Chapter 3 Addressing Economic and Social Challenges

In order to achieve the goals set in the 5th Basic plan: Sustainable Growth and Self-sustaining Regional Development, Ensure Safety and Security for Our Nation and its Citizens and a High-Quality, Prosperous Way of Life and Addressing Global Challenges and Contributing to Global Development we will work to solve challenges strategically by exploiting all scientific and technological innovations.

Considering the reconstruction status from the Great East Japan Earthquake and other disasters, the national and local governments will work together on S&T innovations that will contribute to development of new technologies and new industries in the disaster-stricken areas.

Section 1 Sustainable Growth and Self-sustaining Regional Development

For the continued growth of Japan, it is necessary to ensure appropriate response to the increase of social costs confronting the country now and in the future. To this end, the government is advancing efforts on S&T innovations toward securing of resources, realization of sustainable society addressing super aging, etc., securing of safety and security and high-quality living.

1 Ensuring stable energy, resources, and food

(1) Ensuring stable energy and improving energy efficiency

① Stabilizing and lowering the cost of clean energy supply

(i) Generation technologies pertaining to solar power generation system

The Ministry of Economy, Trade and Industry (METI) is conducting R&D on component technologies, toward the commercial application of innovative technologies such as Perovskite solar cells[1], the development of advanced peripherals and the maintenance technology toward improving the efficiency of the solar power generation system and developing low-cost recycling technology.

The Japan Science and Technology Agency (JST) has selected technological fields, such as solar cell and solar energy systems, in which to promote R&D on innovative technologies within a competitive environment. The targeted technologies are aimed at developments that have a high potential for greenhouse gas reduction and that are not merely extensions of conventional technologies.

(ii) Generation technologies pertaining to floating offshore wind power plant

METI is conducting a demonstration project for the establishment of bottom-mounted offshore wind turbine technology.

The Ministry of the Environment (MOE) conducted a demonstration project to install and operate Japan's first 2MW floating offshore wind power plant. Since fiscal 2016, in order to promote floating offshore wind power generation by the private sector, the ministry has been developing and demonstrating methods for accurate and efficient survey/grasp of animals in the sea area, submarine geology, etc.;

1 Solar cell created in Japan using materials with a crystal structure called Perovskite. Because it can be used in simple processes including application and printing, significant reduction in production costs is expected.

methods to reduce costs and CO_2 emissions arising from construction of floating offshore wind power plants.

(iii) Generation technology pertaining to geothermal, wave power, ocean thermal energy conversion and other renewable energy systems

Regarding geothermal power generation, METI has conducted research to resolve issues such as high development costs and risks. Technologies have been under development for the gathering of accurate data on underground thermal resources, evaluating and controlling geothermal resources necessary for stable power supply, drilling of production wells, reducing wells, etc. in a short period of time and at low cost, and environment-friendly design support tools.

Regarding geothermal power generation, MOE was engaged in developing and verifying a power generation system for high hot spring heat utilization and safety using a non-chlorofluocarbon agent (ammonia) with low environment load.

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has implemented safety and environmental measures for power generation facilities, including floating facilities, to promote renewable marine energy such as thermal energy conversion and currents

(iv) Development of high efficiency thermal power generation systems and coal utilization technologies

METI has been implementing demonstration projects of the Integrated Coal Gasification Fuel-Cell Combined Cycle (IGFC) and development of its element technologies (including large-capacity fuel cells), development and demonstration of high efficiency gas turbine technologies and new high–efficiency power generation using coal/LNG. The ministry is also developing technologies for efficient capture and utilization of carbon dioxide (CCU) emitted from thermal power generation.

(v) Other technology development

In order to ensure production of high value added products using low cost crude oil, etc.(noble use of oil) and stable operation of refinery facilities (improvement of operation reliability) toward strengthening of international competitiveness of refineries in Japan, METI has been developing innovative oil refining technologies to extract all possible petroleum products and petrochemical raw materials from unconventional crude oil and residual oil generated in the course of refining using petroleomics technology for molecular-level structural analysis and reaction modeling.

(vi) R&D related to nuclear power

a) Technologies to improve safety and nuclear security pertaining to nuclear power use

METI conducts R&D under the Safety Enhancement for LWRs Program -R&D Program for Plant Safety Enhancement to enhance safety measures at commercial power-generation reactors. This is based on what has been learned since the accident at the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company, Inc. (TEPCO).

Japan has been working with the International Atomic Energy Agency (IAEA) and the U.S.A. in a leadership role towards advancing international cooperation related to R&D on technologies for nuclear nonproliferation and nuclear security, as well as on those related to human resources development. Japan

Atomic Energy Agency (JAEA) established the Integrated Support Center for Nuclear Nonproliferation and Nuclear Security (ISCN). This center has provided training courses in nuclear nonproliferation and nuclear security. In 2013, the ISCN and the IAEA made a rule regarding the development of human resources for nuclear security. Based on the arrangement, the ISCN and the IAEA have been jointly developing training programs and exchanging lecturers and information regarding human resources development. Japan-U.S.A. joint efforts have also been made in developing technology for the following: 1) the continuous monitoring of the quantity of plutonium in high-level radioactive solutions, 2) the non-destructive detection of nuclear fuel material by means of nuclear resonance fluorescence, and 3) nuclear forensics that identify the origin of illegal nuclear material.

b) Nuclear fuel cycle technology

The Strategic Energy Plan (Cabinet Decision on April 2014) states "In order to solve problems related to disposal of spent fuels and mitigate the risks for and the burden on future generations, GOJ will make efforts to reduce the volume and harmfulness of radioactive waste and create a nuclear fuel cycle that contributes to effective utilization of resources while adequately taking the past history into consideration and continuing to seek the understanding of relevant municipalities and the international community, and will promote reprocessing and plutonium use in LWRs." Also "GOJ will promote R&D of fast reactors, etc. through international cooperation with the U.S. and France etc."

Regarding the prototype fast-breeder reactor "MONJU" the Nuclear Regulation Authority issued a recommendation to the Minister of Education, Culture, Sports, Science and Technology in November 2015 to identify the entity capable of safe output operation that would replace JAEA. In response to the recommendation, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) held the Special Committee on the Management of Monju in December 2015. The committee, after examining and summarizing problems pertaining to Monju, was engaged in studies and discussions to identify requirements for the entity that will operate Monju, and compiled the results in a report in May 2016.

Considering a big change in the environment surrounding the fast reactor development in Japan in recent years, the 5th meeting of the relevant cabinet ministers on nuclear power held in September 2016 decided the "Future Plan for fast reactor development." Concerning Monju the plan calls for "implementing radical revision including decommissioning and deciding a government policy on its handling together with the policy on the fast reactor development at the meeting of relevant cabinet ministers on nuclear power within this year."

Based on the revision, the meeting of relevant cabinet ministers on nuclear power held in December 2016 decided the "policy on fast reactor development" to promote strategy development, improvement of systems, etc. in an integrated manner toward realization of a fast reactor in the future. Regarding Monju, increases in time and economic cost accompanying the new regulatory standard and uncertainty in identification of the new operating body have been revealed, and the "policy on fast reactor development" presented a policy to work to obtain the knowledge that is expected to be obtained from resumption of operation of Monju through new measures. Based on the above, the government decided the "national policy on handling Monju" or not resuming operation of the reactors but rather to move to decommissioning while positioning the facilities for new roles in future fast reactor development. According to the policy, in order to decommission Monju safely and steadily, a new system for Monju

decommissioning will be established: (1) With guidance and supervision of the entire government, (2) undergoing technical evaluations by third parties, and (3) after establishing a system consolidating knowledge in Japan and overseas. JAEA shall implement decommissioning safely and steadily. Going forward, GOJ will proceed with works based on the policy while making steady efforts to ensure safety.

c) Technologies for treatment and disposal of radioactive wastes associated with decommissioning, etc.

JAEA is making efforts to facilitate the disposal of waste from research facilities in accordance with the Basic Policy Concerning the Implementation of Land Disposal (decided in December 2008 by ministers of MEXT and METI) and the General Plan for Implementation of Land Disposal (approved in November 2009; revision approved in March 2016).

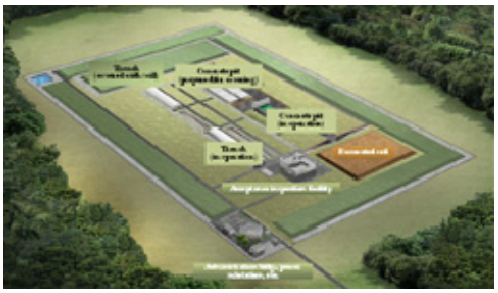


Image of a disposal facility
Source: JAEA

R&D that addresses the need to reduce the volume and hazard potential of high-level radioactive waste is a critical national policy issue. Using an accelerator, basic study has been made on nuclear transmutation and group separation technologies.

d) Development of technologies, etc. for decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company, Inc

Toward the decommissioning of the Fukushima Daiichi Nuclear Power Station, MITI, MEXT and other relevant ministries and agencies have been taking measures in coordination and cooperation based on the Midum-to-Long-Term Roadmap towards abolition of Units 1-4 of the TEPCO's Fukushima Daiichi Nuclear Power Plant (revised on June 12, 2015). In these measures, these ministries have been supporting R&D conducted by business operators on technologies that are technically difficult and that need the government to spearhead work on them. Such R&D includes a technology for extracting fuel debris and a technology for examining the inside of reactor containment vessels.

The Naraha Remote Technology Development Center, a test facility for the smooth decommissioning of the TEPCO Fukushima Daiichi Nuclear Power Station, started the full-scale operation in April 2016.

Schematic diagram of IL-31 production and itching onset mechanism
Courtesy of Kyushu UniversityCollaborative Research Center on Decommissioning

Based on the Acceleration Plan of Reactor Decommissioning R&D for the TEPCO Fukushima Daiichi NPS (Nuclear Power Station) (hereinafter the acceleration plan), MEXT set up the International Collaborative Research Center on Decommissioning under the JAEA in April 2015 to consolidate knowledge in Japan and overseas for safe, steady decommissioning. As a place for gathering knowledge within and beyond the country, an international joint research building will be opened for that center in Tomiokamachi, Fukushima Prefecture, in April 2017.

Furthermore, based on the acceleration plan, under the Research Program for Accelerated Reactor

Decommissioning that has started in FY2015, R&D has been carried out by amalgamating and coordinating studies in various fields, including international collaborative research, and by gathering a wide range of knowledge.

e) Securing and developing human resources in the nuclear field

There is the need to foster and secure a wide range of skilled human resources, in order to support the nuclear technology, ensure greater safety, and secure the safety of nuclear facilities and the smooth decommissioning of reactors in older nuclear power plants.

Under the Human Resource Development and Research Program for Decommissioning of Fukushima Daiichi NPS (Nuclear Power Station), MEXT in cooperation with the International collaborative research center on decommissioning and others has been promoting more effective basic/fundamental research and human resource development based on the needs in the field of the decommissioning. MEXT is supporting development of human resources in an effective, efficient and strategic manner, in collaboration with the relevant sectors of industry, academia and government, and based on the Global Nuclear-HRD Initiative (GN-HRD). For the study and examination of policies for human resource development in nuclear technological fields in view of the current situation and issues, the Nuclear Human Resource Development Working Group was organized under the Nuclear Science and Technology Committee, the Subdivision on Research Planning and Evaluation, the Council for Science and Technology (CST). At the Working Group, experts from universities, research institutes and other organizations in cooperation with METI have been discussing development of professionals in universities and research facilities necessary for human resource development in the nuclear field. The Working Group summarized the discussions and compiled an interim report in August 2016.

METI also has been supporting human resource development using funds provided by the Expenses for Commissioning Human Resource Development toward Improving Nuclear Safety, in order to educate field engineers involved in nuclear facility maintenance and in the nuclear safety industry. This undertaking is expected to contribute to the decommissioning of the TEPCO Fukushima Daiichi Nuclear Power Station and to the safety control of other existing nuclear power stations.

f) Basic and fundamental R&D for nuclear science

MEXT has launched strategic programs that address political requirements for the Center of World Intelligence Project for Nuclear S&T and Human Resource Development to reinforce basic and generic research. MEXT has been establishing strategic programs that address policy needs clearly and has been promoting research at universities and other research institutions under competitive research environments. In response to the new regulation standard for nuclear facilities and changes in the situation including aging of facilities, the Nuclear R&D Infrastructure Working Group was set up under the Nuclear Science and Technology Committee, the Subdivision on Research Planning and Evaluation, the Council for Science and Technology, In January 2016. The Working Group has been discussing and identifying the points of the nuclear R&D functions that the state should possess, facilities necessary for maintaining them and their appropriate operation.

JAEA is conducting basic and fundamental research on nuclear engineering, reactor engineering, irradiation materials science, partitioning and transmutation technology, radiochemistry, computational

science, advanced nuclear science and related areas. R&D has been promoted for improved safety and the diversified application of high-temperature gas-cooled reactors, with high potential for widespread industrial use in power generation and hydrogen production in addition to the inherent safety.

g) Efforts for understanding and co-existence with the public

MEXT has been supporting projects to deepen the understanding of the facilities among people nationwide and in regions where those facilities are located, towards the sustainable development of the region and education on nuclear power and other energy sources.

h) International nuclear energy cooperation

For R&D on highly sustainable nuclear energy systems, Japan is collaborating in various fields with the United States, France and other countries that are advanced in the use of atomic energy. This collaboration falls under frameworks such as the Generation IV International Forum (GIF).

MEXT has been leading the way in the peaceful use of nuclear energy and in nuclear non-proliferation by contributing to projects implemented by IAEA and the Nuclear Energy Agency under the Organization for Economic Co-operation and Development (OECD/NEA). Also as part of MEXT's contributions to the Forum for Nuclear Cooperation in Asia (FNCA), most of whose members are Asian countries, MEXT has been supporting FNCA member countries to develop infrastructure and human resources that facilitate the use of radiation and nuclear research reactors.

METI also has advanced R&D for the establishment of verification technology for fast reactors by means of Japan-French cooperation and other international cooperation frameworks. Fast reactors are expected to contribute to reductions in toxicity and in the volume of radioactive waste.

i) Efforts pertaining to the peaceful use of nuclear energy

Japan concluded IAEA in 1977 and signed the Additional Protocol in 1999. Pursuant to the agreement and the protocol, Japan has been complying with IAEA safeguards whereby IAEA verifies that nuclear materials are used only for peaceful purposes and are not diverted or misused for nuclear weapons assembly. Thus, pursuant to the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (Law No. 166 of 1957) (Nuclear Reactor Regulation Law), Japan has been implementing a system of accounting for and controlling nuclear material, providing reports to IAEA, and accepting IAEA inspections. IAEA in its safeguards implementation report has concluded every year that all the nuclear materials in Japan are used solely for peaceful purposes since 2003.

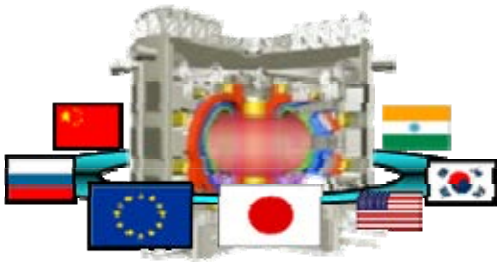
(vii) R&D of super-long-term energy technologies

Fusion energy is expected to be the prime energy source in the future, because fuel resources abound, no greenhouse gases are emitted during power generation and small amounts of fuel can generation power on a large scale. It could completely solve energy and global environmental problems. With regard to the application of fusion energy, three types of reactor have been the subject of advanced R&D and have produced world-class results in fusion: 1) the Tokamak reactor (The National Institutes for Quantum and

Radiological Science and Technology, High-Performance Fusion Experiment System: JT-60SA[1], 2) a helical reactor (National Institute for Fusion Science (NIFS) and the Large Helical Device (LHD)) and 3) a laser fusion reactor (Institute of Laser Engineering, Osaka University, GEKKO-XII Laser).

Based on international agreements, Japan has also been taking part in the International Thermonuclear Experimental Reactor (ITER) Project[2], which demonstrates the scientific and technological feasibility of fusion energy through the construction and operation of an experimental reactor. Japan, in partnership with Europe, is also advancing fusion R&D in Rokkasho Village (Aomori Prefecture) and Naka City (Ibaraki Prefecture) under Broader Approach (BA) activities that complement and support the ITER Project.

International Fusion Energy Research Center
(Rokkasho Village, Aomori Prefecture)
Source: QST



ITER (International Thermonuclear Experimental Reactor)
© ITER Organization

Space-based solar power that can stably supply clean energy free of natural conditions such as it being daytime or nighttime and the weather is expected to become an innovative energy technology in the future.

Toward realization of space-based solar power, METI has been conducting R&D on its core technology, wireless power transmission and reception using micro waves. The focus of the R&D is on enhancement of the efficiency of the power transmission and reception part and making it thinner and lighter.

Japan Aerospace Exploration Agency (JAXA) has been conducting R&D of elemental technologies toward practical use of space-based solar power.

② Stable energy use using energy storage technologies including hydrogen/storage batteries

The Cabinet Office has been working on the SIP "Energy Carrier" since fiscal 2014. With the aim of building a CO2-free value chain using hydrogen derived from renewable energy, etc. the project has been developing technologies for efficient production, transportation, storage and use of hydrogen.

METI is conducting the technological development and demonstration of batteries and fuel cells. For batteries, the ministry is conducting technological development for the performance enhancement and cost reduction of large renewable energy or lithium-ion batteries for next-generation vehicles, such as plug-in hybrids or fully electric cars. R&D on fuel cells for domestic use and other fixed uses, and on vehicle fuel

1 In August 2008, operation of the JT-60 break-even test facility was suspended. The facility was subsequently dismantled for repair and is now being reassembled as the JT-60SA.

2 This project is for demonstrating the scientific and technological feasibility of fusion energy through the construction and operation of an experimental fusion reactor based on a seven-party international agreement (Japan, EURATOM, the U.S.A., Russia, China, South Korea and India) on the application of fusion energy, which is expected to completely solve energy and environmental problems.

cells, has focused on lowering costs while increasing durability and efficiency. Anticipating the launch of fuel-cell vehicles into the market in December 2014, the ministry had installed about 90 hydrogen stations, mainly in four major cities, as of FY 2016.

METI also has launched the R&D of Innovative Utilization Technology of Wasted Heat Energy project, towards reducing and utilizing waste heat energy that has been emitted to the environment through inefficiency usage. Through the advancement and practical application of fundamental technologies, including those for heat insulation and for the storage and transformation of heat energy, the use of heat pumps and the development of thermal management technologies that combine the aforementioned technologies, the ministry has been working to save energy and to reduce carbon dioxide emissions.

The JST has been promoting competitive R&D of innovative technologies that have a big potential for greenhouse gas reduction and that are not an extension of an existing technology, which include next-generation storage batteries with vastly higher performance than current batteries.

③ Improvement of energy utilization efficiency and consumption reduction using new technologies

METI has been conducting a demonstration of a virtual power plant that remotely integrates and controls consumer-side energy resources spread across the power grid including renewable energy power facilities, storage batteries, energy facilities such as heat pumps and demand response, to make them function as one power plant and use for adjustment of supply and demand. METI has been supporting construction of an energy system based on local production and local consumption for coordinated utilization of local energy in a defined area, which includes renewable energy heat such as waste heat energy emitted to the environment through inefficient usage and sewage heat, and renewable power such as solar power by using an energy management system. The support covers the commercialization feasibility study, development of the master plan and system construction, in order to promote the further spread of renewable energy and efficient use of energy.

