FINNISH DRONE STRATEGY

FINNISH DEFENCE AND AEROSPACE INDUSTRIES **PIA**

FOREWORD

The war in Ukraine has demonstrated the significance of drone technology and its disruptive impact on modern warfare. At the same time, it has revealed how quickly technology is advancing and how its applications are extending into various sectors of society. Drones are not merely weapons of war; they represent a broader technological revolution affecting society at large – their impact could be as fundamental as the internet revolution once was.

Drone technologies are among the key future technologies, capable of driving major innovations. Their potential spans across all aspects of society, and Finland cannot afford to be left behind in this development. We must ensure, with determination, that drone technologies become an integral part of Finland's competitiveness and security. The drone industry is experiencing rapid global growth, offering Finland an excellent opportunity to generate economic growth.

Recognising this, stakeholders in Finland's drone sector jointly identified the need for a national drone strategy to guide the industry's sustainable and long-term development. Finnish Defence and Aerospace Industries (PIA) took on the role of facilitating the strategy's development. A working group was assembled for this purpose, bringing together Finland's top experts from various sectors. The group included representatives from industry, government authorities, and research institutions, ensuring a broad and multidisciplinary perspective for the strategy. We would like to express our sincere gratitude to the working group for their valuable expertise and significant contributions to the preparation of this strategy.

This strategy sets clear objectives and guidelines upon which Finland's drone industry can build sustainable growth and international success. Finland's strengths lie in agility and the ability to rapidly adapt to changing challenges – crucial traits in the global technological competition. However, success is ultimately built on collaboration. Only by combining our resources, expertise, and innovative solutions can we ensure that Finland not only keeps up with global developments but also takes a leading role in shaping the future of drone technology.

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SUMMARY

Finland needs a drone strategy. The rapid development of drones and related technologies will have a transformative impact on society as more human-performed tasks are replaced by unmanned systems. The business implications span multiple industries, though their full extent remains partially unpredictable. At the same time, the development of drones and drone technologies presents significant business opportunities for Finland.

This strategy sets the goal of making Finland the world's leading country for drone development and business within five years.

By 2030:

- Finnish drone companies will be among the global leaders.
- Finland will be an attractive location for establishing a drone business.
- Finland will offer a low-threshold innovation environment for drone development.
- Finland will be a desirable country for drone technology investments.
- Drone technology will be widely utilised in Finland to enhance various industries.

This strategy outlines five key areas that need to be developed to achieve these goals:

1. Building and Strengthening Expertise
2. Advancing Drone Concept Development and Experimentation
3. Enhancing Testing and Evaluation Capabilities
4. Ensuring National Security of Supply
5. Facilitating Deployment, Operations, and Maintenance

1. Introduction

Drones as the Next Industrial Revolution

With advancements in artificial intelligence and sensor technologies, machines are becoming increasingly aware of their surroundings, capable of learning, and less dependent on direct human control. These cognitive machines and the development of robotics enable the rise of drones–autonomous, unmanned systems capable of independent movement. Drones will be the next industrial revolution, transforming nearly every aspect of human life, from elderly care to warfare.

This strategy takes a broad view of drones. A drone is defined as an unmanned vehicle that operates on land, in the air, or in water, either remotely controlled or autonomously. These are collectively referred to as UxS ("Uncrewed System"). A drone system includes technology (drones, software, data transmission systems, etc.), people (operators, maintenance personnel, and end users), and the information required for its operation.

The first industrial revolution is often considered to have begun with the harnessing of steam power for industry and transportation. The widespread adoption of the steam engine led to the rise of the textile industry, created a new working-class population in factory labour, established the need for a standardised concept of time, and so on. The changes were immense across all aspects of human life. Later, similar industrial revolutions were driven by electricity and automation. The transformation brought by drones is likely to be of at least the same magnitude. Drones will enable humans to be replaced in long-duration, repetitive, dangerous, or challenging tasks. The human role will shift from piloting machines to defining tasks and overseeing execution. This shift will change the skills required in the workforce, redefine professions, eliminate some job categories, and create new ones.

