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MEDIUM- TO LONG-TERM

TECHNOLOGY OUTLOOK

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Acquisition, Technology & Logistics Agency

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I. Introduction

The medium- to long-term defense technology outlook (DTO) is intended to clarify items such as estimates related to the development of future technologies, in light of domestic and international technology trends, as well as the direction of medium- to long-term (about 20 years) scientific and technological efforts at the Acquisition, Technology & Logistics Agency (ATLA) that was set up in October 2015.

This document is being published to secure the technical superiority of our country and to indicate the direction for delivering advanced defense equipment through efficient and effective research and development (R&D).

The medium- to long-term technology outlook is used and referred to as a document that points out the direction of technology research activities promoted by the former Technical Research and Development Institute (TRDI) of the Ministry of Defense (MOD) since the first outlook report was published by the TRDI in FY2006. However, in the approximately nine years since, remarkable progress has occurred in science and technology. Some technologies have progressed as, or further than, had been predicted in the report, while others have not advanced as expected.

In addition, reflecting on our country's national security policy, it is clear that there has been an increase in the need to advance science and technology in order to accommodate expertise that greatly affects the defense of our country. This is evident in such areas as new unmanned equipment, and outer space and cyberspace endeavors.

A parallel shift in emphasis has been reflected in the *National Defense Program Guidelines* (NDPG), which changed from the desire to "build a dynamic defense force" in FY2010 to that for "building an integrated and agile defense force" in FY2013. The *mid-term defense program* defined in 2013, furthermore, requires that effective, efficient R&D be conducted for equipment development, even under severe fiscal conditions.

Against this background, ATLA is tasked with delivering defense equipment though effective, efficient R&D. To this end, ATLA reviewed the FY2006 medium- to long-term technology outlook and, based on the latest science and technology developments, and those areas of expertise required according to our country's security policy, decided to create a new FY 2016 medium- to long-term DTO for FY2016.

This document is intended to be a guidebook to the effective, efficient delivery of advanced defense equipment by ATLA to secure our country's technical superiority in the future. We hope it will assist those outside the agency to understand the efforts it is undertaking.

II. Medium- to Long-term DTO: Objectives, Background, Roles

1. Purpose and Placement

The DTO, as part of the MOD's technology strategy (DTS), is intended to indicate the direction of efforts being made in the area of advanced equipment and the securing of Japan's technical superiority. As a rule, the commissioner of ATLA publishes it at five-yearly intervals.[1]

First we give a brief description of the DTS. For ATLA, defense technology ensures the technical superiority of our country, and illustrates the basic direction of various measures that should be strategically tackled to carry out the effective, efficient development of advanced equipment.

Documents associated with the DTS include an R&D vision summarizing the concept underlying the future acquisition of equipment; a roadmap indicating the R&D required for this to be realized; and the FY2016 DTO. Also included are policies and doctrines that are timely and appropriately planned to handle a variety of issues (e.g., policies related to domestic and international exchanges, intellectual property management, technology management).

The DTS is being openly published, since sharing it outside the immediately relevant ministries is expected to be of benefit, even for the DTO. This should promote the incorporation of state-of-the-art consumer technology (dual-use technology utilization) and the development of technologies outside of the ministries with a view to them being applied to defense equipment.

Based on the objective above and to secure the technical superiority of our country, it is expected that certain equipment will be developed over the coming 20 or so years. This will depend on plans included in the DTO; research and analysis related to domestic and international trends in science and technology (defense technology research and analysis); overseas equipment analyses (defense technology trend estimates[2]) by ATLA used for reference; and estimates of the progress of technology, where application is possible to equipment that can be expected to be developed in the coming 20 years or so. Thus, the DTO indicates advanced technology fields that can be game

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[1] Through the provisions of Article 8 of the directive (2015 Ministry of Defense Directive No. 37) related to Research and development of equipment, etc., along with contributing to the building of technology strategy to ensure our country's technological superiority in the future, clarify the estimate related to other technology and the direction of medium to long term science and technology field initiatives in order to carry out the creation of advanced equipment, etc.

[2] Through the provisions of Article 6 of the Directive related to research and development of equipment, etc., the Secretary will create defense technology research analysis that researches and analyzes foreign and domestic trends related to science and technology for equipment, etc. in order to contribute to the creation of the Article 8 medium to long term technology outlook.

changers, and capabilities that we should emphasize and aim to acquire.

2. DTO Formulation

There are three main factors on the basis of which this medium- to long-term outlook has been formulated. First, the changes related to Japan’s national security environment; second, the rapid progress in science and technology, and the rapid changes in Japan’s strategic approach; third, the setting up of ATLA to effectively and efficiently address defense equipment-related policy issues.

2.1 Changes in Japan’s National Security Environment

In addition to neighboring countries modernizing and strengthening their military capabilities, there remain certain unpredictable and uncertain elements, including territorial issues. Long-term changes/increases tend to occur in so-called grey zone[3] situations, while the security environment surrounding our country has become increasingly complex, involving the need to respond to space- and cyberspace-related issues, and requiring effective deterrence to deal with various situations.

At the same time, not only is the birthrate in our country declining, but also the economic environment remains harsh. Thus, those requiring budgetary allocations to promote R&D are faced with having to curtail expenses.

To quickly and seamlessly respond to a variety of situations, it is thus most effective to take an integrated approach to the Ground, Maritime and Air Self-Defense Forces capabilities. Since FY2013, force operation has been unified as the Joint Staff of Japan, while work continues to develop a Dynamic Joint Defense Force.

2.2 Changes in the Science and Technology Environment

Japan has made remarkable progress in science and technology over the past few years. In particular,

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[3] For so-called grey zone situations, although those are briefly expressed in a wide range of circumstances that aren't emergencies, even during absolute peacetime, for example, circumstances that may happen, such as the following, are considered. (Source: FY 2015 edition Defense White Paper)
A conflict of claims for issues such as economic interests, including territory, sovereignty and the ocean between parties such as nations,

With respect to such conflict, at least one of the parties appeals the claims are requests of their own country or accepts those of the other party, and regardless of only action such as diplomatic negotiations between the parties,
At least one of the parties contemplates extortion of appeals and acceptance of such claims and requests. By using an able organization in a range that will not be hit by an armed attack, this refers to frequently indicating presence, an attempt to change some current situation or an attempt to change the status quo itself.

there has been significant growth in such areas as unmanned equipment technology, ICT,[4] and material technology. These consumer technologies are having a significant effect on our defense capability, especially in terms of acquisition and R&D related to defense equipment. In addition, the fact that the international community considers Japan's advanced technical capabilities valuable resources serves as a stimulus in defense-related and other fields.

Given this environment, the strengthening of technical capabilities is incorporated into the strategic approach of our national strategy. Under the command of our NSC,[5] which functions as a command center, the government strategically and systematically carries out the nation's security policy, to which end the National Security Strategy was determined on December 17, 2013. As is indicated by the "strengthening of technical capabilities," stated in the policy document, we will continue to conduct research in areas of science and technology, as well as defense equipment development, bearing in mind national security when promoting measures to strengthen technical capabilities on which are based our economic strength and defense capabilities. By mobilizing the power of industry, academia and the government, we are committed to effective utilization of their developments even in national security fields.

In addition, in the "5th Science and Technology Basic Plan"—approved by the Cabinet on January 22, 2016, based on the Basic Law on Science and Technology (1995 Law No. 130) "responding to the challenges of national security" is regarded as one of the most important policy issues. In this document, "Based on the national security strategy, we will promote research and development of necessary technology, including construction of appropriate international cooperation systems under the relevant ministries and collaboration of industry, academia and government towards the challenges of national security," as well as topics related to science and national security are mentioned for the first time. This reflects the belief that our country's advanced technical capabilities are important in ensuring the safety and national security of Japan and its people. The plan also points out that, "There is a lot of ambiguity in science and technology, and the results of research and development for a certain purpose can be utilized for other purposes." In implementation of the "Science and technology innovation policy," it has been stated that there is a need to achieve "promotion while organically cooperating with other important policies such as for the economy, national security, diplomacy and education."

In this way, our country's advanced technical capabilities lead to the creation of newly added economic and social value, while making it extremely important to build a defense force through defense sector innovation. This will contribute to the improvement of deterrence, because it can be

[4] Information and Communications Technology

[5] National Security Council

built with speed (actualized force). In order to ensure such technical capabilities, we will encourage the promotion of greater, even dual-use technology and strengthen our technical capabilities.

2.3 Acquisition, Technology & Logistics Agency Establishment

Based on the changes in the national security and the science and technology environments described so far, in order to effectively and efficiently respond to a variety of challenges related to defense equipment ministration corresponding to various situations, the MOD consolidated an integrated a series of work—covering from defense equipment R&D to production, equipment maintenance and disposal in equipment acquisition-related departments under the jurisdiction of the internal bureau of the MOD, acquisition division of the staff office, technical R&D institute, and the Equipment Procurement and Construction Office—and established ATLA as an external bureau on October 1, 2015.

ATLA has a basic policy with four items: 1. Keep technical capabilities one-step ahead, to ensure technical superiority; 2. Ensure optimal acquisition through project management; 3. Promote international equipment cooperation; and 4. Strengthen defense production and technology bases.

With regard to the policy in 1., in order to ensure technical superiority in the future and not only meet the needs of research and development related to the operation of the Self-Defense Forces, we will make an effort to use applicable consumer technology (dual-use technology) in future defense equipment, through technical cooperation with foreign countries such as the United States, by strengthening cooperation with institutions, such as universities and the national R&D agency, implementation of foreign and domestic comparative analysis of technical capabilities, and by having an ongoing grasp of trends and collecting information related to science and technology.

We will foresee, thereby, important technical fields and their development, and it will be necessary to effectively and efficiently promote strategic research and development based on a medium- to long-term view. In addition, through the utilization of an Innovative Science & Technology Initiative for Security (competitive funding system), along with discovering innovative and original technology in the future, we aim for growth from the seminal stage. It is important to effectively and efficiently utilize R&D for the creation of the defense equipment with excellent results.

3. Medium- to Long-Term DTO Roles

Evaluation of the FY2006 Medium- to Long-term DTO shows that the recent medium- to long-term DTO, for which it serves as the basis, functions effectively. This section considers the role of the FY16 DTO.

It should be noted that the medium- to long-term DTO does not indicate decisions on defense force equipment, and that there are items that are to be determined by the MOD in the future related to specific R&D projects.

3.1 FY2006 Medium- to Long-term DTO Analysis

The first Medium- to Long-term DTO, compiled FY2006, indicated the direction that technological research promoted by the former TRDI would take. Since then, it has been used in the planning and implementation phases of technology-related research.

In the nine years since, the progress of science and technology has been phenomenal, with some technologies having advanced as expected, and others better than expected. Among the "technologies with future potential" indicated in the FY2006 DTO, some—such as power amplification, power storage technologies such as batteries and hybrid power technology have, as of FY2015, made huge progress compared with FY2006. They have become national, not just defense sector strengths.

There are also technologies that have not developed as was had expected. So, for example, digital watermarking technology has practical applications and product creation as a consumer application has progressed. Its use in defense applications, however, has been slower than expected. Superconductive motors also have reached a practical level, but there has not been major progress in the study of superconductive electromagnetic propulsion technology.

As mentioned above, not all of the fields progressed as expected in the outlook, but steady technological progress has been seen in multiple technology fields in which progress was foreseen in the FY06 DTO.

3.2 FY2016 Medium- to Long-term DTO Roles

Based on the evaluation of the FY2006 medium to long-term technology outlook, the following roles are kept in mind, and the FY2016 Medium to Long Term Technology Outlook (FY16 DTO) will be created.

The FY2016 DTO targets a period, some 20 years hence, with a view to creating items such as superior equipment to counter enemies in future combat situations and to secure Japan's technical superiority in the future. The FY2016 DTO contains such guidelines as medium- to long-term planning initiatives related to science and technology-related R&D, as well as equipment implemented by ATLA. It aims to:

1. Promote the delivery of efficient and effective equipment by indicating initiatives related to R&D of ATLA equipment and science and technology.
2. Propose that each branch of the Self-Defense Forces introduce items already at the

commercialization stage, formulate R&D plans, R&D estimation requests[6] for equipment, as well as use the creation of R&D requests[7] for equipment, etc. This should be done while sharing information related to the latest equipment technology obtained from technology seeds that lead to future innovation within each branch of the Self-Defense Forces.

3. Be a guide for the development of seminal technical fields as well as a guideline, for the formulation of a R&D vision that summarizes a necessary research and development roadmap and concept of items such as equipment with an eye to the future

In other words, by using the FY2016 DTO as a guidebook, and by carrying out the creation of equipment, etc. and activities related to the acquisition of technology in the ATLA, we will pursue items 1. to 3. described above, while securing the technical superiority of our country. This will lead to us achieving goals, such as the creation of items such as advanced equipment.

In addition, through the publication of the FY2016 DTO, effects can be expected such as promotion of incorporation of excellent and advanced consumer technology (dual-use technology utilization) and promotion of the development of technology (open innovation) for application to equipment, through concerned parties outside of the ministry. One of the important roles of the FY2016 DTO is said to be the fact that these results can be obtained.

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[6] Related to research and development of equipment, etc. through the provisions of Article 9 of the Directive, with a research and development outlook request for equipment, etc. regarding the need for research and development through ATLA, this aims to clarify requirement in each branch of the Self-Defense Forces, and it will be created for each party such as the Chief of Staff so as to contribute to the creation, etc. of equipment, etc. research and development outlook requests.

[7] Related to research and development of equipment, etc. through the provisions of Article 11 of the Directive, if equipment, etc. research and development is requested to the Secretary, until the required time during the period from the previous year's budget request to when research and development is completed, a research and development request for equipment, etc. will be created, and this will be reported to the Minister of Defense along with submitting the report to the Secretary.

III. Direction of Efforts

In this chapter, the basic idea for derivations is described first, followed by an overview of the derivation procedure, including the relevant functions/capabilities that are to be emphasized and, finally, the items and technology fields that should be stressed as directions in the future.

1. Basic ideas for derivations

Defense technology, in addition to having a role in the improvement of the defense capabilities of our country, is an important element of national security, acting as a deterrent and an element of bargaining power. We are working on strategic aspects of R&D in various technologies, both to gain technical capabilities that may provide us with better equipment than available in other countries, and to improve the performance of, and add functionality to, equipment for other countries.

Given that these defense technologies reflect the direction our efforts are to take, it is important that we undertake the basics that underpin our country's national security, namely, the need for proactive contributions to peace given the surrounding national security environment; progress in science and technology; and improved defense equipment R&D efficiency.

The basic idea governing how the direction of efforts is to be derived, as expressed in the FY2016 DTO, is described below.

(1) Examination range

a Examination premise

The FY2016 DTO contains a study based on technological possibilities and such basic principles of our country's defense as having an exclusively defense-oriented policy and the three non-nuclear principles.

b Technology fields of interest

The *strategy on defense production and technology bases*, formulated by the MOD in June 2016, encapsulates the goals and significance of maintaining and strengthening the foundations of our nation's defense as follows.

1. Ensure national security independence;
2. Help improve deterrence, while maintaining and improving bargaining power; and
3. Contribute to the sophistication of domestic industry through advanced technology.

The FY2016 DTO covers not only technical fields on which the former TRDI had worked, but also those technical fields with which it had worked to achieve, for example, the goals above. (An overview of the DTO is given in Chapter V.)

We will consider future operational concepts and propose new technical possibilities based on technology trends, particularly when it comes to the acquisition of defense equipment that requires both performance based on operational concepts and the need to ensure national security independence.

It is also extremely important that ATLA proceed with R&D, while proactively incorporating advanced technology, as it responds to requests expected from branches of the Self-Defense Forces.

(2) Examination of emphasized items

In order to cope with new situations, such as dealing with international terrorist organizations, and involvement in new areas of strategy, such as space and cyberspace, other countries have been active in their R&D efforts reflecting such technology trends as smart technology,[8] network technology,[9] and unmanned technology. The emphasis has been on precision guidance technology, unmanned technology, information gathering technology, stealth technology, nanotechnology, and cyber-attack response technology. Besides the successes reported in connection with experiments involving high-energy laser weapons and laser guns, the development of hypersonic glide vehicles (HGV[10]) has also been reported.

Even in Japan, as we see in the "*National Defense Program Guidelines: for FY 2014 and beyond*" (NDPG)—National Security Council and Cabinet decision, December 17, 2013—responding to new space-related and other contingencies, such as large-scale disasters and outer space- and cyberspace-related threats has become a major issue. This is also the case for responding to ballistic missile attacks, assaults on isolated islands, and intrusions into Japan's airspace and the seas in its vicinity.

In addition, defense in the future will require that emphasis be placed on the total optimization of functions and capabilities, and that responses be flexible, effective, seamless and situationally appropriate, as demanded by the consolidated undertaking of a variety of activities. Therefore, while giving due consideration to setting up a wide range of logistic support infrastructure, we are ready to build an integrated, Dynamic Joint Defense Force that emphasizes readiness, sustainability, toughness and interoperability, in terms of hardware and software, and that is supported by advanced, as well as communications, command, and control technology.

The direction of efforts to be undertaken should thus be considered focusing on the following.

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[8] Information gathering making full use of information and communication technology, and having advanced control and processing capability with computers.

[9] Multiple and heterogeneous equipment systems are organically linked via a data link, etc.

[10] Hypersonic glide vehicle: In 2014 there were indications of a flight test of the "WU-14 (DF-ZF)," a hypersonic glide vehicle that is difficult to intercept by missile and supersonic flights by China. (2015 defense white Paper).

- Technology that realizes “functions and capabilities that should be emphasized,”[11] according to the NDPG, to build an integrated Dynamic Joint Defense Force Technology to realize advanced defense equipment that, based on military technology trends, may be superior in warfare; and
- Technology that has synergy with defense and civilian technologies.

(3) Items to clarify in the FY2016 DTO

As can be seen from the items above, the FY2016 DTO indicates that we are working on technology elements and fields that will become important in the future and will reveal the direction of efforts in relevant technologies and “future equipment technology.”

Further, while we are currently at the basic research stage, applications to equipment will reveal “technology with future potential” that can be dramatically improve the performance of existing equipment.