MLIT is promoting technological development that contributes to the further improvement of environmental performance of railways, such as the development of battery-powered trains that can travel stably across electrified and non-electrified sections at the minimum unit of one car by mounting a pantograph and storage battery on each car.

MOE is implementing a verification project for a low-carbon energy system in which renewable energy sources are used at their maximum and automatically supply and consume electricity when the power supply is suspended from the grid at the time of a disaster.

RIKEN (Institute of Physical and Chemical Research) has been conducting R&D on technologies for devices that realize radical lower power consumption and great improvement of energy conversion efficiency, with creating new materials science that enables innovation in electricity consumption under completely novel concepts.

JAXA has been conducting R&D on lowering the fuel consumption and environmental load of airplanes. JAXA intends to accelerate R&D in this area because it is directly related to international competitiveness. JAXA intends to make the aeronautics industry a super-growth industry that rates on par with the automobile industry. For instance, R&D will address technologies for making engines lighter and more efficient, and technologies for reducing noise from the airplane body, while taking into account the potential R&D trend for next-generation airplanes and beyond. While preparing, maintaining and improving

large-scale experimental facilities (wind tunnels and Ground-Level Enclosed Jet Engine Test Facility), JAXA will transfer innovative aeronautic technologies to other industries wherever feasible.

The New Energy and Industrial Technology Development Organization (NEDO) implemented the Strategic Energy-Saving Innovative Technology Program through open public invitations for proposals that focused on key technologies listed in the Strategy for Energy Efficiency Technologies 2011 (formulated in March 2011; partially revised in May 2014), in consideration of the fact that energy-saving technology encompasses many fields and widely applied.

The Building Research Agency has been conducting R&D for environmentally-sound and efficient use of resources/ energy in housing, construction and urban planning fields.

④ Application of innovative materials, devices, etc. to a broad range of areas

Toward realization of power devices using gallium nitride (GaN), etc. which will enable significant reduction of power consumption, MEXT has been promoting R&D of the next-generation semiconductor integrally from materials processing to device and system application also using theories and simulations.

The JST has selected technological fields, such as ultra heat-resistant materials, high quality recyclable steel and innovative energy-saving/creating chemical processes to promote the R&D on innovative technology within a competitive environment. The targeted technologies are aimed at developments that have a high potential for greenhouse gas reductions and that are not merely extensions of conventional technologies.

The National Institute for Materials Science (NIMS) has been promoting R&D for stable energy supply and efficient energy use. The R&D includes: high-efficiency solar cells for construction of network systems that promote use of diverse energy sources; energy conversion/storage materials for effective use of energy; R&D toward the breakthrough of high-output semiconductors for energy conservation, high-luminance light materials, etc.; high-efficiency/performance transportation equipment materials and energy infrastructure materials contributing to a low environmental burden society.

METI is making efforts to diversify chemical raw materials, innovate manufacturing processes, promote innovation by applying advanced chemical technology and advanced chemical manufacturing processes, and improve the common evaluation criteria for chemical materials to promote R&D for Green and Sustainable Chemistry that contributes to the realization of a sustainable society in which humans live in harmony with nature. By applying technologies for producing chemical products from inedible biomass and other materials and technologies for printing, the ministry is also developing technologies for electrical devices (electronic paper, large-area sensors) that afford greater energy savings and efficiency than conventional ones and is developing methods for evaluating materials for lithium-ion cells and for evaluating organic EL, in order to accelerate materials development. By applying technologies for producing chemical products from inedible biomass and other materials and technologies for printing, the ministry is also developing technologies for electrical devices (electronic paper, large-area sensors) that afford greater energy savings and efficiency than conventional ones and is developing methods for evaluating materials for lithium-ion cells and for evaluating organic EL, in order to accelerate materials development.

(2) Ensuring stable resources and cyclical use

① R&D of seabed resource exploration/production

In FY2014, the Cabinet Office started to work on a new research project of Next-Generation Technology for Ocean Resources Exploration under the cross-ministerial SIP. This project aims at establishing technologies for efficiently surveying cobalt-rich crusts and submarine hydrothermal deposits containing copper, zinc and rare metals before the rest of the world. These technologies will help create a marine resource survey industry.

MEXT has been developing advanced key technologies necessary for ocean resource exploration and is using these technologies for research and exploration. Within the framework of the program for developing technologies for promoting the use of marine resources: system development for the wide-area exploration of ocean mineral resources, which started in FY2013, MEXT aims at promoting the transfer of technologies to private companies. For this purpose, cutting-edge sensor technologies developed by universities have been further advanced, efficient wide-area exploration systems have been developed by combining multiple sensors, and new exploitation techniques have been developed and verified for practical application.

MLIT aims at market expansion in relation to ocean development. For this purpose, the ministry has been supporting the development of technologies for floating liquefied natural gas (FLNG) operation facilities and deep-water drilling platforms, because the demand for these facilities is expected to grow.

Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has been conducting R&D for clarification of the origin of seafloor resources and establishment of effective survey and environmental assessment methods using ships, probes, cutting-edge sensors and other technologies toward sustainable use of resources buried in the sea areas surrounding Japan. In fiscal 2016, JAMSTEC discovered a vast manganese nodule concentration area on the deep ocean floor (about 5,500m below sea level) within our exclusive economic zone off Minamitorishima based on acoustic survey data collected by research vessels.

The National Institute of Maritime, Port and Aviation Technology (MPAT) is conducting R&D pertaining to oceanographic observation, offshore exploration, submarine construction, transportation/ communication between ocean base and sea floor, transportation/guiding from a base on the land to a base on the sea, etc. MPAT is also conducting research on the development and improvement of techniques for safety evaluation of offshore structures and for reducing environmental impacts. These techniques are the basis of key technologies for the exploitation of ocean resources and energy.

② R&D on technologies for resource saving and substitute materials of rare earths and rare metals

To overcome the constraints imposed by the scarcity of certain elements, such as the rare earths and rare metals that are necessary for next-generation cars and wind power generation and also to save energy, MEXT and METI have been conducting mutual R&D on materials.

To overcome Japan's resource constraints and improve its industrial competitiveness, MEXT is promoting the Strategy for Rare Elements Project (research funding type) in order to find completely new materials that eliminate the need for scarce elements.

METI developed materials that are more magnetic than conventional ones in the Development of

Magnetic Material Technology for High-Efficiency Motors of Next-Generation Automobiles. The ministry also implemented a technology demonstration project regarding an advanced resource circulation system as part of the demonstration project for introduction of the Asia energy-saving resource circulation system.

Based on the interim report pertaining to rare metal recycling compiled at a joint council meeting of the Industrial Structure Council and the Central Environmental Council (published in September 2012), METI and MOE have been promoting demonstration projects and R&D by private businesses, which are expected to contribute to the efficient and economical collection and recycling of rare metals from used products.

③ Development and demonstration of biomass utilization technologies

For biomass energy, METI is conducting R&D to increase the efficiency of a cellulosic ethanol production process while reducing its costs, and to introduce and disseminate next-generation biofuels, such as algal biomass, that are compatible with food production.

Toward practical use of biofuel production using native algae of Fukushima Prefecture, an area which is expected to contribute to production of domestic biofuel, METI is also implementing a demonstration project to improve the economy and energy balance by use of carbon dioxide and sewage derived from thermal power plants, etc.

The ministry is also promoting the development of technologies capable of producing substances that were previously difficult to synthesize, significantly improving the production efficiency of useful materials, reducing energy consumption in material production, vastly reducing environmental loads and dramatically improving the development efficiency of lightweight, high-performance materials through genetic design and recombinant technologies based on large-scale genome information.

MOE is conducting R&D and verification for technology to realize the combustion of fuels with a high-ratio of biomass, included as fuel for thermal power generation plants, with the aim of reducing carbon dioxide emissions.

The JST has been promoting R&D on innovative technologies within a competitive environment, which include a consistent process of synthesizing next-generation chemicals breaking away from fossil resources. The targeted technologies are aimed at developments that have a high potential for greenhouse gas reduction and that are not merely extensions of conventional technologies.

RIKEN has been conducting leading studies on the cyclic use of carbon, that has been consumed in petrochemical products, through interdisciplinary studies on plant science, microorganism science and biochemical and synthetic organic chemistry. Another RIKEN endeavor is R&D on the establishment of innovative bioprocesses towards the discovery of new materials derived from biomass.

The Public Works Research Institute is conducting research on effective utilization of resource and energy with a focus on sewage facilities.

(3) Securing a stable food supply

The Ministry of Agriculture, Forestry and Fisheries (MAFF) is conducting research to develop super-high-yielding crop varieties, crops suitable for harsh environments, breeds of pigs with high feed utilization efficiency and highly reproductive breeds of cow. To help achieve Japan's food self-sufficiency

target, MAFF also works on developing food and feed crops that have novel features in terms of quality and processing and on techniques for producing high-quality meat and other livestock products by using domestic feed.

In order to realize new agriculture (smart agriculture) that will achieve super labor saving and high quality production utilizing robotics and information communication technologies (ICT), MAFF constructed a system of visualization of knowhow of skilled farmers using artificial intelligence (AI), IoT[1], etc., and conducted research on advanced production management using ICT, an automated driving system of farm machines using satellite positioning information, and robots for levee weeding and harvesting, for example. The ministry also worked to verify the safety and establish rules for robotics that need solution of safety issues before installation in the field and studied standardization of agricultural information for utilization of ICT in agriculture in cooperation with other ministries and agencies.

With the aim of sustainable harvesting of marine biological resources, MEXT has been conducting R&D to clarify the physiology of marine organisms for innovative production under the program to develop technologies promoting use of marine resources.

The Public Works Research Institute is implementing research on improvement and maintenance of agricultural production base in snowy cold regions to contribute to enhancement of the food supply, and fisheries base in cold sea to contribute to enhancement of the food supply.

■Table 2-3-1 / Major projects for stable supply of energy, resources and food (FY2016)

Ministry	Implemented by	Project
MEXT	MEXT	Grants for area-locating electric power stations
		Grants for promoting the development of power supply regions
		Grants for nuclear fuel cycle-related promotion coordination, etc.
		Commissioning expenses for nuclear system R&D (nuclear system R&D project) (competitive funds)
		Center of World Intelligence Project for Nuclear S&T and Human Resource Development
		R&D on next-generation semiconductors contributing to realization of energy-saving society
		Strategy for Rare Elements Project
	JST	Advanced Low Carbon Technology Research and Development Program
MAFF	MAFF	Projects for Accelerating the Introduction of Next-Generation Greenhouse Horticulture
		Promotion of science and technology research on agriculture
		R&D to support efforts for market development
		R&D for constructing value chains connected by technology

1 Internet of Things

METI	METI/ Agency for Natural Resources and Energy (ANRE)	Subsidies for Supporting Operators Streamlining Energy Use
		Subsidies for Accelerated Support of Renewable Energy Heat Utilization
		Interest subsidies for measures to address power system restriction
		Subsidies for housing and building innovative energy-saving technology introduction project
		Subsidies for Supporting Operators Streamlining Energy Use (for Private Corporations) (for Natural Gas)
		Subsidy for demonstration projects to produce microalgae fuel
		Project to advance safety regulation for new energy, etc.
		Costs for commissioning the empirical study of a floating offshore wind farm in Fukushima
		Subsidy for development of high-value added oil refinery technology, etc.
		Project to advance coal mining and safety technologies in coal producing countries
		Costs for commissioning the development of technology for safety management of oil gas supply projects
		Demonstration project to construct a virtual power plant
		Subsidy for the introduction of clean energy automobiles
		Subsidy for promotion of utilization of new hydro power technologies
		Project to promote understanding of energy structure transformation
		Subsidy for programs to support renewable energy businesses
		Costs for commissioning research on standards for radioactive waste disposal
		R&D on technologies for the remote detection of oil resources
		R&D on hyper-spectral sensors
		Project for promoting the development of methane hydrates
		R&D on technologies for mining submarine hydrothermal deposits
		Costs for commissioning research on technologies for safety measures for nuclear fuel cycle facilities
		Subsidies for the development of technologies to improve safety measures for nuclear reactors
		Costs for commissioning the development of technologies including international cooperation on fast reactors
		Expenses for commissioning for surveys on geological disposal technology
		Commissioning expenses for Basic Research Programs for the Next Generation Vitrification Technology
MOE	MOE	Technology development and verification project to induce strengthening of the measures for carbon dioxide reduction
		Project for the practical application of technologies for tidal current power generation
		Technology innovation project to create desirable future society and lifestyle
	NRA	Expenses for commissioning work on improvements to nuclear fuel research safety technologies for nuclear fuel cycle facilities
		Development of Criticality Risk Evaluation Methods
		Expenses for commissioning research on earthquake- and tsunami-resistant safety design evaluation standards for nuclear facilities
		Expenses for commissioning research on regulations for reactor design review
		Radiation survey and research expenses
		Costs for commissioning the project for advancing lifetime-extension evaluation technology
		Costs for commissioning of survey and research on geological structures at nuclear facilities

2 Achieving a sustainable society to handle hyper-aging, depopulation, etc.

(1) Establishment of a society in which people enjoy long and healthy lives with world-leading medical technology

To contribute to the realization of a society where citizens stay healthy and live longer, medical R&D that will contribute to the provision of world-leading medical care and to the generation of industrial activities for the realization of such a society will be promoted in a planned, comprehensive manner. To this end, efforts are being made under the leadership of the Headquarters for Healthcare Policy, and based on the Healthcare Policy and the Plan for Promotion of Medical Research and Development.

The Japan Agency for Medical Research and Development (AMED) was established on April 1, 2015. Medical R&D budgets, which used to be spread across ministries, are now consolidated under AMED. AMED has been providing integrated research support seamlessly from basics to practical use based on the Plan for Promotion of Medical Research and Development.

① Drug discovery

(i) Promotion of drug discovery research

To improve drug development and medical technology support bases that link high-quality basic research results with the commercialization of innovative drugs, through AMED, MEXT has been implementing the Platform for Drug Discovery, Informatics and Structural Life Science project to allow industries and universities to share information by developing technological bases, for example, a world-class level radiation facility, a compound library facility and protein production and bioinformatics technology facility and genome/epigenome analysis. MEXT is also implementing the Platform for Dynamic Approaches to Living Systems project to show the course for understanding life phenomena as a dynamic system and use the understanding for drug discovery through research combining life science and mathematical science. Another objective is to develop bases for human resource development

RIKEN is promoting the advancement of structural prediction technology, etc. using protein production technology, structure and function analysis technology and computational science. Riken is also conducting pioneering research on state-of-the-art technology for measurement, quantification and modeling of life phenomena and for the reproduction of cell functions.

AMED under the Advanced Research & Development Programs for Medical Innovation and the JST under the Strategic Basic Research Programs (see Chapter 4 Section 2, 1 (2)) are conducting research to create fundamental technologies in this field. These programs are conducted in coordination with the programs described above.

Under its Development of technology for measuring miRNAs in serum program, METI has accumulated large amounts of clinical information and biobank specimens. Using these, METI aims to achieve the following: the early discovery of markers for 13 cancers, including breast and bowel cancer, and for dementia; the practical use of less invasive and highly sensitive diagnosis system technology.

(ii) Innovations in biomedical structural and synthesis technology

Through AMED, MEXT has been conducting the Basic Science and Platform Technology Program for Innovative Biological Medicine to assist in developing innovative basic technologies in universities for

producing Japanese next-generation, innovative biomedical drugs.

MAFF launched a workshop of experts to establish the world's first fundamental technologies to produce biomedicine and test drugs using silkworms and other local resources and accelerate their industrial use. The ministry has been promoting related R&D.

To develop medicines with high healing effects and minimal side effects, METI has been establishing basic production technology for next-generation antibody drugs that meet international standards, as well as developing innovative drug discovery processes.

② Development of medical equipment

To provide safer treatments for patients, through AMED, Ministry of Health, Labour and Welfare (MHLW) is promoting the development of test drugs appropriately selected for patients who require drug administration and the development of non-invasive/minimal invasive medical equipment utilizing nanotechnology.

In cooperation with MHLW and through AMED, METI is preparing a guideline to clarify items for evaluating the technological and biological stability of medical equipment towards future commercialization, in order to promote the development of medical equipment.

METI is also assisting in a joint project to develop and demonstrate medical equipment made by manufacturers and medical institutions in Fukushima Prefecture and a project led by Fukushima Medical University to found a drug discovery center through the Recovery Fund Concerning Nuclear Emergency Preparedness in Fukushima, established for restoration from nuclear hazards.

The Pharmaceuticals and Medical Devices Agency (PMDA) conducted the pharmaceutical affairs consultations on R&D strategy to commercialize academic startups' excellent seeds.

③ Establishment of centers to create innovative medical technologies

MEXT, in cooperation with MHLW and through Japan Agency for Medical Research and Development, has been promoting the Translational Research Network Program that aims to network translational research support centers, strengthen their ability to nurture seeds, and establish permanent centers. AMED has been working on establishing a system for putting basic research outcomes to practical use in a consistent way.

For the production of innovative Japanese medical drugs and devices, MHLW has been conducting clinical research in accordance with international standards (ICH-GCP) and has been promoting the C Project for the Improvement of the Clinical Research Quality Assurance System and other measures to provide support for all hospitals from core hospitals. In addition, to promote the high-quality clinical research and clinical trials that are required for the development of innovative Japan-made drugs and medical equipment, a system to approve hospitals that play a central role in international-standard clinical research and doctor-centered clinical trials as clinical research core hospitals was outlined in April 2015 in the Medical Treatment Act (Act No. 205, 1948).

④ Realization of regenerative medicine

Aiming at the early realization of regenerative medicine and drug development using stem cells, including iPS cells, the ministries concerned are promoting research in close cooperation with each other.

They are working on establishment of a research system and securing of research funds, and the securing and management of intellectual properties, for example.

Based on the Healthcare Policy, MEXT, in cooperation with MHLW and METI, is promoting the world's first implementation of regenerative medicine and innovative drug development using iPS cells and related materials. To this end, AMED at the Research Center Network for the Realization of Regenerative Medicine is constructing a nationwide framework by enhancing core center functions and improving networking. Basic research is conducted also in JST Strategic Basic Research Programs (see Chapter 4 Section 2, 1(2)) as well as at RIKEN.

MHLW continuously supports endeavors that have moved from the nonclinical phase to the clinical phase. MHLW is also promoting research on basic technologies that will contribute to the search and selection of candidate compounds for medicines using human iPS cells. MHLW is seeking to establish a base of technology for safe and effective regenerative medicine that uses human cells, such as iPS cells, to promote research into tumorigenicity, rejection and other areas, which are hurdles for the early clinical application of regenerative medicine.

Through AMED, METI is implementing the Development of Medical Devices and Systems for Advanced Medical Services. In this project, AMED is conducting R&D on systems, etc. to produce functional 3D tissues and organs for implantation by adopting a technology for 3D modeling using cells. In addition, under the Project Focused on Developing Key Evaluation Technology, Aiming at Industrialization in the Field of Regenerative Medicine, the ministry clarified the safety evaluation items specific to each regenerative medicine product and developed a reasonable evaluation method. And METI is promoting the development of basic technologies for the stable mass production of high-quality stem cells, such as iPS cells, that will be needed for regenerative medicine.

