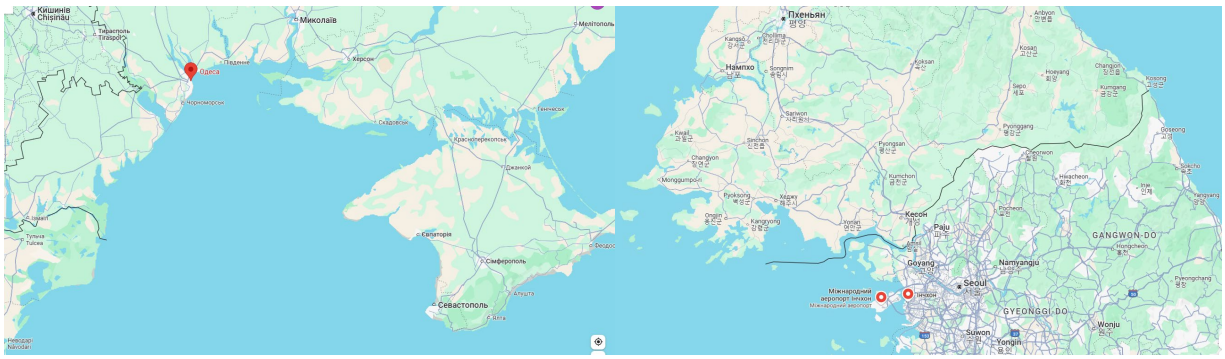


Fig.22 Photo of the smart city Songdo (as part of Incheon Free Economic Zone)

