Chapter 3 Trends Concerning New Domains including Outer Space, Cyberspace, and Electromagnetic Spectrum, and Relevant Challenges Facing the International Community

Section 1 Trends Concerning Military Science and Technology

1 Military Science and Technological Trends

1 General Situation

Recent developments in science and technology have impacted a variety of areas, triggering significant and revolutionary changes in many areas such as economy, society, and lifestyle. As civilian technologies have been rapidly developing, further technological innovation is expected to dramatically change battle scenes in the future. In particular, major countries have focused on the aggressive utilization of artificial intelligence (AI), high-power energy, quantum technology, and other cutting-edge technologies.

2 Military Cutting-edge Technology Utilization Trends

(1) AI Technology

AI technology is one of the technology areas that shows rapid progress in recent years. It has been pointed out that the rapid AI progress has been exerting a great impact on the military field, including the application for autonomous unmanned vehicles and the cyber domain as well as supporting for command and decision-making and improving data processing capacity, among other areas.

The United States, China, and Russia have formulated their AI strategies and promoted relevant research and development under industry-government-academia collaboration. The U.S. Department of Defense (DoD) established the Joint Artificial Intelligence Center (JAIC) in June 2018 and indicated its policy of using AI in a lawful and ethical manner in "Summary of the 2018 Department of Defense Artificial Intelligence Strategy" released in February 2019. The Chinese government announced the "Next Generation AI Development Plan" in 2017, setting a target for China to become a major global AI innovation center by 2030. In Russia, President Vladimir Putin in 2017 acknowledged that AI leaders would rule the world. Its national AI development strategy through 2030, released in October 2019, cited such targets as the acceleration of AI technology development, support for scientific research, and the improvement of human resources development systems.

AI-using technologies being studied include situation assessment support systems to display data collected through various sensors in an easy-to-understand manner, as well as decision-making support systems to provide commanders with available options. The United States conducted demonstration tests on the Advanced Battle Management System (ABMS) in December 2019. The system is reportedly designed to link various systems to networks, analyze collected data with AI, and allow combat troops to promptly access the data. It is noted that China is interested in introducing AI-based decision-making support systems for commanders, allegedly having a plan to develop a decision-making support system for nuclear-powered submarine commanders.

The United States, China, and Russia are developing autonomous unmanned vehicles equipped with AI. Autonomous unmanned vehicles would generally combine unmanned vehicles technologies expected to be utilized in dangerous, dirty, and dull missions with AI technology capable of detecting adversary actions and battle situation changes, and enables intelligence, surveillance and reconnaissance (ISR) missions in a wide range of areas over a long time, without risking human lives. The U.S. Defense Advanced Research Projects Agency (DARPA) is developing AI-equipped unmanned aerial vehicles (UAVs), including swarms of reusable, air-launched and air-recovered small UAVs for ISR missions, as well as unmanned surface vessels for locating submarines. Under its Gremlins program, for example, DARPA conducted the first flight test for the X-61A UAV in November 2019, testing its aerial launching and flying it for more than 90 minutes to verify aerial and ground command and control systems.

In May 2018, China Electronics Technology Group Corporation successfully performed a swarm flight of 200 AI-equipped unmanned vehicles, demonstrating its advanced AI technology. It is assumed that military operations including such swarm flights will be difficult to counter with conventional air defense systems. The Caihong-7 (CH-7), whose prototype was exhibited at the Airshow China, China International Aviation and Aerospace Exhibition, in November 2018, is described as a fighter UAV that can perform advanced autonomous flights.

Russia is developing a nuclear-powered unmanned underwater vehicle (Poseidon) that can carry nuclear warheads, claiming that it has been tested successfully.

Some have argued that autonomous unmanned vehicles could develop into so-called Lethal Autonomous Weapons Systems (LAWS). Within the framework of the United Nations Convention on Certain Conventional Weapons (CCW), discussion on LAWS is continued from the perspectives of their characteristics, human elements, and international law.

Meanwhile, some people indicate that UAVs would not acquire the autonomy at the same level as human pilots until 2040.

