

SECTION «ENGINEERING SCIENCES»

TECHNOLOGICAL FOUNDATIONS OF AUTONOMOUS UNMANNED SYSTEMS AND PATENT LANDSCAPE ANALYSIS

Hennadii Androshchuk¹

Vladyslav Khvostenko²

DOI: <https://doi.org/10.30525/978-9934-26-651-5-1>

Abstract. This study provides an interdisciplinary analysis of autonomous unmanned systems as complex cyber-physical objects in which artificial intelligence algorithms are directly transformed into the defence and economic capacities of the state through intellectual property mechanisms. *Purpose.* The purpose of the study is to substantiate a conceptual framework for the technological and intellectual property governance of autonomous unmanned systems, with a particular focus on visual SLAM as a core algorithmic component of spatial autonomy and on defence intellectual property management as an institutional factor of technological sovereignty. *Methodology.* The methodology of the study is based on general scientific methods of analysis and synthesis, induction and deduction, abstraction and systematisation, as well as patent landscape analysis and comparative legal assessment. These methods are applied to examine algorithmic architectures, intellectual property regimes, and institutional mechanisms governing dual-use technologies. *Results.* It is demonstrated that artificial intelligence constitutes a key driver in

¹ Candidate of Economic Sciences, Associate Professor, Chief Researcher, Scientific Research Institute of Intellectual Property of the National Academy of Legal Sciences of Ukraine, Ukraine

² Candidate of Economic Sciences, Associate Professor, Associate Professor of the Department of Cybersecurity, National Technical University “Kharkiv Polytechnic Institute”, Ukraine; Head of TISC Office & Chair of the Intellectual Property Committee at Lviv Chamber of Commerce and Industry, Ukraine; Patent Attorney

the transformation of unmanned aerial vehicles from remotely operated platforms into autonomous systems capable of independent navigation, environmental perception, and real-time decision-making. Particular attention is devoted to visual SLAM technologies as a fundamental algorithmic component enabling simultaneous localisation and mapping under conditions of degraded or unavailable satellite navigation. Patent landscape analysis establishes that visual SLAM exhibits a predominantly algorithmic patenting profile, a high degree of rights fragmentation, and a concentration of core patent claims within IPC/CPC classes G06, G01S, and G05D, creating both engineering opportunities and substantial risks to freedom of implementation. Unmanned systems are examined as dual-use technologies, and systemic deficiencies in defence intellectual property management in Ukraine are identified, including fragmented legal regulation, uncertainty regarding the legal status of defence R&D outcomes, patent migration, accumulation of service and classified inventions, and limited commercialisation of state-funded technological developments. The principal result is the formulation of a process-oriented model of defence intellectual property management covering the entire technology life cycle—from identification of protectable objects and selection of legal protection regimes to utilisation, scaling, licensing, and international transfer, taking into account national security requirements. *Practical implications.* The proposed model enables coordinated management of research outputs, state defence procurement and legal protection mechanisms, providing a structured basis for reducing implementation risks, improving commercialisation pathways, and strengthening institutional control over strategic technologies. *Value/originality.* The study substantiates a transition from fragmented protection of individual developments toward systematic management of algorithmic autonomy as a strategic resource, thereby forming a conceptual foundation for the technological sovereignty of the state.

1. Introduction

The rapid development of unmanned systems in the current conditions of war and global technological competition is transforming the concept of state defence capabilities. Unmanned aerial vehicles are evolving from remotely controlled platforms to autonomous cyber-physical systems

capable of independently perceiving the environment, planning trajectories and making decisions in real time. Artificial intelligence plays a key role in this transformation, integrating computer vision, machine learning and adaptive control algorithms to form a new class of defence technologies.

Ukraine is in an exceptional situation of accelerated technological evolution: the combat use of drones creates a constant cycle of ‘field mutations,’ within which new engineering solutions are implemented in weeks rather than years. This dynamic is transforming the country into a testing ground for autonomous systems and, at the same time, creating the conditions for Ukrainian developments to enter the global defence tech market. At the same time, the strategic importance of intangible assets is growing: in segments related to unmanned platforms, sensors and artificial intelligence, the share of intellectual property in the cost of the product exceeds the material component.

The algorithmic core of autonomous unmanned systems is simultaneous localisation and mapping (visual SLAM) technologies, which provide a spatial model of the environment based on visual data and enable operation in the absence or degradation of satellite navigation. These algorithms determine the system's ability to move independently, avoid obstacles and adapt to a changing environment. In parallel with the rapid development of such solutions, there is active patenting of algorithmic components of autonomy, which forms a fragmented global patent landscape with a concentration of key rights within classes G06, G01S and G05D. As a result, algorithmic autonomy is becoming not only a technical but also a legal category that determines the possibilities for the implementation, scaling and export of unmanned technologies.

Against this backdrop, unmanned systems are acquiring the status of dual-use technologies, where engineering innovations directly translate into factors of national security. Global practice shows that leading states in the field of defence technologies view intellectual property as a strategic resource and integrate its management into the overall cycle of weapons development. In Ukraine, despite significant scientific and technical potential and practical achievements in the field of unmanned systems, there remains fragmentation in legal regulation, uncertainty regarding the rights holders of defence R&D results, patent migration, and the accumulation of service and secret inventions that are not used in production.

This creates a systemic contradiction: on the one hand, there is the accelerated technological evolution of autonomous systems, and on the other, there is a lack of a comprehensive state model for managing intellectual property in the defence sector. Under such conditions, algorithmic solutions created in wartime risk losing their strategic value due to uncontrolled disclosure, legal fragmentation, or outflow abroad.

The purpose of this section is to develop an integrated approach to the analysis of autonomous unmanned systems, combining the technological level (artificial intelligence and UAVs), the algorithmic level (visual SLAM and the patent landscape) and the institutional level (management of defence intellectual property). The task is to justify a process-oriented model of state management of defence IP, covering the full life cycle of technologies – from creation and legal protection to use, scaling and international transfer, taking into account national security requirements.

Structurally, the section is built on an analysis of the technological foundations of autonomous unmanned systems, through research into the patent architecture of spatial navigation algorithms, to the formation of a model of state management of intellectual property as an instrument of technological sovereignty.

2. ALGORITHMIC BASES OF AUTONOMY OF UNMANNED SYSTEMS: ARTIFICIAL INTELLIGENCE AND VISUAL SLAM

2.1. Artificial intelligence as the architectural basis of autonomous UAVs Theoretical foundations of AI and drones

Artificial intelligence (AI) is a broad field of computer science focused on creating machines capable of performing tasks that typically require human intelligence. Such tasks include learning, image recognition, decision making, natural language understanding, and problem solving. Although the concept of thinking machines has been around for centuries, the term ‘artificial intelligence’ was officially introduced by John McCarthy in 1956 during the Dartmouth Conference, which is considered the starting point of modern AI history. The early period of AI development (1950s–1970s) was characterised by optimism and ambitious goals: the first programmes were developed that could play chess, solve mathematical problems, and prove theorems. At the same time, limited computing power and the lack of large amounts of data led to the emergence of the so-called

‘AI winters’ – periods of declining interest and funding in the 1970s and 1980s. The next revival of interest in AI occurred in the late 1980s and early 1990s with the development of expert systems that used the knowledge of specialists to make decisions in narrow subject areas. The real AI boom began in the 2000s, made possible by the exponential growth of computing power (particularly graphics processors), the emergence of huge data sets (Big Data) and the development of new effective algorithms, especially in the field of machine and deep learning.

Modern AI covers several key areas that form the basis for the creation of autonomous technical systems, including unmanned ones. Machine learning (ML), as a subfield of AI, enables computer systems to ‘learn’ from data without explicit programming: instead of coding every possible situation, algorithms are provided with large data sets, allowing them to identify patterns and make predictions or decisions. Typically, a distinction is made between supervised learning, which uses labelled data and a known output for each input (classical examples are classification for object recognition and regression for predicting numerical values), unsupervised learning (Unsupervised Learning), where the algorithm works with unlabelled data and identifies hidden structures (clustering, dimensionality reduction), and reinforcement learning (RL), in which an agent learns by interacting with the environment, receiving rewards or punishments for its actions in order to maximise the total reward; this approach is particularly valuable for autonomous systems such as drones. Deep learning (DL) is a specialised branch of ML that uses neural networks with many hidden layers to model complex abstractions and is highly effective when working with unstructured data (images, video, sound); Typical examples are convolutional neural networks (CNN) in computer vision tasks and recurrent neural networks (RNN) for sequence processing. Computer vision allows computers to ‘see’ and interpret visual information, solving tasks such as object recognition, motion tracking, image segmentation, and 3D reconstruction. This area is critically important for drones, as it is directly related to navigation, obstacle avoidance, and mission execution. Natural Language Processing (NLP), although less directly applicable to autonomous navigation, plays a role in building human-drone interfaces, voice control, and analysis of mission-related text data.

Drones, or unmanned aerial vehicles (UAVs), are aircraft without a pilot on board, whose flight is controlled remotely by an operator or performed autonomously along a pre-programmed trajectory or using on-board control systems. They can be classified according to various criteria, but the most common distinction is by aerodynamic configuration. Multicopters (copters) are the most common type of UAV, using multiple rotors (usually 4, 6 or 8) to generate lift and control; they are capable of vertical take-off and landing (VTOL), hovering in the air and high-precision manoeuvrability, making them convenient for aerial photography, inspections and short-distance delivery, with sizes ranging from miniature quadcopters to large octocopters with significant payload capacity. Aircraft-type (fixed-wing) drones use wings to generate lift and have a propeller or jet engine for forward motion; they are effective for long flights and long distances, but require a runway or catapult for take-off and a parachute or special landing area, so they are used in mapping, monitoring large areas and logistics. Hybrid systems (fixed-wing VTOL) combine the advantages of both approaches, with rotors for vertical take-off/landing and wings for efficient horizontal flight, providing the flexibility of runway-free take-off and the ability to fly long distances.

The practical applications of drones have rapidly expanded and now include logistics and delivery (rapid transport of small cargo, medicines, and mail to hard-to-reach areas; systems are being actively tested and implemented by Amazon and Zipline), agriculture (precision agriculture for monitoring crop conditions, irrigation, fertiliser and pesticide application; multispectral cameras allow for optimising crop yields and reducing costs), monitoring and inspections (inspection of bridges, pipelines, power lines, wind turbines, construction site control, forest surveys, environmental monitoring), security and law enforcement (monitoring of mass events, search and rescue operations, border patrols, police assistance), media and entertainment (aerial photography, film and television production, sports broadcasts, drone shows), as well as scientific research (data collection in hard-to-reach or dangerous places, climate, wildlife and geology research). With the development of artificial intelligence, the functionality of drones is constantly expanding, allowing them to perform increasingly complex and autonomous tasks, which necessitates considering AI as a cross-cutting component of unmanned system architecture.

The use of AI in drone functionality

The integration of artificial intelligence is critical to transforming drones from simple remote-controlled devices into autonomous systems capable of perceiving their environment, processing information, making decisions, and adapting to changing conditions without constant human intervention. One of the most significant applications of AI is enabling autonomous navigation and flight. Traditional control systems rely on GPS and inertial measurement units (IMUs), but these solutions have significant limitations in the absence of satellite signals or in complex, dynamic environments. AI overcomes these limitations by giving the drone the ability to ‘see’ and interpret its surroundings, which directly improves flight safety and efficiency.

Computer vision is the basis of autonomous navigation, as drones collect large amounts of visual and spatial information through built-in cameras (optical, infrared, stereoscopic, ToF cameras) and lidars. Deep learning algorithms, in particular CNN, are used to recognise and classify objects, allowing the identification of trees, buildings, people, other aircraft, power lines, etc. [1] and the formation of a more reliable situational model. Additionally, image segmentation methods are used to separate objects from the background and refine the boundaries of obstacles, as well as depth estimation based on stereo vision or ToF sensors to reproduce the 3D structure of space. Obstacle avoidance systems operate on this basis, detecting collision threats in real time and ensuring dynamic trajectory changes, which is especially important in forests, urban environments, or indoors. In situations where navigation support is unavailable, AI-enhanced SLAM (Simultaneous Localisation and Mapping) methods are crucial, allowing simultaneous mapping of unknown environments and determining the location of the drone without external signals. This makes UAVs effective for exploring caves, ruined buildings, or performing missions in GPS-denied environments.

Once an understanding of the environment has been formed, the task of route planning and trajectory optimisation arises. In practice, A* (A-star) and RRT (Rapidly-exploring Random Tree) algorithms and their modifications are used to build the optimal path, taking into account the starting and target points, as well as detected obstacles, based on the criteria of the shortest, safest, or most energy-efficient route. If necessary,

these approaches provide dynamic re-planning in the event of unforeseen obstacles or changing conditions, such as weather. Reinforcement learning creates additional opportunities: RL allows drones to ‘learn’ to perform complex manoeuvres, such as flying in confined spaces or compensating for gusts of wind, optimising energy consumption and stability.

Artificial intelligence is also key to real-time data processing. Drones are equipped with various types of sensors (cameras, thermal imagers, multispectral sensors, lidars) that generate significant data streams that need to be interpreted quickly. Deep learning (primarily CNN architecture) enables object recognition and image/video analysis, allowing the identification of people, vehicles and animals in search and rescue operations or during wildlife monitoring; detect infrastructure defects (e.g., cracks in bridges or damage to wind turbine blades); analyse crop conditions and identify areas with diseases or nutrient deficiencies based on multispectral data; and record anomalies or suspicious activity while monitoring the territory. Processing can be performed on the drone itself (Edge AI), which minimises delays and allows for immediate response, or data can be transmitted to a ground station for deeper analysis.

Non-visual data processing is equally important. Liars form point clouds, which are converted by AI into high-precision 3D models of the terrain, needed in cartography, construction, and engineering surveys. Thermal imagers can detect thermal anomalies, useful for finding people in darkness or smoke or detecting heat leaks in buildings. Acoustic sensors can be used to identify sound sources (including searching for victims by voice) or to monitor mechanisms. Sensor fusion combines information from different channels, providing a more complete and reliable model of the environment and compensating for the limitations of individual sensors.

The level of autonomy of unmanned systems is significantly increasing thanks to the capabilities of AI in decision-making and adaptive control. Unlike executing fixed instructions, modern drones can make decisions in real time and change their behaviour depending on the situation. Reinforcement learning allows an agent to optimise its behaviour to achieve a goal (e.g., minimising energy consumption, finding the shortest route, or avoiding detection), determine the sequence of actions to perform complex missions (surveying the territory with optimal coverage or searching for a given object), and adapt to new situations based on accumulated

‘experience.’ In practical terms, AI also compensates for wind effects by dynamically adjusting thrust and pitch, increases fault tolerance (in particular by reconfiguring the control system in the event of engine or other component failure) and supports responses to unforeseen circumstances, such as the appearance of another aircraft in dangerous proximity, when evasive manoeuvres or a safe return to base are possible.