2. Derivation Procedure

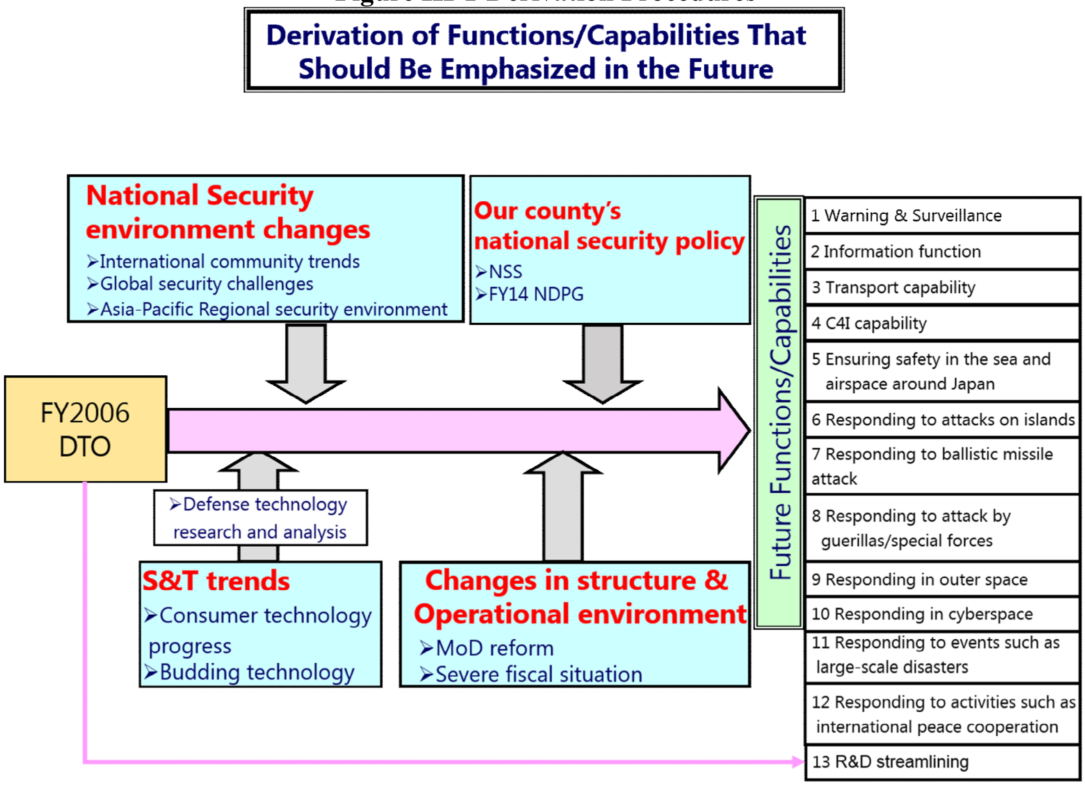
In the FY2016 DTO, in order to gauge the direction efforts should take in the future, and in reference to “defense technology research and analysis,” we will organize new fields that should be incorporated and continue with fields that should be tackled while taking into account trends in science and technology, such as the seeds of emerging technology and trends in defense and civilian technology.

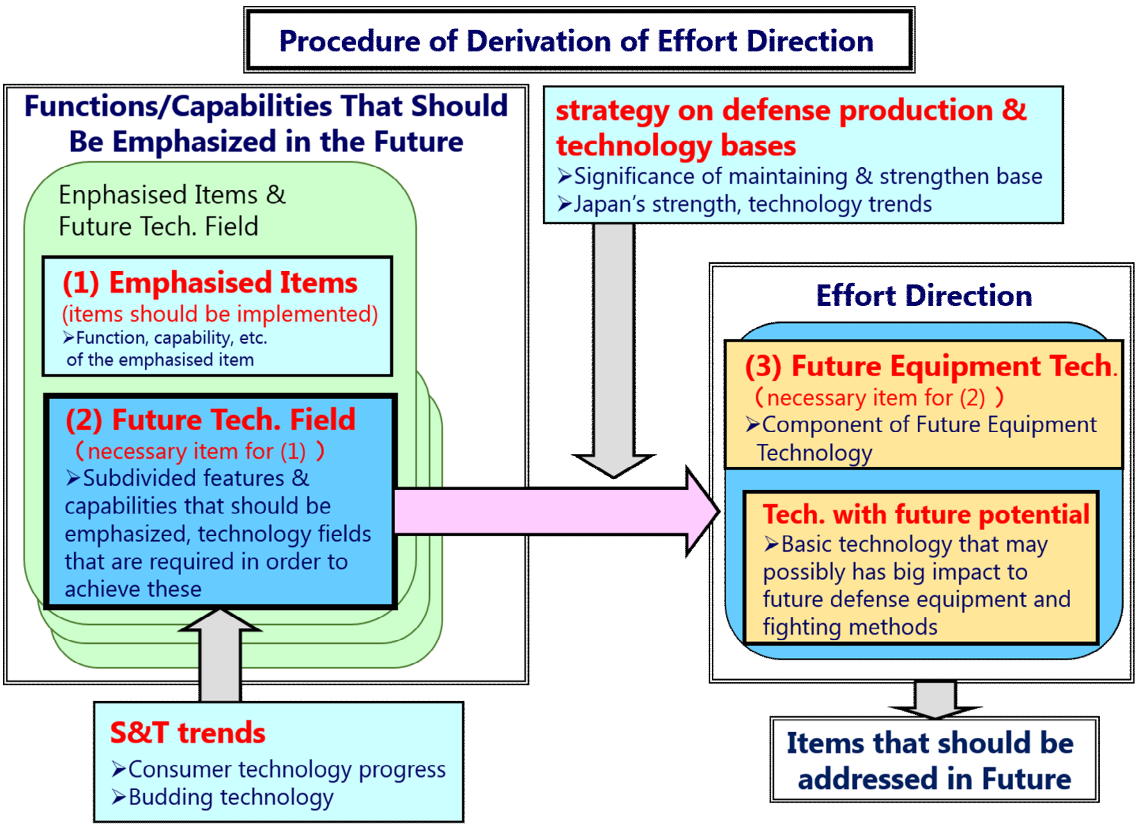
In addition, we will draw from documents such as the *National Security Strategy, NDPG* and *strategy on defense production and technology bases*, the “Functions/capabilities that should be emphasized in the future,” and pinpoint the research needed to deal with future contingencies.

Then, for each of those “Functions/capabilities that should be emphasized in the future,” we will organize one item to be carried out—all arranged according to characteristics and details of required functions—as well as two “future technology fields” for each item, revealed as science and technology fields in order to be able to exert each of the functions, etc. Then, considering the feasibility through advanced technology that is examined emphasis items, based on these results, we will derive the technology elements estimated in each future technology field 3 "future equipment technology" (technology for realizing 2) and "technology with future potential". The Derivation Procedure is shown in Fig. III-1

[11] Table III-2 Reference to the relationship with NDPG

Figure III-1 Derivation Procedures





3. Functions/Capabilities That Should Be Emphasized in the Future

The FY2006 DTO outlines fields that are expected to be needed in the future, bearing in mind trends in science and technology as well as changes in the security environment, defense power roles defined in the NDPG formulated in December 2004, together with responses that have been effective in various indicated situations, and innovation that is presented as RMA information,[12] as a result of which an R&D vision has been formulated, as have responses to battle centered on networks.[13] Attention is focused on the following.

1. Role of requested defense power, especially to cope with various situations;
2. Ability to implement new roles; fighting focused on networking using enhanced information functions and integrated operational capability; and
3. R&D efforts in response to diverse defense equipment, etc. in the future.

The functions/capabilities to be emphasized in the future, based on changes in the security environment, science and technology trends, the structure and/or the operational environment, and Japan's security situation are in Table III-1; relations with the NDPG are in Table III-2.

Table III-1 Functions/Capabilities for Future Emphasis

1	Warning and surveillance capability
2 3 4 5	Information function Transport capability Command and control/information communication capabilities Ensure safety in the sea airspace vicinity of our country[14]
6	Responding to attacks on the islands
7	Responding to a ballistic missile attack
8 9	Responding to an attack by guerillas/special forces Response in outer space[15]
10 11	Response in cyberspace Responding to events such as large-scale disasters
12	Responding such activities as international peace cooperation events
13	Research and development streamlining

[12] Revolution in military affairs.

[13] Network-centric warfare.

[14] The part on functions/capabilities, etc. that should be emphasized are not in the NDPG, but are given as such because "emphasis efforts" (responding to events: such as large-scale disasters; those in outer space and cyberspace; ballistic missile attacks; and attacks on islands.

[15] In the NDPG "Functions/capability, etc. that should be emphasized," "Responding in outer space and cyberspace" are mentioned but, since the science and technology field where study is stressed is different, it is a separate item.

Table III-2 Reference to Relationship with NDPG

			NDPG Items	Response Relationship*
NDPG	Defense power role	Effective deterrence, handling situations	Maintenance of safety in Japan's airspace and surrounding sea	**5**
			Response to attacks on islands	**6**
			Response to a ballistic missile attacks (Response to guerilla/special forces attacks[16])	**7** **8**
			Response to attacks from outer space, cyberspace	**9, 10**
			Response to events such as large-scale disasters	**11**
	Emphasis items for Self-Defense Forces system development	Basic policy	Maintenance of maritime superiority, air superiority	**5, 6**
			Expeditionary capabilities	**3, 6**
		Functions and/or capabilities that ought to be stressed	Warning, surveillance capabilities	**1**
			Information functions	**2**
			Transportation capability	**3**
			Command, control, communication capabilities	**4**
			Response to attacks on islands	**6**
			Response to ballistic missile attacks	**7**
			Response to attacks from outer space, cyberspace	**9, 10**
			Response to events such as large-scale disasters	**11**
			Response to international peace cooperation activities, etc.	**12**

* The numbers in the right-hand column correspond to those in the left-hand column of Table III-1.

[16] In "IV 1 (1) c Responding to a ballistic missile attack," it mentions, "If an attack by guerillas/special forces has occurred concurrently." In addition, responding to a ballistic missile attack is listed in "Functions/capability, etc. that should be emphasized in the future," since the science and technology field where study is emphasized is different.

4. Items Emphasized and Future Technology Fields

Those functions/capabilities that should be emphasized in the future and were mentioned in Section 3 are organized according to characteristics deemed necessary to show the relevant functions and/or capabilities. The necessary detailed functions necessary to realize the emphasis items are given, and the "future technology fields" are shown as science and technology fields required for each of the detailed functions.

(1) Warning and surveillance capabilities

a Emphasized items

In order to ensure effective deterrence in the face of a variety of situations with respect to target sources, such as aircraft and naval vessels at sea in vicinity of our country, information collection functions are required. It is, moreover, important to realize the utilization of unmanned equipment, as well as to implement information gathering, surveillance, and reconnaissance (ISR)[17] activities (ongoing monitoring) over a wide area.

b Future technology fields

Information collection

The functions related to the collection of required information comprise both an important technical field, which includes unmanned aircraft by which are acquired a variety of data, including images, together with equipment technology fields for information collection/detection and type identification.

For this reason, technology related to radio wave/light wave sensor system technology, including utilization in outer space and sonar, as well as technology related to the long-term operation of artificial satellites, UGS[18], UAS[19], and UMS[20] are important.

(2) Information functions

a Emphasized items

It is necessary to strengthen the system for analyzing and sharing collected information, together with the associated information collection/processing system, as well as to quickly respond to and perceiving signs of various situations at an early stage. In addition to achieving the expansion of always ongoing monitoring functions through unmanned aircraft and satellites, as well as collection

[17] Intelligence, surveillance, and reconnaissance activities.

[18] Unmanned ground systems.

[19] Unmanned aerial systems.

[20] Unmanned marine systems.

functions related to public information, radio wave information, and image information, it is also important to achieve the integrated strengthening of geospatial information utilizing a high level of sophistication by fusing various pieces of information in images/on the map. For this to be realized, information collection, situation judgment, and information sharing functions are necessary.

b Future technology fields

Information collection

Depending on the nature of the information, the field that constitutes required information collection functions is important, with technical fields such as information collection/detection equipment technology fields and images, etc. mounted on them that acquire various kinds of data such as that on unmanned equipment and satellites. Also important, in order to strengthen the information collection system, are technology related to radio wave/light wave sensor technology and sonar, as well as technology related to artificial satellites, UGS, UAS and UMS.

Operational decision support

Command and control equipment technology fields are required for operational decision support functions. For sharing information fused with enemy information obtained in advance, or information obtained from multiple sensors in order to strengthen information processing and information analysis systems, it is important to have cooperative arms control technology to enable cooperative engagement with forces such as ships, aircraft, and ground forces, as well as technology to support decision making by parties such as commanders.

Information sharing

Communication equipment technology fields are required for information sharing functions. For underwater technology that enables communication that is difficult underwater by radio waves and transmittable data links over a wide area and with high speed even for information with a lot of data capability, such as video, and in order to transmit and rapidly share between each branch of the Self-Defense Forces information over a wide area items such as enemy information acquired in advance or information from various sensors, it is important to have command and communication technology that responds to various activity areas, such as line of sight communication and satellite communication, to enable information to be shared in remote areas. In addition, security technology to achieve secure and efficient data sharing, even between different domains, is also important.

(3) Transportation capabilities

a Emphasized items

Along with strengthening the required marine transportation force and air transportation force, in order to flexibly deploy and move required troops to ensure rapid and large-scale transportation and deployment capability to activity areas, there is a need to take into account responses to transportation that is required on a small scale and which is adapted to the mission of troops in the front lines, and land (amphibious)/sea and air mobility functions.

b Future technology fields

Land (amphibious)/maritime and air mobility

Technology fields required for land (amphibious)/maritime and air mobility functions are platform technology fields, detection equipment technology fields, CBRNE[21] defense equipment technology fields and logistical support equipment technology fields.

In order to have rapid deployment of troops by air or by sea in response to various situations, the capability building of large aircraft, etc., VTOL[22] machine research converted to long range and high-speed ship-system configuration technology, and amphibious technology are important.

At that time, it is important to have an embarking/disembarking system that can be handle vehicle, cargo, etc. autonomously without resorting to support facilities such as ports or airports, and technology for an airdrop system that can drop supplies, etc. with a high degree of accuracy in a target area, as well as wharf technology that can quickly secure port functions.

In addition, in order to safely and securely transport by land Japanese nationals living abroad, and ensure the safety of personnel traveling by isolating them from the outside by using ballistic/blast technology, power technology, remote control/follow-up traveling technology, and research in CBRNE response technology, it is important to have fast detection technology through X-rays that can be spotted at high speed in car bombs that cause enormous damage when a vehicle passes through or faces dangerous goods on a transportation route. Technology related to airdrop systems, UGS, UAS and UMS, is important in order to transport items such as arms, ammunition, medicine, rations directly to troops in places such as front lines. Other supplies are also important for power technology that can transport with fewer people and low fuel consumption, as well as autonomous technology.

(4) Command and control/information communication capabilities

a Emphasized items

For command and control/information communication capabilities that are a prerequisite for the support of integrated operation, we aim to enhance/strengthen base communication networks in the

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[21] Chemical, biological, radiological, nuclear, and explosive.

[22] Vertical take-off and landing.

islands in particular, and data link functions between each branch of the Self-Defense Forces. For this, electronic attack defense is particularly important in responding to EMP[23] attacks, etc. in order to compensate for the vulnerability of electronic devices that make up command and control and communication systems, and information sharing functions, operational decision support functions, as well as electronic attack defense functions.

b Future technology fields

Information sharing

Communication equipment technology fields are required for operational decision support functions. While in order to ensure data links between each branch of the Self-Defense Forces and command and control/information communication, highly reliable high speed and high capability command and control communication equipment is required, also important is having network technology implementing a communication system comprising a high-capability outdoor digital communication network and broadband high-power device, software radio, non-line of sight communication and satellite communication.

Operational decision support

Technology fields that are required for operational decision support functions are command and control equipment technology fields. In order to strengthen command and control capability in consolidated operation, having technology to support decision making by the commander, etc. by fusing enemy information, etc. obtained in advance or information obtained from multiple sensors is important.

Electronic attack defense

In order to complement the vulnerability of command and control/information communication capabilities, access to electronic pulse protection technology—not only technology related to information communication systems—with high survivability against cyber attacks and EA[24] is important.

(5) Ensuring safety in the sea and airspace around Japan

a Emphasized items

In order to realize a defense buildup to maintain our maritime superiority and air superiority, which

[23] Electromagnetic pulse: A powerful burst caused by an event such as a high-altitude nuclear explosion.

[24] Electronic attack.

are prerequisites for realizing effective deterrence and responding to various situations, it is important to conduct R&D that ensures flexible deployment capabilities, set up of a wide range of logistic support infrastructure, and respond to overflights and surveillance from in the sea and air in the vicinity of our country,[25] which would include responding to submerged submarines as well as to those located in territorial waters,[26] and a response to armed spy ships.

To this end, information collection functions, air/ocean/water mobility functions, operational decision support/information sharing functions, electronic countermeasure functions and precision attack functions are necessary.

b Future technology fields

Information collection

Depending on the nature of the information, in order to secure the reliable maintenance of maritime superiority and air superiority, it is important to have access to information collection/detection equipment technology fields and unmanned equipment technology fields to mount this. To realize this, it is important to have technology related to radio waves/light wave sensor system technology and sonar as well as technology related to UAS and UMS.

Land (amphibious)/maritime and air mobility

From now on, if radio wave stealth[27] aircraft are deployed by the enemy, an earlier advance by us into the relevant airspace will be required, given that our ground warning radar will have less time for detection. We are, thus, in need of technology related to excellent, high-speed aircraft.

In addition, there is a need for technology such as UMS that allows always ongoing autonomous monitoring, excellent submarines that has low signature and long underwater endurance, and ships that can respond to a variety of missions, as well as damage control research in ship integrated electric propulsion system applications.

Further, UUV[28] technology is important for the exertion of surface striking force from underwater, where it is difficult for the enemy to locate targets.

Operational decision support/information sharing

For future integrated operations, it will be necessary to have command and control communication

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[25] According to “4 (1) Warning and surveillance capability.”

[26] The white paper, *Defense of Japan 2007*.

[27] Stealth: The technology improves viability and mission achievement rate by decreasing the chance of detection by an opponent. The technology includes radio waves/light waves, visible and infrared light, and acoustic stealth.

[28] Unmanned underwater vehicle.

equipment covering the mainland and surrounding sea and airspace. Thus, we will need excellent network technology, with resistance to interference and interception, that can carry out smooth communication between each branch of the Self-Defense Forces with a large amount of information transmitted at high speed in the command and control/communication equipment technology field.

Electronic countermeasures

In order to improve our remainder rate, as far as possible we should deal with enemy forces from a behavioral perspective. It is important to inhibit enemy network construction while maintaining our network intact, to secure our superiority in fighting focused on networks.

To this end, it is important that enemy communication operations and defense equipment sensors, etc. are caused to deteriorate, and that electronic jamming technology through radio waves/light waves be utilized in response to enemy activity.

Precision attacks

In order to effectively respond to various situations, it is necessary to carry out precision attacks, for which precision-attack weapons are effective. In terms of precision, the guided missile system is able to ensure expected capability and is feasible for use in the future.

Broadly speaking, there are two types of technology related to discrete components: one relates to the missile system itself. These technologies will allow future missile systems to be realized, enabling our response in various situations to be effective. In the case of the former technology, such functions as firepower allotment, engagement control, and threat information collection have been more broadly optimized than are conventional missile systems.

As missile system technology for improving the degree of freedom of operation, accessory system conversion technology, and system configuration technology—by adding a degree of freedom that can change the system configuration in a timely and appropriate manner—comes online, it will become increasingly necessary to have a range of different missile systems, and a variety of anti-ship and anti-aircraft defense equipment to achieve connection with maritime, aviation command and control, and other systems.

In terms of anti-ship and anti-aircraft defense equipment, missile technology will be necessary. Specifically, it will become necessary to have a high-capability propulsion system that enables attacks from outside the range of counterattack threats against low RCS[29] threat guidance control technology, as well as guided missile element technology such as heat-resistant airframe technology and seeker technology that responds to high-speed conversion through this.

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[29] Radar cross-section.

Other types of technology needed cover a broad scope, from multiple functions and high precision through more intelligent and guided ammunition shells in order to promote the capability building of artillery and rockets. There is also a need to research directional energy technology, EMP bombs, and ammunition technology that makes possible ammunition with a high level of safety that can deal with a wide range of targets.