(2) Hypersonic Weapons

The United States, China, and Russia are developing hypersonic weapons, including Hypersonic Glide Vehicles (HGVs) that would be launched from ballistic missiles, maneuvered to glide at hypersonic speed (Mach 5 or above) after their entry into the atmosphere, and hit targets, as well as Hypersonic Cruise Missiles (HCMs) using scramjet engines and other technologies that enable hypersonic flights. It is suggested that hypersonic weapons would fly in lower orbits than ballistic missiles at hypersonic speed above Mach 5 for a longer period of time and have high maneuverability, which makes it difficult to be detected and intercepted.

The United States, in its Missile Defense Review (MDR) (January 2019), indicates that Russia and China are developing advanced hypersonic weapons that challenge existing missile defense systems. The United States also announced in March 2020 that it had conducted a successful flight test on hypersonic weapons.

Flight test in November 2019
[DARPA]

Medium-range ballistic missile "DF-17" showcased
at the military parade commemorating the 70th anniversary of China's founding [EPA/Jiji]

In the military parade to mark the 70th anniversary of China's founding in October 2019, the DF-17 ballistic missile viewed as capable of carrying an HGV made its first public appearance, suggesting the possibility that hypersonic weapons would be deployed as early as in 2020. Russia announced its deployment of an HGV called "Avangard." It is also continuing the development of an HCM called "Zircon."

(3) High-power Energy Technology

High-power energy weapons, such as electromagnetic railguns, high-power laser weapons, and high-power microwaves, are being developed as a means to counter various airborne threats.

The United States and China are developing

KEY WORD Swarm flight

Swarm flight technology networks numerous UAVs, leading them to autonomously cooperate with each other for swarm flights. The technology is expected to improve warning, surveillance, and reconnaissance capabilities and add to attack capabilities to enable saturation attacks.

Column Technology for Coordination between Crewed Aircraft and Unmanned Aerial Vehicles (UAV)

Currently, major countries are developing highly autonomous UAVs capable of concerted actions with crewed aircraft. It is believed that such technologies can greatly change future air battle. These autonomous UAVs divide roles with crewed aircraft, and are tasked with information gathering, reconnaissance and surveillance in a dangerous situation, combat and other tasks. They are expected to have advanced functions and capabilities, including planning tactics to be taken by each plane based on the battlefield situation and proposing them to the pilot of crewed aircraft to reduce the burden on human operators. Furthermore, the use of UAVs, which have the characteristics of both low costs and no risk to human life, can reduce the risk of missions.

The realization of these technologies requires flight control technology, airframe control technologies including swarm technology for flying in flocks, communication technology to connect UAVs with crewed aircraft, other UAVs, ground-based stations and others, and command and control technology to analyze collected information and develop, update and present tactics in a timely manner. UAVs intended for combat role, such as XQ-58A Valkyrie, which is being developed by the United States, require not only a high level of autonomy but also combat-capable aircraft performance. At the same time, such UAVs tasked for high-risk missions are expected to cost less than crewed aircraft. For this reason, 3D printer and other advanced technologies that can contribute to price reduction are also attracting attention.

In order to ensure Japan's technological superiority, the MOD published "R&D Vision on Future Unmanned Equipment: Focusing on Unmanned Aerial Vehicles" in 2016 and has been also continuing R&D on technologies for coordination between crewed aircraft and UAVs. The ministry believes that the research can contribute to: automation, labor saving and optimization of command and control; expansion of autonomy range of equipment, and; speeding up and high-precision of information collection and judgment.

See Part IV, Chapter 2, Section 2-2 (Defense Technology Strategy, etc.)

The United States is promoting research that plans to fly highly-automated UAVs alongside with crewed aircraft. As a part of the research, the Air Force Research Laboratory has been developing XQ-58A jointly with Kratos, a private company. The USAF expects to obtain game-changing fighting capability at low procurement and maintenance/operation costs. It is reported that the unit cost of the XQ-58A is several million dollars. Details of the performance of the airframe are not disclosed, but according to Kratos, XQ-58A is a long-range subsonic UAV with a total length of 9.4 meters and total width of 8.2 meters, and does not require any runway facilities. In September 2019, Russia announced that the country had implemented a cooperative flight test of S-70 heavy unmanned combat aerial vehicle "Okhotnik" and the 5th generation fighter Su-57 for approximately 30 minutes and disclosed a video of the flight test.