The evolution of drones will disrupt many existing business models while simultaneously creating entirely new ones. As the division of labour between humans and machines changes, entire professions will disappear while new ones emerge. Tasks that are routine, hazardous, dirty, require operation in difficult environments, demand extreme endurance, or necessitate high speed will increasingly be assigned to machines. Meanwhile, the human role will shift from operating machines to leading them–and eventually to commanding fleets of autonomous systems. The human will assess the situation, make decisions, issue commands, and supervise the execution, while machines will coordinate among themselves to determine who performs which task, where, how, and when. This shift in the role of humans and machines will not happen overnight, but it will be fundamental. The potential applications of drones are particularly significant in a country like Finland, where the population is relatively sparse, and operational environments are often challenging. This strategy has been developed to ensure that Finland comprehensively considers the impact of drones across all sectors of society and positions itself as a global leader in drone technology development and application.

Drone technologies also have significant economic implications. Market forecasts estimate that by 2030, the global drone market will be valued between €50 billion and €250 billion, with exceptionally rapid growth continuing beyond that. As a high-tech nation, Finland has the potential to capture at least hundreds of millions of euros annually from this expanding market.

Much like electricity when it first arrived in Finland 150 years ago, drones will initially be seen as a novelty, then as tools for specialists and professionals, and eventually as an ordinary part of everyday life that goes unnoticed. This transition requires safe, interoperable, and innovative solutions that foster public trust in human-machine collaboration. Society must play a key role in facilitating innovation through regulation and infrastructure investments – creating an environment where experimentation is encouraged, barriers to adoption are minimised, and new technologies can be integrated quickly. This demands coherent legal frameworks, regulatory consistency, and cross-sector alignment across all areas of governance. Finland has the potential to become a global leader in drone technology by focusing on selected areas of expertise, leveraging its industrial strengths and northern geographic conditions. As a small nation, Finland benefits from the ability to act swiftly, adapt holistically, and develop a strong national drone ecosystem.

Commercial Perspective

For nationwide drone operations, mobile networks play a crucial role. Safe, reliable, and widely available connectivity is essential for drone operations. Although 4G- and 5G-based drone systems have been successfully tested worldwide, regulatory challenges continue to hinder large-scale deployment. Advancements in data transfer capacity, network integration, and secure communication solutions will unlock new business opportunities and increase economic potential. However, clear regulatory frameworks are required to fully enable business models such as Drones as a Service (DaaS) and autonomous aerial logistics. By establishing trusted and cyber-secure mobile network connectivity, Finland can support safe, regulated, and publicly accepted drone operations. This, in turn, will create new business models and collaboration opportunities between telecommunications companies, drone manufacturers, and public authorities.

These developments will increase market attractiveness, enable additional investments, and create new jobs in an industry poised for rapid growth.

ELECTRICITY IS AN INTEGRAL PART OF MODERN LIFE. Its foundation includes standardised consumer interfaces, safety regulations, approval processes for new technologies, national transmission infrastructure, power plant investments, support for decentralised electricity production, and continuity planning for emergency situations. For drones, similar enablers must be in place: clear, lightweight, and safe approval criteria for land, sea, and air drones, as well as standardised information and energy interfaces to enable seamless nationwide drone operations. Additionally, autonomous drone operations require reliable background data, such as high-resolution 3D terrain and environmental models. To ensure effective integration, the drone ecosystem must also include unified or at least interoperable tools for mission simulation, planning, execution, control, monitoring, and analysis. These tools will enable coordinated civilian and military drone operations, including swarm deployments for specific tasks.

Military Perspective

Drones are radically transforming the battlefield, as they can perform tasks that would otherwise be too dangerous, expensive, or time-consuming. Their use reduces human casualties and enhances operational efficiency. Currently, drones are primarily used for reconnaissance, surveillance, and tactical strikes. Soon, their role is expected to expand into areas such as logistics and resupply operations. Additionally, autonomous and swarm-capable drones introduce a new dimension to military applications. They can operate independently or in coordinated formations, dynamically adapting to mission requirements and responding to threats in real time.

Given Finland's sparse population and geographically demanding terrain, drones capable of operating in cold and extreme conditions are particularly valuable. Ensuring domestic production and supply security is critical for maintaining operational capability and self-sufficiency, especially during crises.

Goal: Making Finland a Global Leader in Drone Development

The goal of this strategy is for Finland to become the best country in the world for drone development and drone-based business within five years. By 2030:

- **Finnish drone companies will be among the global leaders.**
  - Finland will have multiple world-leading companies and a broad network of ambitious SMEs operating in critical areas of drone technology or providing drone-based services.