At the same time, in order to handle parallel increases in power consumption and apparatus performance, it is important to develop technology handling power storage in time-varying demand for power and sufficient power supply capability.

In addition, in order to respond to saturation attacks of enemy anti-ship missiles on our ships and to prevent an enemy invasion by sea, it will be necessary to have anti-aircraft weapons technology such as electromagnetic acceleration guns firing high speed bullets with a high rate of fire and directed energy technology, range-stretching technology through electromagnetic acceleration guns and rocket-assisted technology, in order to carry out attacks from as great a distance as possible. Furthermore, developing anti-ship warhead technology such as sea buster warheads and high-density multi-EFP[30] will be important to more reliably defeat enemy ships.

Because AWACS,[31] which has become the center of enemy strategy and aerial refueling aircraft to increase flying time are generally considered to be located in the rear of the theater of operations, technology related to long-range surface-to-air missiles to eliminate these important objectives is important.

(6) Responding to attacks on islands

a Emphasized items

We will strengthen our ability to respond to attacks through aircraft, ships and missiles in order to maintain our sea supremacy and air superiority. In addition, there is a need to land on, recapture, and secure the islands through full-scale amphibious operation capability along with improving performance in order to safely and promptly transport personnel, equipment, and materials when the islands are invaded, and to strengthen offshore integration capability in order to prevent their invasion. It also is necessary to improve the capability of Self-Defense Forces troops if they are to respond quickly and continuously when a situation occurs in the area southwest of Japan. We will carry our necessary R&D to make this possible.

For us to realize the above, we will need to apply information collection, land (amphibious) and surface/subsurface /air mobility, information sharing, electronic countermeasure, precision

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[30] Explosively formed projectile.

[31] Airborne warning and control systems.

attack, protection, individual combat and logistics support functions.

b Future technology fields

Information collection

In order to quickly and proactively collect information on the islands and surrounding areas, information collection/detection equipment and unmanned equipment is required, while it is also important to have access to sensor technology and technology related to UGS, UAS, and UMS related to mounting it.

Land (amphibious) mobility

A variety of technology is in important if one is to recapture islands that have been invaded by an enemy. For quick landings by sea, with force and involving many human resources to reclaim the islands, it is necessary to have excellent amphibious technology with the ability to pass a variety of obstacles, with high maneuvering capability on the water, from the reefs of the Ryukyu Islands to inland, excellent landing assist technology with high strength, strength against waves, and transportation properties to deal with obstacles installed on the islands by enemies, excellent obstacle processing technology to swiftly and accurately achieve land mobility and high speed water maneuverability, as well as stealth properties in order to insert special forces from a submarine.

There also is a need to ensure a safe route can be detected and processed through obstacles installed on the islands by the enemy, as well as swift, accurate and excellent water obstacle detection technology/water obstacle processing technology that will allow land maneuvers, while not overlooking the importance of high speed water maneuverability.

In addition, to lure or suddenly stop the enemy in combat, it is important to have, at a preparatory stage, excellent obstacle construction technology with speed and reliability on the islands and in the area around the islands in the situation preparation stage in order to create a favorable combat situation for us by increasing the opportunities to exhibit firepower.

Surface/subsurface/air mobility

To ensure maritime superiority and air superiority, fighter technology and ship technology with infrared stealth as well as radio waves, high mobility, and high speed are important. Further, through cloud shooting shared in missile fire control between formations or between fleets, there is a need to improve the hit rate and increase the number of shots fired.

The study of combat-type drones is important in order to counter the emergence of unmanned aircraft in other countries and parties with a numerical inferiority in manned aircraft. Along with combat-type drones using high agility flight and having formation retention capability and mobility equal to or higher than that of manned fighters, they form clouds in the network of manned fighters, and they function as sensor, shooter, and decoy. In addition, the standing time under enemy forces is shortened and, to increase survivability despite enemy threats and quickly insert force from the air, it is important to conduct research into excellent, high-speed aircraft, and develop technology related to airdrop systems.

Further, UUV technology is important to exert surface strike power from where it is difficult for the enemy to discover targets.

Information sharing

In order to share information for integrated operation in a remote location, command and control/communication equipment that is common (functional) between land, sea, and air troops is necessary. So, too, is network technology, where communication with remote locations at high speed and with high stability is possible, as well as multi-band communication technology that enables communication with remote locations and processes large amounts of information at high speed.

In order to realize cloud shooting in air mobility and cooperative engagement of consort ships in a fleet, it is important to have excellent bi-directional sensor network technology that resists interference and interception, and can transmit large amounts of information at high speed throughout the formation or fleet.

Electronic countermeasures

To improve our remainder rate, enemy forces should be dealt with from a behavioral perspective whenever possible. It also is important to inhibit enemy network construction, while maintaining our network in order to secure our superiority in fighting with a focus on networks. This will ensure the disruption of enemy communication operations, sensors such as those in enemy defense equipment, and our use of electronic jamming technology through radio waves/light waves.

Precision attacks

It is necessary to carry out precise attacks remotely, to effectively respond to a variety of situations on the islands. Here, precision attack weapons are effective. A representative example of a precision attack weapon is a guided missile system but, in order to realize future missile systems that can effectively respond to situations in the islands, broadly speaking, there are two types of technology related to discrete components, which form part of the missile system and the technology to support the system.

For the missile system, firepower allotment, engagement control, and threat information collection systems have been optimized with a width wider than that of conventional missile systems. It will thus be necessary to have missile system technology to improve the degree of operational freedom, accessory system conversion technology and system configuration technology with a degree of freedom that is able to change the system configuration in a timely and appropriate manner, and a range of different missile systems, as well as a variety of land, sea, and air defense equipment, and command and control systems for each branch of the Self-Defense Forces.

For the command and control systems, guided missile element technology is important. This includes warhead technology with a high-capability propulsion device that can respond widely in a necessary range and respond to a variety of goals and situations. It serves to realize attacks from a great distance and to provide missiles with high precision using, for example, seeker technology and terrain-position data matching technology for targets with a complex, diverse environment.

In addition, in order to effectively and efficiently destroy enemy landing forces and concentrate firepower as much as possible from a distance on enemy landing forces not only with guided missile systems, rocket-assisted technology that enables elimination through long-range precision firepower, artillery, and precision ammunition technology that can make an early attack from the site of a maritime maneuver with light amphibious armored vehicles, range extension technology with electromagnetic acceleration guns, directed energy technology with items such as lasers, it is necessary to have surface-to-air warhead technology through debris adjustment in order to deal with missile attacks cooperating with an enemy landing force, and fortification technology that improves survivability under enemy attack and increases the number of shooting opportunities.

Meanwhile, when inserting force from the sea, unmanned aircraft should be used to achieve a safe route and landing point with radar information; OTH[32] lines to share and detect aviation and ship threats to troops; shore obstacle processing technology to deal with water mines laid near the water's edge using shells detonated and used underwater at high speed (underwater ballistic missiles); as well as ground warhead technology for high-density, multi-EFP to defeat enemy troops at the landing point; and technology for EMP bullets to neutralize enemy electronic equipment.

Because AWACS have become the center of enemy strategy and aerial refueling aircraft to increase flying time, and are generally located in the rear of the theater of operations, it is important to have technology related to long-range, surface-to-air missiles to eliminate these objectives.

Protection

It protects us from precision attacks by enemy guided missiles, with technology such as active protection technology in order to improve war continuation ability, anti-aircraft cannon technology to down enemy guided missiles, directed energy technology, electromagnetic acceleration gun technology, as well as ballistic technology to localize strike damage.

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[32] Over the horizon.

Individual combat

Personnel must be protected if they are to work safely and have land combat capability in areas removed from Japan proper. Thus, most important are blast resistance technology, which reduces explosion-related damage to the neck and lower extremities of vehicle passengers, and bullet- and explosion-proof personal equipment system technology that reduces traumatic encephalopathy and blunt trauma.

It is also necessary to take into account power assist technology that can make personal equipment systems respond with speed and agility despite increased weight from increased baggage, as well as charging methods at the front, common-use batteries, lightweight conversion, and lower power use by a lot of battery-run defense equipment, such as radios, night vision equipment and data display terminals.

Also important is the adequate supply of goods to personnel, and technology related to UAS and UMS that allows personnel to transport goods by day or night, as well as technology related to the UGS that carry out reconnaissance prior to transportation of luggage or personnel.

Logistical support

In order to improve logistical support capabilities to allow battle to continue even when all logistical contact lines have been cut at times such as an invasion, it is important to have airdrop technology, that allows supplies to be dropped from the air, as well as wharf technology, to land supplies in an emergency even when a port has been destroyed.

(7) Responding to ballistic missile attack

a Emphasized items

The response time, in the event of a ballistic missile attack, is between a few minutes and several tens of minutes, spanning from launch to when the missile reaches its destination. The time required to respond by firing an intercepting missile is limited.

For this reason, there needs to be a rapid transfer and sharing of information obtained early regarding signs that a missile is to be fired, and information about the actual launch in the direction of our country of a missile such as image information obtained through artificial satellites. We will strengthen our ongoing ability not only to respond to such threats, but also to rapidly share early warning information during interception.

There is a clear need to focus on a number of aspects, including the complexity of deceptions such as decoys, the use of multiple warheads (MIRV[33]), mobile warheads (MaRV[34]) and, even more so, on ultra-high speed during reentry. In addition, flight control of an HGV, which uses boosters such as ballistic missiles, may be carried out over all phases. Unlike what happens in the case of ballistic missiles in ballistic flight after booster consumption, it is thought that HGV trajectory projection becomes difficult, so it may be more difficult to deal with than a ballistic missile. The HGV is currently under development, so future trends deserve watching.

For this to be realized, information collection functions, maritime mobility functions, operational decision support/information-sharing functions, and precision attack functions are needed.

b Future technology fields

Information collection

System technology including artificial satellites, high-altitude flight type UAS, and technology to mount radio wave/light wave sensors to these in order to collect early warning information, including detecting the firing of ballistic missiles and tracking in flight, are important. In addition, system technology that not only detects and tracks ballistic missiles and complex sensor technology that performs infrared sensor and radar information fusion, but which also has radar that can distinguish separated warhead sections, is important.

Maritime mobility

Important, too, are advanced ship technology with excellent seakeeping performance, high speed and survivability/radio wave and infrared stealth properties to quickly deploy to protection objectives as a launch, and control platform to intercept threats such as guided missiles.

Operational decision support/information sharing

In order to realize control and communication equipment to enable appropriate decisions to be made, necessary measures to be taken, and the rapid transfer and sharing of information, network technology in order to ensure interoperability with excellent high speed transmission as well as resistance against interference and interception are important. For the HGV in particular, technology for sharing the flight path in real time is important, since flight path prediction and bullet trajectory prediction is difficult.

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[33] Multiple independently targetable re-entry vehicles.

[34] Maneuverable re-entry vehicle.

Precision attacks

In order to intercept ballistic missiles, there is a need for intercept weapons to hit ballistic missiles, which are the target. For this reason, ballistic missile defense missiles with very high guidance accuracy are essential. In order to realize ballistic missile defense missiles, first of all, in order to hit very high-speed ballistic missiles with missiles, guided missile element technology such as high mobility and high response control technology that improves the ability necessary to hit the missile itself and high capability propulsion technology as well as heat resistant aircraft technology of items like multi-segment rocket motors where it is possible to optimize propulsion capability through a combination of propellants become the most important types of technology.

In addition, in order to expand the intercept range and effectively neutralize ballistic missiles, there is a need to establish control technology which does not depend on aerodynamics at the high altitude necessary, and that is effective to expand and intercept at high altitude in a wide area based on the assumption it is a conventional missile.

It is important also to conduct research on the response to the expected HGV orbit prediction, which is difficult, in order to not take a ballistic trajectory. There is a further need to increase interception chances in order to improve interception capability and, for that purpose, there is a need to quickly obtain ballistic missile observation information such as that on a guided missile system.

So, while enabling further improvement of connecting capability and realizing connection of anti-aircraft command and control systems as well as a variety of anti-aircraft defense equipment, there is a need to establish and research missile system technology that can be used in one of the interception systems of multiple types of shells beyond the differences in altitude response, and old and new differences and ranges of various ballistic missile defense missiles.

Along with thus securing a wide protection range, energy technology and electromagnetic acceleration gun technology through lasers, etc. can allow reliable interception through a large number of simultaneous responses with a shortened reaction time and saturation attacks.

(8) Responding to attack by guerillas/special forces

a Emphasized items

When searching for and destroying invading troops and protecting critical facilities such as nuclear power plants, it is important to conduct research on technology related to equipment with protection handling a variety of attack means, including CBRNE weapons.

To realize this, land/water/air mobility functions, information collection functions, information sharing functions, precision attack capability and human damage confinement functions, individual combat functions, and CBRNE response functions are required.

b Future technology fields

Land/maritime/air mobility

There is a need for UGS, UAS and UMS that can respond to the enemy through always ongoing autonomous monitoring and tracking, while reducing the burden on personnel and confining human suffering. In addition, particularly important is the UUS,[35] which responds to infiltration from underwater where discovery seems to be delayed. For platforms used for unattended equipment, it is necessary to suppress factors such as size, sound, magnetic files, and vibration to ensure the equipment is difficult to detect by a variety of sensors, as well as guerrilla and Special Forces.

Information collection

Research of detection technology related to CBRNE threats in order to confine and prevent damage is important. Also important are, technology related to light wave sensors capable of obtaining high quality images from a distance even at night when it is difficult to obtain information, and special radar technology to detect enemies hidden in obstacles such as foliage.

In addition, also valid are systems, such as multiple arrangements of unmanned equipment that can do always ongoing monitoring (UGS, UAS, UMS and fixed underwater sensor networks), and the tracking of unmanned equipment after the discovery of the invasion of guerrillas and Special Forces and that always provide information. Therefore, in order to monitor and track without the enemy noticing, it is important to have technology related to UGS, UAS, and UMS, as well as fixed underwater sensor networks that are less likely to be detected and are smaller and quieter.

Information sharing

Network technology for command and control/communication equipment is important to implement advanced command and control and information sharing, when signaling is required through a general response to guerrillas and Special Forces.

Precision attacks/casualty mitigation

In order to effectively deal with guerrillas and Special Forces in areas around critical facilities, it is necessary to have relatively small precision attack weapons that can accurately attack threats and not add damage to facilities.

To realize such equipment, guided missile element technology is important. This includes warhead technology that can respond to various situations, and high-capability propulsion devices of multi-segment rocket motors, that can optimize propulsion capability, as well as guidance and

[35] Unmanned underwater system.

control technology and seeker technology that can be miniaturized.

In addition, ammunition technology that realizes ammunition which has a high safety potential and responds to many targets, lightweight rockets that can be installed in light vehicles that have multiple functions, are high-precision, and have little firing recoil, though more intelligent, guided, and with higher ballisticity are also considered important. Furthermore, it is also important to conduct research into unmanned turret technology, so that our troops are not vulnerable to attacks from guerrilla and Special Forces. Meanwhile, from the viewpoint of civilian and allied casualty mitigation during an attack, the use of non-lethal equipment is under consideration, and related research is also important.

This can also be said for UGS technologies that have these functions and deal with such threats. In order to avoid human suffering caused by CBRNE threats, UGS technologies that have these functions and deal with such threats are also important.

Individual combat

In the response aspect for urban areas, etc., personal equipment system technology is important in order to realize overall improvement of combat capability by having more information/higher functionality as well as improved performance related to bulletproofing/explosion proofing of personnel, considering the occurrence of injuries such as blunt trauma when in the way of ballistics.

It is also necessary to take into account power assist technology that can make personal equipment systems able to act quickly and with agility while responding to increased weight through increased baggage, as well as charging methods in the front, common use batteries, lightweight conversion, and lower power consumption from a large number of pieces of equipment that run on batteries, such as radios, night vision equipment, and data display terminals.

There is also a need for research into electromagnetic attack technology, as well as radio wave detection identification technology that is effective for electronic attacks against enemy troops with advanced electronic information technology. Also important is technology related to UGS that carries out reconnaissance prior to personnel and luggage transportation.

CBRNE defense technology

It is necessary to research CBRNE protection/detection/decontamination technology from operations under a CBRNE threat environment. In addition, also important are unmanned equipment that can be input without considering casualty mitigation is effective and, for this reason, even while emphasizing acquisition properties which have a highly self-sufficient capability to enable initial response in relation to various types of work and information collection (disposal in one mission is also taken into account), technology related to UGS, UAS, and UMS that has radiation protection functions required for the performance of duties is also important.

(9) Responding in outer space

a Emphasized items

In addition to strengthening command and control/information communication capabilities and information gathering capabilities utilizing a variety of artificial satellites, satellite survivability is increased through initiatives such as space situational awareness (SSA).[36] There is a need to carry out R&D to contribute to the effective and stable use of outer space, so that it can exert continuous capability even when various types of situations have occurred. At that time, with the defense and consumer barriers being low as a characteristic of space development and utilization, we will promote efficient R&D while also promoting participation in initiatives in collaboration with related organizations, and the entire government.

This will be done given that state-of-the-art technology related to outer space has been accumulated in the United States and related agencies such as JAXA in Japan. In addition, among the technologies that we have cultivated in areas other than outer space, we will use areas that have a possible application to the outer space sector.

Information collection functions, information sharing functions and stable usage functions are necessary to realize this.

b Future technology fields

Information collection

Utilizing artificial satellites that can access any part of the planet is an important way to reinforce information-gathering capabilities, and research of satellite-mounted sensor technology aimed at observing the surface situation from outer space is important. At such a time, from the perspective of enhancing the mission effects, the incorporation of altitude control technology that has been implemented in consumer products, as well as utilizing a variety of advanced bands and concerned parties, etc., control technology and artificial satellite agility improvement technology is considered. Furthermore, it is important to consider even air-launched technology using Self-Defense Forces aircraft that can significantly reduce the cost of a satellite launch in order to improve readiness capability. In addition, research to improve durability contributing to reduction of running cost and survivability against light wave interference through lasers or jamming to allow for continuous information collection is also important.

Information sharing

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[36] Space situational awareness.

The use of satellite communication in order to enable the sharing of information in a remote location is important, and research of conductor communication technology corresponding to an activity area is important.

Stable utilization

Space situational awareness (SSA) is an important initiative in order to prevent situations such as those that inhibit the stable use of outer space and, along with promoting information collection for future trends, research in technology such as sensor technology to monitor space objects and data analysis technology are important.

(10) Responding in cyberspace

a Emphasized items

Cyber attacks are daily becoming more sophisticated and complex, and not only is information leaked through targeted attacks, but unauthorized parts and programs are intentionally mixed during the period from product manufacturing to delivery, while new and unprecedented cyber attacks that use artificial intelligence technology are emerging.

Important information is leaked through illegal parts and programs that are pre-embedded, and there are concerns about threats that have deprived system control rights. In order to counter these new threats, it is necessary to conduct research in technology to automatically derive—through the application of effective solutions, such as artificial intelligence technology—that which can investigate unknown vulnerabilities of our system, as well as that whereby one can detect illegal parts and programs, the development of human resources equipped with the expertise to cope with cyber attacks, and technology to build a cyber exercise environment to improve the ability of personnel to respond.

In addition, even in cases where damage occurs due to cyber attacks, to ensure mission capability and maintain stable and effective use of systems and networks, it is necessary to construct an environment that can be promptly recovered in an operable condition and flexibly respond to any impact caused to the system through a cyber attack.