It is reported that in this test the S-70 flew to the front of the Su-57 and communicated the targeting information to its pilot by using mounted sensors. Australia is developing Boeing ATS (Air Teaming System) jointly with Boeing with a view to coordination with F-35A, E-7A early warning and control aircraft, and other crewed aircraft. As exemplified by the success in a swarm flight of 200 fixed wing UAVs in 2018, China is believed to be investing a significant amount of budget and excellent talents in the development of autonomous UAVs in an approach of Civil-Military Fusion while using the ones in the military sector. The military media expressed the effectiveness of the coordination of crewed aircraft and UAVs and suggested that this could change even the organizational configuration of militaries in the future.

XQ-58A Valkyrie

Description

In January 2020 a demo unit of XQ-58A long-range subsonic unmanned air vehicle carried out the fourth flight test.

[U.S. Air Force]

S-70 (Okhotnik)

Description

S-70 heavy unmanned combat aerial vehicle "Okhotnik" (above) flying together with the 5th generation fighter Su-57 (below)

[Ministry of Defense of Russia]

Boeing ATS

Description

Image of multiple Boeing ATSs flying together with E-7A early warning and control aircraft (right in the photo)

[Boeing]

electromagnetic railguns that use electromagnetic fields generated from electric energy to launch projectiles. U.S. Forces aim to develop a railgun with a range of approximately 370 km, about 10 times that of the existing 5-inch (127mm) guns. Unlike missiles, projectiles for electromagnetic railguns have no propulsion systems and are smaller, less costly, and can be stored in smaller space, which supposedly makes it possible for electromagnetic railguns to efficiently counter massive missile attacks, if they become available for intercepting missiles. The United States has offered plans to mount electromagnetic railguns on warships by 2025 and to use electromagnetic railguns not only for anti-ground and anti-ship attacks but also for anti-aircraft attacks. It is pointed out that China has tested its railguns at sea and would deploy them by 2025.

The United States, China, and Russia are developing high-power laser weapons to destroy targets with laser energy. Laser weapons are expected as an effective and less costly means to intercept attacks by multiple small unmanned vehicles and boats. Though it depends on the technological maturity, high-power laser weapons would excel in the speed of response compared with conventional weapons, and they can be free from ammunition constraints. Therefore, laser weapons, if strengthened enough to intercept missiles, would be able to efficiently counter massive missile attacks. The U.S. Air Force acquired an anti-UAV laser system in 2019. The United States has also successfully tested a 30 kW ship-based solid laser weapon system (LaWS) to counter small UAVs in the Persian Gulf since 2014. In a test conducted in the Pacific Ocean in 2020, the U.S. Navy successfully neutralized a flying unmanned vehicle with its shipboard high-powered laser demonstrator. The United States is planning to test mount an Aegis ship with the 100 kW HELIOS solid laser weapon system available for countering projectiles in 2020.

China exhibited the 30-100 kW "Silent Hunter" laser weapon system, capable of countering small UAVs, at the IDEX 2017 international defense exhibition. It is pointed out that China is developing higher-power laser weapon systems to attack satellites.

It is suggested that Russia has deployed the 10 kW Peresvet laser weapon system and been developing a megawatt-class chemical laser weapon system for attacking satellites.

High-power microwave technology can cause destruction and malfunction in the electronic systems responsible for such functions as intelligence-gathering and command & communications aboard UAVs, missiles and other airborne threats. The United States has acquired the Phaser high-power microwave system in 2019. In a U.S. Army drill, the system reportedly countered two to three UAVs at one time and 33 UAVs in total.

Test conducted in 2020
[U.S. Navy]

Phaser
【Raytheon Technologies Corporation】

(4) Quantum Technology

Quantum technology is positioned as an important technology which brings innovation to society by applying quantum mechanics that differs from familiar physics that people sense every day. For example, quantum cryptographic communications is a communication system which utilizes quantum cryptographic technology taking advantage of quantum characteristics, and reportedly cannot be deciphered by third parties. It is pointed out that quantum radar may be able to neutralize the stealth advantage of stealth aircraft by utilizing quantum characteristics. It is pointed out that quantum computers can compute problems in a short amount of time and with less electricity consumption than existing supercomputers and can also be applied to areas such as decryption.