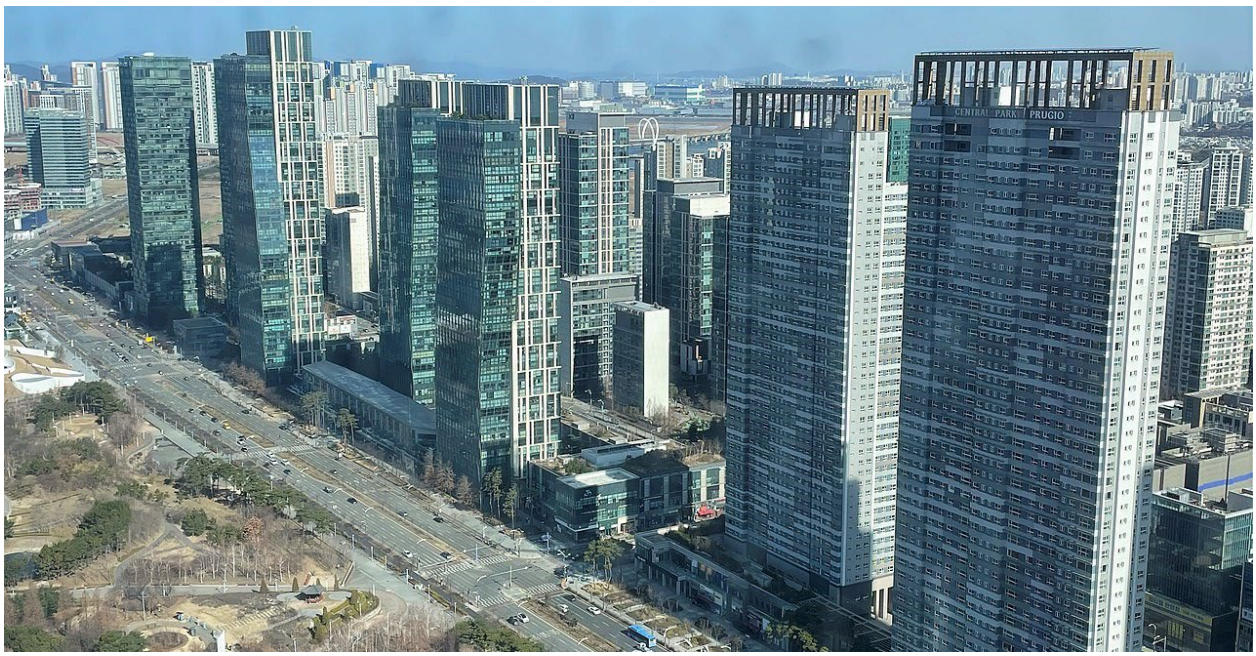


Fig.23 Google Maps screenshots of Incheon, its airport and Seoul

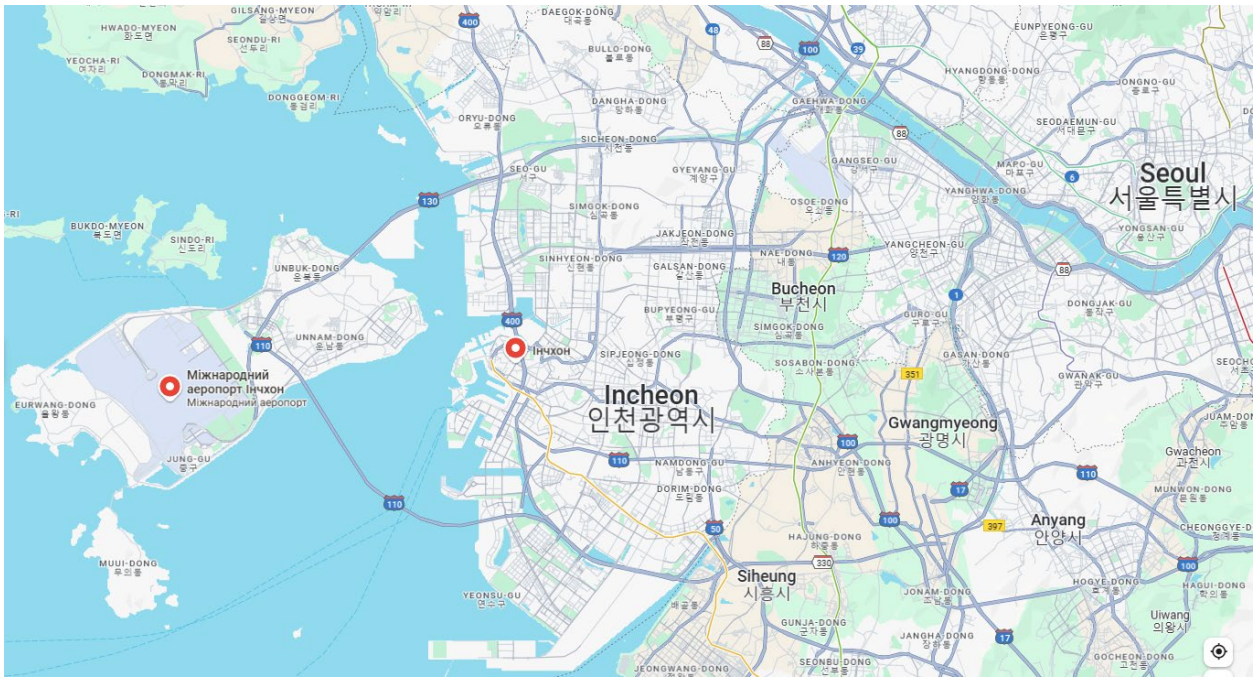


Fig. 24-26 QGIS modeling of urban C-UAV defense complex for Odesa city

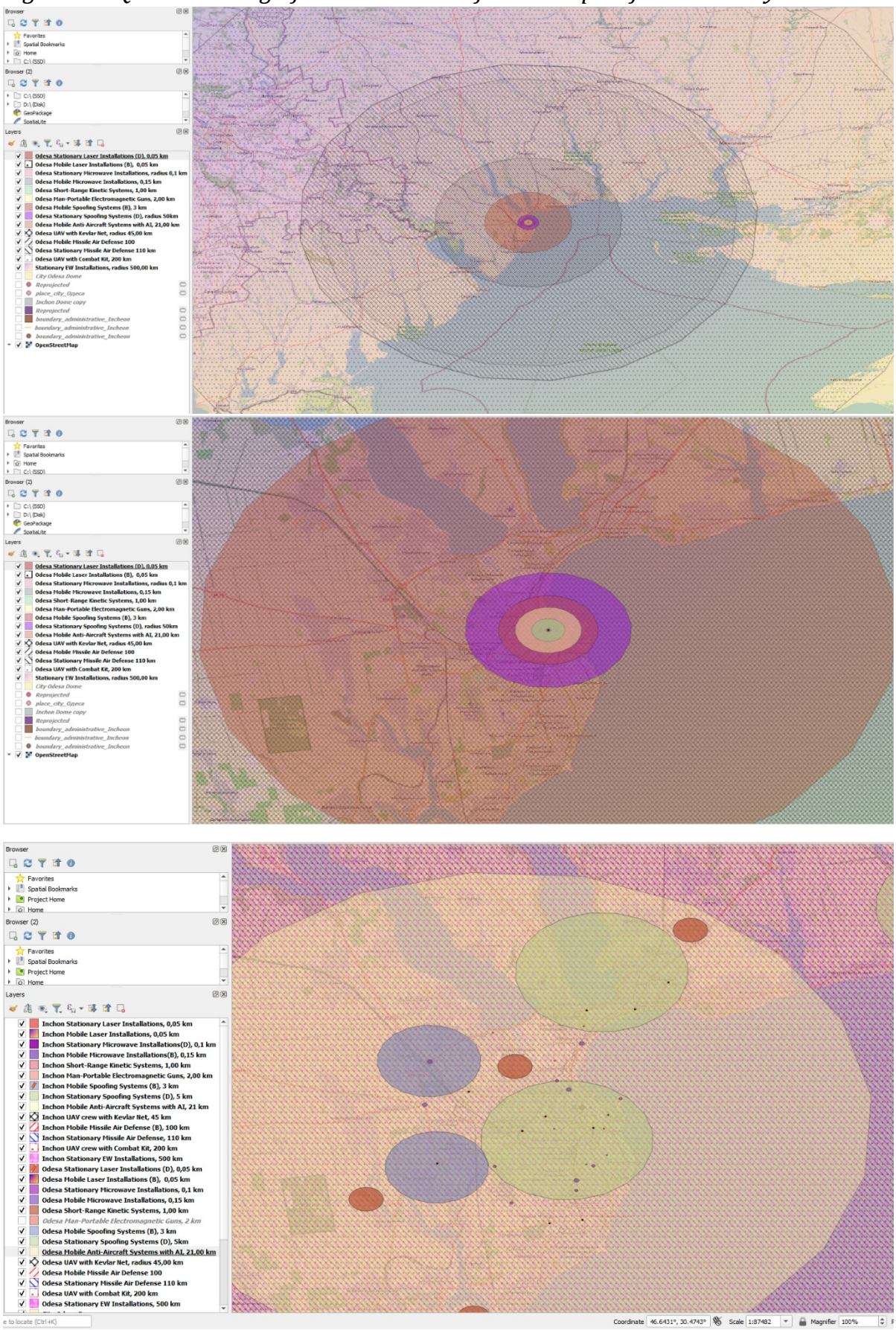


Fig. 27,28. QGIS modeling of urban C-UAV defense complex for Inchon city

Table 14. Framework of stakeholder interests in the UAV/C-UAV industry

NEEDS STAKEHOLDERS	ECONOMIC	SOCIAL	ENVIRONMENTAL
The state (represented by the Ministry of Defense, the Ministry of Digital Transformation, the Ministry of Economy, the State Aviation Service of Ukraine and other agencies)	Ensuring the country's defense capability in a cost-effective manner, stimulating the development of high-tech industries, creating new jobs, and attracting investment.	Ensuring the safety of citizens and critical infrastructure, supporting war veterans through retraining and employment programs, minimizing the negative impact of military operations on the civilian population, taking into account public opinion on the use of drones.	Ensure environmental safety in the use and production of drones, support developments aimed at minimizing environmental impact.
Private companies developing and producing UAVs and counter-drone systems	Access to financing (investments, loans, government grants), support for entering domestic and international markets, protection of intellectual	Opportunity to realize innovative potential, contribution to strengthening the country's defense capabilities, creation of high-tech jobs, attraction of qualified personnel.	Support for developments aimed at reducing energy consumption and the use of environmentally harmful materials in the production of drones.

	property, favorable regulatory environment and simplifying bureaucratic procedures.		