Furthermore, various items that have communication functions are present through IoT conversion,[37] and this includes not only information and communication equipment, such as computers in cyberspace. To ensure the stable use of cyberspace, cyber security technology responding to new threats and inherent risks arising from IoT conversion, becomes important. For example, cyber attack cases such as those aimed at closed systems not connected to the Internet,

[37] Internet of Things

such as plant control systems and cyber attack cases responding to the control systems of automobiles or airplanes have been reported in recent years. While the MOD and the Self-Defense Forces conduct risk analysis of cyber attack threats to our equipment, it is necessary to take appropriate security measures to prevent the outflow of important technical information concerning internal equipment.

Within the large amount of information that has been published on the Internet, there are signs of cyber attacks, etc. against the MOD and the Self-Defense Forces. Thus, since it is possible that this information includes useful snippets on our country's security, it is necessary to collect and analyze public information floating in cyberspace.

b Future technology fields

Cyber attack response

To ensure the MOD's and Self-Defense Forces' equipment, systems, and networks always have sufficient security against cyber attacks, it is important to have the technology to build a combat exercise environment where verification of cyber attack response ability is possible and technology to investigate unknown vulnerabilities is available.

In addition, even if damage or failure has occurred through cyber attacks resulting in physical destruction, it is necessary to carry out research on technology to ensure mission capability to continue operations and be ready in advance to prevent a cyber attack targeting equipment systems.

Furthermore, effective response solutions during the occurrence of cyber attacks are automatically derived depending on the application of artificial intelligence technology, while research is conducted on automatic response technology, which enables rapid response to cyber attacks, as well as on technology to prevent cyber attacks by illegal and embedded unauthorized programs and hardware with which there has been intentional tampering.

In addition, for these technologies, since attack methods change from year to year, it is important to conduct research to respond immediately even to new attacks.

Information leakage prevention

Based on the three principles of defense equipment relocation, when the overseas transfer of equipment is expanded, to prevent the outflow of important technical information, research on the black box conversion of important information on internal equipment is important.

Open-source information collection/analysis

From a large amount of information located on the Internet, it is important to research technology to effectively collect and analyze information that contributes to our country's security.

(11) Responding to events such as large-scale disasters

a Emphasized items

In a variety of disasters, including nuclear and large-scale disasters, such as massive earthquakes that are expected in the future, it is vitally important for the response to be quick to the need for rescue operations, emergency restoration, etc., and the collection of damage information from sea and air utilizing aircraft, etc. in the early stages of a disaster. Also, research on using unmanned equipment for CBRNE response and information collection, etc. is needed for secondary disaster prevention.

To realize this, land, sea and air mobility functions, information collection functions, information sharing functions, CBRNE response functions and human suffering confinement functions are necessary.

b Future technology fields

Land/maritime/air mobility

In order to transport required disaster relief troops and supplies to disaster areas that are difficult to approach from the ground, it is important to conduct research on ship system technology, bridge technology to rebuild collapsed bridges on an emergency basis, and VTOL machines that travel at high speed and have a long cruising distance. At such times, there is a need to equip autonomous embarking/disembarking systems that are capable of handling items such as vehicles and cargo without having to resort to such support facilities as ports or airports.

To rescue victims that have been left behind in disaster areas where more damage is expected, it is necessary to undertake research on VTOL machines powered by rescue equipment such as hoists. Here, efficient air rescue work is needed using a machine that, with a fuselage that is as small as possible with a feasible downwash (downdraft), can be used day or night over extended periods.

In addition, having technology related to airdrop systems, UGS, UAS, and UMS, etc. is important, in order to directly transport high-priority supply items such as blankets, medicine, and rations to isolated disaster areas. Further, it is also conceivable that UGS, UAS, and UMS may be used to transport injured people, while it is also important to have technology that adds functions and performance to quickly and safely carry supplies to the injured.

Information collection

Also important is radar-related technology, which detects survivors under rubble in order to rescue buried survivors as soon as possible. This can also be said for platforms to search for victims and confirm the status of damage, as well as robots and unmanned equipment.

Thus, for technology related to radio wave/light wave sensor system technology, including utilization in outer space, and sonar, as well as technology related to artificial satellites, UGS, UAS and UMS are important. Further, technology for systems that search for victims and which integrate information obtained from each piece of unmanned equipment, while simultaneously using such equipment as UAS, UGS/UAS, and UMS is also important.

Information sharing

Even in situations where there are restrictions, such as on private communication infrastructure, it is important to have information communication equipment for sharing a variety of information among groups, such as local troops, police, fire departments, and governments.

To realize this, it is important to have technology for an open-air digital communication network and an excellent satellite communication network with interoperability and survivability.

CBRNE defense technology, casualty mitigation

To properly respond to nuclear hazards and volcano eruption-related disasters, CBRNE defense technology equipment is needed, making CBRNE protection/detection/decontamination technology important.

While there is a need for technology related to unmanned equipment that can do a variety of work to mitigate casualties, as well as personal equipment system technology, it is also important that technology related to medicine and telemedicine allows injured people to be treated quickly.

(12) Responding to activities such as international peace cooperation

a Emphasized items

International peace cooperation activities are carried out in a different operational environment than are domestic activities, and under a variety of circumstances, such as remote locations where troops have no operational results, as is the case in Africa.

For this reason, we will conduct R&D on equipment with an emphasis on the smooth, ongoing implementation of activities related to supplies, facilities and hygiene, as well as information and communication capabilities, transportation and deployment capabilities that anticipate long-term activity in remote places, as well as detection and protection capabilities in to ensure personnel and troop safety.

For this to be realized, land, sea, and air mobility functions, information collection functions, information sharing functions, CBRNE defense functions, human suffering confinement functions, and logistics support functions are required.

b Future technology fields

Land/maritime/air mobility

Aircraft (VTOL) technology and ship/vehicle technology are needed to safely, reliably, and efficiently transport personnel and supplies by land, maritime, and air routes. Particularly important is technology related to VTOL machines, with high speed and long cruising distances.

It is also necessary to equip autonomous embarking/disembarking systems capable of handling items such as vehicles and cargo without resorting to port and airport support facilities.

In addition, in terms of air routes, a self-defense capability is necessary against MANPADS,[38] since for insurgents are able to pass through controlled airspace.

To ensure the safety of long distance land transportation,[39] including that through dangerous areas, it is important that power technology and ballistic technology be characterized by low fuel consumption and blast properties, and that it provide active protection.

For troops to carry out activities away from bases, technology related to airdrop systems, UGS, UAS, and UMS, etc. for the transportation of high-priority supplies, such as arms, ammunition, medicines and rations is important. Further, it is conceivable that UGS, UAS, and UMS might be used as a means of transporting injured people, so it is important to have technology that adds functions and performance to quickly and safely carry supplies to the injured.

Information collection

Information gathering and detection equipment, such as surveillance cameras/networks to monitor distant situations in order to protect the mission and troops is important, and application-based research on a variety of sensor technologies is important. Also important is UGS technology, with system operation comprising multiple robots equipped with sensors, and which is compact, portable, and includes UAS technology.

To preserve the lives of troops, flight-type, mobile, and balloon-type UAS equipment is necessary. It should have the ability to be airborne for a long time, for the early detection of ambush attacks by IED[40] or rebel forces approaching a camp. In addition, it is important to have technology related to small and lightweight counter-mortar radar, as well as acoustic sensors to detect fire by such munitions as rockets and mortar shells.

Information sharing

For information concerning local forces/related parties, the home country, activity areas and our troops, it is important to have information communication equipment to enable the sharing of

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[38] MAN-portable air-defense systems, which are portable anti-aircraft missiles. Carried by individuals, they usually are fired from the shoulder, and are used to shoot down aircraft and helicopters flying at low altitudes.

[39] Considering safely carrying out missions such as those based on Article 84, Section 4 of the Self-Defense Forces Law (Transportation of Japanese nationals living abroad, etc.).

[40] Improvised Explosive Device

information among relevant groups and cooperating troop organizations from other countries.

To realize this, technology for an open-air digital communication network and an excellent satellite communication network with interoperability and survivability are important.

CBRNE defense technology

Since activities may be held in an environment with CBRNE threats, how to protect personnel from such threats should be studied, as also how to study directed energy technology to quickly deal with situations in distant places, as well as technology related to detection and decontamination of such threats. Explosive sensor technology, to discover such items as explosives, hidden in clothing and on people moving suspiciously, is important to protect personnel from such threats as suicide bombings.

Casualty mitigation

Detection technology for discovering dangerous materials on supply transport paths, active protection technology to protect our vehicles from enemy missiles, and laborsaving autonomous technology that can transport items such as supplies are all-important.

So too are unmanned equipment to dismantle and remove land mines and explosives from activity areas, and UGS technology which serves to detect and deal with land mines and IEDs. In addition, blast resistance technology that considers reducing damage from IED blasts to the neck and lower extremities of vehicle occupants, and personal equipment system technology that is bullet- and explosion-proof, and reduces blunt trauma when resisting ballistics are also important.

The emergence of new threats using small aircraft, such as drones, is expected in the future, and in the face of which electromagnetic attack technology and radio wave detection identification technology are important. Health technology related to telemedicine that allows the quick treatment of injured people is also important, as is technology to non-lethally damage equipment with microwave and sound waves in response to threats from pirate ships.

In order to deal with attacks by rockets or mortars on such places as camps, directed energy technology or anti-aircraft cannons that can intercept these weapons during flight are important.

Logistical support

Activity is expected in a variety of areas and in environments with poor sanitation and where water is scarce. Technology that can purify contaminated water making it potable, generate power from natural energy (renewable energy technology), and energy management technology is important.

(13) R & D streamlining

a Emphasized items

In order to effectively develop organic and complex equipment that comprises multiple systems so as to represent a System of Systems[41], it is necessary to accumulate system integration technology, attempt to cut R&D expenses, and ensure faster development time to reduce development risk.

b Future technology fields

Improve research and development efficiency

To accurately grasp the conceptual phase before embarking on R&D in development outcomes, etc. of equipment systems that are becoming more complex as a System of Systems, M&S[42] is useful. It is important to quantify technical problems; simulate a large number of equipment systems in combat aspects that appear in the battlefield in order to contribute to capability analysis and evaluation; research evaluated integrated simulation technology; and enable the utilization of building/development of M&S.

In addition, by parallel prototyping using 3D printers, and conducting an M&S study to efficiently develop equipment for highly systematized fighters, etc. that requires very expensive R&D, it is important to achieve system integration that accumulates advanced engineering know-how by improving M&S model accuracy.

For aircraft in particular, trends dictate that the time needed for R&D will be prolonged, and the sophistication and complexity of the system increased. Since constant capability building is likely to be required along with a longer operational period, research to maintain and improve overall aircraft system integration technology that considers each piece of organic cooperation and not only elemental technology related to airframes, avionics, engines, etc. is important.

Furthermore, there is a need to conduct research on advanced evaluation systems to evaluate the functionality and performance of these pieces of equipment. In particular, it is important that research related to construction of an evaluation system be indoors, because the possible area where equipment can be tested and evaluated is limited, and serves to discourage the leaking of information concerning Japan to other countries.

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[41] Combining individual systems, each exhibits a synergistic effect by systematization as a whole (National Institute for Defense Studies, *East Asian Strategic Review 2001*).

[42] Modeling and simulation.

IV. Technology: Future Equipment, Future Potential

Study results have been compiled as given in Chapter III, Section 3 (“Functions/capability, etc. that should be emphasized in the future”) and Section 4 (“Emphasized items and future technology fields”), while the correlation between detailed functions and future technology fields is shown in Figure IV-1. In the figure, function details are represented on the X-axis, future technology fields on the Y-axis, and Chapter III Section 4 analysis results in the body of the chart.

The numeric values for each of the functions/capabilities. that should be emphasized in the future are obtained from the number of descriptions corresponding to detailed functions and future technology fields. The direction of efforts such as “Unmanned technology,” “Smart/networking technology,” “High power energy,” and “Existing equipment function improvement” have emphasized trends that can be construed from the table.

Furthermore, based on future technology trends and taking into account technical fields[43] resulting from Japan’s strengths, we will focus on the following initiatives as future directions.

(1) Efforts for unmanned technology

Unmanned equipment technology, such as autonomous, group control and power supply to realize utilization in areas to overcome constraints on function and performance, due to having staff, not only in terms of preventing harm to personnel and 4D[44] mission support, and labor saving based on the declining birth rate.

(2) Efforts for smart/networking technology

Artificial intelligence technology seeks to provide smarter advanced autonomy and quickly process large amounts of information. Meanwhile, the aim of information and communication technology is to achieve a widely distributed System of Systems that has survivability against cyber-attacks.

(3) Efforts aimed at high-powered energy technology

High-powered lasers are needed to improve operation continuation ability in difficult logistical environments, such as when there is a lack of ammunition and a need to overcome enemy quantitative superiority; when instant war capability is required and there is a need for high, sustained combat-capability-directed energy technology utilizing microwaves, etc.; when EMP

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[43] Japan Science and Technology Agency, Center for Research and Development Strategy "Research and Development Overhead Report", etc.

[44] Dangerous, dirty, dull, deep.

bullet technology is present; and in response technology appropriate to the foregoing.

(4) Efforts to improve functions, performance of existing equipment

The goal is to develop more compact, lightweight, information collection equipment, improve stealth performance, develop technology that promises to improve the function and performance of not only future equipment, but also existing equipment, through developments in areas including material, sensor, guided missile element technologies.

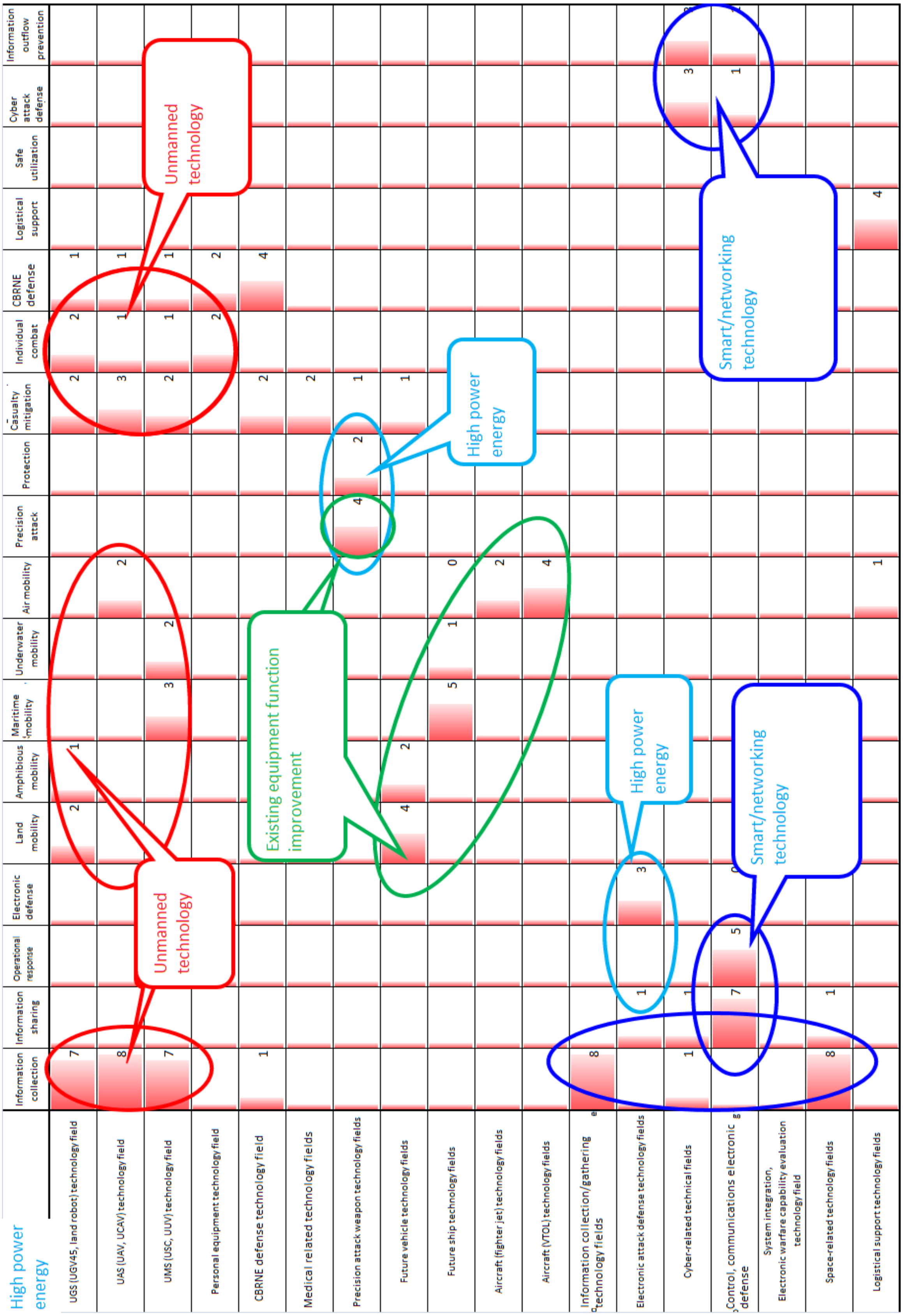

Figure IV-1 Correlation between Cell Functions and Future Technology Fields

Below are summarized the efforts related to “technology with future potential” and “future equipment technology” in future technology fields stated in Chapter 3 as representing the direction efforts in medium- and long-term technology fields are expected to take.

In addition, major technical challenges facing implementation, as well as the time it is expected to require for these to be overcome, are given as points of reference.

1. UGS (UGV[45], Land Robot) Technology Field

(1) Mobile mechanism technology

This is technology to realize mobile mechanisms that can respond to narrow spaces and complex terrain, where response is not possible by widely used mobile mechanisms (e.g., crawlers, wheels, rotary wings). The technology also increases the range of locations accessible to robots but not personnel, as well as places where robots can move with personnel when responding to events such as large-scale disasters and guerilla and Special Forces attacks.

In particular, for climbing non-uniform rock façades, etc., attention is being paid to technology (multi-foot mechanism technology) related to mechanisms to move multiple legs and adjust to similar subsequent locations.

Also attracting attention is technology related to mechanisms that, for example, imitate the flapping of insect wings (flapping mechanism technology). This is technology where small robots can realize complicated flight like insects (sudden stops, steep turns, hovering), enabling them to serve as devices for UGS information collection.

Personnel burden reduction can be realized by moving personnel while transporting goods with robots to which has been applied multi-foot mechanism technology. Meanwhile, more detailed reconnaissance information can be attained from a broader area by having miniature robots using flapping mechanism technology pass through narrow areas.

The research necessary to develop multi-foot mechanism technology involves control algorithms by which robots are moved through multi-foot mechanisms (four legs). It is expected that this technology will be available in 10 years’ time, as also autonomous functions to sort out technical problems.

In addition, by going through the necessary research to develop flapping mechanism technology, in order to realize, in some ten years’ time, small robots that fly using flapping mechanisms, it is expected solutions will appear to such technical problems as how to make components lighter and more compact, while imbuing them with autonomous functions.

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[45] Unmanned ground vehicle.