- **Finland will be an attractive location for starting a drone business.**
  - Relative to its population size, Finland will have the highest number of new startups globally that develop drone technology or provide drone-based services. These companies will grow into international players.

- **Finland will have a world-class innovation ecosystem for drone development.**
  - Finland will offer a comprehensive research, development, testing, and innovation ecosystem for drones operating on land, in water, and in the air, with strong participation from universities and research institutions.

To achieve these goals, the strategy is structured around the following key areas:

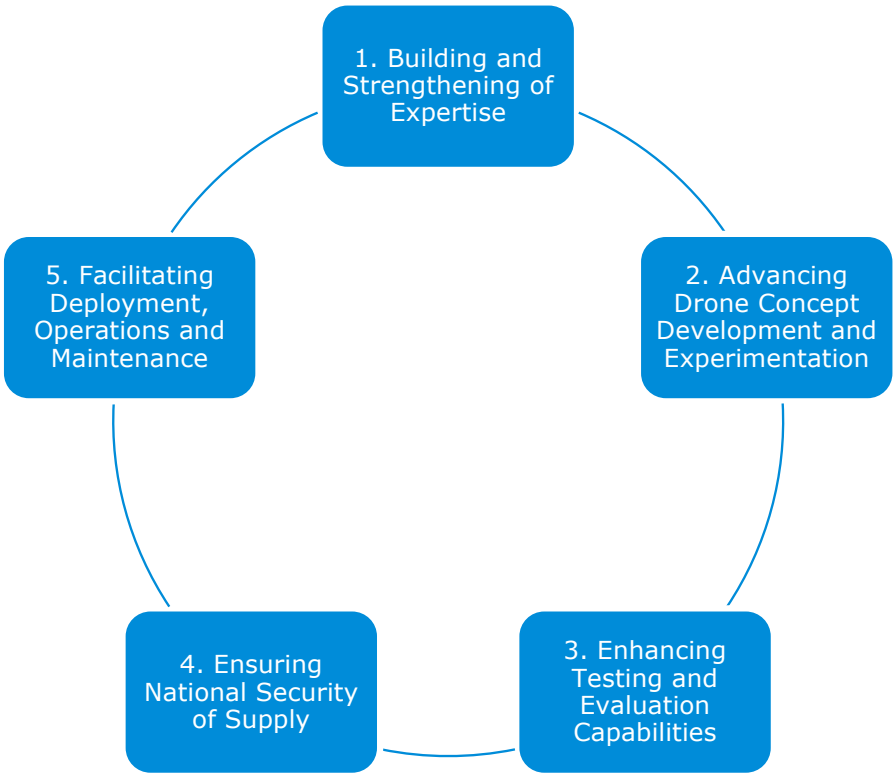
1. **Building and Strengthening of Expertise**
   - Ensuring the availability of highly educated professionals.
   - Defining and prioritising key technologies
   - Establishing a foundation for cutting-edge research.

2. **Advancing Drone Concept Development and Experimentation**
   - Developing nationally critical technologies.
   - Creating a business environment that fosters innovation.

3. **Enhancing Testing and Evaluation Capabilities**
   - Establishing testing and evaluation centres that also support experimentation with low Technology Readiness Level (TRL) systems.

4. **Ensuring National Security of Supply**
   - Securing domestic production and services during crises.

5. **Facilitating Deployment, Operations, and Maintenance**
   - Streamlining approval processes and lowering barriers to adoption.



2. Building and Strengthening of Expertise

Higher Education Pathways for the Drone Sector

Currently, Finland does not offer a formal degree programme dedicated to the drone industry. However, several institutions – including vocational schools, polytechnics, some universities, and a few commercial training providers – offer drone-related education in different formats. The main focus of these programmes is on applied drone usage, such as aerial photography, orthophotography, and oblique scanning. Additionally, civilian drone certification programmes such as A1/A3, A2, SIL-16, and STS courses and exams are available. It is essential to assess the need and feasibility of establishing an academic degree programme that builds upon existing expertise in fields such as aerodynamics, avionics, materials engineering, mechanics and electromechanics, electronics and RF technology, navigation and positioning systems, software development, and human-machine interfaces (HMI).

Given the current funding structure, the most viable option would be to develop master's level (YAMK) conversion programmes, potentially funded through Finland's Ministry of Education and Culture's strategic initiatives. The curriculum should be aligned with industry and research needs to ensure its relevance.