A separate area of focus is improving human-drone interaction and developing group control. Voice control systems based on natural language recognition allow the operator to control the drone with voice commands, reducing cognitive load in complex conditions; gesture control provides intuitive interaction; and predicting the operator's intentions allows AI to analyse behaviour and commands, anticipate further actions and suggest optimal solutions or automatically perform routine operations. Within drone swarms, AI provides centralised or decentralised control of a group of UAVs, prevents collisions, optimises territory coverage, distributes tasks (when one drone is filming, another is patrolling, and a third analyses data) and supports collective decision-making, such as changing formation to fly around obstacles or concentrating resources in a specific area. Collectively, this increases the efficiency of large-scale missions, such as large-scale mapping or search operations in forest areas.

Prospects and challenges of using AI in drones

Despite significant successes, the integration of AI into UAVs is still in the active development stage. On the one hand, the synergy between AI and unmanned technologies creates the conditions for a qualitative leap in autonomy, and on the other hand, it creates a set of challenges of a technological, ethical, legal and security nature. The development of advanced autopilot and fully autonomous robotics is expected, which will allow drones to perform complex missions without human intervention, including autonomous search and rescue in unknown conditions, inspection of large industrial facilities without prior mapping, and decision-making in crisis situations, such as changing routes when unforeseen events occur or searching for alternative landing areas. Integration with the Internet of Things (IoT) and smart cities will be strengthened, where drones will interact with sensor networks and infrastructure, receiving traffic data or following smart traffic light signals to optimise routes. At the same time, drones will become multifunctional platforms for deploying advanced

models on board (Edge AI), reducing delays and dependence on cloud services. Swarm systems will become more intelligent, with the ability to dynamically reallocate resources, adapt to the failure of individual elements, and demonstrate collective intelligence in large-scale tasks such as mapping large areas or search and rescue operations in forest areas.

At the same time, autonomous decision-making creates ethical dilemmas, primarily regarding responsibility for errors or damage caused by an autonomous drone, as well as the formalisation of ethical norms in AI behaviour, especially in military and law enforcement applications. The issue of privacy is becoming increasingly acute, as drones can collect large amounts of data about people and the environment, requiring a clear framework for the collection, storage and use of data and ensuring its protection. Cybersecurity is critical, as autonomous drones can be the target of cyberattacks; compromising systems can lead to loss of control or accidents, necessitating encryption, secure communication protocols, and intrusion detection mechanisms. At the same time, legal regulation often lags behind the pace of technological development, so new rules are needed on liability, licensing, flight zones, international cooperation and standardisation.

Technical and economic challenges include limited computing resources on board, which complicates the deployment of complex models on compact platforms with weight and power consumption constraints and requires more efficient algorithms and specialised hardware. An additional challenge is the reliability and verification of AI systems: the question of ensuring correct decisions in critical situations that may not have occurred during training remains open, and therefore new methods of testing, verification and validation of algorithms are needed, especially in applications with a high cost of error. The cost of developing and implementing advanced AI drones requires significant investment in research, development, testing, and certification, which may limit accessibility for small and medium-sized businesses. Finally, integration with existing systems, particularly air traffic management infrastructure, requires complex technical solutions and coordination between technologies and stakeholders. Overcoming these challenges requires coordinated efforts by governments, scientists, industry, and society to realise the potential of AI in drone development while minimising risks.

Drone production statistics and government orders

Drone production in Ukraine is a priority area, and its volumes are constantly growing. Data from different sources may vary slightly, as the situation is very dynamic, but the overall trend indicates a significant increase in capacity. According to the Ministry of Defence of Ukraine, approximately 600,000 drones were produced in 2023 [2], although some sources mention 300,000 units, but with an emphasis on significant growth. In 2024, President Volodymyr Zelenskyy stated at the International Defence Industry Forum that Ukraine could produce 4 million drones annually [3]. In February 2025 (looking back on 2024), Zelensky also noted that Ukraine had manufactured 2.2 million FPV drones and 100,000 long-range UAVs in 2024 [4]. In the first two months of 2024, Ukrainian manufacturers had already produced about 200,000 FPV drones [5], and the Ministry of Strategic Industries stated that production capacity in 2024 would reach 2 million drones of various types, including FPV [6]. Monthly production of FPV drones in Ukraine was estimated at 50,000 units, although demand is significantly higher – about 200,000 per month [7].

Plans and estimates for 2025 also demonstrate a desire to scale up. Defence Minister Rustem Umerov has announced a potential of 10 million drones per year [7]. Bloomberg, citing the Centre for Strategic Communications, notes that Ukraine plans to manufacture 2.5 million drones in 2025 [8]. Volodymyr Zelenskyy has set a target of producing at least 30,000 long-range drones in 2025 [9], and the Ministry of Defence plans to purchase 4.5 million Ukrainian-made FPV drones in 2025 [10]. At the same time, there has been an increase in institutional and financial support: there are about 200 manufacturers of various types of drones operating in Ukraine, of which almost 60 are already involved in state orders [11]. The Ukrainian Ministry of Defence has allocated more than \$2.5 billion in 2024–2025 to local drone manufacturers, signing contracts with 76 companies [8; 12]. The state budget for 2025 includes 775 billion hryvnia for domestic drone orders [13]. In 2025, the Ministry of Defence will allocate over 110 billion hryvnias for the purchase of drones, of which over 102 billion hryvnias will be channelled through the Defence Procurement Agency [10]. An important change is that the Unmanned Systems Forces Command has been granted the right to place state orders for drones and electronic warfare (EW)

equipment, which will allow it to meet the needs of the front line more quickly and accurately [14].

Overall, Ukraine is demonstrating significant growth in production capacity in the drone industry, moving from hundreds of thousands to millions of units per year, with ambitious plans to further increase volumes and funding for state orders. One of the most important factors supporting this dynamic could be the entry of Ukrainian drone manufacturers into the global arms market, which requires both a strategic decision by the national government and the acquisition of appropriate certification.

2.2. Visual SLAM as the core of spatial autonomy

The rapid development of autonomous systems, robotics, and UAVs is driving the growth of visualSLAM (Simultaneous Localisation and Mapping) technologies as a basic tool for spatial orientation and real-time environment construction. VisualSLAM (Simultaneous Localisation and Mapping) technology is a set of algorithms that allow devices such as robots or drones to simultaneously determine their location in space and build a detailed map of an unknown environment using only visual data (images from cameras) instead of expensive LiDAR sensors. They are key to autonomous navigation, augmented reality, and mapping, as they allow devices to ‘see’ the world and navigate it without GPS by processing visual features (features) of the surrounding world. [15] Unlike traditional navigation approaches based on external infrastructure sources (GNSS, beacons, maps), visual SLAM ensures system autonomy by processing visual data and integrating it with other sensor streams. At the same time, in parallel with the intensive introduction of visual SLAM technologies into applied systems, there is active patenting of relevant technical solutions, which forms a complex and fragmented patent landscape. A distinctive feature of this process is that a significant portion of patent applications are directed not at specific engineering implementations, but at abstract algorithmic approaches, architectural schemes for processing visual information, and methods for integrating localisation and mapping in autonomous systems. As a result, there is a structural gap between the technical development of visual SLAM and the legal mechanisms for its protection: engineering implementation often occurs faster than the realisation of patent restrictions, which creates risks of economic and legal

conflicts, blocking innovation and complicating the commercialisation of developments.

Despite a significant number of scientific publications devoted to visual SLAM algorithms, the issue of the patent landscape structure of this technology has been studied only fragmentarily. Most works focus on comparing algorithmic efficiency, localisation accuracy or computational complexity, while the patent dimension of technology development remains outside the scope of systematic analysis.

The scientific problem lies in the lack of a generalised understanding of how visual SLAM technologies are patented, which technical solutions form the core of patent claims, which entities concentrate IP rights, and how this affects the possibilities for engineering integration and further commercialisation of autonomous systems. In particular, the following questions remain unresolved: Does the visual SLAM patent landscape show signs of concentration or, conversely, fragmentation? at what level (algorithmic, architectural, platform) do the main patent risks arise; are there ‘windows of opportunity’ for developing new solutions without infringing existing patents; to what extent does visual SLAM patenting affect the freedom of engineering activity in autonomous systems.

Existing research in the field of visual SLAM mainly: does not take into account the structure of patent families; does not analyse the distribution of patents by applicants, jurisdictions and IPC/CPC classes; considers patents as separate documents rather than elements of a single IP landscape. As a result, there is a lack of tools that would allow: assessing patent risks at the R&D stage; forming patent-aware development strategies; using patent data for strategic innovation planning. It is this methodological gap that necessitates a comprehensive patent landscape analysis of visual SLAM technologies.

Research in the field of Intellectual Property Analytics (IPA) – an interdisciplinary field that combines methods of mathematics, statistics, computer programming, and operations research – enables the transformation of data arrays on IP objects into structured knowledge, the identification of interrelationships, trends and patterns in management and technological decision-making, which requires special interdisciplinary competencies. One of the key IPA tools is the patent landscape – an information and analytical study of patent documentation that reflects

the overall patent situation in a particular technological field or the patent activity of entities in the innovation sphere, taking into account time dynamics and territorial characteristics (enterprise, region, industry, country or global level). According to experts, the use of patent information can reduce R&D time by approximately 60% and reduce its cost by up to 40%. A patent landscape report provides a ‘snapshot’ of the patent situation in a specific technology, company or region, which creates a basis for making informed decisions in the field of innovation development and IP rights management [16, p. 53]. In this context, this section is a logical continuation of the authors' research in the field of IP analytics and is aimed at applying patent landscape tools to analyse Visual SLAM technologies as a critical element of autonomous systems and unmanned platforms.

The purpose of this section is to justify the methodological correctness of the research and explain the sources and approaches to patent landscape analysis in the field of visual SLAM technologies. Formalisation of data collection and processing methods ensures the reproducibility of results and confirms their analytical and applied value. **Research data sources.** The empirical basis of the study is patent data obtained from international patent analysis platforms, in particular **Orbit Intelligence**. These resources provide access to structured data on patent families, applicants, jurisdictions, IPC/CPC classifications, and patenting dynamics, which is standard practice for conducting patent landscape studies.

Using data at the level of patent families rather than individual patent documents avoids distortions associated with multiple patenting of the same technical solution in different countries. **Sampling criteria.** The patent data sample was formed based on a combination of keywords and thematic restrictions corresponding to the subject of the study. The search query included the following keywords and their combinations: visual SLAM, visual odometry, simultaneous localisation and mapping, visual localisation, visual mapping, as well as related terms associated with autonomous navigation and computer vision.

The time horizon of the study covers the period of active development of visual SLAM technologies, which allows us to trace both the stages of formation and current trends in inventive and patent activity. The analysis included valid and published patent families without restriction by stage

of legal protection, since the aim of the study is to identify the structural characteristics of the technological field, rather than to assess the legal validity of individual patents. The types of documents were limited to patent families containing technical solutions, without taking into account non-patent scientific and technical literature, which is analysed indirectly through citations and classification features.

Parameters of patent landscape analysis. Within the scope of the study, the patent landscape is analysed according to the following key dimensions:

- **applicants** – to identify the concentration of intellectual property rights and types of entities (universities, research institutions, companies);
- **patenting jurisdictions** – to determine the geographical structure of technological development and national centres of patent activity;
- **technological areas** – to identify the main objects of patenting in the field of visual SLAM (localisation algorithms, mapping, semantic processing, computation optimisation, etc.);
- **IPC/CPC classes** – as a tool for formalised description of the technical essence of the claimed inventions and identification of the core of patent claims.

These parameters allow us to move from a descriptive review to a structural analysis of technology as an IP object.

Limitations of the study. The results of the study should be interpreted with a number of limitations in mind. First, visual SLAM technologies are highly **algorithmic in nature**, which blurs the boundaries between individual classes of solutions and makes it difficult to classify them unambiguously. Second, different patent offices and analytical platforms may apply different approaches to the standardisation of applicants and IPC/CPC classifications, which partially affects the detail of the results.

At the same time, these limitations do not diminish the analytical value of the study, as its purpose is to identify **structural patterns in patenting**, rather than to provide a legal review of individual patent documents.

Thus, the methodology used provides a reliable basis for further analysis of the visual SLAM patent landscape and allows the results obtained to be considered representative for the formation of scientific, engineering, and strategic conclusions that go beyond a purely review approach.

2.3. Patent architecture of algorithmic autonomy

Parallel to the engineering development of autonomous systems, there is intensive patenting of algorithmic solutions, which forms a specific global patent landscape for visual SLAM and related technologies. Analysis of patent data indicates the predominantly algorithmic nature of applications, with a concentration of key solutions in classes G06 (computing systems and data processing), G01S (radio navigation and positioning) and G05D (automatic control systems).

This landscape is characterised by fragmentation of rights: individual elements of the algorithmic chain – feature detection, trajectory optimisation, sensor fusion, semantic mapping – may be protected by different patents belonging to different rights holders. This results in a complex network of cross-restrictions that complicates freedom to operate and increases the risk of legal conflicts during the commercialisation or scaling of autonomous platforms.

Another feature of algorithmic patenting is the rapid obsolescence of individual solutions against the backdrop of rapid developments in machine learning. This leads to a tendency to protect not specific implementations, but more abstract methods and architectures, which reinforces the strategic nature of patent portfolios. For states and large corporations, such portfolios become a tool for controlling access to critical technologies, rather than just a means of generating licensing revenue.

In the context of unmanned systems, this means that algorithmic autonomy is becoming the subject of legal regulation, where technical solutions directly affect the possibility of mass production, export and international cooperation. For countries at war or in technological confrontation, the patent landscape is becoming part of a broader security architecture.

Figure 1 shows the absolute distribution of patent families by key applicants. The vertical axis shows the list of main applicants, while the horizontal axis shows the number of patent families in the corresponding technology sample.

Analysis of the data shows a clear dominance of universities and research institutions in the patenting of visual SLAM technologies. Beijing University of Technology has the largest number of patent families, significantly ahead of other applicants. The group of leading applicants also includes Southeast

University, Chongqing University of Posts and Telecommunications, Guangdong University of Technology, Zhejiang University of Technology, Wuhan University and a number of other technical universities in China.

A characteristic feature of the identified landscape is the concentration of patent activity in the academic sector, with no large commercial corporations among the leaders. This structure indicates that visual SLAM technologies are at the stage of active research and development, where fundamental and applied research plays a key role, rather than large-scale industrial exploitation.

Analysis of the data shows a clear dominance of universities and research institutions in the patenting of visual SLAM technologies. Beijing University of Technology has the largest number of patent families, significantly ahead of other applicants. The group of leading applicants also includes Southeast University, Chongqing University of Posts and Telecommunications, Guangdong University of Technology, Zhejiang University of Technology, Wuhan University and a number of other technical universities in China.

