International Journal of Advanced Culture Technology Vol.12 No.2 286-298 (2024)
DOI https://doi.org/10.17703/IJACT.2024.12.2.286

IJACT 24-6-32

The Evolution of Drone and Air Defense Technologies: Implications for the Future Battlefield

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Abstract

The rapid advancement of drone technology has significantly altered the landscape of modern warfare, presenting both opportunities and challenges for military forces worldwide. As drones become increasingly sophisticated, capable of performing complex missions such as reconnaissance, surveillance, and precision strikes, the development of effective air defense systems has become a critical priority. This study examines the current state of drone and air defense technologies, analyzing their impact on military strategies, tactics, and the future battlefield environment. By exploring the patterns of technological evolution, the limitations of existing air defense systems, and the potential consequences of drone proliferation, this research highlights the need for adaptive, innovative approaches to counter emerging threats. The findings underscore the importance of investing in advanced detection and interception capabilities, developing comprehensive counter-drone doctrines, and fostering international cooperation to address the ethical and legal challenges posed by the military use of drones. As the competition between drone and air defense technologies continues to intensify, policymakers and military leaders must proactively engage in shaping the future of warfare to ensure national security and stability in an increasingly complex world.

Keywords: *Drone technology, Air defense systems, Future battlefield, Military strategy, International cooperation*

1. Introduction

1.1 Research Background and Purpose

In the 21st century, drone technology is rapidly advancing, greatly changing the nature of modern warfare. Initially developed for military use, drones have now become innovative weapon systems capable of performing various missions such as reconnaissance, surveillance, and attack. Drones have advantages over existing manned aircraft, such as lower cost, lower risk of loss of life, and the ability to fly for long periods of time, making them increasingly utilized in military operations.

However, the development and proliferation of drone technology is causing new security threats. Non-state actors and terrorist groups can now easily acquire and use drones for attacks, increasing the risk of drone-related terrorism and crime. Accordingly, air defense technologies to counter drone threats are also rapidly developing. Various countermeasures are being developed to detect and track drones using radar and electro-

Manuscript received: March 10, 2024 / revised: April 22, 2024 / accepted: May 10, 2024
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optical equipment, and to intercept drones using missiles and laser weapons.

The competition between drone and air defense technologies is greatly changing the nature of modern warfare. Drones have dominated the battlefield in recent conflicts such as the Azerbaijan-Armenia conflict and the Ukraine war, indicating that the role and importance of drones will further increase in future wars. Therefore, this study aims to analyze the current state of development of drone and air defense technologies, and forecast how their competition will affect the future battlefield. Through this, we seek to enhance understanding of the changing security environment and contribute to the establishment of effective military strategies.

1.2 Literature Review

Research on drone and air defense technologies has been actively conducted in recent years. Singer (2009), in his book "Wired for War," highlighted how the development of military robot technologies, including drones, is changing the nature of warfare. Hammes (2016) analyzed the impact of the development of small weapon systems, such as drones, on the military balance, predicting the strengthening of asymmetric forces and the complexity of warfare.

Kallenborn (2017) analyzed the evolution of air defense technologies to counter drones, introducing the development trends of new countermeasures such as laser weapons and high-power microwave weapons. Birkey & Hamilton (2022) analyzed the opportunities and challenges of counter-drone systems, emphasizing that technological challenges such as multi-sensor integration and intelligent algorithm development must be addressed to effectively respond to drone threats.

Meanwhile, research is also being conducted on the impact of drone technology development outside the military domain. Buckel et al. (2019) analyzed the use cases of drones in agriculture and suggested the potential of drone technology for implementing precision agriculture. Erdelj et al. (2017) explored ways to utilize drones in disaster management, showing that drones enable rapid situational awareness and effective response.

However, most of the existing research is limited to analyzing drone and air defense technologies separately, and there is a lack of comprehensive research that forecasts their interaction and development patterns. In-depth analysis of the impact of drone and air defense technology development on the future battlefield is also needed. Therefore, this study aims to differentiate itself from previous research by examining the development status of drone and air defense technologies together and forecasting the military changes that their competition will bring.

