Chapter 3 Addressing Economic and Social Challenges

In order to achieve the goals set in the 5th Science and Technology Basic Plan (hereinafter referred to as 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

A. Stabilizing and lowering the cost of clean energy supply

(A) 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] that are thin and lightweight to overcome restrictions on installation, 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) is promoting R&D on technologies pertaining to innovative sun light utilization 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, which include development of silicon solar cells with conversion efficiency at 35% or higher.

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

With an eye toward commercialization of floating offshore wind power generation systems that can respond to the steep ocean landscape of Japan, METI is conducting a demonstration of installation and operation of a full-scale wind farm with multiple turbines including the world's first offshore substation in

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.

the waters off Fukushima, for verification of safety, reliability and economy of floating systems.

The Ministry of the Environment (MOE) conducted a development and demonstration of Japan's first 2MW floating offshore wind power plant and established related technologies. Based on the technology development and demonstration, the commercial operation of offshore wind power started first in the country in 2016. Its secondary effects include new fishing places around the windmills. In FY2018 following the previous fiscal year, MOE implemented initiatives aimed at establishment of new methods for low-carbon and high-efficiency construction toward full-scale dissemination of floating offshore wind power generation.

In order to reduce costs of construction, installation, etc. of floating offshore wind power plants, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has been developing guidelines pertaining to design and safety evaluation methods aimed at simplification of the floating structure and installation methods while ensuring safety.

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

In order to solve challenges of geothermal power generation such as high business risks and development costs, METI has been developing a technology that enables gathering of more accurate data on underground thermal resources at an exploratory stage. Also under development are technologies to manage and evaluate geothermal resources necessary for stable power supply, and technology to drill wells for use of geothermal resources in a short period of time and at low cost.

The ministry is continuing feasibility study and detailed prior examination of a high-performance geothermal power generation system for efficient development/operation using IoT/AI technologies contributing to reduction of maintenance costs, and a next-generation geothermal power generation (supercritical geothermal power generation) system.

Regarding geothermal power generation, MOE conducted development and demonstration of a "power generation system based on hydrothermal circulation" where underground hot water is not collected. Instead, circulating fluid (fresh water) that is poured from the ground to the well absorbs underground heat. The resulting hot water circulates in the system and steam generated from the water is used for power generation. As to wave power generation, the ministry is conducting development and demonstration for efficiency improvement of systems that can be used in coastal areas. In FY2018 MOE commenced development and demonstration of a wave power generation plant with vertical hydraulic cylinders to use reflected waves.

(D) 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 further 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.

(E) 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.

(F) R&D related to nuclear power

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

METI has been developing technologies and infrastructure under the Technological Development Program Contributing to Improvement of Nuclear Safety to enhance safety measures including sophistication of comprehensive risk assessment of nuclear power plants. 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. The ISCN and the IAEA have been jointly developing training programs and exchanging lecturers and information regarding human resources development based on the arrangement they made regarding the development of human resources for nuclear security. Efforts have also been made to develop technology for the following: 1) the non-destructive detection of nuclear fuel material using neutrons, and 2) nuclear forensics that identifies the origin of illegal nuclear material.

ii) Basic and fundamental R&D for nuclear science

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 that was set up under the Nuclear Science and Technology Committee, the Subdivision on Research Planning and Evaluation, and the Council for Science and Technology compiled an interim report of its discussion on the nuclear R&D functions that the state should possess, facilities necessary for maintaining them and their appropriate operation in March 2018.

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.

iii) 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.

The Ministry of Education, Culture, Sports, Science and Technology (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). In the Human Resource Development and Research Program for Decommissioning of Fukushima Daiichi NPS (Nuclear Power Station) under the Center of World Intelligence Project for Nuclear S&T and Human Resource Development, MEXT in cooperation with the Collaborative Laboratories for Advanced Decommissioning Science (CLADS) and others has been promoting more effective basic/fundamental research and human resource development based on the needs in the field of the decommissioning.

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.

iv) Research and 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, METI, MEXT and other relevant ministries and agencies have been taking measures in coordination and cooperation based on the Medium-to-Long-Term Roadmap for the Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc. (revised on September 26, 2017). 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.

Development of facilities to establish the technical basis for decommissioning is also advancing. JAEA started full-scale operation of the Naraha Remote Technology Development Center (Naraha town, Futaba-gun, Fukushima), a facility for development and demonstration of remote operation equipment/devices (mock-up facility), in April 2016. In addition, with the aim of developing analysis methods, proper understanding and treatment/disposal of fuel debris and radioactive wastes, Okuma Analysis and Research

Center (Okuma town, Futaba gun, Fukushima) started operation of some facilities in March 2018.

Based on the Acceleration Plan of Reactor Decommissioning R&D for the TEPCO Fukushima Daiichi NPS (Nuclear Power Station) (published in June 2014), MEXT set up the CLADS 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, the International Collaborative Research Building has started operation for that center in Tomiokamachi, Futaba gun, Fukushima Prefecture, in April 2017.

International Collaborative Research Building
Collaborative Laboratories for Advanced Decommissioning Science
Source: JAEA

Furthermore, the operational status of the Center of World Intelligence Project for Nuclear S&T and Human Resource Development that started in FY2015 was changed from a commissioned project of MEXT to a subsidy project conducted by the agency in FY2018. A system that enhanced collaboration with universities, etc. has been built around the CLADS to promote R&D and human resource development with increased focus on the needs in actual decommissioning.

v) Nuclear fuel cycle technology

The Strategic Energy Plan (Cabinet Decision on July 2018) states "In order to solve problems related to reprocessing and 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[1]." 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 meeting of relevant cabinet ministers on nuclear power held in December 2016 decided not to resume its operation but move to decommissioning. Since deciding the policy the government has provided explanations to the local governments at various levels and gained their understanding of the decommission system of Monju. In May 2017 the government set up the Monju Decommission Promotion Team headed by Deputy Chief Cabinet Secretary assisted by Senior Vice Ministers of MEXT and METI who work as deputy heads. In June of the same year, the Conference on Monju was held to provide local governments with explanations on the basic policy of the government on Monju decommission, the basic plan (draft) of JAEA, and other matters. After the explanations, the government held a meeting of the Monju Decommission Promotion Team, decided the Basic Policy on Monju Decommission and approved the Basic Plan on Decommission of Monju. In November of the same year the Conference on Monju was held, where the process and implementation system of Monju decommission were explained, regional development measures were discussed and understanding of local people about Monju decommission was obtained. Based on the above, JAEA submitted an application for approval of decommissioning of the nuclear facilities of the fast breeder reactor Monju to the Nuclear

1 Plutonium separated from spent fuel by reprocessing is mixed with uranium, processed into mixed-oxide fuel and used

Regulation Authority in December of the same year. The application was approved in March 2018 and unloading of the fuel assemblies started in August 2018. MEXT and JAEA have held opinion exchange and briefing sessions with local residents toward decommission and will continue to advance decommission of Monju safely, steadily and systematically while sincerely listening to the voice of the local communities.

vi) Technology development toward radioactive waste disposal

In order to assist the significant reduction of volume and hazardousness of high-level radioactive wastes, which is an important policy challenge, the government is advancing basic/fundamental research of nuclear transmutation and group separation technologies using accelerators.

For disposal of low-level radioactive wastes from research facilities and medical institutions, JAEA has been advancing necessary initiatives according to the "Basic policy for implementation of burial disposal (decision by the Ministers of MEXT and METI in December 2008) and the "Plan on implementation of burial disposal" (approved in November 2009; changes to the plan were approved in March 2018)."

vii) Decommissioning of facilities owned by Japan Atomic Energy Agency (JAEA)

In April 2017, the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (Reactors Regulation Act) was revised. According to the revision all nuclear operators are required to create and disclose their "Decommissioning Implementation Plan" including the estimated amount of materials that will become contaminated by disposed nuclear fuel material at each facility that is subject to the Act, estimation of the expenses involved in decommissioning, methods for raising funds for this purpose and other necessary matters for decommissioning. In April 2018 the Working Group on Nuclear Facility Decommissioning, the Nuclear Science and Technology Committee, the Subdivision on R&D Planning and Evaluation, the Council for Science and Technology compiled an interim report and made a recommendation on decommissioning of nuclear facilities owned by JAEA from the aspect of business and financial management. In response, JAEA published the "Backend Roadmap" that is a long-term policy for decommissioning of the entire facilities of JAEA in December 2018 in addition to the development and publication of its Decommissioning Implementation Plan. JAEA has an important role as a comprehensive nuclear R&D organization. In order to fulfill this role, it is important for JAEA to steadily proceed with decommissioning of the facilities that will not be used for research while at the same time ensuring public understanding and giving the highest priority to safety. MEXT will support JAEA's efforts and advance safe and steady decommissioning of the nuclear facilities owned by JAEA.

viii) 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.

ix) International nuclear energy cooperation

The Ministry of Foreign Affairs has been supporting the promotion of the peaceful use of nuclear science and technologies by IAEA and member countries' efforts to achieve Sustainable Development Goals (SDGs). Through financial support to IAEA with contribution to Peaceful Use Initiative (PUI) and

strengthening of collaboration between IAEA and Japanese universities, research institutions and companies with expert knowledge and technologies, the ministry has been promoting capacity building of developing countries and supporting international deployment of excellent human resources and technologies of Japan.

MEXT has been leading the way in peaceful use of nuclear energy and nuclear non-proliferation by contributing to projects implemented by the 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), which is led by the Cabinet Office, MEXT has been supporting FNCA member countries: Asian countries in particular, in their R&D and infrastructure development for the use of radiation and nuclear research reactors, for example.

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.

Japan is also involved in wide-ranging cooperation in nuclear system R&D, etc. with the United States, France and other countries advanced in nuclear science through activities of the Generation IV International Forum (GIF).

x) 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.

On May 16, 2018 the government reported the result of safeguard implementation activities in Japan during 2017 to the Nuclear Regulation Authority. The result is provided to IAEA as information for its evaluation of our safeguard implementation activities. IAEA: in its safeguards implementation report, concluded that all the nuclear materials in Japan are used solely for peaceful purposes in 2017 as well. Broader Conclusion has been reached since the implementation result in 2003.

(G) R&D of super-long-term energy technologies including fusion energy

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, based on the "Roadmap for R&D on prototype reactor (first report)" formulated on July 24, 2018, 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

1 In August 2008, operation of the JT-60 break-even test facility was suspended. The facility was subsequently dismantled for repairs and is now being reassembled as the JT-60SA, with a launch date scheduled for 2020.

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[1], 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.

Space-based solar power that can stably supply clean energy free of natural conditions such the state of being daytime or nighttime, or the weather, is expected to become an innovative energy technology in the future. In FY2018 a demonstration of wireless microwave power transmission to an overhead multicoptor was conducted, which confirmed that electric power can be extracted this way.

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.

<Reference> The way to fusion energy - ITER

https://www.youtube.com/watch?v=QEohCE1famE (Source: iter japan – QST)

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

Construction of ITER (International Thermonuclear Experimental Reactor) in October 2018
(Cadarache in Saint-Paul-Lès-Durance, France)
Source: ITER Organization

B. Stable energy use using energy storage technologies including hydrogen/storage batteries

The Cabinet Office has been working on the SIP "Energy Carrier" since FY2014. 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. Specifically, the ministry conducted technological development of optimal control and management

1 Joint project for the scientific and technological realization 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)

methods when introducing large batteries for power systems that will become necessary with the expansion of renewable energy introduction. Technological development was conducted also for the performance enhancement and cost reduction of lithium-ion and post 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 cells, has focused on lowering costs while increasing durability and efficiency. Toward further spread of fuel-cell vehicles, the ministry had installed about 102 hydrogen stations, mainly in four major cities, as of FY2018.

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.

MOE has been implementing "Construction of autonomous distributed energy system using hydrogen" since FY2018. With a view to a future society that will use a huge amount of renewable energy, the project aims to establish methods to introduce and use an autonomous hydrogen energy supply system by constructing a system that can supply renewable energy as power and heat without depending on a power system but instead by using storage batteries and hydrogen based on regional conditions.

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. One of the R&Ds is on the next-generation storage batteries with vastly higher performance than current batteries. In FY2018 the JST started R&D of a high-efficiency, low-cost, compact and long-life hydrogen liquefaction technology that will contribute to expansion of use of hydrogen including hydrogen power generation, storage of surplus power and transportation, while at the same time encouraging prompt social implementation of new generic technologies and inviting private investments.

C. Improvement of energy utilization efficiency and consumption reduction using new technologies

The Cabinet Office through SIP has been working on "Energy system for realization of decarbonized society" since FY2018. In this effort, it envisions total optimization of key technologies through study of energy management systems, while implementing R&D of innovative technologies[1] whose practical use is expected and studying how to commercialize them.

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 energy facilities such as renewable energy power facilities and storage batteries, and demand response, to make them function as one power plant and use them 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,

1 Wireless power transmission system, innovative technology for intensive use of carbon resources and universal smart power module

development of the master plan and system construction, in order to promote the further spread of renewable energy and efficient use of energy.

MOE has been implementing projects to establish an advanced model for implementation of CO_2 emissions reduction measures with high cost performance across regions by introducing independent/distributed energy systems that will use renewable energy, independent cables, etc. in public and other facilities together with energy-saving renovation, which will be followed by optimization of energy supply and demand beyond individual districts.

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 Innovative Energy-Saving Technology Program through open public invitations for proposals. The program focuses on key technologies listed in the Strategy for Energy Efficiency Technologies 2016 (formulated in September 2016), for effective promotion of R&D and the spread of energy-saving technologies.

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.

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

Toward practical use of power devices using the next-generation semiconductors including gallium nitride (GaN) which will enable significant reduction of power consumption by 2030, MEXT has been promoting R&D on the next-generation semiconductor integrally from materials processing to device and system application, also using theories and simulations. In FY2018 the Ministry also started research on high frequency devices.

The JST has been promoting the R&D on innovative technologies that have a big potential for greenhouse gas reduction and that are not an extension of existing technologies within a competitive environment. They include innovative material development/application and chemical processes. In FY2018 the JST succeeded in establishing a production method with a simplified process for bio jet fuel synthesis that was previously a complicated process with many production steps.

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 batteries or 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 has been developing technologies for: producing plastic materials and other major chemical products from carbon dioxide and water using solar energy (artificial photosynthesis project); highly efficient production of organosilicon materials without using metallic silicon; production of chemical products such as engineering plastic from inedible biomass and other materials; accurate and speedy evaluation of performance and characteristics of lithium-ion cell materials; application of printing technology to produce electronic devices with significantly greater energy saving and efficiency at lower cost compared with conventional ones, and; integrated manufacturing process and component production of highly functional lignocellulose nanofiber[1].

(2) Ensuring stable resources and cyclical use

A. 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 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.

MLIT aims to advance into the ocean development market. For this purpose, the ministry has been supporting technology development for integrated control equipment of an electric system for Floating Production Storage and Offloading System (FPSO) and autonomous unmanned underwater vehicles (AUVs[2]) for submarine pipeline maintenance.

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.

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.

B. 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

1 Light-weight, high-intensity and low thermal expansion nanofiber derived from sustained wooden biomass. Its use as resin reinforcement fiber is expected.
2 Autonomous Underwater Vehicle

promoting the Strategy for Rare Elements Project (research center development type) in order to find completely new materials that eliminate the need for scarce elements such as rare earth and rare metals by theoretically elucidating and applying the functions of elements.