A characteristic feature of the identified landscape is the concentration of patent activity in the academic sector, with no large commercial corporations among the leaders. This structure indicates that visual SLAM technologies are at the stage of active research and development, where fundamental and applied research plays a key role, rather than large-scale industrial exploitation.

To deepen the analysis of the concentration of IP rights, Figure 2 shows the partial distribution of patent families by standardised applicants in relative terms.

The results show that there is no dominant monopolistic player in the field of visual SLAM. The largest share of the patent portfolio belongs to Beijing University of Technology (approximately 6–7%), followed closely by Southeast University, Chongqing University of Posts and Telecommunications, Wuhan University, Guangdong University of Technology and other technical universities. The shares of most applicants are within the range of 2–4%, which indicates a high level of fragmentation in the patent landscape.

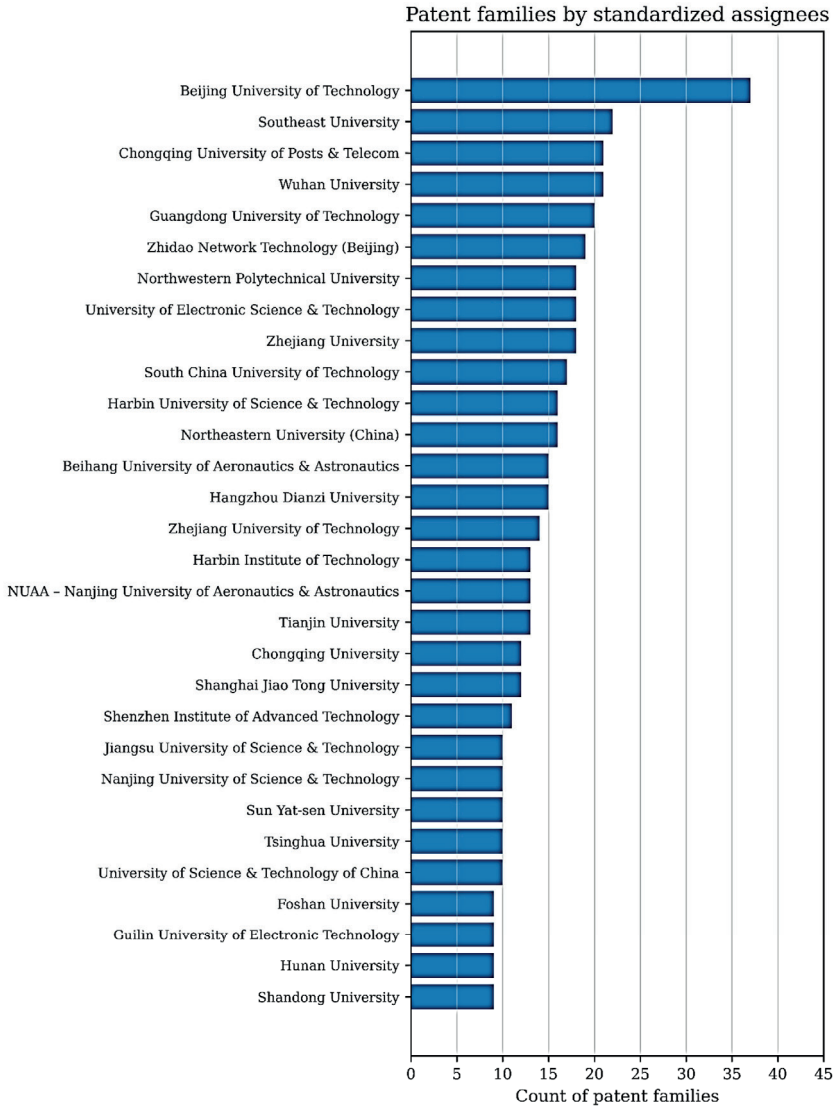
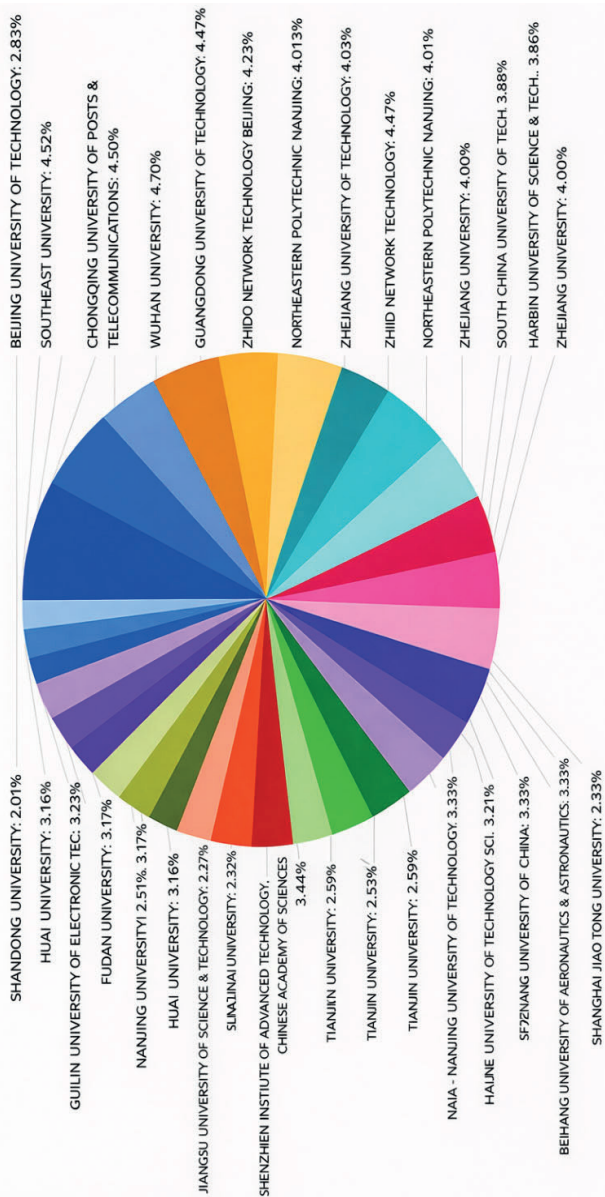


Figure 1. Number of patent families by standardised applicants in the field of visual SLAM

Patent families by Standardized Assignees



© Questel 2025

Figure 2. Partial distribution of patent families by standardized applicants

The predominance of universities and research institutes among key applicants confirms the algorithmic nature of most patent solutions in the field of visual SLAM. The main focus is on improving visual localisation methods, mapping, semantic image processing, and increasing the robustness of SLAM algorithms in complex and dynamic environments without strict ties to a specific type of hardware platform.

This structure of the patent landscape has a dual effect on the further development of the industry. On the one hand, the lack of concentration of rights in a few corporations reduces the risks of patent blockages and creates opportunities for new developers and engineering teams. On the other hand, the high number of algorithmic patents requires careful analysis of patent purity when integrating relevant solutions into application systems, in particular in UAVs and robotic complexes.

Summarising the results of the analysis of key applicants and the structure of patent family distribution, it can be concluded that the patent landscape of visual SLAM technologies is characterised by a low level of IP rights concentration and the dominance of the academic sector. This indicates that the technology is at the stage of intensive scientific and algorithmic development, when the main competitive advantage is created not through large-scale commercial exploitation, but through the accumulation and variability of localisation and mapping methods. The identified fragmentation of the patent portfolio means that there is no structural monopolisation of the industry, which, on the one hand, reduces the risks of blocking innovation, and on the other hand, creates increased requirements for systematic analysis of patent purity when moving from research and development to applied engineering integration, in particular in autonomous platforms and unmanned systems

Geographical structure of patent protection and jurisdictional orientation of visual SLAM technologies. Analysis of the geographical structure of patent protection allows us to assess not only the spatial distribution of innovative activity in the field of visual SLAM, but also the strategic priorities of applicants regarding the commercialisation and legal protection of relevant technologies. The distribution of patent families by priority jurisdictions reflects the degree of orientation of developments towards local or global markets, as well as the level of technological maturity of the industry.

Section «Engineering sciences»

Figure 3 shows the distribution of patent families in the field of visual SLAM and related autonomous navigation technologies by main priority jurisdictions. As can be seen from the data presented, the People's Republic of China occupies a dominant position, accounting for the vast majority of patent families. The share of international applications under the PCT procedure, as well as applications in regional and national jurisdictions of the United States and the European Patent Office, is significantly smaller.

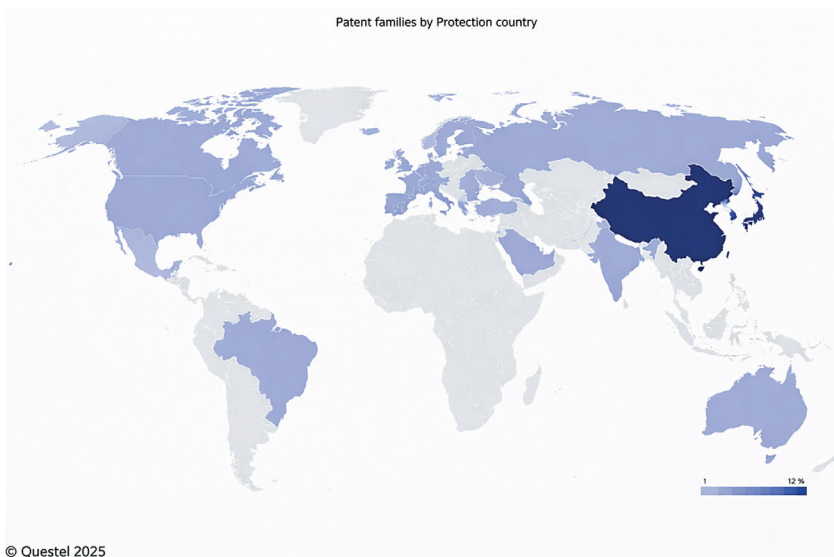


Figure 3. Distribution of patent families in the field of visual SLAM by priority jurisdictions

The predominance of Chinese national jurisdiction indicates that visual SLAM technologies are mainly patented within domestic research programmes and are focused on local implementation. This structure is typical for industries that are in the stage of active technological formation, when patent protection is used primarily as a tool for recording research results, rather than as a means of long-term blocking of international markets.

At the same time, the relatively low share of international and regional patent applications indicates that most applicants do not have established strategies for global legal expansion. This suggests that a significant portion of visual SLAM solutions are universal in nature and can be adapted to different platforms without being tied to specific markets or regulatory environments.

Thus, the geographical structure of the visual SLAM patent landscape confirms the scientific and algorithmic nature of most developments and also indicates the potential openness of the niche for further engineering integration, particularly in the field of autonomous robotic systems and UAVs. At the same time, this structure requires consideration of jurisdictional risks and an in-depth analysis of patent purity when entering international markets.

Technological directions and objects of patenting in visual SLAM.

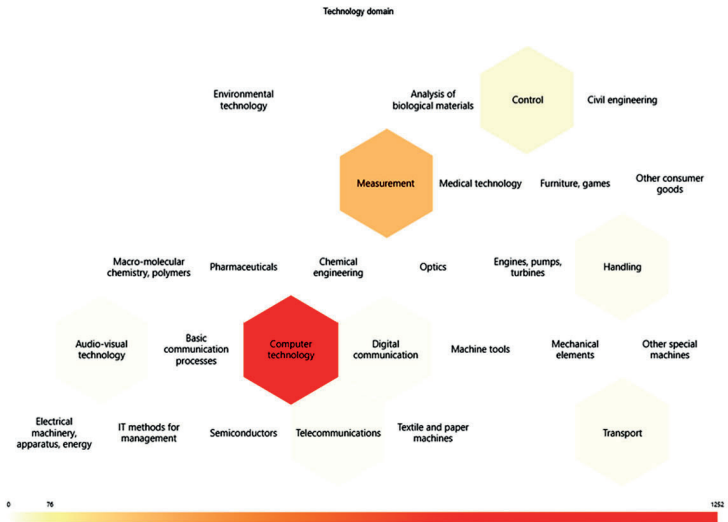
Analysis of technological directions of patenting in the field of visual SLAM allows us to establish which technical domains and IP objects form the core of the corresponding patent landscape, as well as to assess the degree of interdisciplinarity of the claimed solutions. To this end, we used the Orbit (Questel) platform's technological domain classification tools, which are based on a combination of IPC/CPC codes and semantic analysis of invention descriptions.

As shown in Figure 4, the main body of patent families in the field of visual SLAM is concentrated in the Computer technology domain, which significantly exceeds all other technological areas in terms of the number of applications. This confirms that most patents are algorithmic and software-mathematical in nature and relate to visual data processing, optimisation of computational procedures, environment mapping and spatial localisation.

The fields of Measurement, Optics, Digital communication and Control play a significant but secondary role, reflecting the applied aspect of visual SLAM as a component of autonomous navigation systems. At the same time, the share of sectors related to mechanical elements, transport or civil engineering is insignificant, indicating the absence of a rigid hardware link for most patented solutions.

Thus, in terms of patents, visual SLAM appears primarily as a universal computer technology suitable for integration into various types of autonomous systems, from mobile robotics to UAVs.

Section «Engineering sciences»



© Questel 2025

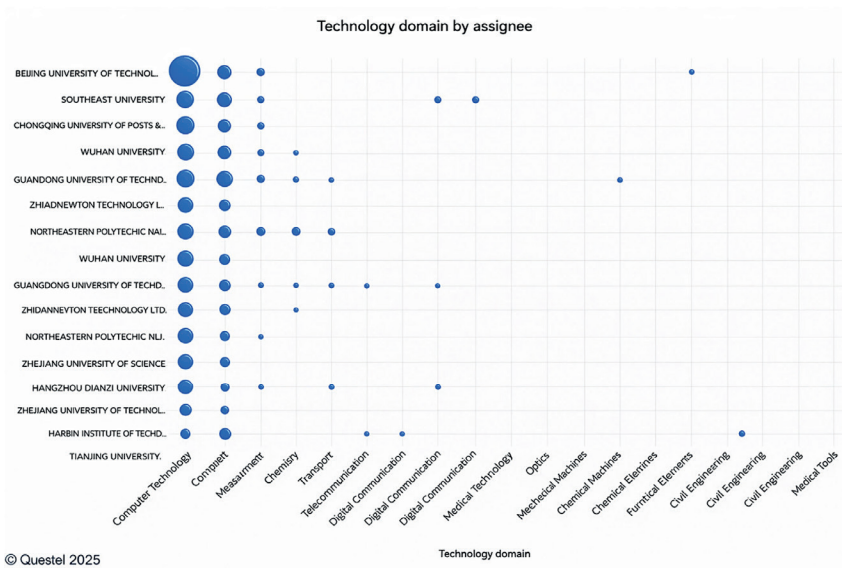
Figure 4. Distribution of patent families in the field of visual SLAM by technology domain

Distribution of technological areas by applicants. A more detailed picture of the nature of patenting is provided by the ‘applicant – technological domain’ matrix shown in Figure 5. It shows that the leading applicants – mainly universities and research institutions – concentrate their patent activity in the field of computer technology, supplementing it with selective applications in the fields of measurement, optics and control.