⑤ Realization of Tailor-made Genome Medical Treatment

Through AMED, MEXT is implementing the Tailor-made Medical Treatment with the Biobank Japan Program (the 3rd term) and established one of the world's largest biobanks of patient DNA, biological samples and clinical information collected from cooperating medical institutions. MEXT is also promoting the Tohoku Medical Megabank Project, which is a long-term genome cohort study on areas affected by the Great East Japan Earthquake. The project intends to promote long-term epidemiological research (genomic cohort research), to restore community medical systems in the affected regions and to attain next-generation medical care, such as personalized prevention. Furthermore, through AMED, the ministry has been promoting the Platform Program for Promotion of Genome Medicine to restructure the existing biobanks, etc. described above into hubs for research bases/cooperation while at the same time to carry out cutting-edge R&D with defined goals in an integrated manner using the research bases.

⑥ Cancer research

In Japan, one in two people will develop cancer. One in three people die from the disease (about 370,000 persons/year as of FY 2014.) Cancer remains a serious problem for life and health.

Therefore, aiming at joint efforts by patients and society, the government has promoted studies on cancer with a permanent cure and prevention in mind and on living with cancer. These efforts are based on the Comprehensive 10-Year Strategy for Cancer Control (decided by the Ministers of MEXT, MHLW and

METI on March 31, 2014), the Cancer Control Act (Act No.98 of 2006) and the Basic Plan to Promote Cancer Control Programs (Cabinet decision in June 2012). In December 2016 the Cancer Control Act was revised to incorporate the state's consideration of promotion of research of orphan and/or refractory cancer. Also based on the revision, Japan is further promoting development of effective cancer treatment.

MEXT, through AMED and in cooperation with MHLW, METI and others, has been implementing the Project for Cancer Research and Therapeutic Evolution. In order to create next-generation cancer therapies, this research program promotes research aimed at elucidating the biological properties of cancer, research based on patients' clinical data including cancer genome information, and research combining both aspects.

Through AMED, METI is implementing Development of Medical Devices and Systems for Advanced Medical Services to develop devices such as a high-precision radiotherapy apparatus that applies a technology for irradiating organs that move during breathing, and a device for diagnosing cancer metastasis that uses an atomized contrast agent to make metastasized cancer cells detectable.

Aiming at early application of these technologies, through AMED, MHLW is implementing the Practical Research for Innovative Cancer Control project based on the Comprehensive 10-Year Strategy for Cancer Research. The project aims for the early detection of disorders, mainly orphan and refractory cancers, and is promoting R&D for the practical application of innovative diagnostic methods using new biological indicators specific to cancer.

MHLW is continuing prior strategic cancer research and is promoting the development of innovative therapies that either use genome information including mutation of cancer-related genes or restrict and eradicate cancer stem cells, and that mainly target orphan and refractory cancers. Cancer vaccine therapies are rapidly advancing as a fourth type of therapy, following surgical operations, radiation therapies and chemotherapy. Therefore, MHLW is promoting high-quality, non-clinical trials and international-level, doctor-centered clinical trials for drug development, mainly for refractory and/or orphan cancers, by taking advantage of Japan's rich history of such studies. These studies include those on cancer vaccine therapies, molecular target drugs (such as antibody drugs), nucleic acid medicines and cancer peptide vaccines. This includes methods for effective cancer pain evaluation, advanced information communication and palliative care quality assessment. The goal is to improve treatments for physical pain, cancer-specific pain, depression and anxiety, psychological and mental pain, and social distress, including work and financial problems.

National Institutes for Quantum and Radiological Science and Technology (QST) is promoting research on heavy-ion cancer therapy, which is expected to be a breakthrough therapy for refractory cancers. Efforts will be made to disseminate its use domestically and internationally. Based on R&D performed by QST, heavy-ion cancer therapy facilities were installed in Hyogo, Gunma, Saga and Kanagawa prefectures for medical treatment. In the field of molecular imaging, QST is promoting development of radioactive drugs including PET probes [1] and biometric devices, research regarding application to Targeted isotope (radionuclide) therapy that is expected to be next-generation therapy using pathological diagnosis and radioactive drugs, and other projects.

1 Radioactive drugs emitting a very small amount of radiation are used for PET examination to make a picture of radiation distribution in a living organism for diagnosis of the cause, conditions, etc. of Alzheimer and other diseases.

⑦ Research on Mental and Neurological Disorders

MEXT has been implementing the Strategic Research Program for Brain Sciences (SRPBS), which aims at brain science that contributes to society. The program includes R&D aiming at the support for patients' independence using Brain Machine Interface (BMI) technology and permanent cure of mental and neurological disorders by strengthening coordination of clinical and basic research, and R&D to clarify the brain function principles that support behavior selection and adaptation to environment. Since fiscal 2014, MEXT has been implementing the Brain Mapping by Integrated Neurotechnologies for Disease Studies (Brain/MINDS).

At RIKEN and the JST, under the Strategic Basic Research Program (see Chapter 4 Section 2, 1(2)), and AMED under the Advanced Research and Development Programs for Medical Innovation, research into brain science is also being promoted in the fields of molecular structures, nerve cells, neural networks and other areas.

⑧ Research on Emerging and Reemerging Infectious Diseases

Through AMED, MEXT is implementing the Japan Initiative for Global Research Network on Infectious Diseases. The 9 research centers in 9 countries throughout Asia and Africa have been collaborating with the relevant organizations of their countries on epidemiological research that addresses the pathogens of infectious diseases widely suffered by the people of the country, in order to promote the basic study of diagnostic/ therapeutic medications and to develop new technologies that contribute to infection control and prevention, and to diagnosis and treatment.

For the formation of an infectious disease research center with the laboratory of the highest Biosafety level (BSL4) scheduled for establishment at Nagasaki University, a meeting of relevant cabinet ministers decided "involvement in the development of the laboratory of the highest Biosafety level (BSL4) of Nagasaki University" in November 2016, and necessary supports have been provided based on the decision.

Through AMED, MHLW is also conducting research into cell culture-based vaccines and intranasal vaccines, so that simpler and more effective vaccines can quickly be provided to people to contain novel flu pandemics. With particular concern for preventive inoculations that are an important means to fight infectious diseases, MHLW is researching the evaluation of medical safety and economic efficiency, helping the vaccination administration. MHLW is working on the development of proper diagnostic techniques, treatment strategies and preventive methods that facilitate the necessary administrative responses. In the field of novel influenza, MHLW is also conducting research into cell culture-based vaccines and intranasal vaccines, so that simpler and more effective vaccines can quickly be provided to people to contain novel flu pandemics.

⑨ Research on intractable diseases

MHLW, through AMED, has been implementing the Rare/Intractable Disease Project of Japan in cooperation with MEXT. Toward overcoming intractable diseases, the project supports research in areas where research is not making progress due to a small number of patients. The project aims to elucidate pathologic conditions, while at the same time promoting development of new effective remedies and expansion of application of existing drugs, etc. in an integrated manner.

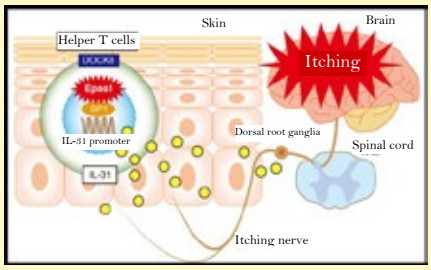
⑩ Promotion of utilization of health information taking advantage of ICT

Ministry of Internal Affairs and Communications (MIC) has conducted research on enhancing the quality of health, medical and nursing services by utilizing ICT to help users manage and make use of medical and nursing care information, and information on their health. The ministry is also implementing experimental studies on the use of mobile devices to realize telemedicine services and linkage between medical care and nursing care in a secure manner at low cost, and demonstrations aimed at development of endoscopes and telemedicine with application of 8K technology[1]. In the field of public administration, MIC has been promoting efforts to improve public services by utilizing ICT across Japan. MIC is also studying and verifying data items, data links and linkage methods for facilitating data linkages among public service authorities through cloud computing services.

Column 2-2 Investigating hitherto unknown cause of itching of atopic dermatitis

Itching significantly harms quality of life. Atopic dermatitis, in particular, is a national affliction affecting 7 to 15% of the population. However, the cause of itching of atopic dermatitis has not been explained and there are only indirect treatments such as steroid and immunosuppressant. There is an urgent need for identification of new drug targets and development of remedy.

Yoshinori Fukui (Professor, Medical Institute of Bioregulation, Kyushu University) et al discovered EPAS1, an important protein for generation of IL-31 that is an itching substance involved in onset of atopic dermatitis, as part of AMED's Advanced Research and Development Programs for Medical Innovation. When they suppressed the function of EPAS1 in cells of atopic dermatitis patients, generation of IL-31 decreased sharply, which shows the importance of EPAS1 for generation of itching substances. It is expected that highly effective drugs that can radically eliminate itching of atopic dermatitis may be developed by setting as drug target the IL-31 generation pathway elucidated by this research.



Schematic diagram of IL-31 production and itching onset mechanism
Courtesy of Kyushu University

(2) Building infrastructure for sustainable cities and regions

① Compact and functional town development

With the aim of promoting the use of ICT in school education, MIC has been collaborating with MEXT in implementing the Future School Promotion Project, an empirical study for establishing low-cost educational ICT systems (the Education Cloud Platform) to provide seamless cloud-based learning at home and school via various terminals and OSs. The project is currently conducted at 12 schools in three areas: Shinchimachi Town in Fukushima Prefecture, Arakawa Ward in Tokyo, and Saga Prefecture. Regarding R&D that benefits welfare, grants have been provided to R&D projects to defray the costs of R&D on technologies necessary for delivering more convenient communications and broadcasting services to

1 Technology to realize ultrahigh definition video of 33 million pixels that is 16 times of that of the currently broadcasted high-definition television. The technology developed in Japan is expected to be used in various fields including medical care, advertisement and crime prevention.

elderly and/or disabled citizens.

In response to diversifying housing life needs of the people, the National Institute for Land and Infrastructure Management is conducting "development of maintenance and siting evaluation techniques for systematic contraction and reorganization of cities" and other research.

② Research on transportation systems

The Comprehensive Strategy on Science, Technology, and Innovation determines the government's direction of the advanced road transportation system and indicates the policy to promote technology development in the field toward its early realization. With the SIP automated driving system, the Cabinet Office is promoting R&D with focus on five fields: dynamic map necessary for automated driving, HMI[1], information security, reduction in pedestrian accidents and next-generation urban transportation. In March 2017, demonstration test of automated driving of buses will be conducted in Okinawa ahead of other projects to accelerate achievements. In September 2017 a large-scale experiment test will be conducted to identify issues and realize early commercialization. In addition, international workshops, citizen dialogs[2], media meeting, etc. have been held to promote international cooperation and standardization and to understand the public's demands, anxieties, questions, etc. concerning automated driving.

MIC has been implementing R&D on high-accuracy/high-reliability network technology toward early commercialization and spread of autonomous mobility systems (electric vehicles, electric wheelchair, etc.) using the automated driving system. The National Police Agency (NPA), MIC and MLIT have been promoting efforts to introduce and advance driving safety support systems that rely on vehicle-to-infrastructure and vehicle-to-vehicle communications.

In FY 2016, National Research Institute of Police Science (NRIPS) of National Police Agency (NPA) promoted research on traffic accident analysis technology concerning driver support systems.

MLIT has also been enhancing R&D that helps to improve the safety of railway traffic, including developing platform screen gates that are available to various train door positions relative to the platform and help reduce construction cost.

MPAT has been conducting R&D of technologies pertaining to vessels and use of the oceans using the technologies as well as electronic navigation. In this field, the institute has been implementing research that helps to realize a safe and secure society. Specifically, for the purpose of ensuring the safety of marine transportation, this institution is formulating safety regulations that are socially feasible and that help to substantially reduce accidents at sea. Research is also being conducted on promoting modal shifts, increasing the efficiency of maritime transportation for better logistics and developing transportation systems.

In the field of electronic navigation, the Institute has been conducting R&D including "advancement of air traffic management through trajectory-based operation," "advancement of airport operation," "optimization of air traffic by utilization of onboard information" and "information sharing among parties concerned and advancement of aircraft flight." The aim of the R&D is to contribute to expansion of air

1 Human Machine Interface
2 Two-way communication to hear expectations and concerns of general public concerning automated driving and reflect them in R&D activities (three sessions in FY2016)

traffic capacity, improvement of the convenience of air traffic, improvement of aircraft flight efficiency and reduction in environmental impact of aircraft, while improving the safety of air traffic.

The National Traffic Safety and Environment Laboratory is responsible for the following: preventing accidents involving vulnerable road users; research on technologies for ensuring the safety of land transportation including the promotion of the development and practical application of next-generation heavy vehicles; testing and research of technologies for environmental conservation; conformity inspection regarding technological standards of automobiles; and the verification of technological requirements for automobile recalls.

③ Construction of a comprehensive life care foundation system in the communities

For the purpose of clinical applications and life support, MEXT and MHLW are working to develop BMIs that can decode information in the brain in non-invasive or minimally invasive ways, to treat, recover and complement physical functions.

In support of disabled people's independence and participation in society, MHLW has been implementing the Project for Development and Promotion of Equipment to Support Independence of Persons with Disabilities. They seek to develop convenient support apparatuses that can be used easily by disabled people, as per their needs.

METI is promoting a project to provide support to private business operators who are engaged in R&D on welfare apparatuses. To facilitate the practical application of robot care devices in needed areas, METI has been implementing the Project to Promote the Development and Introduction of Robotic Devices for Nursing Care. The ministry is supporting the development on robotics technology by private businesses that address the needs of the elderly and care service personnel.

MLIT is developing technologies for creating and updating indoor 3D maps that form a new social foundation necessary to support people's moving and activities and technologies for outdoor, indoor and outdoor-indoor seamless positioning.

Toward construction of a universal society where everyone including the elderly and people with disabilities can engage in activities freely without stress, MLIT developed indoor digital maps and positioning environment in the vicinities of Tokyo and Shinjuku Stations, Narita Airport and the International Stadium Yokohama (Nissan Stadium) and conducted demonstration tests of movement support services for wheelchair users, etc.

(3) Extending service life for efficient and effective infrastructure

Concerning the research topic of "infrastructure maintenance, renovation and management technologies" under SIP, the Cabinet Office considers it important that the needs for maintenance be matched with the seeds of technological development. By translating new technologies into practical applications and by elevating the level of maintenance and management at low cost through preventive maintenance, the Cabinet Office aims to uphold high standards of maintenance and management for important domestic infrastructure. It is intended that the technologies used for this purpose help create an attractive and sustainable market for infrastructure maintenance and management. The Cabinet Office also promotes the export of infrastructure maintenance and management technologies.

MIC conducted R&D on telecommunications technologies for the collection and dissemination of data

with high reliability but ultra-low power consumption. Those data are strain and vibration data gathered by sensors at structures. The aim is the effective and efficient management and maintenance of infrastructure using ICT.

MLIT and METI have promoted the development and introduction of robots to maintain social infrastructure and implement anti-disaster measures more effectively and efficiently. METI is implementing the System Development Project to Solve Social Problems for Infrastructure Maintenance and Renewal to develop robots for priority fields.

MLIT is promoting i-Construction where ICT is used in all construction production processes from investigation/survey to design, installation, inspection, maintenance and renewal. The aim is 20% improvement of productivity in construction sites by FY2025.

National Institute for Land and Infrastructure Management (NILIM) is conducting research on i-Construction that contributes to innovation of construction processes.

In cooperation with other MLIT departments and agencies, NILIM has been developing technologies for the following: road structure maintenance; the prompt, automated, low-cost inspection of sewerage pipelines; the maintenance of river structures; the maintenance and service life prolongation of sea ports and airports; and efficient transportation of marine containers, in order to ensure continued safe use of existing social capital stock through more efficient and advanced inspection, repair and renewal.

Public Works Research Institute has been working on the development of: methods contributing to an effective (efficient, advanced) maintenance cycle of existing structures (bridges, pavements and management facilities); methods for renewal/construction of structures, which enables maintenance and long service life in accordance with the management level for bridges, civil engineering structures and tunnels, and; cross-cutting (roads, rivers, harbors, fishing ports and agriculture) technologies and systematization for maintenance and renewal of infrastructure susceptible to frost damage , complex deterioration and other damages.

MPAT has been working on: enhancement of functions of airports in the Tokyo Metropolitan area by conducting R&D pertaining to improvement of safety and maintenance efficiency of airport infrastructure including runways; technology development regarding inspection and monitoring of coastal zone infrastructure supporting the economic/social activities of the country, and; research contributing to maintenance efficiency and reduction in lifecycle cost.

NIMS has comprehensively conducted R&D in the material field, in which Japan excels, for technologies and new structural materials to inspect, diagnose, repair and upgrade infrastructure with the aim of extending the service life and enhancing the earthquake resistance of the social infrastructure.

■Table 2-3-2 / Major policies for the realization of sustainable society in response to super aging and population decline (FY2016)

Ministry/ Agency	Implemented by	Project
MEXT	AMED	Grants for promoting the development of medical and health care research
MHLW	MHLW	Project for Securing Safety in Clinical Research on Unapproved Drugs
		Subsidies for promotion and survey of the administration of the Ministry of Health, Labour and Welfare
		International joint clinical study promotion program
		Development of infrastructure for promotion of clinical study on regenerative medicine
		Development of Clinical Genomic Information Integrated Database
METI	METI/ Agency for Natural Resources and Energy (ANRE)	Project to Promote the Development and Introduction of Robotic Devices for Nursing Care
		Program to promote measures for aged buried pipes
		R&D and demonstration of smart mobility system
		Project focused on developing key technology for discovering and manufacturing drugs for next-generation treatment and diagnosis
		Project to develop key evaluation technologies toward industrialization of regenerative medicine, etc.
		Development of Medical Devices and Systems for Advanced Medical Services
		Medical-engineering collaboration business promotion project
		International cooperation in basic research on biofunction
MLIT	MLIT	Research on road technologies (ITS, etc.)

3 Improving competitiveness in manufacturing and value creation

(1) New manufacturing systems

① Construction of a platform for supply chain system

Construction of a new platform to integrate engineering system chains and production process chains will promote data utilization, improve productivity and create new added values.

Toward construction of a new manufacturing system across the supply chain using ICT, the Cabinet Office has been implementing demonstration tests of supply chain systems.

In an effort to promote creation of the platform, METI is supporting creation of advanced cases and developing compatible formats for sharing data of various machines and equipment. For small and medium manufacturers facing challenges in data utilization, METI has started to develop consultation centers to train and dispatch specialists who propose improvement plans and technologies tailored to each challenge.

In order to maintain and strengthen the international competitiveness of our maritime industry, MLIT has been promoting technology development for productivity improvement of the industry through efficiency improvement and advancement of ship operation, shipbuilding/shipboard design and production by utilizing information technologies including IoT and big data.

The National Institute of Information and Communications Technology (NICT) is conducting pioneering R&D on brain activity measuring technology to enable exploration of latent needs based on brain information.

② Development of innovative production technologies

In order to provide high-performance and high-quality products promptly and flexibly responding to diverse user needs, the Cabinet Office is developing innovative production technologies including 3D printers that process complex shapes at high speed and high accuracy.

METI is implementing the 3D printer technology-based manufacturing innovation program. Under this program, fundamental development is conducted for three-dimensional laminating molding technology suitable for manufacturing of high value-added parts, etc. (increasing speed, precision, functions, etc.) taking advantage of materials, machine control and other technologies where Japan is strong.