METI has developed materials that are more magnetic than conventional ones and that greatly reduce use of rare metals in the Technological Development of New Structural Materials Contributing to Drastic Weight Reduction of Transportation Equipment. METI is also implementing technology demonstration of a sophisticated resource circulation system as part of introduction demonstration of an Asia energy-saving resource circulation system. Furthermore, in order to promote effective use of Japan's urban mines[1] and realize stable supply of resources as well as resource and energy conservation under the R&D on Recycling Technology to Build, a Highly Efficient Resource Circulation System, the ministry is working on the development of technologies for automatic sorting of waste products and components and high-efficiency refining.

C. 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. 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.

The JST has been promoting R&D on innovative technologies that have a big potential for greenhouse gas reduction and that are not an extension of existing technologies within a competitive environment, which include innovative biotechnologies. In FY2018 the JST succeeded in synthesis of a plastic material from biomass by optimizing the structure of manganese dioxide catalyst.

RIKEN has been conducting leading studies on the cyclic use of carbon, which 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

In addition to medium- to long-term R&D, Ministry of Agriculture, Forestry and Fisheries (MAFF) is promoting technology development with a view to field implementation with clear goals in order to overcome challenges in the agriculture field by using science. For example, aiming at stable food supply, productivity improvement of agriculture and other purposes, MAFF is conducting research to develop super-high-yielding crop varieties, crops suitable for harsh environments, and breeds of cow with high

1 Useful metals in the enormous quantity of disposed home appliances are likened to a mine

lifetime productivity. To help achieve Japan's food self-sufficiency target, MAFF is also working to develop food and feed crops that have novel features in terms of quality and processability and techniques for differentiation and quality improvement of livestock products by using domestic feed.

In order to promote "smart agriculture" combining robotics, AI, IoT, drones and other advanced technologies with agricultural technologies that have been cultivated in Japan, in FY2018 MAFF 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. As environmental improvement for realization of data-utilization in farming, the ministry pursued verification of the safety and established rules for robotics that require solution of safety issues before installation in the field and worked for standardization of agricultural information for utilization of ICT in agriculture in cooperation with other ministries and agencies. With the cooperation of relevant ministries, private companies, universities, national research and development agencies and other partners, MAFF worked to construct the Agriculture Data Coordination Platform to create an environment for data utilization in farming toward full-scale operation in April 2019.

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 "sophistication of technologies to secure living marine resources" among the programs to develop technologies that promote 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.

Colum 2-2

Improvement of crop varieties using genome editing

Selective breeding of crops has created Koshihikari, Shine Muscat and other high-quality varieties demanded by consumers and increased our food variety. Creation of high-yielding or disease-resistant varieties also contributes to improvement of productivity and stable supply of food. New varieties are created through human selection of desirable property changes caused by gene mutation of the crop. This process of selective breeding used to take many years.

Tomato with high GABA (functional component) content created through genome editing
Provided by University of Tsukuba

In recent years, "genome editing" has been developed and attracts attention as a technology for efficient mutation of genes. Conventional methods of using naturally occurring gene mutations or using radioactive rays, etc. to generate mutations cause random mutations on a large number of genes on genomes. These methods require enormous time and effort to obtain desirable properties. Genome editing can efficiently generate needed properties by cutting target genes to make them mutate with high probability. It is expected to greatly reduce the time required for breeding.

Using this technology, tomatoes with a high content of functional component GABA, potatoes with greatly reduced natural toxin, ultra-high-yield rice, etc. have been developed in Japan. Efforts for their practical use are underway. More advanced genome editing technologies are also under development, which include methods to change target genes without cutting them.

For dissemination of new technologies such as genome editing, it is important to deepen public understanding of the technologies so that they are accepted by society. For this purpose, MAFF has been conducting outreach activities where professionals provide easy-to-understand explanations of genome editing and carefully answer questions from participants at traveling university classes and other events.

■Table 2-3-1/Major projects for stable supply of energy, resources and food (FY2018)

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
		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 International Thermonuclear Experimental Reactor (ITER) Plan
		Broad Approach (BA) activities
		Businesses related to nuclear non-proliferation and security
MAFF	MAFF	Strategic project research promotion program
METI	Agency for Natural Resources and Energy (ANRE)	Subsidy to support promotion of energy saving investments Subsidy for operating costs of energy-saving diagnosis of SMEs
		R&D for cost reduction of offshore wind power generation, etc.
		Development of next-generation electric power control technology toward large-volume introduction of renewable energy R&D to reduce costs and improve reliability of solar power generation
		Subsidy for demonstration of virtual power plant construction using energy resources on demand side
		Commissioning expenses of experimental study of floating offshore wind power generation system off Fukushima
		Commissioning expenses for technology development on stratum disposal of high-level radioactive wastes, etc.
	Japan Space Systems	R&D on hyper spectrum sensors for remote detection of oil resources
	ANRE	Subsidy for development and operation costs of hydrogen stations to promote spread of fuel cell cars
	Japan Petroleum Energy Center (JPEC)	Subsidy to support R&D on highly efficient oil refining technologies
	Japan Oil, Gas and Metals National Corporation (JOGMEC)	Technology development to expand introduction of geothermal power generation (JOGMEC's funding)
	METI NEDO	Technological development of new structural materials contributing to drastic weight reduction of transportation equipment
		Technological development of integrated manufacturing process and component production of highly functional lignocellulose nanofiber R&D on energy-saving production process of chemicals
		R&D on energy-saving production process of electronic devices using printing technique
		Development of evaluation techniques for energy-saving electronic device materials
		Technology development for construction of a bio fuel production system R&D on the next-generation thermal power generation
	Environmental Partnership Council	Construction of simulation platforms pertaining to acceleration of development of next-generation cars, etc.
	Next Generation Vehicle Promotion Center	Grant for operating costs of introduction of clean energy cars

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

In order 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 and comprehensive manner. To this end, efforts are being made under the leadership of the Headquarters for Healthcare Policy, and, based on the Healthcare Policy (Cabinet Decision on July 22, 2014, partially changed on February 17, 2017) and the Plan for Promotion of Medical Research and Development (decided by the Headquarters for Healthcare Policy on July 22, 2014 and partially changed on February 17, 2017).

With the aim of promoting implementation of clinical trials by ensuring the confidence in them, the Clinical Trials Act (Act No. 16 of April 14, 2017) was enacted in April 2018. The act establishes procedures for the conduct of clinical trials, measures for appropriate provision of reviews and opinions by the certified review board and systems such as publication of information on provision of funds and other benefits for clinical trials.

A. Drug discovery

(A) 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 Japan Agency for Medical Research and Development (AMED), MEXT has been implementing the Platform Project for Supporting in Drug Discovery and Life Science Researches to allow industries and universities to share information by developing technological bases, for example, a world-class level radiation facility, cryo-electron microscopy[1], a compound library facility and protein production and bioinformatics technology facility and genome/epigenome analysis.

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.

The Ministry of Health, Labour and Welfare (MHLW) has been implementing the Project Promoting Support for Drug Discovery through AMED. The project aims at early practical application of excellent drug seeds of researchers of universities, public research institutions, etc. through technical support, support for biomarker search, non-clinical trials, intellectual property management, and through bearing of expenses of these activities. In order to help pharmaceutical approval of the results of basic research produced in Japan and create innovative medicine, the ministry has been implementing the "Project to

1 See Part 1, Chapter 3-4 Method to observe proteins in their actual conditions (cryo-electron microscopy)

Promote Clinical Study and Trials" to promote high-quality clinical study and trials led by doctors where science and ethics are sufficiently secured. Toward development of innovative medicines, MHLW has been implementing the "Research Project to Promote Development of Infrastructure for Drug Discovery to promote drug target/biomarker search in industry-academia-government collaboration, construction of next-generation drug seeds library and research on technology development for drug discovery.

Through AMED, METI has been implementing "technology development for innovative middle-molecule drug discovery" as fundamental technology for middle-molecule drug discovery that can dramatically expand drug targets. The program includes technology to expand structural diversity of middle molecules and simulation to predict structures that can penetrate into cells. As a fundamental technology that can promote new drug development, the ministry is implementing "the project for utilizing glycans in the development of innovative drug discovery technologies" to identify and examine as drug target glycoproteins that are specifically exhibited in cancer cells and other disease-specific cells.

(B) 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 basic technologies in universities for producing Japanese next-generation, innovative biomedical drugs.

Based on the "recommendation on the direction of appropriate environment improvement for early social implementation of innovative technologies" compiled by the workshop of experts to establish the world's first fundamental technologies to produce biomedicine and test drugs using silkworms and other local resources and to accelerate their industrial use, MAFF has been promoting related R&D.

Through AMED, METI has been implementing "Development of advanced production technology for biomedicines" aiming to establish new cell lines for enhanced production of biomedicine and continuous production of biomedicine that will enable adjustment of production amount based on the demand.

B. Development of medical equipment

Through AMED, MEXT has been implementing the "Development of Advanced Measurement and Analysis Systems" to promote development of medical equipment by discovering and utilizing innovative technology seeds of promising researchers through partnership between universities and enterprises, toward creation of unprecedented medical equipment.

Through AMED, MHLW is implementing the "Project to Promote Development of Medical Equipment" with the aim of providing safer treatments for patients. The project is promoting the development of diagnosis support software that supports accurate and speedy diagnosis by doctors and development of non-invasive/minimal invasive medical equipment.

Through AMED, METI has been implementing the Program to Promote Commercialization in Medical-Engineering Collaboration in order to promote development and commercialization of medical equipment that meets needs in medical practice by taking advantage of manufacturing technologies of Japan. In FY2018 the program supported 34 medical equipment development projects. Furthermore, the ministry has been implementing the "Program for R&D on Medical Equipment/Systems for Future Medical Care" with the aim of promoting development of innovative medical equipment based on the results of excellent basic research. The program has been promoting development of innovative medical

equipment/systems made in Japan taking advantage of robotics, diagnosis and other technologies where Japan has strengths. In cooperation with MHLW, METI has prepared a guideline for development of medical equipment to clarify detailed evaluation criteria contributing to the technological and biological stability of medical equipment towards future practical application, in order to promote the development of medical equipment.

The Pharmaceuticals and Medical Devices Agency (PMDA) conducted the regulatory science strategy consultations and comprehensive regulatory science consultations for practical application of excellent seeds held by academia and startups, etc.

C. Establishment of centers to create innovative medical technologies

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

In order to promote high-quality clinical studies necessary for development of innovative Japanese medical drugs and devices, since 2015 MHLW has been approving hospitals that play a central role in international-standard clinical study and doctor-centered clinical trials as clinical study core hospitals based on the Medical Care Act (Act No. 205 of 1948) and conducting the Project for Comprehensive Promotion of Practical Use of Medical Technologies through AMED.

D. 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.

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. Through AMED, 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 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, and the development of basic technologies for safety evaluation of medicine candidates in the application of regenerative medicine.

E. Realization of Genome Medical Treatment

Through AMED, MEXT is implementing the Biobank Japan Program for genome research and has established one of the world's largest biobanks of patient DNA, biological samples and clinical information collected from cooperating medical institutions. MEXT is also conducting 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, the ministry has been conducting 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.

F. Cancer research

In Japan, one in about three people die from cancer (about 370,000 persons/year as of FY2017). It is estimated that one in about two people will develop cancer during their lifetime. 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) that establishes the future direction of cancer research to be advanced by the whole country, specific research items and other matters. Based on the Cancer Control Act (Act No.98 of 2006), the 3rd Basic Plan to Promote Cancer Control Programs (Cabinet decision on March 9, 2018) was formulated with the overall objective: "the public including cancer patients know cancer and aim to overcome cancer." The plan incorporates focused promotion of genomic medicine and immune therapy which promise development of new treatments. In keeping with the goals set in the plan: (1) enhancement of cancer prevention and screening based on scientific evidence; (2) realization of patient-centered cancer treatment, and;(3) creation of a society where people can live with dignity and in safety, we will further promote research in accordance with the progress of science and technologies and clinical needs.

MEXT, through AMED, 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, MHLW is implementing the Practical Research for Innovative Cancer Control Project and powerfully advancing research aimed at practical application of cancer treatment including innovative diagnosis and treatment from the latter half of the application stage to clinical stage based on the Comprehensive 10-Year Strategy for Cancer Research.

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, Kanagawa and Osaka 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.

G. Research on Mental and Neurological Disorders

Through AMED, 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 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 environments. In addition, MEXT has been implementing the Brain Mapping by Integrated Neurotechnologies for Disease Studies (Brain/MINDS) and the Strategic Global Promotion of Brain Science with the aim of clarifying action principles of the human brain at the neural circuit level by taking advantage of Japan's strength and features including non-human primate study. 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.

Through AMED, MHLW has been implementing the Comprehensive R&D Project on Measures for Persons with Disabilities and conducting research aimed at clarification of the developing mechanism of mental diseases and establishment of proper diagnosis and treatment methods. Based on the Comprehensive Strategy to Accelerate Dementia Measures (New Orange Plan) formulated in 2015 and through AMED, the ministry has been conducting research toward R&D of dementia prevention, diagnosis and treatment methods, rehabilitation and nursing care models, etc. and working to spread the outcomes under the

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.

Research and Development Project for Dementia.

H. Research on Emerging and Reemerging Infectious Diseases

Through AMED, MEXT is implementing the Japan Initiative for Global Research Network on Infectious Diseases and the Japanese Initiative for Progress of Research on Infectious Disease. 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. Based on the "Action Plan for Strengthening Measures on Emerging Infectious Diseases (February 2016)" decided at the ministerial meeting for measures against emerging infectious diseases, "National Action Plan on Antimicrobial Resistance (AMR) (April 2016)" and "Involvement in the Development of the Laboratory of the Highest Biosafety Level (BSL4) of Nagasaki University (November 2016)," the ministry has been providing support for research by BSL4 facilities and other infectious disease research centers and conducting target search of drug seeds against pathogens, etc. of high pathogenicity with the aim of discovery of innovative medicines against infectious diseases.

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.

I. 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.

J. Promotion of utilization of health information taking advantage of ICT

With the aim of promoting use of anonymously processed medical information for industry-academia-government R&D in the medical field and thereby contributing to formation of a "society of health and longevity," the Act on Anonymously Processed Medical Information to Contribute to Medical Research and Development (Act No. 28 of 2017) was enforced on May 11, 2018.

In order to further promote networking using ICT in medical treatment, nursing care and health fields, Ministry of Internal Affairs and Communications (MIC) established rules for data distribution in medical treatment-nursing collaboration and conducted a demonstration contributing to the development of online

medical examination. Through AMED, MIC conducted research for realization of a system where users can manage their own medical and other data in chronological order throughout their lives and use the data for multiple purposes (PHR[1]) and research toward development of a health guidance planning model using AI. The ministry also implemented research toward development of endoscopes with application of 8K technology and construction of an AI diagnosis support system utilizing high definition image data. In the field of public administration, MIC promoted efforts to improve public services by utilizing ICT across Japan, while also studying and verifying data items, data links and linkage methods for facilitating data linkages among public service authorities through cloud computing services.

Through AMED, METI implemented "Promotion of behavior modification taking advantage of health/medical information." This program aims to promote behavior modification of patients of mild lifestyle diseases including diabetes through intervention based on daily health information obtained from the patients' wearable terminals, etc., construct evidence for prevention/improvement of lifestyle and other diseases and develop a basic analysis method (algorism) for health information, etc. by collecting and analyzing high-quality health information obtained through the study.