At the same time, there is no clear specialisation of individual applicants in narrow hardware or industry areas. Most institutions patent a wide range of algorithmic solutions covering various aspects of visual SLAM – from image processing and map building to improving localisation stability in noisy and dynamic environments.

This distribution pattern confirms that patenting in the field of visual SLAM is focused not on closed specialised solutions, but on basic technological blocks that can be used as components of various autonomous platforms. The results show that patentable objects in the field of visual

SLAM are predominantly algorithmic and computational in nature, and the technological landscape is formed around computer methods of visual information processing. The dominance of universal technological industries and the absence of strict industry ties lead to a high level of reuse and overlap of patent rights, which complicates ensuring patent purity when commercialising solutions.



© Questel 2025

Technology domain

Figure 5. Ratio of technology domains and applicants in the visual SLAM patent landscape (Technology domain by assignee)

At the same time, this structure creates favourable conditions for the engineering integration of visual SLAM into various classes of autonomous systems, in particular UAVs, but requires an in-depth analysis of patent restrictions at the algorithm level rather than at the end product level.

IPC/CPC classes and the core of patent claims in the field of visual SLAM/ For a deeper understanding of the content of the visual SLAM patent landscape, it is important to analyse the International Patent Classification (IPC) and the Common Patent Classification (CPC), within which technical

solutions claimed as IP objects are formalised. It is the IPC/CPC classes that reflect not the applied field of use, but the **technical essence of the claimed inventions**, which allows identifying the **core of patent claims** in the relevant technological field.

The cluster structure of patent families by IPC/CPC classes in the field of visual SLAM is presented in Figure 6, which reflects the ratio of the main technical areas within which the patent portfolios of applicants are formed.

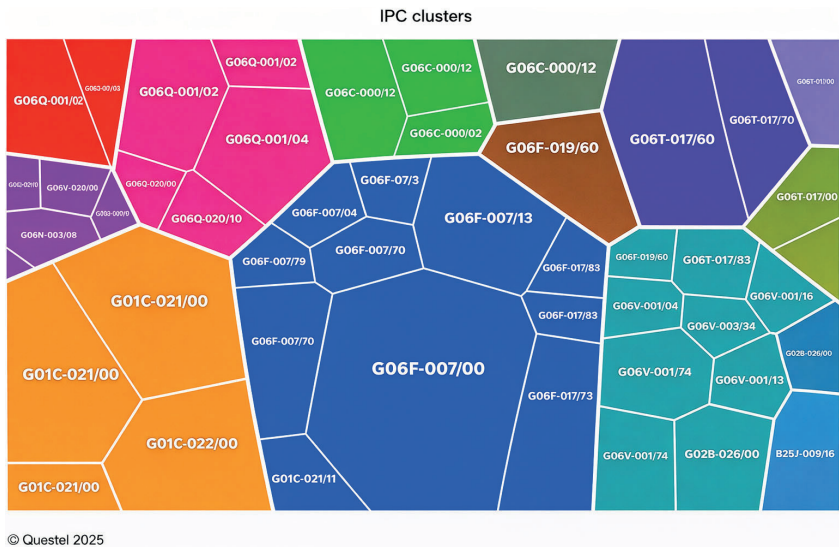


Figure 6. Cluster structure of visual SLAM patent families by IPC/CPC classes

Dominant IPC/CPC classes. Analysis of the distribution of patent families by classification codes shows that the key core of patenting in the field of visual SLAM is formed within section G06 (Computing technology; data processing). The most represented groups and subgroups are: G06T – image processing and analysis, computer vision, mapping and spatial modelling; G06F – computational methods, data processing architectures, algorithm optimisation and memory management; G06V – image recognition, visual scene analysis, feature extraction; G01S – positioning, navigation and

coordinate determination systems; G05D – motion control and navigation algorithms.

The predominance of these classes confirms that patent claims in the field of visual SLAM focus not on physical devices, but on mathematical, algorithmic, and software solutions that implement localisation and mapping processes. This is consistent with the cluster visualisation in Figure 6, where the largest segments are in the computer-algorithmic domains.

The structure of the core of patent claims. A substantive analysis of patent formulas within the dominant IPC/CPC classes allows us to identify several typical groups of technical features that form the core of patent claims in the field of visual SLAM.

Visual data processing methods. Patent claims cover methods for extracting, matching and optimising visual features (feature extraction, feature matching), processing multi-camera streams, and integrating visual and inertial data. These solutions form the basis of most algorithmic approaches to visual SLAM.

Localisation and mapping algorithms. Methods for simultaneously estimating the position of the camera and updating the environment map, methods for optimising observation graphs, filtering and Bayesian approaches are patented. Such claims form the central array of algorithmic protection within classes G06T and G06F.

Improving the stability and accuracy of SLAM systems. A significant portion of patent documents is aimed at ensuring the operability of systems in complex conditions: the presence of dynamic objects, changes in lighting, partial loss of visual information, or sensory interference.

Semantic interpretation of scenes. A separate group is formed by patents that combine visual SLAM with semantic image analysis, object classification, and contextual interpretation of space. This reflects the trend away from geometric localisation towards cognitive models of environmental perception.

Computational optimisation. Patent claims also cover reduced computational complexity, parallel processing, adaptive resource utilisation, and real-time SLAM implementation, which is critical for autonomous systems with limited hardware capabilities.

Generalisation of IPC/CPC analysis results. Thus, the analysis of IPC/CPC clusters (Figure 6) shows that the patent core of visual SLAM has

a clearly expressed algorithmic and software character, characterised by a high level of fragmentation and significant overlap of technical solutions in related classes. This creates a complex legal environment in which the same implementation can potentially be subject to several patent claims formulated in different classification domains.

The results obtained confirm that the key problem of patenting visual SLAM lies not in a lack of legal protection, but in the vagueness of the boundaries of patentability of algorithmic solutions, which is of fundamental importance for the further commercialisation and engineering integration of these technologies into autonomous platforms, in particular UAVs.

Conceptual structure of patent claims in the field of visual SLAM.

For an in-depth analysis of the content of patent claims in the field of visual SLAM, it is advisable to move from formal IPC/CPC classification to conceptual analysis, which reflects the key technical concepts used by applicants in the formulation of inventions. This approach allows identifying not only technological directions, but also real objects of patenting around which legal protection is formed.

Figure 7 shows a heat map of the distribution of concepts by main applicants (Concepts by assignee), which reflects the intensity of use of certain technical concepts in the patent portfolios of leading universities and research institutions.

Dominant patenting concepts. Analysis of the heat map shows that, regardless of the specific applicant, the core of patent claims is formed around a limited set of recurring concepts, in particular:

Camera / image / visual data – basic concepts related to the acquisition and processing of visual information;

Feature extraction / feature matching – feature extraction and matching as a key stage of SLAM algorithms;

Pose estimation / localisation – estimation of the position of a camera or platform in space;

Mapping / environment model – construction and updating of an environment map;

Optimisation / graph / filtering – algorithmic methods for optimisation and processing of observations;

Sensor fusion / inertial data – integration of visual and inertial data sources.



Figure 7. Distribution of key concepts in visual SLAM patent claims by applicants

The intensity of cell colouring in Figure 7 shows that these concepts are present in virtually all large patent portfolios, indicating a high degree of conceptual overlap between applicants.

Conceptual unification of patent portfolios. An important feature is the lack of clear conceptual specialisation among individual applicants. Even leading universities with the largest number of patent families use virtually the same set of basic concepts, confirming the algorithmic nature of patenting in the field of visual SLAM.

Such unification means that most patents do not cover unique physical or hardware solutions, but focus on variations of known algorithmic approaches – changing the order of calculations, optimisation methods, combining data sources, or increasing the stability of algorithms.

Formation of the core of patent claims. Based on conceptual analysis, the core of visual SLAM patent claims can be identified, which consists of the following groups:

Algorithmic methods for processing visual data. The claims cover mathematical and software procedures for converting images into spatial representations.

Simultaneous localisation and mapping methods. These are formulated as methods, systems, or computer programs that implement the SLAM process.

Optimisation and filtering approaches. Protection extends to methods for improving accuracy, speed, and stability.

Integration of sensor streams. A significant part of the claims concerns the combination of visual, inertial and other data.

Thus, the conceptual structure of the visual SLAM patent landscape is characterised by a **high degree of repetition of technical concepts**, which significantly complicates the clear demarcation of legal protection between individual patents.

Generalisation of the results of the conceptual analysis. The results obtained allow us to conclude that visual SLAM is patented mainly by **imposing legal protection on algorithmic variations of basic concepts**, rather than on fundamentally new technical solutions. This creates a dense patent environment with a high risk of overlapping claims, which is critical for the engineering implementation and commercialisation of SLAM solutions.



Figure 8. Dynamics of patent applications by year by major applicants in the field of visual SLAM

This feature confirms the existence of a systemic problem with visual SLAM patenting, associated with the limited distinctiveness of algorithmic solutions, which requires particularly careful analysis of patent purity when implementing such technologies in autonomous systems and unmanned platforms.

Dynamics of patent activity and inter-institutional cooperation in the field of visual SLAM. An important element of patent landscape analysis is the study of the temporal dynamics of patent applications and the nature of interaction between key applicants. Such indicators allow us to assess the stage of development of visual SLAM technologies, the level of maturity of scientific and technical solutions, as well as the intensity of knowledge transfer between scientific centres.

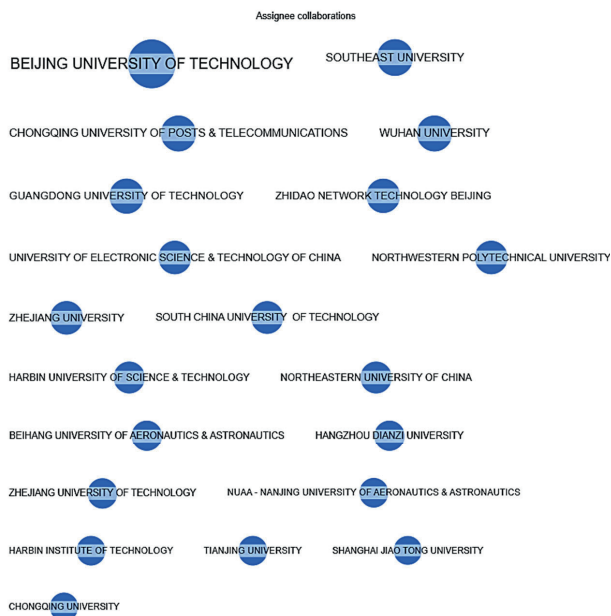
Patenting dynamics by year. Figure 8 shows the distribution of patent families in the field of visual SLAM by year of application filing, with details on the main applicants.

An analysis of the temporal structure of patenting indicates a gradual increase in inventive activity since the mid-2010s, with the most intense phase occurring between 2018 and 2023. For most leading universities, there has been a steady accumulation of patent families without sharp peaks.

Such dynamics are characteristic of technologies that are in the stage of intensive scientific and algorithmic development but have not yet reached the stage of mass industrial standardisation. In this case, patenting inventions serves to fix methods of localisation, mapping and optimisation of calculations, rather than aggressive market capture.

Inter-institutional cooperation between applicants. The structure of cooperative links between applicants is shown in Figure 9, which presents a network of joint patent applications in the field of visual SLAM.

The cooperation graph shows that the key nodes of the network are formed around leading technical universities, in particular Beijing University of Technology, Southeast University, Wuhan University, South China University of Technology, Northwestern Polytechnical University and other academic institutions. Cooperation is mainly inter-university and research-based, indicating a pooling of expertise in the fields of computer vision, navigation and visual data processing. The participation of industrial corporations in joint patenting of inventions is limited, confirming the dominance of research-driven technology development over commercial development.



© Questel 2025

Figure 9. Network of cooperative ties between applicants (joint patent families) in the field of visual SLAM

An analysis of temporal dynamics and inter-institutional cooperation leads to the conclusion that the visual SLAM patent landscape is characterised by growing, but not yet peak, patent activity, a high level of academic interaction and the absence of dominant industrial players. This confirms that visual SLAM technologies are in a phase of technological development, where patenting is used primarily as a tool for consolidating algorithmic and methodological solutions, creating the conditions for further engineering integration and commercial use.

Conclusions. A systematic study of the patent landscape of visual SLAM technologies has made it possible not only to describe the current state of patenting in a structured way, but also to formulate practically significant conclusions for developers of autonomous systems, engineers, patent specialists, and technology integrators. Patenting in the field of visual

SLAM is concentrated mainly in the academic and research environment and is distinctly algorithmic in nature. The dominance of universities and research institutes among the leading applicants, as well as the absence of large industrial or defence corporations among the leaders in patent activity, indicate that most patents are aimed at protecting general methods of visual data processing, localisation and mapping, rather than complete engineering systems or platform-oriented solutions.

This has direct practical significance: patent risks in the field of visual SLAM are primarily concentrated at the level of algorithms, methods and mathematical models, while the integration of such solutions into specific platforms – UAVs, mobile robotic complexes or autonomous transport systems – remains relatively open to engineering implementations. Accordingly, the practical development of applied SLAM systems is possible provided that direct reproduction of algorithmic formulations already under patent protection is avoided and alternative architectural or computational approaches are used.

Analysis of IPC/CPC classifications has made it possible to clearly identify the core of patent claims formed within classes G06 (computing, computer vision), G01S (positioning and navigation) and G05D (motion control). This makes it possible to use the research results as a preliminary patent navigation tool when designing new solutions in the field of autonomous navigation and robotics, as well as for assessing freedom to operate in the early stages of R&D.

Freedom to Operate is the legal and economic ability of a company or other business entity to commercially use a product, process or service (manufacture, use, offer for sale, sale or distribution) without infringing the existing intellectual property rights of third parties, primarily patent rights. **FTO analysis is a critical step before a technology enters the market**, as it allows identifying potential patent restrictions, assessing the risks of litigation and financial losses, and determining possible ways to minimise legal risks (modification of technical solutions, licensing, patent circumvention). In high-tech and dynamic industries, particularly in the field of autonomous systems and unmanned platforms, FTO analysis is particularly important due to the fragmentation of the patent landscape and the high concentration of rights to basic technological solutions.

In addition, it has been established that a significant proportion of patents are characterised by a high level of conceptual similarity and repetition of technical features. This indicates the formation of a dense patent environment, within which new patent applications should focus not on the general principles of visual SLAM, but on specific architectural, computational or applied aspects of implementation. The results obtained can be used to improve the quality of patent strategies, reduce the risks of patent rejection, and optimise patent claim formulations.