METI is also implementing "the project for development and practical application of 3D printer molding technology toward energy-saving manufacturing process." The project aims to establish new energy-saving manufacturing processes using the three-dimensional laminating molding technology before the rest of the world through obtaining experimental proof by quality confirmation, which a challenge for full-fledged introduction of the technology, and through development of optimal molding conditions and quality assessment methods for molded objects.

(2) Integrated materials development system

① Construction of highly reliable materials database

For strengthening of the international competitiveness of our materials industry, it is important to build a materials development system merging all science technologies necessary for materials development, including numerical simulation, theory, experiments, analyses and data science. The government is promoting consolidation and database compilation of reliable materials data held in industry, government and academia for the system construction.

② Establishment of materials development technologies utilizing databases

As part of the program to support establishment of innovation hubs, the JST is promoting the MI²I: Materials Research by Information Integration Initiative, under which computer and data sciences are used for the short-term development of materials with innovative functions. Under this program, NIMS that is a central organization of materials study works as the hub to gather human resources from industry, academia and governments to advance database building and merging with data science. At the same time, the JST is encouraging participation of a broader range of companies and working on implementation of new material designs including groundbreaking magnets, batteries and electric heat control.

■Table 2-3-3 / Major policies for strengthening of the competitiveness of monozukuri/kotozukuri (FY2016)

Ministry	Implemented by	Project
METI	METI	3D printer technology-based manufacturing innovation program
		Project for development and practical application of 3D printer molding technology toward energy-saving manufacturing process
		Demonstration project for robot introduction

Section 2 Ensure Safety and Security for Our Nation and its Citizens and a High-quality, Prosperous Way of Life

In order to ensure safety and security for our nation and its citizens and a high-quality, prosperous way of life, it is necessary to work toward disaster prevention, mitigation, and national resilience, as well as to ensure comfortable living environments and occupational health for citizens. In addition, it is essential to appropriately deal with changes in the national safety and security situations and the occurrence of crime, terrorism, and cyber attacks. We are working on science and technology innovation to address these issues.

1 Addressing natural disaster

(1) Improvement of prevention capabilities

Under the Special Project for Mitigation of Great Disaster which the Vulnerability of Cities Causes, MEXT is implementing survey and research for maintenance and restoration of urban functions. In order to contribute to improving the country's resilience against massive earthquake disasters including the feared Nankai Trough earthquake or earthquake that hits the Tokyo area directly, the National Research Institute for Earth Science and Disaster Prevention (NIED) has been conducting R&D of next generation antiseismic technologies and other seismic engineering research using the 3-D Full-Scale Earthquake Testing Facility (E-Defense).

MLIT has been developing and operating the Nationwide Ocean Wave Information Network for Ports and Harbors (AS) in mutual cooperation with MPAT and other research institutions. Data on waves and tidal levels observed across Japan are collected through this network, and details are published on MLIT's website in real time.

NILIM has been conducting research including the following: (1) Visualization of flood risk for appropriate use of river information for evacuation behavior, (2) method for high-accuracy prediction of sediment disaster using real-time observation/monitoring data, (3)measures for extremely severe disasters, such as landslides and urban flooding due to sudden torrential rainfall, (4) the development of strategic flood mitigation methods that are incorporated with urban development and that address the needs posed by climate change, (5) urban inundation countermeasures, using flexible pump operation through ICT, (6) road cleaning and restoration of infrastructure immediately after disasters, using airborne portable SAR, existing camera/sensors and other technologies, (7) faster initial response to large earthquakes, including R&D to support TEC-FORCE[1] activities, (8)evaluation criteria of evacuation support technologies for the elderly and people with disabilities in apartment buildings at the time of a disaster, 9) methods for utilization of natural/regional infrastructure in developing tsunami disaster prevention areas, 10) assessment of urban areas vulnerable to fire at the time of earthquake and effects of disaster prevention measures, 11) methods for safety/use performance evaluation of buildings afflicted by fires induced by an earthquake, 12) "the creation of tsunami- and fire-resistant towns," including the development of buildings that can be continuously used immediately after an earthquake and 13) advancement of tsunami and high-tide observation technologies to improve the safety of harbor areas.

Public Works Research Institute is working on technology development to reduce damage of flood disasters that have become extreme in recent years and damage of tsunami and sea level rise, prevent and

1 Technical Emergency Control FORCE

mitigate sediment disaster caused by sudden natural phenomenon, and reduce damage of snow/ice disaster caused by extreme weather.

The Building Research Agency is conducting technology development to ensure the structural safety of buildings, thus contributing to prevention of damage/collapse due to natural disasters and ensuring continued use of buildings.

Towards early recovery and reconstruction after a major earthquake, MPAT is conducting research on forecasting earthquake- and tsunami-related deformation and performance degradation for structures in coastal areas and the areas behind them, and on improved safety and reliability for facilities in coastal areas.

(2) Improvement of predictive capability

Under the Headquarters for Earthquake Research Promotion (Director: the Minister of MEXT; Hereinafter: Earthquake Headquarters), administrative agencies are working in close cooperation on seismological investigations and research.

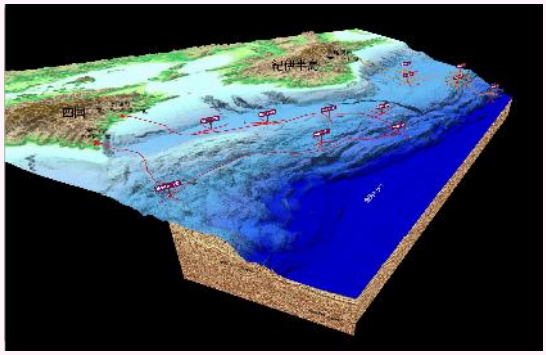
Because the long-term evaluations of the probability and scales of earthquakes conducted by the Earthquake Headquarters did not cover massive multi-segment earthquakes such as the 2011 Great East Japan Earthquake, conventional evaluation methods have been reviewed to discuss the renewal of evaluation methods.

At the time of the 2016 Kumamoto Earthquake, a M6.5 earthquake was followed by an even larger M7.3 earthquake. Because the existing method to predict aftershocks based on the assumption that main shock will be followed by an aftershock could not be used, Japan Meteorological Agency (JMA) cancelled announcement of aftershock probability on April 16 and after. The phenomenon revealed the issues for assessment of the prospect of seismic activities based on the existing method for assessment of aftershock provability as well as communication of the assessment results. In response, the Earthquake Headquarters compiled guidelines on announcement for disaster prevention after a major earthquake beyond aftershock provability assessment. The guidelines were published on August 19, 2016.

Kumamoto Earthquake taught us a lesson that results of earthquake survey and research including information of active faults had not been well known to local governments and residents, which led to insufficient disaster prevention/mitigation actions. In the light of this lesson, deliberation was made on review of descriptions of long-term assessment of active faults and a ranking was introduced combining the likelihood of earthquake occurrence and elapsed time ratio.

MEXT has conducted investigation and research into potential earthquakes which may cause tremendous social and economic damage under the Research Project for Compound Disaster Mitigation on the Great Earthquakes and Tsunamis around the Nankai Trough Region for Nankai Trough earthquakes. In the Project for Investigations of Earthquakes and Tsunamis in the Sea of Japan, controlled-source surveying and

■Figure 2-3-4 / IDense Oceanfloor Network System for Earthquakes and Tsunamis (DONET)

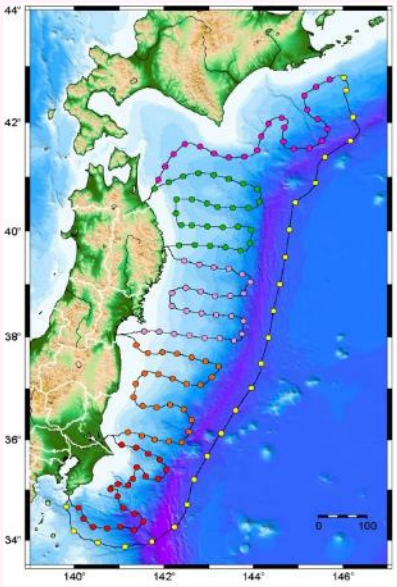


Source: MEXT

investigations of tsunami deposits were conducted to advance research on an earthquake source fault model and a tsunami source model that would be applicable to the Sea of Japan and its coast.

After the Great Hanshin-Awaji Earthquake, comprehensive earthquake observation networks were densely built in land areas. Although several sea-area observation networks have been built, there are far fewer observation points in these networks than in land-based observation networks. Accordingly, MEXT is operating the Dense Ocean floor Network system for Earthquakes and Tsunamis (DONET) that is a dense submarine network equipped with seismometers and hydraulic gauges for real-time seismic observation in the hypocentral region of the assumed Nankai Earthquake (Figure 2-3-4). Furthermore, off the Pacific Coast of Tohoku where large aftershocks and tsunamis are likely to occur, the Seafloor Observation Network for Earthquakes and Tsunamis along the Japan Trench (S-net) started operation to directly detect earthquake and tsunami to contribute to accurate and prompt communication of disaster information in fiscal 2015 (Figure 2-3-5).

■Figure 2-3-5 / Seafloor observation network for earthquakes and tsunamis along the Japan Trench (S-net)



Source: MEXT

In the field of volcanology, the FY2016 Integrated Program for Next Generation Volcano Research and Human Resource Development was launched to promote integrated research of "observation, prediction and measures" in coordination and jointly with other fields including geochemistry in response to the eruption of Mt. Ontakesan in 2014. At the same time a consortium for human resource development in volcanology was formed to strengthen cooperation among universities. The consortium has been providing systematic education programs linked to cutting-edge volcano research.

NIED is observing various tremors ranging from feeble tremors imperceptible to the human body to strong tremors causing big damage by using about 1,800 high-performance and high-precision seismometers covering the entire area of Japan evenly and densely. In addition, NIED is advancing research and implementation of real-time prediction of earthquake and tsunami as well as observation and prediction of volcanic activities by using its earthquake, tsunami and volcano observation networks including S-net, DONET and V-net (volcano observation network) described above. NIED is also conducting research on highly accurate rainfall prediction and sediment, storm and flood damage prediction based on multi-sensing and research contributing to reduction of damage caused by natural disasters including coastal disaster. Toward creation of new innovations of science and technology for disaster prevention, NIED launched formation of "an innovation hub to realize active reduction of weather hazard toward aggressive disaster prevention" with the goal of mitigating/preventing weather hazards and generating positive ripple effects for industry. In cooperation with convenience store companies, NIED is working to increase the precision of snow cover prediction by developing and installing new snow cover

sensors at convenience stores and thereby ensure physical distribution at the time of heavy snow and reduction of snow and ice related disaster.

JMA in cooperation with MEXT is collecting, processing and analyzing data of the fundamental observation/research network for earthquake, using the results for disaster prevention information, and providing them to the Earthquake Research Committee Headquarters for Earthquake Research Promotion and others. JMA collaborates with NIED to conduct R&D and further advance technologies for the earthquake early-warning system.

To collect geological information useful for disaster prevention, the National Institute of Advanced Industrial Science and Technology (AIST) conducts deposit surveys of active faults and tsunami sediment, conducts geological surveys of active volcanoes, and publishes the results of these surveys. Its geological surveys included 5 major fault zones nationwide on land and in the nearshore sea to clarify the fault distribution and the history of fault activities. AIST's database on tsunami deposits was released to the public in October 2015. Data collected in the each partial areas in Shizuoka, Mie and Wakayama prefectures, were added to the database. For short-term predictions of Nankai Trough Great Earthquakes, AIST continued to operate its integrated groundwater observation points to measure groundwater levels (water pressures), groundwater temperatures, crustal strains and seismic waves. Concerning the volcanoes where eruption activities were observed (Mt. Aso, Sakurajima and Nishinoshima), AIST conducted field investigations and analyzed volcanic products. The investigation and analysis results were used for material scientific studies that are expected to help understand the ongoing eruption activities and predict changes in these activities.

JAMSTEC is developing and deploying technologies to grasp changes in the fixation of plate boundaries directly above hypocentral regions continuously and in real-time using devices for long-term observation in boreholes of the deep sea drilling vessel "CHIKYU" and the submarine cable observation network. JAMSTEC is also conducting high-accuracy survey of the sub-seafloor structure of the sea areas with high urgency and importance with focus on segment borders of the Nankai Trough, which are important for assessment of linkage of the Tokai, Tonankai and Nankai earthquakes. A more realistic model will be built by incorporating the survey and observation results to contribute to more accurate crustal movement and tsunami simulations.

Geospatial Information Authority of Japan (GSI) engages in R&D on technologies for the observation and analysis of crustal and plate movements through continuous GNSS[1] observation at electronic reference stations[2], through Very-Long-Baseline Interferometry (VLBI[3]) and through SAR4 Interferometry[4], and R&D for advancement of tsunami prediction methods using information including earthquake source models that are obtained real-time based on GNSS data. Detailed monitoring of crustal movements in and around volcanoes has been implemented through integrated analysis of GNSS volcanic observation data, which have been collected in and around volcanoes by JMA, NIED, AIST, the Hot Springs Research Institute of Kanagawa Prefecture and the Earthquake Research Institute of the University of Tokyo.

1 Global Navigation Satellite System
2 There were 1,300 electronic reference stations across the country as of the end of March 2017.
3 Very Long Baseline Interferometry: an advanced technique that utilizes radio waves from deep space as far as billions of light years away for precisely measuring the distance between two radio telescopes situated thousands of kilometers away from each other within a tolerance of a few millimeters.
4 Synthetic Aperture Radar: a technique for using an artificial satellite for obtaining information about the evolution and state of earth's surface.

The Japan Coast Guard (JCG) has been advancing observations of crustal movements on the sea floor by means of GPS and echo ranging, as well as advancing surveys of submarine topography and active faults and announcing the observation results from time to time.

The Meteorological Research Institute (MRI) of JMA researches the following topics: the development of real-time scale estimation of tsunami/earthquake to mitigate damage by tsunamis, and tsunami forecasting based on offshore tsunami monitoring data; technologies for seismic intensity estimation that help improve the accuracy of earthquake early warnings; research of technologies for monitoring and analyzing crustal movements that help improve the accuracy of grasping of changes in fixation between plates along the Nankai Trough, and development of a monitoring method to advance volcanic activity assessment and prediction.

(3) Improvement of response capabilities

Natural disasters have been expanding in scale, so damage caused by them has been exacerbating and Japanese society has become increasingly vulnerable to these disasters. In light of these situations and the concept of disaster resilience, the Cabinet Office has been promoting R&D on technologies for a disaster-resilient information system under the SIP Program "Enhancement of Societal Resiliency against Natural Disasters." Resilient infrastructure minimizes disaster damage, thereby helping communities to withstand and rapidly recover from shocks and helping affected people to regain control of their lives. The "disaster information system for resilience" is based on advanced technologies for predicting, preventing and responding to disasters as well as for sharing information, and it can be used to improve the disaster prevention and mitigation capabilities of the national government, local governments, businesses and the public. At the time of Kumamoto Earthquake in April 2016, disaster response support was provided by using this system to integrate disaster-related data of relevant ministries and agencies.

MIC has been conducting R&D on ICT for improving the disaster-resistance of information and communications facilities, and for collecting data on damage at times of disaster. Having learned lessons from these problems, MIC has vigorously applied its research results, such as a communication system that can be carried in disaster-stricken areas for emergency restoration of communications (a movable and deployable ICT resource unit) in communities in Japan and worldwide.

In the Research Project for Supporting Regional Disaster-prevention Measures, MEXT developed a database based on research for disaster prevention measures from universities nationwide. Additionally, the utilization of research results in the formulation of regional anti-disaster measures was promoted.

NIED conducts research on the development of systems to summarize and use information of various natural disasters as well as research on methods and technologies to develop regional disaster prevention plans and maps using the system. At the time of the Kumamoto Earthquake in April 2018 NIED restored the damaged volcano observation facilities on Mt. Aso, installed attached seismographs as a backup and investigated eruption products of the explosive eruption in October 2016. In response to this earthquake, using the Sharing Information Platform for Disaster management (SIP4D) and NIED Crisis Response Site (NIED-CRS), NIED centrally summarized information disseminated from external organizations and information printed on paper in the disaster area in addition to the information of its own observation, analysis, assessment and survey. The results were used to support information sharing and utilization to contribute to unified situation recognition among responding organizations. In response to various natural

disasters that followed (e.g. Typhoon No.10, eruptive activities of Mt. Aso, earthquakes in Tottori, Ibaraki, etc., heavy snow on the Sea of Japan coast) NIED provided similar support for information sharing and use. Furthermore, NIED conducted emergency survey of topographic/ground information lost due to ground changes caused by the Kumamoto Earthquake, restored information necessary for the restoration/reconstruction plans of the local governments and created and published sediment movement distribution diagrams. NIED also made public GIS-based radar rainfall as reference information on danger zones due to heavy rain after an earthquake.

In response to the Kumamoto Earthquake and the Itoigawa big fire, for the purpose of speedy administrative procedures and the livelihood rehabilitation of victims, NIED, as an entity to support livelihood rehabilitation in industry-government-academia cooperation, supported certification of damage for victims, issuance of disaster certificate, compilation of victims' list and comprehensive livelihood rehabilitation support based on them. NIED also held briefing sessions on results of the Kumamoto Earthquake to report the efforts in April and June 2016.

MOD is conducting research on high-mobility powered suits that enables quick and agile action and travel on uneven ground while reducing weight load on personnel (See Chapter 3 Section 2, 4(2)).

FDMA's National Research Institute of Fire and Disaster has been conducting R&D on fire-fighting robots for deployment in the event of disasters at energy or industrial infrastructure sites. These robots feature sophisticated autonomy based on geospatial information technology and ICT, as well as cooperation and coordination among the robots. Thus, they will be able to collect information and to discharge fire-fighting water at disaster sites that are accessible only to robots. The institute completed the primary experimental models of four types of robots constituting the firefighting robot system. In addition, it started R&D of the following technologies: (1) high-accuracy prediction of earthquake damage to oil tank (identification of characteristics of short-period ground motion that is likely to cause damage to the oil tank body, influence of long-period ground motion on individual tanks due to differences in underground structure, etc.); (2) Powerful foam extinguishing technology tailored to the scale of fire, oil type, etc. of oil tank; (3) More suitable assessment of fire risk of highly reactive chemical substances (e.g. water reactive substance, substance prone to ignition caused by heat accumulation) stored or handled in petrochemical complexes) and safety management while firefighting.

In preparation for large-scale spread of fire in built-up area, which is feared after a Nankai mega thrust earthquake or earthquake that hits the Tokyo area directly, the institute has been conducting R&D to advance simulations of urban fire spread, elucidation of the phenomena of fire whirlwinds and flying sparks that expand damage, utilization of the results for evacuation guidance for residents and firefighting activities. In addition, it is conducting R&D on improvement of capability to investigate the cause of a fire in order to take effective fire prevention measures, and also launched R&D on effective evacuation from a building. Furthermore, the institution started R&D on search and rescue using image information from above obtained by UAV[1], etc. and a method to remove debris piled up all over the place.