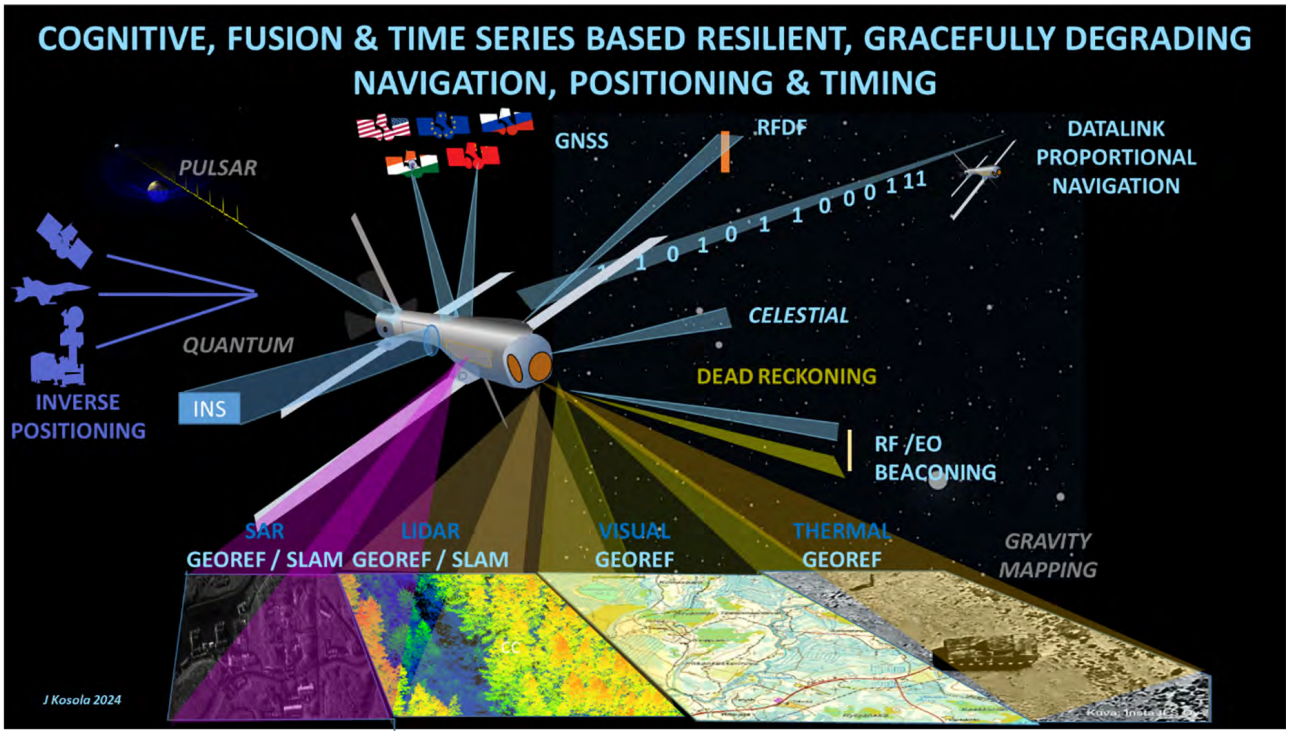
Key Technological Choices for Research

Expertise and education should be viewed as part of a continuous knowledge pipeline, where strategic research leads to the discovery and prediction of new phenomena. Basic research verifies and defines these phenomena, and applied research translates them into commercially viable innovations. The industrial sector then focuses on scaling these technologies for mass adoption. To sustain this pipeline, funding must start at the early research stages, ensuring that strategic and basic research continue to generate breakthrough innovations, even if their commercial potential only becomes apparent over the long term.

Nationally, Finland should prioritise the following core research areas:

- Secure, reliable, and low-detectability communication solutions
  - Cognitive, interference-resistant radio technologies (including C2, DAA)
  - Nationwide and regional secure drone data transmission infrastructure

The Finnish terrain is difficult to navigate, and the climate presents challenging conditions for both mobility and sensors.'



Positioning and navigation solutions that function in all conditions utilise all available sources of information, ensuring reliability without dependency on a single system.