The study proves that the key problem with patenting visual SLAM is not a lack of legal protection, but the dominance of universal algorithmic patents, which complicate the commercial use of the technology without specialised patent analysis. At the same time, this landscape structure creates favourable conditions for the engineering integration of visual SLAM into applied autonomous systems, provided that IP is managed correctly.

Using the results of the visual SLAM patent landscape to form a national strategy for the development of autonomous systems in Ukraine. Full-scale war has significantly transformed the role of UAVs and autonomous robotic systems in the structure of Ukraine's defence technologies. Drones have evolved from an auxiliary surveillance tool to a key element of tactical, operational and strategic advantage, which leads to increased demands for their autonomy, resilience and adaptability in conditions of electronic warfare, GNSS signal degradation and dynamic combat environments. In this context, visual SLAM technologies and related methods of visual-inertial navigation are becoming critical for ensuring the functional independence of autonomous platforms.

The patent landscape analysis allows us to consider visual SLAM not only as a technical task of algorithmic navigation, but also as a strategic object of innovation and intellectual property policy. The results obtained create the basis for the transition from fragmentary engineering solutions to the systematic formation of a national strategy for the development of autonomous navigation technologies, taking into account patent risks, commercialisation potential and long-term technological sovereignty.

The architectural specificity of visual SLAM as a factor in strategic planning. An analysis of the patent landscape structure shows that the key core of patent claims in the field of visual SLAM is focused not on hardware platforms, but on algorithmic and software solutions formalised within the

IPC/CPC classes G06T, G06V, G06F, G01S and G05D. This means that the risks of IP infringement arise not at the level of the physical design of the unmanned vehicle, but at the level of the implementation of localisation methods, image processing, observation graph optimisation, semantic scene interpretation and adaptive motion control.

This is of fundamental importance for Ukraine, as it allows it to build a strategy for the development of autonomous systems not by copying foreign solutions, but by creating its own engineering implementations adapted to the specific conditions of combat use. In this case, the patent landscape serves as a tool for identifying both areas of increased legal risk and ‘windows of opportunity’ for developing new technical approaches that do not overlap with dominant patent formulas.

The significance of the fragmentation of the patent field for Ukraine. A characteristic feature of the landscape studied is the absence of monopolistic concentration of patent rights in the field of visual SLAM. The leading applicants are mainly universities and research institutions, rather than global defence or aerospace corporations. This structure of the patent field indicates that the technology is at the stage of active scientific and algorithmic formation, rather than complete industrialisation.

For Ukraine, this creates favourable conditions for entering the technological niche without the need to overcome tough patent barriers from transnational players. At the same time, the fragmentation of the portfolio requires a high culture of IP management, since the risks of patent conflicts arise not from a single dominant patent, but from a set of narrow algorithmic claims distributed among many applicants.

The patent landscape as an instrument of state innovation policy. The results obtained can be directly used to shape state policy in the field of autonomous systems and UAV development. In particular, the patent landscape allows: to identify priority areas of research and development with the lowest level of patent saturation and high applied value for defence and dual-use technologies; integrate freedom-to-operate analysis into state programmes for financing autonomous navigation; formulate requirements for the results of R&D projects, taking into account patentability or defensive publication opportunities; reduce dependence on foreign navigation technologies through the targeted development of proprietary algorithmic solutions. It is particularly important to use the patent landscape

during the transition from prototypes to mass production, when the risks of IP infringement can significantly limit the export potential of Ukrainian developments in the post-war period.

The role of patent analysis in the post-war commercialisation of technologies. The UAV industry, which has developed rapidly in the context of war, will inevitably transform into civilian and dual-use technologies – logistics, infrastructure monitoring, agrotechnologies, and unmanned transport. In this context, the visual SLAM patent landscape becomes a critically important tool for selecting patenting jurisdictions, forming export strategies, and attracting international partners.

The results of the study show that Ukraine has the potential to move from being a user of autonomous navigation technologies to being their developer and supplier. To do this, it is necessary to combine the engineering expertise gained in combat conditions with systematic IP management focused on global markets.

Summary of strategic implications. Thus, the patent landscape analysis of visual SLAM has not only scientific and analytical significance, but also clear practical and strategic importance for Ukraine. It forms the basis for: developing a national strategy for the development of autonomous navigation technologies; reducing patent risks in the field of military and civilian UAVs; increasing the innovative capacity of Ukrainian developers; ensuring technological sovereignty in the critically important field of autonomous systems.

In this context, the visual SLAM patent landscape should be viewed not as a review tool, but as an element of strategic innovation management capable of directly influencing the state's defence, innovation and export policies.

2.4. Algorithmic autonomy as a prerequisite for technological sovereignty

The combination of artificial intelligence and visual SLAM creates a new quality of unmanned systems – algorithmic autonomy, which determines their tactical effectiveness and strategic value. Unlike traditional weapons, where material characteristics were key, software models, training data and patent-protected information processing methods play a decisive role in modern autonomous platforms.

For Ukraine, which is undergoing rapid engineering evolution due to the combat use of UAVs, algorithmic autonomy is becoming a critical resource. It is this autonomy that ensures rapid innovation, adaptation to enemy tactics, and the ability to scale solutions. At the same time, the lack of systematic management of such algorithmic assets creates risks of losing technological advantage due to legal fragmentation, uncontrolled disclosure, or patent migration.

Thus, the algorithmic level of autonomous unmanned systems acts as an intermediate link between engineering implementation and institutional management. It is at this level that the link between technical solutions and intellectual property mechanisms is formed, which necessitates a transition from fragmented protection of individual algorithms to systematic state management of defence technologies.

3. STATE MANAGEMENT OF DEFENCE INTELLECTUAL PROPERTY AS AN INSTRUMENT OF TECHNOLOGICAL SOVEREIGNTY

3.1. Unmanned systems as dual-use technologies and objects of national security

The algorithmic autonomy of unmanned systems causes them to transition from the category of individual technical means to the class of strategic dual-use technologies. The combination of artificial intelligence, sensor systems and spatial navigation algorithms creates universal platforms suitable for both civilian applications (logistics, monitoring, agriculture) and military operations. As a result, unmanned technologies acquire a special legal status, falling simultaneously within the scope of innovation policy, export control and national security.

Global practice shows that leading states integrate intellectual property management into the defence cycle as a separate strategic planning function. Patent portfolios in the field of autonomous systems are seen not only as a commercialisation tool, but also as a mechanism for controlling access to critical algorithms, hardware solutions and architectural principles. In this context, intellectual property becomes a form of intangible defence infrastructure.

For Ukraine, which is in a state of full-scale war, such a transformation is of fundamental importance. Combat testing of unmanned systems

creates unique technological advantages, but in the absence of systematic management, these advantages can be quickly levelled out through patent migration, uncontrolled disclosure of algorithmic solutions, or loss of rights to the results of state R&D.

The defence industry as a global innovation sector and technology carrier

The military industry, also known as the defence industry or arms trade, is a global industry that manufactures and sells weapons and other military technology to various customers, including state armed forces, civilians and organisations. The products of the military industry include weapons, ammunition, weapon platforms, communication systems, and other electronics and related equipment. The military industry also provides defence-related services such as logistical and operational support.

As a matter of policy, many governments of industrialised countries maintain or support a network of organisations, facilities and resources for the production of weapons and equipment for their armed forces (and sometimes for other countries). This is often referred to as the defence industrial base. Entities involved in the production of weapons for military purposes vary widely and include private commercial firms, state-owned enterprises and public sector organisations, as well as scientific and academic institutions. [16] These entities perform a wide range of functions, including research and development, design, production, and maintenance of military materials, equipment, and facilities. The weapons they produce are often manufactured, maintained, and stored in arsenals.

Conclusion for the defence IP management model: the defence industry systematically combines R&D, production, operation and service; therefore, IP objects arise and ‘move’ throughout the entire life cycle, and their management must be institutionally integrated, with defined roles and control points at each stage.

Market size, defence spending and concentration of manufacturers

In 2024, the Stockholm International Peace Research Institute (SIPRI) estimated global military spending at \$2.443 trillion, the highest level ever recorded by SIPRI and the sharpest annual increase since 2009. Ukraine currently leads the world in terms of defence spending as a share of GDP, at 31.1%. The combined revenues of the 100 largest defence companies amounted to \$632 billion in 2023, with the five largest companies by

revenue being Lockheed Martin, RTX, Northrop Grumman, Boeing and General Dynamics. Between 2019 and 2023, the five largest arms exporting countries were the United States, France, Russia, China and Germany (together they accounted for about 75% of global arms exports during this period).

In some regions of the world, there is a significant legal trade in firearms for use by private individuals (usually for self-defence and hunting/sporting purposes). Illegal trade in small arms occurs in many countries and regions affected by political instability. In 2017, the Small Arms Survey estimated that there were approximately one billion firearms in circulation worldwide; of these, 857 million (85%) were owned by civilians, 133 million (13%) by national militaries, and 23 million (2%) by law enforcement agencies. The Small Arms Survey also found that the number of firearms in circulation increased significantly between 2006 and 2017, mainly due to an increase in the number of weapons in circulation among civilians. [16]

Conclusion for the defence IP management model: the scale of expenditure and concentration of manufacturers means a high level of competition for technological superiority; therefore, IP management in defence should include strategic functions – monitoring the patent landscape, managing infringement risks, planning legal protection, and controlling technology transfer.

IP management in war: compulsory use and ‘circumvention’ of rights as a tool of state policy: The example of the Russian Federation: institutionalisation of access to foreign IP

Russia ‘legalises espionage’ to strengthen its military potential. Russian President Putin has granted chief designers the authority to use foreign IP without the consent of the rights holder. This decree, published on the Legal Acts portal, allows designers to specify and integrate the necessary foreign technologies, equipment or software for the development of weapons, bypassing traditional licensing protocols. This came after Russia, on Putin's instructions, initiated the creation of a ‘compulsory licensing’ body that issues permits for the use of foreign IP without the consent of patent owners.

Conclusion for the defence IP management model: wartime practice shows that IP can be seen as a tool for strategic advantage. For Ukraine, this reinforces the need for a formalised model that combines rights protection with national security regimes, including admission procedures, access

control and responses to external threats (violations, ‘circumvention’ of rights, compulsory use, etc.).

Global inventive activity in the field of UAVs

Inventive activity in the field of unmanned aerial vehicles (UAVs) is demonstrating rapid growth on a global scale, which is associated with the formation of a new ‘arms race’ and the active use of this technology directly on the battlefield [17]. According to the World Intellectual Property Organisation, the number of patent applications filed for UAV-related technologies increased by 16% between 2022 and 2023, from 16,800 to 19,700 applications, respectively.

China, the Russian Federation and the United States are among the top five countries developing unmanned technologies. At the same time, between 2022 and 2024, Russia received 342 patents in the field of UAVs, while Ukraine received only four patents. In total, 82% of all global drone patents filed since 2015 belong to Chinese companies, and in 2023, 87% of all relevant applications came from China. The most active applicant in this field is the Chinese drone manufacturer DJI, whose technologies are widely used, in particular, by the Armed Forces of Ukraine.

It is also noteworthy that certain DJI models (in particular, the Mavic line) remain commercially available on the international market at a relatively low price, creating a paradoxical situation: high-tech military solutions are widely distributed in the civilian segment and can be easily adapted for combat use. Compact quadcopter platforms can be quickly equipped with cameras and explosive devices, making them an effective tool for asymmetric warfare.

The United States is second to China as the largest applicant in this field: 858 patents were filed in 2023, and a total of 5,631 patent applications since 2015.

Patent statistics in the field of UAVs convincingly demonstrate that technological dominance is directly reinforced by the scale and concentration of patent rights. For Ukraine, this means the need to develop a systematic model for managing defence intellectual property, which should ensure:

- the rapid acquisition of rights to critical technologies where possible and safe;
- identification of bottlenecks in technology chains through patent landscape analysis;

– mandatory freedom-to-operate checks prior to mass production and scaling.

Ukrainian practices: first cases of intellectual property rights registration in the Ministry of Defence system

A striking example of the beginning of institutional changes in the field of defence intellectual property management is the Ministry of Defence of Ukraine obtaining its first patent for technology to detect enemy FPV drones. The Vitryak-M device was developed by military engineers at the Centre for Scaling Technological Solutions (CSTS) and is designed to detect enemy unmanned aerial vehicles, providing an additional tactical advantage on the battlefield.

Vetryak-M has already been codified and approved for use by the Armed Forces of Ukraine. This is the first recorded case where a military unit has acted as a full-fledged developer of a model of weapons and military equipment (WME) and has successfully passed the codification procedure as a supply item.

The registration of intellectual property rights was made possible by the creation of a specialised IP department within the Ministry of Defence as part of the Main Directorate of Military Justice. The department currently has nine specialists, four of whom have the status of patent attorneys. In fact, a new management practice for the protection of IP rights in the field of defence is being formed, which has been absent throughout the entire period of Ukraine's independence.

FPV (first person view) drones are widely used by both sides of the conflict to target enemy manpower, equipment and positions, including attacks on civilian infrastructure. It is expected that over the next five years, the United States, Ukraine and European countries will invest significant resources in this industry. Ukraine has already announced plans to invest about \$1 billion in the development of unmanned technologies, given that more than 10,000 drones are lost on the battlefield every month.

Even isolated success stories, such as Vetryak-M, demonstrate the critical need to integrate the processes of ‘R&D → codification → approval for operation → supply’ with the processes of ‘identification of IP objects → selection of legal protection regime → registration of rights → accounting and control of use.’ It is at these junctions in the management model that control points must be established to prevent the loss of rights or premature disclosure of technologically sensitive information.

3.2. Systemic dysfunctions in intellectual property management in Ukraine's defence sector

Despite significant scientific and technical potential, intellectual property management in Ukraine's defence-industrial complex has long remained fragmented. An analysis of the practices of the Ministry of Defence and defence enterprises indicates the absence of a unified policy on the registration of rights to R&D results, weak accounting of intangible assets, and a systemic gap between the creation of technologies and their practical use.

A separate problem is the accumulation of a significant number of official and secret inventions that are not used in production and are effectively 'dead' intellectual property. This situation leads to a loss of potential defence and economic returns from state investment in science and development.

At the same time, there are processes of patent migration, when competitive technical solutions are registered abroad without prior national submission, which contradicts the requirements of the law and creates risks of losing technological sovereignty. The lack of state support for foreign patenting, the complexity of procedures and financial barriers further stimulate the outflow of innovation.

Court practice in the field of defence technologies demonstrates cases of unfair patenting, conflicts of interest and the invalidation of patents for critically important developments. Taken together, these phenomena create institutional weakness, whereby the state effectively has no control over algorithmic and technological assets created with budget funds.