2. Current Status and Prospects of Drone Technology Development

2.1 Drivers of Drone Technology Development

a. Technological Factors

The rapid development of drone technology is due to various technological innovations. First, the development of battery technology has greatly improved the flight time and range of drones. As high energy density battery technologies such as lithium polymer batteries and hydrogen fuel cells have advanced, the endurance of drones has increased and their range of use has expanded. Second, the development of miniaturization and lightweight technologies has reduced the size and weight of drones, improving their operability and mobility. The development of small drones has accelerated with the application of ultra-small sensors using MEMS (Micro-Electro-Mechanical Systems) technology and lightweight composite materials to drones. Third, the development of autonomous flight technology has greatly improved the mission performance capabilities of

drones. Autonomous navigation systems using GPS, inertial navigation devices, vision sensors, etc., and artificial intelligence-based obstacle avoidance and path planning algorithms have been developed, increasing the autonomy of drones. Fourth, the development of communication technology has improved the remote control and data transmission capabilities of drones. As high-speed and high-capacity wireless communication technologies such as 5G, satellite communications, and MIMO (Multiple-Input and Multiple-Output) have advanced, real-time video transmission, remote control, and swarm control of drones have become possible.

b. Economic Factors

Another driver of drone technology development is economic factors. First, the cost of manufacturing drones has greatly decreased, leading to the popularization of drones. For small drones, the price has dropped to the level of hundreds of dollars, and with the development of open-source hardware and software, individuals can now easily manufacture drones. Second, as the civilian market for drones is rapidly growing, investment in drone technology development is expanding. The use of drones is increasing in various fields such as agriculture, logistics, surveying, and infrastructure inspection, and accordingly, the size of the drone market is growing rapidly. The United States, China, Europe, and other major countries are promoting deregulation for drone commercialization, designation of drone-specific test airspace, and investment in drone technology R&D, which is promoting drone technology development in the private sector.

c. Social Factors

The development of drone technology is also being driven by social needs and changes. First, as social demands for disaster and safety management increase, the use of drones in the public sector is expanding. Drones are being used for real-time monitoring of disaster sites, assessment of damage situations, transportation of relief supplies, etc., improving disaster response capabilities, and the use of drones is also increasing in various public safety areas such as crime prevention, maintenance of public order, and facility safety inspections. Second, as interest in eco-friendly mobility increases, the development of urban air mobility (UAM) such as drone taxis and drone delivery is actively underway. Urban traffic innovation using drones is expected to bring effects such as reducing carbon emissions and alleviating traffic congestion. Third, the use of drones is increasing in the leisure and entertainment fields. New forms of leisure activities such as drone racing and drone performances are emerging, and drone filming is widely used in the production of media content such as movies, broadcasting, and advertising.

The drivers of drone technology development are the result of a complex interplay of various factors such as technology, economy, and society. In the era of the Fourth Industrial Revolution, unmanned vehicle technologies including drones are rapidly developing, and this is expected to bring innovation across industries. In particular, as the convergence of advanced ICT technologies such as 5G, artificial intelligence, and big data with drone technology accelerates, the autonomy, safety, and efficiency of drones are expected to greatly improve. Drone technology is attracting attention as an innovative technology that can fundamentally change our society, economy, and way of life, beyond simply being a new means of transportation.

2.2 Impact of Drone Technology Development on Society

The rapid development of drone technology is having a wide-ranging impact across our society. In particular, drone technology is simultaneously presenting new opportunities and challenges in the economic, social, and military domains. This section will specifically examine the impact of drone technology development in each domain and discuss the resulting social changes and tasks.

a. Economic Impact

The rapid development of drone technology is due to various technological innovations. First, the development of battery technology has greatly improved the flight time and range of drones. As high energy density battery technologies such as lithium polymer batteries and hydrogen fuel cells have advanced, the endurance of drones has increased and their range of use has expanded. Second, the development of miniaturization and lightweight technologies has reduced the size and weight of drones, improving their operability and mobility. The development of small drones has accelerated with the application of ultra-small sensors using MEMS (Micro-Electro-Mechanical Systems) technology and lightweight composite materials to drones. Third, the development of autonomous flight technology has greatly improved the mission performance capabilities of drones. Autonomous navigation systems using GPS, inertial navigation devices, vision sensors, etc., and artificial intelligence-based obstacle avoidance and path planning algorithms have been developed, increasing the autonomy of drones. Fourth, the development of communication technology has improved the remote control and data transmission capabilities of drones. As high-speed and high-capacity wireless communication technologies such as 5G, satellite communications, and MIMO (Multiple-Input and Multiple-Output) have advanced, real-time video transmission, remote control, and swarm control of drones have become possible.

b. Social Impact

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c. Military Impact

The development of drone technology is bringing revolutionary changes to the way wars are conducted. As the role of drones expands in various military operations such as reconnaissance, surveillance, and precision strikes, drones have emerged as a key asset on the modern battlefield. In particular, drones are attracting attention as an asymmetric force because they can precisely strike key enemy targets while minimizing the risk of loss of life from manned fighters or ground troops.