(2) Building infrastructure for sustainable cities and regions

A. Compact and functional town development

In response to the diversifying living needs of the people, the National Institute for Land and Infrastructure Management is conducting "development of urban structure analysis and evaluation techniques based on the diversifying living support functions" and other research.

B. Research on transportation systems

The Comprehensive Strategy on Science, Technology, and Innovation determines the government's direction of the Intelligent Transport 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[2], information security, reduction in pedestrian accidents and next-generation urban transportation.

Toward a society where connected cars are widely used, MIC is conducting research and study of radio systems that can be used for a new Intelligent Transport System. Anticipating that an enormous volume of information including camera images, radar data and map information will be exchanged for driving aid and automated driving through a radio system, the ministry has been conducting R&D for appropriate collection and distribution of a huge amount of information while reducing the network load.

In FY2018, National Research Institute of Police Science (NRIPS) of National Police Agency (NPA) promoted research on an analysis technology using a recording device concerning traffic accidents of vehicles with driver support systems.

MLIT has been promoting technology development that helps to improve the safety of railway traffic, including developing a system to guide the getting on/off position of new platform screen gates with wide openings.

MPAT has been conducting R&D of technologies pertaining to vessels and use of the oceans using the

1 Personal Health Record
2 Human Machine Interface

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 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 Agency for Automobile and Land Transport Technology 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.

C. 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 Brain-machine interfaces (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, which is one of the priority areas for development, METI has been implementing the Project to Promote the Development and Standardization of Robotic Devices for Nursing Care to support development of robotic devices by private businesses, which contributes to the independence of elderly people.

Toward construction of a universal society where everyone including the elderly and people with disabilities can engage in activities freely without stress, MLIT implemented a demonstration experiment of a bird's-eye-view disaster information sharing service using a high-accuracy indoor digital map installed in the area around Tokyo Station, as a model case to use indoor/outdoor position information at the time of a disaster.

Colum 2-3 Safety technology to reduce aircraft accidents by "visualizing turbulence"

Anyone who has ridden in an airplane may have experienced shaking of an airplane due to "turbulence." If turbulence occurred at a low altitude during airport landing, because turbulence rapidly changes the posture and speed of an airplane, the pilot may not be able to cope with the changes fast enough and make the airplane crash into the runway. In fact, a cargo airplane crashed on landing at Narita Airport in 2009. One of the causes was loss of control due to a turbulence that occurred at a low altitude.

"Can we visualize turbulence?"

JAXA jointly with the Japan Meteorological Agency developed a system to visualize turbulence. This is a system to measure wind direction and speed in the sky over an airport using wind sensors (radio wave radar) installed at the airport, detect turbulence that influences landing based on the data, visualize the turbulence in a graph, table, etc., and provide them to pilots (ALWIN*1) In the past only wind information on the ground (airport) was available, and information necessary for safe landing was complemented mainly by pilots' experience. This system is expected to contribute to safer landing, because it visualizes the wind in the sky above the runway, pilots can grasp turbulence above the runway accurately in detail and in real time. The system started operation at actual airports (Tokyo International Airport (Haneda) and Narita International Airport) in April 2017. Pilots think highly of the system in that it contributes to stable take-off and landing. This kind of wind information service is first in the world.

A system using wind observation sensor (acoustic radar) with more limited observation range but at a lower cost (SOLWIN*2) is under development in collaboration between JAXA and private businesses. Its operation was evaluated at Oita Airport in FY2017 and at Tottori Airport and Shonai Airport in FY2018 with a view to practical application within several years. It is expected that these domestic technologies will be used at overseas airports as well.

As it is expected that flying will become a part of daily life and people will fly more frequently, these quiet technology developments that support operation safety will become important for safer and more comfortable air travel.

*1 ALWIN: Airport Low-level Wind Information

*2 SOLWIN: SOdar-based Low-level Wind Information

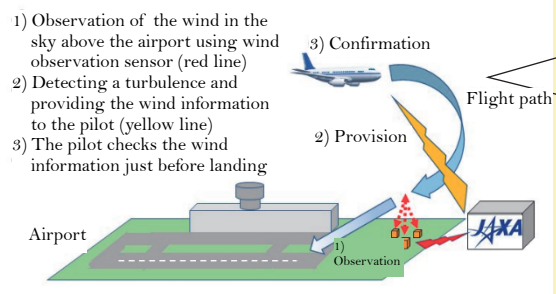


Image of ALWIN operation

Checking wind information on board
Provided by JAXA
(Filming in cooperation with Japan Airlines)

(3) Extending service life for efficient and effective infrastructure

Concerning the research topic of "infrastructure maintenance, renovation and management technologies" (FY2014-FY2018) under SIP, the Cabinet Office considers it important that the needs for infrastructure 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 reasonable prices 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 assist in the creation of an attractive and sustainable market for infrastructure maintenance and management. The Cabinet Office also has promoted the export of infrastructure maintenance and

management technologies. Utilization of various data obtained through the developed technologies will further accelerate the shift from corrective maintenance to preventive maintenance.

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 implemented the System Development Project to Solve Social Problems for Infrastructure Maintenance and Renewal. The program includes development of monitoring technologies that enable accurate grasp of the conditions of infrastructure with small and low power consumption equipment that is maintenance free for a long period of time (sensors, imaging, etc.).

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.

For promotion of i-Construction, National Institute for Land and Infrastructure Management (NILIM) is conducting the following research: development of 3D models for data distribution, development of procedures/standard proposals for work progress control/inspection using ICT for various types of works, "research on improvement of construction productivity with full utilization of ICT" to develop methods for central management of information useful for maintenance/management on a 3D model. In cooperation with other MLIT departments and agencies, NILIM has been developing technologies for the following: road structure maintenance; more efficient maintenance of sewerage facilities; the maintenance of river structures; utilization of existing buildings and; the maintenance and service life prolongation of port facilities, in order to ensure continued safe use of existing housing and 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 to inspect, diagnose, repair and upgrade infrastructure and evaluate reliability of materials as well as for development of new structural materials 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 (FY2018)

Ministry/ Agency	Implemented by	Project
MEXT	AMED	Grants for promoting the development of medical and health care research
MHLW	MHLW	Project related to a nationwide health and medical information network
METI	AMED	Project to Promote the Development and Introduction of Robotic Devices for Nursing Care
		Promotion of behavior modification taking advantage of health/medical information
		Development of Medical Devices and Systems for Advanced Medical Services
		Medical-engineering collaboration business promotion project
	NEDO	The development of systems for responding to social issues, such as the maintenance and renewal of infrastructure
MOE	MOE/ National Institute for Environmental Studies/ National Center for Child Health and Development/ regional centers s (universities in 15 regions nationwide)	Japan Environment and Children's Study (JECS)

3 Improving competitiveness in manufacturing and value creation

(1) New manufacturing systems

A. 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.

In an effort to develop 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 supporting technology development for productivity improvement through more efficient and advanced steps of ship development, shipbuilding and operation by utilizing information communication technologies including IoT and big data. The ministry also developed a roadmap for practical application of automatic navigating vessels in June of 2018 and is implementing demonstration projects.

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.

B. 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

A. Construction of highly reliable materials database

For strengthening of the international competitiveness of our materials industry, the government is building a materials development system by merging numerical simulation, theories, 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.

B. 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.

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. The government is working on science and technology innovation to address these issues. "Safety and Security" section of the Integrated Innovation Strategy states that 'Amid the ever-increasing severity of our country's security environment," in order "to realize comprehensive security against a wide range of threats to people's lives and socioeconomic activities which include large-scale natural disasters, international terror/crimes and attacks in such new zones as cyberspace' 'We will get a broad overview of scientific technologies, "know" those which contribute to safety and security, "develop"

such technologies through concerted initiatives of the relevant ministries and collaboration among industry, academia and government, "keep" such technologies for securing and maintaining our superiority in these areas and for preventing such technologies from being used to manufacture such products as weapons of mass destruction and "utilize" the results gained through such approaches for ensuring safety and security via social implementation.'

1 Addressing natural disaster

(1) Improvement of prevention capabilities

Under Tokyo Metropolitan Resilience Project, MEXT has been building an ultra-high density seismic observation system in public-private collaboration by integrating seismic observation data held by government agencies, local governments, private companies, and others. The ministry is also collecting sensor information concerning the collapse margin of structures including non-structural components (piping, ceiling, etc.) by using a 3D Full-Scale Earthquake Testing Facility to collect large amounts of diverse data that will contribute to integrated public-private disaster response, business continuity, disaster prevention actions by individuals, etc. for maintenance of urban functions. The data will be shared and analyzed by industrial, public and academic sectors, which will lead to creation of new value.

MLIT has been developing and operating the Nationwide Ocean Wave Information Network for Ports and Harbors (NOWPHAS) 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[1].

NILIM has been conducting research including the following: "measures for extremely severe disasters" including (1) visualization of flood risk for appropriate use of river information for evacuation behavior, (2) method for advance estimation of sediment disaster caused by a large-scale earthquake, (3) measures against landslides and urban flooding due to sudden torrential rainfall; "the creation of disaster-resistant towns," including (4) development of techniques for renovation of equipment, etc. to ensure health and safety of evacuees in shelters, and; (5) 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 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.

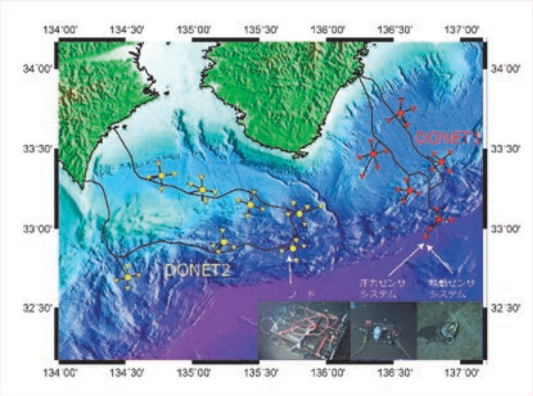
Towards early recovery and reconstruction after a major earthquake, MPAT is conducting research on forecasting earthquake- and tsunami-related deformation and performance degradation for structures in coastal areas and the areas behind them, and on improved safety and reliability for facilities in coastal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

1 http://www.mlit.go.jp/kowan/nowphas/

(2) Improvement of predictive capability

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

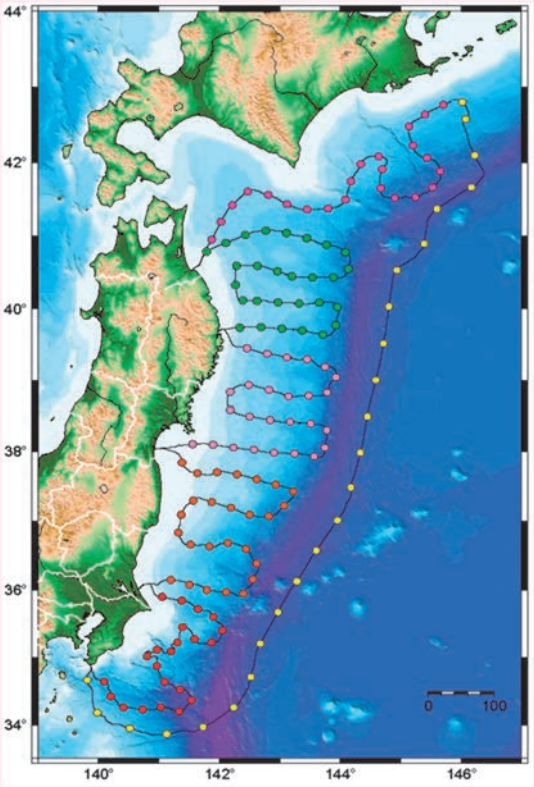
■Figure 2-3-3/Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET)



Source: MEXT

Considering that the long-term evaluations of the probability and scale of earthquakes conducted by the Earthquake Headquarters did not cover massive earthquakes with multiple adjacent source regions such as the 2011 off the Pacific coast of Tohoku Earthquake, and also in light of the Kumamoto Earthquake that was caused by active faults, the Earthquake Headquarters has been reviewing its long-term evaluation and publication methods sequentially. In light of the tremendous damage caused by the tsunami of the 2011 off the Pacific coast of Tohoku Earthquake, the Earthquake Headquarters is also implementing evaluation of tsunamis caused by various earthquakes.

■Figure 2-3-4/Seafloor observation network for earthquakes and tsunamis along the Japan Trench (S-net)



Source: MEXT

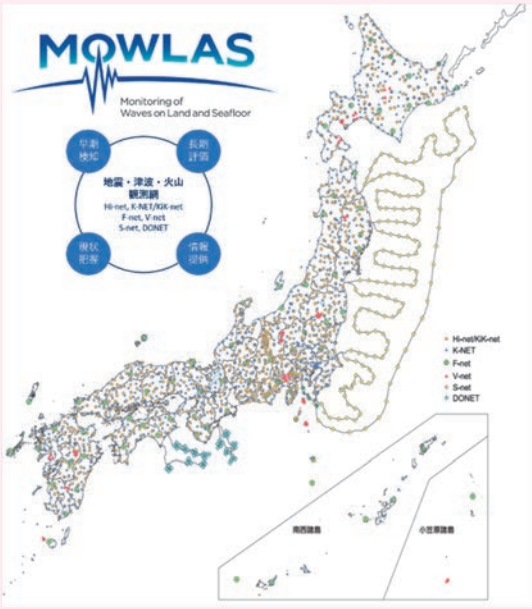
MEXT has conducted investigation and research into potential earthquakes which may cause tremendous social and economic damage under the Research Project for Compound Disaster Mitigation on the Great Earthquakes and Tsunamis around the Nankai Trough Region for Nankai Trough earthquakes. In the Project for Investigations of Earthquakes and Tsunamis in the Sea of Japan, controlled-source surveying and 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 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 2-3-3). 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) has been operated to directly detect earthquake and tsunami to contribute to accurate and prompt communication of disaster information (Figure 2-3-4).

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.

■Figure 2-3-5/Monitoring of Waves on Land and Seafloor (MOWLAS)



Source: MEXT

National Research Institute for Earth Science and Disaster Resilience (NIED) is observing various tremors ranging from feeble tremors imperceptible to the human body to strong tremors causing big damage by using about 1,900 high-performance and high-precision seismometers covering the entire land area of Japan evenly and densely. It operates about 200 seismometers and tsunami meters in sea area and started full-scale operation of Monitoring of Waves on Land and Seafloor (MOWLAS) in November 2017. MOWLAS is an earthquake, tsunami and volcano observation network covering all land and sea areas of Japan, including the fundamental volcano observation network (V-net) for 16 volcanoes in Japan. 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 MOWLAS and has provided observation data to Japan Meteorological Agency. NIED also promoted use of the data by railway companies (Figure 2-3-5).