Declarative incentives and lengthy application review periods

The state of invention in Ukraine. Article 38 of the Law of Ukraine 'On the Protection of Rights to Inventions and Utility Models', adopted 30 years ago, only declares that 'the state encourages the creation and use of inventions (utility models), establishes preferential tax and credit terms for inventors and persons who use them, and provides other benefits in accordance with the current legislation of Ukraine.' In reality, this is not the case. The average time for consideration of applications for inventions before a patent is granted in Ukraine is about two years. The database 'Promising Inventions of Ukraine' has been missing for more than 10 years.

There are significant distortions in inventive activity. The number of applications for utility models is 2.3 times higher than the number of

applications for inventions, and the number of patents issued for utility models is 3.2 times higher than the number of patents issued for inventions. However, it is known that patents for utility models are issued without substantive examination. During the year, almost 75% of patents of national owners become invalid due to non-payment of fees for maintaining the validity of patents for inventions and utility models! [6] Such low efficiency of inventive activity is probably not found in any other country in the world.

Conclusion for the defence IP management model: the long cycle of rights registration (≈ 2 years) and the bias towards utility models (without substantive examination) are systemic barriers to defence technologies. The model should include acceleration tools (including 'priority areas of the defence industry') as well as mechanisms that ensure high-quality legal protection without loss of time and security risks.

Fiscal decisions on fees as a factor in reducing inventive activity

This is a negative consequence of the Cabinet of Ministers' resolution adopted in 2007, which increased the fees for filing applications and maintaining the validity of patents for inventions and utility models by 35 times. Since then, applications have been filed mainly for utility models and for individuals. Instead of drawing the appropriate conclusions, the Cabinet of Ministers of Ukraine, by Resolution No. 496 of 12 June 2019, again increased the fees fourfold for inventions and twelvefold for utility models. Such actions are economically unjustified and aimed at reducing the level of inventive activity.

The explanatory note to the new draft resolution of the Cabinet of Ministers 'On Amendments to the Procedure for Payment of Fees for Actions Related to the Protection of Intellectual Property Rights' states that the draft resolution does not apply to the field of scientific and scientific-technical activities. Regarding the amount of fees for utility models, the explanatory note states that the amount of fees was determined taking into account the working time and salaries of NOIP experts and other factors affecting their cost. However, it is known that patents for utility models are issued without substantive examination.

It is further noted that the draft resolution does not contain any provisions that create grounds for discrimination. Discrimination (Latin *discriminatio*, 'distinction') is any difference, exclusion, restriction or preference that denies or diminishes the equal exercise of rights. This

resolution unreasonably restricts the inventor's right to apply for a utility model. The negative impact of the adoption of the resolution on the innovative development of Ukraine, the inconsistency of its objectives with the legislative requirements of scientific and technical development, the significant slowdown due to the increase in fees for inventive activity in Ukraine, and the lack of justification have been repeatedly pointed out by the National Academy of Sciences of Ukraine, the Ministry of Education and Science of Ukraine, and representatives of public organisations. This problem has been studied in detail by Y.M. Kapitsa, Doctor of Law.

A comparison of the fees with those in force in EU member states shows that the fees in Ukraine are inconsistent with EU practice, where there are generally no increased fees for actions related to the protection of utility model rights compared to inventions. This practice also indicates a complete lack of justification for the actual costs of protecting utility model rights. This approach is a clear indication of the Ministry of Economy of Ukraine's administration, which is detached from the practice and interests of the inventive community in Ukraine and is attempting to reduce the number of utility model patents through fiscal methods, using mechanisms that are not found in the EU or in countries with significant volumes of utility model applications... However, even these fiscal methods have not achieved their goal. Despite everything, Ukraine remains the leader in the Global Innovation Index 2024 in the sub-index of utility models by origin (1st place, as in 2023).

Conclusion for the defence IP management model: fiscal logic without taking into account technology policy creates barriers to the registration of rights. For defence IP, the model should provide for separate rules for stimulation and support (including remuneration for inventors and persons contributing to implementation), as well as 'fast' and accessible protection mechanisms within the priority areas of the defence industry.

3.3. Secret inventions, patent migration, and risks of algorithmic technology leakage

Secret inventions, which are formally protected by state secrecy but often not integrated into production processes, constitute a special category in the defence sector. The lack of regular review of the secrecy regime leads

to the accumulation of thousands of technical solutions that are not used even in critical situations for the state.

At the same time, the algorithmic nature of modern unmanned systems creates additional risks of leakage through software, open publications and international cooperation. Unlike traditional weapons, where the object of protection is the physical structure, in the case of autonomous platforms, machine learning models, training data and control architectures, which are easily copied and modified, are of key value.

Patent migration in the field of IT and unmanned technologies exacerbates these risks, as the most promising solutions often become the property of foreign companies and then return to Ukraine in the form of imported products. Such a scenario means the loss not only of economic benefits, but also of strategic control over algorithmic autonomy.

Circumvention of national priority and the growth of ‘patent refugees’

The outflow of innovative technologies from Ukraine. The uncontrolled outflow of innovative technical solutions from Ukraine abroad has been going on for a long time. Bypassing Article 37 of the Law of Ukraine ‘On the Protection of Rights to Inventions and Utility Models’ [18], which provides for the registration of a priority application for an invention (utility model) in Ukraine, many inventors submit applications directly to other countries without submitting them in Ukraine. The so-called ‘patent migration’ from Ukraine is constantly growing. The level of ‘patent refugees’ is 10-12% of the annual volume of patenting.

The most active sectors of migration are: medical products, IT technologies (systems and equipment), and pharmacology. The geography of migration is expanding: Russian Federation (51%), USA (11%), South Korea (9%), Taiwan (3%), Germany (2%). The group of ‘runaway patents’ usually includes the most competitive inventions, which then return to Ukraine as innovative products of foreign companies. Among the technical solutions patented in Russia, for example, were new models of weapons, equipment and dual-use technologies. Legal entities predominate among the applicants (80%), but there are also many individuals (20%).

Conclusion for the defence IP management model: the model should include a separate block for controlling foreign patenting and compliance with national priority. This includes not only regulations, but also mechanisms of

responsibility and sanctions for persons who submit applications to foreign countries, bypassing the national authority (especially for defence/dual-use technologies).

Multinational inventions and lack of state support for foreign patenting

The patenting of multinational inventions created by inventors from different countries also remains an unresolved issue in Ukraine. This issue is particularly acute in connection with the creation of such inventions in the course of joint scientific projects by Ukrainian scientists within the EU Framework Programmes for Research and Innovation, in particular the Horizon Europe programme, as well as national scientific programmes of EU member states. The lack of regulation of these issues in Ukrainian patent law and the impunity for the unauthorised transfer of promising scientific and technical developments abroad (national legislation does not provide for liability for such actions) contribute to the outflow of technology.

Unlike European and many post-Soviet countries, Ukraine still lacks state support for foreign patenting. Although the Decree of the President of Ukraine of 27 April 2001 No. 285/2001 ‘On Measures for the Protection of Intellectual Property in Ukraine’ of the Cabinet of Ministers of Ukraine, in order to ensure the constitutional rights of citizens to protect IP, favourable conditions for the creation of intellectual property objects, and the development of the Ukrainian market for these objects, it was instructed to take measures to introduce mechanisms for state support for the patenting of domestic IP objects in foreign countries.

After all, the cost of obtaining a patent for an invention in foreign countries is significant (taking into account the costs of foreign patent attorney services: Germany – 2-3 thousand euros, USA – 6-10 thousand dollars), which does not allow obtaining patent protection for promising inventions created in higher education institutions and scientific institutions abroad.

According to the materials of the rating ‘Champions of inventions. Top 100 patents of Ukrainian inventors for global companies’ (Champions of inventions. Top 100 patents of Ukrainian inventors for global companies), presented by Innolytics Group, DLA Piper and Advanter Group, based on research of patents from more than 100 countries, the initial registration of which took place outside Ukraine (we are talking about ‘runaway patents’

issued in recent years in foreign countries for Ukrainian inventions), the authors of the study estimated the value of the top 100 patents at almost \$400 million [18]. Thus, the outflow of highly efficient technologies from Ukraine continues.

Conclusion for the defence IP management model: without state instruments to support foreign patenting and without regulation of multinational inventions, Ukraine is losing the economic and security benefits of R&D. The model should provide for decision-making processes regarding foreign patenting, sources of funding, security criteria and the distribution of rights between the customer, developer and authors.

Unused reserves of secret inventions

Unused reserves and threats. The State Register of Patents of Ukraine for secret inventions and utility models contains thousands of promising technical solutions that lie ‘dead weight’ and are not used by domestic scientists and designers in the development of weapons and military equipment. It is not for nothing that secret inventions are called dead inventions. In the context of the war with Russia, this situation is unacceptable! The Ministry of Economy, together with the Ministry of Defence of Ukraine, must urgently resolve this issue.

Conclusion for the defence IP management model: the model should provide for a regular and formalised process of reviewing the secrecy regime, with the possibility of declassifying secret inventions and using them. This is critical, as tens of thousands of secret inventions may not be used, creating a ‘dead portfolio’ with no defence return.

Barriers for authors/military personnel and the role of pro bono

The war has led to a surge in technical creativity among the creative part of Ukrainian society, resulting in the creation of a significant number of technical solutions aimed at improving weapons and military equipment, means of protecting the civilian population, etc. At the same time, most of these creators-inventors do not even attempt to obtain legal protection for their creations for the following reasons: 1) most of them do not have sufficient knowledge of IP law to properly prepare application materials; 2) the costs associated with hiring a patent attorney and the application procedure exceed the applicant's current financial capabilities; 3) a significant number of authors are military personnel and, accordingly, do not have the time and physical capabilities necessary to carry out the procedures related

to acquiring IP rights. It is clear that under such conditions, the opportunities provided by pro bono programmes are the most acceptable solution for most creators, small businesses, scientists, etc.

Conclusion for the defence IP management model: mechanisms for involving authors (in particular military personnel) in legal protection should be included as separate processes: simplification of submission, support, proactive identification of IP objects, as well as remuneration for inventors and persons contributing to the implementation of technologies.

Starting point: lack of an IP system in the Ministry of Defence and the start of reforms

Prior to the full-scale invasion, there was virtually no IP protection system in the Ministry of Defence, which posed a serious threat to the security of innovations. In February 2024, on the instructions of Defence Minister Rustem Umerov, a study was conducted on the registration and protection of IP rights in the departments of the Ministry of Defence and the Armed Forces of Ukraine. The results showed that the Ministry of Defence does not own any IP rights, and there is a complete lack of systematic work in this area. The start of reforming the IP system in the Ministry of Defence of Ukraine lays the foundation for further changes. In 2025, it is planned to expand this area and create an IP department within the Main Directorate of Military Justice. This approach, similar to practices already in place in the UK and US Ministries of Defence, will make it possible to more effectively protect and implement technologies in the interests of the country's defence capabilities.

Conclusion for the defence IP management model: a system without a responsible ‘policy owner’ cannot register rights or manage a portfolio. Therefore, the model should define the role of the authorised body/unit of the Ministry of Defence, its powers, interaction with developers, IPOs, state secrecy regimes and procurement.

Effectiveness of IP management in the Ministry of Defence: anti-corruption dimension and factual data

Effectiveness of the creation and use of IP objects in the system of the Ministry of Defence of Ukraine. The Anti-Corruption Strategy for 2021-2025 states that the ineffective use and disposal of intellectual property (IP) objects is one of the main problems in the defence sector. A recent study by the Main Directorate of Military Justice on the state of

regulatory regulation, accounting and management of IP rights assigned to the Ministry of Defence (hereinafter MO) in business entities and other divisions of the MO and the Armed Forces of Ukraine confirmed the negative state of IP protection in the defence sector: loss of control over IP, lack of policy and management system for IP and innovation development, systematic abuse of official position by officials, technologies created with public funds are lost or appropriated by third parties, passive position of the state regarding the protection of IP rights, IP activities in the MoD have no practical application [19; 20].

According to the budget request for 2022-2024, more than one billion hryvnias will be spent on the operation of approximately 60 models of Ukrainian and foreign-made military equipment in the armed forces, and the list of new items for the Armed Forces of Ukraine includes technical means that the Ministry of Defence spends on R&D. In February 2024, the Ministry of Defence codified and approved demining, dynamic protection elements for armoured vehicles, and ammunition for UAVs.

The study found 512 patents (269 patents for inventions, 136 patents for utility models, and 106 patents for industrial designs) owned by companies that are part of JSC Ukroboronprom. The analysis shows that R&D performers are actively registering IP rights to military equipment. However, no patents registered under the Ministry of Defence were found. We believe that patents should be registered to the developing organisations – research institutes, design bureaus, etc.

At the same time, it was found that the number of patents registered to officials of the Ministry of Defence structures exceeds the number of patents registered to these structures. At the same time, the influence of these individuals on decision-making regarding military equipment is obvious. The vast majority of such cases were recorded at the Central Research Institute of Armament and Military Equipment (CRI AME of the Armed Forces of Ukraine), which coordinated activities related to the protection of intellectual property of new developments and modernisation of armaments and military equipment (388 official IP objects are registered to officials (private individuals) of the Central Research Institute of Armament and Military Equipment of the Armed Forces of Ukraine, compared to 49 patents owned by the Central Research Institute of Armament and Military Equipment of the Armed Forces of Ukraine).

Thus, according to the data of the Central Research Institute of Armament and Military Equipment of the Armed Forces of Ukraine, no IP objects were created or identified during the R&D work on the modernisation of the L-39 aircraft (2006-2014). At the same time, officials (private individuals) registered two patents in their names: 1) Patent No. 80048 of 2013 ‘Method for modernising the L-39 training aircraft into a light multi-role combat aircraft’, 2) Patent for KM No. 80066 from 2013 "Method for modernising the L-39ZA aircraft. The authors of the study note that as of 2024, the Ministry of Defence does not own any intangible assets in the form of registered IP rights (inventions, utility models, industrial designs).

Conclusion for the defence IP management model: the figures provided (512 patents held by Ukroboronprom entities and no patents held by the Ministry of Defence; 388 ‘service’ objects held by private individuals versus 49 held by the Central Research Institute) require the following processes: (1) accounting for rights and intangible assets; (2) regulation of service objects; (3) prevention of conflicts of interest; (4) ‘locking’ rights to the state/developer depending on roles in R&D; (5) remuneration of authors and mechanisms for controlling implementation.

Court cases as a manifestation of systemic failures in IP rights management

Examples of court cases involving unfair patents. Court case No. 910/11005/17 concerning the RLZ-36D6M1-1 radar station, which was purchased for the needs of the US Army In 2000, Innovative Technologies Company LLC obtained patents for inventions No. 37865 and No. 37870. Among the authors of these inventions are employees of KP ‘NVK Iskra’ (Kononovich V. Ya. – as of 2020, deputy head of KP ‘NVK Iskra’). NVK ‘Iskra’ paid 7.1 million hryvnias for the right to use IP objects.