Software, hardware, and operational safety in aviation
- Compliance with aviation safety regulations (continuous airworthiness management)
- AI-assisted flight control systems and automated navigation
- Secure command and control (C2) software for autonomous drone operations

Payload and algorithm development for networked environments
- Advanced sensor fusion integrating data from SAR, ESM, laser, hyperspectral imaging, and optical sensors
- Real-time data processing using Edge AI and decentralised computing
- Machine learning for autonomous target recognition and adaptive mission execution

Testing in Arctic conditions
- Large-scale land, sea, and air environmental testing facilities
- System-level stress testing under extreme conditions (temperature, wind, precipitation, electromagnetic interference)
- GPS jamming and electronic warfare resilience in controlled environments

Advanced propulsion and energy technologies
- High-performance battery solutions optimised for cold environments
- Alternative propulsion technologies, including jet and gas turbines, hybrid-electric propulsion, internal combustion engines (ICE), hydrogen fuel cells, and rocket-based propulsion
- Energy-efficient autonomous recharging stations for drone fleets

UxS systems expertise
- Multi-modal drone platforms capable of land, sea, and aerial integration
- Autonomous mission coordination between multiple drone types

Counter-Unmanned Aerial Systems (C-UAS)
- Surveillance, threat detection, jamming, and kinetic interception technologies
- AI-driven anomaly detection for hostile drone identification
- Swarm disruption tactics and electronic warfare countermeasures

Positioning, navigation, and timing (PNT) solutions
- Redundant positioning systems that function independently of satellite GPS
- Quantum navigation and alternative localisation methods for GPS-denied environments
- Time synchronisation networks for multi-drone coordination

Human-machine teaming technologies (MUM-T)
- Swarm intelligence algorithms for coordinated mission execution
- Gesture-, voice-, and thought-controlled interfaces for human-drone interaction
- AI-assisted decision support systems for high-intensity operations

Industrial manufacturing capabilities
- Advanced materials technology for lightweight, durable drone structures
- 3D-printed components and modular drone design for rapid deployment
- Domestic production and supply chain security for critical drone parts

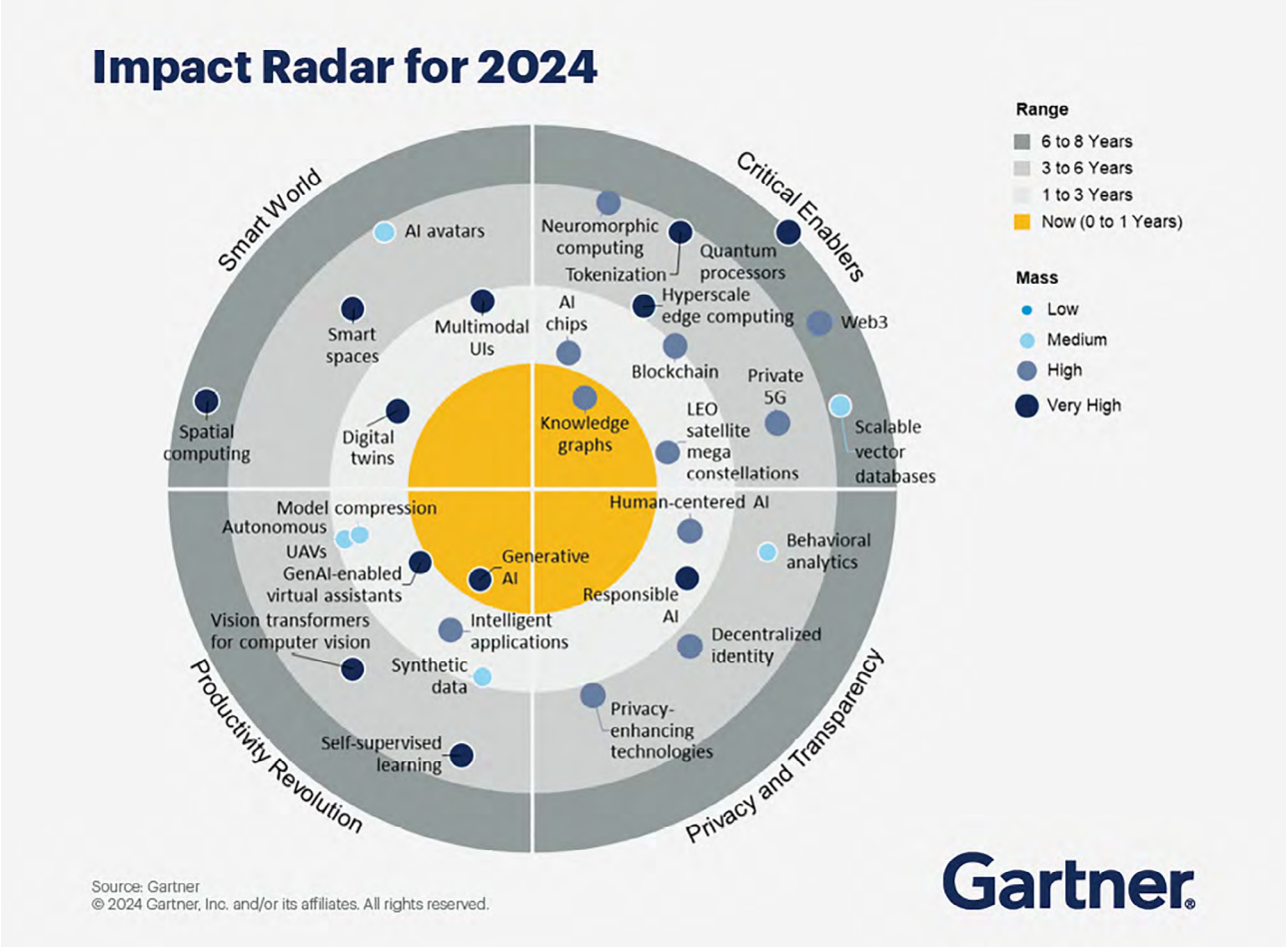
3. Advancing Drone Concept Development and Experimentation