China has developed the world's longest quantum cryptographic communications network, extending over approximately 3,000 km and connecting Beijing and Shanghai. In addition, in August 2016, China launched "Mozi," the world's first satellite to test quantum cryptographic communications. In January 2018, China said that it succeeded in using Mozi for long-distance quantum cryptographic communication between China and

Austria. Positioning quantum computer development as a key science and technology project, China has also invested approximately 7 billion yuan in a national laboratory for quantum information and technology and other facilities.

(5) Other Civilian Technologies Seen as Available for Defense Purposes

As civilian technological innovation has been remarkable, each major country has been trying to proactively utilize cutting-edge civilian technologies for defense purposes.

For example, fifth-generation (5G) mobile communication systems, subjected to commercial services in various countries from April 2019 as a new civilian mobile communication infrastructure, have been attracting attention. The 5G systems achieve far faster speed, less delays, larger capacity and more simultaneous connections than the previous 4G systems. Compared to 4G systems, 5G technology allows for providing services with better quality (high speed, low latency, high capacity, high number of simultaneous connections, and high reliability) despite complicated data processing, by combining advanced information communications technologies, including directional antennas to communicate in higher frequency bands, data processing quality-based segregation and decentralization in the cloud space, and data processing control using AI. The U.S. Defense Innovation Board (DIB) has evaluated 5G as a promising technology that can improve real-time information sharing, communications across military service branches, geographic divergence, and territories, and enhance the ability to connect multiple systems to a broader network.[1]

Addictive manufacturing technology as typified by three-dimensional printing can produce goods that are too complex to be produced conventionally, at a much lower cost. Given this, 3D printer technology can bring revolutionary changes in logistics, such as not depending on the stock when procuring parts, and nations point out the military use of the technology. For example, the U.S. Army named 3D printer technology as one of the top 10 technologies regarding science and technology development on its website in December 2019, noting that the technology could trigger a real logistics revolution by making the transportation of spare goods unnecessary. In February 2019, Finland, France, Germany, the Netherlands, Poland, Sweden, and Norway launched a four-year joint project to study potential applications of 3D printer technology. The Australian Navy is considering using 3D printers for producing parts for patrol boats. In India, state-run and private companies agreed in January 2020 to cooperate in a 3D printer project for armed forces.

2 Trends Concerning Defense Technological and Industrial Bases

In recent years, the sophistication of military science and technology, and the greater complexity of equipment have caused a steep rise in equipment development and production costs and have raised unit prices for equipment procurement, while Western countries in particular have continued to face difficulties in increasing defense budgets significantly. Under these circumstances, many countries are taking on a variety of initiatives in order to maintain and enhance their national defense technological and industrial bases.

Western countries have set a target to increase competitiveness through the realignment of their defense industry, in light of the aforementioned situation related to national defense budgets. The United States has experienced repeated mergers and integrations among domestic corporations, while Europe has experienced cross-border mergers and integrations of the defense industry, especially in Germany, France, the United Kingdom, and Italy. In response to the escalation of development and production costs, Western countries are promoting joint development and production of equipment and technological cooperation among their allies and partners. This move aims for (1) sharing development and production costs, (2) expanding demand in all countries participating in joint development and production, (3) mutual complement of technologies, and (4) raising domestic technology levels by obtaining state-of-the-art technology.

For example, the joint development and production of the F-35 fighter jet led by the United States is the largest joint program. At present, there is anticipated demand for more than 3,300 aircraft.[2] This project will have impacts on the defense technological and industrial bases of the countries involved, through the operation, sustainment and maintenance stages

1 According to the U.S. DIB (April 2019)

2 There are nine countries involved in the joint development and production of the F-35 fighter jets: Australia, Canada, Denmark, Italy, the Netherlands, Norway, Turkey, the United Kingdom, and the United States. The other countries acquiring them are Israel, the ROK, Belgium, Poland and Japan, whose defense technological and industrial base is involved in their production and maintenance. However, after Turkey purchased Russian S-400 missile systems, the United States decided in July 2019 to initiate the process to formally remove Turkey from the joint program.