The state-owned enterprise Kharkiv Armoured Plant developed a modernisation kit for the TPN1 tank sight. In 2018, private individual Safonov D. V. obtained Ukrainian patent No. 130938 for utility model “Kit for upgrading TPN-1 series tank sights”. On the basis of this patent, a lawsuit was filed with the Commercial Court of Kyiv (case No. 910/1006/20) with a request to prohibit the Ministry of Defence of Ukraine from issuing orders on admission to operation and orders on the adoption of military equipment samples for the TPN1-49-23TPV tank night sight and the TPN1-49-23UM night vision device.

An analysis of the specialised database ‘Inventions (utility models) in Ukraine’ for the period from 1991 to 2024 revealed cases of patents being obtained by the Central Research Institute of Armament and Military Equipment of the Armed Forces of Ukraine (formerly military unit A-4566) in joint ownership with private individuals. Thus, 56 of the 105 patents owned (previously owned) by the Central Research Institute of Armament and Military Equipment of the Armed Forces of Ukraine were registered jointly with private individuals, which makes it impossible to dispose of them without their consent. As for the other 49 patents for inventions and utility models owned by the Central Research Institute of Armament and Military Equipment of the Armed Forces of Ukraine, 40 of them were not maintained in force during the first year of their registration.

Patenting technologies as objects of IP rights while failing to maintain the validity of the patent de facto reveals the secret of the technology. In this situation, it is logical to provide this information (technology) with protection as a state secret or know-how.

Conclusion for the defence IP management model: court cases and facts of co-ownership/loss of validity emphasise the need for control points in the process: ‘creation → registration of rights → maintenance of validity → admission to operation → purchase/supply’. The model should provide that without resolving rights issues (ownership, licences, secrecy/know-how regime, maintenance of validity), decisions on admission and supply create legal and security risks.

State secrecy as a protection mechanism and the need for synchronisation with IP

An analysis of registered IP rights in the MO system revealed: 1) minimal innovation activity by MO system entities, as evidenced by the virtual absence of registered IP rights for the period 2013-2023; 2) failure to take measures to manage existing IP objects: technologies under development and official developments are registered by private individuals, in particular, officials of scientific institutions; failure to maintain the validity of existing IP objects, as a result of which the vast majority of such objects have lost their validity (most patents are not maintained in the first year of validity).

This indicates a lack of real intent to obtain legal protection and leads to the uncontrolled disclosure of defence technologies; uncontrolled

information leaks and a lack of monitoring of the patenting of objects developed with budget funds by third parties.

It should also be noted that at all stages of the circulation of defence technologies, there is a need to classify as state secrets information containing: discoveries, inventions, scientific and technical solutions, scientific and technical achievements, areas of research, and R&D results that are of fundamental importance for the development or improvement of new types of weapons and military equipment; descriptions, tactical and technical characteristics, composition, operating algorithms, and results of controlled (leading) operation; information about advanced technical solutions in the creation of a complex model (system, complex or their components) or a model (system, complex or their components) of weapons, military equipment or ammunition, etc. At the same time, the functions of ensuring the implementation of state policy in the field of state secrecy are also referred to the powers of the Ministry of Defence. The system of protecting IP rights through the classification of physical information carriers within a single central executive body – the Ministry of Defence – by controlling access to such information and other mechanisms for protecting state secrets will contribute to the maximum level of protection against the uncontrolled use of technology by third parties.

Thus, the state secret regime cannot exist in parallel with IP “on its own”. The model should include a mechanism for selecting the protection regime for each R&D result (patent/secret patent/know-how/state secret), as well as procedures for reviewing the regime and rules for access/disclosure.

3.4. Intellectual property as intangible defence infrastructure

In today's environment, intellectual property is no longer an auxiliary legal instrument but is transforming into a form of intangible defence infrastructure. The algorithmic autonomy of unmanned systems, protected by patents, secrecy regimes and know-how, determines the state's ability to rapidly implement innovations, scale up production and integrate into international defence chains.

For Ukraine, the formation of such infrastructure means a transition from the situational use of individual developments to the systematic management of technological assets. The proposed process model creates the preconditions for reducing the risks of critical algorithm leakage,

increasing the efficiency of R&D results utilisation, and strengthening the state's position in the field of military-technical cooperation.

As a result, state management of defence intellectual property emerges as a key instrument for ensuring technological sovereignty, combining engineering innovation, algorithmic autonomy and legal mechanisms into a single national security system.

Redistribution of state management functions in the defence industry

The Ministry of Strategic Industries has been liquidated and its functions transferred to the Ministry of Defence. From now on, the Ministry of Defence will be responsible not only for security and defence, but also for the formation and implementation of state policy in the defence industry, aviation and space sectors. The relevant provision on the ministry is set out in the new edition.

Conclusion for the defence IP management model: the concentration of functions in the Ministry of Defence reinforces the need for a single centre of responsibility for defence IP and technology policy. In the model, this should be reflected as ‘managerial influence’ and as a set of powers (regulation, accounting, transfer, secrecy, control of foreign patenting).

DPP and experimental mechanism for transferring technologies to serial production

On 19 June 2025, the Verkhovna Rada of Ukraine adopted European integration bill No. 7508, which introduces a number of tools to simplify the functioning of the public-private partnership (PPP) mechanism and introduces the possibility of creating joint defence projects between state-owned and private defence companies. The law introduces for the first time the possibility of creating joint defence projects between state and private defence companies, introduces additional guarantees for investors (for example, regarding the stability of contract terms), and updates more than 30 sectoral laws. The PPP mechanism is expected to bring up to \$1 billion in investments in specific projects in the coming years.

In October 2025, the Cabinet of Ministers adopted a resolution launching an experimental mechanism for transferring defence technologies developed within the Ministry of Defence system into serial production. This decision opens up state developments to private manufacturers and forms a new model of public-private partnership in the defence sector [21].

The resolution launches a new legal model for managing defence technologies developed within the Ministry of Defence system for their implementation in serial production. Manufacturers will be able to produce weapons and equipment based on state technologies whose effectiveness has been proven in combat conditions. The technologies remain the property of the state, and the finished products will be supplied to the Armed Forces of Ukraine through state procurement, which guarantees transparency and control of resources.

The experiment is open to Ukrainian manufacturers who meet one of three criteria: have state contracts in the field of defence; are identified as critical to the Armed Forces; are included in the electronic register of participants in the selection and execution of state contracts. The Ministry of Defence may provide access to technologies within the framework of international cooperation with the defence departments of partner countries, provided that the manufactured goods are supplied to Ukraine as military-technical assistance. Solutions that have proven effective can be quickly scaled up by several manufacturers simultaneously.

This will allow: increasing production volumes and saturating the front with proven equipment; expanding the range of weapons using existing state developments; removing bottlenecks in the production capacities of individual companies; attracting the potential of NATO partners to improve the Ministry of Defence's technologies through a new export procedure. The ministry added that state ownership of the technology will be retained. Access will be granted to proven manufacturers according to clear criteria, with mandatory technical, legal and security checks. Production will be subject to state quality control, audits and contractual terms that protect national interests.

The practical dynamics of innovation in warfare as a challenge to traditional procedures

Ukraine has become a military laboratory for future technologies and a training ground for Western weapons systems. The 'robot war' is still in its early stages, but it has already begun. This was reported on 22 April by The Telegraph in an article devoted to the 'Ukrainian army of robots,' a technology whose goal is not to replace infantry on the battlefield, but to integrate machines into military operations in order to gain an advantage over the aggressor country, Russia. The article cites the Zmiya robot,

which operates on the front lines, as an example. This machine is one of 15,000 that will be deployed on the battlefield in 2025 to compensate for the lack of manpower. The proliferation of machines on the battlefield in Ukraine also gives a glimpse into a future in which humans and robots will increasingly fight each other.

However, even the most highly trained soldiers are unlikely to be able to compete with an engineer who controls the machine from a shelter, the article notes. The ‘robot war’ is still in its early, experimental stages, but it has already begun. According to experts, the country has become a military laboratory for future technologies and a training ground for Western weapons systems. The Telegraph notes that there are currently more than 500 defence start-ups in Ukraine focused on unmanned systems.

Ukraine has become a world leader in robotics, not in terms of technological sophistication, but in terms of practicality. The country is focused on creating robots in large quantities and at an affordable price. There is a direct link between soldiers and designers, thanks to which changes are made ‘within a week.’ UAVs are ‘responsible’ for 60-70% of Russian equipment losses on the battlefield, making them significantly more effective than any other weapon in the Ukrainian Armed Forces' arsenal.

The article also mentions the first military operation involving only robots, which Ukrainian defenders carried out in the village of Lyptsi in the Kharkiv region at the end of 2024. It is still partially classified, but it is known that dozens of different drones were involved, as well as unmanned aerial vehicles equipped with machine guns. ‘The enemy was completely taken by surprise,’ The Telegraph quotes. The next step will be the joint autonomous operation of UAVs and unmanned ground vehicles.

On 5 February, the Ukrainian Ministry of Defence announced that it was launching a project that would enable the scaled-up use of unmanned ground robotic systems in the armed forces. Minister of Digital Transformation Mykhailo Fedorov announced that DroneUA, a resident of Diia.City, is starting to supply robots to NASA. A test batch of robots has already been sent to Virginia (USA), where they will be tested and the optimal areas of application will be determined. The war has significantly accelerated the development of the defence tech market in Ukraine. An important goal is the export of technologies, which could bring billions in revenue to the budget.

Conclusion for the defence IP management model: the dynamics of ‘change within a week’, the scaling of solutions by several manufacturers, and the export potential mean that classic slow procedures do not work. The defence IP management model should include fast-track routes for priority areas of the defence industry, security checkpoints and decision-making mechanisms for security regimes (patent/secretcy/know-how), as well as reward and accountability/sanction tools to prevent technology leaks and abuse.

The data presented demonstrate that the problems in Ukraine are systemic in nature and manifest themselves simultaneously in several ‘nodes’: the duration and cost of protection procedures, patenting imbalances, lack of state support for foreign patenting, patent migration, ‘dead’ secret inventions, weak institutional accounting of rights in the Ministry of Defence system, as well as legal conflicts and risks of unfair patenting. At the same time, new opportunities are being created through PPPs and technology transfer experiments [22], as well as through the rapid development of defence tech [23]. This objectively requires a formalised management model that covers the entire life cycle of defence technologies, defines the actors, their powers, control points, security regimes, and incentive and accountability mechanisms.

Defence intellectual property management

Figure 10 shows a vertical process model for defence intellectual property management, built using IDEF3 notation. The model reflects the end-to-end life cycle of research and development results in the field of defence technologies – from the emergence of an idea and the implementation of R&D to the use, scaling, export or transfer, taking into account national security requirements.

The process begins with the stage of idea formation and R&D, followed by a mandatory check for compliance with national submission requirements in accordance with Article 37 of the Law of Ukraine ‘On the Protection of Rights to Inventions and Utility Models.’ This stage is aimed at preventing uncontrolled filing of applications abroad and the loss of state rights to the results of defence developments. Control of national priority and the application of sanctions for circumventing the national authority are reflected in the model as managerial influences.

Section «Engineering sciences»

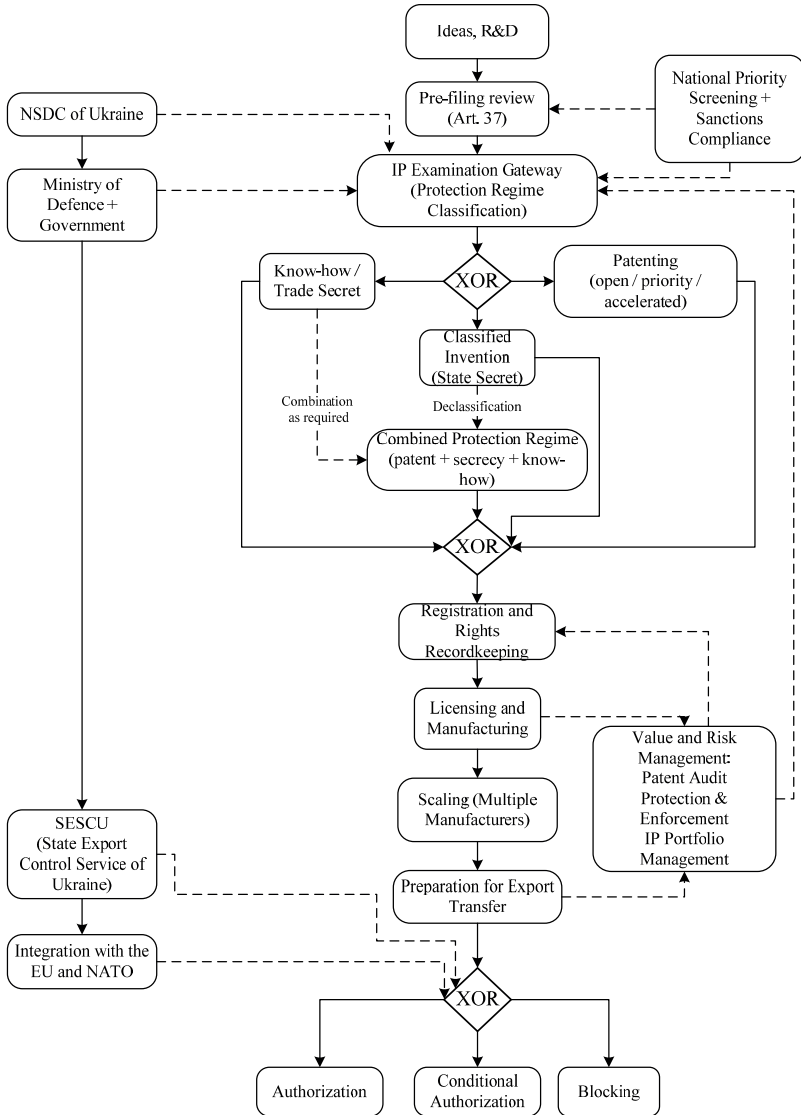


Figure 10. Model of the defence intellectual property management process (IDEF3)

A key element of the model is the IP examination gateway, within which the results of R&D are classified and the optimal legal protection regime is determined, taking into account the sensitivity level of the technology, its defence or dual use, as well as risks to national security. Based on the results of the IP examination, one of the basic protection regimes is selected: patenting (open, priority or accelerated), classification as a secret invention (state secret) or preservation in the know-how regime (commercial secret). The model also provides for the possibility of applying a combined protection regime that combines patenting, classification and elements of know-how, depending on the needs of practical use and the level of permissible disclosure of information.

Once the protection regime has been determined, intellectual property rights are registered and recorded, which is a prerequisite for further licensing and production organisation. The next stages include licensing and production of defence products, as well as scaling up developments with the involvement of several manufacturers within the framework of public-private partnerships or other permitted forms of cooperation.