Drone technology is fundamentally disruptive only when it is not simply used to replace a crewed system with an autonomous one but when the entire operational concept is reshaped around the opportunities that drones enable. For example, replacing a mine-laying vessel with an unmanned vessel would not be revolutionary, nor necessarily cost-effective. However, replacing ship-deployed naval mines with self-deploying mines would fundamentally change naval warfare.

Change is often slowed by people's attachment to traditional roles. A pilot may find it difficult to accept a technology that replaces them, just as a taxi driver resists self-driving cars. This challenge is particularly significant in a technologically advanced country like Finland, where alongside learning new skills, unlearning is also necessary. For example, Skype would probably not have been developed in Finland, as the country's traditional telecom operators had such a strong grip on the market.

Overcoming organisational and cultural barriers is slow and sometimes even impossible. Therefore, new operational and funding models are needed that bypass traditional structures and create space for innovation. Finland should enable a low-threshold operating model for developing new concepts and experimenting with them in environments relevant to drone operations.

Testing and experimentation environments should be easily accessible on a commercial basis, freely reservable, and available for different types of trials with minimal bureaucratic obstacles. International experience has shown that such test centres naturally foster local innovation ecosystems, where different companies' activities support and catalyse new innovations.



The combination of unmanned aerial vehicles (UAVs) and artificial intelligence (AI) points to a future where drones are not only more autonomous but also capable of performing increasingly complex tasks thanks to AI's learning and adaptation capabilities. (Gartner Impact Radar for 2024).

A commercially operated environment that specialises in testing and has mastered all necessary regulatory processes and approvals presents the most promising opportunity for building such a system. This way, users of the service can focus on developing their solutions without having to handle regulatory requirements themselves. In its initial phase, this kind of activity requires public support to enable full-scale operations.

Finland's business environment should encourage companies to engage in innovation through, for example, tax incentives. Additionally, the government should actively implement long-planned innovation partnership models and foster public-private partnerships, whose realisation so far has been below expectations. These models encourage the industry to invest in innovation activities and the commercialisation of innovations.

4. Enhancing Testing and Evaluation Capabilities

Finland offers unique environmental conditions for drone testing. Finnish conditions include challenging arctic environments, forests, and water bodies. The country's four distinct seasons create a demanding operational environment for any equipment, making it an ideal location for testing drones under extreme conditions. A drone that performs well in Finland will perform well anywhere in the world.

A nationally standardised testing environment – including common standards, environmental testing laboratories, and outdoor test areas – would benefit both end users and original equipment manufacturers (OEMs). The testing infrastructure should offer a wide range of services, including climate-controlled facilities for equipment and personnel, flight support systems, and test sites for sensor calibration.