NICT has been promoting R&D on an airborne polarimetric and interferometric synthetic aperture radar system (Pi-SAR2) that can observe the ground surface in disaster-stricken areas as needed, regardless of weather conditions, and electromagnetic wave sensing technology for nondestructive

1 Unmanned Aerial Vehicle

diagnosis of soundness of structures that might be damaged by an earthquake. MIC is also developing the following technologies: disaster-resistant wireless mesh network technologies that will allow local wireless networking even when the communication infrastructure is devastated, and a wireless relay technology that uses aerial drones as virtual communication towers. Together with the municipality, MIC is conducting field demonstration experiments of these technologies.

NILIM included disaster prevention and mitigation in its "disaster prevention, mitigation and risk management" issues to cope with a new stage of climatic changes, such as concentrated and regional heavy rainfall on the rise in recent days and is conducting research into anti-disaster measures for landslide and urban flooding caused by regional heavy rain, control of maximum possible river flooding and anti-inundation measures for cities through flexible ICT pump operation.

Public Works Research Institute is developing technologies to support risk management of water disasters in Japan and abroad, and technologies for minimizing damage of a major earthquake to structures and their early restoration

JAXA has been contributing to various disasters monitoring and grasping of the state of disaster using the second Advanced Land Observing Satellite DAICHI (ALOS-2[1]) and other satellites (See Chapter 3 Section 4.)

■Table 2-3-6 / Major policies for response to natural disasters(FY2016)

Ministry	Implemented by	Project
MEXT	MEXT	Financial contributions to the ITER International Fusion Energy Organization
		Integrated Program for Next Generation Volcano Research and Human Resource Development
METI	METI/ ANRE	Support for earthquake resistance reinforcement works for high-pressure gas equipment
MLIT	MLIT	Comprehensive R&D on construction technology (technical management) (flood control expenses)
		Comprehensive R&D on construction technology (technical management) (road improvement expenses)
	JMA	Development of the HIMAWARI geostationary meteorological satellite
MOD	Acquisition, Technology & Logistics Agency (ATLA)	Improvement of technology for environment recognition of CBRN-compatible remote-controlled work vehicles
		Research on high-mobility powered suits

(4) Response to the Great East Japan Earthquake and reconstruction/rebirth

① Industrial recovery from, and reconstruction after, the Great East Japan Earthquake in the afflicted regions

For the restoration of the offshore marine ecosystem, which was damaged by tsunamis on the Pacific coast of Tohoku, MEXT has established the Tohoku Marine Science Center in collaboration with local municipalities and national ministries. The center has been conducting surveys and other research on the offshore marine ecosystem. The results have been used to draft a local fishery plan and to select the

1 Advanced Land Observing Satellite-2

locations of fish farms.

Aiming at revitalizing agriculture, forestry and fishery, which are the main industries in the areas affected by the disaster, at accelerating the restoration and reconstruction of farm and fishery villages, and at fostering new types of agriculture, forestry and fishery that have high growth potential, MAFF has been conducting large-scale empirical research by applying cutting-edge technologies in agriculture, forestry and fishery, analyzing the effects of such technologies and promoting the dissemination of the research results. In doing so, MAFF has established empirical research sites for agriculture at farming villages in Iwate, Miyagi and Fukushima prefectures and has established empirical research sites for fishery at fishing villages in Iwate and Miyagi prefectures. Empirical research topics include land-extensive farming; greenhouse horticulture; and shellfish and fish culture, release and processing.

To realize the restoration of the areas affected by the Great East Japan Earthquake, as well as innovative R&D on renewable energy, not only is MEXT establishing an R&D base for super-efficient solar cells in Fukushima Prefecture, but it is also implementing R&D on renewable energy technologies in cooperation with the local governments, industry and research institutes, including universities, in the affected areas based on the Basic Guidelines for Reconstruction in Response to the Great East Japan Earthquake (decided by the Reconstruction Headquarters in Response to Great East Japan Earthquake, July 29, 2011) (hereinafter: "the Restoration Basic Plan").

■Table 2-3-7 / Major projects for recovery and reconstruction from the earthquake disaster (FY2016)

Ministry/ Agency	Implemented by	Project
Reconstruction Agency	Reconstruction Agency	Expenses needed for the promotion of R&D on the environment
		Tohoku Ecosystem-Associated Marine Sciences program
		Maintenance for National Universities and Inter-university Research Institute Corporations
		Tohoku Innovative Materials Technology Initiatives for Reconstruction
		Scheme to Revitalize Agriculture and Fisheries in the Disaster Area by Deploying Highly Advanced Technology (Reconstruction Special Account)
		Forest Decontamination Demonstration Project (Reconstruction Special Account)
		Verification of the Radioactive Decontamination of Forests and the Recovery of the Forestry Industry (Reconstruction Special Account)
		Promotion of projects for industry-academia-government collaboration and for regional scientific technology
	AIST	Fukushima Renewable Energy Industry Support Program
	AMED	Grants for promoting the development of medical and health care research
MEXT	MEXT	Expenses for the operation of the earthquake and tsunami observation/surveillance system

② Efforts on compensation for nuclear damage

The purpose of the Act on Compensation for Nuclear Damage (Act No. 147 of 1961) is to protect persons suffering from nuclear damage and to contribute to the sound development of the nuclear industry by establishing the basic system regarding compensation in case of nuclear damage caused by reactor

operation etc. The act concentrates liability for nuclear damage on the nuclear operators and places unlimited liability without fault on them. In order to ensure prompt payment of compensation by the nuclear operators, the act provides an obligation of provision of financial security by nuclear operators and the aid from the government when nuclear damage exceeds the financial security amount, as well as establishment of the Dispute Reconciliation Committee for Nuclear Damage Compensation to ensure smooth and appropriate payment of damages.

Since the accident at the TEPCO Fukushima Daiichi and Daini Nuclear Power Stations (hereinafter: the accident), a number of residents have been forced to live in evacuation shelters or to give up business activities such as manufacturing and sales. It is essential that these victims receive compensation promptly, equitably and appropriately, so that they may return to safe, secure living as quickly as possible. To this end, various measures have been taken for victims of the accident based on the Act on Compensation for Nuclear Damage.

MEXT instituted the Dispute Reconciliation Committee for Nuclear Damage Compensation. The committee has been formulating guidelines to indicate the damaged items that can be classified with certain criteria and the extent of compensation, with the input of local opinions, and it has been reviewing these guidelines as needed. Furthermore, the Nuclear Damage Compensation Dispute Resolution Center has been conducting reconciliation of alternative dispute resolutions while improving its operations and increasing in personnel.

The government approved the New Comprehensive Special Business Plan in January 2014 (followed by revisions in April and July 2015, March 2016 and January 2017), which made mention of providing prompt and appropriate compensation for nuclear damage and streamlined management in TEPCO. The government has been providing assistance to TEPCO through the Nuclear Damage Compensation and Decommissioning Facilitation Corporation for providing compensation smoothly.

The Advisory Committee on Nuclear Damage Compensation System of the Atomic Energy Commission has been studying review of the compensation system, using specialized and cross-sectional viewpoints. The Advisory Committee compiled "Issues, Direction of Rebuilding of Japan's Nuclear Damage Compensation System" in August 2016 and has been considering deliberation of individual issues.

2 Ensuring food safety, living environments, and occupational health

(1) Ensuring food safety and security

MEXT publishes the Japanese Standard Tables of Food Composition, which lists the composition of the Japanese diet. As high-quality data pooling had been required to address the needs of the modern Japanese diet, MEXT compiled "the Standard Tables of Food Composition in Japan 2015 (seventh revised edition) Supplementary edition 2016" in FY2016. The new table lists a greater variety of foods.

MAFF is working on development of technologies for reducing the risk posed by hazardous microbes and chemicals during the production, distribution and processing processes in order to ensure the stable supply of safe agricultural, livestock and marine products and; the enhancement of accuracy and efficiency of communicable disease control and development of diagnostic methods, with the aim of lowering the risk of spreading of major livestock diseases and thereby reducing farmers' economic losses.

(2) Ensuring safety and security of the living environment

①Implementation of radiation monitoring

With respect to the radiation monitoring necessitated by the accident at the Fukushima Daiichi Nuclear Power Station of TEPCO, ministries, local municipalities and other authorities are measuring air dose rates at monitoring posts, analyzing radioactive substances in soil in terms of nuclides, analyzing radioactive substances in the water and deposit in rivers and seas, and monitoring radioactive substances in food and tap water. This is being done in line with the Comprehensive Monitoring Strategy (adopted by the Monitoring Coordination Meeting in August of 2011 and revised in April 2015) (Figure 2-3-8).

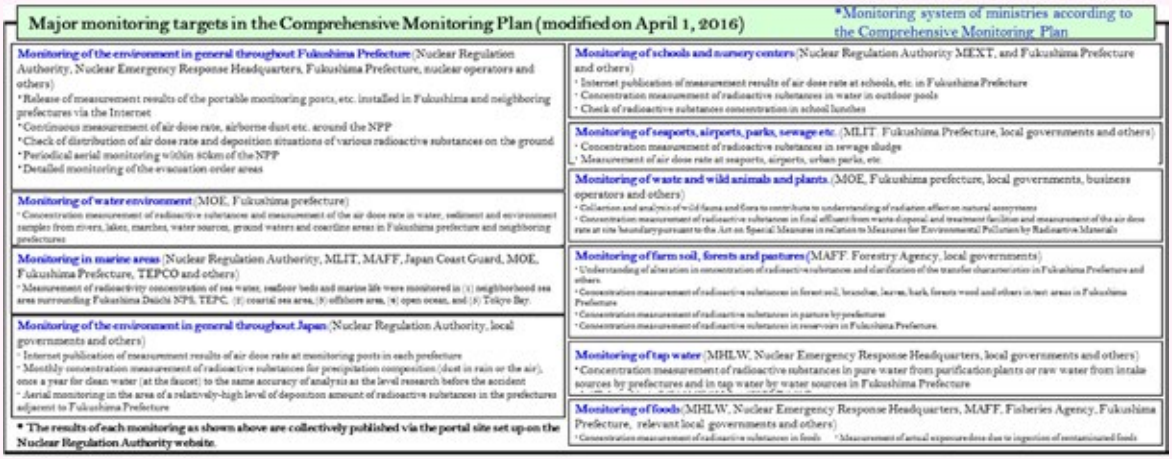
The Nuclear Regulatory Authority is the governing body for radiation monitoring. It confirms and analyzes monitoring data from organizations concerned and publishes a monthly summary on its website[1].

In FY2016, to clarify the distribution of radioactive substances released as a result of the accident at the TEPCO Fukushima Daiichi Nuclear Power Station, the ministry collated information concerning the distribution radio cesium and the like (Figure 2-3-9). The ministry also published the results of travel surveys conducted in cooperation with local governments. In addition, the ministry conducted aerial monitoring within and beyond an 80-km circumference from the TEPCO Fukushima Daiichi Nuclear Power Station and announced the air dose rates (Figure 2-3-9). In coastal areas, sea water, seafloor beds and marine life off the coasts of Fukushima, Miyagi and Ibaraki prefectures were jointly monitored by the relevant ministries and local governments in line with the Implementation Guides on Sea Area Monitoring formulated on April 1, 2016.

Air dose rates are measured by a real-time dose measurement system set up in Fukushima Prefecture, using portable monitoring posts set up in the whole of the prefecture and neighboring prefectures and by fixed monitoring posts set up in all prefectures throughout Japan in order to strengthen the nationwide radiation survey system. These measurements are displayed on the website on a real-time basis (Figure 2-3-10).

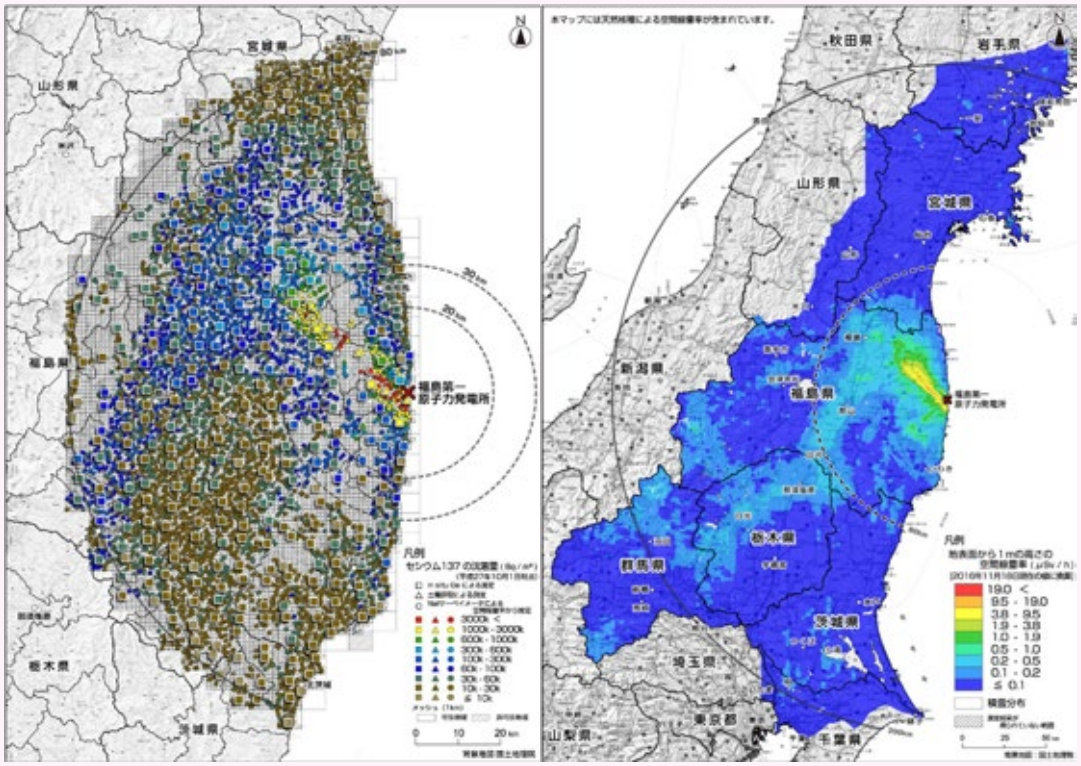
1 http://radioactivity.nsr.go.jp/ja/index.html

■Figure 2-3-8 / Monitoring system implementation by ministries in accordance with the Comprehensive Monitoring Strategy (FY2016)



Source: Nuclear Regulatory Agency (NRA)

■Figure 2-3-9 / Radioactive substances distribution map



* Cesium 137 soil concentration map (as of October 1, 2015: 54 months after the accident) (left)
* Spatial dose rate map of Fukushima and neighboring prefectures (as of November 18, 2016: 68 months after the accident) (right)

Source: Nuclear Regulatory Agency (NRA)

■Figure 2-3-10 / Sample of Radiation measurement map

* The system has been managed by the Nuclear Regulation Authority (NRA) since April 2013

Monitoring information of environmental radioactivity level, Nuclear Regulation Authority: http://radioactivity.nsr.go.jp/ja/

Source: Nuclear Regulatory Agency (NRA)

MAFF conducted surveys on the distribution of radioactive materials in farmland soil to advance efforts to restart farming. These include farmland decontamination.

② Efforts for measures against radioactive substances

The organizations concerned are working together on development of technology and research and study towards establishing measures to deal with radioactive substances, for the purpose of remediating the environment contaminated by radioactive materials released in the accident at the TEPCO Fukushima Daiichi Nuclear Power Station.

Not only does MAFF develop technologies aimed at the effective and efficient countermeasures on radioactive materials in forests and farmlands, but it also has demonstrated the technologies so far developed, to establish them as methods applicable in the needed places. Their results are published swiftly.

MAFF is also developing technologies to deal with various post-decontamination challenges, such as technologies for controlling the luxuriant growth of weeds and for controlling soil runoff after the decontamination of agricultural land.

MOE has compiled a strategy for developing technologies regarding the volume reduction and recycling of radioactive substances towards the disposal of soil derived from decontamination within Fukushima Prefecture outside the prefecture. The ministry has also been carrying out a project to verify technologies for volume reduction from the viewpoint of assessing the effectiveness, economy and safety of technologies that can be utilized in fields.

JAEA moved into the research building of the Fukushima Environment Creation Center, which opened

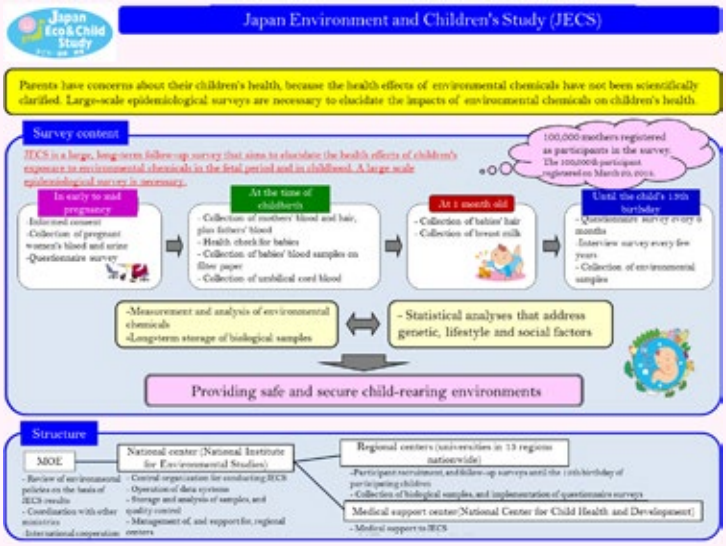
in April 2016. In coordination and cooperation with Fukushima Prefecture, the National Institute for Environmental Studies (NIES) and others, JAEA is conducting R&D into technology for measuring radiation doses, research on the behavior of radioactive substances in the environment and R&D on technologies for the volume reduction and recycling of radioactive substances. The aim is to restore environments that were contaminated by radioactive substances released in the accident at the TEPCO Fukushima Daiichi Nuclear Power Station.

③Efforts to clarify environmental risks to children

In FY 2010, MOE started a large-scale, long-term birth cohort study, the Japan Environment and Children's Study (JECS), by enrolling 100,000 pairs of parents/children across the country in the study.

In this study, blood of mothers, umbilical blood, breast milk and other biological samples of the subjects were taken, preserved and analyzed. Follow-up studies will be conducted using questionnaires, until the children reach 13 years of age to clarify the influences of environmental chemical agents on children's health[1] (Figure 2-3-11).

■Figure 2-3-11 / Japan Environment and Children's Study (JECS)



Source: MOE

Under JECS, NIES serves as the core center and the National Center for Child Health and Development (NCCHD) serves as the medical support center. NIES develops research plans and analyzes biological samples. The NCCHD provides medical support. Concurrently, unit centers, which are publicly recruited from 15 districts throughout Japan, have been conducting follow-up studies. Based on the results of this study, MOE will re-examine environmental policies. In fiscal 2016, follow-up using questionnaires and detailed investigations were continued, which include collection of environmental specimens and medical examinations covering about 5,000 children chosen from the 100,000 children enrolled in the nationwide survey.