A separate element of the model is a continuous validity and risk control loop, which includes patent auditing, monitoring of rights enforcement, protection against unauthorised use, and management of the defence intellectual property portfolio. This loop provides feedback on key stages of the process and is aimed at preventing the loss of rights and technological advantage of the state.

The final stage of the process is the preparation of a package of documents for export or international technology transfer. The decision on export is made through a separate process gateway and may involve granting permission, conditional permission (with restrictions, disclaimers or special conditions) or blocking the export. At this stage, export control requirements, the position of the State Export Control Service of Ukraine, as well as the conditions for integration with the European Union and NATO are taken into account.

The proposed model allows for the formalisation of defence intellectual property management as a coherent system of processes and decisions, the elimination of fragmented regulation, the reduction of risks of technology loss, and the creation of institutional prerequisites for the effective

use of R&D results in the interests of the state's defence capability and national security.

The proposed process model for managing defence intellectual property eliminates a key systemic problem characteristic of current practice in Ukraine, namely the fragmentation and lack of synchronisation of decisions on the legal protection, use and control of the results of defence R&D.

The integration of a single IP expertise gateway at an early stage of the technology life cycle ensures a reasonable choice of protection regime (patenting, state secret, know-how or a combination thereof), taking into account security, economic and legal risks. This makes it possible to overcome the practice of chaotic or belated patenting, minimise the loss of rights due to uncontrolled disclosure of information, and create the conditions for the involvement of secret and service inventions in legal production and use, instead of their prolonged status as 'dead' intellectual property.

In addition, the model forms a closed loop of defence intellectual property management, within which registration of rights, licensing, production scaling and export control are considered as interrelated stages of a single process, rather than isolated administrative actions. The introduction of a permanent control loop for validity and risks ensures the monitoring of rights enforcement, patent portfolio auditing, and timely response to threats of technological advantage loss. A separate process gateway for export and transfer allows national security requirements to be combined with international cooperation, particularly in the context of integration with the EU and NATO, without allowing uncontrolled leakage of critical technologies. Taken together, this transforms intellectual property from a formal result of R&D into a managed strategic resource for the state's defence capability.

The intellectual property sphere in Ukraine's defence-industrial complex faces a number of systemic problems that hinder the innovative development of the industry, reduce its technological and economic efficiency, and create additional risks to national security. In the context of full-scale war and the need to accelerate the creation and implementation of new models of weapons and military equipment, these problems become particularly acute and go beyond purely legal or economic regulation.

The analysis identified key problematic aspects of defence intellectual property management in Ukraine. These include the imperfection of the regulatory framework, which does not fully take into account the specifics of the creation and use of official and secret IP objects; the complexity and ambiguity of determining the owner of the results of R&D carried out under state contracts or with the participation of several entities; low level of commercialisation and technology transfer; lack of effective incentives for inventors and persons ensuring the implementation of technologies; insufficient protection of IP rights and high risks of their uncontrolled leakage abroad.

Patent migration and the accumulation of a significant number of service and secret inventions that are not involved in production and are not actually used in the interests of the state's defence capability pose a particular threat. Ineffective management of such objects leads to the loss of technological advantage, disclosure of critical information, and a decrease in the return on state investments in R&D. An analysis of the practices of entities within the Ukrainian Ministry of Defence system confirmed the existence of systemic abuses, the absence of a unified IP policy, and an insufficient level of institutional responsibility for the results of intellectual activity created with budget funds.

At the same time, research into global trends in patent activity in the field of defence and dual-use technologies, in particular the example of unmanned aerial vehicles, has shown that the technological dominance of states directly correlates with the scale and systematic nature of patent portfolio management. The patent landscape in this area performs not only a protective but also a strategic function – as a tool for controlling access to key technologies, reducing the legal risks of serial production, and ensuring national security.

The article argues that it is impossible to overcome the identified problems through fragmentary changes or exclusively through regulatory measures. It is necessary to transition to a comprehensive, formalised and process-oriented model of defence intellectual property management that covers the entire life cycle of R&D results – from the identification of potential IP objects and the selection of a legal protection regime to their use, scaling, licensing, international transfer and state control.

The model of defence IP management proposed in the article, formalised using a process approach (IDEF3), is the key scientific and practical result of the study. It allows integrating the processes of creating weapons and military equipment with the processes of intellectual property rights management, introducing control points at critical stages of the defence cycle, ensuring expedited consideration of applications in priority areas of the defence industry, review the secrecy regime for unused inventions, and form mechanisms for motivating and holding accountable participants in the innovation process.

The implementation of such a model creates the conditions for reducing the risks of defence technology leaks, increasing the efficiency of R&D results, growing the innovative capacity of the defence-industrial complex, and strengthening Ukraine's position in international military-technical cooperation. The proposed approach can be used as a basis for shaping state policy in the field of defence intellectual property, further improving legislation and the institutional architecture of innovation management in the context of military and post-war development.

4. Conclusions

This monograph provides a comprehensive interdisciplinary synthesis of autonomous unmanned systems as complex cyber-physical objects in which artificial intelligence-driven algorithmic architectures are directly transformed into military-technical, economic, and institutional capacities of the state through intellectual property mechanisms. It is demonstrated that the transition from remotely controlled platforms to autonomous systems capable of independent perception, spatial orientation, and real-time decision-making fundamentally alters the structure of defence technologies, shifting their strategic core from material components toward algorithmic sovereignty.

The conducted patent landscape analysis of visual SLAM and related autonomy technologies confirms that the functional nucleus of autonomy is formed by the integration of artificial intelligence with simultaneous localisation and mapping algorithms operating under conditions of degraded or unavailable satellite navigation. These algorithmic components determine not only the tactical effectiveness of unmanned platforms, but also their scalability toward cooperative multi-agent systems and robotic complexes.

At the same time, the global patent environment is characterised by high fragmentation, dominance of algorithmic claims, concentration within IPC/CPC classes G06, G01S and G05D, and asymmetric geographical distribution of ownership. Ukrainian developers therefore operate under structurally constrained freedom-to-operate conditions, where access to core methods is limited by foreign patent portfolios, while domestic patenting remains focused primarily on applied implementations rather than foundational algorithms.

The study establishes that unmanned systems constitute critical dual-use technologies in which engineering innovations directly translate into national security parameters. In this context, intellectual property functions as an element of intangible defence infrastructure, comparable in strategic significance to material production facilities. Analysis of Ukrainian practice reveals persistent systemic deficiencies, including fragmented legal regulation, uncertainty regarding ownership of defence R&D outcomes, outward patent migration, accumulation of service and classified inventions, insufficient integration of publicly funded developments into production chains, and the absence of a coordinated national patent strategy in the field of autonomy technologies.

Particular attention is devoted to the phenomenon of “dead” classified inventions and to the risks of uncontrolled leakage of algorithmic solutions through foreign patenting and international cooperation. It is demonstrated that the lack of systematic selection of protection regimes and centralised registration of rights results in the loss of economic returns on defence R&D investments and undermines strategic control over critical autonomy technologies. In practice, this leads to the erosion of technological advantages obtained through combat-driven innovation and reduces the long-term competitiveness of domestic developers in post-war markets.

Based on the obtained results, a set of applied recommendations is formulated, including: mandatory early-stage IP examination for defence R&D projects; differentiation of protection regimes depending on technological criticality and export sensitivity; establishment of a unified registry of defence intellectual property; continuous monitoring of patent validity and freedom-to-operate risks; institutionalisation of licensing mechanisms enabling scaling through multiple manufacturers;

and integration of patent analytics into state defence procurement and innovation funding programmes.

The principal scientific and practical outcome of the monograph is the development of a process-oriented model of defence intellectual property management that integrates legal protection, secrecy regimes, licensing, production scaling, and international transfer into a unified technology life cycle. The proposed model formalises decision points for selecting protection regimes, introduces feedback loops between R&D, production, and IP governance, and provides an institutional framework for aligning defence innovation with national security priorities. The model explicitly accounts for the movement of intellectual property objects across all stages of the defence-industrial cycle, from early research through deployment and post-war commercialisation.

The results also demonstrate that the current fragmentation of the visual SLAM patent landscape creates both risks and strategic opportunities for Ukraine. The absence of monopolistic concentration among global industrial players allows entry into the technological niche without confronting dominant patent barriers. At the same time, this fragmented environment requires a high level of IP management maturity, as conflicts arise not from single blocking patents but from distributed algorithmic claims held by multiple entities. Proper utilisation of patent landscape analytics therefore becomes a prerequisite for effective engineering design, export planning, and international partnership formation.

Overall, the transition from fragmented protection of isolated developments toward systematic management of algorithmic autonomy forms a conceptual and institutional foundation for national technological sovereignty. Implementation of the proposed model enables reduction of risks associated with loss of critical algorithms, increases the effectiveness of defence R&D utilisation, supports transparent integration of state and private developers, facilitates post-war dual-use commercialisation, and strengthens Ukraine's position within international military-technical cooperation frameworks. In this sense, algorithmic autonomy and intellectual property governance emerge not merely as technical or legal instruments, but as strategic resources shaping the long-term resilience and competitiveness of the state.

References:

1. Katkuri A. V. R., Madan H., Khatri N., Abdul-Qawy A. S. H., Patnaik K. S. Autonomous UAV navigation using deep learning-based computer vision frameworks: A systematic literature review. *Array*, 2024, Vol. 23:100361. DOI: <https://doi.org/10.1016/j.array.2024.100361>. Available at: <https://www.sciencedirect.com/science/article/pii/S2590005624000274> (accessed February 02, 2026).
2. Defence Express. Ukraine reached a record level of drone production: plans exceeded. Available at: https://defence-ua.com/news/ukrajina_dosjagla_rekordnoji_tsifri_u_virobnitstvi_droniv_plani_perevikonano-16979.html (accessed February 02, 2026).
3. Fakty ICTV. Ukraine will need 4 million drones in 2025 – EU Commissioner Kubilius. Available at: <https://fakty.com.ua/ua/ukraine/20250610-ukrayini-bude-potribno-4-mln-droniv-u-2025-roczi-yevrokomisar-z-pytan-oborony/> (accessed February 02, 2026).
4. Censor.NET. Last year Ukraine produced 2.2 million FPV and 100 thousand long-range UAVs – Zelenskyy. Available at: <https://censor.net/ua/news/3537464/skilky-droniv-vygotovyla-ukrayina-u-2024-rotsi> (accessed February 02, 2026).
5. ZAXID.NET. Since the beginning of 2024 Ukraine has produced about 200 thousand FPV drones. Available at: https://zaxid.net/vid_pochatku_2024_roku_v_ukrayini_virobili_blizko_200_tis_fpv_droniv_n1580927 (accessed February 02, 2026).
6. KYIV24. Ukraine is capable of producing up to 10 million drones per year – Ministry of Defence. Available at: <https://kyiv24.news/news/ukrayina-zdatna-vyroblyaty-do-10-miljoniv-droniv-na-rik-minoborony> (accessed February 02, 2026).
7. Espresso.TV. Forbes: Ukraine produces about 50 thousand FPV drones per month. Available at: <https://espresso.tv/forbes-ukraina-vigotovlyae-shchomisjatsya-blizko-50-tis-fpv-droniv-uf-ushestero-bilshe> (accessed February 02, 2026).
8. IBM. What is Artificial Intelligence (AI)?. Available at: <https://www.ibm.com/cloud/ai-overview> (accessed February 02, 2026).
9. IBM. Deep Learning. Available at: <https://www.ibm.com/cloud/learn/deep-learning> (accessed February 02, 2026).
10. NVIDIA. How AI Is Making Drones Smarter and More Autonomous. Available at: <https://www.nvidia.com/en-us/ai/industries/robotics/drones/> (accessed February 02, 2026).
11. Towards Data Science. Computer Vision for Drones: Real-Time Object Detection and Tracking. Available at: <https://towardsdatascience.com/computer-vision-for-drones-real-time-object-detection-and-tracking-34c8d5c4b18d> (accessed February 02, 2026).
12. Deloitte Insights. Drones for Good: How Drones Are Transforming Industries. Available at: <https://www2.deloitte.com/us/en/insights/focus/industry-4-0/drones-for-good-industry-use-cases.html> (accessed February 02, 2026).
13. Androshchuk H. O. Artificial Intelligence and Intellectual Property: Regulatory Issues. Kyiv: Interservis, 2023. 204 p.

14. Reznikova V. V., Poiedynok V. V., Holovachova A. V. (2025). Problems and prospects of legal regulation of economic activity carried out using unmanned aerial vehicles (UAVs). *Pravo ta innovatsii – Law and Innovations*, no. 2(50), pp. 148–154. Available at: <https://pti.org.ua/index.php/ndipzr/uk/article/view/1299> (accessed February 02, 2026).
15. Gao X., Zhang T. Introduction to Visual SLAM: From Theory to Practice. Singapore: Springer, 2021. DOI: <https://doi.org/10.1007/978-981-16-4939-4>. Available at: <https://link.springer.com/book/10.1007/978-981-16-4939-4> (accessed February 02, 2026).
16. Androshchuk H. O. (2017). Patent landscape as a strategic tool of innovative development (on the example of 3D printing). *Science and Science Studies*, no. 2, pp. 52–68. Available at: http://nbuv.gov.ua/UJRN/NNZ_2017_2_5
17. Androshchuk H. O. (2018). Patent landscape in the system of economic analysis: methodology. *Intellectual Property in Ukraine*, no. 11, pp. 20–24.
18. Androshchuk H. O., Kvasha T. K. (2019). Patent landscape as a tool for forecasting global technological trends: weapons and military equipment. *Science, Technologies, Innovations*, no. 4(12), pp. 28–40. DOI: <https://doi.org/10.35668/2520-6524-2019-4-04>
19. Androshchuk H. O., Kvasha T. K. (2021). Patent landscape as an intellectual property analytics tool (case of military technologies). In: Issues of Intellectual Property, Kyiv: Interservis, Issue 18, pp. 94–105. Available at: http://www.ndiiv.org.ua/Files2/vydannia_2021/Zbornik_18.pdf#page=94
20. Butnik-Siverskyi O. B., Androshchuk H. O. (2021). Methodological foundations of patent landscape in the system of national intellectual security. *Theory and Practice of Intellectual Property*, no. 4, pp. 71–85.
21. Androshchuk H. O. (2021). Patent landscape in artificial intelligence: analysis of the USPTO report. *Modern Problems of Law and Innovation Economy*, no. 3, pp. 5–12.
22. Androshchuk H. O. (2022). Global patent owners landscape 2021. *Intellectual Property in Ukraine*, no. 1, pp. 4–9.
23. Androshchuk H. O. (2025). Global intellectual property landscape and intangible assets: growing impact. *Science and Science Studies*, no. 3, pp. 3–23.