IJACT 24-6-28

Analysis of Iran's Air Defense Network and Implications for the Development of South Korea's Air Defense Network

[1]Hwang Hyun-Ho

[1]Prof., Dept. of Military Technology, Woosuk Univ., Korea
E-mail dhmk85h3@naver.com

Abstract

This study analyzes the current status and prospects of Iran's air defense network, focusing on the Russian-made S-300 system, and derives implications for the development of South Korea's air defense network. Iran's air defense network exhibits strengths such as long-range detection and interception capabilities, multi-target processing, high-altitude interception, and electronic warfare response. However, it also reveals weaknesses, including lack of mobility, difficulty in detecting low-altitude targets, obsolescence, training level of operating personnel, and vulnerability to electronic warfare. Real-world cases confirm these weaknesses, making the system susceptible to enemy evasion tactics, swarm drone attacks, and electronic warfare. Drawing from Iran's case, South Korea should establish a multi-layered defense system, strengthen low-altitude air defense and electronic warfare capabilities, foster the domestic defense industry for technological self-reliance, and enhance international cooperation. By addressing these aspects, South Korea can establish a robust air defense network and firmly protect its national security. Future research should aim to secure and analyze materials from the Iranian perspective for a more objective evaluation of Iran's air defense network and continuously track Iran's efforts to improve its air defense network and the trend of strengthening drone forces to predict changes in the Middle East security situation.

Keywords: air defense network, S-300 system, multi-layered defense, electronic warfare, international cooperation

1. Current Status and Prospects of Iran's Air Defense Network

1.1 Composition and Functions of Iran's Air Defense Network

Iran's air defense network has established a multi-layered defense system to respond to various airborne threats at different altitudes and ranges. Among these, the S-300 system plays a crucial role as the core force of Iran's air defense network, serving as a long-range surface-to-air missile system. The technical characteristics of the S-300 system make a decisive contribution to Iran's air defense network's ability to defend a wide airspace and intercept enemy aircraft early on.

The S-300 system has the capability to detect and intercept various airborne threats such as aircraft, missiles, and drones within a maximum range of 200km. This allows Iran to cover a wide area and enables early warning and response to aerial threats from the enemy. Additionally, the S-300 system is equipped with a multi-target processing capability that can simultaneously detect, track, and intercept multiple targets, effectively responding to numerous aerial threats such as Israel's F-35 fighter jets or large-scale drone attacks.

The S-300 system can operate various types of missiles, including the 48N6E long-range missile and the 9M96E/E2 medium-range missile, allowing flexible response to airborne threats at various distances and altitudes. This flexibility contributes to enhancing the strategic defense capabilities of Iran's air defense network.

The ability to intercept aircraft and missiles flying at high altitudes plays a significant role in strengthening Iran's strategic defense capabilities. The S-300 system is equipped with functions to counter the enemy's electronic warfare attacks, preventing radar jamming and missile guidance interference, and increasing the system's survivability.

However, the S-300 system also has several weaknesses. One major disadvantage is its lack of mobility; due to the system's size and weight, it is difficult to move or redeploy quickly. Additionally, it may face difficulties in detecting low-altitude targets due to the curvature of the Earth, which can make it vulnerable to low-altitude threats such as small drones and cruise missiles. The S-300 system is a complex system, so the training level of the operating personnel is crucial. Although the training level of Iran's operating personnel is not precisely known, it may be lower compared to Russia. This can degrade the system's performance and increase the possibility of malfunctions.

Considering these technical characteristics and operational limitations, Iran's air defense network is being strengthened through a multi-layered defense system centered on the S-300 system, suggesting the need for additional efforts to enhance low-altitude air defense capabilities and electronic warfare capabilities.

1.2 Operation and Limitations of Iran's Air Defense Network

Iran's S-300 system revealed limitations in its practical operation during the Syrian civil war and the Nagorno-Karabakh war. These conflicts clearly showed the operational problems of the S-300 system and the need to improve low-altitude air defense capabilities and electronic warfare response capabilities.

In the Syrian civil war, Russia provided the S-300 system to the Syrian government forces to counter airstrikes by rebel forces and the Israeli Air Force. However, the Israeli Air Force employed tactics such as long-range attacks from outside the S-300 system's detection range or using low-altitude flight and electronic warfare to evade the S-300 system. This suggests that the S-300 system is facing difficulties in detecting low-altitude targets and may be vulnerable to electronic warfare.