1 http://www.env.go.jp/chemi/ceh/

■Table 2-3-12 / Major policies to ensure food safety, living environment, occupational health, etc. (FY2016)

Ministry	Implemented by	Project
MHLW	Radiation Effects Research Foundation	Expenses required for R&D on technology using radio waves for radio use financial source
	Prefectural governments	Cost for Commissioning Toxic Gas Disability Person Investigation
MAFF	MAFF	Regulatory science for stable supply of safe agricultural, forest and fishery products
MOE	MOE	Expenses for comprehensive measures against particulate matter (PM 2.5), etc.
	Nuclear Regulation Authority (NRA)	Costs for commissioning surveys on the level of radioactivity
		Costs for commissioning surveys on a comprehensive radiation assessment of the marine environment
		Costs of surveying the effects of the nuclear power plant accident
		Cost of commissioning of establishment of aircraft monitoring operation technology

3 Ensuring Cybersecurity

For the purpose of comprehensively and effectively advancing measures for Cybersecurity pursuant to the Basic Act on Cybersecurity (Act No. 104, 2014), R&D on technologies for Cybersecurity have been promoted on the basis of the Cyber Security Strategy, which was decided by the Cabinet in September 2015 after deliberations by the Cybersecurity strategy headquarters led by the government.

In August 2016 the "General Framework regarding Security for Safe IoT System" was formulated to study specific measures for promotion of security of IoT systems.

In order to protect critical infrastructure supporting the people's everyday life from cyber attacks, the Cabinet Office launched the Cyber-Security for Critical Infrastructure (SIP). Under this program, it is conducting R&D of operation monitoring/analysis and defense technologies including authenticity determination (technology to confirm authenticity and integrity of equipment/software) of control/communication equipment, while promoting R&D activities aimed at strengthening of international competitiveness of critical infrastructure industries and contribution to stable operation of the 2020 Tokyo Olympic and Paralympic Games.

In order to address damage caused by malware infection of users that is increasing in recent years, MIC is calling the attention of Internet users to malware infection, and also conducting a demonstration test to accumulate information regarding malware distributing sites and warning users trying to access the sites. To respond to an increasing number of targeted attacks that aim at stealing confidential information, practical exercises have been implemented to defend against cyber attacks that target government offices, significant infrastructure operators and local authorities.

■Table 2-3-13 / Major policies for cyber security (FY2016)

Ministry	Implemented by	Project
METI	METI	The development of economic infrastructure for Cybersecurity

4 Addressing national security issues

The National Security Strategy states: "The advanced technology of Japan constitutes the foundation of its economic strength and defense forces, and is also a valuable resource that the international community strongly seeks from Japan. Therefore, Japan should encourage the further promotion of technologies, including dual use technologies, thereby strengthening Japan's technological capabilities."

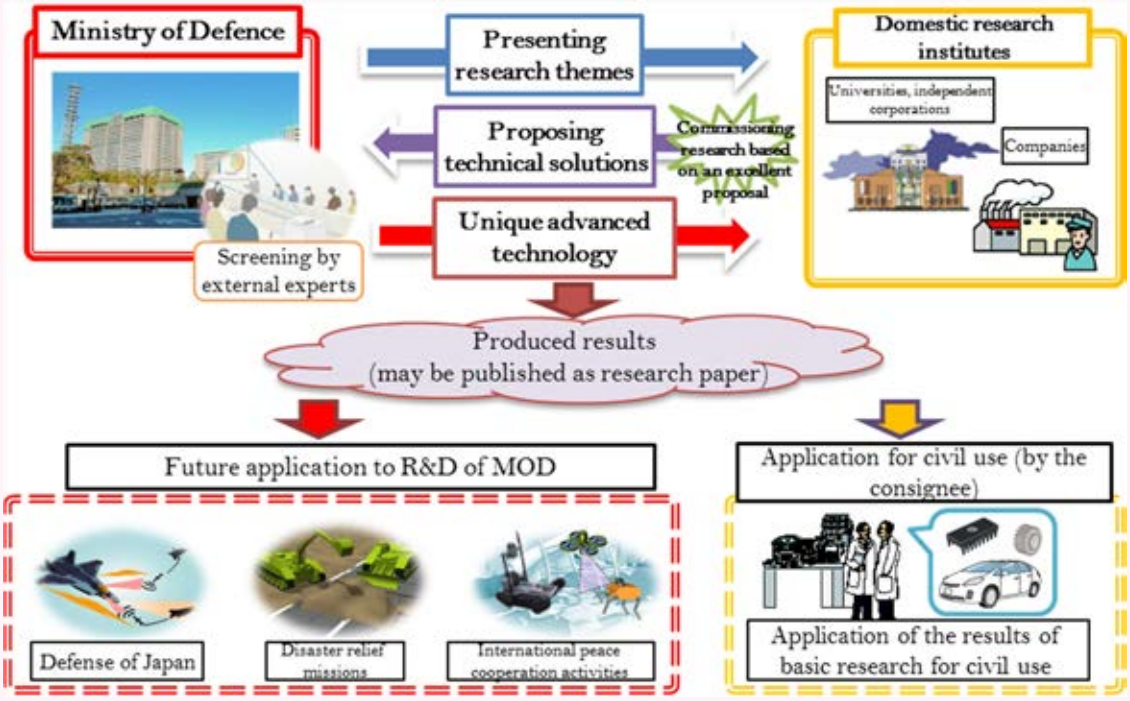
The 5th Science and Technology Basic Plan suggests that "the fruit of science and technology have the potential to make impacts in multiple areas" and "In view of the increasingly challenging environment surrounding national security, in order to ensure the safety and security of the nation and its citizens, it is important to make use of Japan's many outstanding technological strengths." Based on the National Security Strategy and the 5th Science and Technology Basic Plan, it is necessary to promote R&D on technologies necessary to address national security issues in cooperation with relevant ministries and through industry-academia-government collaboration.

(1) National Security Issues

Comprehensive Strategy on Science, Technology and Innovation 2016 holds up "relevant ministries shall cooperate to strengthen the system to grasp, overview, survey and analyze science and technology trends in Japan and abroad, while at the same time enhancing R&D to strengthen technologies contributing to the safety and security of citizens and the nation" as "priority initiatives."

Hoping for future contribution to R&D in the field of defense, MOD launched Innovative Science & Technology Initiative for Security to publicly invite and commission research on advanced civil technologies (Figure 2-3-14) in fiscal 2015. The initiative seeks research projects based on the freewheeling thinking of researchers in the field of basic research. In order to contribute to broad development of research, all research results may be made public. No secret: including specially designated secrets, will be provided to consignees or no research result will be designated as secret: including specially designated secrets. Results of research conducted under the initiative have been published at conferences and in academic journals.

■Figure 2-3-14 / Outline of Innovative Science & Technology Initiative for Security

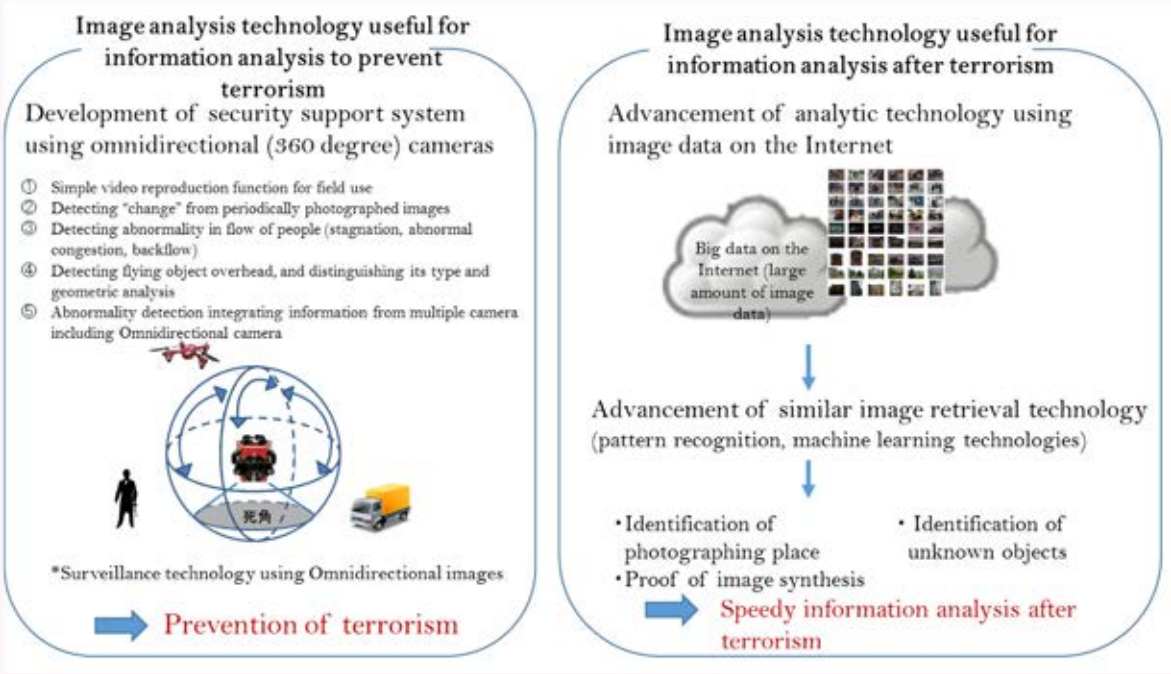


Source: Acquisition, Technology & Logistics Agency (ATLA)

(2) Anti-terrorism policy

With the aim of advancing image analysis technology useful for information analysis for terrorism prevention or reviews after terrorist acts, the National Research Institute of Police Science is working on the development of a security support system using omnidirectional cameras and R&D on analytic technologies using image data on the Internet (Figure 2-3-15).

■Figure 2-3-15 / Outline of research for advancement of image analysis technology to address terrorism



Source: National Police Agency

MOD has been conducting research to greatly improve the workability of unmanned vehicle operators by swiftly creating overview displays and 3D area maps suitable for remote control by integrating images obtained from multiple unmanned vehicles and laser scanner information in inhospitable disaster sites such as a the CBRN[1] contaminated environment. In order to support disaster relief activities of the SDF (Self-Defense Force), MOD is also conducting research on high-mobility powered suits that enable quick and agile action and travel on uneven ground while reducing weight load on personnel. Furthermore, in order to visualize CBRN contamination and present detailed contamination status and damage estimation, research is conducted on a threat determination system to estimate contamination source areas based on dispersion prediction considering detailed topography including buildings in midtown and information from sensors.

1 Chemical, Biological, Radiological, Nuclear

Column 2-3 Security and Science &Technology

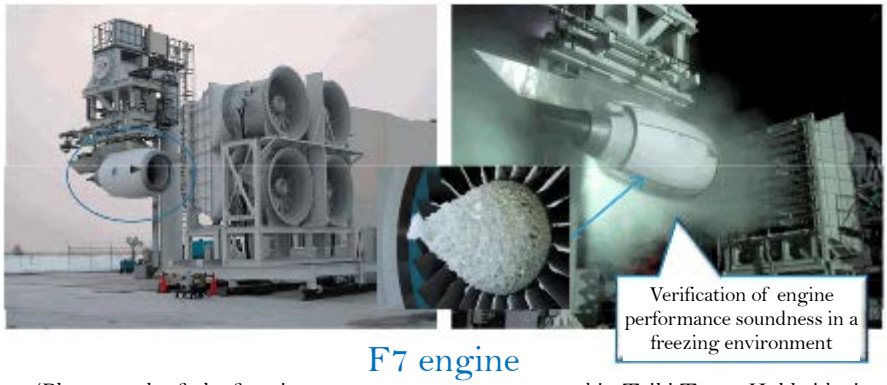
In August 2016, the Ministry of Defense announced the Defense Technology Strategy and the medium- to long-term defense technology outlook (DTO) for the coming 20 years for effective and efficient strengthening of technologies that are the foundation of defense of the nation.
(http://www.mod.go.jp/atla/soubiseisaku_plan.html)

With the aim of strengthening Japan's technological capabilities, the strategy sets two goals to achieve the objective. One is "to create superior defense equipment effectively and efficiently" for operational needs of the Self-Defense Forces including disaster relief operation; the other is "ensure technical advantage" that contributes to enhancement of our defense capacity.

As suggested by terms such as "potential to make impacts in multiple areas" and "dual use" superior science and technologies in recent years have become the foundation of economic and defense power. Japan is rich in superior science and technology.

Japan's superior technological capabilities are supported by the government, company, university and other research institutes. Strengthening our technological capabilities is critically important to realize affluent and high-quality life for the people and continue to guarantee safety and security of the nation and its citizens.

An example of the potential of science and technology to make impacts in multiple areas
—F7 engine developed by the Acquisition, Technology & Logistics Agency contributes to the development of domestic aviation industry—



F7 engine

(Photograph of the freezing environment test conducted in Taiki Town, Hokkaido, in 2006. Left: setup engine; right: testing)

In December 2016, ATLA and IHI agreed on the transfer of F7 Engine technology developed for P-1 fixed-wing patrol pane for civil use toward utilization for R&D by JAXA.

By introducing the F7 Engine to JAXA, the world-leading engine technologies developed by JAXA and industry can be demonstrated using practical engines, which is expected to contribute to the development of the domestic aviation industry in the future.

■Table 2-3-16 / Major policies to address national security issues (FY2016)

Ministry	Implemented by	Description
MOD	ATLA	Innovative Science & Technology Initiative for Security
		Improvement of the environment recognition technology of CBRN-compatible remote-controlled work vehicles
		Research on technologies of CBRN threat determination systems
		Research on high-mobility powered suits

Section 3 Addressing Global Challenges and Contributing to Global Development

Response to Climate Change is a pressing issue for Japan and the world. Based on the Paris Agreement that became effective in November 2016, the country needs to enhance efforts to mitigate climate change by greatly reducing greenhouse gas emissions while making efforts for adaptation.

1 Addressing global climate change

(1) Development of technologies for observation of the earth environment and continued observation

①The promotion of Earth observation

To understand current global warming trends, many countries and organizations worldwide have been observing the Earth by satellite, ground-based and maritime observation systems. To enhance the effectiveness of global efforts for tackling climate change problems, Earth observation data should be integrated and analyzed through international collaborations, to accumulate useful scientific knowledge as a basis for policymaking in each country. It is also important to develop the Global Earth Observation System of Systems (GEOSS), which consists of multiple systems that facilitate access by many countries and institutions to observation and other scientific data. The Group on Earth Observations (GEO) was established as an international framework to promote the development of GEOSS. It had 210 countries and institutions as members as of February 2017. Japan has been playing a leading role on the GEO Executive Committee.

② Satellite-based observation

To promote satellite observations of the earth, JAXA has been operating the Global Change Observation Mission - Water "SHIZUKU" (GCOM-W) and the Advanced Land Observing Satellite-2 "DAICHI-2" (ALOS-2), and has been conducting R&D for the Global Change Observation Mission - Climate (GCOM-C) and for other satellites (See Chapter 3, Section 4.)

MOE has promoted the observation of global carbon circulation in collaboration with related ministries and agencies to help clarify climate change and its effects. Specifically, the ministry has developed global carbon dioxide and methane observation technologies using the Greenhouse Gases Observing Satellite "IBUKI" (GOSAT) and has continuously monitored greenhouse gases using airplanes and ships, and monitors on the ground. With the aim of further promotion of global warming countermeasures, this satellite has been used for the collection of observation data on global GHG (greenhouse gas) concentration distributions and changes. The data are needed to improve the estimation accuracy of GHG absorption and emission. GOSAT has been successfully clarifying the global concentration distributions of carbon dioxide and methane, as well as seasonal changes in these distributions. Based on GOSAT data, absorptions and emissions of carbon dioxide and methane are estimated by month and by subcontinent, three-dimensional carbon dioxide distribution data, and average carbon dioxide concentration in the global atmosphere are estimated. These estimation results are made available to the public. An analysis of observation data of IBUKI indicated their usability as a verification tool for GHG emission inventory. The ministry started development of the successor to GOSAT with the aim of further improving the observation accuracy. It is scheduled for launch in FY 2018. Multi-point observation data collected by the

IBUKI (GOSAT) and the successor of IBUKI (GOSAT-2) satellites will contribute to the science of climate change, global environmental monitoring and the formulation of measures against climate change. These satellites will also be used to collect data on carbon dioxide emissions from large cities and other large-scale emission sources.

Data of the SHIZUKU (GCOM-W) launched for the purpose of elucidating the global mechanisms of climate change and the water cycle in May 2012, and the data of the core satellite launched in February 2014 in cooperation with NASA under the international Global Precipitation Measurement (GPM) project are used to improve the accuracy of precipitation estimates. Not only are the data used for research on climate change, but they are also used for various other purposes, including weather forecasting and fishing ground detection.

JMA verified that the use of SHIZUKU (GCOM-W) data has helped to increase the accuracy of precipitation estimates in numerical prediction as well as the accuracy of analyses for sea surface temperature and sea ice. Since FY2013, JMA has used the same data from GCOM-W for a numerical prediction system that JMA operates routinely and for analyzing sea surface temperatures and sea ice. Since 2016, Observation data of the GPM core satellite has been used in the numerical forecasting system, which contributes to the improvement of the accuracy of precipitation estimates.

③ Ground and oceanographic observations

The marine environment is rapidly changing in recent years: sea temperature is rising and ocean acidification is progressing worldwide, for example. We need to understand the changes in the marine environment for preservation of oceans and marine resources and their sustainable use, and elucidation of global environment changes. To this end, JAMSTEC has been comprehensively observing global environmental changes, which are significantly influenced by the oceans. For this purpose, JAMSTEC is capitalizing on its advanced observation technologies that rely on research vessels and observation buoys.

MEXT and JMA are participating in an ocean observing system (the Argo program[1]) for continuous observation of oceans around the world through international cooperation. The Argo program aims at the real-time monitoring and evaluation of oceans around the world based on Argo floats deployed in these oceans.

MEXT is promoting research and observation in various fields related to the Antarctic and Arctic, where it is possible to accurately measure global environmental changes. The Antarctic Research Programs have been administered by the Headquarters for the Japanese Antarctic Research Expedition (Chief of the headquarters: the minister of MEXT), in cooperation with other ministries and research institutions, including the National Institute of Polar Research (NIPR). They are collaborating with other nations and research and observation in the Antarctica was conducted based on the 9th Six-Year Antarctic Research Program (FY2016- FY2021).

Regarding the Arctic, the Headquarters for Ocean Policy at the Prime Minister's Office decided Japan's Arctic Policy on October 16, 2015. The Arctic Challenge for Sustainability Project (ArCS) started in FY 2015. Under the project, climate change in the Arctic and the impacts of such change on the global

1 Based on the understanding that environmental issues significantly and seriously affect the humanosphere, the Environment Research and Technology Development Fund, a policy-oriented competitive research fund, was created.

environment have been comprehensively studied to forecast such change and impacts with high accuracy and to clarify the socioeconomic effects of such impacts. The project aims to provide stakeholders with the obtained information so that they can make appropriate decisions and address issues. To this end, international joint research has been promoted, a center for international research has been developed and the fostering of young researchers has been promoted. In addition, CST's Subdivision on Ocean Development compiled the future direction of arctic study. Furthermore, the "Investigative Commission on Arctic Research Vessels" was convened to discuss the direction of Arctic research from the viewpoint of technical specialists for steady promotion of Arctic research.

JAMSTEC has established the Institute of Arctic Climate and Environment Change Research to promote Arctic research. JAMSTEC is also developing autonomous unmanned exploration vehicle (AUV) capable of autonomous navigation and observation under sea ice and technologies for other elements. In FY2016 JAMSTEC implemented test observation using small AUVs and succeeded in conducting Japan's first autonomous navigation under sea ice, acquisition of observation data including salt content and water temperature, and photography under sea ice.

JMA has been conducting observation and analysis of GHGs, aerosols, ground radiation, the ozone layer and ultraviolet radiation in the atmosphere and oceans. By collecting and analyzing various observation data from ships, Argo floats and satellites, JMA provides information related to the global environment.