From an end-user perspective, comprehensive testing improves the operational performance of existing drone systems by identifying and mitigating limiting factors and optimising usage. It also supports procurement decisions by precisely defining performance requirements for drones in arctic conditions, including temperature, humidity, wind, and other environmental factors. For manufacturers, a well-structured testing environment provides clear standard parameters and helps identify weaknesses before field deployment.

Testing environments also ensure that drones can operate safely and reliably even in disrupted communication or navigation scenarios, such as in cases of electronic interference or jamming. To achieve this, Finland must maintain nationally controlled and managed test sites and laboratories that, together with regulatory frameworks, enable performance validation and security assessments of drone subsystems and full systems operating in the radio spectrum.

The development of national drone testing capabilities requires investments in modern test facilities that support diverse and interoperable drone systems. The goal is to create an infrastructure that serves both domestic and international stakeholders, reinforcing Finland's position as a global leader in drone technology development and testing.

5 Ensuring National Security of Supply

From a resilience perspective, domestic production is a key factor in national preparedness. Security of supply is an essential component of a society's contingency planning for various crisis scenarios. Security of supply can be divided into four critical areas required in times of crisis:

- Knowledge, research, development, and training capabilities
- Production and upgrade capacity
- Maintenance, damage repair, and operational support
- Operational planning, tasking, and command capabilities

Lessons learned from the war in Ukraine show that drones are at the centre of a constant race between offensive and defensive measures. This makes continuous research and development, rapid system updates, and fast operational training crucial in crisis conditions. As conflicts extend over time, domestic production becomes essential. Unlike traditional munitions, drone production can be scaled up significantly faster, making it a key asset in prolonged crises. At the same time, drone consumption in warfare is extremely high, requiring a sustained production and maintenance capability. For reusable drones, it is essential to ensure that they can be kept operational without relying on foreign repairs or spare parts supply chains. Finland must achieve full operational independence in drone operations.

To ensure Finland's security of supply in drone technology, the following measures must be taken:

- Securing expertise and production resources by maintaining a national manufacturing base and a contract-based production network.
- Identifying critical components and ensuring their availability through commercial agreements and state-level procurement deals. If necessary, Finland must be prepared to establish domestic production and pre-stock critical components that may become unavailable in times of crisis.

In wartime, the electronic warfare environment changes rapidly, requiring adaptable technological solutions. Finnish drone systems must be modular and flexible, allowing for rapid adaptation to new threats. This adaptability should be considered from the procurement phase through the entire system lifecycle, ensuring that domestic engineering and NATO collaboration support ongoing technological evolution.

Given the rapid advancement of drone technology, preparing for wartime mass production means developing methods and processes that ensure production readiness without compromising technological competitiveness. Some critical systems cannot be mass-produced in peacetime because their technological advantage would degrade over time. Instead, Finland must focus on storing only those components that remain technologically relevant and designing drones with software-defined features that can be updated as needed.

Preparing for large-scale production of rapidly advancing technology in wartime requires methods and processes that ensure production readiness without compromising the technological competitiveness of the systems. Some systems and devices cannot be stockpiled in peacetime because their performance would decline relative to adversarial developments. Instead, only components unaffected by technological progress should be stored. Planning for innovative production also requires designing products and systems with software-upgradable capabilities and components that remain relevant despite technological advances.

Ensuring continuity, protection, and decentralisation of drone production is a critical national security concern, particularly in times of crisis. This requires a comprehensive preparedness plan, which includes defence industrial agreements, supply security treaties, and cooperation with other Nordic and European countries. Additionally, NATO cooperation offers opportunities to develop shared standards and ensure interoperability between allied nations

In defence material production, cooperation between domestic and international partners in research and technology development enables more efficient and cost-effective manufacturing. Industrial collaboration strengthens national expertise and ensures that Finland's defence industry aligns with international security standards. The goal is to ensure that drones developed and produced in Finland meet both national and international requirements and are suitable for both domestic use and export.

Export potential plays an important role in drone technology development. From the early design phase, regulatory requirements of export markets should be considered, and if necessary, separate export versions should be developed to comply with target market regulations and security standards. Export opportunities directly support national production and enhance Finland's technological competitiveness. In this way, Finland's security of supply develops organically, as demand for both civilian and defence solutions in international markets increases domestic production capacity.

Managing advanced technologies and continuous innovation are key pillars of military security of supply. To maintain operational capability in crisis conditions, Finland must invest in the development of advanced drone systems and emerging technologies to ensure rapid response capability and maintain technological leadership.