In addition, NIED is also conducting research on storm and flood damage prediction based on multi-sensing and research contributing to reduction of damage caused by natural disasters including snow disaster and coastal disaster. Furthermore, toward creation of new science and technology for disaster prevention, NIED is advancing formation of "an innovation hub to realize active reduction of weather hazards toward aggressive disaster prevention" with the goal of mitigating/preventing weather hazards and generating positive ripple effects for industry. One example is an initiative in collaboration with convenience store companies to combine securing of goods distribution at the time of heavy snow and mitigation of snow and ice disasters by developing new snow cover sensors and installing them in stores for high-precision snow cover prediction. In order to solve regional disaster prevention problems, NIED developed censors for snow damage and sediment disaster and installed them in model areas. It also started a demonstration experiment to collect data and provide information using IoT technology in cooperation

with local stakeholders and producers. For promotion of R&D on lightening risk prediction based on comparative analysis with MP radar[1] data, etc., NIED is conducting continuous observation of lightening using a lightening discharge path 3D observation system in the Tokyo metropolitan area.

Japan Meteorological Agency (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 also developed the Automatic Hypocenter Determination Method (PF method) and introduced the method in April 2016. For earthquake early warning, JMA developed IPF method[2] and PLUM method[3] in preparation for future multi-segment earthquakes and massive earthquakes for which the risk has been widely recognized after the off the Pacific Coast of Tohoku Earthquake. IPF and PLUM methods have been introduced in December 2016 and March 2018 respectively. JMA is also advancing technology development for their further sophistication in cooperation with NIED. Against tsunami, JMA introduced a method for high-accuracy prediction of tsunami height based on the observed offshore tsunami waveform (tFISH[4]) in March 2019.

The Meteorological Research Institute (MRI) 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.

To collect geological information useful for disaster prevention/mitigation, 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. In order to elucidate the fault distribution and the history of fault activities, AIST conducted geological surveys of three land fault zones (Shibetsu, Itoigawa-Shizuoka Tectonic Line and Hinagu) and one coastal zone fault zone (Tokachi Plain). AIST's database on tsunami deposits was released to the public in October 2015. Data collected in the partial areas in Aomori and Kochi 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 constantly measure groundwater levels (water pressures), groundwater temperatures, crustal strains and seismic waves. In order to increase precision of observation equipment, AIST started development of methods to downsize and reduce cost of strain meters and methods to use existing unused wells. Concerning the volcanoes where eruption activities were observed Kuchinoerabujima, Sakurajima and Kirishimayama (Shinmoedake / Iodake), AIST conducted field investigations and observed/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.

1 Multi-parameter radar that can simultaneously transmit / receive two types of radio waves (horizontally and vertically polarized waves)
2 Integrated Particle Filter method for accurate estimation of seismic centers even when multiple earthquakes occurred simultaneously has been developed in cooperation with the Disaster Prevention Research Institute, Kyoto University.
3 Propagation of Local Undamped Motion method. Method for appropriate estimation of seismic intensity of large-scale earthquakes with a very wide area of strong vibration
4 tsunami Forecasting based on Inversion for initial sea-Surface Height

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 DONET. 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 SAR Interferometry[4]. 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.

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

(3) Improvement of response capabilities

The Cabinet Office promoted R&D under the SIP Program "Enhancement of Societal Resiliency against Natural Disasters (FY2014-2018)" with the aim of constructing a disaster resilient information system through development of technologies for sophistication of disaster prediction, prevention and response as well as information sharing, and using them for improvement of the disaster prevention/mitigation capability of relevant organizations. At the time of the earthquake in the northern part of Osaka prefecture in 2018, Hokkaido Eastern Iburi earthquake and Torrential Rain in July 2018, the Information Support Team (ISUT[5]: a trial initiative of the disaster prevention department of the Cabinet Office) provided disaster response support by using this system to integrate disaster-related data of relevant ministries and agencies. In SIP "Strengthening of National Resilience (disaster prevention/mitigation) that started in FY2018, the Cabinet Office is promoting R&D and social implementation that maximize the latest technologies including satellites, IoT and big data in order to construct an information system to support decision making by the central and municipal governments in case of a large-scale disaster.

Quasi-zenith satellite system Michibiki started service on November 1, 2018. The service consists of disaster crisis management reporting to provide disaster weather information from satellites and collection of safety information of evacuees in shelters, etc.

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

1 Global Navigation Satellite System
2 There were 1,300 electronic reference stations across the country as of the end of March 2019.
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.
5 Information SUpport Team

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.

NIED conducts research on the development of systems to share and utilize information of various natural disasters, and has been demonstrating them and providing information for public disaster response based on its responsibility as a designated public institution. NIED conducted investigation and analysis to determine the cause of the avalanche disaster that occurred in Nasu town of Tochigi in March 2017. NIED found out that snowfall caused by a cyclone off the south coast of Japan was a major factor of the avalanche and held seminars on snow and avalanches to prevent accidents in the future.

NIED analyzed the observation results of the earthquake that occurred in the northern part of Osaka prefecture in June 2018 and used the Sharing Information Platform for Disaster Management (SIP4D) and NIED Crisis Response Site (NIED-CRS), which are results of R&D on disaster information sharing and dissemination, to support information sharing and utilization.

In response to the heavy rain in Hiroshima, Okayama, Ehime and other prefectures in July 2018, NIED published the result of conformational analysis of the cumulonimbus ensembles on its website and supported information sharing and utilization through SIP4D and NIED-CRS.

After the Hokkaido Eastern Iburi Earthquake in October 2018, NIED analyzed the earthquake observation results, restored damaged observation facilities and conducted an extraordinary observation in the aftershock area. NIED also supported information sharing and utilization through SIP4D and NIED-CRS.

After the eruptions of Mt. Kirishima (Mt. Iou) in April 2018, Mt. Kirishima (Shinnen Dake) in June 2018 and Kuchino-Erabushima in August 2018, NIED surveyed eruption products on the sites and published the results through NIED-CRS.

The Ministry of Defense (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. In order to quickly secure an alternative means for damaged bridges after a large-scale disaster to support rescue of victims and rapid deployment of restoration teams, NIED has been conducting research for establishment of an emergency bridge foundation technology using light-weight and high-intensity composite materials.

FDMA's National Research Institute of Fire and Disaster (NRIFD) has advanced R&D on a fire-fighting robot system 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 discharge fire-fighting water at disaster sites that are accessible only to robots. The institute completed a firefighting robot system for field deployment. In addition, the NRIFD is conducting 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.

Furthermore, the NRIFD is conducting research on optimization of ambulance operation, R&D on

search and rescue technologies using image information taken from the air obtained by UAV[1], etc. in segment disaster sites and a method to remove debris piled up all over the place in order to improve firefighting capabilities at the time of disaster. 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 NRIFD 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, the NRIFD 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.

NICT has been promoting R&D on sophistication of an airborne polarimetric and interferometric synthetic aperture radar system (Pi-SAR[2]2) that can observe the ground surface in disaster-stricken areas as needed, regardless of weather conditions. NICT 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, NICT 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, and control measures of maximum possible river flooding. NILIM also conducts research on acceleration of initial response after a large-scale earthquake through development of technologies that support elimination of road obstacles, restoration of infrastructure, TEC-FORCE[3] and other activities immediately after the disaster taking advantage of small on-airplane SAR[4] and existing cameras and sensors. For the port sector, NILIM is conducting research on methods for immediate estimation of damage to port facilities after a large-scale earthquake. In the airport sector, NILIM is conducting research on methods for speedy inspection and restoration of airport pavement after an earthquake disaster.

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[5]) and other satellites (See Chapter 3 Section 4).

1 Unmanned Aerial Vehicle
2 Polarimetric and Inferometric Airborne Synthetic Aperture Radar
3 Technical Emergency Control Force: A team organized by MLIT in FY2008 for survey of damage and technical support for afflicted local governments at the time of a large-scale natural disaster.
4 Synthetic Aperture Radar
5 Advanced Land Observing Satellite-2

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

A. 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 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 locations of fish farms.

Toward realization of the Fukushima Innovation Coast Framework, MAFF has been supporting development and demonstration of cutting-edge agriculture and forestry robots in the Hamadori area of Fukushima Prefecture damaged by the nuclear disaster. The aim of the project is to reconstruct these industries by implementing advanced agriculture, forestry and fisheries using high technologies first in Japan.

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 farming and fishery villages, and at fostering new types of agriculture, forestry and fishery that have high growth potential, MAFF has been conducting on-site empirical research by applying cutting-edge technologies and promoting the dissemination of the research results. In doing so, MAFF has established empirical research sites for agriculture in Iwate and Fukushima prefectures and empirical research sites for fishery in Iwate, Miyagi and Miyagi prefectures, while setting up social implementation centers in Miyagi and Fukushima prefectures. Specifically, distinctive empirical studies (crop rotation in rice paddies, greenhouse horticulture, fishing-boat fisheries and fish culture, release and processing, etc.) are conducted in cooperation with farmers and fishermen in the affected area and according to the conditions of the respective prefectures.

B. 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 revised New Comprehensive Special Business Plan in May 2017 (several changes were approved later,) which made mention of providing prompt and appropriate compensation for nuclear damage by TEPCO and for its streamlined management. 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 (set up in May 2015) of the Atomic Energy Commission under the Cabinet Office conducted a series of studies on review of the compensation system and compiled "Revision of the Nuclear Damage Compensation System" in October 2018. Based on the studies at the committee, the Act to Amend Part of the Act on Compensation for Nuclear Damage (Act No.90 on December 12, 2018) was enacted. The amendment includes: (1) mandatory development and disclosure of a policy for damage compensation; (2) establishment of a system to lend funds for provisional payment; (3) special provisions for interruption of prescription pertaining to use of settlement mediation procedures, and; (4) extension of time limits pertaining to conclusion of new indemnity agreements for compensation of nuclear damage. Currently necessary governmental and ministerial ordinances are under development toward full-scale enforcement on January 1, 2020.

■Table 2-3-6/Major projects for recovery and reconstruction from the earthquake disaster (FY2018)

Ministry/ Agency	Implemented by	Project
Reconstruction Agency	Reconstruction Agency	Scheme to Revitalize Agriculture and Fisheries in the Disaster Area by Deploying Highly Advanced Technology (Reconstruction Special Account)

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 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 2018" in December 2018. The new table lists a greater variety of foods.

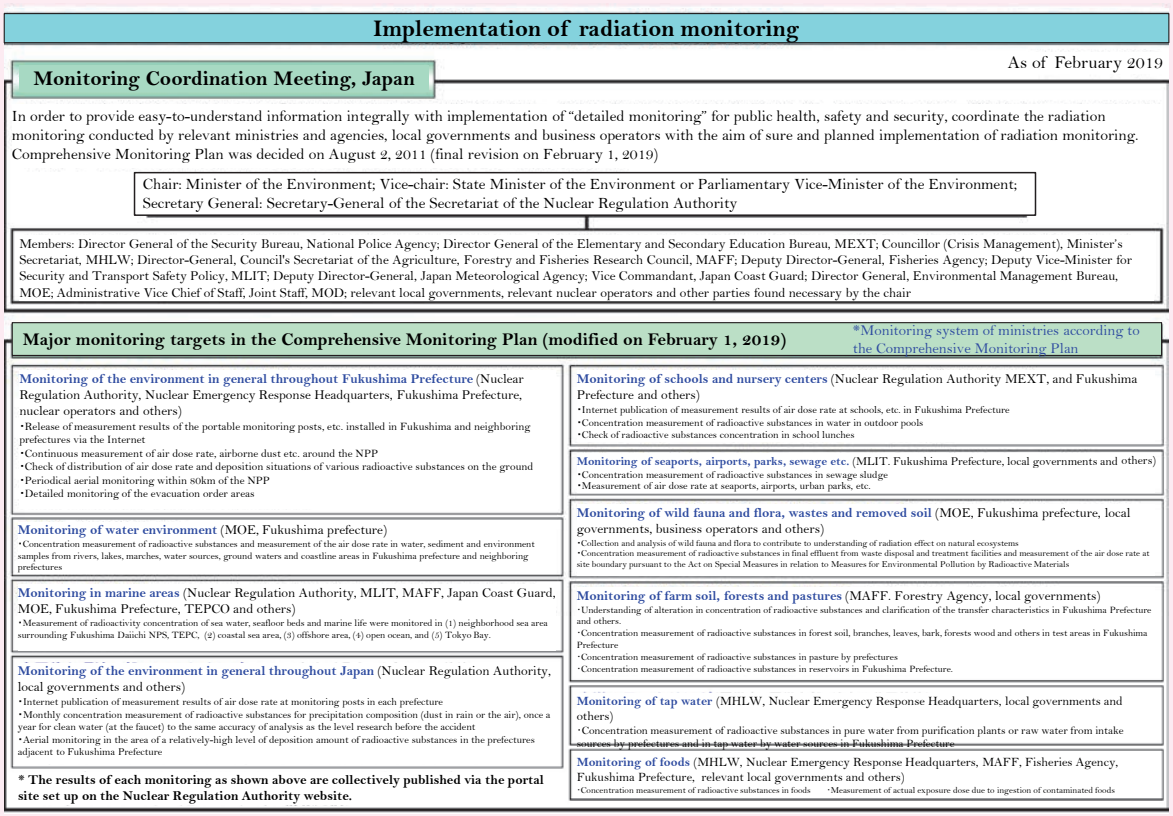
MAFF is working on development of technologies for reducing the risk posed by hazardous chemicals and microbes during the production, distribution and processing processes in order to ensure the stable supply of safe agricultural, livestock and marine products; more effective communicable disease control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

(2) Ensuring safety and security of the living environment

A. Implementation of radiation monitoring

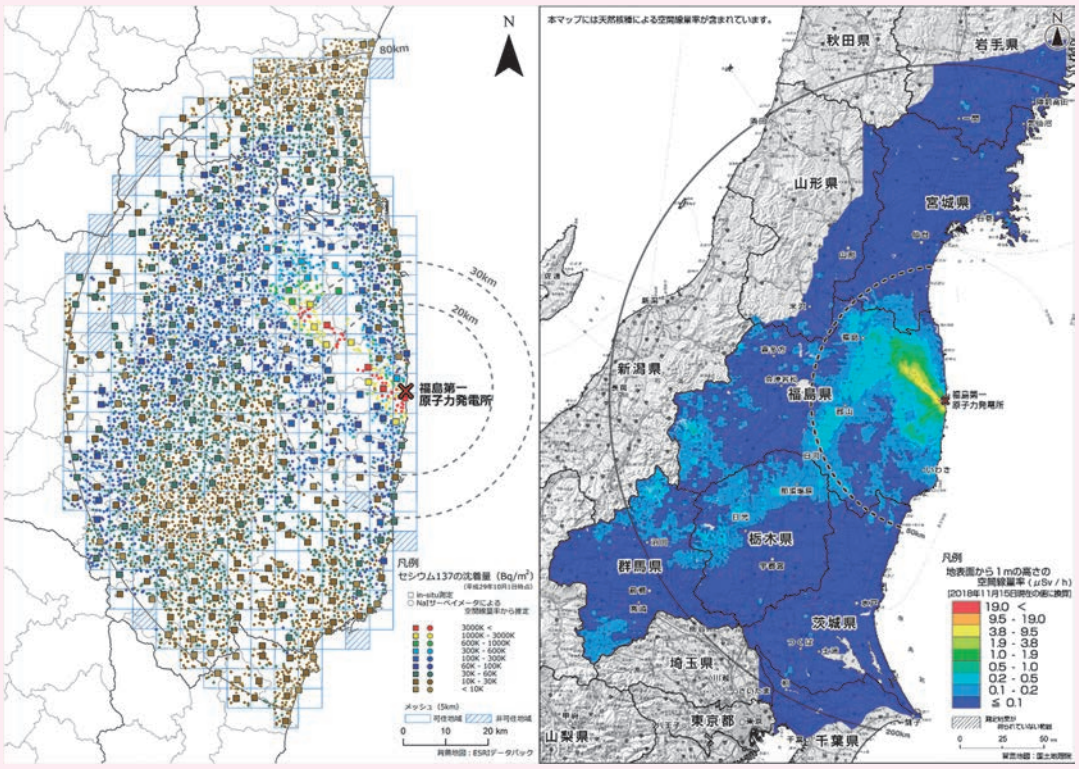
With respect to the radiation monitoring necessitated by the accident at the Fukushima Daiichi Nuclear Power Station of TEPCO, ministries, local municipalities and other authorities are measuring air dose rates at monitoring posts, analyzing radioactive substances in soil in terms of nuclides, analyzing 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 February 2019) (Figure 2-3-7).