(2) Area sensing/recognition technology

As responses to events such as attacks by guerilla/special forces, large-scale disasters and international terrorist activities, there are three-dimensional information extraction functions included in obstacle removal and SLAM[46] functions to open routes, search for and rescue injured people, and detect CBRNE threats. It will be necessary to have recognition and tracking functions to counter suspicious target technology to realize functions necessary in a robot system to efficiently carry out reconnaissance, information collection, and various types of work over a relatively wide range with multiple robots that have functions such as those enabling multiple robot coordination, body motion/audio steering, and information presentation to personnel.

By conducting the research necessary to realize, in roughly 10 years' time, robot systems that carry out information collection and reconnaissance using multiple robots, it is expected that solutions will be found for such issues as those associated with technical problems related to coordinated control of multiple robots.

(3) Autonomous technology

This technology realizes the functions of robots that move autonomously to search for and rescue-injured people, as well as detect CBRNE threats. It is used as a countermeasure to international terrorism and in response to such events as large-scale disasters and guerilla/special forces attacks.

Robot movement is achieved by remote control or is autonomous but even when it is remote controlled, often some of the functions are autonomous. Autonomous movement is achieved by having the robot move by proceeding along a route to generate a movement path based on surrounding environmental data and the estimated self position determined by path-generation functions, self position estimation and environmental recognition.

Currently, a study of automatically operating vehicles in consumer applications has been carried out, and demonstrations are being conducted on highways. Automatic operation is based on the premise that robots will seek their own positions, using map data and GPS information, recognizing white lines on roads, obtaining positions on a road, and traveling on roads that have been developed.

Meanwhile, in defense applications and cases where response to movement on rough terrain is necessary, there are cases where map data cannot be prepared in advance, and where response to movement on rough terrain is necessary, as is also technology that is different from consumer-friendly automatic traveling.

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[46] Simultaneous localization and mapping.

In particular, it is necessary for the Self-Defense Forces, even in adverse weather conditions such as rain and fog, to have technology that enables environmental recognition and obstacle detection. In addition, it is also important to have technology to detect and avoid moving obstacles and act together with personnel and other vehicles.

By conducting the research necessary to realize, in five to 10 years' time, robots that can move in dynamic environments, as well as bad weather environments, it is expected there will be solutions to technical problems associated with the detection of obstacles in bad weather and the detection of moving obstacles.

(4) Humanoid robot technology

This recognizes the surrounding environment when used to respond to large-scale disasters, and it is technology that will make possible humanoid robots that have the ability to move and work autonomously and generate their own action plans.

Research on humanoid robots has been carried out previously in Japan, but after the Great East Japan Earthquake in 2011, the momentum for disaster response robot development increased. Thus, the possibility has been pursued of having humanoid robots respond during a disaster, when responding is difficult in a vehicle-type UGV. Since the DARPA Robotics Challenge—a competition sponsored by the Defense Advanced Research Projects Agency (DARPA[47]) of the US Department of Defense—that considered humanoid robots but ended in 2015, there has been growing momentum to commercialize humanoid robots.

Although it is difficult to ensure stability during work and when moving with robots that have multiple legs, when moving and working in buildings made by humans, it is possible that robots will take the same approach as people. Humanoid robots thus are considered more suitable for climbing stairs and opening and closing doors. It would also be advantageous were they to use conventional tools, making it possible for them to perform the same work as personnel.

By undergoing studies necessary to realize such a robot in some five to 10 years' time, solutions could be found for technical problems surrounding such issues as task execution in real time and expanding an applicable operation environment.

(5) Seafloor mobility technology

It will be necessary to have technology to realize UGV seafloor running technology in order to implement work in shoreline areas during large-scale disasters and failure detection processing in

[47] Defense Advanced Research Projects Agency.

island waterfront areas. In this context, technology for heterogeneous cooperation technology, such as UMS and multiple robot cooperative control technology, is also important.

By conducting the research necessary to realize, in five to 10 years' time, UGV that can work underwater, it is expected that solutions will appear to technical problems—such as recognition of the surrounding environment in terrain and obstacles underwater—that are experienced in the response of traveling mechanisms to underwater running, including soft ground.

(6) Technology with future potential

It can be expected that artificial intelligence (AI) and cognitive computing technology (CCT), when applied to UGS-based computers, will experience an autonomous expansion of the range of possible tasks and actions they can undertake.

Power storage technology can expect a significant increase in operating time as a result of the application of AI and CCT to UGS-equipped batteries (in particular, technology related to next-generation rechargeable batteries).

2. UAS (UAV,[48] UCAV[49]) technology field

(1) Autonomous technology

Autonomous technology that responds to changes in the environment and autonomously recognizes situations in unmanned aircraft without passengers is becoming important. Generally, there is a reciprocal relationship between required autonomy and control. The required control in highly autonomous systems is low, and the need for autonomy in a system where advanced control is possible is reduced. Autonomous advances in unmanned aircraft applications decrease the necessary control frequency, and there are merits to reducing the probability of detection through wiretapping. In addition, through autonomy and control that are highly compatible, unmanned aircraft pilots effectively lead multiple unmanned aircraft, and it is possible to perform flight duties while reducing risk.

Flight status and the soundness of our own equipment and other machines in the initial period of autonomous technology are acknowledged, and the automatic operations of formation flying and aerial refueling are done with limited capability.

However, in the future, along with avoiding threats by estimating enemy behavior based on a large amount of data, including external sensor information, the technical goal will be to take optimal action by group control of the entire formation, enabling tactical goals to be achieved by

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[48] Unmanned aerial vehicle.

[49] Unmanned combat aerial vehicle.

multiple, unmanned aircraft with minimal instructions from operators.

In addition, GPS navigation equipment has been widely used to grasp the position of our own equipment, but in order to respond to GPS interference or device failures, technology related to navigation systems that does not depend on GPS (non-GPS technology) is also important.

Air combat maneuvering is learned using specific maneuvers with unmanned aircraft in simulated combat, using actual planes and simulation in air-to-air warfare. We may even be able to acquire more effective maneuvers from enemy combat maneuver data in actual combat.

The failure and flight conditions of our own equipment are recognized. For the degree of autonomous technology performed with avoidance judgment, etc. along with flight path changes, technical problems are expected to be resolved in about five years, while performing demonstrations as well through OPV.[50] In addition, wingman behavior is recognized, and for non-GPS navigation system technology as well as autonomous technology to the extent of carrying out air-to-air refueling by determining its own behavior, technical problems are expected to be solved in about 10 years. Furthermore, a large amount of data based on enemy action is estimated, and for autonomous technology to the extent of carrying out air combat maneuvering, technical problems are expected to be resolved in 15 to 20 years.

(2) Air platform technology

From the broad selection of mission-related aircraft shape systems in unmanned aircraft design, early efforts in system integration are important in advancing efficient R&D. In addition to having a system developed in line with the international standards of the ICAO,[51] it is also necessary to ensure there is a high level of safety for health monitoring technology, etc. that assesses injuries resulting from being shot or bombed.

In aircraft that perform air combat maneuvers, high agility flight technology is also important to realize agility that exceeds the limits of manned aircraft.

For system integration technology to ensure safety, including during non-line-of-sight flight, performance-related technical problems are expected to be made clear through demonstrations in about five years' time. For long-term flight unmanned aircraft, it is expected to take about 10 years, and for combat-type unmanned aircraft system integration technology, 15 to 20 years.

Technical problems related to analytical methods for judging soundness, based on large amounts of data, as well as compact and conformal sensors for health monitoring technology, are expected to be resolved in five to 10 years.

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[50] Optionally piloted vehicle.

[51] International Civil Aviation Organization.

Technical problems in high-agility flight technology, such as thrust deflection to enable highly kinetic and lightweight/high strength airframe structures, should be resolved in 15 to 20 years.

(3) Propulsion/power source technology

In unmanned aircraft that perform air combat maneuvers, the use of the HSEs, similar to those in manned aircraft, make it possible to attain high speed and high movement. Meanwhile, with hypersonic cruising using scramjet combined-cycle engine technology, unmanned aircraft are expected to be capable of monitoring and reconnaissance in high-threat environments.

The use of high-efficiency solar cells and wireless power supply is expected to allow unmanned aircraft to fly at high altitudes for long periods.

Resolution of scramjet combined cycle engine technology-related technical problems, such as attaining stable supersonic combustion and turbine engine integration, is expected in 10 to 20 years.

(4) Technology with future potential

There is expected to be a dramatic reduction in RCS, without any attempt to improve radio wave stealth through current metamaterial technology.

Through morphing technology to smoothly change the airframe configuration, the frame's optimal shape is selected for a variety of flight conditions, with improved flight characteristics and reduced fuel consumption expected by deforming (empty bullet control) the wing's optimum shape.

Power challenges faced by unmanned equipment, etc. are expected to be overcome by using a battery-less system that applies wireless transmission technology.

By using MEMS[52] semiconductor technology, in addition to advancing inertial navigation systems with smaller size and higher performance, further improvement of position accuracy through non-GPS navigation can be expected as a result of the development of technology, such as a gyro utilizing cold atoms, and the improvement of existing equipment.

3. UMS (USV[53], UUV) Technology Field

(1) Long-endurance large UUV technology

There is a large equipment mounting space for responding to international terrorism and events such as large-scale disasters, attacks by guerrillas and special forces, attacks on islands, and technology to realize large UUV (LDUUV[54]) activities that can be undertaken for more than one month are needed.

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[52] Microelectromechanical systems.

[53] Unmanned surface vehicle.

[54] Large-displacement unmanned underwater vehicle.

Also needed are reliability technology that can be trusted with an extended mission, underwater energy supply technology, and technology to supply large amounts of energy to UUVs for long-term activities. In addition, there is a need for onboard equipment miniaturization technology to ensure equipment-mounting space for increasing UUV size.

By undertaking the necessary research to realize this technology in some 10 years' time, technical problems related to large-type UUV technology will be resolved.

(2) Heterogeneous cooperative control technology

For responding to international terrorism, large-scale disasters, attacks by guerrillas and special forces, and attacks on the islands, it will be necessary to deploy technology to implement unmanned task force missions, such as autonomous information collection by multiple heterogeneous unmanned machines at sea.

To operate UAV at sea, it is necessary to have coordinated control of UAV and USV for sea takeoffs and landings. In addition, when collecting information at sea, one must ensure proper use is made of hovering, precision search UUV and area search cruising UUV. This requires the use of control and various kinds of communication technology for cooperative control.

By conducting the necessary research so that this technology may be realized in some 10 years, technical problems associated with heterogeneous UMS cooperative control must be resolved.

(3) Harbor warning target detection technology

For responding to attacks on the islands, and by guerillas and Special Forces, it will be necessary to have technology to realize UMS, etc. suitable for difficult environments such as underwater target detection sensors.

Stable cruising technology in the ever-changing ocean currents, requires self-position estimation technology, and target detection technology for situations with complex, multiple paths. It is important that technology for small robot buoys and underwater gliders have acceptable underwater acoustic measurement levels and can be operated over the long term.

By conducting the necessary research so that this technology might be realized in 10 years' time, technical problems associated with stable cruising, self-position estimation technology, and target detection technology will be resolved.

(4) Combat UUV technology

Anti-ship missiles and torpedoes are equipped to respond to attacks on the islands and secure the safety of the seas and airspace in the vicinity of our country. To guarantee this, it is necessary to have UUV technology to strike targets in response to settlement/firing instructions from onshore/a mother ship. This requires fire command technology that cannot be disturbed or copied by the enemy, launcher technology, and capsules technology for protection against anti-ship missiles, etc.

By conducting the necessary research, so that this technology might be realized in some 20 years' time, the technical problems, such as those related to launching devices, will be resolved.

(5) Human support technology

For responding to attacks on the islands, to events such as large-scale disasters, and by guerillas and Special Forces, it is necessary to have technology to realize UMS to support personnel in transporting equipment underwater. Also needed are UUVs with technology to track personnel and sail.

By conducting the necessary research to realize this technology in some 10 years, such technical problems as tracking cruising will be resolved.

(6) Unmanned aircraft, mother ship, etc. connecting technology

This technology is used between unmanned aircraft[55] by USV and UUV when there is a launching/retrieval from a mother ship.

By doing the necessary research, technical problems will be resolved within about 10 years.

(7) Technology with future potential

It is to be expected that using power storage technology and power MEMS technology to power various devices and for the power supply, will result in smaller/lightweight equipment, extended continuous operating time, and a broader range of activities.

4. Personal Equipment Technology Field

(1) Power assist technology

For responding to attacks on the islands and such events as large-scale disasters, it is necessary to have the technology that will make possible a powered suit with safety characteristics to protect the wearer from falling objects. Such a suit has a balance-maintenance function to permit action on such terrain as soft ground and mountains, and a drive system with high response and a large output to enable rapid, agile movement.

Conduct of the research needed to realize a powered suit will take five to 10 years, during which time technical problems such as actuator miniaturization, output increase, and enhanced safety, will be resolved.

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[55] The combination of flying UAS (rotary wing) from UMS is also important.

(2) Man/machine system technology

It will be necessary to have the technology to needed to realize non-invasive movement BMI[56] that can control external devices to reduce the burden of operating personal equipment in various items; electron holography that allows naked-eye stereoscopic vision for training through efficient simulations; and systems to create the training settings needed to evaluate the perception and judgment of an operator.

By conducting the research necessary to realize man–machine systems that generally take 10 years to develop, technical problems such as how to increase the amount of detail in extracted brain information (BMI-related), and how to improve the capability of computers, so that a huge amount of pixels might be displayed on-screen (training simulation-related).

(3) Brace-type technology

To respond to attacks on the islands and by guerillas and special forces, it will be necessary to have technology to realize ballistic performance improvement of ceramics and super fibers used in bulletproof and explosion-proof braces. Also needed is technology to improve anti-medium- to long-range infrared impersonation features, as well as a moisture-permeable and waterproof function for clothing to be used in battle.

In the R&D for bulletproof braces, it is necessary to consider injury evaluation of personnel injuries, such as neck and lower extremity injuries, resulting from blasts, caused people in vehicles; traumatic encephalopathy; and blunt trauma caused by ballistics.

By conducting through the research necessary to realize the improvement in performance of brace types, it is expected that technical problems, such as production methods to improve material performance and the manufacturing methods, will be resolved.

(4) Wearable technology

To improve the operability of personal equipment in various items, it will be necessary to develop technology to realize wearable terminals that have AR[57] functions, as well as hands-free capability, and wearable sensors that can measure brain activity.

By carrying out the necessary research that will allow wearable sensors and wearable terminals to be realized in five to 10 years' time, it is expected that technical issues, such as noise removal and improving the accuracy of AR displays, will be resolved.

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[56] Brain–machine interface.

[57] Augmented reality.

(5) Technology with future potential

A number of improvements can be expected, including strategic flexibility improvement through continuous operation, and personnel physical burden reduction through the use of smaller, lightweight equipment. To this end, built-in information and communication electronics will be used in clothing; power supplies for various pieces of equipment using new energy technologies and power storage technology; as well as in power MEMS technology.

Personnel burden reduction for the operation of mounted equipment can be expected through the application of brain–machine interface technology.

The adoption of new production methods, including those using super fibers, is also currently being developed, and composite materials that are lighter and have higher, more specific strength are expected to be introduced. Composite materials already have been adopted in machines such as vehicles and airplanes, so personnel burden reduction through more significant weight reduction by applying future composite materials in bulletproof braces using a super fiber can be expected.

5. CBRNE Defense Technology Fields

(1) Detection technology

For responding to attacks by guerillas and special forces, events such as large-scale disasters and international terrorism, it will be necessary to develop technology to realize detection equipment with SPR[58] sensors, etc. using antigen–antibody reactions or gene analysis, pods for radiation measurement that can be mounted on unmanned aircraft, and a detection/alarm system for stand-off chemical agents using a laser or hyperspectral camera.

By conducting the necessary research, producing each piece of detection and measurement equipment will take five to 10 years. During this time, technical problems regarding, for example, lasers with both stability and high output that can create more types of antibodies will be resolved.

(2) Defense system technology

For responding to attacks by guerillas and Special Forces, events such as large-scale disasters and international terrorism, it is necessary to have technology to realize simulations that carry out contaminant spreading predictions.

By conducting the research necessary to realize spreading prediction simulations that take five to 10 years, technical problems, such as how to improve the accuracy of simulation models based on observation information, will be resolved.

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[58] Surface plasmon resonance.

(3) Protection technology

For responding to attacks by guerillas and Special Forces, and to events such as large-scale disasters and international terrorism, technology to realize personal protective equipment that is integrated with general personal equipment will be necessary. The technology involved includes nanotechnology, separation membranes, non-woven material, antibacterial processing, photo catalyst technology, lightweight protective clothing of highly advanced materials with a fine blocking effect, combat uniforms and protective masks that have air cleaning functions which use catalytic oxidation with a filter, or an activated carbon filter.

By conducting the necessary research to realize personal protective equipment with advanced protection functions, that takes five to 10 years, technical problems will be resolved, including those related to protection performance maintenance that improves durability (protective clothing-related) and extends filter life (protective mask-related).

(4) Decontamination technology

For responding to attacks by guerillas and Special Forces, large-scale disasters and international terrorism, technology to realize a variety of decontamination applications will be necessary. The applications include radioactive substance removal where radioactive effluent filtration is possible after decontamination, as well as decontamination through non-toxic decontamination agents that can help decontaminate people. Other relevant technology includes biological agent removal, where self-decontamination is possible through material to which antibacterial agents have been added.

Finally, for technology to decontaminate precision equipment, specific selective binding/adsorption/inactivation of biological agents, it will be necessary to have chemical agent removal technology that can be applied to precision equipment, ensure harmless securing, and equipment corrosion reduction.

By conducting the necessary research to realize highly effective decontamination of each pollutant that will take five to 10 years, it is expected that technical problems, such detoxification or decontamination agents for people and the environment, as well as the preparation of functional proteins to bind to target biological agents, will be resolved.

(5) Counter-IED technology

Technology to realize IED response that effectively carries out unmanned detection, and the processing of IEDs to confine human suffering, experienced by personnel involved in activities such as international peace cooperation, will be necessary.

By conducting the necessary research to realize unmanned IED response technology that takes in to account urban environments and the IED detection capability of unmanned aircraft, technical problems such as casualty mitigation and safe IED processing will be resolved.

(6) Technology with future potential

Through the application of terahertz wave technology to biological and chemical agent detection equipment, personnel protection improvement can be expected through remote sensing and a faster/wider range of detection of biological and chemical agents.

Easier handling can be expected, by using artificial substances not antibodies, and making detection devices smaller and lighter by using biosensor technology will cut detection time.

6. Medical-related Technology Fields

(1) Telemedicine technology

In order to improve therapeutic capability in places that are hard to access, as part of international peace cooperation activities, it is necessary to have technology that allows injured people in remote locations to be treated through manipulation by surgical robots and by incorporating multimedia technology and robotics into the field of medicine.

Conducting the research necessary to reproduce medical procedures and accurately carry out the treatment necessary will take five to 15 years. During this time, we should see the resolution of technical problems, including those associated with tactile transmission, manipulator, and image processing technologies, to correct blood vessel pulsation and organ fluctuations.

(2) TCCC[59] simulation technology

It will be necessary to have technology to simulate a training environment, to practice TCCC through virtual reality and realize front-line aid capability improvement of staff, including medical and nursing officers, and emergency medical technicians.

By conducting the research necessary to realize highly realistic simulated environments will take five to 15 years, during which time technical problems associated with such tactile transmission technology and three-dimensional image simulation technology will resolved.