Investors (risk capital, angel investors)	High return on investment, minimization of risks, clear mechanisms for exiting investments, market predictability.	Participation in the development of promising technologies, support for innovative entrepreneurship, contribution to national security and the strategic importance of investments in the drone industry.	Support for investments in green technologies and projects that have a positive impact on the environment.
Research institutions and educational institutions	Financing of research (government grants, private investment), commercialization of research results, attraction of talented students and researchers.	Development of science and education in Ukraine, training of highly qualified personnel for the UAV industry, participation in solving important social and economic problems of the country.	Conducting research in the field of clean energy for drones, development of eco-friendly materials.
Volunteer organizations and public initiatives	Raising charitable funds to support the development and purchase of drones for the military.	Active participation in the defense of the country, support for innovation from below, prompt response to the needs of the frontline.	Ensuring environmental safety when using drones, raising public awareness of environmental aspects.
Media	Attracting an audience, generating revenue from advertising and affiliate programs.	Informing the public about the development of UAV technologies and anti-drone systems, shaping public opinion, supporting innovative entrepreneurship.	Coverage of environmental aspects of drone use and their impact on the environment.
End users of technologies (military, civilian population, critical infrastructure enterprises)	Access to efficient and cost-effective solutions for security and various tasks.	Ensuring personal and collective safety (especially in urban environments), protecting critical infrastructure, improving quality of life.	Use of environmentally friendly technologies, minimization of negative environmental impact.

Fig. 29-32. MIRO project of multi-level model of UxS/C-UxS innovative ecosystem