In the Nagorno-Karabakh war, Armenia operated the S-300 system but failed to effectively respond to Azerbaijan's drone attacks. Azerbaijan operated a large number of kamikaze drones introduced from Turkey and Israel, neutralizing Armenia's S-300 system. The S-300 system struggled to detect and intercept small drones flying at low altitudes. Additionally, Azerbaijan used electronic warfare to jam the S-300 system's radar and interfere with missile guidance.

These real-world cases reveal that the S-300 system is vulnerable to low-altitude targets and electronic warfare attacks, which have been pointed out as operational problems of Iran's air defense network. Consequently, it has become clear that there is a need to improve low-altitude air defense capabilities and electronic warfare response capabilities. Iran is investing in the development of indigenous air defense systems, enhancing low-altitude air defense capabilities, and improving electronic warfare capabilities to overcome these limitations.

The operational problems and areas for improvement of the S-300 system are primarily related to low-altitude air defense capabilities and electronic warfare response capabilities. While the system excels in intercepting high-altitude targets, it has limitations in detecting and intercepting low-altitude targets. Moreover, its vulnerability to electronic warfare is also a problem.

Limitations in low-altitude air defense capabilities: The S-300 system faces difficulties in detecting low-altitude targets due to the curvature of the Earth. This means that its defense capabilities against low-altitude threats, such as small drones and cruise missiles, may be limited. This limitation was clearly demonstrated in the case of Armenia operating the S-300 system during the Nagorno-Karabakh war, where it was vulnerable to Azerbaijan's low-altitude drone attacks.

Vulnerability to electronic warfare: The S-300 system is susceptible to electronic warfare attacks, which means that its radar detection capabilities may be degraded or missile guidance may be disrupted when exposed to strong electronic warfare attacks from the enemy. This can reduce the overall efficiency and survivability of the system. This issue can be observed in the case of the Israeli Air Force using electronic warfare to evade the S-300 system during the Syrian civil war.

To address these problems, it is necessary to strengthen low-altitude air defense capabilities and improve electronic warfare response technologies. Iran is pursuing technological independence through the

development of indigenous air defense systems to overcome the limitations of the S-300 system and is investing in the development of low-altitude air defense systems and the enhancement of electronic warfare capabilities. These efforts will make Iran's air defense network more robust and enhance its ability to effectively respond to various aerial threats.

1.3 Future Prospects of Iran's Air Defense Network
a. Efforts to improve the air defense network and strategic directions

Iran's air defense network requires continuous improvements to respond to current and future threats. Iran is making various efforts to overcome the limitations of the S-300 system and enhance the overall performance of its air defense network. These efforts include the development of indigenous air defense systems, strengthening low-altitude air defense capabilities, and improving electronic warfare capabilities. Through the development of indigenous air defense systems, Iran aims to reduce its dependence on Russian weapons and respond to Western countries' arms embargoes. Iran has developed long-range surface-to-air missile systems like the Bavar-373, which provides performance similar to the S-300 system, and seeks to improve the autonomy and flexibility of its air defense network.

Strengthening low-altitude air defense capabilities is crucial for responding to low-altitude threats such as drones. Iran is focusing on developing systems that can detect and intercept small drones flying at low altitudes to compensate for the vulnerabilities of its air defense network. Improving electronic warfare capabilities is essential for countering the enemy's electronic warfare attacks. Iran is investing in the development of technologies to disrupt enemy drone communications and hijack control, aiming to increase the survivability of its air defense network.

b. International cooperation and defense industry development

International cooperation plays a significant role in Iran's efforts to improve its air defense network. Iran has introduced the S-300 system through military cooperation with Russia and is introducing other air defense systems through cooperation with China. This international cooperation contributes to Iran's modernization of its air defense network and its ability to respond to various threats.

The development of the defense industry strengthens Iran's ability to independently improve and maintain its air defense network. Iran aims to develop key technologies through the defense industry and enhance its production and maintenance capabilities for air defense systems. Through this, Iran seeks to increase the autonomy and sustainability of its air defense network.

Iran's efforts to improve its air defense network and strategic directions have a significant impact on the security environment in the Middle East, and Iran aims to continuously strengthen its air defense network through international cooperation and the development of the defense industry. These efforts are expected to enhance Iran's ability to effectively respond to current and future threats.