(3) Technology with future potential

With the application of tactile sensor technology and through the stimulation of seven skin senses (e.g., touch and warm feeling), feedback of response senses is possible as virtual reality, so further aid capability improvement on the part of medical and nursing officers, as well as the accurate provision of treatment, can be expected.

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[59] Tactical combat casualty care.

7. Precision Attack Weapon Technology Fields

(1) Guided missile system technology (cloud shooting)

Optimally utilizing each resource and configuring the network of items such as fire-control systems, platforms, sensors, and weapons can realize cloud shooting. In addition, the system concept is defined and concatenated with other equipment, in addition to missiles, among precision-guided weapons that are targets for attack.

For the ground-to-air missile system, technology is needed that reliably performs extensive protection in a multi-layer structure over long to short distances, as well as interference resistance, high-response interception, simultaneous and multiple response high precision guidance, and the capability to respond to a wide range of altitudes, from ultra-low to high, and to high speed. By conducting the research necessary to realize this system, which generally takes some 10 years, it is expected that technical problems will be resolved.

(2) Guided missile component technology

In order to effectively respond to situations such as the need to maintain security in open waters, attacks on the islands, saturation attacks, and ballistic missile attacks, it is important to localize the damage and precisely intercept targets. To make this possible, it is necessary to have technology that allows the miniaturization of guided missiles, as well as expansion of the response area to high altitudes (outer space), high-precision guidance, wide-area coverage, and long-range reduction.

By conducting the research necessary, technical problems are expected to be resolved to allow the realizing of compact, light-wave missiles and response area expansion missiles. These are expected to take some five years to develop, while high-precision ground target response guided missiles will take some 10 years, and long-range/wide-area coverage fire support guided missiles that can be networked, some 15 years.

(3) Ammunition technology

For responding to attacks on the islands and by guerrillas an special forces, it is necessary to research ammunition technology, so that highly safe ammunition can be developed that can deal with a wide variety of targets, has high precision and multiple functions through intelligent and guided ballistic correction, and which has reliable and effective destructive power.

To deal with shoreline obstacles, it is necessary to research underwater—not just airborne—ballistic missiles of which a precise trajectory is required, despite the high resistance of water.

Research has already begun on these technologies, and technical problems are expected to be resolved in five to 10 years.

(4) Directional energy technology

In order to respond to situations such as maintaining security in open waters, deflecting attacks on the islands, as well as responding to ballistic missile and saturation attacks, one can resort to the use of microwave technology and high-powered lasers that can destroy and intercept flying targets by quickly and accurately irradiating them.

High-powered laser technology is also an important technology for applications such as underwater communication, seeker invalidation of guided missiles, and the processing of items such as IEDs. Even when responding to guerrillas and armed spy ships, it will be necessary to have access to direct and indirect destruction technology, using irradiation by such sources as high-powered lasers or microwaves that can deprive only enemy personnel of combat capability and information/command/communication functions, while mitigating casualties. In this context, research on technical problems, including the implementation of such items as power supply miniaturization, heat treatment (cooling), dust and vibration resistance is important.

By conducting the research necessary, it is expected that, with respect to high-powered laser irradiation technology, technical problems related to high-energy and compact-light-source technology will be resolved in some 10 years. Technical problems with respect to microwave irradiation technology, such as small power modules, larger power and wider range, will generally be resolved in some 15 years' time.

(5) EMP munitions technology

It will be necessary to have ammunition technology that uses irradiated electromagnetic pulses to neutralize the functions of the information/command/communication functions of enemy personnel electronic equipment. Research has already begun on this technology, and technical problems will be resolved in some five to 10 years.

(6) Electromagnetic acceleration gun technology

In order to allow significant improvements in the range and power of leveled off working artillery, electromagnetic acceleration gun high initial bullet velocity is realized by utilizing electrical energy. The research necessary to realize electromagnetic acceleration guns will take some 15 years, at which time technical problems, such as how to improve the rate of fire and miniaturize the power supply will be resolved.

(7) Technology with future potential

By using new material technology (nanotechnology), the development of propellants such as highly safe and highly flammable explosives, through control of crystals and explosive particle size propellants, is being considered.

The use of nanotechnology has allowed the development of ammunition that dramatically improves capability by improving the performance of various types of ammunition bullet core material to be considered.

In addition to the mechanical force of composite particles of items such as metal, one finds that ceramics and plastic at the nano-level, heat resistance improvement and lightweight conversion through a strength increase by functional composite particle technology can bind particles to each other and mold them into any shape. Further, characteristic improvements, such as of the lithium-ion secondary battery, through particle and integrated body microstructure control, is considered possible by making particles more complex and achieving particle synthesis through non-heating.

By scramjet technology that is downsized and applied to guided missiles, and by performing combustion in supersonic flow, appropriate thrust is demonstrated even during hypersonic flight, making possible hypersonic cruising.

UAS and rocket miniaturization can be expected, by means of electromagnetic propulsion technology, which is the source of energy for items such as microwave beams.

8. Future Vehicle Technology Fields

(1) Vehicle system, chassis, and power technology

As land-based weapon platforms, in order to respond to a variety of missions, such as the need for transportation, to be on alert to reinforce international terrorism countermeasures at home and abroad, and to respond to international peace cooperation activities, it will be necessary to have technology for remote control and steering assistance to efficiently and rapidly transport personnel and supplies to activity areas.

Also necessary are electric drives to evacuate the wounded and conceal the movement of personnel in activity areas; and travel suspension systems, such as high-performance suspension and vehicle simulation technology, to make future vehicle conceptual designs as efficient as possible. By conducting the research necessary, in about five years' time the technical problems related to vehicle simulations, for which future vehicle conceptual designs are efficient and feasible, as well as electric drives that can be supplied with a large amount of power and that improve fuel consumption, heat and acoustic stealth, will be resolved.

(2) Ballistic/blast protection technology

In order to respond to a variety of missions, related to strengthening international terrorism countermeasures at home and abroad, and to international peace cooperation activities, it will be necessary to have technology that allows the evaluation of passenger injuries and vehicle protection, reflecting the need to reduce such injuries as those to passengers' necks and lower limbs while in a vehicle. The injuries in question are caused by explosive blasts and ballistic structures to protect individuals against bullets, etc. in activity areas and on their way to those areas.

By conducting the research necessary, technical problems related to the ballistic/explosion structure that can withstand large explosives are expected to be resolved in five years' time. Meanwhile, technical problems regarding active protection functions in rockets and anti-tank missiles are expected to be resolved in 10 years, while technical problems related to the active protection functions to counter armor-piercing ammunition should be resolved in 20 years.

(3) Amphibious vehicle technology

Technology will be required to facilitate the mobility and rapid deployment of troops to the shore in response to attacks on the islands.

Meanwhile, in about five years, technical problems related to future vehicles with amphibious functions that can go off-road on difficult terrain and cruise on the water at high speed when recapturing the islands, are expected to be resolved with the assistance of current combat vehicle technology. Research in amphibious vehicle technology is expected to allow technical issues related to submerged traveling and movement over difficult terrain to be resolved in 15 years.

(4) Technology with future potential

This can contribute to improving the safety of our harbors, stealth technology, and traveling distance extension. These points can be achieved through power storage technology, as well as the application of new energy technologies to future vehicles that are electrically driven.

9. Future Ship Technology Fields

(1) Naval ship system component technology

Naval ships, such as destroyers and submarines, will respond aggressively to the situation on the islands, guerillas and Special Forces, and it is assumed that they will expand their target waters from coastal areas to the reefs of the Ryukyu Islands through mission expansion by dealing with armed spy ships.

For this reason, escort ships have a high seakeeping capability, ranging from low to high speed, while there is a recognized need to improve acoustic and magnetic field/underwater signature performance in response to underwater threats, as well as advanced radio wave and light wave stealth performance to counter enemy search/detection sensors and guided missile seekers. It is essential that detection capability be increased by the use of high-powered radar, to improve air defense and information-sharing capability through a sensor network.

Further, realization of energy plant technology for advanced vessels is necessary in order to mount equipment that requires large amounts of power, such as electromagnetic acceleration guns, directed energy, and responses to the large output of onboard sensors. In addition, it is necessary to improve structural fitting technology—that allows the easy substitution of equipment and can be used as a ship platform for a long time is necessary to reduce the life-cycle costs of ships for submarines—in order to respond to enemy detection sensor capability improvements; technology to achieve silence during sailing, when shooting equipped torpedoes, and to silence the ship's own acoustics; as well as magnetic field and underwater stealth performance.

Technology to deal with capability improvement is also required, including unmanned aircraft operation and improvement of information sharing capability with other ships, through an underwater acoustic communication network. New and small vessels that can be used for various purposes and in a cost-effective manner are also needed.

This will require mobility spanning low to high speed for rapid deployment and patrols; a large deck area relative to the amount of wastewater; technology to realize a versatile, high-speed, and multi-cylinder ship to facilitate the transportation of goods and personnel; and the operation of a large number of unmanned aircraft.

By conducting the research necessary to realize future ship systems that generally takes some 10 years it is expected that such technical problems as the connection of unmanned systems to sensor networks and stealth conversion will be resolved.

(2) Integrated electric propulsion system technology

By increasing the power to achieve generator capability expansion through power demand increases for various pieces of equipment, as well as by sharing the power source for propulsion, it is expected that there will be an improvement in the degree of freedom available to design the layout of ships. In addition, realization of a further low signature that improves a currently used propulsion system that is quieter is also expected. By conducting the research necessary to realize an integrated electric propulsion system that generally takes 10 years, it is expected that technical problems associated with such dedicated components as superconducting generators will be resolved.

It should be noted that, through the introduction of this technology, power electronics that are used for the propulsion system power source are able to become the source of energy of a high-output energy system for electromagnetic acceleration guns that are seen as equipment of the future.

In addition, by applying the regeneration cycle for gas turbine engines, which are the current mainstay energy plants (regenerative cycle gas turbine: low pressure air that flows into a combustor is cooled by the heat exchanger, high pressure air is preheated or low pressure air is cooled and high pressure air is preheated in conjunction with technology that improves engine cycle efficiency), significant improvement of fuel efficiency can be expected.

(3) Technology with future potential

Improvement of ship electric propulsion performance can be expected through power storage technology and new-energy technology.

By applying super conducting propulsion technology that has features such as small size and high efficiency (low power consumption) and output that is higher than that currently used by electric motors for submarine propulsion equipment, effects such as low signature due to quieter operation and improved mobility due to higher speed can be expected.

10. Aircraft (Fighter Jet) Technology Fields

(1) Air platform technology

It is necessary to realize fighter jets, which can secure air superiority and confront unmanned combat aircraft and 5th generation fighters[60] of neighboring countries that are more numerous than ours. Thus, air platform technology with good aerodynamic characteristics and radio wave stealth properties is important.

In terms of air platforms that have aerodynamic and radio wave stealth properties, we are working on clarifying technical problems in existing advanced technology demonstrators. It is expected that technical problems of integration technology to achieve more advanced radio stealth wave properties in actual flight will be resolved within the coming 15 years.

For lighter air platform structures, technical problems associated with the necessary integrated fastener-less structure technology will be resolved in some five years' time.

When it comes to weapon interior conversion, technical problems of weapon injection technology in supersonic environments necessary for realization should be resolved in five years.

(2) Propulsion/power technology

In order to realize high maneuverability in aircraft with applied weapon interior conversion, thrust deflection technology and HSEs that obtain a high thrust despite their small size are important. Also essential, because of stealth conversion, is heat treatment (heat management) technology to comprehensively examine airframes and engines for defects.

While working on resolving technical problems related to research on existing fighter jet systems, in some 15 years it should be possible to resolve HSE-related technical problems of integration technology so that it performs acceptably and stably operates in various flight conditions.

In the area of highly mobile thrust deflection technology, it will take about five years to resolve such technical problems as how to achieve the necessary airframe thrust integrated control.

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[60] The term 5th generation fighter refers to fighters with advanced avionic capabilities, such as compatibility with advanced stealth and mobility, that can integrate network and sensor information.

(3) Avionics technology

In order to deal with 5th generation fighters, it is important to have data links to tie cloud conversion and highly information oriented networks to both unmanned aircraft and large machines, LPI[61] radar that doesn't reveal its own existence, as well as the ability for the early detection of stealth machines.

Avionics to be mounted on stealth machines require emission control over CNI[62] overall in order to reduce (LPI) interception through target machine ESM[63]. In particular, as well as concealing such reflection sources as radar antennas from targets, it is essential to mount avionics on stealth machines that localize detection/identification through target ESM equipment of equipment radar waves. Based on current developments in fighter jet radar systems, it should be possible to resolve technical problems related to LPI technology in five to 10 years' time.

Where data links of existing equipment differ in terms of the frequency and bandwidth used, technical problems related to data link LPI technology should be resolved in five years. It is expected that the same time will be required to resolve technical problems in confidential data link technology, which allows high-speed and high-capability communication between wingmen.

(4) Stealth technology

Stealth technology—that involves radio waves, light waves (visible light, infrared) and sound—is applied when long-range, weatherproof radio waves are fired from many fighters that have the requisite radar and radio communication equipment to reflect and observe opponent radar waves. For this reason it is important, when developing advanced fighters, that radio wave stealth technology and counter-stealth capability[64] be incorporated, given the use overseas by 5th generation fighters of directional radio wave stealth.

In addition to low observable technology to reduce observability, such as shape stealth technology, radio wave absorbers (RAM[65]) and wave absorption structures (RAS[66]), technology for reducing the interception (LPI) in fields such as flight control/flight management technology to enable highly reflective surface control of the equipment itself, as well as radiated wave reduction from radar, etc. avionics will be necessary. By going through the necessary research, it is expected

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[61] Low probability ofintercept.

[62] Communications, navigation and identification.

[63] Electronic support measures.

[64] To be realized by stealth exceeding that of enemies (stealth technology), high-powered radar (avionics technology), and high-powered slim engines (propulsion and power technology).

[65] Radiation absorbing material.

[66] Radiation absorbing structure.

that the required technical problems will be resolved in some five to 10 years.

(5) Technology with future potential

It is expected that the application of small, lightweight and compact directed-energy systems which can be mounted on aircraft will lead to the entrapment, dysfunction, and destruction of enemy guided missiles by high powered lasers and high powered microwaves.

Also anticipated is the possibility that metamaterial technology will allow a dramatic reduction of RCS, in addition to improved radio wave stealth through the current shape.

Also expected is morphing technology that smoothly changes airframe configurations, selects optimum airframe shapes in a variety of flight conditions, and allows for improved flight characteristics and reduced fuel consumption.

The use of new material technologies, such as heat resistant alloys that transcend the heatproof temperature of Nickel (Ni) based alloys that are jet engine materials, it is even that even higher engine thrust output will be achieved.

11 Aircraft (VTOL) Technology Fields

(1) Composite helicopter technology

In order to achieve a helicopter in which more high-speed flight is possible, helicopter technology with a main rotor primary to generate lift apart from providing a mechanism for generating thrust will be necessary. Although some forms have been assumed, technical problems related to system integration and thrust generation mechanisms will be resolved in some 15 years' time.

(2) Tilt rotor wing technology

This technology will reconcile both high speed cruise performance and vertical/short range takeoff and landing capability by shifting aircraft's rotors or wings.

We will be able to solve all technical issues of the rotor-shifting propulsion technology within 15 years

(3) Technology with future potential

Through metamaterial technology, it is possible to expect a drastic reduction of RCS, even in a fuselage with an exposed rotor.

12. Information Gathering/Collection, Detection Technology Fields

(1) Radar technology

It will be necessary to develop technology, which has importance that does not change in the future, with radar characteristics such as positioning to detect targets at long distance and in all weather and where there is no alternative. It is necessary to improve this capability and continue it in order to reliably respond to ballistic missile and saturation attacks, as well as attacks on the islands, and to ensure security in open waters.

Particularly important, in terms of harbors and ground background that is difficult to identify or targets that are difficult to discover such as stealth planes, is radar technology that can quickly and reliably search and detect targets hidden under obstacles such as foliage. By conducting the necessary research, it is expected that within some 10 years, such technical problems as higher efficiency radar output and multiple, high-speed and large-scale signal processing to realize these radar technologies will be resolved.

(2) Light wave sensor technology

In order to effectively respond to threats such as an invasion of the islands, guerrilla/special forces, and armed spy ships, it is imperative that light wave sensor technology which can more clearly reveal information concerning not only a target, but also its surroundings be available. In particular, in order to provide personnel with difficult-to-obtain, high-quality video with clear images, it is important to have technology that allows the detection and identification of hidden and distant targets. By conducting the necessary research, it is expected that technical problems related to, for example, detector elements for microscopic light detection needed to realize light wave sensors, will be resolved in some five to 10 years.

(3) Composite sensor technology

In order to reliably detect hard-to-find targets, such as stealth aircraft, when responding to ballistic missile and saturation attacks, and attacks on the islands, to ensure security in the surrounding open waters, it is important to have the technology that allows the detection and identification of targets that are difficult to find by sensors alone. These targets are detected by using information from multiple sensors. By conducting the necessary research, it is expected that technical problems, related to such technologies as infrared sensor and radar integration processing for complex sensor realization, will be resolved in five to 10 years.

(4) Radio wave monitoring technology

In recent years, digital signal processing technology has allowed military communication to use communication methods with excellent levels of secrecy, including variable bandwidth, short period, and frequency-spreading communication.

In order to collect points that are apart such as communication waves in radio monitoring, received radio waves are congested and weak, and the reception quality through the influence of interference and noise other than the desired waves are extremely degraded compared with the reception of normal communication equipment. Therefore, even under such a poor radio wave environment, it is necessary to have technology to accurately detect, identify, and capture target communication waves, analyze communication elements, and demodulate them.

By conducting the necessary research, it is expected that technical problems such as adaptive and variable receiving methods that depend on the above-mentioned radio wave environments, will be resolved in the coming 10 years.

(5) Sonar technology

Technology will be required that can realize future sonar typified by autonomous and distributed types available in various marine acoustic environments, and in shallow waters in particular. This technology will permit the detection and classification of items such as mines buried in the seabed, small underwater targets, and floating items, as well as the monitoring of and search for suspicious ships and people entering harbors from the sea, and submerged submarines that threaten our country.

By conducting the necessary research to further improve the detection of quiet sonar targets, it is expected that technical problems, associated with passive acoustic processing systems that respond to a variety of acoustic signal characteristics, will be resolved in some 10 years' time.

(6) Sensor technology for detecting explosives, etc.

It will be necessary to have technology that will allow the discovery of large and hidden amounts of explosives, lethal weapons, and explosives hidden under clothing, as well as suspect individuals, if personnel are to be protected while involved in such activities as international peace cooperation.

By conducting the necessary research, it is expected that technical problems associated with fast-scanning identification technology that can respond to explosives planted in oncoming vehicles and millimeter waves, as well as technology that can detect objects hidden under clothing will be resolved in some 15 to 20 years.

(7) Technology with future potential

- It is possible to obtain underwater video with depth in real time using small, light underwater video sonar technology, and to achieve low power consumption by using an acoustic lens system. This is expected to greatly improve target identification and classification.
- With photonic crystal technology improving orientation and target identification/detection, faster information gathering, higher accuracy, and faster analysis are expected.
- Diamond thin-film manufacturing technology is expected to improved radar output, detection distance extension, low power consumption, as well as system-wide size reduction.
- Through utilization of high electrical conductivity, thermal conductivity and strength with graphene, improvement is expected in the performance of the electrical components of various

sensors, with lower environmental resistance, smaller size and lower power consumption.