Fig. I-3-1-1 Top Ranking Countries in Major Conventional Arms Export [2015-2019]

	Country or region	Shares in the total global exports of defense equipment (%) 2015-2019	Comparison with 2010-2014 export value (%)
1	United States	36	+23
2	Russia	21	−18
3	France	8	+72
4	Germany	6	+17
5	China	6	+6
6	United Kingdom	4	−15
7	Spain	3	+13
8	Israel	3	+77
9	Italy	2	-17
10	Republic of Korea	2	+143

(Note) Created based on "SIPRI Arms Transfers Database." Only the top 10 countries by export value for 2015 to 2019 are indicated (figures are rounded to unit).

Fig. I -3-1-2 Trends in Import Value of Major Conventional Arms in Asia and Oceania [2015-2019]

	Country or region	Import value (100 million US dollars) 2015-2019	Comparison with 2010-2014 import value (%)
1	India	134.12	-32
2	Australia	71.33	+40
3	China	63.00	+3
4	Republic of Korea	50.04	+3
5	Pakistan	38.30	−39
6	Viet Nam	32.12	-9
7	Japan	25.74	+72
8	Indonesia	25.53	−5
9	Singapore	24.11	-29
10	Thailand	17.41	67

(Note) Created based on "SIPRI Arms Transfers Database." Only the top 10 countries by import value for 2015 to 2019 are indicated.

of the aircraft. The European Union (EU) has created the European Defence Fund (EDF)[3] to provide funding for joint research and development by the EU member states in order to promote their cooperation in developing and acquiring defense equipment and facilitate the efficient production of state-of-the-art and interoperable equipment.

There is an increasing number of cases where governments provide funding for national defense-related research and development conducted by the private sector. In the United States, for example, approximately US$3.556 billion in research and development funding was requested for FY2020 for DARPA, whose mission is to make investments in breakthrough technologies that will contribute to national security. The U.S. defense authority has long provided substantial funding for the research conducted by companies and universities. In some other countries, such as the United Kingdom and Australia, responding to the recent utilization of dual-use technologies in defense equipment development, the governments have launched initiatives to provide funding for private sector research and development on innovative technologies in order to acquire advanced civilian technologies.[4]

Countries have exported equipment overseas since the Cold War era, and still today, many countries are taking measures to promote exports. While the United States, Russia, European countries and China have remained as leading defense equipment exporters, countries such as the Republic of Korea (ROK) and Turkey have been expanding exports of affordable equipment, which is an outcome of their success in developing the equipment manufacturing bases, together with their history of importing equipment in the past and improvement of capabilities in science and technology.

Defense equipment imports by Asian and Oceanian countries have continued an uptrend in recent years, seemingly against the background of economic growth in the region as well as the expansion of the influence of China, the existence of territorial disputes, and responses to the military buildup in neighboring countries.

Some of defense equipment importing countries adopt offset policies[5] in order to keep a good balance between improving defense capabilities through imports and developing domestic defense technological and industrial bases by requesting domestic companies' participation in parts production and others as conditions for procuring equipment and services from abroad.

See Fig. I-3-1-1 (Top Ranking Countries in Major Conventional Arms Export [2015-2019]);
Fig. I -3-1-2 (Trends in Import Value of Major Conventional Arms in Asia and Oceania [2015-2019])

3 The EDF was founded in June 2017.

4 In 2016, the United Kingdom launched the Defence and Security Accelerator (DASA) to build an innovation network of government, private sector and academics and created a fund for innovative research. In the same year, Australia established a Next Generation Technologies Fund for emerging technologies as well as a fund for innovative technology development.

5 Offsets in defense trade are defined as encompassing a range of industrial and commercial benefits, such as co-production, licensed production, subcontracting, technology transfer, and assistance in purchase and payment, according to "Offsets in Defense Trade Twenty-First Study" by the U.S. Department of Commerce Bureau of Industry and Security.