However, the development of drone technology also poses new security threats. Terrorist groups or criminal organizations may abuse drones to carry out attacks, and competition for drone technology between countries may lead to an arms race. Hacking attacks exploiting the cyber security vulnerabilities of drones can also become a serious threat. Therefore, in the military use of drone technology, thorough security measures and establishment of international norms are necessary.

The development of drone technology is bringing many changes to our society. Economically, it provides opportunities for creating new industries and jobs, while promoting innovation in existing industries. Socially, it contributes to improving public safety and quality of life, but faces new challenges such as privacy infringement and safety issues. Militarily, drones have emerged as a key force, but a response to the abuse of drones and security threats is needed.

It is necessary to closely analyze the social impact of drone technology development, maximize positive effects while minimizing negative impacts, and make policy, technological, and social efforts. For the sound development of drone technology, communication and cooperation among various stakeholders such as government, companies, and civil society are essential. It is time to gather wisdom so that drone technology can bring positive changes to our society.

2.3 Drivers of Drone Technology Development

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The drivers of drone technology development are the result of a complex interplay of various factors such as technology, economy, and society. In the era of the Fourth Industrial Revolution, unmanned vehicle technologies including drones are rapidly developing, and this is expected to bring innovation across industries. In particular, as the convergence of advanced ICT technologies such as 5G, artificial intelligence, and big data with drone technology accelerates, the autonomy, safety, and efficiency of drones are expected to greatly improve. Drone technology is attracting attention as an innovative technology that can fundamentally change our society, economy, and way of life, beyond simply being a new means of transportation.

3. Evolution and Limitations of Air Defense Technologies

3.1 Patterns of Air Defense Technology Evolution

As the military threat of drones increases with the rapid development of drone technology, air defense technologies to counter them are also constantly evolving. Early air defense systems were mainly developed to counter large targets such as aircraft or missiles, but recently, the focus is on developing technologies to detect and intercept small, low-speed, low-altitude flying drones.

a. Improvement of Detection Capabilities

Air defense technologies are continuously developing to improve detection capabilities. The rapid development of drone technology is due to various technological innovations. First, the development of battery technology has greatly improved the flight time and range of drones. As high energy density battery technologies such as lithium polymer batteries and hydrogen fuel cells have advanced, the endurance of drones has increased and their range of use has expanded. Second, the development of miniaturization and lightweight technologies has reduced the size and weight of drones, improving their operability and mobility. The development of small drones has accelerated with the application of ultra-small sensors using MEMS (Micro-Electro-Mechanical Systems) technology and lightweight composite materials to drones. Third, the development of autonomous flight technology has greatly improved the mission performance capabilities of drones. Autonomous navigation systems using GPS, inertial navigation devices, vision sensors, etc., and artificial intelligence-based obstacle avoidance and path planning algorithms have been developed, increasing the autonomy of drones. Fourth, the development of communication technology has improved the remote control and data transmission capabilities of drones. As high-speed and high-capacity wireless communication technologies such as 5G, satellite communications, and MIMO (Multiple-Input and Multiple-Output) have advanced, real-time video transmission, remote control, and swarm control of drones have become possible.

b. Diversification of Interception Capabilities

Weapon systems for drone interception are also diversifying. In addition to existing surface-to-air missiles, interception systems using laser weapons, high-power microwaves, and electromagnetic pulses (EMP) are being developed. South Korean military also operates various interceptor missiles such as Patriot, M-SAM, and L-SAM, and is working to improve interception capabilities by promoting the introduction of the SM-3 missile capable of high-altitude interception. The diversification of interception weapons is expected to contribute to improving defense capabilities against drone threats.

c. Utilization of Artificial Intelligence (AI)

Attempts to incorporate artificial intelligence technology into air defense systems are also active. Research is underway to automatically detect, identify, and track drones using AI algorithms and establish optimal interception strategies. In fact, Israel is known to have used an AI system to select bombing targets and conduct operations in a recent battle with armed forces in the Gaza Strip.

