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. The military sphere is no exception. Major countries place emphasis on developing weapons utilizing cutting-edge technologies, such as unmanned technology (e.g., drones),[1] autonomous technology leveraging artificial intelligence (AI), big data analysis,[2] and hypersonic technology.[3] Recently, reports have been published of successful tests and planned deployment of electromagnetic railguns[4] and high-power laser weapons[5] that are expected to provide more effective firepower than existing weapons, such as artillery, in terms of cost per firing, range, precision, promptness, and other aspects. Further technological innovation is expected to dramatically change battle scenes in the future.

2 High-tech Weapon Development Trends

(1) AI Autonomous Drones

The United States, China and Russia are developing autonomous drones equipped with AI. Given that AI-equipped drones have the potential to conduct flexible operations with AI recognizing adversary actions and battle condition changes, they are expected to exert a great influence on the military sphere.

The U.S. Defense Advanced Research Projects Agency (DARPA) is developing AI-equipped unmanned aerial vehicles (UAVs), including small UAVs that are air-launched, recovered and reused for swarm flights for intelligence, surveillance, and reconnaissance (ISR) missions,[6] as well as drone ships[7] for finding submarines. The U.S. Air Force is developing autonomous UAVs to support manned aircraft. In addition, in "2018 DoD Artificial Intelligence (AI) Strategy" released in February 2019, the DoD indicates that it will articulate its vision and guiding principles for using AI in a lawful and ethical manner.

The Chinese government released "Next Generation Artificial Intelligence Development Plan" in 2017, expressing its intention to become a global AI innovation center by 2030.[8] In June 2017, China Electronics Technology Group Corporation displayed a swarm flight of 119 fixed-wing UAVs equipped with AI. In May 2018, it successfully performed a swarm flight of 200 drones, demonstrating its advanced technology to allow numerous UAVs to fly while keeping a distance from each other. The Caihong-7 (CH-7), of which a prototype was exhibited at the Airshow China

1 Drones developed for military use include unmanned aerial vehicle (UAV), unmanned ground vehicle (UGV), and unmanned maritime vehicle (UMV) (UMVs may be classified into unmanned surface vehicles [USV] and unmanned underwater vehicle [UUV]).

2 In the "Third Offset Strategy," the United States has given the example of "deep-learning machine" technology using AI, which can analyze big data for indications and warning of cyber attacks.

3 For example, in the United States, Defense Advanced Research Projects Agency (DARPA) and the Air Force are engaged in joint research and development of the Hypersonic Air-breathing Weapon Concept (HAWC), aiming to apply the technology to hypersonic missiles, etc. in the future. Unlike cruise missiles that use jet engines to fly at subsonic speed, HAWC uses the technology of the scramjet engine, which enables hypersonic flight by taking in air at hypersonic speed and burning it without reducing the speed to below the speed of sound.

4 The electromagnetic railgun is a weapon that shoots projectiles by using the magnetic field generated from electric energy instead of gunpowder. The U.S. Forces are developing a railgun with a range of about 370 km, or about ten times that of the existing 5-inch (127 mm) gun. A single railgun shot reportedly costs 1/20th to 1/60th the price of a missile.

5 The U.S. Forces are developing laser weapons to strengthen low-altitude air defense capabilities against small boats and drones. Tests have been carried out to shoot down unmanned aircraft by using lasers in efforts to put the technology to practical use.

6 DARPA has announced plans to carry out flight tests in 2019 with the aim of testing the airborne launch and recovery of unmanned aircraft.

7 The Anti-Submarine Warfare Continuous Trail Unmanned Vessel (ACTUV) ("Sea Hunter") is capable of navigating several thousand kilometers for months without crewmembers on board through constant remote supervision by humans. In August 2016, this vessel allegedly completed its initial sea trials.

8 "Next Generation Artificial Intelligence Development Plan" sets goals of AI development by 2030 according to three steps. At the first step by 2020, "overall AI technology and application reach a globally advanced level"; at the second step by 2025, "some technologies and applications achieve a world-leading level"; and at the third step by 2030, "AI theory, technology and application reach a globally advanced level. China becomes a global AI innovation center."

international aerospace show in November 2018, is described as a fighter UAV that can perform advanced autonomous flights.[9]

Russia is developing a nuclear-powered underwater drone (named Poseidon) that can carry nuclear warheads, claiming that the drone has been tested successfully. In addition, a test flight of Okhotnik, an unmanned stealth fighter jet pointed out to be operated in coordination with manned aircraft, was conducted in August 2019. The Russian government has published a video of the flight.