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Table 1   Components and functions of Iran's air defense network

Component	Description of Functions
S-300PMU-2	Long-range surface-to-air missile system capable of detecting and intercepting aircraft, missiles, and drones within a maximum range of 200km
Bavar-373	Long-range surface-to-air missile system with performance similar to the S-300, intercepting aerial threats within a maximum range of 300km
Sayyad series	Medium-range surface-to-air missiles, deployed and operated on various platforms, with excellent mobility
Raad/3rd Khordad	Medium-range surface-to-air missile system, intercepting aircraft, missiles, and drones within a maximum range of 50km
Tor-M1	Short-range surface-to-air missile system, intercepting aircraft, missiles, and drones within a maximum range of 12km
Qadir radar	Long-range detection radar, detecting aerial threats early by linking with the air defense network's command and control system

2. Current Status of South Korea's Air Defense Network and Implications

2.1   Current Status of South Korea's Air Defense Network

South Korea's air defense network operates various layers of air defense systems to counter threats at different altitudes and ranges. The main air defense systems include the Cheongung surface-to-air missile system and the Patriot PAC-3, which form the core of the South Korean Air Force's air defense operation system. Additionally, the efficiency of the air defense network is enhanced through collaboration with the Defense Intelligence Agency.

A. Roles of the Cheongung surface-to-air missile system and Patriot PAC-3

The Cheongung system is a medium-range surface-to-air missile with the capability to intercept aircraft and ballistic missiles. Cheongung uses an inertial navigation system (INS) and ground-based search radar to detect the location of enemy aircraft and performs active guidance by updating coordinates to the missile through a data link. This system plays a crucial role in South Korea's air defense network, particularly contributing to strengthening low-altitude defense capabilities.

The Patriot PAC-3 system provides high-altitude air defense capabilities and is primarily used for ballistic missile defense. PAC-3 enables highly precise interception through high-performance radar and high-speed interceptor missiles. This system is responsible for the upper layer of South Korea's air defense network and plays a significant role in countering North Korea's missile threats.

B. South Korean Air Force's air defense operation system

The South Korean Air Force conducts air defense operations through an integrated command and control system combined with advanced air defense systems. The Air Force utilizes various radars and sensor networks to detect aerial threats early and promptly responds to threats by deploying appropriate air defense assets. This integrated air defense system plays a decisive role in protecting South Korea's airspace.

C. Role of the Defense Intelligence Agency and collaboration

The Defense Intelligence Agency provides essential information for the efficient operation of the air defense network. These agencies analyze information collected through satellites, unmanned aerial vehicles (UAVs), and reconnaissance aircraft to identify threats in advance and respond to them. Additionally, the Defense Intelligence Agency cooperates with intelligence agencies of other countries to share international information and monitor and respond to a wider range of threats.

This systematic operation of the air defense network and collaboration with the Defense Intelligence Agency contribute to South Korea's ability to effectively respond to various aerial threats and strengthen national security.

Table 2. Current status of South Korea's air defense network and major air defense systems

Air Defense System	Description of Functions
Cheongung system	Medium-range surface-to-air missile system with the capability to intercept aircraft and ballistic missiles
Patriot PAC-3	Provides high-altitude air defense capabilities, primarily used for ballistic missile defense
M-SAM	Medium-range surface-to-air missile system, countering various aerial threats
L-SAM	Long-range surface-to-air missile system under development, aiming to strengthen future high-altitude defense capabilities
KAMD	Korea Air and Missile Defense, establishing an effective missile defense system through multi-layered defense

2.2 Vulnerabilities of South Korea's Air Defense Network and Directions for Improvement
A. Need for strengthening low-altitude air defense capabilities

South Korea's air defense network has vulnerabilities in low-altitude air defense capabilities, which is particularly important in the confrontation with North Korea. There are criticisms that the defense capabilities against low-altitude threats such as low-flying drones and cruise missiles are relatively insufficient. These vulnerabilities can become more serious threats as North Korea diversifies its low-altitude attack means.

The development and introduction of low-altitude air defense systems are necessary as a direction for improvement. For example, the development of laser-based anti-aircraft weapons or advanced low-altitude radar systems can be pursued. Additionally, it is essential to strengthen the integrated operation with existing air defense systems to enable prompt and effective response to low-altitude threats.

B. Current status and improvement plans for electronic warfare response capabilities

South Korea's electronic warfare response capabilities are relatively advanced, but continuous technology development is required to respond to the latest electronic warfare threats. Not only North Korea but also other countries' electronic warfare technologies are rapidly advancing, necessitating thorough preparations.

As a direction for improvement, it is necessary to strengthen research and development of electronic warfare technologies and continuously modernize and upgrade electronic warfare equipment. Moreover, it is crucial to enhance response capabilities in real-world situations through electronic warfare training and simulations. To this end, active technology exchange and joint research and development should be sought through cooperation with domestic and foreign specialized institutions.

B. Fostering the domestic defense industry and technological self-reliance

South Korea's defense industry is globally competitive, but it is necessary to strengthen core technology self-reliance and independent development capabilities. The localization of core technologies related to air defense systems is important not only in terms of security but also has significant economic advantages.