■Figure 2-3-7/Monitoring system implementation by ministries in accordance with the Comprehensive Monitoring Strategy



Source: Secretariat of the Nuclear Regulation Authority

■Figure 2-3-8/Radioactive substances distribution map



* Cesium 137 soil concentration map (as of October 1, 2017: 78 months after the accident) (left)
* Spatial dose rate map of Fukushima and neighboring prefectures (as of November 15, 2018: 92 months after the accident) (right)
Source: Secretariat of the Nuclear Regulation Authority

In FY2017, to clarify the distribution of radioactive substances released as a result of the accident at the TEPCO Fukushima Daiichi Nuclear Power Station, the ministry continued to collate information concerning the distribution of radio cesium and the like (Figure 2-3-8). 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 of the area (Figure 2-3-8). Seawater, 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 (Attachment "Comprehensive Monitoring Plan").

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 2-3-9).

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

■Figure 2-3-9/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: Secretariat of the Nuclear Regulation Authority

B. 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. Their results have been published swiftly. MAFF is also developing technologies to deal with various post-decontamination challenges, such as technologies for restoration/improvement of soil fertility of agricultural land after the decontamination and proper potassium application to control absorption while ensuring safety of agricultural products.

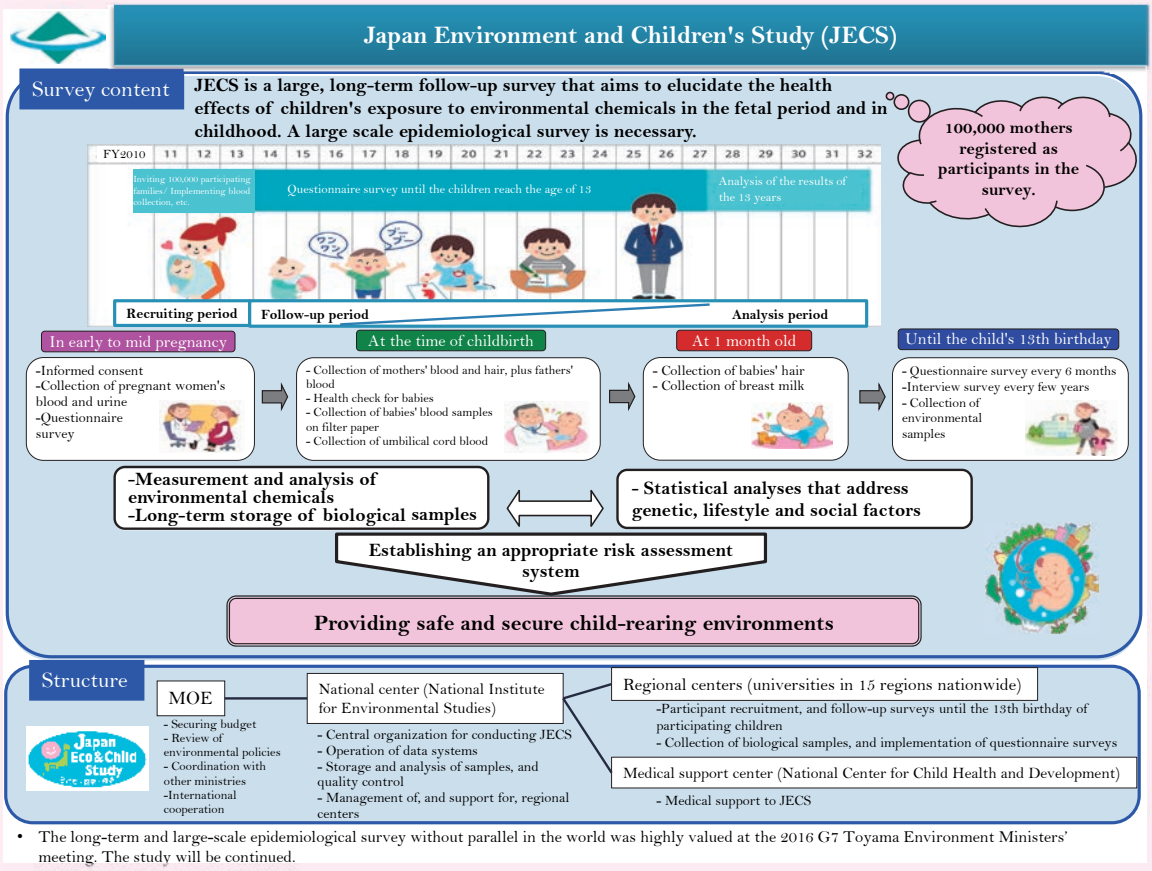
MOE has compiled a strategy for developing technologies regarding the volume reduction and recycling of radioactive substances towards the disposal of soil derived from decontamination within Fukushima Prefecture outside the prefecture. The ministry has also been carrying out a project to verify the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

JAEA moved into the research building of the Fukushima Environment Creation Center. 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.

C. Efforts to clarify environmental risks to children

In FY2010, 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 (Figure 2-3-10).

■Figure 2-3-10/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, regional 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 FY2018, follow-up using questionnaires and detailed investigations were continued, which include medical examinations covering about 5,000 children chosen from the 100,000 children enrolled in the nationwide survey.

■Table 2-3-11/Major policies to ensure food safety, living environment, occupational health, etc. (FY2018)

Ministry	Implemented by	Project
MOE	MOE/ NIES/ NCCHD/ regional centers (universities in 15 regions nationwide)	Japan Environment and Children's Study (JECS)

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), the Cyber Security Strategy was decided by the Cabinet on July 27, 2018 after deliberations by the Cybersecurity strategy headquarters led by the government. R&D on technologies for Cybersecurity has been promoted on the basis of the Strategy.

Since FY2015 the Cabinet Office has been working on SIP "Cyber-Security for Critical Infrastructure". In order to protect critical infrastructure supporting the people's everyday life from cyber attacks, the program is promoting 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 aimed at strengthening of international competitiveness of critical infrastructure industries and at contributing to stable operation of the 2020 Tokyo Olympic and Paralympic Games. Since FY2018 the Cabinet Office has been working on SIP "Cyber Physical Security for IoT Society." Toward realization of secure Society 5.0, the program is promoting R&D for development and demonstration of Cyber Physical Security Infrastructure that can be used for protection of an entire large supply chain including IoT system services and SMEs, and its social implementation in multiple industrial fields.

Through NICT, MIC has been promoting R&D in the field of cyber security. MIC aims to use its technical knowledge on cyber security to train security human resources who have practical ability to handle increasingly sophisticated and complex cyber attacks. To this purpose, the ministry has been implementing initiatives such as practical cyber defense exercise (CYDER[1]) for national administrative organs, local governments, and others at the National Cyber Training Center organized in the institute in April 2017. The Ministry is also working on the Cyber Colosseo for practical cyber exercise toward the 2020 Tokyo Olympic and Paralympic Games and SecHack563 to train young security innovators.

Aiming at cyber security of the entire supply chain in Society 5.0 that will be realized through IoT and AI, METI is formulating the Cyber Physical Security Framework that is compiling an overview of the measures required from industry. In November 2018, AIST established the Cyber Physical Security Research Center to promote R&D to address increasingly sophisticated and complex threats with integration of cyber space and physical space. The Industrial Cyber Security Center of Excellence launched at the Information-technology Promotion Agency has been promoting activities such as development of human resources who will play central roles for cyber security of control systems at critical infrastructure operators in addition to information systems by critical infrastructure businesses.

1 Cyber Defense Exercise with Recurrence

■Table 2-3-12/Major policies for cyber security (FY2018)

Ministry	Implemented by	Project
MIC	NICT	The establishment of the National Cyber Training Center
METI	METI	Presentation of a draft of Cyber Physical Security Framework
	IPA	Promotion of industrial cyber security
	METI/ IPA/ Japan Computer Emergency Response Team Coordination Center	The development of economic infrastructure for Cybersecurity

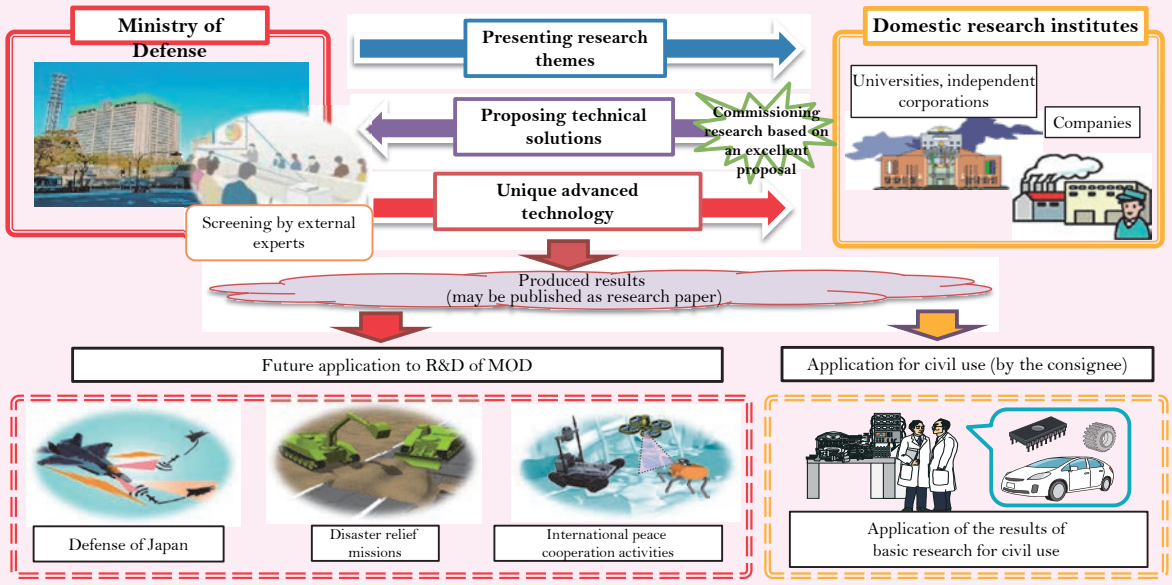
4 Addressing national security issues

The National Security Strategy (National Security Council/Cabinet decision on December 17, 2013) 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 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.

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 2-3-13) in FY2015. The ministry expanded the initiative in FY2017 and started to foster exploratory research in advanced technology fields where large-scale investments are effective in terms of the budget and research period. 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. In November 2018 evaluation of research results was conducted and made public.

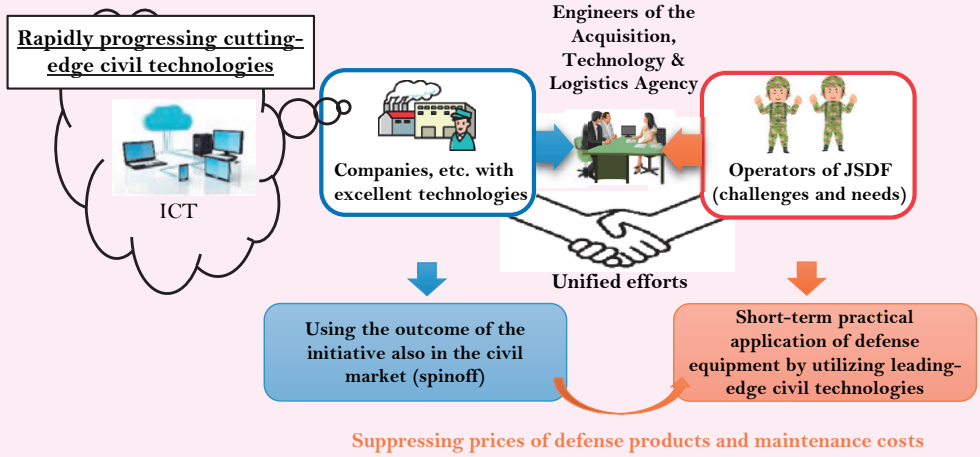
■Figure 2-3-13/Outline of Innovative Science & Technology Initiative for Security



Source: Acquisition, Technology & Logistics Agency (ATLA)

Since FY2017 MOD has been working for practical application of ICT and other civilian technologies that progress rapidly with a short innovation cycle in a short period of time of 3 to 5 years in close collaboration of engineers and operators (Figure2-3-14).

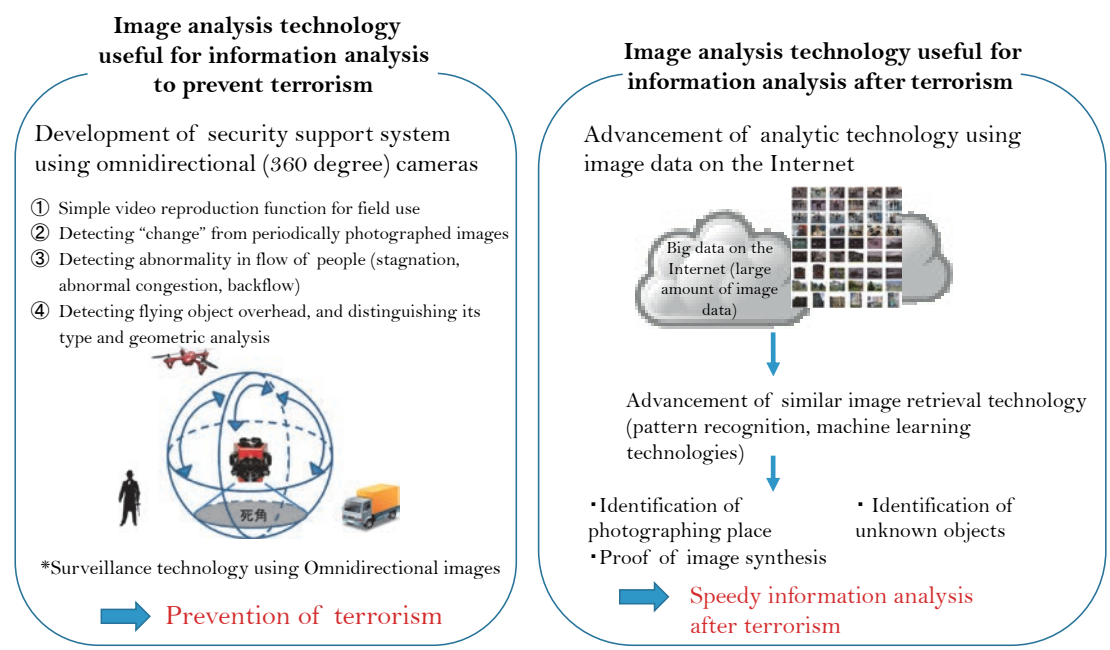
■Figure 2-3-14/Outline of the initiative for early practical use of rapidly progressing cutting-edge civil technologies



Source: ATLA

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. 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.