South Korean is also promoting the establishment of an intelligent air defense system utilizing AI technology. In 2017, the Defense Acquisition Program Administration presented plans to utilize AI technology for countering drones, minimizing friendly losses, and improving the survivability of friendly forces through a study on the "Defense Artificial Intelligence Utilization Plan." AI technology is expected to improve the efficiency of air defense system operation by supporting rapid and accurate decision-making through analysis of vast amounts of data.

c. Air Defense System

To effectively respond to drone threats, it is essential to establish an integrated air defense system that organically links detection, tracking, and interception systems. Accordingly, each country is building an integrated air defense system that connects various surveillance assets and interception means through a network to share real-time information and enable rapid response.

South Korean military is also securing ballistic missile defense capabilities across the Korean Peninsula by linking various surveillance and interception assets such as ballistic missile early warning radars, Aegis ships, and Patriot through the establishment of the Korea Air and Missile Defense (KAMD) system. In the future, there are plans to strengthen integrated air defense system capabilities by continuously deploying long-range radars and interceptor missiles and upgrading the tactical data link system such as Link-16.

3.2 Patterns of Air Defense Technology Evolution

Despite the development of air defense technologies, there are still limitations in responding to drone threats. Small drones are difficult to detect because they have a small radar cross-section and fly at low altitudes. It is also not easy to identify drones that maneuver while hiding under terrain features. Defense becomes even more difficult when multiple drones attack simultaneously.

There is a risk of civilian casualties even if drones are intercepted by air defense systems. In particular, if drones are shot down in urban areas, secondary damage from falling objects is a concern. It is also inefficient in terms of cost-effectiveness to counter low-cost drones with expensive interceptor missiles.

In the Ukraine-Russia war, the air defense systems of both sides showed vulnerability to the other's drone threats. The Ukrainian military struggled with Russia's suicide drone attacks, and the Russian military also failed to properly block the surprise strikes of Ukrainian military drones. With the current air defense systems, it is difficult to effectively respond to evolving drone threats.

3.3 Prospects for Changes in the Future Battlefield Environment

a. Intensification of Competition between Drone and Air Defense Technologies

Drone and air defense technologies are in a co-evolutionary relationship, developing in competition with each other. As the stealth, mobility, autonomy, and swarm operation capabilities of drones become more advanced, air defense technologies to detect, track, and intercept them will also evolve. Conversely, as air defense technologies develop, competition to develop drone technologies to overcome them is also expected to accelerate.

b. Accelerated Development of Artificial Intelligence (AI)-Based Weapon Systems

In the future, the development of drone and air defense systems incorporating AI technology is expected to

begin in earnest. The autonomous flight, target identification, and attack functions of drones will be advanced, and swarm tactics through collaboration between drones will also develop. In the air defense field, threat detection and interception command automation using AI are expected to be implemented. Competition in the development of AI-based weapon systems is expected to greatly change the future battlefield.

c. Emergence of New Threat Scenarios such as Urban Warfare

With the development of drone technology, the threat of terrorism in urban areas may increase. Various terrorist scenarios, such as dropping explosives, assassinating figures, and attacking civilian facilities using small drones, may become a reality. Due to the miniaturization and stealthiness of drones, it is expected to be difficult to effectively respond to drone threats in urban areas with existing air defense systems.

d. Necessity of Changes in Military Strategies and Tactics

The development of drone technology is causing revolutionary changes in the way wars are conducted. Accordingly, military strategies and operational tactics also need to change. Establishing a defense concept against drones, developing counter-drone operational doctrines, and training specialized personnel for drone operations require multifaceted military innovation.

In addition, it is necessary to think about the strategic instability that the proliferation of drones may cause. With the development of drone technology, the barrier to entering a war may be lowered and the possibility of military provocations may increase. Research on the strategic impact of drone proliferation and preparation of response measures are urgent.

Lastly, an approach at the international norm level is also necessary. It is necessary to seek ways to cooperate at the international community level, such as revising international laws related to the military use of drones, controlling drone exports, and cooperating on counter-terrorism. The wisdom of the international community must be gathered so that the development of drone technology can contribute to human security.

Table 1. Comparison of Air Defense Technology Evolution Patterns

Category	Main Content
Detection Capabilities	- Improvement of detection range and accuracy with the development of low-altitude radars, 3D radars, etc .- Enhancement of target detection capabilities by applying Active Kalman Filter- Improvement of detection performance with the development of new maritime surveillance radars
Interception Capabilities	- Development of various interception means such as lasers, high-power microwaves, EMP - Demonstration of Israel's Iron Dome's high interception success rate- South Korean military's deployment of interceptor missiles such as Patriot, M-SAM
AI Utilization	- Research on automatic drone detection, identification, tracking, and optimal interception strategy establishment - Israel's case of AI-based target selection and operation execution- South Korean military's promotion of intelligent air defense system establishment
Integrated Air Defense System	- Establishment of real-time response system through linkage of surveillance and interception assets - South Korean military's acquisition of ballistic missile defense capabilities through KAMD system- Advancement of integrated air defense system with long-range radars, tactical data links, etc.