Some have argued that drones with AI and autonomous functions 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 element, and international law.

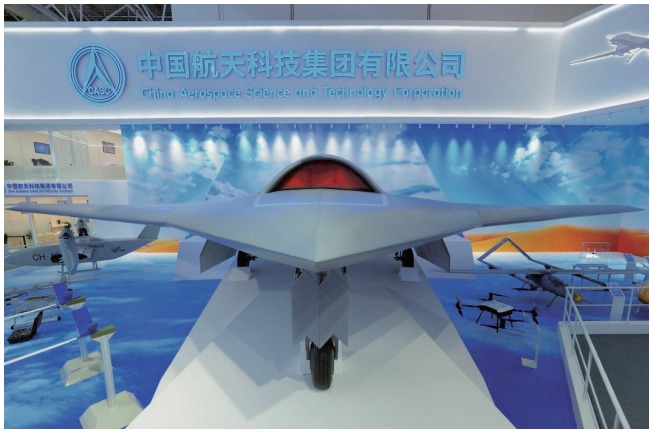
Meanwhile, some people indicate that UAVs would not become as autonomous as human pilots until 2040.

(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 and 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 flight by utilizing incoming supersonic airflow to be maintained at the speed of sound or faster for combustion. It is suggested that hypersonic weapons would fly in lower orbits longer and be more maneuverable than ballistic missiles, being more difficult to detect or intercept.

The United States in its Missile Defense Review (MDR) (January 2019) indicates that Russia and China are developing advanced hypersonic missile capabilities that challenge existing missile defense systems.[10]

China has been developing multiple models of HGVs since 2012.[11] It is suggested that these HGVs would be deployed as early as 2020. On the other hand, Russia has claimed that it has developed an HGV called "Avangard"[12] and would deploy it within 2019. It has asserted that existing and future missile defense networks would fail to counter the Avangard. Russia is also developing a hypersonic cruise missile called "Zircon."[13]



Caihong-7, a prototype of which was exhibited at the Airshow China international aerospace show in 2018 [Jane's by IHS Markit]

CG of an HGV contracted by the U.S. Air Force [Jane's by IHS Markit]

(3) Electromagnetic Railgun

The United States and China are developing electromagnetic railguns that use electromagnetic fields generated from electric energy to launch projectiles. Unlike missiles, projectiles for electromagnetic railguns have no propulsion systems and are smaller, less costly and stored in smaller space. If electromagnetic railguns are made available for intercepting missiles, they may reportedly be able to efficiently counter numerous missiles.

The United States achieved a range of 185 km and a projectile impact speed of Mach 5 in tests in December 2010, planning to mount electromagnetic railguns on warships by 2025. It plans to use electromagnetic railguns not only for anti-ground and anti-ship attacks but also for anti-aircraft attacks.

9 It is pointed out that China plans to introduce not only drones but also a decision-making support system using artificial intelligence for supporting nuclear-powered submarine commanders.

10 The United States is developing an HGV called Advanced Hypersonic Weapon (AHW). In October 2017, it conducted an improved version's flight test in which the AHW flew about 3,700 km and hit a target.

11 Multiple flight tests have been conducted.

12 In a flight test conducted in December 2018, the Avangard flew over an estimated distance of 6,000 km and hit a target.

13 In the State of the Union address in February 2019, the Zircon was described as capable of flying at the maximum speed of about Mach 9 to hit a maritime or ground target more than 1,000 km away.

It is pointed out that China has tested its railguns at sea and would deploy them by 2025.

(4) High-power Laser Weapons

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 drones and boats.[14] Given the speed of light and the absence of constraints on ammunition, laser weapons, if strengthened enough to intercept missiles, could be able to efficiently counter massive missile attacks.

The United States has tested a 30 kW ship-based solid laser weapon system (LaWS) to counter small unmanned aerial vehicles (UAVs) in the Persian Gulf since 2014, planning to test mount an Aegis ship with the 100 kW HELIOS solid laser weapon system available for countering projectiles by 2020. It has also indicated the effectiveness of using a high-power laser weapon system to intercept a ballistic missile in the boost phase,[15] assessing technology for mounting drones with laser weapon systems.

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 is test deploying the 10 kW Peresvet laser weapon system[16] and developing a megawatt-class chemical laser weapon system for attacking satellites.

(5) Quantum Science & Technology

Quantum science and technology is positioned as an important technology to innovate society by applying quantum mechanics that differs from familiar physics that people sense every day. For example, quantum cryptographic communications use quantum cryptographic technology taking advantage of quantum characteristics for cryptographic communications that cannot be deciphered by third parties. It is pointed out that quantum radar may be able to neutralize the stealth of stealth aircraft by utilizing quantum characteristics.