JMA has also been observing greenhouse gasses in the atmosphere at three sites in Japan and at the Showa Station in Antarctica. In addition, JMA is observing greenhouse gasses in seawater and in the atmosphere near seawater by using an ocean weather observation ship, and in the atmosphere at high elevations in the northwest Pacific Ocean by using an aircraft. These data and other observed global warming related data and their analyses are made available to the public. JMA has also been observing the ozone layer and ultraviolet rays in the atmosphere at four sites in Japan and at the Showa Station in Antarctica.

(2) Advancement of climate change prediction technologies using super computers, etc.

MEXT has been promoting R&D towards the creation of basic information that will be necessary for the management of diverse risks posed by climate change. For this purpose, the world's fastest supercomputers including the Earth Simulator are used to advance climate change prediction technologies through development of climate models, etc.

MRI under JMA has developed the MRI Earth System Model for global warming prediction. It can simulate the effects of aerosols on clouds, changes in the ozone layer and the carbon cycle. Using this model, the institute is making near-future climate change predictions (i.e., about 10-year lead time) and long-term predictions based on IPCC emissions scenarios. The institute has also developed a sophisticated cloud-resolving regional climate model that has sufficient resolution to simulate Japan's unique local climatic phenomena. The aim is spatially detailed regional climate warming prediction.

JAMSTEC has been making full use of its supercomputer systems to develop the most advanced predictive models and simulation techniques. These are used to elucidate the possible impacts of global environmental changes on Japan and to help solve climate change problems from the viewpoint of marine science.

(3) Development of information base integrating observation and prediction data

MEXT has developed the Data Integration and Analysis System (DIAS). DIAS integrates and analyzes Earth Observation data, climate change and social and economic data gleaned from Earth Observation satellites and from land and ocean observations to create useful information. The system has supported R&D in Japan and abroad and produced results especially for water issues. In FY2016, MEXT launched the Program for the Develoment of Earth Environmental Information Platform. Under the program the ministry is working to establish a management structure to ensure its long-term stable use by a large number of users including enterprises in Japan and abroad, and also promoting development of common fundamental technologies contributing to solution of social challenges in various fields including disaster prevention, energy and agriculture. For the creation, under the World Data System (WDS), of a scientific data platform that will be the largest size in the world and that is being promoted by the International Council for Science (ICSU[1]), NICT has been selected to host this endeavor's International Program Office. NICT is building a network with the Science Council of Japan (SCJ) and related domestic and international research institutions. By gathering scientific papers and their reference data on Earth observation, NICT is developing a global-scale science data platform that allows the stored data to be analyzed and is conducting R&D for reference relation analysis among reference data of different papers.

NICT is also analyzing data from the Superconducting Submillimeter-wave Limb-Emission Sounder (SMILES[2]) that NICT developed in cooperation with JAXA, and is providing stratospheric observation data. MIC has implemented R&D on the electromagnetic environment and on the use of radio waves in geospace, and has collected, managed, analyzed and distributed space/Earth observation data in an integrated manner. Additionally, the development of space environment informatics technology[3] has been promoted, with the aim of enhancing technologies for observation, sensing and numerical calculation, and for the processing of large amounts of data.

In addition, JMA is collecting observation data on the above items from ships, Argo Floats and satellites and by using other means, and has been analyzing such data. These results have been published in a report called The State of the Ocean Climate, which provides information on current conditions and the prospects for changes in oceanic fluctuations related to global warming.

With international cooperation, GSI of Japan is promoting earth observation and the Earth Map, which is fundamental geospatial information to be used for a field, such as measures against global warming. GSI is developing technologies for data development using earth observation satellite data.

(4) Efforts for reduction in carbon dioxide and other emissions

Aiming at the practical use of Carbon Dioxide Capture and Storage (CCS), METI is advancing R&D for the demonstration of an integrated system designed to separate and capture carbon dioxide from large carbon dioxide sources and store it underground at depths of more than 1,000 m, as well as developing technology to drastically reduce costs and improve safety.

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1 The International Council for Science (ICSU): This non-governmental, non-profit, global academic organization was established in 1931. Its mission is to strengthen international activities in the applied science and other science for the benefit of society.

2 Superconducting Submillimeter-Wave Limb-Emission Sounder: SMILES performs observations of the atmospheric limb by using an offset Cassegrain antenna. The high-sensitivity, low-noise superconducting receivers of SMILES receives submillimeter waves emitted by atmospheric trace species in order to measure the concentrations of ozone and other molecules. The frequency range from 300 GHz to 3,000. GHz is the submillimeter-wave range. GHz is the submillimeter-wave range. SMILES uses sub-millimeter waves ranging from 624 GHz through 650 GHz.

3 Space environment informatics technology is used for processing large quantities of diverse data collected from observations and simulations of the space environment and for extracting information from the processed data.

In steel manufacturing, the ministry is developing innovative carbon dioxide reduction technologies, including a technology to partially substitute hydrogen for coke as a reductant in steel manufacturing and to separate and capture carbon dioxide from blast furnace gas toward further improving the utilization efficiency of fossil fuels.

MOE has been compiling (1) costs of separating and recovering most of carbon dioxide from exhaust gas from coal fired power plants, (2) design and construction of carbon dioxide separation/recovery equipment toward assessment of degradation in power generation efficiency and environmental impact, and (3) methods for smooth introduction of CCS suitable for Japan.

METI and MOE have jointly conducted geological investigations, including elastic wave explorations, to determine areas suitable for CCS in Japan.

With the aim of further reducing carbon dioxide emissions in international marine transportation, MLIT made integrated efforts to support R&D on innovative energy-saving technologies for ships and to forge an international framework for regulating carbon dioxide emissions from ships. The developed technology is expected to be deployed around the world.

With the aim of greatly reducing carbon dioxide emissions from ships, MPAT is conducting research on basic technologies that afford great reductions in environmental impact by facilitating the implementation of common-sense environmental regulations aimed at zero emissions.

MPAT is promoting research that includes onsite surveys in coastal areas and experiments aimed at quantitatively measuring the atmosphere/seawater gas exchange rate and the carbon flow between the seawater and benthic ecosystems (benthic flora, fauna and sediments). The aim is to establish a method for measuring blue carbon, which has potential for both domestic and international applications.

NILIM is conducting studies on sewerage disposal technology to reduce greenhouse gas emissions and collect energy and resources, technology to improve energy-saving performance of houses, and low-carbon urban development through improvement of the thermal environment of cities by using vegetation.

(5) Development of technologies to address climate change and their spread to economic and social activities

The Synthesis Report estimates total GHG emissions of the world in 2030 at about 56 billion tons. Based on the estimation, in order to achieve the goal of "below 2 degrees C" set by the Paris Agreement, it is necessary to control emissions to about 24 billion tons by 2050, which requires additional reduction exceeding 30 billion tons. In response, the National Energy and Environment Strategy for Technological Innovation (NESTI 2050) identifying innovation technologies with large reduction potential was decided in April 2016. The government is promoting these technologies and working to construct a system for R&D promotion.

To enable local governments to adapt to the effects of climate change, which will vary by region, by using results of R&D conducted by MEXT including forecast information on climate change, the ministry is conducting research on the following technologies in collaboration with local governments: 1) the highly reliable forecasting of climate change effects in the near future, 2) the high-resolution down-scaling of forecast data, 3) impact assessment of climate change and 4) assessment of the effectiveness of measures to address issues related to climate change. MEXT is also promoting Future Earth, which is a global initiative

on global environment research including climate change in collaboration with stakeholders in Japan and abroad.

MAFF has further enhanced development of climate change adaptation technology in agriculture, forestry and fishery, and technologies to address damage by wildlife. The ministry also developed a high-precision yield and quality prediction model and other means to assess the impact of climate change on agricultural and marine products. Furthermore, from a medium- to long-term viewpoint based on evaluation, MAFF promoted the development of plant varieties that are resistant to high temperature and drought by making the most of genome information, technologies for stable production adapted to the progress of warming and technologies to address pest damage.

MOE has been working on three strategic research tasks: (1) "comprehensive studies on ways of formulating global climate change risk management strategies" towards the understanding of risks and uncertainties that arise from global warming in Japan and throughout the world (S-10), (2)"Promotion of climate policies by assessing environmental impacts of SLCP (short-lived climate pollutants) and exploring their reduction pathways" to propose best pathways for reduction of SLCP believed to be a factor of climate change and effective measures for their realization(S-12), and (3)"Comprehensive Strategic Research on the Mitigation of and Adaptation to Climate Change" to develop quantitative basic data for effective and efficient ways to take mitigation/adaptation measures and contribute to appropriate planning of climate change countermeasures as risk management(S-14). The ministry is comprehensively promoting the strategic studies and other research on observation/monitoring of climate change and its impact as well as prediction, assessment and countermeasures using the Environment Research and Technology Development Fund.

In order to promote consistent efforts for adaptation to the impact of climate change in a systematic and comprehensive way, the Cabinet decided the National Plan for Adaptation to the Impacts of Climate Change in November 2015. Based on the plan, the Climate Change Adaptation Platform, Japan (A-PLAT) was set up at NIES in August 2016 to support efforts by local governments and business operators. The platform has been providing the latest information regarding adaptation in coordination with relevant ministries and agencies. For comprehensive and systematic promotion of necessary measures in close cooperation of relevant ministries and agencies, the Inter-ministry Liaison Conference on adaptation to the impact of climate change was held and it was decided that the conference provide follow-up of the adaptation plan. Furthermore, the Expert Committee on Climate Change Impact Assessment under the Global Environmental Subcommittee of the Central Environmental Council was held to discuss concrete strategies for continued accumulation of scientific findings, periodic assessment of the impact of climate change, support for local governments and other tasks indicated in the adaptation plan. The committee compiled an interim report on "policies regarding scientific findings and climate risk information in order to promote climate change adaptation measures" in March 2017.

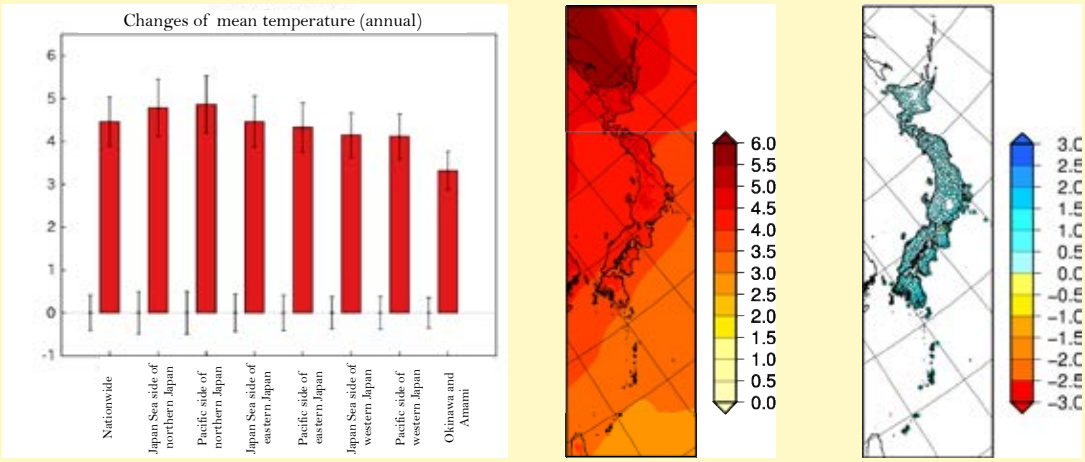
MRI is addressing the development of real-time observation and monitoring technology for the detection of unusual meteorological phenomena, such as intense localized downpours (known in Japanese as "guerrilla rain"), by means of dual polarization radar, phased array radar and global positioning system (GPS). MRI is also advancing the development of a numerical prediction model with high enough resolution to display intense localized downpours, in order to improve the accuracy of weather information and thereby to help reduce damage from local meteorological phenomena.

Column 2-4 Release of "Japan 100 years from now if warming progressed at the current pace – Global Warming Prediction Information Vol.9"

With the aim of contributing to study of global warming mitigation/adaptation measures and spread of scientific knowledge pertaining to the issue, Japan Meteorological Agency has been publishing prediction of global warming based on a numerical model as "Global Warming Prediction Information" since FY 1996. In March of 2017, JMA compiled and published the latest "Global Warming Prediction Information Vol.9 (hereinafter Vol.9)" using the prediction results under the program for risk information on climate change commissioned by MEXT.

In order to raise awareness of disasater prevention, the Vol.9 provides prediction based on the RCP8.5 scenario that is the scenario with continued GHG emissions at the highest level among the GHG emission scenarios assumed by the Intergovernmental Panel on Climate Change (IPCC). JMA added the flucutation ragne by year and the results of reliability evaluation to the scenario.

Vol.9 predicts: substantial increase in annual mean temperature (3.3 to 4.9°C depending on the region) around the end of the 21st century compared with the end of the 20th century; the number of extremely hot days (daily maximum temperature is over 35C) will increase significantly, whereas the number of ice days (daily maximum temperature is below 0°C) will greatly decrease; frequency of heavy rain and short-time heavy rain will increase nationwide; the days with precipitation exceeding 200mm and annual frequency of torrential rain (short-time heavy rain of over 50mm hourly precipitation) will more than double. At the same time, the number of days without precipitation is predicted to increase throughout the country, which might influence water resource management. Snowfall is expected to greatly decrease and snow falling season will become shorter on the Japan Sea side of Honshu. However there will be the continuing need to prepare for heavy snow because amount of snowfall is predicted to be at the level of the end of the 20th century in some years also in the late 21st century.



Predicted changes in temperature and precipitation in the late 21st century in comparison with the late 20th century.
(Left) thin line to the left of each region shows the fluctuation range of annual mean temperature by year at the end of the 20th century; bar graph to the right shows the amount of change in annual mean temperature at the end of the 21st century; thin line to the right shows fluctuation range by year(℃)
(Middle) Distribution of changes in annual mean temperature (℃)
(Right) Distribution of changes in annual frequency of rainfall over 50mm per hour (only points with reliable data are displayed)
Source: JMA

■Table 2-3-17 / Major policies to address global climate change (FY2018)

Ministry	Implemented by	Project
MEXT	MEXT	Initiative for Strategic Adaptation to Climate Change
		Program for Risk Information on Climate Change
	JAXA	Subsidies for R&D on the global observation system
MAFF	MAFF	R&D for response to climate change in the field of agriculture, forestry and fisheries
METI	METI／Agency for Natural Resources and Energy (ANRE)	Expenses of the Carbon Dioxide Reduction Technology Demonstration Project
		Carbon dioxide storage potential investigative project
		Carbon capture technology commercialization project
		Project to develop technologies for safety management of large-scale underground storage of carbon dioxide
		International cooperation on clean coal technologies to address climate change
		Commissioning expenses for infrastructure development projects such as green contribution certification systems
MOE	MOE	Contributions to the Institute for Global Environmental Strategies
		Comprehensive study to ensure implementation of CCS under the sea bottom appropriate for preservation of the marine environment

2 Responding to biodiversity loss

The Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services (IPBES) was established with the aim of strengthening the coordination of science and policies regarding biodiversity and ecosystem service. The fifth session of IPBES was held in Bonn, Germany, in March 2017. At the session, MOE actively participated in international discussions of IPBES. In order to contribute to the IBES work plan through effective input of Japan's knowledge, the ministry held the domestic liaison conference two times, gathering experts involved in IPBES and relevant ministries and agencies. MOE also held international workshops contributing to strengthening of capacity of writers by using the Japan Biodiversity Fund.

Japan has a part in Global Biodiversity Information Facility (GBIF) that aims to collect data on biodiversity so that the data can be made available worldwide. Data accumulated by GBIF are expected to serve as fundamental data for evaluation at IPBES. MOE attended the 23th Governing Board meeting held in Brasilia, Brazil, in October 2016.

MAFF is developing a database and a system for higher-level analysis of fragmentary genomic information produced by next-generation genome analyzers, for the purpose of providing breeders and researchers at universities and private companies with information on the genes and genomes of agricultural, forestry and fishery products. In its gene bank project concerning agricultural biological resources, MAFF collects, preserves, assesses and provides biological genetic resources related to agriculture, and preserves and provides genomic resources, including DNA, of rice and other crops.

To reduce the impacts of global warming on agriculture, forestry and fisheries, a MAFF plan for adaptation to climate change has been formulated. Based on the plan, techniques are being developed for accurately predicting and assessing the future impacts of climate change on each sector of industry and on each production item. Prediction results have been used to promote the development of techniques for

stable production as well as for developing breed varieties that are adaptable to climate change. MAFF is also supporting international efforts to help developing countries formulate climate change strategies and promote sustainable food supply.

The National Institute of Technology and Evaluation (NITE) has been collecting, preserving and distributing biological genetic resources and has also been organizing information on these resources in terms of their genes and genetic lineages so as to make the information accessible to researchers and others.

It also joined a network[1] of 23 organizations from 13 countries that aims for the preservation and sustainable use of microbial resources and has actively supported Asian countries in their efforts to preserve biological resources through multilateral interchange programs according to the Convention on Biological Diversity (CBD).

Furthermore the ministry has been promoting the development of empirical studies on basic technologies for the high-efficiency production of high value-added products (e.g., vaccines, functional foods) from genetically modified plants, thereby promoting the commercialization of safe, high-efficiency material production technologies that make the most of plant biological functions.

The adverse effects of global warming, ocean environmental degradation and overexploitation of marine species have become increasingly obvious. The conservation of marine biodiversity is also significant challenges for humans. In the Ocean Resource Use Promotion Technology Development Program, MEXT is implementing R&D for the purpose of comprehensively elucidating marine ecosystems. In the Strategic Basic Research Program of the JST, R&D has been conducted on technologies for observing and monitoring marine species. Research has been conducted for restoration of the marine ecosystem off the Pacific coast of Tohoku region damaged by tsunami.

Section 4 Pioneering Strategically Important Frontiers

In addition to enhancing industrial competitiveness and addressing economic and social challenges a range of science and technology to support the appropriate development, utilization, and management of the oceans and space serves as a firm foundation for Japan's subsistence. At the same time, since such science and technology have additional value, such as enabling Japan to earn admiration and respect in the international community and promoting the scientific education of citizens, it is necessary to continually enhance this asset based on a long-term perspective.

1 The promotion of oceanographic R&D

As an "oceanic state" that ranks as sixth in the world in terms of the size of the country's exclusive economic zone (EEZ), Japan needs to produce STI results befitting this status. For this purpose, it is important to steadily work on R&D of technologies for ocean surveys and observation—including areas of sea ice, deep seas, and below the seabed—and technologies for contributing to sustainable development and utilization of the seas, which includes biological resources, transportation, tourism, and environmental conservation, as well as technologies to help ensure the safety of the seas, and the scientific knowledge and

1 Asia Consortium, founded in 2004

fundamental technologies necessary to support all these efforts.

The Cabinet Office is promoting efforts to solve technology development challenges related to oceans in cooperation with the Headquarters for Ocean Policy and ensuring consistency with the Basic Plan on Ocean Policy.

With regard to R&D of fundamental technologies, MEXT is promoting R&D in the marine S&T fields contributing to innovations toward creation of future industries based on the R&D plan pertaining to ocean science and technology formulated at the CST's Subdivision on Ocean Development.