Table 2. Limitations and Challenges of Air Defense Technologies

Category	Main Content
Detection of Small Drones	- Limited detection due to small size and radar cross-section of small drones- Detection becomes even more difficult when flying at low altitudes and using terrain
Response to Drone Swarms	- Lack of tracking and interception capabilities against simultaneous attacks by multiple drones - Limitations in responding to drone swarms with current air defense systems
Cost Issues	- Massive costs incurred in establishing and operating high-performance air defense systems - Inefficient to use expensive interceptor missiles against low-cost drones
Civilian Casualties	- Concerns about civilian casualties when intercepting drones in urban areas- Urgent need to develop technologies to minimize damage
Advancement of Drones	- Increased survivability of drones with miniaturization and stealthiness - Increased threats with electronic warfare capabilities, incorporation of AI technology - Need for improvement of mobility and survivability of air defense assets, development of doctrines

Air defense technologies are continuously evolving to counter drone threats, but there are still limitations to be overcome. To keep up with the speed of drone technology evolution, multifaceted efforts are needed, such as improving detection and interception capabilities, strengthening integrated response systems, and establishing cost-effective response strategies. In particular, in preparation for the future warfare environment where the military use of drones is expected to further increase, in-depth research on the direction of air defense development and proactive preparation are required.

4. Impact of Drone and Air Defense Technology Development on the Future Battlefield

4.1 Characteristics and Cases of Drone Warfare

The rapid development of drone technology is greatly changing the nature of modern warfare. Drones are playing a key role on the battlefield by performing various missions such as reconnaissance, surveillance, and precision strikes. Drone warfare shows characteristics such as strengthening of asymmetric forces, improvement of precision strike capabilities, continuous surveillance and reconnaissance, and psychological effects. The rapid development of drone technology is greatly changing the nature of modern warfare. Drones are playing a key role on the battlefield by performing various missions such as reconnaissance, surveillance, and precision strikes. Drone warfare shows characteristics such as strengthening of asymmetric forces, improvement of precision strike capabilities, continuous surveillance and reconnaissance, and psychological effects.

a. Strengthening of Asymmetric Forces

Drones are attracting attention as an attractive weapon system for countries or non-state actors with inferior military power due to their low cost and ease of operation. Weak countries or rebel forces have become able to effectively counter powerful countries using drones. The proliferation of drones is breaking the existing military power balance and deepening the asymmetric force structure.

b. Precision Strike Capabilities

Drones can accurately strike key enemy targets from outside the engagement range by carrying precision-guided weapons. This increases the value of drones as an asymmetric force because it can inflict serious

damage on the enemy while minimizing friendly casualties. The Ukrainian military achieved military gains by precisely striking Russian military armored vehicles and air defense systems with Turkish-made Bayraktar TB2 drones.

c. Continuous Surveillance and Reconnaissance

can perform real-time surveillance and reconnaissance missions by staying airborne over the target area for a long time. The information collected through drones is used for the establishment and execution of friendly operation plans. The Ukrainian military greatly improved its battlefield awareness capabilities by monitoring Russian military movements with drones and guiding artillery fire.

d. Psychological Effects

The very existence of drones can exert psychological pressure on enemy forces. The threat of drone surveillance and surprise attacks lowers the morale of enemy forces and creates a sense of fear. A representative case is the sharp drop in the morale of Nagorno-Karabakh soldiers due to the drone attacks by the Azerbaijani military in the 2020 Nagorno-Karabakh conflict.

e. Case of the Ukraine-Russia War

The Ukraine-Russia war is a case that well demonstrates the role and influence of drones on the modern battlefield. The Ukrainian military achieved great military gains by attacking Russian military armored vehicles, air defense systems, ammunition depots, etc. using Turkish-made Bayraktar TB2 drones and domestically produced Switchblade drones. On the other hand, the Russian military also joined the drone war by introducing Iranian-made Shahed-136 suicide drones and attacking Ukrainian civilian facilities and energy infrastructure. Both sides are fiercely competing between drones and air defense systems, such as strengthening air defense systems to shoot down each other's drones.