China developed the approximately 2,000 km-long, world's longest quantum cryptographic communications network between 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 Australia. In the United States, DARPA is conducting research and development on quantum cryptographic communications and quantum laser technologies. Going forward, new technologies such as quantum cryptography communications could potentially be applied to the military field in various countries.

2 Trends Concerning Defense Technological and Industrial Bases

In recent years, Western countries in particular have continued to face difficulties in increasing defense budgets significantly. On the other hand, the sophistication of military science and technology, and the greater complexity of equipment have escalated development and production costs and have raised unit prices for equipment procurement. 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 realignment of their defense industry, based on 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 and technological cooperation related to equipment among their allies and partners. This move aims for (1) splitting 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 the latest 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 3,200 aircraft.[17] This project will have impacts

14 For terrorists' use of UAVs, see Part I, Chapter 3, Section 7

15 It is pointed out that a ballistic missile in the boost phase before taking anti-interception measures could be the most vulnerable to interception.

16 In the State of the Union address in February 2019, it is explained that the Peresvet laser weapon system would enter full operation in late 2019.

17 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, and Japan, whose defense technological and industrial bases 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.

on the defense technological and industrial bases of the countries involved, through the operation, sustainment and maintenance stages of the aircraft. The European Union (EU) has created the European Defence Fund (EDF)[18] 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 are providing funding for national defense-related research and development conducted by the private sector. In the United States, for example, approximately US$3.44 billion in research and development funding was requested for FY 2019 for DARPA,[19] 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 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.[20]

Countries have exported equipment overseas since the Cold War era, and still today, many countries are taking measures to promote exports. While Western countries exporting advanced equipment have remained as leading defense equipment exporters, countries such as China, the Republic of Korea (ROK), and Turkey have been expanding exports of affordable equipment along with the development of the manufacturing bases required for production of equipment with the past imports of equipment and the improvement of capabilities in science and technology.

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

Some of defense equipment importing countries adopt offset policies[21] 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 as a condition for procuring equipment and services from abroad.

See Fig. I-3-1-1 (Top Ranking Countries in Major Conventional Arms Export (2014-2018));
Fig. I -3-1-2 (Trends in Import Value of Major Conventional Arms in the Asia and Oceania (2014-2018))

Fig. I-3-1-1 Top Ranking Countries in Major Conventional Arms Export (2014 - 2018)

	Country / Region	Global shares in defense equipment export (%), 2014 – 2018	Comparison with 2009 – 2013 export values (%)
1	United States	36	+29
2	Russia	21	-17
3	France	7	+43
4	Germany	6	+13
5	China	5	+3
6	United Kingdom	4	+6
7	Spain	3	+20
8	Israel	3	+60
9	Italy	2	-7
10	Netherlands	2	+16

Note: Created based on "SIPRI Arms Transfers Database." The top 10 countries by export value between 2014 – 2018 are listed (decimals are rounded).

Fig. I-3-1-2 Trends in Import Value of Major Conventional Arms in the Asia-Pacific Region (2014-2018)

	Country / Region	Import values ($ as billion), 2014 – 2018	Comparison with 2009–2013 import values (%)
1	India	138.76	-24
2	Australia	67.93	+37
3	China	61.03	-7
4	Republic of Korea	44.92	-9
5	Viet Nam	42.40	+78
6	Pakistan	40.12	-39
7	Indonesia	35.90	+86
8	Taiwan	24.26	+83
9	Japan	21.00	+15
10	Singapore	18.57	-63

Note: Created based on "SIPRI Arms Transfers Database."
The top 10 countries by import value between 2014 - 2018 are listed.

18 The EDF was founded in June 2017 to reduce duplication in the member states' spending on defense research, development, and acquisition and to achieve efficiency while their defense budgets are reduced. It plans to finance 90 million euros for joint defense research in three years from 2017 and invest 500 million euros for joint development in 2019 and 2020. The funding from 2021 is anticipated to be scaled up.

19 DARPA is a Department of Defense (DoD) agency in which approximately 100 program managers, who are hired for three to five years, oversee around 250 research and development programs. It does not have its own research and development facilities.

20 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 to provide about 800 million pounds for innovative research over 10 years. In the same year, Australia established a Next Generation Technologies Fund (about Australian $730 million over a decade) for emerging technologies as well as a fund (about Australian $640 million over a decade) for innovative technology development.

21 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.