■Table 2-3-16/Major policies to address national security issues (FY2018)

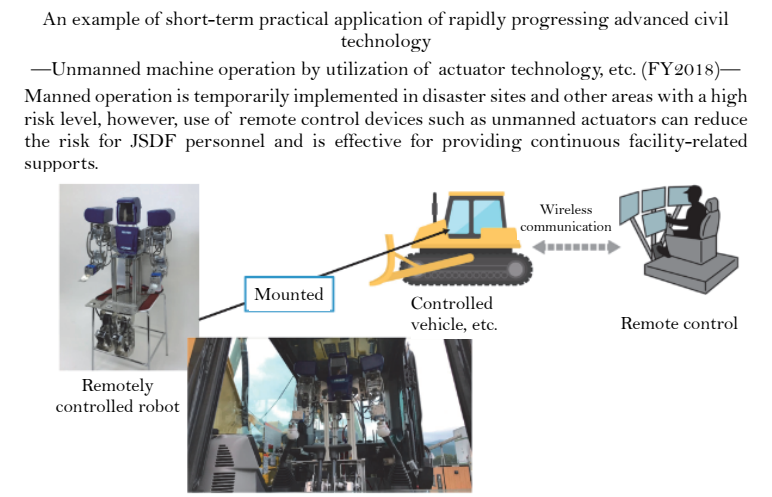
Ministry	Implemented by	Description
MOD	ATLA	Innovative Science & Technology Initiative for Security

1 Chemical, Biological, Radiological, Nuclear

コラム 2-4 Initiative for early practical application of rapidly progressing advanced civil technologies

Because progress of innovation is significant in the fields of ICT, robotics and AI, it is difficult to respond by conventional R&D methods that have been used for defense equipment. In Japan various R&D ingenuities have been studied and implemented led by the private sector and measures to materialize technological or operational ideas have been taken repeatedly in a short period of time. Adopting this approach in the defense sector, since FY2017 MOD has been implementing projects to put new defense equipment to practical use in a short period of time of three to five years through concerted efforts by engineers and operators to introduce rapidly progressing advanced civil technologies with a view to their application in consumer sectors. Five projects whose conceptual design started in FY2017 commenced demonstration this fiscal year. In FY2018 conceptual design started for an additional three projects.

In light of the accelerated progress of technologies, a shorter R&D cycle by sure matching between challenges of the SDF (needs) and technology seeds through this initiative will contribute to solution of our security issues. At the same time utilization of the results of the initiative in the civil market is expected to contribute to lower prices of civil and defense products as well as to continuous development of technologies for safety and security. This can be viewed as an essential initiative.



Conceptual design: Kanamoto Co., Ltd.

Figure: An example of short-term practical application of rapidly progressing advanced civil technology

Table: List of subjects for short-term practical application of rapidly progressing advanced civil technology

FY2017	- Wireless network in ship, etc. - Large-scale near-real-time data analysis - Reduction of unnecessary radiation of satellite communication antennas - Network flight simulation - Silencing of off-road bikes
FY2018	- Unmanned machine operation using actuator technology, etc. - Construction of automatic ship identification device analysis tools using AI - Automation and efficiency improvement of monitoring/inspection using drones, etc.

Section 3 Addressing Global Challenges and Contributing to Global Development

Response to Climate Change is a pressing issue for the world as well as Japan. Based on the Paris Agreement that became effective in November 2016 and the Climate Change Adaptation Act (Act No. 50 of June 13, 2018), 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

A. The promotion of Earth observation

To understand current global warming trends, many countries and organizations worldwide have been observing the Earth from the outer space by satellite, as well as by 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 232 countries and institutions as members as of February 2019. Japan has been playing a leading role on the GEO Executive Committee.

B. Satellite-based observation

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

In order to help clarify climate change and its effects, MOE, with related ministries and agencies as well as relevant organizations at home and abroad, has developed and is operating global carbon dioxide and methane observation technologies using the Greenhouse Gases Observing Satellite "IBUKI" (GOSAT[1]) and "IBUKI-2" (GOSAT-2). In addition, the ministry is conducting continuous monitoring by using airplanes and ships, and monitors on the ground. With the aim of further promotion of climate change countermeasures, this satellite has been used for clarification of the global concentration distributions of carbon dioxide and methane, as well as estimation of absorptions and emissions by month and region. The project revealed a trend of rising concentration of carbon dioxide and methane through seasonal changes since 2009 when the observation started. The project also suggested a possibility of identifying the sources and amounts of greenhouse gasses emissions from human activities. "IBUKI-2" improved the accuracy of observation of carbon dioxide and methane that have been observed by IBUKI and added carbon monoxide to its observation

1 Greenhouse gases Observing SATellite

targets. Carbon dioxide is emitted not only from human activities such as industrial activities and fuel consumption but also from forests and activities of other living things. On the other hand, carbon monoxide is emitted from human activities but not from forests and activities of other living things. Its aim is to estimate carbon dioxide emissions of "human origin" through observation and analysis of carbon dioxide emissions in combination with carbon monoxide emissions. The successor "IBUKI-2" was launched in October 2018. In addition to succeeding the mission of "IBUKI" that is to observe global greenhouse gas concentration, it aims to contribute to transparency increase of emissions reporting based on the Paris Agreement through new functions to identify sources and amounts of emissions of human origin. The ministry has been conducting study on the next greenhouse gas observation sensor with a view to mounting it on the third IBUKI together with the GCOM-W successor sensor, and started its design in order to continue the mission and further enhance its emission source monitoring ability.

Data of SHIZUKU (GCOM-W) launched for the purpose of elucidating the global mechanisms of climate change and the water cycle, and the data of the core satellite launched in cooperation with NASA under the international Global Precipitation Measurement (GPM) project are used to improve the accuracy of precipitation estimates by Japan Meteorological Agency. Not only are the data used for research on climate change, 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. 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. 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.

C. Ground and oceanographic observations

The marine environment is rapidly changing in recent years: sea temperature is rising, ocean acidification is progressing worldwide and oceans are polluted by plastic wastes, 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 constructing an integrated marine observation network by combining drifting floats, moored buoys, observation by vessels and other means.

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 the Arctic, where it is possible to accurately measure global environmental changes. Under the Antarctic Research Programs, research and observation in the Antarctica have been conducted based on the 9th Six-Year plan for Antarctic Research Program (FY2016- FY2021).

Regarding the Arctic, under the Arctic Challenge for Sustainability Project (ArCS), climate change in the

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.

Arctic and the impacts of such change on the global environment have been comprehensively studied to forecast such change and impacts with high accuracy and to clarify the socioeconomic effects of such impacts. In order to provide stakeholders with the obtained information so that they can make appropriate decisions and address issues, international collaborative research has been promoted.

JAMSTEC has established the Institute of Arctic Climate and Environment Research to promote Arctic research. JAMSTEC is also developing autonomous underwater vehicle (AUV) capable of autonomous navigation and observation under sea ice and technologies for other elements. In order to clarify changes in the marine environment and ecosystem in the Arctic Ocean and its surrounding seas, it is conducting observation using the oceanographic research vessel Mirai from August to October when sea ice poses least obstacles. Furthermore, in FY2018 JAMSTEC conducted preliminary design on arctic region research vessels that provide research platforms.

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 three sites in Japan and at the Showa Station in Antarctica.

(2) Advancement of climate change projection/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 projection/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 projection/prediction data

MEXT has developed the Data Integration and Analysis System (DIAS). DIAS is an information system that accumulates, integrates and analyzes big data of the global environment (observation information, projection/prediction information, etc.) to contribute to solving global issues including climate change. The system has supported R&D in Japan and abroad and produced results especially for water issues. 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 is also promoting development of common fundamental technologies contributing to solution of social challenges in various fields including, energy, weather, disaster

prevention 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.

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.

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[4]), 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. In steel manufacturing, the ministry is developing innovative carbon dioxide emissions reduction technologies, including a technology to partially substitute hydrogen for coke as a reductant in steel manufacturing and separate and capture carbon dioxide from blast furnace gas toward further decarbonization.

MOE has been compiling (1) costs of separating and recovering most of the carbon dioxide from exhaust gas from coal fired power plants, (2) design and construction of Japan's first full-scale 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. Since FY2018 the ministries have been implementing demonstration of Carbon dioxide Capture and Utilization (CCU), artificial photosynthesis and methanation[5] initiative as well as

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.

4 Carbon Dioxide Capture and Storage

5 Technology to synthesize methane that is the principal component of natural gas from carbon dioxide and hydrogen.

examination and evaluation of the carbon dioxide reduction effects over their lifecycle.

With the aim of further reducing greenhouse gas (GHG) emissions in international marine transportation, METI proposed a GHG reduction strategy to the International Maritime Organization (IMO). Based on the proposal, IMO adopted the "IMO GHG Reduction Strategy" including the long-term target to eliminate GHG emissions within this century. METI and MOE have jointly launched a demonstration of a large LNG fuel ship model for maximization of CO2 emissions reduction during actual operation.

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 development to combine a comfortable indoor environment of homes/buildings and energy-saving performance, and; effects of greening to improve urban environment.

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

The Cabinet Office formulated the Integrated Innovation Strategy (Cabinet Decision on June 15, 2018). The strategy positions environment and energy as key areas to strengthen efforts. Toward construction of the world's cutting-edge energy management system, globalization of energy creation and storage technologies and realization of a hydrogen society leading the world, the Cabinet Office will set goals with a global perspective and establish paths to achieve them so that relevant ministries and agencies, industry and academia can cooperate to promote consistent efforts from R&D to social implementation.

In order to support planning and promotion of adaptation measures of local governments and other partners, based on actual needs including disaster prevention, agriculture and heat countermeasures, MEXT has been developing ultra-high resolution climate change projection information for the near future that can be used for general application. The R&D results are provided to local governments through the "Regional Adaptation Consortium" in cooperation with MOE and other relevant ministries and agencies in addition to DIAS. 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.

In FY2018 MAFF worked on development of climate change adaptation technologies in agriculture, forestry and fishery, and technologies to address damage by wildlife. The ministry also promoted development of technologies to predict productivity of artificial forests for assessment of the impact of climate change on artificial Japanese cedar forests. In addition, MAFF has been promoting the development of crop varieties and breeding materials that are adapted to the progress of warming, technologies for stable production, technologies to address pest damage, and GHG emissions reduction technology in animal husbandry. The ministry is also promoting development of GHG emissions reduction and climate change adaptation technologies for agriculture through global cooperation.

MOE implemented "Promotion of climate policies by assessing environmental impacts of SLCP[1] and exploring their reduction pathways (S-12)" as one of the studies using the Environment Research and Technology Development Fund, and assessed climate and environmental impact of SLCP and best pathways for reduction of SLCP that is believed to be a factor of climate change. The ministry also implemented "Comprehensive Strategic Research on the Mitigation of and Adaptation to Climate Change (S-14)" 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. 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.

Based on the Climate Change Adaptation Act and the Climate Change Adaptation Plan decided by the cabinet in November 2018, the government has been further enhancing adaptation measures. Based on the act and the plan, NIES has been providing the latest information on adaptation in cooperation with relevant ministries, agencies and research institutions through the Climate Change Adaptation Platform, Japan (A-PLAT) that was established in 2016. In December 2018, NIES set up the "Climate Change Adaptation Center" to support studies on the impact of and adaptation to climate change and adaptation efforts by local governments and others in scientific aspects. For promotion of adaptation measures in cooperation with relevant people of the region, NIES holds the Regional Council on Climate Change Adaptation in seven blocks across the country to exchange and share information on adaptation activities.

MRI is addressing the development of real-time observation and monitoring technology for the detection of unusual meteorological phenomena, such as intense localized downpours, 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.

■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
MAFF	MAFF	Promotion of strategic project research (repost)
METI	NEDO	Large-scale CCS demonstration experiment at Tomakomai
MOE/ METI	MOE/ METI	Survey of sites suitable for CO_2 storage

2 Responding to biodiversity loss

The Intergovernmental Science-policy Platform on Biodiversity and Ecosystem Services (IPBES) has been producing evaluation reports with the aim of strengthening the coordination of science and policies regarding biodiversity and ecosystem service. At Japan's proposal a technical support organization for evaluation of Asia and Oceania was set up under the Institute for Global Environmental Strategies (IGES) in 2015 and Japan

1 Short-Lived Climate Pollutants

continued to support its activities. On February 1, 2019 when the organization contributed to report production, another technical support organization for evaluation regarding invasive alien species was set up under IGES and supported its activities. In order to ensure effective reflection of Japan's knowledge in assessment reports in the process of creation, the country held the domestic liaison conference in July 2018 and February 2019 by gathering experts involved in IPBES in Japan and relevant ministries and agencies. Furthermore, in order to disseminate the key conclusions of the IPBES evaluation report published in 2018 to people in private companies, a symposium was held in Tokyo in November 2018. In addition, MOE continued to implement the "Predictive Estimation of Natural Capital and Ecosystem Services through Integration of Social and Ecological Systems" by using the Environment Research and Technology Development Fund. The research aims to strengthen the international link between science and policies through provision of knowledge for assessment by IPBES.

Japan has a part in and supports activities of the Global Biodiversity Information Facility (GBIF) that aims to collect data on biodiversity so that the data can be made available worldwide. Japan also provided GBIF with biodiversity data in cooperation with National Science Museum and National Institute of Genetics which are both GBIF nodes (data providing centers). Data accumulated by GBIF are expected to serve as fundamental for evaluation at IPBES.

In order to support development of new breeds using genetic resources of plants in foreign countries, an activity which is conducted by private companies and others, MAFF has been promoting bilateral joint research with focus on Asian countries and conducting surveys, collection and evaluation of such genetic resources. In its gene bank project concerning agricultural biological resources, NARO collects, preserves, assesses and provides biological genetic resources related to agriculture, and preserves and provides genomic resources, including DNA, of rice and other crops.

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 of 27 organizations from 15 countries and regions that aims for the preservation and sustainable use of microbial resources and has actively supported Asian countries in their efforts to use biological resources by constructing cooperative relationships with them 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 "Advancement of Technologies for Securing Living Marine Resources" under 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 is surrounded by the sea on all sides, Japan needs to produce STI results befitting this condition. 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 fundamental technologies necessary to support all these efforts.

Deep-sea scientific drilling vessel
Chikyu
Source: JAMSTEC

Manned research submersible
SHINKAI 6500
Source: JAMSTEC

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 Third Basic Plan on Ocean Policy (Cabinet Decision on May 15, 2018).

In light of the formulation of the 3rd Basic Plan on Ocean Policy, in January 2019 MEXT revised the R&D plan pertaining to ocean science and technology (formulated at the CST's Subdivision on Ocean Development in 2016) and has been promoting R&D in the marine S&T fields contributing to innovations toward creation of future industries.

Using vessels, probes, observation equipment and other means, JAMSTEC has been conducting survey and research in ocean including the deep sea bottom and ice-infested waters that are difficult to access, as well as simulation using the obtained data and archiving and dissemination of the data. Using these technologies JAMSTEC is promoting basic research to elucidate the actual state of the areas that need further elucidation.