6. Facilitating Deployment, Operations, and Maintenance

The goal of this strategy is to facilitate the adoption of drones and drone services and to enable the rapid development of operational environments. Achieving this requires a critical review and streamlining of existing regulations to ensure that safety and type approval procedures allow for the swift deployment of drones without unnecessarily complex permitting processes. Regulations must also be harmonised at the EU level to prevent Finland from becoming a marginal market due to unique national requirements. The regulatory framework must be flexible and consistent across road, aviation, and maritime regulations to support the efficient and safe integration of drones into all sectors.

The use of drones must be safe and strictly regulated to meet the needs of both public authorities and commercial operators. This requires clear operational guidelines across all environments – on land, at sea, and in the air. The use of drones by authorities is governed by specific regulations and accountability requirements to ensure safe and reliable operations. A particularly important factor is ensuring that public safety authorities have reliable and secure communication links for drone operations that comply with national cybersecurity standards.

To avoid a fragmented and incompatible drone ecosystem, Finnish authorities should procure a standardised drone fleet that can serve multiple agencies. A shared fleet ensures uniform technical and safety requirements, improving reliability and interoperability across different public sector operations. A common fleet also enables resource-efficient and rapid response to various crisis situations, as authorities can flexibly allocate drones for tasks such as border surveillance, rescue operations, environmental monitoring, and disaster management.

Standardising and harmonising the use of drones across different public sector needs significantly contributes to the development of the national drone market. It also enables an efficient and coordinated network for both public sector agencies and private companies providing drone equipment and services.

The technical minimum requirements for drones used by authorities must be clearly defined. This includes requirements for technological components, communication security, manufacturing and maintenance standards, and operational performance in all weather conditions. Drones function best as part of integrated systems where data and real-time situational awareness can be efficiently shared across multiple stakeholders.

The long operational lifespan of drones in public sector use means that lifecycle upgrades and modernisation must be considered. Lifecycle management requires continuous monitoring and updates to ensure that drone performance, safety, and usability remain at the highest standards. Additionally, to secure the maintenance and reliability of drones, Finland must develop domestic maintenance infrastructure and system design expertise to ensure that drones meet national security requirements even under exceptional circumstances.

7. Recommendations for Action

To implement this strategy, a separate execution programme should be set, and its progress will be systematically monitored, for example, by an appointed independent evaluator.

1. **Establish a five-year national drone programme with the following objectives:**
   - Define education and competence development goals in collaboration with higher education institutions.
   - Attract international top experts and students to Finland.
   - Develop technology, material, and procurement strategies that support the drone strategy.
   - Initiate national product development, production, and operational capabilities.
   - Define the requirements of defence and security authorities and procure a shared fleet of drones in a way that facilitates the development, testing, and commercialisation of drone technologies and systems.
   - Create low-threshold experimentation and development environments and establish conditions for testing and evaluation activities in collaboration with the Ministry of Economic Affairs and Employment of Finland, Business Finland, the Ministry of Defence, and the Ministry of Transport and Communications.
   - Define the national service architecture, launch business operations, ensure continuity, and secure the scalability of production.
   - Identify regulatory and administrative bottlenecks and seek solutions in cooperation with the responsible ministries and agencies, with the aim of streamlining legislation and administrative processes across all sectors: the Ministry of Economic Affairs and Employment of Finland, the Ministry of Transport and Communications, the Ministry of Defence, the Ministry of the Interior, the Ministry for Foreign Affairs, and the Ministry of Education and Culture.

2. **Invest in national environmental testing infrastructure:**
   - Establish a large-scale environmental laboratory for system-level testing with operational equipment.
   - Develop open test areas that allow field experiments in real weather and environmental conditions, including, for example, a GPS jamming test area in an open-pit mine.

3. **Define a national policy that builds on a shared drone fleet for authorities (drone-as-a-service), ensuring that public sector decision-making considers not only individual optimisations but also the overall national economic benefit and security of supply**

4. **Increase research funding:**
   - Significantly expand funding for unmanned aviation research within the Finnish Defence Forces, VTT Technical Research Centre of Finland, the National Land Survey of Finland's Geospatial Research Institute, and universities.
   - Establish a dedicated and well-funded drone research programme (e.g., under Business Finland), supplemented as needed by direct ministerial-level funding programmes.

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