4.2 Limitations of Air Defense Response to Drone Threats

As the threat of drones increases, air defense systems to counter them are also developing, but limitations still exist. Small drones are difficult to detect because they have a small radar cross-section and fly at low altitudes. It is also not easy to identify drones that maneuver while hiding under terrain features. Defense becomes even more difficult when multiple drones attack simultaneously.

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4.3 Prospects for Changes in the Future Battlefield Environment

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In the future, the development of drone and air defense systems incorporating AI technology is expected to

begin in earnest. The autonomous flight, target identification, and attack functions of drones will be advanced, and swarm tactics through collaboration between drones will also develop. In the air defense field, threat detection and interception command automation using AI are expected to be implemented. Competition in the development of AI-based weapon systems is expected to greatly change the future battlefield.

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4.4 Necessity of Changes in Military Strategies and Tactics

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Table 3. Characteristics and Cases of Drone Warfare

Characteristic	Main Content	Case
Strengthening of Asymmetric Forces	Utilization of drones by weak countries/non-state actors	Azerbaijan-Armenia conflict
Precision Strike Capabilities	Precision strike on key targets	Ukrainian military's attack on Russian military
Continuous Surveillance and Reconnaissance	Long-term surveillance of targets	Ukrainian military's monitoring of Russian military movements
Psychological Effects	Lowering enemy morale and creating fear	Azerbaijan-Armenia conflict
Ukraine War	Both sides' utilization of drone warfare	Ukrainian military's TB2, Russian military's Shahed-136

Table 4. Prospects for Changes in the Future Battlefield Environment

Category	Main Content
Drone-Air Defense Competition	Intensification of competition in drone/air defense technology development
AI-Based Weapon Systems	Development of autonomy and AI-based drones/air defense systems
New Threat Scenarios	Diversification of drone utilization such as urban area terrorism

Changes in Military Strategies/Tactics	Need for establishing counter-drone doctrines, drone defense concepts
Revision of International Norms	Seeking regulation of military use of drones, international cooperation

*Source: Author's creation

The development of drone technology and air defense technology is expected to fundamentally change the appearance of the future battlefield. Drones are asymmetrically changing the nature of warfare, and their autonomy and swarm combat capabilities will be enhanced with the incorporation of AI technology. Air defense technologies are also trending toward being intelligentized and automated in line with drone threats.

To respond to new security challenges such as drone-air defense competition and urban warfare threats, innovation in military strategies and operational tactics is needed. Proactive preparation is required, such as establishing drone defense doctrines and training specialized personnel for counter-drone operations. In addition, it is urgent to establish norms and prepare cooperation measures at the international community level regarding the military use of drones.

It is time to deeply think about the strategic instability that the development of drone technology may cause. As the military use of drones approaches as both a new opportunity and threat, policy and institutional responses in line with technological developments must be hastened.

5. Impact of Drone and Air Defense Technology Development on the Future Battlefield

This study analyzed the current status of development of drone and air defense technologies, and forecasted how their competition and collision will affect the future battlefield. Drone technology is rapidly developing in combination with advanced technologies such as artificial intelligence, swarm flight, and stealth functions, emerging as an innovative weapon system capable of performing various missions such as reconnaissance, surveillance, and attack. Air defense technologies are also constantly evolving by incorporating advanced technologies such as artificial intelligence, laser weapons, and drone-to-drone systems to counter drone threats. The development of drone and air defense technologies is accelerating the characteristics of the future battlefield such as unmanned, automation, intelligentization, and networking, and this is demanding major changes in existing military strategies and tactics. As asymmetric forces increase and new security threats emerge due to the proliferation of drone technology, countries must establish new national defense strategies to respond to them. Also, as massive budgets and resources must be invested in the development of drone and air defense technologies, changes in national defense budget allocation and resource management strategies will also be needed.

academic significance in that it enhances understanding of the military and security impacts that the development of drone and air defense technologies will bring, and seeks ways to prepare for changes in the future battlefield environment. In particular, analyzing the patterns in which advanced technologies such as artificial intelligence, swarm flight, and stealth functions are incorporated into drones and air defense systems, and forecasting the resulting changes in combat patterns can be used as an important basis for future related research.

In terms of policy, the necessity of changes in national defense strategies and budget allocation according to the development of drone and air defense technologies was raised. In order to effectively respond to drone threats, it is necessary to stably secure the budget and resources necessary for upgrading air defense systems, while developing strategies to utilize drone technology for strengthening friendly forces. In addition, social discussions and efforts to establish international norms on the ethical and legal issues that may arise from the military use of drone technology should be carried out in parallel.

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