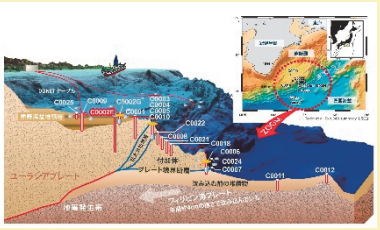
(1) Ocean survey and observation technologies

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 scientific drilling vessel *Chikyu* and technologies for real-time observation by using DONET. 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.

Colum 2-5 *Chikyu* making an attempt at drilling of the source region of Nankai megathrust earthquakes

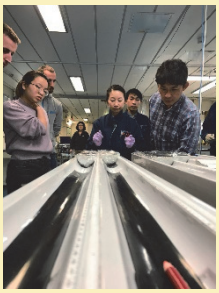
Deep-sea Scientific Drilling Vessel *Chikyu* is the world's first scientific drilling vessel and was constructed in 2005 by combining the best science technologies of the time. One of the purposes of constructing *Chikyu* was to directly access the place of repeating occurrence of great earthquakes (earthquakes of magnitude 8 and higher that occur at the plate subduction boundary) in order to carry out field measurement and sampling. In September 2007 *Chikyu* started drilling in the Nankai Trough off Kii Peninsula in its first voyage as a scientific drilling vessel. By September 2018 *Chikyu* conducted drilling at 15 points of Nankai Trough and the total length of the drilling reached as long as 34km. Its scientific achievement so far is that: through clarification of the stress on the Nankai Trough off Kii Peninsula, *Chikyu* discovered changes in the faults that had generated earthquakes and tsunami up to the vicinity of the trench where oceanic plates begin to subduct. Beyond sampling of geological materials, *Chikyu* enabled high-accuracy crustal movement observation under the sea floor and succeeded in observation of slow earthquakes that occur frequently offshore but could not be observed on land. It is pointed out that slow earthquakes may trigger huge earthquakes. *Chikyu* succeeded in observation of the conditions of the huge earthquake occurrence zones and high-accuracy measurement of various phenomena occurring there first in the world.



Sectional view of Nankai Trough
Source: JAMSTEC

Operation on *Chikyu*
Source: JAMSTEC

Spending about half a year from October 2018, *Chikyu* attempted drilling to reach the shallowest part of the huge earthquake occurrence zone first in the world. In the past three voyages the vessel completed drilling of about 3,000m from the depth of about 2,000m. It was planned to further drill about 2,200m to reach the shallowest part of the huge earthquake occurrence zone. However, the mission encountered a very complicated geological structure that did not allow drilling as planned using the current drilling technology. It was found impossible to reach the plate boundary fault. Nevertheless, *Chikyu* succeeded in the deepest scientific drilling (Water Depth: 1,939m, Drilling Depth: 3,262.5m) and collected valuable samples. It is expected that research will progress using the samples.



Analysis of collected samples
Source: JAMSTEC

We will further evolve the scientific drilling by *Chikyu* that has opened a new understanding of huge earthquakes and thereby contribute to building of a safe and secure society.

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

Since FY2018, MEXT has been implementing R&D of observation/measurement technologies for efficient and highly accurate understanding of marine ecosystem, marine environment and other marine information using a wide range of advanced technologies and knowledge held by universities, etc. under the "Technology Development for Understanding of Marine Information" within the framework of the program for developing

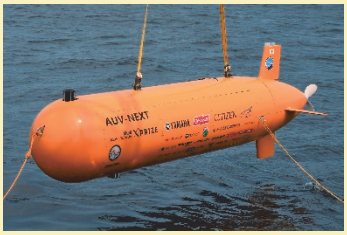
technologies for promoting the use of marine resources.

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 (See Chapter 3 Section 1, 1(2)).

MIC has been conducted 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.

Colum 2-6 Team KUROSHIO's attempt to win XPRIZE

XPRIZE is a global competition run by XPRIZE Foundation, an American nonprofit organization, with the aim of solving the world's grand challenges. As part of the competition, Shell Ocean Discovery XPRIZE has been held sponsored by the leading oil company Royal Dutch Shell and others since 2016. This is the world's first global competition of ultra-high speed and ultra-wide area submarine prospecting using search robots. 32 teams from around the world entered the competition. Three teams including Team KUROSHIO participated from Japan.



Unmanned probe used in Round 2
Source: JAMSTEC

Round 2 test
Source: JAMSTEC

Team KUROSHIO is an industry-government-academia partnership team consisting of more than 30 young researchers and engineers from: Japan Agency for Marine-Earth Science and Technology; the Institute of Industrial Science, the University of Tokyo; Kyushu Institute of Technology; the National Institute of Maritime, Port and Aviation Technology; Mitsui E&S Shipbuilding Co., Ltd.; Nippon Marine Enterprises, Ltd.; KDDI Research, Inc. and Yamaha Motor Co., Ltd. The team passed the document review in February 2017 and the Round 1 technology readiness test in March 2018 to proceed to Round 2 final field test as the only team from Asia. The mission of Round 2 testing off Kalamata of Greece was to map an area of at least 250 km2 at depths down to 4,000 meters, and take 10 pictures of undersea targets, all within 24 hours. Eight teams that passed Round 1: Team KUROSHIO, three US teams and four European teams competed in the test.

Team KUROSHIO was to go through Round 2 for 11 days from December 9 to 19 of 2018. December is a rainy season in Greece. The final was held in Kalamata under difficult oceanographic conditions where clear weather and thunderstorms alternated.

Commemorative photo after Round 2
Source: JAMSTEC

At the initial trial on 13th and 14th of December, the team's unmanned probes had operation troubles in front of the target sea area. However, at the retrial on the 16th and 17th after their repair the team could maximize the given time without major trouble and obtained submarine topography data off Kalamata. Later the team analyzed the data, created submarine topographic maps meeting the required definition and completed the submission to XPRIZE Foundation at 22:50 Japanese Time on December 19 concluding the mission of Round 2.

Result of the final will be announced by the organizer in early June. Further technology development is expected by advancing the exploration technology and operation knowhow developed through this challenge in order to globalize the oceanographic survey technology of Japan

(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 "Advancement of Technologies for Securing Living Marine Resources" under 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 JST, R&D has been conducted on technologies for observing and monitoring marine species (See Chapter 3 Section 3-2).

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.

<Reference> JAMSTEC NEWS HILIGHTS 2018
https://www.youtube.com/watch?v=4PmS1MotXXM (Source: jamstecchannel)

2 Promotion of R&D in space science

Space technologies including weather, communication, positioning and broadcasting satellites are indispensable for everyday lives of the people. They are also important in expanding the intellectual property of mankind and in nurturing the 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 (Act No. 43 of 2008) and the Basic Plan on Space Policy (Cabinet Decision on April 1, 2016) (Table 2-3-18).

■Table 2-3-18/Points of the Implementation Plan of the Basic Plan on Space Policy (Revised in FY2018)

Points of the Implementation Plan of the Basic Plan on Space Policy (revised FY2018) (Draft)

As of December 11, 2018
National Space Policy Secretariat

Policy Objectives: (1) Ensure space security, (2) Promote the use of civil space, (3) Maintain and strengthen the science and technology industrial base

An implementation plan aimed at achieving the goals of the space policy

Satellite positioning

- Quasi-Zenith Satellite System development, improvement and operation
  - Reinforcement of partnership with JAXA to improve its functions and performance
  - Launch the first successor in FY2020 and establish a seven-satellite system around FY2023.
- Promote utilization of the Quasi-Zenith Satellite System
  - Set up "TF for promotion of utilization of the Quasi-Zenith Satellite System" under the Minister in charge of outer space to promote utilization of the quasi-zenith satellites

Satellite remote sensing

- Information Gathering Satellites (optical / radar)
  - Launch the 1st data relay satellite and the 7th optical satellite in FY2019
  - Start development of the 9th optical satellite and the 1st diversified radar satellite in FY2019
- Advanced optical/radar satellites (ALOS-3 and 4)
  - Promote development toward the launch in FY2020
- Geostationary Meteorological Satellites
  - Start technology survey at home and abroad in FY2019 for study of performance, specifications, etc. of the successor model.
- Greenhouse Gas Observing satellites (GOSAT)
  - Promote identification of GHG emission sources, improvement of the accuracy of emission estimation and development of the 3rd model.
- Other remote sensing satellites
  - In FY2019 undertake the development of the next microwave radiometer for observation of water cycle change to be mounted also on GOSAT-3
  - Continue research on LIDAR observation (surface observation using laser radar) with a view to development and deepen the accumulated technologies

Satellite communications and satellite broadcasting

- Next-generation Engineering Test Satellite
  - Advance detailed design of the Next-generation Engineering Test Satellite (9th satellite) with an eye toward its launch in FY2021
- Optical Data Relay Test Satellite
  - Complete the development and launch the satellite in FY2019
- X-Band Satellite-Based Defense Communication Network
  - Aim to launch the 3rd satellite in FY2022

Space transportation systems

- Next Generation Mainstay Launch Vehicle (H3)
  - Toward the launch of the first real test rocket in FY2020, continue combustion tests of the first- and second-stage engines and the system as well as fabrication of real model
- Epsilon Launch Vehicle upgrades
  - Based on the synergy development plan with the H3 rocket, start detail design, electrical system tests, etc. in FY2019.
- Launch sites
  - Perform the procedures of launch facility certification appropriately and without delay, while taking measures necessary for project feasibility study.

Space Situational Awareness (SSA)

- Advance necessary measures and adjustments including operation guidelines before start of the system operation after FY 2023.
- Promote partnership with JAXA and specific initiatives in bilateral and multilateral cooperation with the United States, France, etc.
- Survey global trend of Space Traffic Management (STM), etc.

Maritime Domain Awareness (MDA)

- Consider strengthening of utilization of government and private sector satellites in coordination with activities of the Basic Plan on Ocean Policy by around the end of FY2019

Strengthening of mission assurance (guarantee for functions) of the overall space systems

- Deliberation of risk scenarios contributing to strengthening of mission assurance (guarantee for functions) by FY2019

Space science and exploration, manned space activities and international space exploration

- Space science and exploration
  - Promote programming and implement front loading
  - Steadily promote Smart Lander for Investigating Moon (SLIM) and implement front loading of Sample return from Martian moon Phobos (Martian Moons eXploration: MMX)
  - Promote activities toward substantiation of Deep Space Exploration Technology Demonstrator (DESTINY+), Jupiter ICy moons Explorer (JUICE), etc.
- Manned space activities including international space station plan
  - In FY2019 coordinate our low orbit manned space activities after 2025.
- International space exploration
  - Regarding participation in the US initiative to establish a manned base near the moon (Gateway), proactively promote international cooperation and technological demonstration while keeping in mind our contribution to scientific exploration.
  - Implement international coordination and specific technical consideration of exploration activities on the moon under international cooperation

Measures and projects to strengthen the science and technology industrial base and infrastructure

Comprehensive initiatives to encourage new entrants to the space industry and expand space utilization

- Expand space utilization by identifying potential needs in various fields and areas including automated driving, agriculture, fisheries, environment, disaster prevention, national resilience and other fields that have not had much relation with outer space in cooperation with local governments promoting creation of space businesses
- Strengthen activities for venture support through the space-based business idea contest (S-Booster) and the Space Business Investment Matching Platform (S-Matching), which includes expansion of the activities to Asian and other countries (S-Booster Asia)
- Develop a prototype of the data platform for open government satellite data within the fiscal year. Improve its convenience based on users' opinions with a view to business promotion led by private business operators after FY2021.
- Promote G Space projects and the activities based on the discussion of the expert committee set up in FY2018 to discuss ideal public organizations that facilitate secondary and tertiary use of geospatial information.
- Study necessary environmental improvement for suborbital flight considering private activities and international trends

Environmental improvements for facilitating the stable supply of core components/ Initiatives aimed at expanding future space utilization

- In addition to implementation of the innovative satellite technologies demonstration program, start activities toward provision of on-orbit demonstration opportunities for competitive parts/components in FY2019 in order to strengthen competitiveness of small satellite/rocket businesses.
- Develop software and avionics necessary for the SERVIS project by FY2020 toward early establishment of autonomous flight safety system.
- With flight experiment of one stage reuse in international cooperation in mind, implement flight experiment of small experimental units in FY2019. Study challenges for realization of space transportation system based on reuse with these experiments in mind.
- Promote demonstration experiment of a LNG propulsion system, research on space photovoltaic power generation and activities to strengthen functions to provide space weather information

Measures to strengthen systems and frameworks supporting the development and use of space as a whole

- Strengthen survey and analysis functions in cooperation with private think tanks, and carry out surveys contributing to study of missions and technologies that will become necessary for our advanced satellites by around the middle of 2019.
- Start expansion of opportunities to learn skills to use satellite data and operation of a platform for talents specialized in space business in FY2019.
- Start activities to enhance cost estimation and risk management skills in FY2019 toward introduction/deepening of firm contracts.

Other initiatives to maintain and strengthen space industry and science technology

Space debris countermeasures

- Build a framework for promotion of the government-wide initiatives and coordinate basic initiatives to reduce debris by the first half of FY2019.

Promotion of space diplomacy and strengthening of strategies for international outreach in space-related fields

- Promote international rule setting and build multi-layered cooperation with foreign countries
- Microsatellites released from the ISS Japanese Experiment Module "Kibo"
- Strengthen the Japan-US collaboration in outer space through specific studies regarding hosted payload
- Promote space cooperation in collaboration with the APRSAF and the ERIA, etc. / Contribute to the SDGs with space technologies

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 FY2014 and various combustion tests have been conducted to expand Japan's autonomous space activities and ensure international competitiveness. The first new rocket is scheduled for launch in FY2020. Synergy development of Epsilon rocket with H3 rocket started in FY2017 to reduce costs.

Using H-IIA, H-IIB and Epsilon, our key rockets, Japan successfully launched an information-gathering satellite Radar 6 in June 2018, Cargo Transfer Vehicle "KOUNOTORI-7" in September 2018,

Launch of H-IIA F40 (left) and Epsilon-34(right)
Source: JAXA/Mitsubishi Heavy Industries (left)
JAXA (right)

IBUKI-2 in October 2018 and the Innovative Satellite Technology Demonstoration-1 in January 2019

(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. Cabinet Office started a high-precision positioning service based on a 4-satellite constellation of Quasi-Zenith Satellites MICHIBIKI on November 2018. The office decided specifications of the satellite system toward the 7-satellite constellation to be established in FY2023 as well as its function and performance improvement and embarked on the development of MICHIBIKI-5. Toward further utilization of MICHIBIKI, relevant ministries and agencies are working together on various demonstration experiments including automated driving of automobiles and farm machines, physical distribution and disaster prevention.

Ceremony to start service of Quasi-Zenith Satellite-1 MICHIBIKI (November 1, 2018)
Source: Cabinet Office

(3) Satellite communication and broadcasting systems

The Japanese government's intention to launch an engineering test satellite around FY2021 is explicitly stated in its Basic Plan on Space Policy in order to realize internationally competitive next generation stationary geostationary communication satellites. To this end, MIC and MEXT have been developing the Engineering Test Satellite 9 since FY2016. This satellite will be developed for the purpose of demonstrating technologies of electric propulsion, high-power generation, and flexible payload.

(4) Earth observing system

MOE launched IBUKI in FY2012 and IBUKI-2 in FY2018 to promote climate change countermeasures through long-term observation of global GHG concentration.