13. Electronic Attack Defense Technology Fields

(1) Electromagnetic wave transmission control technology

It will be necessary to have technology that enables a variety of missions, such as search and surveillance, to be conducted without detection by enemy sensors to allow the response to an enemy invasion to be reliable, and especially important to have technology that makes radar antennas harder to detect from far away. By conducting the necessary research, technical problems associated with radar deflection control technology, low-RCS radome technology for reflection control, and selectively transmitted frequencies to make radar harder to detect will be resolved in some 10 years.

(2) Electromagnetic pulse defense technology

Powerful electromagnetic pulses damage electronic device equipment, and disable command-and-control functions. It is important to have technology to protect electronic equipment, and to respond to electromagnetic pulse (EMP) attacks. By conducting the necessary research, such technical problems as those related to electromagnetic shielding should be resolved in some 10 years.

(3) Technology with future potential

If application of visible light control technology with metamaterial, etc. can be applied to optical camouflage, the rate of detection can be expected to be greatly lowered in such platforms as vehicles and personnel, making possible safe maneuvers that escape detection by the enemy.

14. Cyber-related Technical Fields

(1) Cyber exercise environment construction technology

To appropriately respond to the threat of cyber attacks that target MOD and the Self-Defense Forces systems, there is a need to implement exercises in accordance with the level of participants in an updatable environment, which simulates various systems. Further, to improve personnel response capabilities, it is necessary to simulate a wide variety of possible attack methods in a command system, while incorporating new attack methods on a day-to-day basis.

Although networks in outdoor systems are particularly limited, technology to construct an outdoor-based cyber exercise environment is necessary to conduct effective verification of responses to cyber attacks that target systems with these characteristics. By conducting the necessary research, it is expected that technical problems in such areas as the reproduction and control of cyber attacks that pose a threat in outdoor systems will be resolved in five to 10 years’ time.

(2) Cyber resilience technology

To appropriately respond to cyber attacks, and threats of attack, against systems operated by the MOD and Self-Defense Forces, it is necessary to have technology to improve survivability and availability through dynamic and centralized control, and that seeks to continue operations. By conducting the necessary research, it is expected that, in five to 10 years' time, technical problems related to realizing a cloud environment where system survivability is ensured, and that combines cyber-attack diffusion prevention and critical-system operational continuity, will be resolved.

(3) Equipment system cyber attack countermeasure technology

Technology to prevent cyber attacks on equipment systems that advance the application of general-purpose products is required to appropriately respond to cyber attack threats that target equipment systems of the MOD and the Self-Defense Forces. By conducting the necessary research, it is expected that, in five to 10 years' time, technical problems associated with realizing equipment systems resistant to various forms of cyber attack will be resolved.

(4) Cyber attack automatic response technology

In order to respond to the threat of unprecedented and new cyber attacks, such as the use of AI technology, it is necessary to conduct an automatic analysis of accumulated logs, with respect to network response, to prevent damage expansion and operational continuity if attacks and damage have been detected early, and to have AI technology to overcome the attacks. By conducting the necessary research, technical problems associated with automatic response algorithms to reduce personnel burdens related to cyber attack response should be resolved in 10 years' time.

(5) Vulnerability survey technology

In order to appropriately respond to the threat of new cyber attacks, it is necessary to have technology to investigate unknown vulnerabilities that make use of methods such as penetration testing[67] and fuzzing[68] against our command systems and equipment systems. By conducting the necessary research, technical problems such as survey method establishment according to the characteristics of systems to be surveyed will be resolved in five to 10 years.

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[67] If network systems in operation are attacked, what kind of damage is assumed is implemented in a form close to the actual attack, and there is an inspection to clarify how much damage can be expected.

[68] A large amount of data that causes problems called "fuzz" in software products to be inspected is fed in, and this is a method to detect vulnerabilities through monitoring the behavior and its response.

(6) Supply chain integrity[69] technology

It is necessary to use hardware uniqueness technology, to determine authenticity and track product flow, to respond to the threat of cyber attacks through software with illegal programs embedded and hardware that is intentionally tampered with. By conducting the necessary research, technical problems associated with the detection of illegal products will be resolved in five to 10 years.

(7) Tamper-resistant technology

Technology is needed to respond to possible outflows of important technical information about internal equipment. Conducting the necessary research should allow technical problems related to black boxing of important information and program obfuscation will be resolved in five to 10 years.

(8) Collection of open-source information and analysis technology

Technology is needed to effectively collect and analyze information related to our country's security, given the large quantities of information on the Internet. By conducting the necessary research, technical problems, such as those related to extracting algorithms through statistical analysis of information that contributes to decision-making, should be resolved in five to 10 years' time.

15. Command and Control, Communications, Electronic Countermeasures

(1) Command and communication technology

High speed network and integrated data link technology to be able to share each unit without information from each sensor being delayed in order to reliably deal with an enemy invasion will be necessary. By going through the necessary research, technical problems linked to these items' multi-band data links for command communications device realization will be resolved in five to 10 years. In addition, satellite communication and over-the-horizon communication technology will be needed, to enable the sharing of large amounts of data, such as video, from remote locations. Conducting the necessary research, technical problems such as those associated with large capability communication needed to realize remote communication devices will be resolved in some 15 years.

(2) Decision-making support technology

In order to reliably deal with enemy invasions, it will be necessary to have technology to support accurate decisions for commanders performing target extraction, etc. by information fusion and

[69] A set of policies, procedures, and technologies used to provide visibility and traceability of products within the supply chain.

sharing a variety of sensor information through a high speed, high capability communication network. Also necessary is technology that anticipates major changes in combat, such as the cooperative engagement capability of naval vessels, aircraft, and ground forces. By conducting the necessary research, such technical problems as are associated with real time conversion of sensor data fusion to realize command and control systems will be clarified in five to 10 years.

(3) Electronic countermeasures technology

Integrated electronic jamming technology using radio waves and light waves will be needed to help inhibit various enemy maneuvers to improve our residual ratios and to degrade enemy network combat. By conducting the necessary research, technical problems regarding, for example, high efficiency interference technology to realize electronic jammers will be resolved in some 10 years.

(4) Underwater network technology

In one of the technologies that make up an underwater acoustic communication network, digital information transmission and reception to a difficult horizontal direction is enabled in current analog communications. It is also expected that this capability will be used for underwater sensor networks, such as integrating autonomous sonar, which is broadly distributed from submarines in wide-area communication of anti-surface and anti-submarine ships. By conducting the necessary research, technical problems such as that related to underwater acoustic data link technology to realize these underwater acoustic communication networks will be resolved in some 10 years' time.

(5) Technology with future potential

- Photonic crystal technology improves communications capability (notification distance, noise tolerance, and interference resistance). Better integration and interoperability; faster information gathering; higher accuracy, faster signal transduction; and faster analysis are expected.
- The application of large capability beam control technology allows larger capacity through a free-space optical communication system between the various platforms of ships, so faster information transmission and information collection can be expected.
- With development of AI technology and its utilization, it is expected that command support capability will improve through faster information processing, enabling fast, accurate detection and identification of targets.
- The development of quantum cryptography technology is expected to enhance communication capability that responds to electronic attacks and ensures high-level confidential communication.

16. System Integration, Electronic Warfare Capability Evaluation Technology Fields

(1) Integrated simulation technology

To deal with analysis and evaluation related to the response to newly emerging future threats and expanding Self-Defense Forces operation scenes, as well as increasingly sophisticated and complex equipment system R&D, it will be necessary to have technology that realizes construction of an effective, efficient combat simulation system that uses items such as the R&D concept study stage. There is a possibility that this technology can be applied to strategy simulations, etc.

By conducting the necessary research, with analysis of the performance of various types of equipment systems and quantitative analysis of the effects when replacing them with other equipment, it is expected that the resulting technical problems related to realizing the analysis and evaluation of the defense force represented by each piece of equipment will be resolved.

(2) Aircraft system integration technology

Technology to comprehensively verify Japan's technical capabilities in radio wave stealth, engines, avionics, and airframes is needed, to respond to innovation in next-generation, high-performance aircraft, and ensure improved aircraft system integration technology for transport aircraft, anti-submarine patrol aircraft, and technology demonstration units.

This is done using mockup confirmation through CAM utilizing 3D CAD,[70] 3D printers,[71] and accumulated basic data for simulated flight demonstrations. Sub-system integration technology is expected to be to be demonstrated in five years, while integration technology of all aircraft systems is expected to be demonstrated in 10 years.

Also important is technology to optimize compatible platforms in various applications subjected to large power response, and the equipment of sensors in existing transport aircraft.

(3) Electronic warfare evaluation system technology

It will be necessary to have technology to evaluate the functions and performance of such items as sensors, communication equipment, and jamming equipment. Evaluating the functions and operation of this equipment has become much more difficult, since it has become more sophisticated and complex in recent years. For efficient R&D, an equipment evaluation system will be required.

It is expected that such technical problems as what is needed to achieve both electronic warfare evaluation and electronic warfare environment simulation technologies will be resolved.

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[70] Computer-aided design.

[71] Computer-aided manufacturing.

17. Space-related technology fields

(1) Satellite-mounted infrared sensor technology

Technology to mount infrared sensors on artificial sensors, and infrared sensor technology that has environmental resistance in space and contributes to an early warning will be required.

By conducting the necessary research, in order to realize geostationary orbit of satellite-mounted infrared sensors with improved functionality and performance, it is expected that technical problems, such as the mirror and gimbal mechanisms, optical-path-changing function cooler that reduces vibration to the satellite body for the monitoring and capture of large-diameter infrared reflective optics, and higher performance space infrared detectors, will be resolved.

(2) Space situation awareness technology

Technology to grasp the situation surrounding space objects by monitoring them using sensors and analyzing the data obtained will be needed. Space dust (space debris) tracking technology research has already been carried out by related organizations. However, it is necessary to carry out a wide range of basic investigations and research if technology is to identify space objects. Meanwhile, also needed is technology to accurately detect the artificial movement of space objects (for example, spectroscopic analysis technology such as optical sensor technology and light curve observation technology, and satellite laser ranging,[72] on-orbit debris observation sensors) to protect satellites from attack by anti-satellite weapons.

Under consideration is the building of an effective space surveillance network, based on the geographical characteristics of our country and the US space surveillance network, that is not only technically feasible for surveys and research. In addition, active participation in meetings with the United States by the MOD head office and each branch of the Self-Defense Forces, given that this is positioned as an initiative based on Japan–US cooperation in space-status monitoring.

(3) Air-launched technology

Satellite launching costs are greatly reduced, and chances to utilize satellites with advanced readiness are greatly increased. In particular, air-launched systems used in Self-Defense Forces aircraft is weatherproof, and there is a need to improve the promotion of study which also takes into account the application of advanced solid rocket technology held by our country.

(4) Mission effectiveness technology

The following is technology to improve the results of artificial satellite missions by incorporating

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[72] Satellite laser ranging.

research results in the consumer field and related organizations, even though there is no technology specifically required for defense equipment.

a Altitude control technology

Technology will be needed with higher output altitude control actuators and higher precision orientation sensors, for the construction of high-speed altitude control algorithms.

To realize artificial satellites that make high-speed and high-precision altitude control possible, it is necessary to solve technical problems related to the altitude control actuator such as developing a more accurate gyro, achieving higher output, and saving more energy.

b Control technology

Technology that makes autonomous avoidance functions possible to protect satellites from debris, etc., will be needed, as also practical applications of auto tasking technology for photography.

Needing resolution will be technical problems, such as those associated with avoidance trajectory generation to suppress propellant consumption, and multiple-task processing automation to realize artificial satellites that can avoid obstacles, and autonomous task execution.

If technical problems related to avoidance trajectory generation to suppress propellant consumption are resolved, the technology may be applied to orbit changes for photography.

c Agility improvement technology

This technology makes possible long-term satellite storage, shortens integration time, and boosts safety during satellite transportation. In particular, high-performance and small SAR[73] sensor technology is responsive, weatherproof, and suitable for small size/high-performance items that can greatly cut satellite costs and the launch costs of responsive satellites.

SAR sensor technologies include SAR sensor-specific instant large power supply technology, advanced altitude stabilization technology, broadband transmission technology, sensor and bus integrated technology, and object identification technology. Still needing clarification are such issues as standardization of satellite hardware and software, and management automation for their storage.

18. Logistical Support Technology Fields

(1) Airdrop technology

This is technology to airdrop large amounts of supplies in response to attacks on the islands.

Research has shown that technical problems are being resolved, including shock absorbing

[73] Synthetic aperture radar.

during landing, the need to ensure payload for equipping supplies, automatic induction for landing, and automatic guidance to target areas for large supplies.

(2) Bridge/pier technology

In response large-scale disasters and attacks on the islands, it will be necessary to apply pier technology for coming alongside ships, even if berthing is difficult because of destroyed harbors, and bridge technology for emergency rebuilding of collapsed bridges.

Research is expected to resolve issues associated with such technical problems as floating structures for pier building and gate bridge towing.

In terms of these future equipment technologies, the direction that efforts are taking is indicated in Table IV-1, while examples of technology with future potential are given in Table IV-2.

Table IV-1 Future Equipment Technology

Technology Field		Direction of Efforts	Time to Clarify Technical Issues	Possible Use for Equipment
1	Mobile mechanism technology	Multi-foot mechanism technology: Practical application of four-legged robots for goods transport, etc. Flapping mechanism technology: (Assuming reconnaissance for an insect-type robot to be a UGS component.) Smaller, lightweight components such as sensor, battery, and motor; autonomic functions for practical use; better maneuverability, environment	Roughly 10 years	UGS
2	Area sensing/recognition technology	Better performance of following functions: Three-dimensional information extraction, SLAM, suspicious target recognition, tracking, information presentation to personnel, body motion/audio steering, practical coordination of multiple robots	Roughly 10 years	
3	Autonomous technology	Bad weather environment (rain, fog, etc.) response capability and dynamic environment (where a moving obstacle such as a vehicle is present) capability building of up to a practical level of response capability	5 to 10 years	
4	Humanoid robot technology	Develop capability to execute tasks, recognize environment, and generate action plans to a practical level	5 to 10 years	
5	Seafloor mobility technology	Traveling mechanism for waterside areas and soft ground	5 to 10 years	
6	Autonomous technology, body technology, propulsion/power technology	**UAV**: Long flight characteristics, aerial autonomous behavior, group control, compact portability, health monitoring, non-GPS navigation, hypersonic aircraft, ramjet combined-cycle engine, large-capacity network, low load control **UCAV**: High-agility flight, air combat maneuverability, other machine/attack situation assessment/response, enemy position estimation, multiple machine mission sharing, manned system concerted action	5 to 20 years	UAS
7	Long-term operation large UUV technology, heterogeneous cooperative control technology, target detection for harbor warning technology, combat-type UUV technology, human support technology, unmanned aircraft or mother-ship connecting technology	**LDUUV**: Underwater autonomous behavior, long-term operation, periphery perception, objective identification/judgment, networking of communication, etc. platforms **UUV**: Long distance detection, autonomous monitoring activities, cooperative control, activities at the border, combat capability through command, human support. **USV**: Remote control, autonomous navigation, speeding-up, seakeeping performance, activities at the border, cooperative control, human support	10 to 20 years	UMS

8	Power assist technology	Drive system high response/large output to realize rapid and agile action, soft ground, enhanced safety to protect wearer from balance maintenance function performance improvement, collision, overturning to allow for action in mountainous areas, etc.	5 to 10 years	Individual equipment
9	Man/machine system technology	Man/machine interface: Noninvasive exercise-induced BMI (brain-machine interface) practical training system, electron holography that allows naked-eye stereoscopic vision, and practical application of simulations that enable appropriate training settings to evaluate the perception and judgment ability of the operator	Roughly 10 years	
10	Brace-type technology	Combat clothing: Waterproof and breathable material, performance improvement, practical realization against medium- to far-range infrared camouflage Personal protective equipment: Ceramics and super fiber, ballistic performance improvement as well as construction of a damage-evaluation technology method for personnel who suffer blunt trauma due to ballistics	10 to 20 years	
11	Wearable technology	Wearable sensor: Practical application of brain activity measurement sensors Wearable terminal: Hands-free capability and augmented reality function practical realization	5 to 10 years	
12	Detection technology	Chemical agent detection: Lasers that have both variable stability and high power wavelength, or practical radiation measurement technology for a standoff, chemical agent detection and alarm system using a hyperspectral camera. Practical application of a pod for radiation measurement that can be mounted on a drone Biological agent detection technology: Polymerase chain reaction, sensing device through gene analysis using DNA microarrays and practical application of a sensing device using an antigen-antibody reaction type surface plasmon resonance sensor	5 to 10 years	CBRNE defense technology equipment
13	Defense System technology	Simulation construction that performs contaminant-spreading prediction	5 to 10 years	
14	Protection technology	Protective clothing: Application of nanotechnology, nano-coating, nanofibers, adoption of technology such as separation membranes, non-woven material, antibacterial processing, photo-catalysts, as well as performance improvement of protective masks through the application of lightweight and fine highly advanced materials with a blocking effect: Activated carbon used in filters as well as a study of additives and systematization of personal protective equipment, practical application of air purifiers using filters and catalytic oxidation. Integration of typical personal equipment such as combat uniforms so that they can be worn anytime	5 to 10 years.	