JAMSTEC has been advancing development and operation of cutting-edge technologies for survey, observation and development including deep-sea exploration and drilling, as well as information infrastructure including simulation, big data collection and analysis technologies. Using these technologies JAMSTEC is promoting basic research to elucidate the actual state of the deep sea bottom and ice-infested waters that are difficult to access, as well as a variety of unknown species and other areas that need further elucidation.

(1) Ocean survey and observation technologies

For the purpose of understanding the subseafloor microbiosphere, the mechanisms of ocean-trench earthquakes and tsunamis, and the genesis as well as the possible existence of marine resources, JAMSTEC has been advancing the development of technologies for drilling by using the deep-sea drilling vessel CHIKYU and technologies for real-time observation by using submarine cable networks. These technologies are also utilized for surveys, research and the development of other technologies.

The ministry has also been conducting research and surveys that focus on the seas around the Japanese archipelago and the entire Pacific Ocean. Specifically, crustal structures are explored by using research vessels, the manned research submersible SHINKAI 6500 and unmanned submersibles, towards deepening our understanding of phenomena related to the deep ocean floor, such as tsunamis and huge earthquakes that can cause devastating damage. With the aim of studying systems applicable to deep water exploration, MEXT set up Next-generation Deep-water Exploration Systems Committee under the Subdivision on Ocean Resources Development Subcommittee of the Council for Science and Technology.

(2) Technologies contributing to sustainable ocean development, use, etc.

MEXT has been developing advanced key technologies necessary for ocean resource exploration and is using these technologies for research and exploration. Within the framework of the program for developing technologies for promoting the use of marine resources: system development for the wide-area exploration of ocean mineral resources, which started in FY2013, MEXT aims at promoting the transfer of technologies to private companies. For this purpose, cutting-edge sensor technologies developed by universities have been further advanced, efficient wide-area exploration systems have been developed by combining multiple sensors, and new exploitation techniques have been developed and verified for practical application.

In FY 2014, MIC started R&D on next-generation satellite communication technologies for marine resource surveys, in order to improve the efficiency of marine resource surveys. MIC has been developing technologies to make Earth stations more compact and energy-efficient, and has been developing automatic satellite tracking systems.

The JAMSTEC aims at accelerating research on submarine resources around Japan. For this purpose, JAMSTEC has been conducting wide-area surveys of seafloor topography and subseafloor structure by using autonomous underwater vehicles (AUV) and remotely operated underwater vehicles (ROV[1]). In FY2015, the KAIMEI, a research vessel capable of performing detailed wide-area seafloor research, was built. Operation of this vessel will start in FY2016 after familiarization training.

(3) Technologies contributing to the securing of safety and security on the Oceans and preservation of ocean environment

The adverse effects of global warming, ocean environmental degradation and overexploitation of marine species have become increasingly obvious. The conservation of marine biodiversity and the sustainable use of marine biological resources are significant challenges for humans. In the Ocean Resource Use Promotion Technology Development Program, MEXT is implementing R&D for the purpose of realizing innovative production based on an understanding of the physiology of marine species and for the purpose of comprehensively elucidating marine ecosystems. In the Strategic Basic Research Program of the JJST, R&D has been conducted on technologies for observing and monitoring marine species.

MPAT is conducting research on the development and improvement of techniques for safety evaluation of offshore structures and for reducing environmental impacts. These techniques are the basis of key technologies for the exploitation of ocean resources and energy.

JCG has been gathering information of ship movements for the purpose of ensuring safe marine transportation and improving operational efficiency. JCG is developing a system to predict vessel traffic flow and feed back the information to the vessels based on the analysis of these big data.

2 Promotion of R&D in space science

Space development and utilization including weather, communication, positioning and broadcasting satellites are indispensable for everyday lives of the people. They are also important in expanding intellectual property of mankind and nurturing dreams and hopes of the people. Japan is promoting space development and utilization comprehensively and systematically as a national strategy based on the Space Basic Law and the Basic Plan on Space Policy.

1 Remotely Operated Vehicle

■Table 2-3-18 / Points of the Implementation schedule of the Basic Plan on Space Policy (Revised in FY2016)

Points of the Roadmap for the Basic Plan on Space Policy (Revised in FY 2016)

December 13, 2016
Strategic Headquarters for Space Policy, Cabinet Office

Policy system of the Basic Plan on Space Policy
1) Securing space security, 2) promoting the private sector utilization of space and 3) maintaining and strengthening industrial, science and technology infrastructure.

Policy for implementing the Space Project towards achieving the Space Policy goals

Satellite positioning

・Establishment of the 7 quasi-zenith satellites System
⇒Toward establishment of 7-satellite system (by 2023), No.2, No.3 and No.4 satellites will be launched in FY2017, a satellite succeeding No.1 satellite will be launched in 2020, and an R&D system will be developed for performance improvement.
⇒Realization of a safety confirmation system, etc. by FY2018 to strengthen regional disaster prevention functions including tsunami countermeasures

Space transport systems

・New Main Launch Vehicle (H3 rocket)
⇒Completion of detailed design in FY2017 toward launch of the first rocket in FY2020
・Epsilon launch Vehicle
⇒Start of development for synergy with the H3 rocket in FY2017
・Rocket launching Facility
⇒Development of launch complex certification criteria of the Space Activity Act in FY2017

Satellite communications and broadcasting

・The Next Engineering Test Satellite
⇒Start of the detailed design in GY2017 toward its launch in FY2021
・Optical Data Relay Satellite
⇒Launch around FY2019
・X-band Defense Communication Network
⇒Launch of the third satellite around FY2020

Space conditions information

・Development of SSA-related facilities, and establishment of an operation system by unified government organizations
⇒Starting the system design and development of the organizational system
⇒Conducting deliberations on stronger collaboration with the United States Strategic Command, etc.

Satellite remote sensing

・Strengthening of the functionality of, and numerical increases in, information gathering satellites
⇒Developing optical diversification satellite No.1 and data relay satellite No.1; launching optical satellite No.6 in FY2017 and examining a plan to develop 10 such satellites.
・Small rapid-response satellites
⇒Carrying out research and study on the operational concept behind small rapid response satellites
・Advanced Optical Satellite & Advanced Rader Satellite
⇒Launch around 2020
・Geostationary Meteorological Satellites (GMS)
⇒Starting production of the successor satellite by FY2023 at the latest
・The Greenhouse Gas Observing Satellites (GOSAT)
⇒Consider mounting of the successor sensor of GCOM-W for observing water circulation changes in addition to the satellite No.3 sensor in FY2017
・Other remote sensing satellites
⇒Consideration toward substantiating infrastructure development contributing to utilization of satellite data

Ocean condition information

⇒Starting the development of "ocean situation display system" in FY2017, studying information provision to the system, and conducting survey and study of further utilization possibility of satellite information.

Early warning system, etc.

⇒Promoting research on satellite borne 2-wavelength infrared sensors and mounting on the advanced optical satellite scheduled for launch around FY2020.

Strengthening of Survivability of Space Systems

⇒Formulating basic approach and starting specific efforts in FY2017

Space science, exploration and manned space activities

・Starting development of alternative satellite to the X-ray astronomy satellite toward launch in FY2020
・ISS (International Space Station): Extending to 2024 and starting detailed design of the new transfer vehicle HTV-X integrating functions
・International Manned Space Exploration: The 2nd International Space Exploration Forum (ISEF2) will be held in Tokyo during the second half of 2017.

Measures for strengthening industrial, science and technology infrastructure that support each project

Comprehensive efforts to expand space utilization by promoting the entry of new players

・Formulating the Space Industry Vision by spring of 2017 (promotion of space equipment and industries that utilize space)
・In response to the enactment of the Remote Sensing Records Act, ensure proper balance between regulation and promotion in the first half of FY2017. Formulating Policy concerning measures related to satellite remote sensing
・Support creation of new businesses/services in coordination with the Fundamental Plan for National Resilience and the Basic Plan for the Advancement of Utilizing Geospatial Information (G Space) (development and maintenance of social infrastructure, disaster prevention and mitigation, transportation and physical distribution, agriculture, forestry, and fisheries, individual service and tourism)

Improvements to ensure an environment for the stable supply of machine parts crucial for space systems

・Follow up based on the technological strategies for parts and components of FY2015
・Provision of opportunities for orbital demonstrations (releasing ultra-small satellites from ISS, executing material exposure tests, etc.)

Measures based on future expansion of space utilization

・Examinations on the execution of a state-of-the-art social demonstration test by utilizing the opportunity of Tokyo Olympics and Paralympics
・Demonstration test for LNG Propulsion System, R&D for Reusable Space Transportation Systems, and Space-based Solar Power Generation
・Studying future undertakings of exploration and development of space resources while collecting information on international trends.
・Working on space debris issue in the public and private sectors (development of international rules/guidelines, R&D, etc.)

Measures for strengthening systems that support the holistic development and utilization of space

Comprehensive implementation of the policy promotion system

Strengthening of functions for survey and analysis and for strategic plan formulation

Comprehensive strengthening of the human resource foundation in Japan, and awareness-raising among the citizenry

Improvement of the legal environment

・"Space Activity Bill" and "Policy concerning measures related to satellite remote sensing"
⇒Enacted in a Diet session in November 2016 and promulgated on November 16
⇒The Space Activity Act will be enforced within 2 years after the promulgation; the Remote Sensing Records Act will be enforced within 1 year after the promulgation.

Promotion of space diplomacy, and strengthening of overseas development strategies concerning space development

Realization and enforcement of the rule of law in space

・Contributions to the establishment of rules in international society

Development of multilayered cooperative relations with other countries

・with United States, France, EU, Australia, APRSAF, etc.

Promotion of international cooperation with industry-academia-government participation

・Consider development of a framework for integrated promotion by the public and private sectors
・Promote initiatives based on the Basic Policy of Support for Capacity Building of Developing Countries in the Space Field
・Promote pilot projects cooperating with Thailand, Indonesia and other ASEAN countries

Source: Cabinet Office

(1) Space transportation systems

Space transportation systems are essential for the utilization of space, because these are an integral part of technologies for satellite launches. Technologies for sending satellites to their designated altitudes whenever needed are vital for the autonomy of Japan's space activities. The development of a new flagship rocket was formally started in FY 2014 to expand Japan's autonomous space activities and ensure international competitiveness. The first new rocket is scheduled for launch in FY2030.

Launch of H-IIA F32 (left) and Epsilon-2 (right)
Source: JAXA

H-IIA, H-IIB and Epsilon are our key rockets. They succeeded in launching the geostationary meteorological satellite HIMAWARI 9 in November 2016, H-II Transfer Vehicle KOUNOTORI 6 and geospace exploration satellite ARASE in December of the same year, an X-band communications satellite KIRAMEKI 2 in January 2017 and a reconnaissance satellite RADAR 5 in March of the same year.

(2) Global positioning satellite systems

Regarding global positioning satellite systems, MIC, MEXT, METI and MLIT have been collaborating on demonstration experiments that utilize the Quasi-Zenith Satellite-1 MICHIBIKI, which affords high-precision positioning that is unaffected by mountains or tall buildings. The Cabinet Office launched the development of a practical system in FY2012 and has been advancing R&D of positioning technologies with the aim of establishing the 7-satellite system that will enable continuous positioning by around FY2023. MICHIBIKI was relegated from JAXA to the Cabinet Office in February 2017.

(3) Satellite communication and broadcasting systems

The Japanese government's intention to aim for the launch of an engineering test satellite around FY2021 is explicitlystated in its Basic Plan on Space Policy; thus, MIC and MEXT launched the development of the Next Engineering Test Satellite in FY2016. This satellite will be developed for the purpose of demonstrating technologies of electric propulsion, high-power generation, and flexible payload. Experiments was conducted to develop and demonstrate the following: large-scale satellite bus technology; large-scale deployable antenna and mobile satellite communications technology, using the Engineering Test Satellite VIII KIKU No.8 (ETS-VIII); satellite-based gigabit-class Internet communications technology, using ultra-fast Internet satellite Wideband Inter-Networking engineering tests and the Demonstration Satellite KIZUNA (WINDS).

(4) Earth observing system

MOE launched Ibuki in FY 2012 to promote global warming countermeasures. In addition, the development of Greenhouse Gases Observing Satellite 2 (GOSAT-2) started with the aim of further improving the observation accuracy. It is scheduled for launch in FY 2018.

SHIZUKU (GCOM-W) was launched by JAXA in May 2012. The data collected by the satellite are used by JMA to improve the accuracy of precipitation estimates and for various other purposes, including weather forecasting and fishing ground detection.

Global Change Observation Mission - Water "SHIZUKU" (GCOM-W)
Source: JAXA

MOE is operating the GPM core satellite that was launched in February 2014 under an international cooperation project with NASA, and also conducting R&D on GCOM-C scheduled for launch in FY2017.

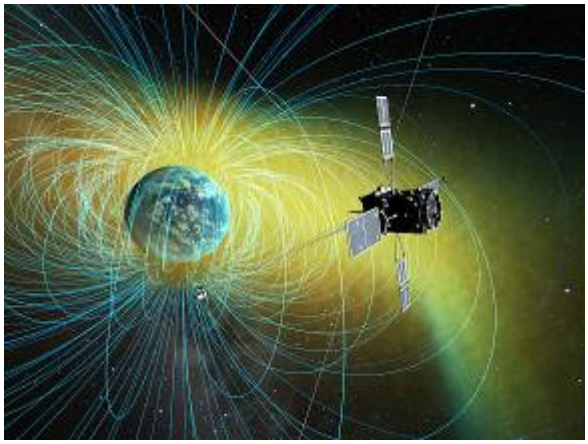
In addition, DAICHI-2 (ALOS-2) was launched in May 2014. The satellite is contributing to disaster prevention and management, and in solutions to global issues such as global warming through monitoring of various disasters, grasping of damage situations and the observation of forests, ice of Polar Regions, etc.

MEXT and JAXA are jointly working with MOD on development of a space monitoring system for the ground-based observation of space debris to contribute to stable operation of Japan's satellites, and also conducting research on technologies for mounting highly sensitive infrared sensors on satellites. Their other development efforts include advanced optical satellites capable of wide-area, high-resolution imaging,

advanced radar satellites, and the development of optical data relay satellites that can achieve inter-satellite optical communication.

(5) Space science and exploration

Regarding R&D in space science, JAXA has been playing a pivotal role. JAXA has achieved globally unrivaled results in X-ray and infrared astronomical observation, such as by developing and operating the world's first satellite for simultaneous X-ray photography and X-ray spectrography and by using the Hayabusa probe to collect samples from a celestial body orbiting around the sun. Geospace probe ARASE launched in December 2016 is observing plasma in geospace around the earth with the aim of deepening the understanding of the space environment and interaction between the earth and solar activities including aurora and space storms. HAYABUSA 2, an asteroid explorer launched in December 2014, is scheduled to arrive at the Ryugu asteroid in 2018 and return to Earth in 2020 after collecting samples.



Geospace Probe ARASE
Source: JAXA

Venus Climate Orbiter AKATSUKI (PLANET-C) that was put into orbit around Venus in December 2015 started steady observation in April 2016 and has been conducting observation aimed at elucidation of mechanism of the atmosphere of Venus. Operation of the X-ray astronomy satellite HITOMI was abandoned two months after its launch. Considering its scientific significance and high expectations at home and abroad, development of an X-ray astronomy satellite replacing HITOMI is scheduled to start in FY2017 after taking recurrence prevention measures including review of the development system. In addition, JAXA is conducting development of small moon landing demonstrator (SLIM) in an attempt to conduct Japan's first lunar landing, and the Mercury Magnetospheric Orbiter for the BepiColombo international collaborative mission to Mercury, which is being conducted in cooperation with the European Space Agency (ESA). JAXA has been active in establishing a leading position in the world as well as in promoting R&D on space science that helps broaden the frontiers of space for humankind.

(6) Manned space activities

The International Space Station (ISS) Program[1] is an international project collaboratively implemented by fifteen countries: Japan, the U.S.A., Europe, Canada and Russia. In this project, Japan assumes the role of developing and operating the KIBO (JEM[2]) and the KOUNOTORI (HTV[3]) automated cargo spacecraft. KIBO has been in service since its completion in July 2009, and KOUNOTORI has been used to resupply KIBO and the ISS. Japanese astronauts have carried out long-stay missions aboard the International Space Station. The Japanese team has achieved various things, such as establishing manned and unmanned space technologies, establishing an international presence for Japan, expanding the space industry, contributing to society based on social benefits accruing from the use of space (e.g. generating high-quality protein crystals leading to drug discovery, acquiring medical knowledge, creating materials useful for next-generation semiconductors and launching ultra-small satellites), and educating young people. During a long stay at ISS for the period from July to October 2016 Astronaut Takuya Onishi conducted various science experiments using KIBO and operated systems of ISS facilities. In December 2016 JAXA launched H-II Transfer Vehicle KOUNOTORI 6 and successfully completed the supply mission to ISS. Especially, transportation of made-in-Japan lithium-ion batteries essential for ISS operation was highly appreciated by ISS member countries. In December 2015, the Japanese government signed an agreement with the U.S.A. government on a new framework for bilateral cooperation and formally decided to extend Japan's participation in the space station program through 2024. Japan started development of a new spacecraft (HTV-X) in FY2016, considering future ripple effects.

Astronaut Takuya Onishi (top)
Astronaut Kimiya Yui (lower left)
Astronaut Norishige Kanai (lover right)
Source: JAXA and NASA

KOUNOTORI 6 grasped by an ISS robot arm
Source: JAXA and NASA

The International Space Exploration Coordination Group (ISECG), which consists of 15 space agencies from countries around the world, has been advancing studies on a sustainable international space exploration plan. Under this plan, the ISS will be maximally used for staged missions to Mars that start with unmanned exploration and are followed by manned exploration.

1 The International Space Station is a cooperative program based on the ISS Intergovernmental Agreement between Europe, the U.S.A., Russia, Canada, and Japan for the joint development, operation and utilization of a permanently inhabited Space Station in low Earth orbit (about 400 km above the Earth's surface).
2 Japanese Experiment Module
3 H-II Transfer Vehicle

(7) Efforts for enhancing the use of space

Concerning the use of space, MEXT established a system for increasing the utilization of expertise possessed by government, industry and academia. Under this system, entrustment expense fees for the promotion of aerospace science and technology is used for the purpose of expanding the base of space users by discovering potential users of satellites and developing new utilization methods. Using this system MEXT continues R&D on space utilization technologies with a view to their practical use in human resource development, disaster prevention, the environment and other aerospace fields.

METI has been promoting R&D on small high-performance satellites that compare well with large satellites in performance and are built at low cost in a relatively short period of time. R&D is also advanced regarding space equipment that is internationally competitive. METI is also advancing the development of sensors for the exploration of mineral resources using satellite remote sensing technologies and other satellite-based technologies, including those of data processing and analysis.

■Table 2-3-19 / Major policies to open up frontiers important for national strategies (FY2016)

Ministry	Implemented by	Project
CAO	National Space Policy Secretariat	Promotion of practical Quasi-Zenith Satellite System project
MEXT	MEXT	Japanese Antarctic Research Program
		The Arctic Challenge for Sustainability Project
		The development of wide-area ocean mineral resource exploration systems
		Expenses necessary for the coordinated promotion of aerospace technologies
	JAXA	Grants for ISS development
		Subsidy for R&D on earth observation system
MLIT	MLIT	Comprehensive measures for the strategic promotion of the marine industry
	JCG	Promotion of marine research in the EEZ of Japan