As a direction for improvement, investment in research and development in the defense industry should be expanded, and the development of new technologies should be promoted through cooperation with domestic universities and research institutes. Additionally, to enhance the global competitiveness of the defense industry, it is important to actively seek entry into overseas markets and expand international defense industry cooperation.

These improvement directions will make South Korea's air defense network more robust and contribute to strengthening the nation's ability to protect itself from North Korea and other potential threats.

2.3 Air Defense Network Status of Neighboring Countries and Implications for South Korea: Composition and operation cases of neighboring countries' air defense networks
A. North Korea

North Korea's air defense system is integrated under the Air Force Command, consisting of aircraft, surface-

to-air missiles, anti-aircraft artillery, and radar detection units. It is evaluated as one of the densest air defense networks in the world. North Korea lacks fuel even to fly fighter jets, resulting in limited air force training, and is increasing investment in air defense forces and various air defense missiles. North Korea's air defense network focuses mainly on intercepting intruding enemy aircraft and relatively neglects the expansion of fighter jets.

B. China

China has not fully established an integrated air defense network system due to its vast territory, but it has ballistic and cruise missile air defense systems in specific regions. China is enhancing its defense capabilities through the dispersion of nuclear bases and the strengthening of air defense networks, and is striving to modernize its naval and air forces and develop cutting-edge weapons to narrow the military gap with the United States.

C.. Japan

Japan pursues maritime air defense systems, missile air defense systems, special operations, and IT revolution response systems, and is promoting the reinforcement of long-range operational capabilities. Japan is converting existing helicopter carriers into aircraft carriers and developing cruise missiles and hypersonic missiles by adopting counterattack capabilities.

D. Impact of neighboring countries' air defense networks on South Korea's air defense network

The air defense networks of neighboring countries have a significant impact on the development of South Korea's air defense network. North Korea's air defense network presents a direct military threat to South Korea, which is an important factor in South Korea's efforts to strengthen its air defense network and enhance its ability to respond to various aerial threats. The development of China's air defense network emphasizes the need for South Korea to recognize the necessity of strengthening its air defense network through the introduction of advanced air defense technologies and international cooperation in response to changes in the regional security environment. The development of Japan's air defense network emphasizes the importance of South Korea seeking strategies to strengthen its air defense network through international cooperation.

E. Strategies for strengthening the air defense network through international cooperation

In response to the development of neighboring countries' air defense networks, South Korea should seek strategies to strengthen its air defense network through international cooperation. This includes strengthening military cooperation with friendly countries such as the United States and promoting the introduction of the latest air defense systems. Additionally, South Korea should be able to effectively respond to North Korea's aerial threats by establishing an information-sharing and joint response system with neighboring countries. South Korea should also strengthen efforts to increase its role in the international community by expanding cooperation with regional cooperative bodies such as ASEAN in response to changes in the regional security environment.

Table 3. Air defense network status of neighboring countries and implications for South Korea's air defense network

Country	Air Defense Network Status	Implications for South Korea's Air Defense Network
North Korea	Dense air defense network, operating various air defense systems	Emphasizes the importance of strengthening low-altitude air defense capabilities and a multi-layered defense system
China	Establishing regional air defense systems, possessing advanced missile defense systems	Recognizes the need to introduce advanced air defense technologies and strengthen the air defense network through international

		cooperation
Japan	Operating advanced air defense systems and integrated air defense networks, strengthening missile defense systems	Emphasizes the importance of developing multi-layered defense systems and advanced air defense technologies

3. Suggestions for the Development of South Korea's Air Defense Network
3.1   Establishing a Multi-Layered Defense System
Establishing a multi-layered defense system is essential for the development of South Korea's air defense network. This means formulating an air defense strategy that can effectively respond to various aerial threats by integrating long-range, medium-range, and short-range air defense systems.
A. Integration of long-range, medium-range, and short-range air defense systems
Long-range air defense systems, such as missile defense (MD) systems, are utilized to counter high-altitude threats like ballistic missiles. Medium-range air defense systems, such as the Cheongung system, are used to counter aircraft and medium-range missiles, while short-range air defense systems, such as the Patriot PAC-3, are employed to intercept low-flying aircraft or missiles.

This multi-layered defense system should be designed so that each system performs complementary roles. For example, if the long-range missile defense system fails to detect and intercept, it is important to link the operation so that the medium-range or short-range air defense systems can perform subsequent defense. To this end, it is essential to establish an integrated command and control system and radar network, and the efficiency of the air defense network should be maximized through real-time information sharing and coordination.
B. Air defense strategies to counter various aerial threats
Geographically, South Korea is adjacent to North Korea and is also located close to China and Japan. This geopolitical situation means that it is exposed to various aerial threats. Therefore, South Korea should establish an air defense strategy that can effectively respond not only to traditional aerial threats but also to unconventional threats such as the recently increasing drones.