15	Decontamination technology	Chemical agent removal: Reduction of equipment corrosion, ensuring non-toxicity to the body and the	5 to 10 years	

		environment as well as application of precision equipment with possible decontamination technology Practical biological agent removal: Removal technology for binding, adsorption and inactivation that specifically and separately recognizes only biological agents, and practical use of radioactive material, removal of self-decontamination material, as well as gas decontamination technology for decontamination of precision equipment. Practical realization of filtration technology of radioactive liquid waste after decontamination as well as non-toxic decontamination agents that can also be decontaminated from a human body		
16	Counter-IED technology	Practical realization of IED separation detection technology, flight-type detection technology, deeper degree detection technology, IED processing technology, car bomb detection technology	5 to 15 years	
17	Telemedicine technology	Tactile transmission technology through robotics applications, manipulator technology, as well as image processing technology, etc. to correct blood vessel pulsation	5 to 15 years	Medical-related equipment
18	TCCC simulation technology	Three-dimensional image simulation technology, tactile transmission technology	5 to 15 years	
19	Guided missile system technology	Connection of various pieces of equipment and systems, improvement of wide coverage and robustness through increased freedom of system configuration, etc., realization of simultaneous response to large number of items, reaction time shortening	Roughly 10 years	Precision attack equipment
20	Guided missile element technology	Long-range reduction, wide area coverage, high precision guidance, response area expansion, miniaturization	5 to 15 years	
21	Ammunition technology	Multi-function, high precision items such as more intelligent, guided ballistic modification (self-position orientation, automatic ranging in), terminal control, high safety, range extension (rocket-assisted technology, lightweight rocket technology, wide-target response bullet technology, electromagnetic acceleration guns), anti-ship-to-ground warhead technology (high density multi EFP, sea buster warheads), surface-to-air warhead technology (adjusted debris), unmanned turret technology, shore obstacle processing technology (underwater ballistics), material technology (various materials used in explosives and ammunition)	5 to 10 years	

22	Directional energy technology	Direct and indirection destruction through high powered laser, microwave, etc. irradiation (pursuit of smaller size and lighter weight including power source)	10 to 15 years	Precision attack equipment
23	EMP bullet technology	Technology for ammunition generated by electromagnetic pulse	5 to 10 years	
24	Electromagnetic acceleration gun technology	Power supply miniaturization, automatic fire performance improvement for realization of high initial velocity electromagnetic acceleration guns	Roughly 15 years	
25	Vehicle system technology, car body technology, power technology, ballistic/blast technology, amphibious vehicle technology	Remote control, steering assistance, high performance suspension, lightweight crawlers, electric drive (hybrid power conversion, etc.), stealth properties, active defense, amphibious, vehicle simulation, casualty mitigation evaluation methods, protection vehicles considering passenger neck, lower extremity damage reduction by IED, etc. blasts while riding in a vehicle, and ballistic structures to protect from bullets, etc.	5 to 20 years	Future vehicles
26	Ship system construction technology	Integrated electric propulsion system technology, wide seakeeping performance from the low speed to high speed range, high survivability to underwater threats with advanced stealth against ship magnetic/underwater electric, acoustic, radio wave/light wave fields, air defense response to anti-ship missiles with energy plants that can stably supply a large pulse load to the response capability	Roughly 10 years	Future ships
27	Airframe technology propulsion and power technology, avionics technology, stealth technology	Aircraft: With high aerodynamic and high stealth characteristics Airframe structure: Lightweight, high power slim engine, thrust deflection mechanism integration, avionics system cloud shooting, integration/fastener-less structure, heat resistant composite material	5 to 15 years	Aircraft (fighter jets)
28	Composite helicopter technology/tilt rotor wing technology	Impact resistance, high-speed/long voyage distance/high motorization, composite helicopters (new form anti-torque)	Roughly 15 years	Aircraft (VTOL)
29	Radar technology	Construction of excellent, high-output and high-efficiency smart radar technology in detection tracking performance, etc. of stealth aircraft/ballistic missiles which are mounted to various platforms of unmanned aircraft, etc., construction of special radar technology to detect targets under complex backgrounds, as well as warning and surveillance from sky to ground	Roughly 10 yrs.	Information collection/ detection equipment
30	Light wave sensor technology	Construction of light wave smart technology that can obtain high-quality video from a longer distance day or night, which can be mounted on various platforms of unmanned aircraft, etc.	5 to 10 years	
31	Composite sensor technology	Construction of multi-target response multi-sensor technology to respond in conjunction with weapons,	5 to 10 years	

		etc., to detect new threats early such as stealth aircraft from long distances, mounted on large machines		
32	Radio monitoring technology	Adaptive variable receiving systems, etc. in response to poor radio wave environments	Roughly 10 yrs.	
33	Sonar technology	Underwater measurement system construction technology for construction of distributed and autonomous sonar technology that can detect and classify targets, underwater response equipment system configuration technology	Roughly 10 yrs.	
34	Explosives, etc. sensor technology	Detection separation technology for explosives under clothes by equipment such as millimeter wave sensors	15 to 20 years	
35	Electromagnetic wave transmission control technology	Electromagnetic wave metamaterial technology construction for radio wave/light wave cloaking which is not detected by threat sensors	Roughly 10 yrs.	Electronic attack defense equipment
36	Electromagnetic pulse defense technology	Construction of electromagnetic pulse protection countermeasure technology that can withstand threats such as EMP bombs	Roughly 10 yrs.	
37	Cyber exercise environment construction technology	Technology to build a practice environment and conduct effective verification, etc. for response procedures to simulate a variety of cyber attack methods in which target systems can be updated. In particular, construction of cyber exercise environments for field systems specific to the Self-Defense Forces	5 to 10 years	Cyber-related equipment
38	Cyber resilience technology	Aims to continue operation for response after cloud environments are subjected to a cyber attack, construction of technology in order to improve availability and survivability	5 to 10 years	
39	Equipment system cyber attack response technology	Construction of technology to prevent cyber attacks against equipment systems	5 to 10 yrs.	
40	Cyber attack automatic response technology	Construction of technology to enable an automatic cyber attack response	Roughly 10 yrs.	
41	Vulnerability survey technology	Technology to investigate unknown vulnerabilities using methods such as penetration testing and fuzzing against command and equipment systems	5 to 10 years	
42	Supply chain integrity technology	Technology to respond to cyber threats through software with illegal programs embedded and intentionally tampered with hardware	5 to 10 years	
43	Tamper-resistant technology	Program obfuscation, black boxing of important information	5 to 10 years	

44	Collection and analysis of public information technology	Technology to collect, analyze information from the large amount of public information on the Internet, that contributes to our national security	5 to 10 years	
45	Conductor communication technology	High speed network technology to understand enemy invasions more extensively and earlier, transmitting information from warning and monitoring sensors at a high speed, integrated data technology for prompt sharing of necessary information in a secure and efficient way even between different domains, construction of sensor network technology and a highly endurable and high capability open air digital communication network system	5 to 15 years	Command and control/ communication/ electronic equipment response
46	Decision-making support technology	Construction of decision-making support technology so that the commander can carry out timely, appropriate judgment and instruction through fusing pieces of information along with being able to cooperatively deal with precise tracking by integrating information from sensors	5 to 10 years	
47	Electronic countermeasure technology	Construction of electronic handling technology that carries out electronic interference using radio waves and light waves to neutralize enemy network combat and improve our survival rates	Roughly 10 yrs.	
48	Underwater network technology	Construction of underwater acoustic data link technology	Roughly 10 yrs.	
49	Integrated simulation technology	An effective and efficient combat simulation system using the R&D concept study stage, quantitative analysis for the performance of various types of equipment systems, analysis of the effects when replacing other equipment, practical application related to analysis and evaluation of defense force in all of the equipment	5 to 10 years	System integration/electronic warfare capability evaluation
50	Aircraft system integration technology	An effective and efficient combat simulation system using the R&D concept study stage, quantitative analysis for the performance of technology infrastructure maintenance and improvement, small and high-performance machine system integration, flight demonstration of advanced technology with actual equipment, HMI[74] technology	5 to 10 years	
51	Electronic warfare evaluation system technology	Electronic warfare capability evaluation technology of various sensors, communication equipment and jamming equipment, and electronic warfare environment simulation technology	Roughly 10 yrs.	

[74] Human machine interface.

52	Satellite-mounted infrared sensor technology	Practical realization of infrared sensor technology, as well as infrared sensors with target detection and identification performance improvement	5 to 10 years	Space-related equipment
53	Space condition monitoring technology	Technology, etc. to identify space objects, etc.	5 to 15 years	
54	Air-launched technology	Air-launched technology using aircraft	10 to 15 years	
55	Mission effectiveness technology	Attitude-control technology, control technology, agility improvement technology	5 to 15 years	
56	Airdrop technology	Autonomous guiding and landing technology to lower large supplies, etc. to destinations, shock absorbing during landing, etc.	5 to 10 years	Logistical support equipment
57	Bridge/pier technology	Lightweight advanced materials fitting technology	Roughly 10 yrs.	

Table IV-2 Examples of Technology with Future Potential

Item		Outline	Applicable future equipment example	Expected effects	Tendencies/trends
1	Electric power storage technology	Storage technology to convert to other forms of electrical energy (chemical energy, magnetic energy, etc.)	Robot/unmanned aircraft UUV, individual equipment platform	If this is high density, system lightweight/ compact size conversion, long-term operation	Secondary battery high energy density conversion
2	Terahertz wave application technology	Technology in applications such as detection, measurement and imaging using terahertz wave characteristics	CBRNE response equipment	Biological and chemical agents detection, explosives detection	Reduction in size and weight, environment resistance are challenges
3	Super-conductivity propulsion technology	Stator and rotor are cooled in liquid nitrogen, technology to realize superconductive electric motors	Platform (ship)	Ship speed increase, quietness	Partial demonstration phase, slight time required for migration
4	Biosensor technology	Using biological reactions and performing sensing technology	CBRNE response equipment	Equipment, etc. miniaturization, weight reduction	• Partial demonstration phase • Period required for practical use
5	Functional composite particle technology	Combination of composite particles of plastics, ceramics and metal at the nano level together into any shape, molding technology for characteristic improvement such as of the lithium-ion secondary battery through particle and integrated body microstructure control is possible through making particles more complex and particle synthesis through non-heating.	Platform (aircraft, vehicles) precision attack weapon electronic equipment (battery) strength increase	Weight-saving, heat resistance improvement, secondary battery characteristics/ improvement	・Partial demonstration phase ・Slight period of time required for migration

6	New material technology	Technology to control physical properties such as electrical characteristics through photonic crystal structures, etc. and graphene, material technology using carbon with small size and high performance such as carbon nanotubes and diamonds lightweight bulletproof bracing through super fiber material technology such as heat resistant alloys with high temperature strength properties that transcend a Ni base	Aircraft precision attack weapon personal equipment such as various types of electronic equipment	Ultra-compact and lightweight equipment, high functionality, high strength and high elasticity, personnel burden reduction	・Partial demonstration phase (some practical application) ・Practical application in five to 10 years
7	Advanced underwater video sonar technology	Underwater sonar technology through acoustics that obtained sharp images even during night or in turbid water	Information collection/detection instrumentation (sonar)	Underwater target identification performance improvement	・Partial demonstration phase ・Slight period of time required for migration
8	Quantum cryptography technology	Encryption key transmission using eavesdroppers that can detect communication paths depending on quantum state characteristics technology	Command and control/communication equipment	Ensuring absolute security	・Partial demonstration phase ・Slight period of time required for migration
9	Metamaterial technology	Granting of light wave, radio wave, acoustic stealth capability	Information collection/detection instrumentation, UAS, aircraft	Mobility, protection changes	・Partial demonstration phase ・Slight period of time required for migration
10	Brain-machine interface	Technology for input and output between man and machine using brain waves and nerve signals	Individual equipment	Workload reduction, survivability improvement, platform weight reduction	・Partial demonstration phase ・Extraction of information in the brain, accuracy analysis improvement are challenges

11	New energy technology	Extracts energy from non-fossil fuels and use it as electrical energy	Future vehicle power supply equipment	Improvement of operational ability to continue, reduction of transport and supply amounts	・Fuel cells → High efficiency, high durability, low cost ・Thermoelectric conversion →Exploration of new principles, development of thermal conductivity reduction methods based on characteristic atomic structures such as nano structuring and cages
12	Artificial intelligence/ cognitive computing	Data processing function improvement. information analysis given to judgment capability to unmanned aircraft, operation support capability improvement	Unmanned equipment, M&S decision support system, cyber	Information collection/ judgment capability higher speed and higher precision	Promotion of research for practical use
13	MEMS technology	Technology to fabricate machine functions in ultra-compact devices, inertial navigation equipment, ballistic modification bullets for small arms (small-caliber bullets that hit targets which are not visible) and realization of a compact power supply and power source which produces very large output will be necessary	Precision guided weapon robot/unmanned aircraft UUV, individual equipment platform	Equipment miniaturization, lightweight conversion, high precision, high functionality	・Partial demonstration phase ・Slight period of time required for practical use
14	Quantum measurement technology/ quantum sensing technology	High precision clocks utilizing cold atoms, gyro and gravity accelerometers, etc.	Overall	Non-GPS navigation and high-precision measurement	Partial demonstration phase
15	Scramjet technology	Flight that can go faster than Mach 5	UAS, precision guidance weapons, aircraft	Realize cruising at hypersonic speeds	・Partial demonstration phase ・Slight period of time required for practical use

16	Large capability beam control technology	Adaptive optics technology to compensate for fluctuations in the atmosphere as well as necessary high precision visual axis stabilization, and millimeter wave/ sub-millimeter wave device technology to realize large-capability communication using items such as beams with sharp lasers and millimeter waves	Communication equipment	Large amounts of data	・Partial demonstration phase ・Slight period of time required for migration
17	Electro-magnetic propulsion technology	With microwave beams, etc. as the energy source, specific thrust improvement through propulsion technology propellant changes	UAS, precision guidance weapons	Firing range and payload improvement	・Partial demonstration phase ・Slight period of time required for practical use
18	Detonation engine technology	Utilization of energy generated by a detonation	Precision guided weapons, UAS, aircraft, ships	Better fuel consumption by downsizing and higher efficiency	・Partial demonstration phase ・Period for transition necessary
19	Battery system technology	System that utilizes electricity without using a battery (wireless transmission technology, etc.)	Small unmanned equipment, high-altitude unmanned aircraft	Overcoming unmanned equipment, etc. power challenges	Some practical application experiments
20	Morphing technology	Airframe shapes according to a variety of flight conditions	UAS, aircraft	Better flight characteristics, fuel efficiency	Period required for practical use
21	Tactile sensor technology	Skin sensory transduction through remote presence technology	Health-related equipment	Sense of response transmitted to remote locations	Partial demonstration phase

V. Items That Should Be Addressed in the Future

In this chapter, items to be tackled in the future are described in relation to "future equipment technology" that will be major component technology in future technology fields mentioned in chapter III and chapter IV, and "technology with future potential," which is advanced, exploratory technology that can result in great innovation in related and relevant future equipment.

1. Overall

To develop our technical superiority for offsetting[75] a potential competitor's advantage and to maintain technical deterrence in peacetime, the limited budgets, resources of equipment and researchers must be effectively and efficiently focused and oriented to reflect DTS. In particular, in important areas for DTS, an R&D vision is drawn up that defines the direction of medium- to long-term R&D intended for items that can be major equipment in our country in some 20 years' time. We will continue to ensure implementation including substantial strengthening of information dissemination, such as technology symposia and acquisition system improvement that can be realized to ensure technical superiority.

In addition, for civilian technology that can be applied to defense (dual-use technology), we will actively work to introduce research on equipment, carried out in each ATLA laboratory, which is assumed, will be applied to future equipment. Additionally, the research is deepened through information sharing related to technology that can be dual-use technology in the future by cooperation with other ministries and agencies involved in the R&D of basic technologies.

Further, through discovering and maturing by an Innovative Science & Technology Initiative for Security (funding system) for basic technology which may be able to be applied to research and development of future equipment, we will effectively and efficiently continue to utilize R&D for the delivery of superior future defense equipment. The use of additive manufacturing (laminate shaping) that has become easy to carry out with the spread of 3D printing technology is also being studied, not only the utilization of M&S in more efficient R&D. We will also promote R&D in close cooperation with parties such as the National Research and Development Agencies in the field of outer space, along with adapting operations that effectively utilize advanced civilian technology in fast-developing cyber fields where significant progress has been made.

[75] In the United States, the Third Offset Strategy has been investigated following the First Offset Strategy in the 1950s (nuclear weapons) and the Second Offset Strategy (stealth aircraft, precision-guided weapons, etc.).

2. Future Equipment Technology

(1) Implementation of priority equipment, etc. research

In research planning, we aim to implement research items corresponding to future equipment technology presented in the FY2016 DTO. Furthermore, prioritization of the research contents shall be carried for highly important research. In addition, setting research objectives will not remain at the level of mere clarification of individual technical problems regarding implementation, but will include aspects of future concepts of operations and detailed functions related to integrated operation, where functions can be achieved as part of an entire system. Regarding the implementation of research, we aim to establish future equipment technology by promoting and accumulating the technological results of individual projects within a suitable framework.

(2) Firm implementation of technical verification

To achieve smooth transition to the equipment acquisition phase, including the development of equipment, we will undertake technical verifications and perform evaluations that as much as possible resemble actual scenes of operations. At the same time, we will carry out stringent technical verifications using measures including M&S, right from the early stages of technological research, while remembering that "future" equipment technology will be with us in the near future.

(3) Aggressive incorporation of practical technologies

In addition to developing basic technology through the Innovative Science & Technology Initiative for Security funding system, we will also consider so-called outreach efforts more than to date. We are also working on the discovery of practical technologies developed by SMEs[76] and vendors that expand the field of the entire supply chain.

3. Technology with Future Potential

(1) Focused study of seminal technology

During the selection of technology with future potential, a wide range of research on seminal technology will be carried out. To check the likelihood that research may leak from an investigation, we will provide forums at which research activities may be presented, and will closely investigate advanced and promising technology that may be presented at these events.

As well as evaluating the technology that has been investigated in order to understand the associated technological characteristics, we will promote the use of outside knowledge on top of the ATLA's evaluations, in the belief that technological implementation should be backed by a wide

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[76] Small and medium-sized enterprises.

range of knowledge and flexible thinking, and not be bound by existing concepts.

(2) Development of seminal technology

As part of these efforts, the MOD’s funding system—the Innovative Science & Technology Initiative for Security—has been made available since FY2015.

In the present system, wide research issues from external researchers are publicly offered, and contract research is done which adopts excellent research agenda for commission. Contract research content is assumed to be basic research potentially applicable to future equipment rather than the research and development of defense equipment itself. For research obtained results that are superior, we will continue to do research in ATLA. While it is assumed that future equipment is utilized, from the viewpoint of maximum utilization of research results, this is also expected to be utilized in consumer products with research results widely obtained.

In addition, in the basic research field, which is targeted by this system, we will publish research results from the fact that better research results (open innovation) can be expected through discussions held among researchers.

VI. Conclusion

The Medium- to Long-term Technology Outlook has recently been reviewed for the first time in about 10 years. So, in addition to the establishment of ATLA and changes in the science and technology environment, the FY2016 Medium- to Long-term DTO has been formulated to incorporate national security policy and the latest science and technology trends.

While revealing the direction efforts related to outer space and cyber space endeavors are taking, it covers not only the technology fields related to “technology research implemented independently by the technical research and development institute” targeted by the FY2006 DTO but also FY2016 DTO has been created to target technology fields corresponding to the R&D requirements of Self-Defense Forces and related initiatives.

Thirteen items are derived from functions/capabilities that should be emphasized in the future, and 18 items from science and technology fields are required for their implementations.

Four items have been cited as indicating the basic direction of efforts that should be emphasized in the future, namely, efforts in the areas of unmanned technology, smart/networking technology, high-power energy technology, and related to functions and performance improvement of existing equipment.

In addition, 57 future equipment-related technologies and 21 examples of technology with future potential have been identified.

By reviewing the potential of technologies and progress that has been made in some areas of science and technology, and by indicating what efforts are being made reflecting ATLA’s basic policy, the above descriptions offer more than just a bland list.

It is becoming increasingly difficult to produce accurate science and technology estimates, in areas of significant technological innovation that might be valid in 20 years’ time. But with the FY2016 DTO, ATLA aims at least to indicate the direction of future technology. In addition, by sharing information concerning future technological possibilities (seeds), it is expected that the intended purpose of contributing to the creation of future equipment capable of meeting operational needs shall be achieved.

ATLA ensures the technical superiority of our country, as indicated in chapter II. Advanced equipment has been effectively and efficiently created and, in order that timely, appropriate responses may be made and policy issues formulated, technology must be won and obtained based on defense technology strategies, including the medium- to long-term DTO.

We continue to assertively plan measures and policies to protect acquired technology, thus for the FY2016 DTO, the contents will be updated as necessary. As a result, the latest technology will be reflected, and we will continue our studies to reflect the deepening discussions surrounding defense technology strategies.

By reflecting the spirit of the FY2016 DTO at ATLA, we hope to promote the acquisition of technology and advanced equipment while closely cooperating and coordinating with relevant departments, so that Self-Defense Forces' missions may appropriately respond to operational needs.