Data collected by SHIZUKU (GCOM-W) launched by JAXA in May 2012 and the GPM core satellite launched in February 2014 in cooperation with NASA under the international Global Precipitation Measurement (GPM) project are used by JMA to improve the accuracy of precipitation estimates and for various other purposes, including weather forecasting and fishing ground detection (See Chapter 3 Section 3, 1(1)).

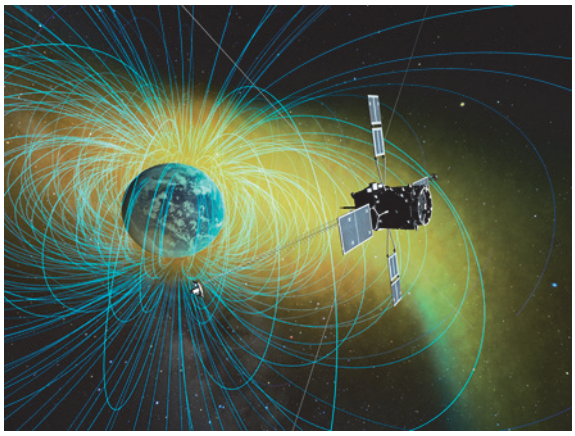
JAXA is also operating SHIKISAI that was launched in December 2017. In addition, DAICHI-2 (ALOS-2) was launched in May 2014. The satellite is contributing to disaster prevention and management, and in solutions to global issues such as global warming through monitoring of various disasters, grasping of damage situations and the observation of forests, ice of Polar Regions, etc.

Global Change Observation Mission - Climate "SHIKISAI" (GCOM-C)
Source: JAXA

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 (ALOS-3) capable of wide-area, high-resolution imaging, advanced radar satellites (ALOS-4), 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 the asteroid Itokawa. Geospace probe ARASE launched in December 2016 is observing plasma in geospace around the earth and has contributed to deepening of the understanding of the space environment and interaction between the earth and solar activities including space storms through identification of the physical process of aurora generation, for example. HAYABUSA2, an asteroid explorer launched in December 2014, arrived at the Ryugu asteroid and succeeded in asteroid exploration by rover in September 2018 first in the world. It is scheduled to collect samples of the asteroid in 2019 and return to



Geospace Probe ARASE
Source: JAXA

Earth at the end of 2020.

Venus Climate Orbiter AKATSUKI (PLANET-C) that was put into orbit around Venus in December 2015 contributed to elucidation of the mechanism of the atmosphere of Venus. In addition, JAXA is conducting development of the small moon landing demonstrator (SLIM[1]) in an attempt to conduct Japan's first lunar landing and XRISM[2] (both are scheduled for launch in FY2021) as well as the Mercury Magnetospheric Orbiter MIO for the BepiColombo international collaborative mission to Mercury (launched in October 2018), 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.

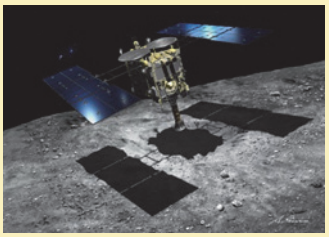
1 Smart Lander for Investigating Moon
2 X-Ray Imaging and Spectroscopy Mission

Colum 2-7 HAYABUSA2 demonstrated Japan's space science and exploration technologies

On June 13, 2010, asteroid explorer HAYABUSA developed by JAXA navigated about 6 billion km of a round trip between the earth and asteroid Itokawa for about 7 years and succeeded in bringing back samples from the asteroid to the earth (Sample Return). HAYABUSA is a project realized using Japan's own technologies from design to launch and survey. In particular, the first electric engine (ion engine) that was put into practical use, had only small driving force but was very fuel efficient and thereby enabled long-hour acceleration demonstrating the innovative technology.

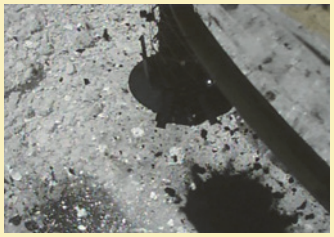
Asteroid Ryugu
(about 900m in diameter)
(Provided by JAXA and others)

On December 3, 2014, asteroid explorer HAYABUSA2 that succeeded the technologies and experience of HAYABUSA was launched toward Asteroid Ryugu. Its purpose is to elucidate the formation of the earth and origin of the solar system by analyzing samples from Ryugu, which is believed to be similar to planets at the early stage of the solar system. HAYABUSA2, developed by improving the first HAYABUSA and loading the latest technologies, arrived in good condition at its destination, Ryugu, on June 27, 2018 after about a 3.2 billion km journey. In September of the same year it dropped Minerva II*1 that is a small exploration robot developed by JAXA, University of Aizu and others to Ryugu and succeeded in the world's first asteroid exploration. In October the explorer dropped the small lander MASCOT developed jointly by Germany and France and thereby contributed to the international cooperation mission.



Imaginary drawing of Touchdown on the crater formed by a collider
(Illustration by IKESHITA Akihiro)

On February 22, 2019, HAYABUSA2 succeeded in landing on Ryugu and sampling (Touchdown). As Ryugu is covered with huge rock lumps, Touchdown was a difficult challenge. Toward touchdown HAYABUSA2 surveyed the topography of Ryugu in detail and looked for a point for safe touchdown without any damage to its body. The target point carefully selected by postponing the original schedule was a place with a radius as small as 3m. The first HAYABUSA lost its balance when it attempted touchdown, was damaged and could not take enough samples. Making use of the experience, HAYABUSA2 repeated simulations, made touchdown at the point just 1m from the target point and collected rocks. The sophisticated technology to correctly guide the explorer far removed from the earth to the determined point gained praise from the world.



Surface of Ryugu photographed just after the touchdown
(Provided by JAXA and others)

For FY2019 it is planned to form an artificial crater on the asteroid first in the world and collect samples within the crater. Return to the earth is scheduled at the end of 2020 after the Tokyo Olympic and Paralympic Games. HAYABUSA2 mission will be followed by plans including Martian Moons eXploration (MMX) to clarify the origin of the two Martian moons and the evolution process of the Martian sphere. Japan's technologies are expected to produce new results of space science.

Reference: images shot by monitor cameras mounted on HAYABUSA2
https://www.youtube.com/watch?v=-3hO58HFa1M (Source: JAXAChannel)

(6) Manned space activities

Astronaut KANAI Norishige
Source: JAXA and NASA

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) and the KOUNOTORI (HTV) automated cargo spacecraft. KOUNOTORI has been used to resupply KIBO and the ISS. Japanese astronauts have carried out longstay missions aboard the International Space Station. The Japanese team has various achievements, such as establishing manned and unmanned space technologies, establishing an international presence for Japan, expanding the space industry, contributing to society through 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 from December 2017 to June 2018 Astronaut KANAI Norishige conducted various science experiments using KIBO, operated systems of ISS facilities and carried out extravehicular activities. Furthermore, in November 2018 Japan succeeded in the return of a small reentry capsule aimed at demonstration of atmospheric reentry technology and recovery of goods from ISS. In December 2015, the Japanese government signed an agreement with the U.S. government on a new framework for bilateral cooperation and formally decided to extend Japan's participation in the space station program through 2024. For the future, Japan is advancing development aimed at the launch of a new supply spacecraft (HTV-X) with future space exploration in mind.

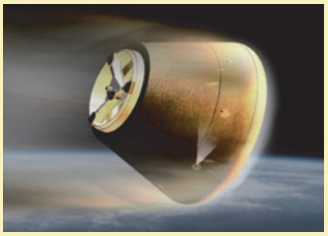
1 The International Space Station is a cooperative program based on the ISS Intergovernmental Agreement between Europe, the U.S.A., Russia, Canada, and Japan for the joint development, operation and utilization of a permanently inhabited Space Station in low Earth orbit (about 400 km above the Earth's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

Colum 2-8 Successful return of a small recovery capsule from the International Space Station

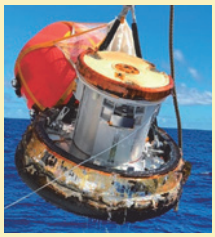
Schematic diagram of the small recovery capsule

On November 11, 2018, the small reentry capsule containing samples obtained from protein crystallization experiments at the ISS Japanese Experiment Module "KIBO" returned from ISS and landed on the Pacific Ocean near the Minamitorishima Island. The capsule had been developed by the Japan Aerospace Exploration Agency (JAXA) with the aim of demonstrating atmosphere entry technology and developing the ability to recover goods from ISS as the first such attempt by Japan. The capsule had been mounted on the Cargo Transfer Vehicle "KOUNOTORI-7" that was launched on September 23 of the same year.

In order to bring the capsule back to the earth while maintaining the quality of protein crystals generated in ISS, the temperature inside the capsule needs to be maintained at 4±2°C by an insulating container and refrigerant at least for 3.5 days (from departure from ISS, atmospheric re-entry, and landing on water up to recovery). Private companies took part in the development of the insulating container. Technologies including those for household thermos kettles, etc. were used. When the temperature data inside the capsule was checked after the return, it was found that the temperature had been controlled at 4±0.4°C for about 5.5 days as planned. No damage was found to the protein crystals housed in the capsule. Analysis and evaluation are underway at SPring-8, etc.



Atmospheric reentry of the capsule (Imaginary drawing)



Retrieved small recovery capsule

The atmospheric re-entry technologies demonstrated by the reentry capsule include "guided lift flight" to guide the body to the target point at low acceleration less than 4G during the lift-guided flight and "light-weight thermal protection" to protect the body from the high temperature (about 2,000°C) during the atmospheric reentry. These are part of many technologies that will become necessary for manned spacecraft

In addition to these technologies that had been unexplored by Japan but acquired through the new challenge, it is significant that the country gained the means to recover samples from ISS without relying on other countries. The success is expected to contribute to the strengthening of Japan's competitiveness in space utilization.

Reference: Aspiration of Engineers (KOUNOTORI 7, small re-entry capsule and future projects)
https://www.youtube.com/watch?v=6WFJFjXGhX8
(Source: JAXAChannel)

Source: JAXA

(7) International space exploration

Many countries have been increasing interest in space and planning Lunar surface and Mars exploration. The United States announced a plan to construct a manned base near the Moon (Gateway) in 2017 and is calling for participation by other countries. Japan plans to launch the Smart Lander for Investigating Moon (SLIM) in FY2021 and is studying feasibility of a joint moon landing and exploration mission by JAXA and ISRO[1]. Because Gateway as a relay point of communication and sample collection is expected to increase the efficiency and effectiveness of Lunar surface exploration, Japan is advancing international coordination and specific technical investigation toward its participation while presenting the uniqueness of the country.

1 Indian Space Research Organisation

(8) 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. The small high-performance radar satellite (ASNARO-2) was launched in January 2018. R&D is also advanced regarding space equipment that is internationally competitive and sensors for the exploration of mineral resources using satellite remote sensing technologies. In addition, in order to increase the use of space data that has been becoming big data, the ministry provides the government's satellite data for open and free use and is also developing a user-friendly satellite data platform.

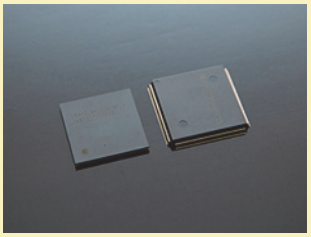
Colum 2-9

From Space to Earth
Beyond quasi-zenith satellites and agriculture - Space technology used on the ground

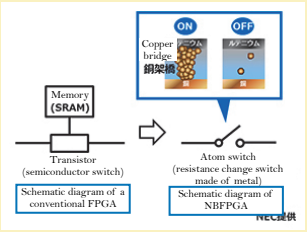
The Innovative Satellite Technology Demonstoration-1
Provided by JAXA

Outer space has become very familiar in our daily life. Our lives are supported by space technologies including weather satellites, satellite broadcasting and GPS for accurate positioning without our being aware of them. Rocket launch and satellites are often mentioned as typical examples of space technologies, but ISS Experiment Module "KIBO" that was completed 10 years ago in 2009 has also produced results of various space experiments with focus on drug discovery. In the future it will become important not only to "go into outer space" and "observe the earth" but also to "use outer space" and "make trials in space".

MEXT provides demonstration opportunities in outer space to universities, private companies and others who are conducting activities with a potential to expand the range of space utilization. In January 2019 the ministry launched the Innovative Satellite Technology Demonstoration-1 for which demonstration themes had been publicly solicited. Many of the themes involve demonstration of technologies that will contribute to innovation of artificial satellites in the future, but NEC Corporation tries to demonstrate in outer space a groundbreaking FPGA (field-programmable gate array) that is small, has low power consumption and is less influenced by radiation.



FPGA developed by NEC
Provided by NEC



Schematic diagram of NanoBridge with atom switch replacing memory
Provided by NEC

FPGA is an integrated circuit with rearrangeable functions. NEC adopted NanoBridge that switches circuits by moving metal atoms instead of semiconductors that are susceptible to radiation. The company is working on this demonstration to assess the reliability of the NanoBridge FPGA with a view to its application not only to spacecraft but also to automobiles, the medical area and other fields that require higher reliability.

In FY2018 MEXT and JAXA initiated J-SPARC aimed at creation of new businesses by incorporating new ideas that are not limited to current space development and utilization but include non-space fields. The potential of space utilization is infinitely expanding like outer space itself. They will continue to tackle space technologies that will contribute also to the improvement of our daily living.

■Table 2-3-19/Major policies to open up frontiers important for national strategies (FY2018)

Ministry	Implemented by	Project
Cabinet secretariat	Cabinet Intelligence and Research Office	R&D of information-gathering satellites
CAO	CAO	Promotion of practical Quasi-Zenith Satellite System project
MEXT	MEXT	Japanese Antarctic Research Program
		The Arctic Challenge for Sustainability Project
	JAXA	Grants for ISS development
		Subsidy for advancement of core rockets
METI	METI	Expenses for open architecture of the government's satellite data and environmental development for data use
		Expenses for demonstration of integrated use of satellite data
MLIT	JCG	Promotion of marine research in the EEZ of Japan

Colum 2-10 Successful photographing of black hole

On April 10, 2019, the team of the Event Horizon Telescope, a global joint research project consisting of researchers from Japan, the United States, Europe and other regions announced the success of photographing a black hole*1 first in history. Under the project, eight radio telescopes at six sites around the world simultaneously observed the huge black hole at the center of Galaxy M87 in Virgo, located 55 million light years away from the earth, in April 2017. The team succeeded in the first imaging of a black hole after analysis of the observation data and images.

Image of a huge black hole at the center of M87 Galaxy. Black part at the center is shadow of the black hole.
Provided by the Event Horizon Telescope

By synchronizing and connecting the eight radio telescopes around the world, the team configured a global radio telescope to realize an extremely high definition. The ALMA telescope that had been set up on the Atacama Plateau, Chili, and jointly operated by Japan, the United States and Europe also participated in the observation and contributed to the improvement of the accuracy.

22 Japanese researchers*2 among over 200 researchers from around the world participated in the project and made their contribution through observations and theories, simulations, image analysis and other activities using the codes produced through the application development for the successor of K computer.

Analysis of the heavenly bodies observed during the same period is underway and further unraveling of mysteries of outer space is expected.

*1 Black Hole: black heavenly bodies that swallow nearby matter, etc., by strong gravity. Even light cannot escape.
*2 Including researchers who belong to an overseas organization.