To this end, South Korea should expand investment in the development of systems for low-altitude drone defense, which may include laser weapon systems or electronic warfare technologies. Additionally, it is important to strengthen cyber defense capabilities to protect the air defense network from the enemy's cyber attacks. Along with this, South Korea should introduce the latest air defense technologies through international cooperation and strengthen its practical response capabilities by conducting multinational air defense training. Establishing such a multi-layered defense system and an air defense strategy that responds to various aerial threats will make South Korea's air defense network more robust and contribute to strengthening national security.

3.2 Advancement of Air Defense Technologies and Strengthening Cooperation
A. Development and introduction of advanced air defense systems
South Korea is improving the efficiency and response speed of its air defense network through the development and introduction of advanced air defense systems. This is an essential measure to respond quickly and accurately to various aerial threats and contributes to enhancing the technological capabilities and international competitiveness of the domestic defense industry.

South Korea is developing advanced air defense systems in cooperation with domestic defense companies. For example, major defense companies such as LIG Nex1 and Hanwha Systems have developed and are operating medium-range air defense systems like the Cheongung, which are becoming core elements of South Korea's air defense network. Additionally, through technological cooperation with global defense companies such as Thales, South Korea is introducing advanced air defense technologies and promoting the development of domestic defense technologies.
B. Establishing an international air defense cooperation network
Establishing an international air defense cooperation network plays a crucial role in South Korea's ability to identify trends in global air defense systems and introduce the latest technologies. Through this, South Korea

can proactively respond to changes in the international security environment and increase the reliability of its air defense network through military cooperation with various countries.

South Korea is strengthening military cooperation with allies such as the United States, Japan, and Australia. This cooperation includes information sharing, joint military exercises, and joint development of advanced air defense technologies. For example, the ROK-US-Japan security cooperation serves as an important platform for responding to North Korea's missile threats, enabling South Korea to enhance its air defense network operation capabilities.

Moreover, South Korea is strengthening cooperation with ASEAN countries in the field of air defense. This is one way for South Korea to play a significant role in the Asia-Pacific region's air defense security network and contribute to regional security.

Establishing such an international air defense cooperation network contributes to South Korea's ability to identify the latest trends in global air defense systems and equip itself with the capabilities to effectively respond to various threats. This plays a crucial role in making South Korea's air defense network more robust and strengthening national security.

4. Conclusion

Through this study, we analyzed the current status and prospects of Iran's air defense network, particularly the Russian-made S-300 system, and derived implications for the development of South Korea's air defense network. Iran's air defense network has strengths such as long-range detection and interception capabilities, multi-target processing capabilities, high-altitude interception capabilities, and electronic warfare response capabilities. However, it also revealed weaknesses such as lack of mobility, difficulty in detecting low-altitude targets, obsolescence, training level of operating personnel, and vulnerability to electronic warfare. Analysis of real-world cases confirmed that these weaknesses are susceptible to the enemy's evasion tactics, swarm drone attacks, and electronic warfare attacks.

Referring to the case of Iran, South Korea should establish a multi-layered defense system and strengthen low-altitude air defense capabilities and electronic warfare capabilities. To this end, investment in the development of low-altitude radars, laser weapons, and the enhancement of electronic warfare capabilities is necessary, and technological self-reliance should be pursued through the fostering of the domestic defense industry. Additionally, South Korea should effectively respond to North Korea's aerial threats by strengthening military cooperation with friendly countries such as the United States and establishing an information-sharing and joint response system with neighboring countries.

The analysis of Iran's air defense network provides important implications for the direction of South Korea's air defense network development. To respond to North Korea's various aerial threats, South Korea should pursue the establishment of a multi-layered defense system, strengthening low-altitude air defense capabilities, enhancing electronic warfare capabilities, fostering the domestic defense industry, and strengthening international cooperation. Through this, South Korea will be able to establish a solid air defense network and firmly protect national security.

This study was limited to literature research, making it difficult to identify specific information or classified matters related to the actual operation of the S-300 system. Furthermore, since most of the research materials were published in Western countries, there is a possibility that a biased perspective on Iran's air defense network may have been reflected. Therefore, future research needs to secure and analyze materials from the Iranian side for a more objective evaluation of Iran's air defense network. Additionally, research is needed to predict changes in the security situation in the Middle East by continuously tracking Iran's efforts to improve its air defense network and the trend of strengthening drone forces.

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